ILI Research (Sleeves) Phase 1A2

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Client: UKOPA

Author: Ian Martin
Checked by: Daniel Finley
Approved by: Simon Daniels

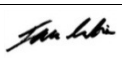
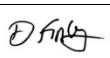
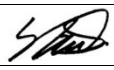
MACAW Engineering Ltd

Quorum Business Park
Benton Lane
Newcastle upon Tyne
United Kingdom
NE12 8BS

Tel: +44 (0) 191 215 4010

www.macawengineering.com

REPORT HISTORY

Issue	Date	Description	Author	Checked By	Approved By
1	18/11/2015	First Issue	Ian Martin	Daniel Finley	Simon Daniels
					

EXECUTIVE SUMMARY

The UKOPA Risk Assessment and Integrity Working Group established a sub group to determine a 'Sleeve Management Strategy' for its members. Work to date has included the development of a maintenance algorithm, review of best practice for sleeve maintenance and the development of a prioritisation process for sleeves based on risk.

As part of the latter, it was proposed to carry out a review of the In-Line Inspection (ILI) results for the sleeves of pipelines operated by UKOPA members – the initial focus being on natural gas transmission pipelines, as these have the greatest number of sleeves, but other pipelines can be included.

MACAW Engineering Ltd (MACAW) completed Phase 1A1 of a study for UKOPA in 2014, this piece of work successfully demonstrated the feasibility of extracting information relating to sleeves from In-Line Inspection data.

The Phase 1A1 report identified that some sleeves had close external corrosion features that were not directly underneath them. The number and depth of these features could be significant as they may indicate some form of corrosion mechanism that is influenced by the proximity of a sleeve.

It was agreed at a meeting between MACAW engineers and UKOPA member companies (UKOPA meeting, Newcastle University, 4 December 2014) that the apparent phenomena of corrosion features in close proximity to sleeves should be further investigated. At the same time, it was agreed that the project should look at available data for sleeve type and attempt to correlate this with ILI data.

Conclusions and Recommendations

1. This work and the work in Phase 1A1 shows that it is feasible to evaluate external corrosion reported from ILI in an effective manner and identify those features related to sleeves.
2. This phase of work has shown that the number and depth of features within 12 m of a sleeve is higher than for the remainder of the pipeline for three of the five pipelines considered.
3. Corrosion features and sleeve assets that occur along the pipeline can be referenced at a certain distance or coordinate location. Using this information it has been demonstrated that an individual corrosion feature can be linked to a sleeve. This has been successfully demonstrated for three of the operators' data.
4. Where sleeve information is not currently available or attributes are missing, operators should undertake the collection of missing data.
5. Following a data collection exercise, or with data from a limited number of operators, the research work can continue into Phase 1B to evaluate a large population of sleeve and pipeline data.

CONTENTS

1. INTRODUCTION

The UKOPA Risk Assessment and Integrity Working Group established a sub group to determine a 'Sleeve Management Strategy' for its members. Work to date has included the development of a maintenance algorithm, review of best practice for sleeve maintenance and the development of a prioritisation process for sleeves based on risk.

As part of the latter, it was proposed to carry out a review of the In-Line Inspection (ILI) results for the sleeves of pipelines operated by UKOPA members – the initial focus being on natural gas transmission pipelines, as these have the greatest number of sleeves, but other pipelines can be included.

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It was agreed at a meeting between MACAW engineers and UKOPA member companies (UKOPA meeting, Newcastle University, 4 December 2014) that the apparent phenomena of corrosion features in close proximity to sleeves should be further investigated. At the same time, it was agreed that the project should look at available data for sleeve type and attempt to correlate this with ILI data.

2. SCOPE OF WORK

2.1 Task 1 – Corrosion in Proximity to Sleeves

Using the sample of four (4) ILI reports collected from UKOPA members during Phase 1A1, plus one additional ILI report for a liquids pipeline, data will be further analysed to develop an understanding of the relationship that may exist between the location of sleeves and corrosion features that occur in close proximity. The approach will be as follows:

1. Investigate and compare the depth distribution of corrosion features that are directly under sleeves, with those in close proximity to sleeve (upstream/downstream) and in general along the pipeline. Use this information to determine whether corrosion is different under the sleeves.
2. Investigate changes in the depth distribution that may occur as distance to the nearest sleeve changes. Initially this will look at 12 m increments (steps), the step size may however be altered (reduced or increased) depending on findings of the investigation.

2.2 Task 2 – Correlating Sleeve Type with ILI Data

In Phase 1A1, no consideration was made for Sleeve Type. As part of the extended feasibility study, there will be an investigation of data available in each of the participating UKOPA member companies relating to Sleeve Type. It is expected that this data which is used by the UKOPA Sleeve Risk Ranking Model will include parameters such as sleeve fill, age, end seal type, coating, carrier pipe wall thickness, CP operation, etc.

The approach will be as follows:

1. Obtain sleeve data for the same five (5) pipelines for which MACAW has ILI data. The source of this may be the Sleeve Risk Ranking Model, company GIS systems, or other asset data management sources.
2. Investigate the best approach for 'aligning' sleeve data with pipeline route information from GIS and the ILI data used in Task 1 and Task 2 of this extended feasibility study. This Task will report on the feasibility of applying the 'alignment' approach to a much larger population of sleeves/pipelines in a later Phase of work.

The report presents the findings from the extended feasibility study and discusses whether the process can be scaled up for the analysis of a larger population of sleeves to be considered in a later phase of work.

3. INPUT DATA

ILI listings were provided by UKOPA member companies for thirty (30) separate pipelines. Four (4) of these listings were previously selected for analysis in Phase 1A1 and an additional listing from Valero for Phase 1A2.

The sample included listings in ROSEN, T.D. Williamson and PII reporting format. Table 1 summarises the input data.

Operator	NGGD	NGN	SGN	WWU	Valero
Name	**Kynnersley to Swindon Junction**	**East Bierley to Pannal**	**Uddingston to Wishaw**	**Filton to Rolls Royce**	**Seisdon to Manchester**
Launch	Kynnersley	Pannal	Uddingston	Rolls Royce	Seisdon
Receive	Swindon Junction	East Bierley	Wishaw	Filton	Manchester
Product	Natural Gas	Natural Gas	Natural Gas	Natural Gas	Oil
ILI Vendor	ROSEN	PII	PII	ROSEN	TD Williamson
Length (km)	36.1	24.4	15.5	7.9	113.2
Number of sleeves	36	40	15	11	14
Number of External Corrosion	544	1063	302	40	2962
Number of Internal Corrosion	7	0	0	0	148769

Table 1: Input data

4. ANALYSIS & RESULTS

4.1 Task 1 – Corrosion in Proximity to Sleeves

The Phase 1A1 report identified 13 sleeves with external corrosion features within 12 m but not directly underneath them. Further analysis of the reported external corrosion features both within a sleeve and within 12 m of a sleeve has been completed and summary results are shown in Table 2.

Pipeline Operator	Number of Sleeves	External Corrosion Within Sleeves	External Corrosion Within 12 m of Sleeves	Total Number of External Corrosion Features
NGGD	36	20	3	23
NGN	40	24	58	82
SGN	15	12	23	35
WWU	11	18	9	27
Valero	14	14	3	17
TOTAL	**116**	**88**	**96**	**184**

Table 2: Summary of reported external corrosion features

Table 3 compares the average feature depth, as a percentage of the pipe wall thickness, of external corrosion features within the sleeve and for the remainder of the pipeline. This shows that average feature depth within the sleeve is greater in all cases, however, it should be noted that differences between the values is small, the largest is approximately 6%.

Operator	Average Feature Depth within Sleeve (%)	Average Feature Depth Remainder of the Pipeline (%)
NGGD	10.95	9.46
NGN	11.63	9.92
SGN	25.25	18.91
WWU	8.28	7.14
Valero	10.21	7.14

Table 3: Summary of feature depths within sleeves and outside of sleeves

It is recognised that a comparison of the total number of external corrosion features in each pipeline could be misleading given the differences in pipeline and sleeve lengths. Therefore the data has been normalised and the output is reported as the number of features per meter, this allows data trends to be more easily identified.

Figure 1 shows the count of external corrosion features per meter within sleeves, 12 m either side of a sleeve and for the remainder of the pipeline, for each pipeline operator. Three of the pipelines, NGN, SGN and WWU, show a significant increase in the number of features reported within 12m of sleeves.

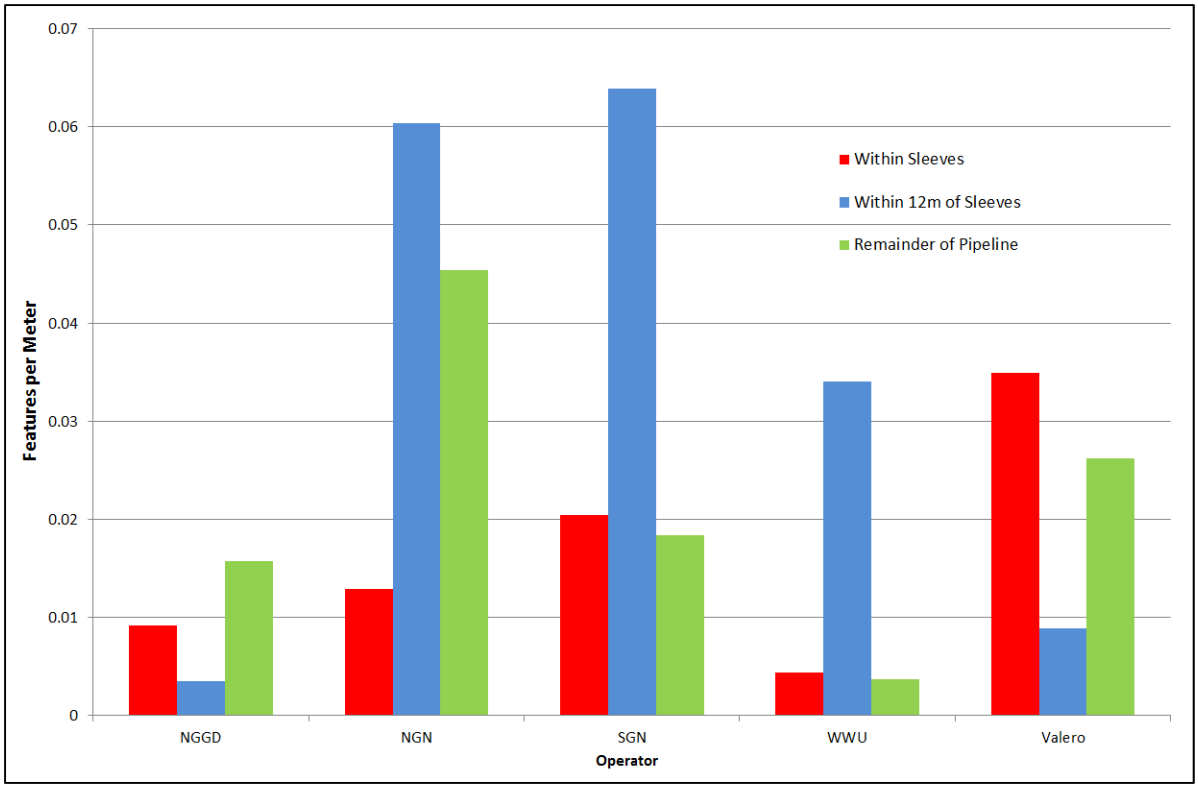


Figure 1: Feature count per meter on all pipelines

Figure 2 shows a feature depth distribution of external corrosion for all pipelines. This is broken down to features within sleeves, 12 m either side of a sleeve and for the remainder of the pipeline.

