Using ILI to Establish Confidence in TVC Records

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Abstract

The use of In-Line Inspection (ILI) technology can be critical in establishing confidence in records that are considered Traceable, Verifiable, and Complete (TVC), especially where TVC status was established prior to recent amendments under 49 CFR 192. Accurate records are essential to many pipeline integrity management and operational functions including but not limited to: Maximum Allowable Operating Pressure reconfirmation (MAOP-R), anomaly failure pressure calculations, Engineering Critical Assessment, quantitative risk assessments (QRA), and compliance with the proposed revisions to class location change requirements. Validating these records can be a complex and labor-intensive process.

The use of ILI can significantly streamline the validation process, reducing the burden of manual verification and enhancing the reliability of records. This approach not only ensures compliance with current and proposed regulations but also supports the integrity and safety of pipeline operations. The integration of ILI data with GIS data and records offers a comprehensive solution for pipeline operators, facilitating more informed decision-making and proactive risk management.

This study explores the application of ILI as a tool to validate existing records. By comparing ILI data with GIS data and historical records, we aim to establish a higher level of confidence in the accuracy and completeness of these records and the ability of the GIS data to accurately represent the current materials in the pipeline. The methodology involves a detailed analysis of ILI data to identify discrepancies and gaps in the existing GIS data and records, thereby providing a robust foundation for regulatory compliance and risk management.

Background

Several sections of 49 CFR 192 require Operators to have Traceable, Verifiable and Complete records of material properties and attributes to support Pipeline Integrity (PI) processes. For many Operators MAOP-reconfirmation under § 192.624 method 1, Pressure Test, method 3, Engineering Critical Assessment (ECA) conducted in accordance with § 192.632, or certain methodologies under method 6, Alternative Technology[1] are top-of-mind. Other sections of 49 CFR 192 that require TVC records for material properties and attributes include:

- Predicted failure calculations under §192.712
- Repair Criteria under §192.714
- Direct Assessment for Stress Corrosion Cracking under §192.929
- Address Integrity Issues under §192.933
- Maximum safe pressure after considering and accounting for records of material properties under §192.619(a)(4)
    - Several other regulatory sections reference those listed above, thereby indirectly referencing material verification requirements

[1] Certain approaches to MAOP-R under method 6, Alternative Technologies, may not require material verification. Example; MAOP-R using pipeline reinforcement. Other approaches under method 6 or MAOP-R under method 1, Pressure Test or method 3 ECA require material verification.

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Where Operators consider the use of conservative assumptions for material properties and attributes lacking TVC records, operators must[2] also include those non-TVC material attributes in their material verification program.

One of the key variables impacting the results of the PI processes listed above, and the quality of the decisions based thereon, is how accurately the material attributes used in the analysis represent the current materials in the pipeline. While TVC records are a key foundation for material attributes, available records may not reflect poorly documented or undocumented changes to the pipeline. Integrating material attribute information from other sources, whether such sources address all required attributes or not, may assist in either validating or identifying gaps in TVC records and related GIS data.

'In a risk-based IM approach, data collection and integration is the backbone of an effective IM program.' [1]

The foregoing quote from the preamble to the revisions to 49 CFR 192 published in August of 2022 (RIN-2) provides a key insight into the importance of data integration in federal regulations. The term 'data integration' appears many times in 49 CFR 192 including but not limited to; §192.911, elements of an IM program; §192.917, identification of potential threats to pipeline integrity and threat identification; §192.925, use of ECDA; §192.937, continual process of evaluation and assessment to maintain a pipeline's integrity, and, §192.939, required assessment intervals.

ASME/ANSI B31.8S, Managing System Integrity of Gas Pipelines, section 4.5 discusses data integration at length using the word 'shall' in reference to the process.

'For integrity management program applications, one of the first data integration steps includes development of a common reference system (and consistent measurement units) that will allow data elements from various sources to be combined and accurately associated with common pipeline locations.' [2]

API Standard 1163, In-line Inspection System Qualification, section 8.2.4 Discrepancy Analysis of Pipeline Component Records states, in part;

'this section is provided as a method for validating that pipeline component location and attributes are consistent with records contained in a pipeline operators GIS system and/or alignment sheets.' [3]

[2] The regulatory guidance and FAQs are somewhat at odds on this point. §192.712(e)(2) indicates "If documented data required for any analysis is not available, an operator must obtain the undocumented data through § 192.607." FAQ-60 indicates "PHMSA considers pipeline segments that have an established and documented MAOP using 24,000 psig for the yield strength (per § 192.107(b)(2)) to have a TVC material property record for yield strength." Note this FAQ only addresses yield strength and in many cases the established and documented MAOP is not supported by 24,000 psig for yield strength. Further, under FAQ-60 material attributes other than yield strength are not addressed and therefore must be included in the operator's material verification program.

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Data integration is not a new concept in the management of pipeline systems. Alignment sheets, whether manually drafted in the pre-CAD era, created via CAD or output from GIS, are a good example of the output of integrated data. Bands of information/data correlated with a map of the pipeline route allow users to observe and analyze the relationships between various data layers. The process of creating and checking alignment sheets in preparation for publication may identify situations where data does not integrate correctly triggering further data analysis and improvements. Subject matter experts (SME) using alignment sheets as part of pipeline integrity or operational activities may identify data inconsistencies and refer them for further analysis.

Conversion of historic pipeline data and records into electronic forms that included station references at the inception of GIS implementation projects caused many operators to carefully scrutinize and integrate historic information before digitizing records, drawings and other information sources. Operators performed records and data integration activities in responding to PHMSA's Advisory Bulletin dated January 10, 2011, advising operators that records required for the purpose of establishing MAOP must be traceable, verifiable, and complete (TVC). [4] Both GIS conversion and records and data research activities related to establishing MAOP were predominately desktop studies, very little if any field work was conducted to validate results. This has led to instances where integrated data and records meet TVC criteria yet material attributes may differ from values obtained from ILI surveys or other field-based observations.

Process

The figure below outlines the key steps in the process of using ILI to establish confidence in material attribute data.

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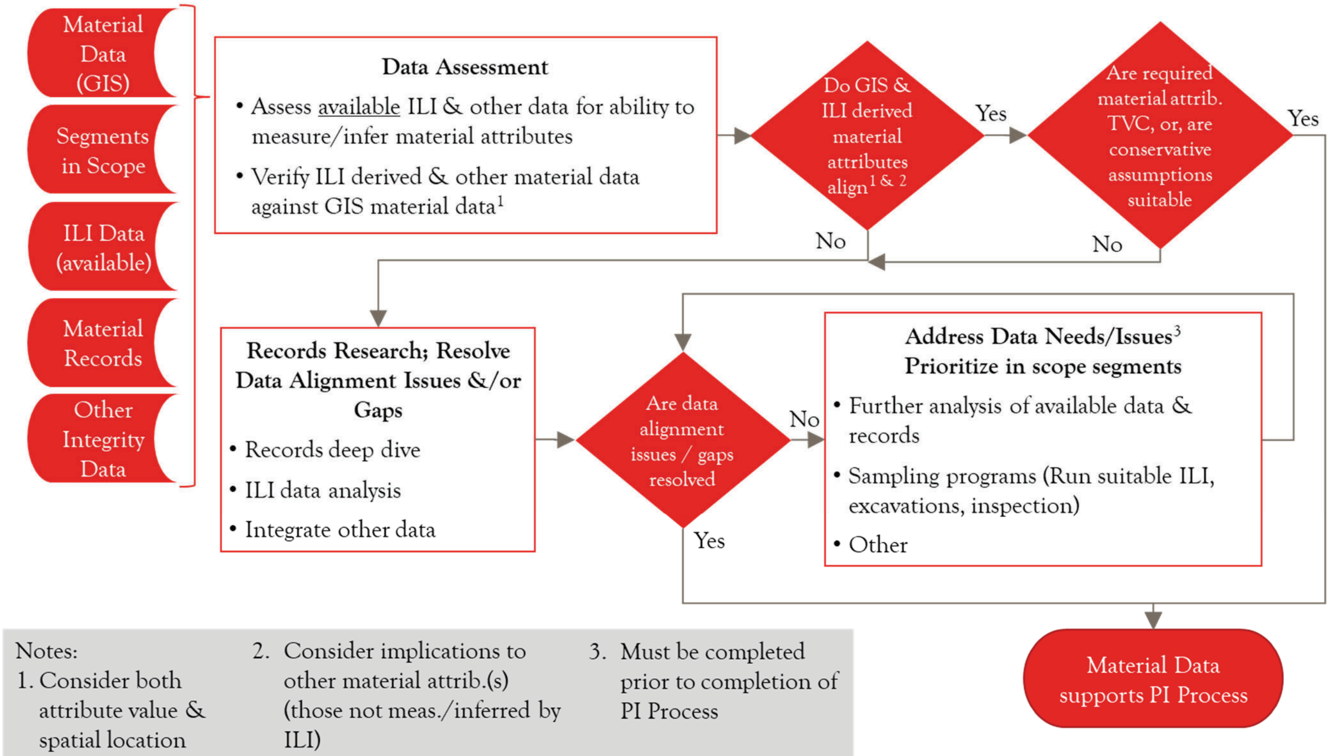