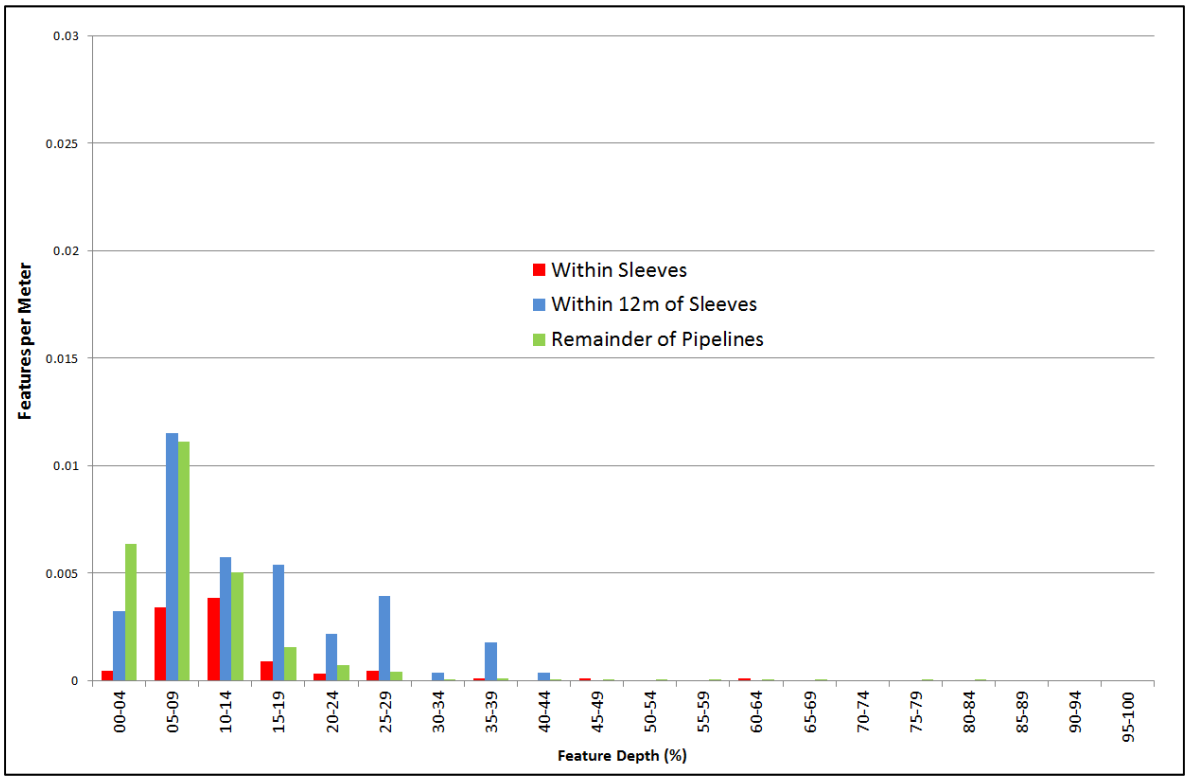


Figure 2: External corrosion depths banded for all pipelines

It was concluded in Phase 1A1 that including external corrosion features within 12 m of a sleeve made a significant difference to both the number and depth of associated external corrosion features. This phase of work has shown that the observation is particularly evident in 3 of the 5 pipelines considered in this work.

Further analysis of data for the NGN pipeline shows that the majority of these observations can be attributed to one particular sleeve, where a total of 44 out of 58 external corrosion features within 12 m of a sleeve are associated to this location. Removing these features from the dataset reduces the count per meter for features within 12 m of a sleeve to 0.014 for the pipeline (compared with 0.060 per metre including the features). Analysis of the WWU and SGN pipelines has shown that the features within 12 m of a sleeve are generally evenly distributed throughout the pipeline.

Figure 2 shows that in addition to there being a large number of features within 12 m of a sleeve, the features are also reported to be deeper, this observation is particularly apparent in data for the SGN pipeline. Feature depth distributions for each individual pipeline are presented in the respective Appendix of this report.

It should be noted that observations reflect the analysis of a small sample of data intended to test the feasibility of analysis it is not intended to draw conclusions regarding statistical significance of the findings. However, this work and the work in Phase 1A1 shows that it is feasible to evaluate external corrosion reported from ILI in an effective manner and identify those features related to sleeves. Extending the study to a larger population of pipelines/sleeves would allow statistically valid conclusions to be drawn.

4.2 Task 2 Correlating Sleeve Type with ILI Data

In Phase 1A1, no consideration was made for Sleeve Type attributed to particular external corrosion features. The alignment of external corrosion features with sleeve information would allow the influence of various sleeve attributes on corrosion to be investigated. This would subsequently allow the learnings to be applied to non-piggable pipelines where only the sleeve attribute information is known. The aim of Task 2 is to assess the feasibility and best approach for 'aligning' sleeve data with pipeline route information and the ILI data used in Task 1 of this study.

To support the study, sleeve location and attribute data was requested from each of the participating UKOPA members. Table 4 shows that sleeve data was supplied for all pipelines, with the exception of that operated by WWU. NGGD data was found to be missing sleeve location information.

Information	NGGD	NGN	SGN	WWU	Valero
ILI Pipe Tally	✓	✓	✓	✓	✓
Sleeve Location	×	✓	✓	×	✓
Sleeve Attributes	✓	✓	✓	×	✓
Pipeline Route Data	✓	✓	×	×	×

Table 4: Data Provided by Suppliers

4.2.1 Data Requirements

It is common for pipeline operators to refer to the location of corrosion features or assets (sleeves, valves, etc) that occur along the pipeline as events occurring at a certain distance (chainage) or coordinate location (X/Y). Using this location information it should be possible, for example, to relate an individual corrosion feature to a sleeve.

In order for alignment and subsequent analysis to be successful the pipeline operator needs to maintain a sleeve data source with both location and detailed attribute information. This allows sleeves in the ILI data to be matched to the correct asset information and thus determine which features are beneath which sleeves and of what type. Examples of data types required for sleeves are shown in Table 5.

Sleeve Attributes	
Location/Reference	Crossing Name, Easting/Northing, Girth Weld Number, Pipe Chainage
Sleeve Material	Steel, Concrete
Sleeve Length	(m)
Sleeve Diameter	(mm)
Sleeve Wall Thickness	(mm)
Fill Type	Nitrogen, Cement Grout, Air, Unknown
End Seal Type	Link, U Seal, Epoxy
Sleeve Classification	1, 2, 3, Unknown

Table 5: Example information required for sleeve and feature alignment

4.2.2 Data Alignment Analysis

NGN, SGN and Valero supplied location data for their sleeves. NGN and SGN use Ordnance Survey (OS) coordinates and Valero provided girth weld numbers. This exercise has shown that the alignment of the features to sleeves is feasible with both types of location data. An extract of aligned data can be seen in Table 6 for NGN and Appendix C.2 and E.2 for SGN and Valero respectively.

Girth Weld Number	Absolute Distance (m)	Defect Depth (%)	Feature	Sleeve length (m)	Sleeve diameter (mm)	Sleeve Class	Sleeve end-seal	Annular fill material
12950	14,148.68	9	EXT ML	76.2	1000	1	Other	Unknown
12950	14,149.15	13	EXT ML	76.2	1000	1	Other	Unknown
12950	14,149.28	10	EXT ML	76.2	1000	1	Other	Unknown
12950	14,149.29	9	EXT ML	76.2	1000	1	Other	Unknown
12950	14,149.29	12	EXT ML	76.2	1000	1	Other	Unknown
12950	14,149.40	11	EXT ML	76.2	1000	1	Other	Unknown
12950	14,149.42	7	EXT ML	76.2	1000	1	Other	Unknown
12960	14,155.21	10	EXT ML	76.2	1000	1	Other	Unknown
…								

Table 6: Example of corrosion features and sleeve data combined for NGN

This work has highlighted the importance of complete data. It can be seen with the Valero data in Appendix E.2 that corrosion features have been identified by the ILI tool for which no asset data is available. An extract of aligned data for Valero can be seen in Table 7.

Girth Weld Number	Absolute Distance (m)	Defect Length (mm)	Defect Depth (%)	Feature Class	Sleeve Length (m)	Sleeve Diameter (mm)	Spacer Type
76450	89,626.51	24	2	CIGR	Unknown	406.4	M2 Plastic
76450	89,626.52	35	4	GENE	Unknown	406.4	M2 Plastic
76450	89,634.24	15	20	PITT	Unknown	406.4	M2 Plastic
76470	89,658.95	18	4	CIGR	Unknown	406.4	M2 Plastic
76470	89,658.87	47	18	GENE	Unknown	406.4	M2 Plastic
76470	89,658.69	25	13	PITT	Unknown	406.4	M2 Plastic
76470	89,658.54	94	18	GENE	Unknown	406.4	M2 Plastic
76470	89,658.12	86	7	GENE	Unknown	406.4	M2 Plastic
…							

Table 7: Example of corrosion features and sleeve data combined for Valero

In the case of NGGD and WWU, where location information could not be supplied, it is recommended that the operators investigate collection of this data. For NGGD this location data should be incorporated with the existing sleeve attribute data that is already available and used in their UKOPA sleeve risk ranking model. WWU should consider creation of an asset data repository for sleeve information and a data collection exercise to populate it.

4.2.3 GIS Data Alignment

It has also been demonstrated that where GIS pipeline route information and sleeve location data is available, this can be used to align the pipeline and the ILI features geographically. This could be used to identify potential causes of the corrosion or plan work required. Figure 3 shows a comparison of the location information from the NGN sleeve data (white circles) and sleeves reported by the ILI (black circles with dots), based on the absolute distance reported by the ILI. This shows that while there is a difference between the actual locations from the two sources of data, it is still possible to align the two datasets.

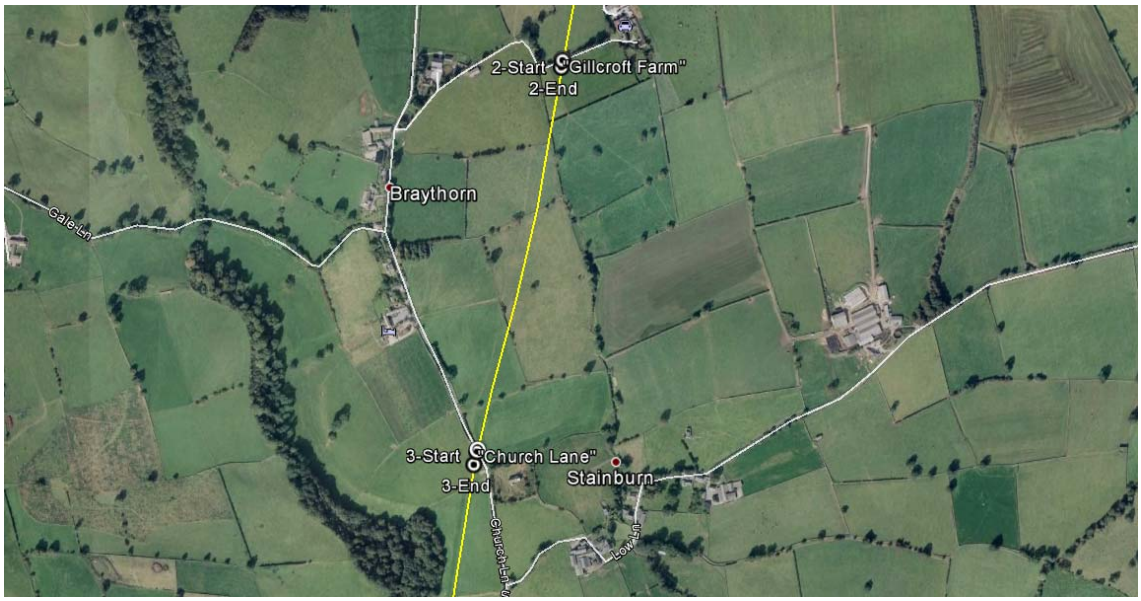


Figure 3: Alignment of sleeve data and ILI data for the NGN pipeline

It has been demonstrated that where the required location information is available sleeve and ILI data can be linked, this process could be extended to a larger population of sleeves/pipelines. To ensure this process is successful it will require the GIS pipeline route information for each pipeline and an accurate coordinate or linear reference (chainage) for the sleeve location.

Detailed results showing the aligned sleeve/ILI data, where available, are presented in the respective Appendix for each pipeline.

5. CONCLUSIONS AND RECOMMENDATIONS

1. This work and the work in Phase 1A1 shows that it is feasible to evaluate external corrosion reported from ILI in an effective manner and identify those features related to sleeves.
2. This phase of work has shown that the number and depth of features within 12 m of a sleeve is higher than for the remainder of the pipeline for three of the five pipelines considered.
3. Corrosion features and sleeve assets that occur along the pipeline can be referenced at a certain distance or coordinate location. Using this information it has been demonstrated that an individual corrosion feature can be linked to a sleeve. This has been successfully demonstrated for three of the operators' data.
4. Where sleeve information is not currently available or attributes are missing, operators should undertake the collection of missing data.
5. Following a data collection exercise, or with data from a limited number of operators, the research work can continue into Phase 1B to evaluate a large population of sleeve and pipeline data.