Figure 1: Establishing confidence in material attribute data

In many cases the most complete and up-to-date information about a pipeline comes from recent ILI surveys. While all ILI survey data has value, the most recent data will reflect changes made to the pipeline (e.g. replacements, repairs or other changes) prior to the date of the survey. Other sources of data and information may exist, some of which may be managed in silos, or if integrated, may not be fully leveraged. As an example, records of excavations for the purposes of anomaly digs or other assessments of a pipeline may contain information related to the condition of the pipeline and certain material attributes. Operators may have other sources of useful data and information that, when integrated, may further elucidate the condition of a pipeline and certain material attributes. The integration of data from these sources can be used to validate GIS data and Records.

The challenges associated with integrating ILI data and GIS data fall into two related categories: spatial alignment challenges and attribute alignment challenges. Operators should consider these challenges and develop guidelines prior to embarking on data integration programs. It is impracticable to develop a data integration procedure that addresses all possible challenges and outcomes, rather SMEs must evaluate situations while considering program guidelines, best practices, practices in place when data was initially created or gathered, and knowledge of the specific pipeline system under consideration.

The bullet points below outline challenges associated with ILI and GIS data integration.

- Spatial alignment: ILI with IMU, suitably located AGMs and post processing can result in a spatially accurate three-dimensional representation of a pipeline segment. In some cases, the spatial representation of the same segment in the corporate GIS is based on historic records including but not limited to, time of construction alignment sheets, survey notes and other engineering drawings. In most cases this results in a two-dimensional representation of the pipeline centerline. In some cases, the records-based alignments have been updated based on ortho-rectified aerial or satellite imagery, field surveys or other sources. Aligning the ILI, and GIS representations can be challenging. Operators should consider the following when spatially aligning ILI and GIS data:
    - Prior to commencing integration of spatial data Operators should have a clear understanding of the origin and accuracy of the GIS and ILI centerline.
        - GIS centerline: The origin and spatial accuracy may vary from one part of an Operator's system to another and therefore the approach to spatial integration may also vary. Determining the accuracy of the GIS centerline for each subset of an Operator's system may be based on a combination of quantitative and qualitative inputs.
        - ILI centerline: Through a review of the ILI vendor's report or other information, the spatial accuracy claimed by the ILI vendor must be understood and validated. The claimed accuracy is based on; the technical specifications of the ILI system, the spacing and spatial accuracy of the coordinates of above ground markers (AGM), the level of success of the tool sensing the AGMs, and, the post processing methods. The claimed accuracy may vary between ILI surveys even when the same ILI system and processes are used.
        - Understanding the spatial uncertainty between the GIS and ILI centerline will provide useful context when selecting the approach to integrating spatial data and decision-making.
    - Choosing one of the spatial representations and adjusting (rubber banding) the other representation to fit presents challenges depending on which spatial representation is chosen as a 'baseline' (i.e. ILI or GIS).
        - Choosing the ILI as the baseline will, in most cases, provide the most spatially accurate representation. An ILI based centerline will, in most cases, facilitate the integration of GPS coordinate based spatial data from excavations or other sources. Significant impacts of this choice include but are not limited to: interaction of the centerline with polygons representing Class areas, consequence areas, taxation districts, and other polygon or point data. The result may lead to adjustments of the extent of Class and consequence areas, ad valorem tax remittances, amongst others.