REFERENCES

1 MACAW Report 6942. ILI Research (Sleeves) Phase 1A. Issue 1, Issued 23/9/2014

APPENDIX A: NGGD RESULTS

A.1 Task 1

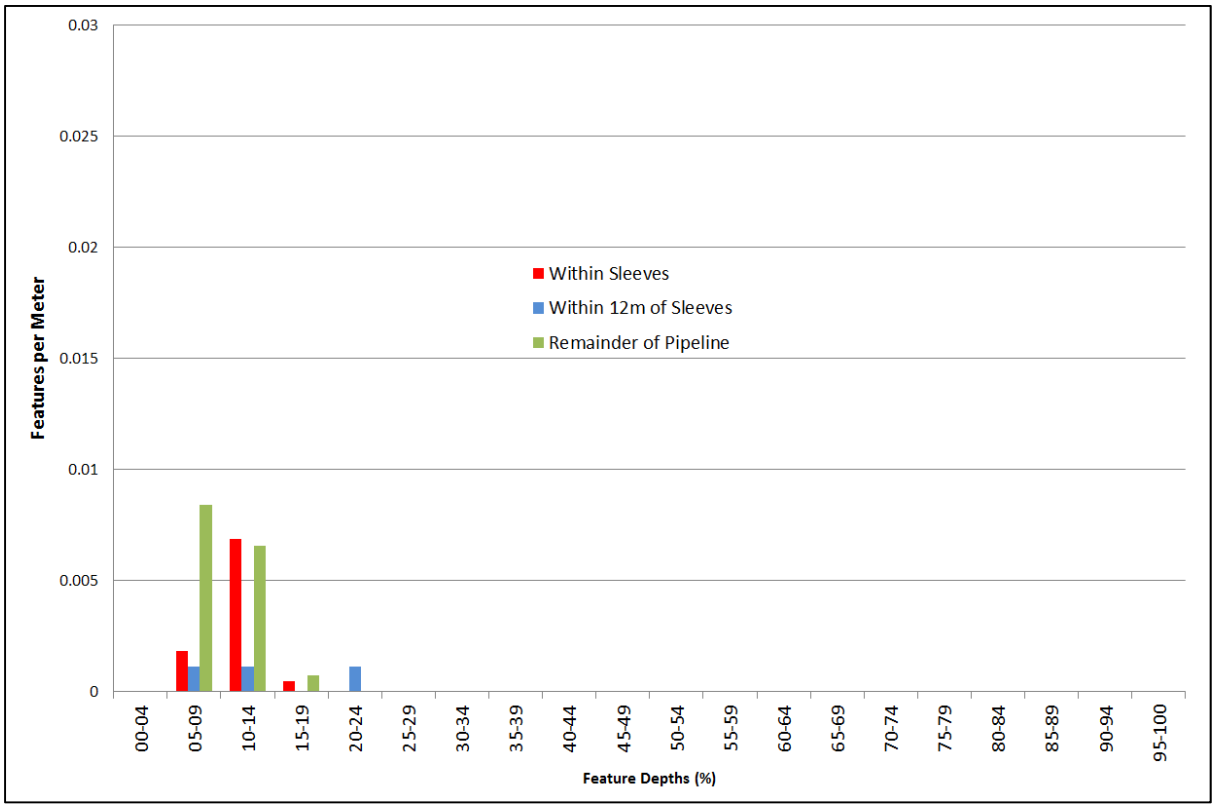


Figure A-1: Feature Distribution along the NGGD Pipeline

Location	Feature Depth (%)																			Total
	00-04	05-09	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-100	
Within Sleeves		4	15	1																	20
Within Sleeves Plus 1m		4	15	1																	20
Within Sleeves Plus 2m		4	15	1																	20
Within Sleeves Plus 3m		4	15	1																	20
Within Sleeves Plus 4m		4	16	1																	21
Within Sleeves Plus 5m		5	16	1																	22
Within Sleeves Plus 6m		5	16	1																	22
Within Sleeves Plus 7m		5	16	1																	22
Within Sleeves Plus 8m		5	16	1	1																23
Within Sleeves Plus 9m		5	16	1	1																23
Within Sleeves Plus 10m		5	16	1	1																23
Within Sleeves Plus 11m		5	16	1	1																23
Within Sleeves Plus 12m		5	16	1	1																23
Within Sleeves Plus 13m		5	16	1	1																23
Within Sleeves Plus 14m		5	16	1	1																23
Within Sleeves Plus 15m		5	16	1	1																23
Within Sleeves Plus 16m		5	17	1	1																24
Within Sleeves Plus 17m		5	19	1	1																26
Within Sleeves Plus 18m		5	20	1	1																27
Within Sleeves Plus 19m		5	20	1	1																27
Within Sleeves Plus 20m		5	20	1	1																27
Within Sleeves Plus 21m		5	21	1	1																28
Within Sleeves Plus 22m		5	21	1	1																28
Within Sleeves Plus 23m		5	21	1	1																28
Within Sleeves Plus 24m		5	21	1	1																28

Table A-1: Feature Counts within, and in close Proximity to, NGGD Sleeves

A.2 Task 2

The sleeve data provided did not contain coordinate information to identify the sleeve location therefore it has not been possible to complete alignment with the ILI data.

APPENDIX B: NGN RESULTS

B.1 Task 1

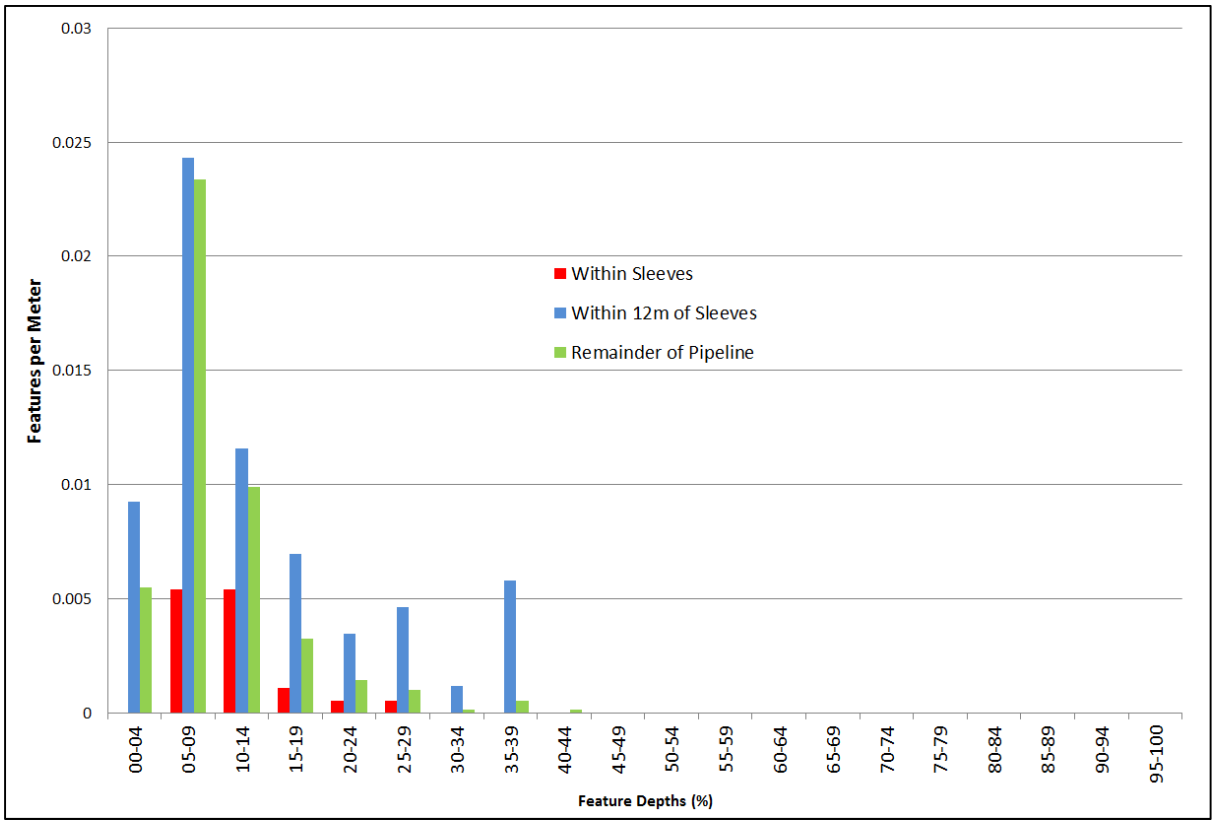


Figure B-1: Feature Distribution along the NGN Pipeline

Location	Feature Depth (%)																			Total
	00-04	05-09	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-100	
Within Sleeves		10	10	2	1	1															24
Within Sleeves Plus 1m		14	12	2	2	2															32
Within Sleeves Plus 2m		14	12	3	2	2		1													34
Within Sleeves Plus 3m	3	18	13	4	4	2	1	2													47
Within Sleeves Plus 4m	3	18	14	4	4	2	1	2													48
Within Sleeves Plus 5m	3	18	14	4	4	2	1	2													48
Within Sleeves Plus 6m	5	24	17	7	4	4	1	4													66
Within Sleeves Plus 7m	5	25	18	7	4	4	1	4													68
Within Sleeves Plus 8m	5	29	19	7	4	4	1	5													74
Within Sleeves Plus 9m	5	29	19	8	4	4	1	5													75
Within Sleeves Plus 10m	6	3	19	8	4	4	1	5													77
Within Sleeves Plus 11m	7	3	19	8	4	5	1	5													79
Within Sleeves Plus 12m	8	31	2	8	4	5	1	5													82
Within Sleeves Plus 13m	13	37	22	8	5	6	1	5	1												98
Within Sleeves Plus 14m	13	46	22	8	5	6	1	5	1												107
Within Sleeves Plus 15m	14	52	23	8	5	7	1	5	1												116
Within Sleeves Plus 16m	14	54	24	9	7	9	1	5	1												124
Within Sleeves Plus 17m	14	55	25	9	7	9	2	5	1												127
Within Sleeves Plus 18m	14	55	25	9	7	9	2	5	1												127
Within Sleeves Plus 19m	15	6	28	10	7	9	2	6	1												138
Within Sleeves Plus 20m	15	62	29	10	7	10	2	6	1												142
Within Sleeves Plus 21m	17	66	3	11	8	11	3	6	1												153
Within Sleeves Plus 22m	17	71	32	13	11	11	3	6	1												165
Within Sleeves Plus 23m	17	73	32	14	11	12	3	6	1												169
Within Sleeves Plus 24m	18	78	33	14	12	12	3	6	1												177

Table B-1: Feature Counts within, and in close Proximity to, NGN Sleeves

B.2 Task 2

NGN Sleeve Information								ILI Data from Pipe Tally	
Location	Easting	Northing	Length	Diameter	Material	Classification	Grout Filled	Absolute Distance to Start (m)	Absolute Distance to End (m)
A651 Bradford Road	419870	429480		1050		1	Not Known	24134.2	24379.0
Yorkshire Martyrs School	420010	429800	61	1050	Steel	1	Pozament	23916.7	23978.1
Raikes Hall Farm	420260	430750	24	1050	Steel	1	Pozament	22957.1	22981.7
Off Raikes Lane	420280	430820	16	1050	Steel	1	Pozament	22882.1	22898.3
Off Tyersal Lane	420340	432000	15	1050	Steel	1	Pozament	21651.4	21666.7
Tyersal Lane	420250	432260	24	1050	Steel	1	Pozament	21339.9	21364.4
Off Tyersal Lane	420250	432420	20	1050	Steel	1	Pozament	21203.9	21223.9
Proposed Motorway	420250	432660	62	1050	Steel	1	Pozament	20892.9	20954.2
Wild Grove Farm Track	420210	432960	21	1050	Steel	1	Pozament	20609.6	20630.7
Rail, Daleside Road/Wild Grove	420080	433367	42	1000	Steel			20158.3	20196.0
A647 Leeds Road	419880	434080	62	1050	Steel	1	Pozament	19366.2	19430.0
Woodhall Lane	420130	435190	32	1050	Steel	1	Pozament	18220.1	18252.4
Priesthorpe Road	420410	435700	30	1050	Steel	1	Pozament	17604.7	17634.1
Down Monson Avenue & across Calverley Lane and Rodley Lane	420995	436670	278.7	1050	Steel			16316.8	16598.8
Rail near River Aire	421471	437630	51.25	1050	Steel			15324.8	15376.0
Sewage Works	421550	437850	9	1050	Steel	1	Pozament	15122.3	15131.6
Woodlands Drive	421700	438270	27	1050	Steel	1	Pozament	14651.2	14679.8
Crossing Knott Lane	422053	438434	76.2	1000	Steel			14145.8	14225.2
Rawdon Road	422180	438500	23	1050	Steel	1	Pozament	14036.0	14071.9
West End Lane	422870	438820	28	1050	Steel	1	Pozament	13219.3	13247.5
Lee Lane	423250	438980	48	1050	Steel	1	Pozament	12727.2	12788.9
Trinity College	423200	439100	248	1050	Steel	1	Pozament	12416.1	12665.0
Scotland Lane	423740	439890	38	1050	Steel	1	Pozament	11422.5	11460.9
Tanhouse Lane	423850	440270	20	1050	Steel	1	Pozament	10954.9	10973.8
Proposed Motorway	423810	440360	14	1050	Steel	1	Pozament	10756.6	10893.9
Dean Grange Farm	423740	440800	12	1050	Steel	1	Pozament	10390.0	10402.2
Oaks Farm	423720	441000	11	1050	Steel	1	Pozament	10193.2	10204.5
None-Go-Bye Farm,Otley Old Rd	423840	442040	27	1050	Steel	1	Pozament	9096.9	9124.2