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        - Choosing the GIS as the baseline will require current and future ILI to be adjusted to fit the representation of the centerline and make assessment of ILI identified features and pipe movement more complex.
    - Operators must carefully consider the impacts of either choice when determining the most practicable approach to spatially integrating ILI and GIS data.

- Attribute integration – Where ILI data is available that is suitable for identifying certain material attributes, aligning the ILI material data with GIS and records can increase confidence in data or identify potential information conflicts. Since most material attributes change at girth welds and most ILI tools identify the location of girth welds, the alignment, assessment and integration of material properties and attributes from ILI with GIS data and records must be based on the location of girth welds. Operators that do not have GIS data segmented at the girth weld level may wish to consider adding all girth welds or key girth welds where material attributes change. Adding girth welds to a GIS database requires time and effort, however, once complete, output of future ILI surveys may be more efficiently corelated to the GIS centerline.

- An alternative to identifying girth welds to the GIS database is to use engineering stationing from the GIS to calculate length (i.e., contiguous distance from one end of a section of pipeline with a specific material property to the other end) and comparing GIS based lengths to the lengths of the same material property reported by the ILI survey. This approach, to determine the contiguous lengths based on engineering stationing in the GIS, must address station equations or other anomalies which may make the determination of the contiguous distance challenging.

- Considerations when integrating In-Line Inspection (ILI) and Geographic Information System (GIS) data include but are not limited to:
    - Alignment of material properties and attribute changes to the correct girth weld. Segmenting GIS data at the girth weld level may result in material and attribute changes falling on the 'incorrect' weld (i.e., the change represented in the data falls one or more welds upstream or downstream of where the change actually occurs). Using both GIS & ILI known attributes such as AGMs, elbows, tees, and valves, will assist in minimizing this misalignment.
    - Addressing misalignment of material properties and attributes between ILI and GIS/records usually initiates a review of all relevant data sources. This review may include but not be limited to:
        - Validation that the interpretation of the ILI signal is correct.
        - Validation that the records supporting the GIS data are correctly interpreted for: attribute values, TVC status of the record, and spatial position.

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- Integration and assessment of other available records and data sources (e.g., information from historic excavations).
- Validation/redefinition of the extents of populations based on available data where an Operator is using populations of multiple comparable segments under §192.607(e). Once populations are validated/redefined material attribution may be applied based on the best available data and information.
- Input from SMEs with expertise in procurement, construction, pipeline engineering and regulatory compliance for the era when the subject section of pipeline was constructed.
- Development of a summary of all data, records, information, population validation/redefinition and SME input. The summary should indicate the source of each data element with associated TVC status (for records) or assessment of reliability (for ILI or other non-record data). Equally, non-TVC data elements must be identified as non-confirmed, but likely relevant. Indicating whether records have been researched and confirmed is critical to understanding the level of uncertainty when making data-driven decisions.
- Development of an action plan to address the data uncertainties identified. The action plan may include recommendations for additional data gathering, expanded sampling under §192.607(e)(4) or other approaches to addressing the issue. The action plan document is not required to meet TVC criteria under §192.607(b). However, records of measurements taken, or data gathered to validate material attributes must meet TVC criteria and must be maintained for the life of the pipeline under §192.607(b).

- Where ILI and GIS/records do not align on one material property or attribute, operators must consider the impact on other material attributes on the same record. As an example;
  - Records and GIS indicate a section of pipeline has a welded long seam.
    - The records meet TVC requirements.
    - MFL ILI data indicates this section of pipe is seamless.
  - This scenario appears to identify a material property that is not consistent with available information or existing expectation under §192.607(e)(4). FAQ-28 indicates that ‘PHMSA expects operators to define the term “not consistent” in their material verification procedures as it relates to pipe properties, and to detail how they will establish an expanded sampling program in response to such information.’
  - In this scenario Operators must consider, and take a position on, whether the other material attributes shown on the TVC record in question are valid, i.e., where it is demonstrated that the record is incorrect for long seam, are the other material attributes on the same record valid (e.g.,

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diameter, wall thickness, grade)? By definition, the record is no longer 'verifiable', in this case the long seam is not verified by complementary but separate documentation. Does this mean only manufacturing process (long seam) is not TVC or are all values on the record no longer considered TVC?

- To address this question Operators must consider, define and document:
  - The term 'not consistent';
  - The approach to records where an individual property is not verified and the impact on other properties on the same source record; and,
  - The applicability and structure of an expanded sampling program to address such issues. Where Operators plan to use an expanded sampling program under §192.607(e)(4), prior notification is required under §192.18.

Addressing these challenges requires input from subject matter experts potentially from several disciplines including but not limited to: GIS, pipeline records research, ILI signal data interpretation, pipeline construction (expertise related to the era of construction for a pipeline under consideration and/or pipeline replacements or repairs), pipe and component procurement (again, related to the era of construction and/or replacement or repair projects) and regulatory compliance. The inputs from these SMEs must be coordinated and results of analysis and decisions must be documented and retained for future reference.

Examples

The tables below outline some real-world scenarios where ILI data is used to establish confidence in TVC records based material data.

Example 1

Table 1: Example of Pipe Segment Appearing in GIS not Verified by ILI data

GIS Data			ILI data			Comment
Length (ft)	**Wall Thickness (in)**	**Manufacturing Process**	**Length (ft)**	**Wall Thickness (in)**	**Manufacturing Process**	
479	0.3125	SMLS	1,491	0.3125	SMLS	Original construction
12	0.3120	DSAW				Post regulation pipe replacement appears in GIS
995	0.3125	SMLS				Original construction
1,486	(sum of 3 segments)					

In the example above the records supporting the GIS data meet TVC criteria. The GIS indicates 12' of 0.312" wall thickness DSAW pipe was added to the pipeline as a post regulation replacement. The ILI data is based on EMAT-C, MFL-C and IMU technology. MFL-C is able to differentiate between seamless and welded long seam pipe (note, MFL-C may be able to differentiate between various types of welded long seam in some scenarios).

Table 2: Analysis of Pipe Segment Appearing in GIS not Verified by ILI data

Analysis						
Comparison in Length (ft)	**Distance to Upstream Crossing (ft)**			**Distance to Downstream Crossing (ft)**		
	GIS	ILI	Diff.	GIS	ILI	Diff.
5.0	2,120	2,127	-7	3,017	3,026	-9

The analysis table above indicates the difference of 5' in the total length in the three segments from the GIS, 1,486', and the one segment from the ILI data, 1,491'. The distance from the upstream end of these segments to the nearest crossings is also shown.

Taken together the agreement in the distances to the crossings indicates this is the same location and the overall length for the segments closely agrees. Further analysis is required to address this issue including, but not limited to:

- Verify the pipe replacement is located correctly, and the material attributes are correct in the GIS.
- Verify the ILI signal data to ensure the 12' segment of seam welded pipe was not overlooked.
- If one of the two options above address the issue, GIS data and records may be updated accordingly.
- If the GIS/record verification and the ILI data verification both support the results shown in table 1, the following should be considered;
    - If the purpose of the analysis is to support calculation of Maximum Allowable Operating Pressure (MAOP), the longitudinal joint factor under § 192.113 for both seamless and double submerged arc welded pipe is 1.00 and therefore the uncertainty of which manufacturing process is applicable does not impact the calculated MAOP.
    - If the purpose of the analysis is to support MAOP reconfirmation under certain methods within § 192.624 or analysis of threats that may be different for seamless and DSAW pipe, further action is required.
    - If the ILI signal data is carefully analyzed and clearly indicates all pipe in the vicinity of the replacement indicated in the GIS is seamless, an excavation will not provide any additional useful information. The excavation will expose seamless pipe.