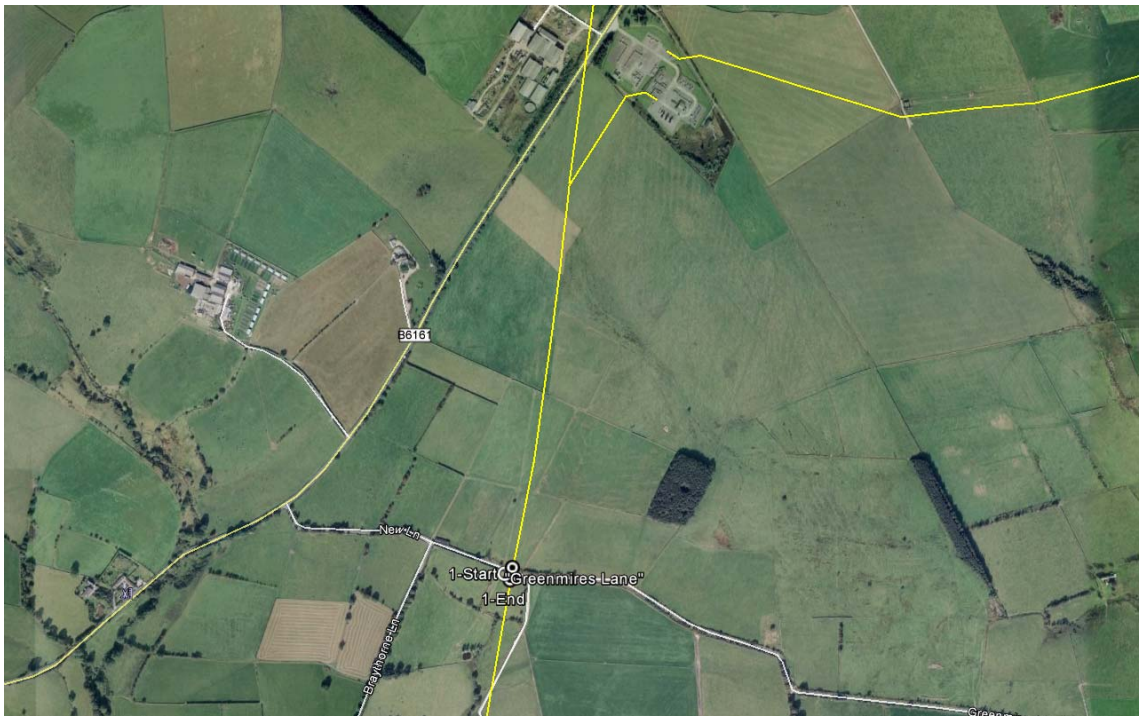
NGN Sleeve Information								ILI Data from Pipe Tally	
Location	Easting	Northing	Length	Diameter	Material	Classification	Grout Filled	Absolute Distance to Start (m)	Absolute Distance to End (m)
Abbey House Farm,Moorland Rd	424040	442620	26	1050	Steel	1	Pozament	8504.1	8530.2
Old Bramhope Lane	424160	443370	24	1050	Steel	1	Pozament	7736.4	7760.7
Track	424190	443449	12	1050	N.K.	1	Pozament	7124.7	7162.9
A660	424320	443950	41	1050	Steel	1	Pozament	6912.3	6952.8
Pool Bank	424370	444150	35	1050	Steel	1	Pozament	6322.9	6348.6
Track	424130	445200	12	1050	Steel	1	Pozament	5781.4	5793.6
A659	424060	445460	30	1050	Steel	1	Pozament	5470.1	5499.4
Leathley Lane	424110	445930	29	1050	Steel	1	Pozament	5005.5	5034.1
Stainburn Lane	424580	447690	29	1050	Steel	1	Pozament	3125.9	3155.4
Church Lane	424680	448600	23	1050	Steel	1	Pozament	2232.8	2256.3
Gillcroft Farm	424830	449280	12	1050	Steel	1	Pozament	1533.1	1545.3
Greenmires Lane	424910	449800	24	1050	Steel	1	Pozament	991.4	1015.8

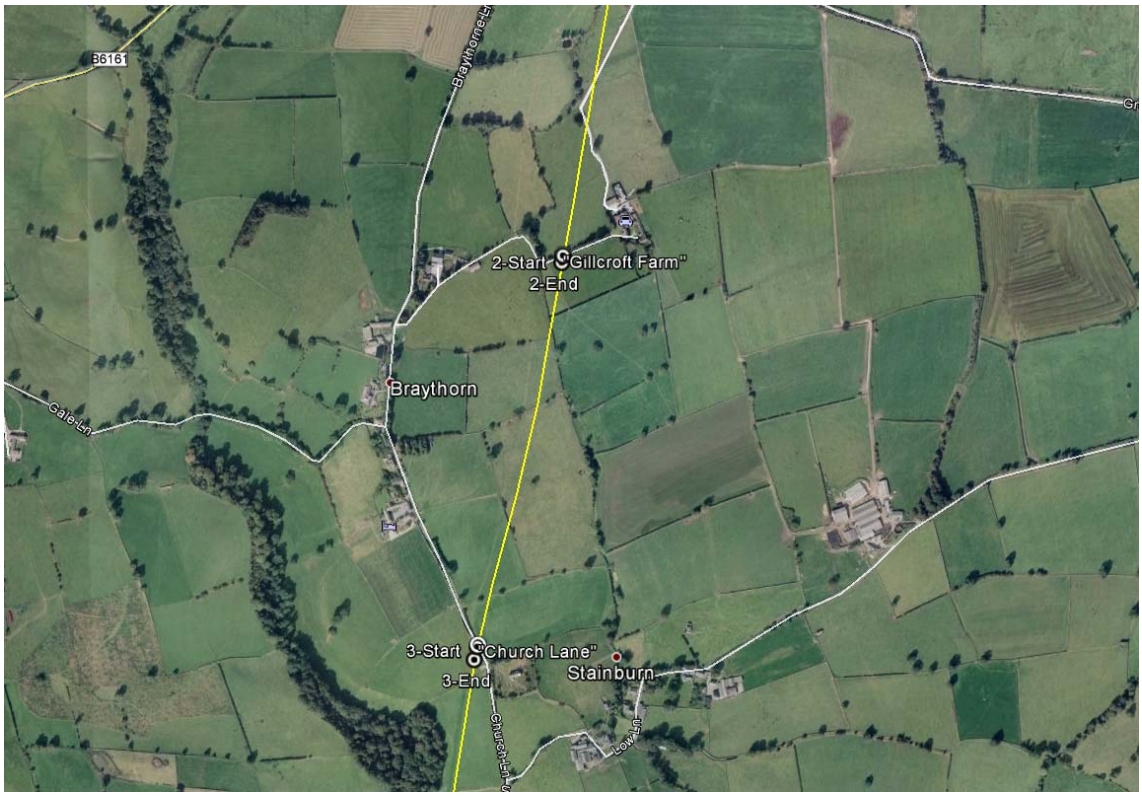
Table B-2: Aligned NGN Sleeve Data and ILI Information

Feature Reference	Absolute Distance (m)	Orientation	Defect Depth (%)	Sleeve Ref	Year of pipe laying	Pipeline Diameter (mm)	Wall thickness (mm)	Coating	Operating pressure (barg)	Piggable (Y/N)	Location	Sleeve Class	Sleeve installation date	Sleeve length (m)	Sleeve diameter (mm)	Sleeve material	Sleeve end-seal	Annular fill material	CP status	N2 annulus status
1	1,008.59	05:00	12	1	1969	762	12.7	Coal Tar	38	Y	Greenmires Lane	1	1969	24	1050	Steel	Other	C/G	Unknown	Not
2	1,533.09	08:45	7	2	1969	762	12.7	Coal Tar	38	Y	Gillcroft Farm	1	1969	12	1050	Steel	Other	C/G	Unknown	Not
3	1,533.11	07:15	15	2	1969	762	12.7	Coal Tar	38	Y	Gillcroft Farm	1	1969	12	1050	Steel	Other	C/G	Unknown	Not
4	1,534.28	07:00	14	2	1969	762	12.7	Coal Tar	38	Y	Gillcroft Farm	1	1969	12	1050	Steel	Other	C/G	Unknown	Not
5	2,246.96	05:45	16	3	1969	762	12.7	Coal Tar	38	Y	Church Lane	1	1969	23	1050	Steel	Other	C/G	Unknown	Not
6	5,011.79	06:30	13	5	1969	762	12.7	Coal Tar	38	Y	Leathley Lane	1	1969	29	1050	Steel	Other	C/G	Unknown	Not
7	5,029.53	09:00	7	5	1969	762	12.7	Coal Tar	38	Y	Leathley Lane	1	1969	29	1050	Steel	Other	C/G	Unknown	Not
8	5,031.41	05:45	9	5	1969	762	12.7	Coal Tar	38	Y	Leathley Lane	1	1969	29	1050	Steel	Other	C/G	Unknown	Not
9	5,033.60	06:00	24	5	1969	762	12.7	Coal Tar	38	Y	Leathley Lane	1	1969	29	1050	Steel	Other	C/G	Unknown	Not
10	6,943.69	08:15	6	9	1969	762	12.7	Coal Tar	38	Y	Pool Bank	1	1969	35	1050	Steel	Other	C/G	Unknown	Not
11	9,117.98	07:30	6	13	1969	762	12.7	Coal Tar	38	Y	None-Go-Bye Farm-Otley Old Rd	1	1969	27	1050	Steel	Other	C/G	Unknown	Not
12	9,118.04	07:15	9	13	1969	762	12.7	Coal Tar	38	Y	None-Go-Bye Farm-Otley Old Rd	1	1969	27	1050	Steel	Other	C/G	Unknown	Not
13	9,118.24	07:15	8	13	1969	762	12.7	Coal Tar	38	Y	None-Go-Bye Farm-Otley Old Rd	1	1969	27	1050	Steel	Other	C/G	Unknown	Not
14	10,891.77	07:15	27	16	1969	762	12.7	Coal Tar	38	Y	Proposed Motorway	1	1969	14	1050	Steel	Other	C/G	Unknown	Not
15	14,148.68	04:15	9	23	1969	762	12.7	Coal Tar	38	Y	Crossing Knott Lane	1	1969	76.2	1000	Steel	Other	Unknown	Unknown	Not
16	14,149.15	12:45	13	23	1969	762	12.7	Coal Tar	38	Y	Crossing Knott Lane	1	1969	76.2	1000	Steel	Other	Unknown	Unknown	Not
17	14,149.28	04:45	10	23	1969	762	12.7	Coal Tar	38	Y	Crossing Knott Lane	1	1969	76.2	1000	Steel	Other	Unknown	Unknown	Not
18	14,149.29	06:30	9	23	1969	762	12.7	Coal Tar	38	Y	Crossing Knott Lane	1	1969	76.2	1000	Steel	Other	Unknown	Unknown	Not
19	14,149.29	08:15	12	23	1969	762	12.7	Coal Tar	38	Y	Crossing Knott Lane	1	1969	76.2	1000	Steel	Other	Unknown	Unknown	Not
20	14,149.40	05:15	11	23	1969	762	12.7	Coal Tar	38	Y	Crossing Knott Lane	1	1969	76.2	1000	Steel	Other	Unknown	Unknown	Not
21	14,149.42	08:15	7	23	1969	762	12.7	Coal Tar	38	Y	Crossing Knott Lane	1	1969	76.2	1000	Steel	Other	Unknown	Unknown	Not
22	14,155.21	03:15	10	23	1969	762	12.7	Coal Tar	38	Y	Crossing Knott Lane	1	1969	76.2	1000	Steel	Other	Unknown	Unknown	Not
23	16,556.88	11:45	11	27	1969	762	12.7	Coal Tar	38	Y	Down Monson Avenue - across Calverley Lane and Rodley Lane	1	1969	278.7	1050	Steel	Rigid	C/G	Unknown	Not
24	23,976.01	12:00	14	39	1969	762	12.7	Coal Tar	38	Y	Yorkshire Martyrs School	1	1969	61	1050	Steel	Other	C/G	Unknown	Not