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- If the ILI data is reliable the confidence in the record of the replacement (be it TVC or not) is reduced. While the location of the replacement and material attributes shown on the record may have been correctly reflected in the GIS, the question becomes is the record content incorrect? Errors could be in either the spatial location or the material attributes.

Example 2

This example illustrates the challenges associated with this work. Certain cases require input from several SMEs together with – importantly – a process to assess results and drive issues to conclusion.

Table 3: Example of Pipe Segment Appearing in GIS not Verified by ILI data

GIS Data			ILI data			Comment
Length (ft)	Wall Thickness (in)	Manufacturing Process	Length (ft)	Wall Thickness (in)	Manufacturing Process	
2,486	0.3750	DSAW	124	0.3750	Seam Welded	Post regulation pipe replacement appears
			2	0.5000	Indiscernible	
			451	0.3750	Seam Welded	
			87	0.5000	Seam Welded	
			302	0.3750	Seam Welded	
			2	0.5000	Indiscernible	
			52	0.3750	Seam Welded	
			1	0.5000	Indiscernible	
			271	0.3750	Seam Welded	
			2	0.5000	Indiscernible	
			988	0.3750	Seam Welded	
			2	0.5000	Indiscernible	
			27	0.3750	Seam Welded	
			3	0.5000	Indiscernible	
			176	0.3750	Seam Welded	
			2,491			(sum of ILI segments)

In the example above the records supporting the GIS data meet TVC criteria. The ILI reports several short segments of 0.500" wall thickness pipe most of which are reported with an 'indiscernible' manufacturing process. The total length reported by the ILI along with the 0.3750" wall thickness

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seam welded material attributes agree with the corresponding length and material attributes shown in the GIS.

Table 4: Analysis of Pipe Segment Appearing in GIS not Verified by ILI data

Analysis						
Comparison in Length (ft)	**Distance to Upstream Crossing (ft)**			**Distance to Downstream Crossing (ft)**		
	GIS	ILI	Diff.	GIS	ILI	Diff.
5	3,197	3,239	42	9,705	9,674	31

The analysis table above indicates the difference of 5' in the total length in the fifteen segments from the ILI, 2,491', and the one segment from the GIS data, 2,486'. The distance from the upstream end of these segments to the nearest crossings is also shown.

Taken together the agreement in the distances to the crossings indicates this is the same location and the overall length for the segments closely agrees. Further analysis is required to address this issue including but not limited to;

- Verify the pipe replacement is located correctly, and the material attributes are correct in the GIS. Consideration should be given to the presence of fittings or other non-pipe components as part of the replacement.
- Verify the ILI signal data to ensure the short segments of 0.500" wall thickness pipe are correctly characterized.
- If one of the two options above address the issue, GIS data and records may be updated accordingly.
- If the GIS/record verification and the ILI data verification both support the results shown in table 3, the following should be considered:
    - Are construction techniques or materials used in the pipe replacement capable of creating a signature that causes the ILI to report the short sections of pipe with 0.500" wall thickness? It is likely that the short joints are due to the use of fittings to achieve required bends in the pipeline route. Concluding this will require input from SMEs with knowledge of construction and procurement practices specific to the pipeline operator or asset owner dating from the era the replacement was constructed.
- If SME input cannot resolve this discrepancy, the ILI data may be used as a basis to group the 0.500" wall thickness segments into a population of similar pipeline segments. Since the cumulative length of these segments is less than one mile, one excavation where in-situ material properties are gathered will suffice (as per 49 CFR 192.607) to address the material verification requirements.