Table B-3: Aligned ILI Features to NGN Sleeve Data

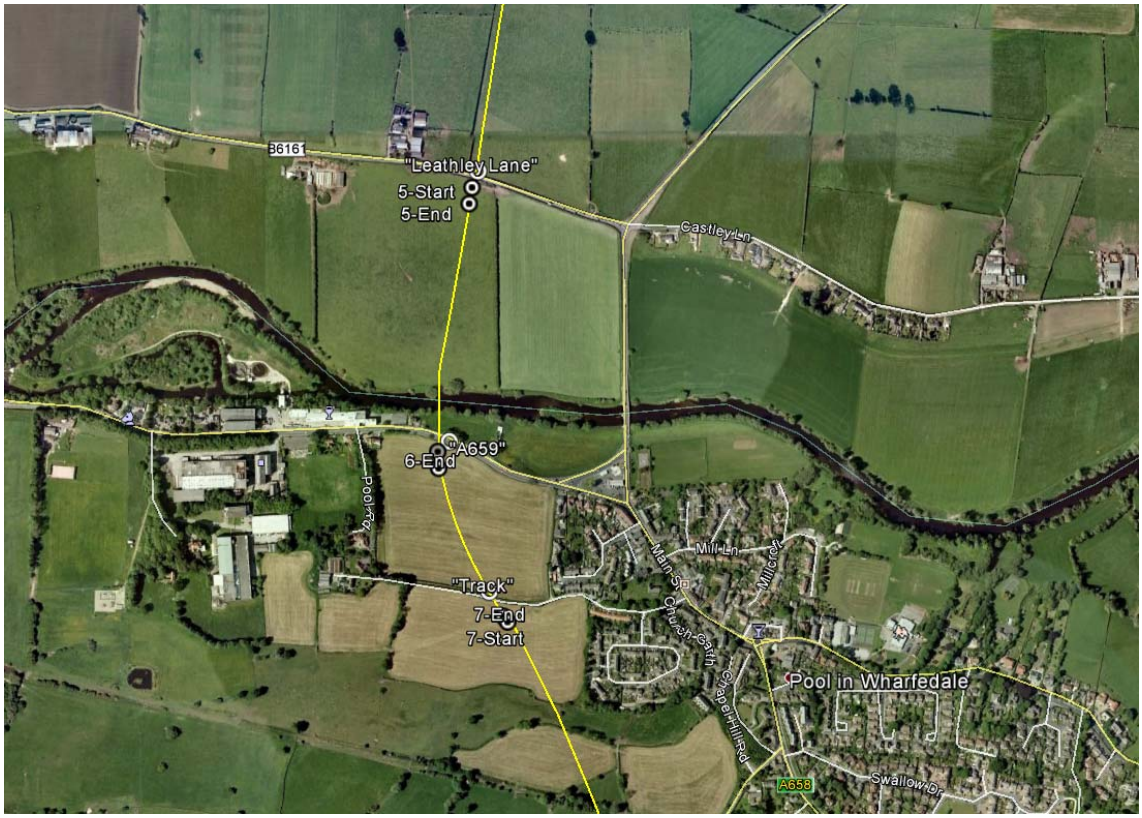
The following figures show aerial photography of the sleeve locations:






Church Ln
Low Ln
Baxter Gate
4-Start
"Stainburn Lane"
4-End
Riffa Ln

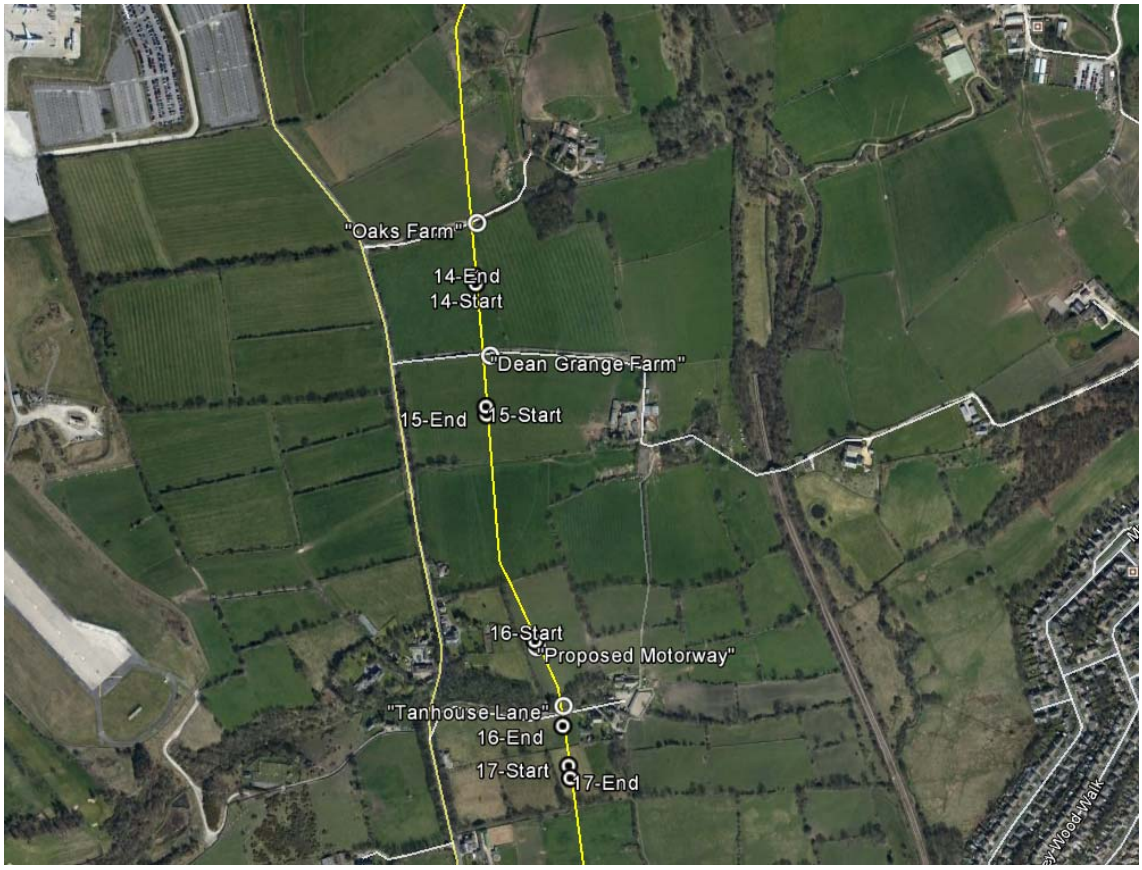

Riffa Ln
Hall Ln
A658


B6161
"Leathley Lane"
5-Start
5-End
Castley Ln
"A659"
6-End
Pool Rd
"Track"
7-End
7-Start
Mill Ln
Main St
Church Garth
Chapel Hill Rd
Mill Cres
Pool in Wharfedale
A658
Swallow Dr

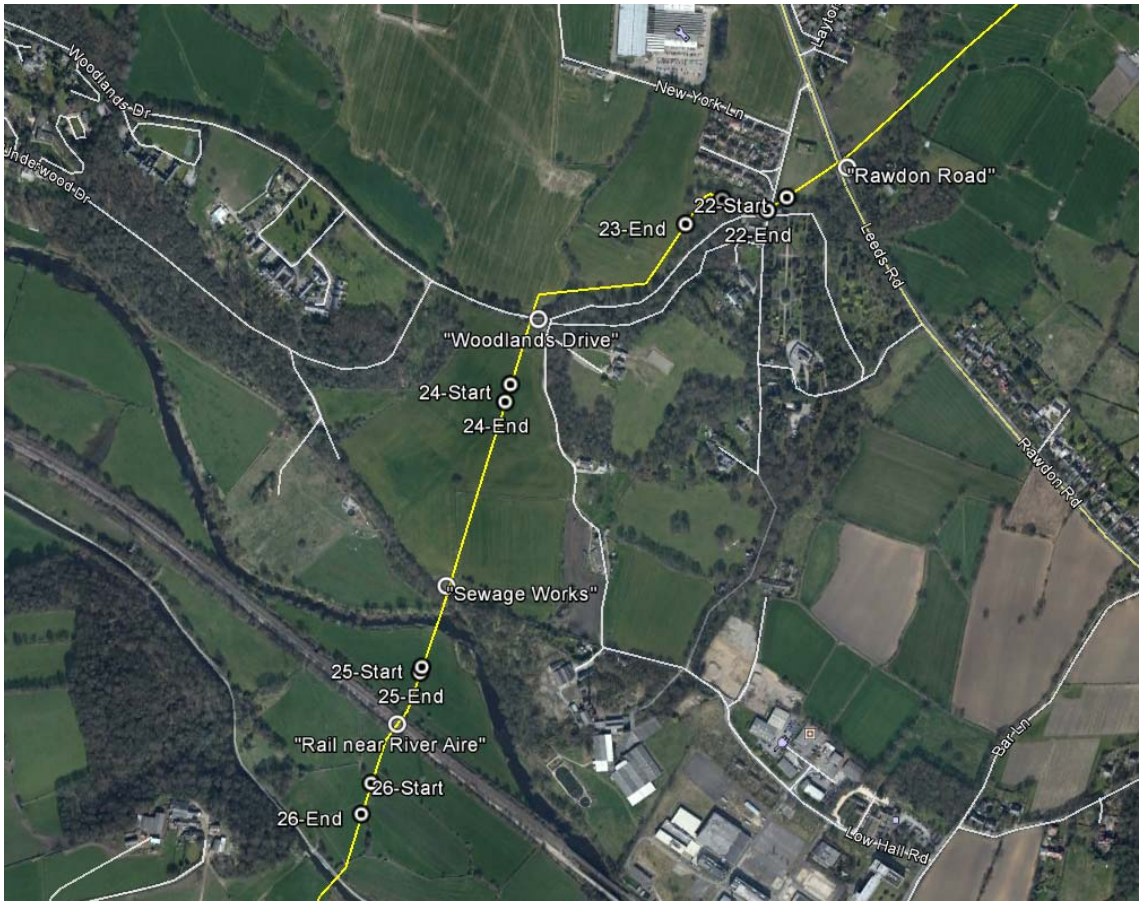

A658
Swallow Dr
Old Pool Bank
8-End
Avenue Des Hirondelles
Acorn Way
The Tower Dr
Cabin Rd
A660
"Pool Bank"
9-Start
9-End
Pool Bank New Rd
"A660"
10-Start
10-End
Staircase Ln


Milton Grange
Old Bramhope
"Track"
"Old Bramhope Lane"
11-End
Churchgate
Eastgate
Occupation Ln
Moor Rd
"Abbey House Farm Moorland Rd"
12-End
12-Start


"None Go Bye Farm Otley Old Rd"
Otley Old Rd
13-Start
13-End
Dean Ln
Dean Head
Scotland Ln


"Oaks Farm"
14-End
14-Start
"Dean Grange Farm"
15-End
15-Start
16-Start
"Proposed Motorway"
"Tanhouse Lane"
16-End
17-Start
17-End

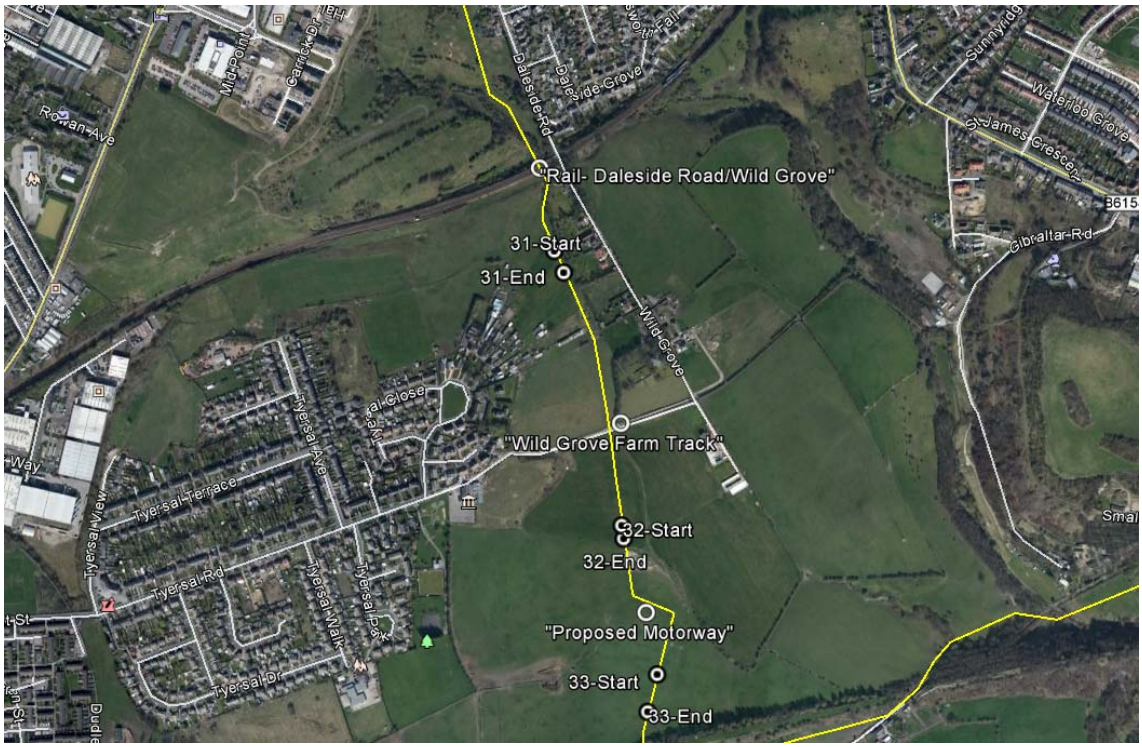

18-Start
18-End
"Scolland Lane"
Baylon Ln
Layton Rd
Brownberrie Ln
19-Start
"Trinity College"
"Lee Lane"
19-End
20-Start
20-End
21-End
"West End Lane"
Southway
W End Ln
Westbrook Ln
St Margarets Rd
Stanhope Ave
© 2015 Google

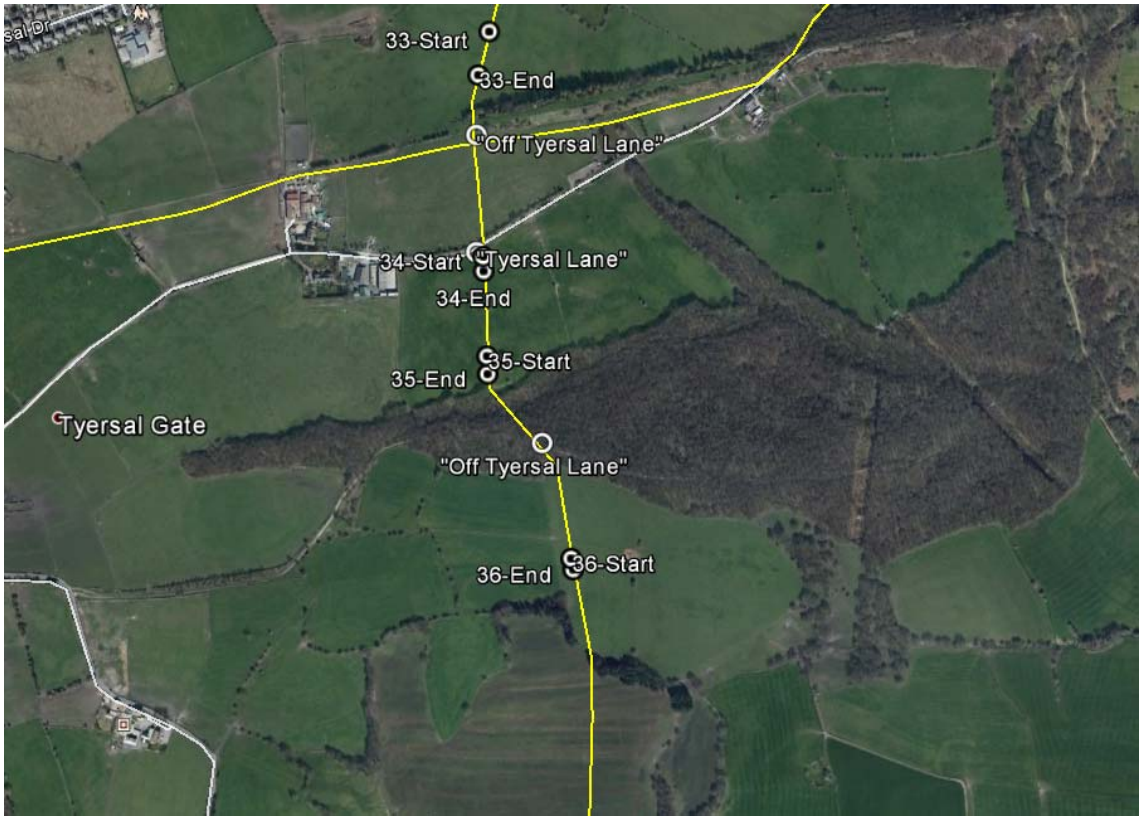

Woodlands-Dr
New-York-Ln
"Rawdon Road"
22-Start
23-End
22-End
Leeds-Rd
"Woodlands Drive"
24-Start
24-End
Rawdon-Rd
"Sewage Works"
25-Start
25-End
"Rail near River Aire"
26-Start
26-End
Low-Hall-Rd
Bar-Ln

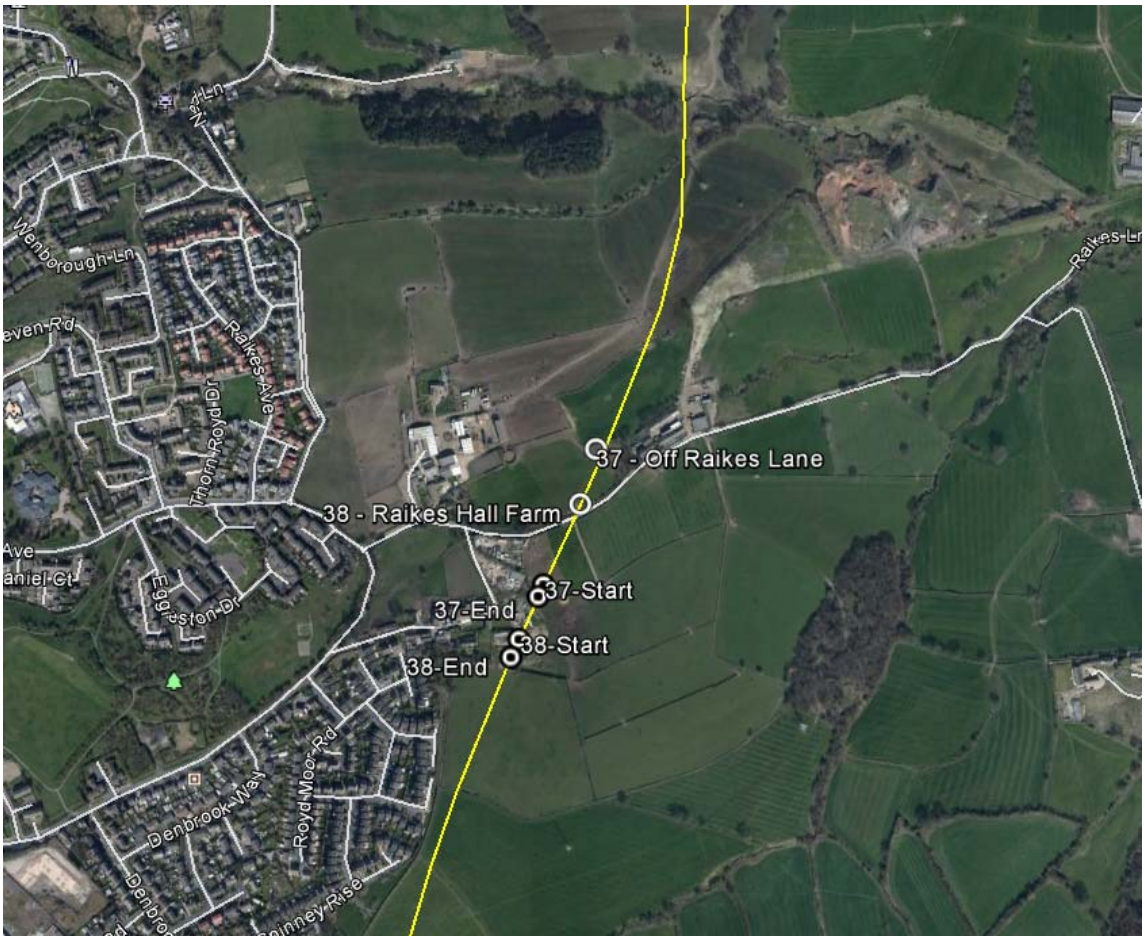

A657
Calverley
Pearson-St
St-Wilfreds-St
Blackett-St
W-End-Rd
Portman-St
Victoria-St
Thornhill-St
Chapel-St
Town-Gate
B6156
Rodley-Ln
27-Start
"Down Monson Avenue & across Calverley Lane and Rodley Lane"
Upper-Carr-Ln
Foxholes-Crescent
Woodhall-Rd
Hollin-Park-Rd
27-End
Farsley

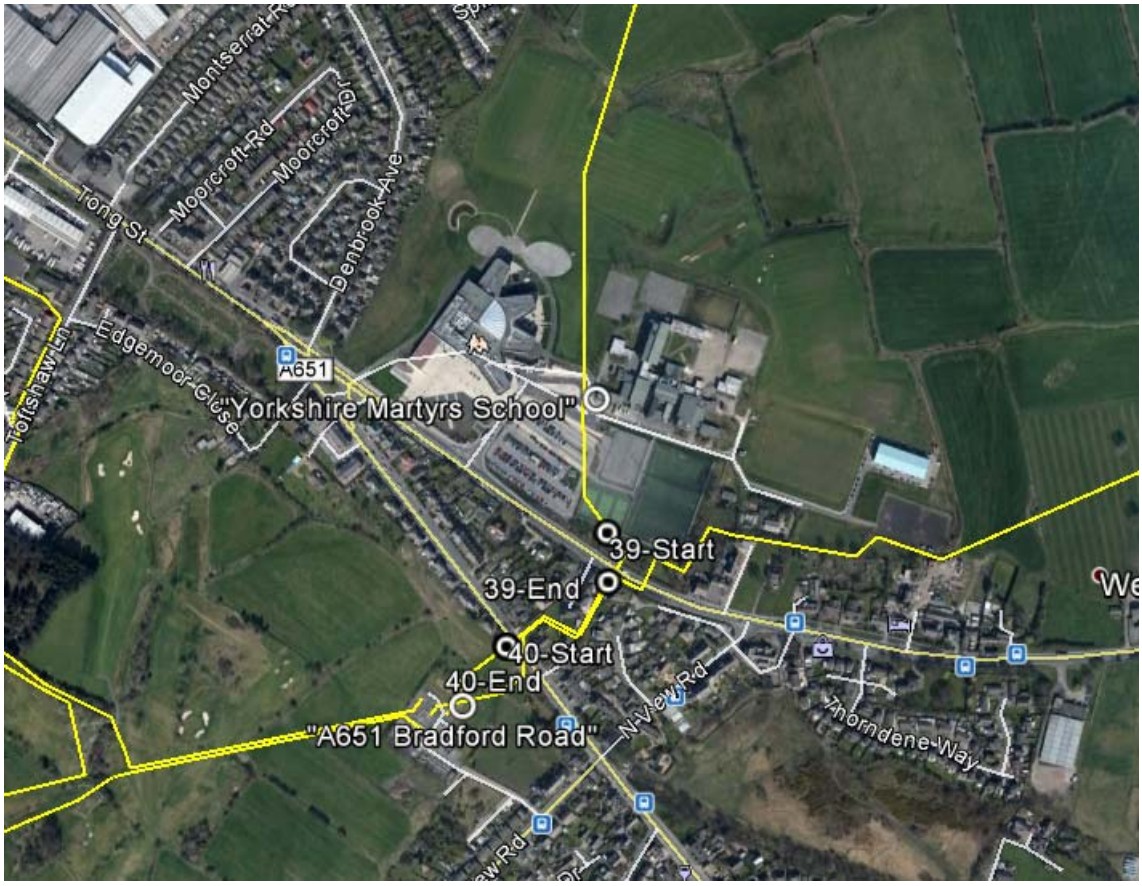

Woodhall Rd
Shell Ln
Priesthorpe Rd
"Priesthorpe Road"
28-Start
28-End
Woodhall Hills
"Woodhall Lane"
Rockwood Crescent
29-Start
29-End