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Example 3

Table 5: Example of Pipe Segment Appearing in ILI not Verified by GIS data

GIS Data			ILI data			Comment
Length (ft)	Wall Thickness (in)	Manufacturing Process	Length (ft)	Wall Thickness (in)	Manufacturing Process	
1,453	0.375	SMLS	1,105	0.3750	seamless	
			38	0.4060	seamless	0.406 wall thickness pipe did not appear as a standard wall thickness in API-5L until after 1970
			315	0.3750	seamless	
			1,458			(sum of ILI segments)

In the example above the records supporting the GIS data meet TVC criteria. The ILI data indicates the presence of 38' of 0.4060" wall thickness pipe that does not appear in the GIS data. The ILI data is based on EMAT-C, MFL-C and IMU technology. MFL-C is able to differentiate between seamless and welded long seam pipe (note, MFL-C may be able to differentiate between various types of welded long seam in some scenarios). API 5L 25th edition, April 1970 [5] does not include 0.4060" as a standard wall thickness for 24" pipe. This may indicate the 0.4060" pipe identified by the ILI survey is an undocumented post-regulation replacement.

Table 6: Analysis of Pipe Segment Appearing in ILI data not Verified by GIS data

Analysis						
Comparison in Length (ft)	Distance to Upstream Crossing (ft)			Distance to Downstream Crossing (ft)		
	GIS	ILI	Diff.	GIS	ILI	Diff.
5	35,524	35,585	61	87,539	87,711	172

The analysis table above indicates the difference of 5' in the total length in the three segments from the ILI data, 1,458', and the one segment from the GIS, 1,453'. The distance from the upstream end of these segments to the nearest crossings is also shown.

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Taken together the agreement in the distances to the crossings indicates this is the same location and the overall length for the segments closely agrees. Further analysis is required to address this issue including, but not limited to:

- Records research for pipe replacements of other maintenance activities related to this area to determine if a records package has been overlooked or if a recent pipe replacement has occurred.
  - This may require consultation with and/or record research at field locations.
- Review records associated with known pipe replacement of maintenance projects or programs in this area to determine if a replacement location was overlooked or positioned inaccurately in the GIS.
- Verify the ILI signal data to ensure the 38' segment of 0.4060" wall thickness pipe is correctly characterized.
- If one of the options above address the issue, GIS data and records may be updated accordingly.
- If the GIS/records research and the ILI data verification both support the results shown in table 5, the most likely conclusion is the 38' segment of pipe is an undocumented replacement. Since the segment is undocumented placing this segment in a population of similar segments with unknown material properties may present risks associated with determining the correct values for material attributes. It is unlikely that an opportunistic excavation will present itself within the MAOP reconfirmation timeframe for a pipe segment of this size. In-situ testing for wall thickness, manufacturing process and grade are required.

Conclusion

ILI survey data from technologies that provide either direct measurements or reliable inference of certain pipe material attributes (e.g. diameter, wall thickness, welded long seam versus seamless from MFL-C with IMU) is useful in establishing confidence, or lack thereof, in material attributes supported by records meeting TVC criteria. Experience indicates that for virtually all ILI surveys, multiple locations will be identified where confidence in records meeting TVC criteria is challenged.

Spatially aligning and integrating attributes from GIS/records and ILI presents technical challenges and requires expertise in the areas of GIS, records research, spatial analysis and an understanding of ILI data. Identifying locations where ILI data reduces confidence in GIS/records is only the first, and perhaps easiest, step in the process. As the examples above indicate, while each step is not technically difficult, the assimilation of the results and development of a final and defensible determination of the values for the material attributes in question is often complex. In many cases the fallback conclusion of an excavation to positively determine the material attributes through in-situ testing may be of little to no technical value and in many more cases the value will not be commensurate with the cost and operational impacts of the excavation and testing.

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In most cases this process does not clearly fall within the mandate of one team within an Operator's organization. Input and expertise are required from GIS, pipeline records research, ILI signal data interpretation, pipeline construction (expertise related to the era of construction for a pipeline and/or pipeline replacements or repairs under consideration), pipe and component procurement (again, related to the era of construction and pipeline and/or replacement or repair projects under consideration) and regulatory compliance. Obtaining timely input from SMEs in these areas can be challenging and achieving consensus on a final conclusion may be time consuming.

The technical and organizational challenges associated with this methodology are offset by compliance with current and proposed regulations, a more robust foundation for risk management and enhanced integrity and safety of pipeline operations.

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