Farm Pass
Rockwood Rd
Woodhall Park Ave
Woodhall Close
Woodhall Park Grove
Woodhall Ln
Sunnybank Ln
Woodhall Rd
Woodhall Terrace
"A647 Leeds Road"
B6154
Calverley Moor Ave
Moorland Rd
Moorland Dr
Galloway Ln
30-Start
30-End
B6381
Old Rd
Gipsy St
Alder Dr


Rail- Daleside Road/Wild Grove"
Daleside Rd
Daleside Grove
Waterloo Grove
St James Cresc
Gibraltar Rd
31-Start
31-End
Wild Grove
"Wild Grove Farm Track"
Tyersal Terrace
Tyersal Ave
Tyersal Rd
Tyersal Walk
Tyersal Park
Tyersal Dr
32-Start
32-End
"Proposed Motorway"
33-Start
33-End


33-Start
33-End
"Off Tyersal Lane"
34-Start
Tyersal Lane"
34-End
35-Start
35-End
Tyersal Gate
"Off Tyersal Lane"
36-End
36-Start


Wenborough Ln
Rakes Ave
Thorn Royd Dr
37 - Off Raikes Lane
38 - Raikes Hall Farm
37-Start
37-End
38-Start
38-End
Royd Moor Rd
Denbrook Way
Rakes Ln


Montserrat Rd
Moorcroft Rd
Moorcroft Dr
Tong St
Genbrook Ave
Edgemoor Close
Tofts Shaw Ln
A651
"Yorkshire Martyrs School"
39-Start
39-End
40-Start
40-End
"A651 Bradford Road"
N View Rd
Thorndene Way

APPENDIX C: SGN RESULTS

C.1 Task 1

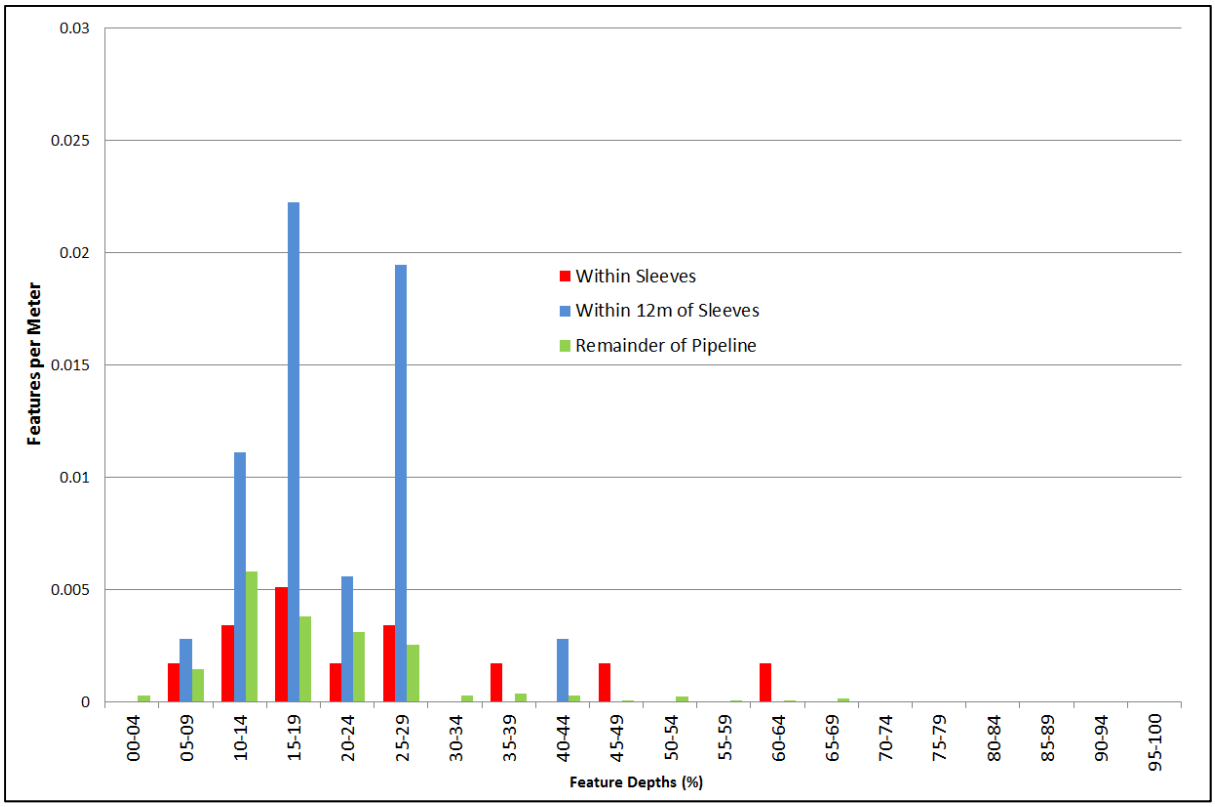


Figure C-1: Feature Distribution along the SGN Pipeline

Location	Feature Depth (%)																			Total
	00-04	05-09	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-100	
Within Sleeves		1	2	3	1	2		1		1			1								12
Within Sleeves Plus 1m		1	3	4	3	3		1		1			1								17
Within Sleeves Plus 2m		1	4	4	3	3		1		1			1								18
Within Sleeves Plus 3m		1	4	4	3	3		1		1			1								18
Within Sleeves Plus 4m		1	4	4	3	3		1		1			1								18
Within Sleeves Plus 5m		1	4	4	3	4		1		1			1								19
Within Sleeves Plus 6m		1	4	4	3	4		1		1			1								19
Within Sleeves Plus 7m		1	5	4	3	4		1		1			1								20
Within Sleeves Plus 8m		1	6	5	3	4		1		1			1								22
Within Sleeves Plus 9m		1	6	9	3	5		1		1			1								27
Within Sleeves Plus 10m		1	6	11	3	9		1		1			1								33
Within Sleeves Plus 11m		2	6	11	3	9		1		1			1								34
Within Sleeves Plus 12m		2	6	11	3	9		1	1	1			1								35
Within Sleeves Plus 13m		2	6	11	3	9		1	1	1			1								35
Within Sleeves Plus 14m		2	6	11	3	9		1	1	1			1								35
Within Sleeves Plus 15m		2	6	11	3	10		2	1	1			1								37
Within Sleeves Plus 16m		2	6	12	3	10		2	1	1			1								38
Within Sleeves Plus 17m		2	6	12	3	10		2	1	1			1								38
Within Sleeves Plus 18m		2	6	12	3	10		2	1	1			1								38
Within Sleeves Plus 19m		2	6	13	3	10		2	1	1			1								39
Within Sleeves Plus 20m		2	6	13	3	10		2	1	1			1								39
Within Sleeves Plus 21m		2	6	13	3	10		2	1	1			1								39
Within Sleeves Plus 22m		2	6	13	3	10		2	1	1			1								39
Within Sleeves Plus 23m		2	8	14	3	10		2	1	1			1								42
Within Sleeves Plus 24m		2	8	16	3	10		2	1	1			1								44

Table C-1: Feature Counts within, and in close Proximity to, SGN Sleeves

C.2 Task 2

Feature ID	Absolute Distance m	Defect Depth	Sleeve Ref	Sleeve ID	Coating	Protection reason	Sleeve Class	Sleeve installation date	Sleeve length (m)	Sleeve diameter (mm)	Sleeve material	Sleeve end-seal	Annular fill material	DESCRIPTION	Start OS Grid Reference	End OS Grid Reference	Drawing Number	Wall Thickness (mm)
1	4,975.88	15	6	640046649	UNKNOWN	Road		1965	82.3	350	STEEL	Other	AIR	BELLSHILL RD RDX UDDINGSTON - MOTHERWELL	0271675 0659016	0271594 0659027	T/CE19/E44/9003	7.92
2	7,093.45	8	8	640046575	UNKNOWN	Rail		1965	25.6	350	STEEL	Rigid	NITROGEN	RYX NEAR BELLSHILL G.C. UDDINGSTON - MOTHERWELL	0273426 0658605	0273418 0658582	T/CE19/E44/9005	7.92
3	7,099.12	13	8	640046575	UNKNOWN	Rail		1965	25.6	350	STEEL	Rigid	NITROGEN	RYX NEAR BELLSHILL G.C. UDDINGSTON - MOTHERWELL	0273426 0658605	0273418 0658582	T/CE19/E44/9005	7.92
4	7,100.29	15	8	640046575	UNKNOWN	Rail		1965	25.6	350	STEEL	Rigid	NITROGEN	RYX NEAR BELLSHILL G.C. UDDINGSTON - MOTHERWELL	0273426 0658605	0273418 0658582	T/CE19/E44/9005	7.92
5	7,093.45	22	8	640046575	UNKNOWN	Rail		1965	25.6	350	STEEL	Rigid	NITROGEN	RYX NEAR BELLSHILL G.C. UDDINGSTON - MOTHERWELL	0273426 0658605	0273418 0658582	T/CE19/E44/9005	7.92
6	7,093.89	49	8	640046575	UNKNOWN	Rail		1965	25.6	350	STEEL	Rigid	NITROGEN	RYX NEAR BELLSHILL G.C. UDDINGSTON - MOTHERWELL	0273426 0658605	0273418 0658582	T/CE19/E44/9005	7.92
7	7,100.20	61	8	640046575	UNKNOWN	Rail		1965	25.6	350	STEEL	Rigid	NITROGEN	RYX NEAR BELLSHILL G.C. UDDINGSTON - MOTHERWELL	0273426 0658605	0273418 0658582	T/CE19/E44/9005	7.92
8	8,114.29	26	11	640046578	BITUMEN	Road	2	1965	24.4	350	STEEL	Rigid	NITROGEN	A721 BELLSHILL ROAD UDDINGSTON - MOTHERWELL	0274267 0658465	0274244 0658453	T/CE19/E44/9006	6.4
9	8,758.52	13	12	640046576	UNKNOWN	Road		1965	16.4	350	STEEL	Rigid	NITROGEN	SOUTH CALDER RVX UDDINGSTON - MOTHERWELL	0273754 0658650	0273736 0658647	T/CE19/E44/9005	7.92
10	8,758.53	17	12	640046576	UNKNOWN	Road		1965	16.4	350	STEEL	Rigid	NITROGEN	SOUTH CALDER RVX UDDINGSTON - MOTHERWELL	0273754 0658650	0273736 0658647	T/CE19/E44/9005	7.92
11	8,758.58	25	12	640046576	UNKNOWN	Road		1965	16.4	350	STEEL	Rigid	NITROGEN	SOUTH CALDER RVX UDDINGSTON - MOTHERWELL	0273754 0658650	0273736 0658647	T/CE19/E44/9005	7.92
12	8,758.58	39	12	640046576	UNKNOWN	Road		1965	16.4	350	STEEL	Rigid	NITROGEN	SOUTH CALDER RVX UDDINGSTON - MOTHERWELL	0273754 0658650	0273736 0658647	T/CE19/E44/9005	7.92

Table C-2: Aligned ILI Features to SGN Sleeve Data

APPENDIX D: WWU RESULTS

D.1 Task 1

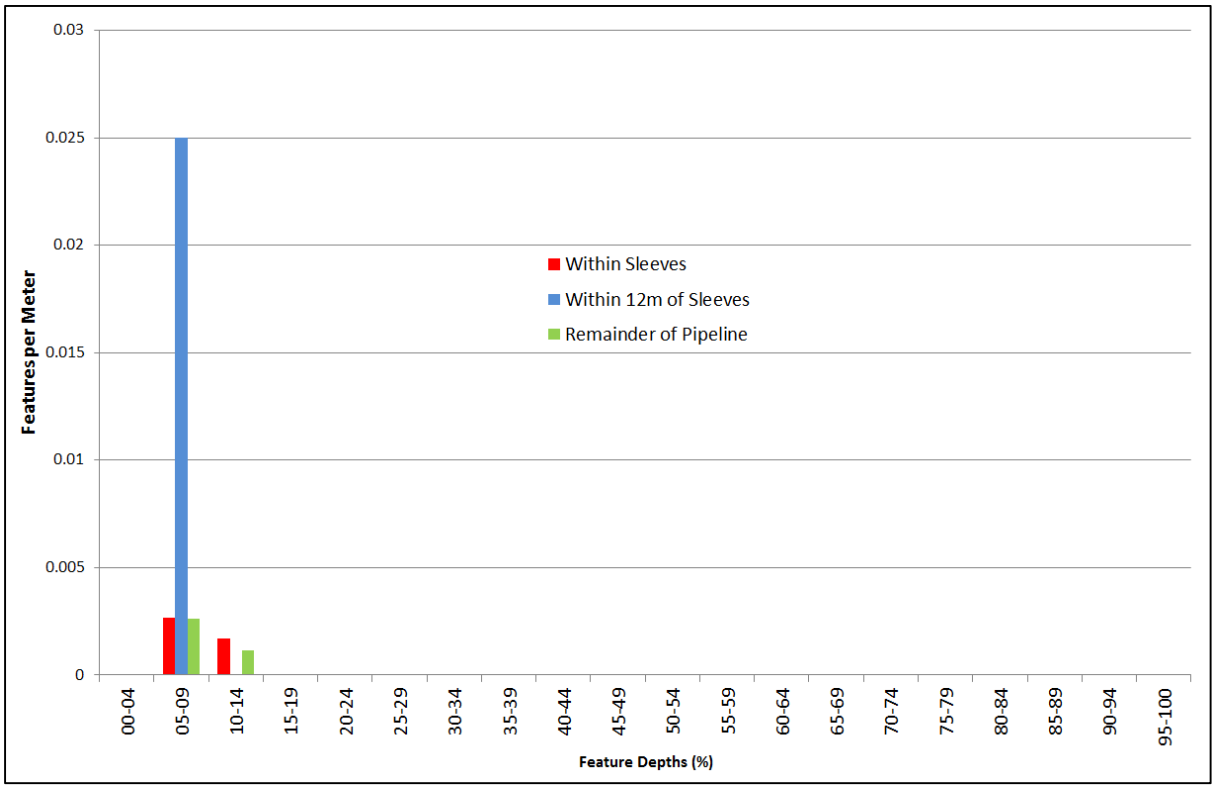


Figure D-1: Feature Distribution along the WWU Pipeline

Location	Feature Depth (%)																			Total
	00-04	05-09	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-100	
Within Sleeves	0	11	7																		18
Within Sleeves Plus 1m	0	20	7																		27
Within Sleeves Plus 2m	0	20	7																		27
Within Sleeves Plus 3m	0	20	7																		27
Within Sleeves Plus 4m	0	20	7																		27
Within Sleeves Plus 5m	0	20	7																		27
Within Sleeves Plus 6m	0	20	7																		27
Within Sleeves Plus 7m	0	20	7																		27
Within Sleeves Plus 8m	0	20	7																		27
Within Sleeves Plus 9m	0	20	7																		27
Within Sleeves Plus 10m	0	20	7																		27
Within Sleeves Plus 11m	0	20	7																		27
Within Sleeves Plus 12m	0	20	7																		27
Within Sleeves Plus 13m	0	20	7																		27
Within Sleeves Plus 14m	0	20	7																		27
Within Sleeves Plus 15m	0	20	7																		27
Within Sleeves Plus 16m	0	20	7																		27
Within Sleeves Plus 17m	0	20	7																		27
Within Sleeves Plus 18m	0	20	7																		27
Within Sleeves Plus 19m	0	20	7																		27
Within Sleeves Plus 20m	0	20	7																		27
Within Sleeves Plus 21m	0	24	7																		31
Within Sleeves Plus 22m	0	25	8																		33
Within Sleeves Plus 23m	0	25	8																		33
Within Sleeves Plus 24m	0	25	8																		33

Table D-1: Feature Counts within, and in close Proximity to, WWU Sleeves

D.2 Task 2

No sleeve data was supplied for this project.

APPENDIX E: VALERO RESULTS

E.1 Task 1

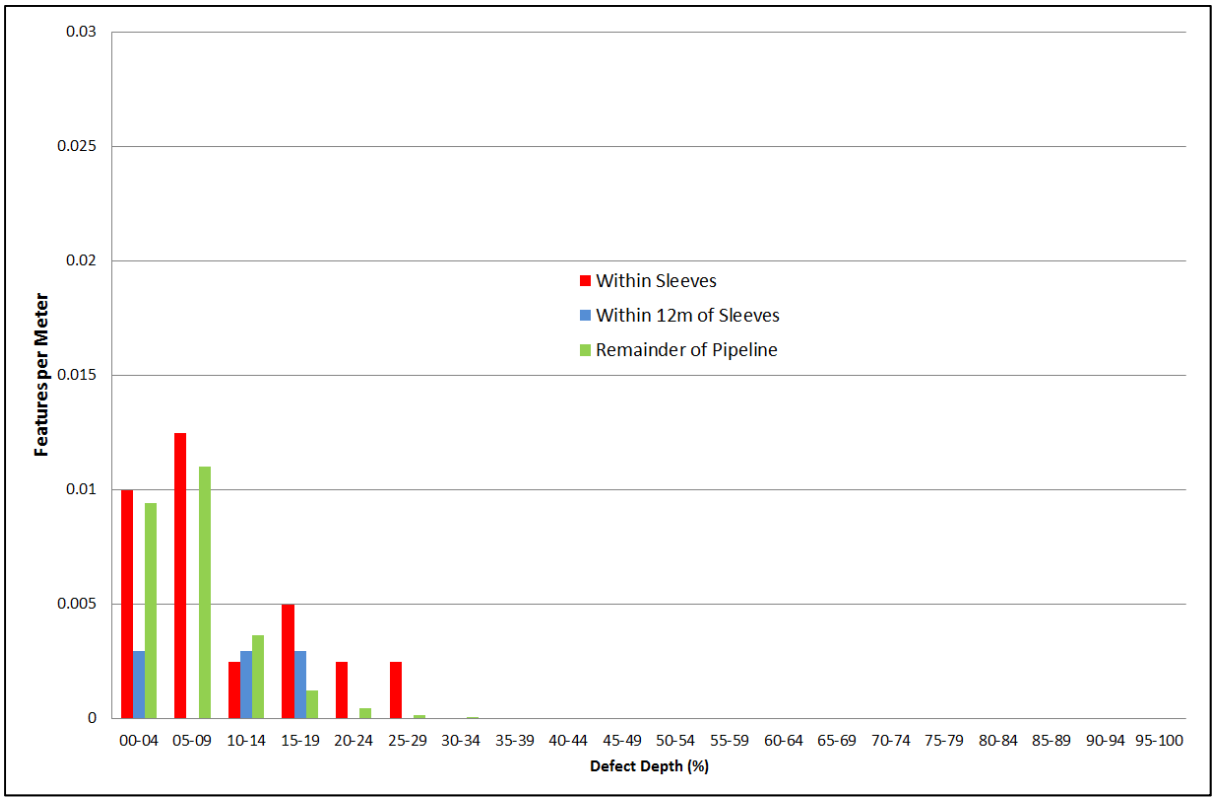


Figure E-1: Feature Distribution along the Valero Pipeline

Location	Feature Depth (%)																			Total
	00-04	05-09	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-100	
Within Sleeves	4	5	1	2	1	1															14
Within Sleeves Plus 1m	4	5	1	2	1	1															14
Within Sleeves Plus 2m	4	5	1	2	1	1															14
Within Sleeves Plus 3m	5	5	1	2	1	1															15
Within Sleeves Plus 4m	5	5	1	2	1	1															15
Within Sleeves Plus 5m	5	5	1	2	1	1															15
Within Sleeves Plus 6m	5	5	1	2	1	1															15
Within Sleeves Plus 7m	5	5	2	3	1	1															17
Within Sleeves Plus 8m	5	5	2	3	1	1															17
Within Sleeves Plus 9m	5	5	2	3	1	1															17
Within Sleeves Plus 10m	5	5	2	3	1	1															17
Within Sleeves Plus 11m	5	5	2	3	1	1															17
Within Sleeves Plus 12m	5	5	2	3	1	1															17
Within Sleeves Plus 13m	5	5	2	3	1	1															17
Within Sleeves Plus 14m	5	5	2	3	1	1															17
Within Sleeves Plus 15m	5	5	2	3	1	1															17
Within Sleeves Plus 16m	5	5	2	3	1	1															17
Within Sleeves Plus 17m	5	5	2	3	1	1															17
Within Sleeves Plus 18m	5	5	2	3	1	1															17
Within Sleeves Plus 19m	5	5	2	3	1	1															17
Within Sleeves Plus 20m	5	6	2	3	1	1															18
Within Sleeves Plus 21m	5	7	2	3	1	1															19
Within Sleeves Plus 22m	5	7	2	3	1	1															19
Within Sleeves Plus 23m	6	8	2	3	1	1															21
Within Sleeves Plus 24m	7	9	3	3	1	1															24

Table E-1: Feature Counts within, and in close Proximity to Valero Sleeves

E.2 Task 2

Feature Number	Girth Weld Number	Absolute Distance m	Relative Distance m	Joint Length m	Wall Thickness mm	Orientation	Defect Length mm	Defect Width mm	Defect Depth	Feature Class	Sleeve Ref	Distance	Type	Girth Weld Number	Length	Diameter	Sleeve Thickness	Spacer Type
1	76,450	89,626.51	4.632	12.622	6.35	01:48	24	70	2	CIGR	5	89,616.77	Road	76440	Unknown	406.4	N/A	M2 Plastic
2	76,450	89,626.52	4.635	12.622	6.35	00:42	35	59	4	GENE	5	89,616.77	Road	76440	Unknown	406.4	N/A	M2 Plastic
3	76,450	89,634.24	12.352	12.622	6.35	04:52	15	13	20	PITT	5	89,616.77	Road	76440	Unknown	406.4	N/A	M2 Plastic
4	76,470	89,658.95	11.754	11.802	6.35	05:40	18	262	4	CIGR	5	89,680.29	Road	76440	Unknown	406.4	N/A	M2 Plastic
5	76,470	89,658.87	11.673	11.802	6.35	05:50	47	55	18	GENE	5	89,680.29	Road	76440	Unknown	406.4	N/A	M2 Plastic
6	76,470	89,658.69	11.494	11.802	6.35	06:16	25	49	13	PITT	5	89,680.29	Road	76440	Unknown	406.4	N/A	M2 Plastic
7	76,470	89,658.54	11.353	11.802	6.35	05:58	94	94	18	GENE	5	89,680.29	Road	76440	Unknown	406.4	N/A	M2 Plastic
8	76,470	89,658.12	10.931	11.802	6.35	04:20	86	80	7	GENE	5	89,680.29	Road	76440	Unknown	406.4	N/A	M2 Plastic
9	76,470	89,658.06	10.871	11.802	6.35	03:48	35	15	7	AXGR	5	89,680.29	Road	76440	Unknown	406.4	N/A	M2 Plastic
10	76,470	89,647.20	0.009	11.802	6.35	06:02	34	326	8	GENE	5	89,616.77	Road	76440	Unknown	406.4	N/A	M2 Plastic
11	76,470	89,647.22	0.024	11.802	6.35	03:06	20	104	6	CIGR	5	89,616.77	Road	76440	Unknown	406.4	N/A	M2 Plastic
12	86,840	101,746.25	6.894	9.321	6.35	07:50	26	38	3	PITT	9	101,746.04	Sleeve not identified					
13	87,400	102,361.51	8.774	12.658	6.35	03:26	38	32	5	GENE	10	102,363.34	Sleeve not identified					
14	93,220	108,667.75	0.051	6.242	6.35	11:40	15	10	28	PITT	12	108,656.68	Rail	93200	Unknown	Unknown	7.9248	M2 Plastic

Table E-2: Aligned ILI Features to Sleeve Data