Integrity Data Management and Integration

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Integrity Data Management and Integration

1 Scope

This bulletin provides a compendium of methodologies and considerations for integrating the underlying data used to support integrity management. Any one approach, let alone the entirety of the document, may not be appropriate or applicable in all circumstances. The document reviews possible approaches for consideration by operators in the context of their specific circumstances.

The primary focus of this bulletin is the methodologies and processes used to spatially integrate and normalize the data to support the application of comparative techniques used in interpreting integrity data, with particular emphasis on in-line inspection (ILI) data. The document begins with a discussion of general data-quality processes, goals, and considerations such that data quality approaches can be considered in the context of the data integration processes.

An impediment to informed integrity decisions is the inability to efficiently review a broad spectrum of data in a format that has been normalized and spatially aligned. With the variations in organizational structures, integrity management programs, and technologies used across the pipeline sector, individual operators design data integration procedures that are customized to their organizational structure, processes, and pipeline systems.

Properly managed and integrated data supports agile analytics to integrate new data as they become available and to recognize coincident events and patterns. The data source may be from within an organization, or may be external to the company, as in the case of representative data based on industry experience or manufacturing processes. The intent is to empower operators to efficiently analyze and integrate threat- and integrity-related data to support their integrity management programs.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document applies (including any addenda/errata).

API RP 1163, *In-Line Inspection Systems Qualification*

API RP 1176, *Recommended Practice for Assessment and Management of Cracking in Pipelines*

3 Abbreviations

AC	alternating current
ACVG	alternating current voltage gradient
BSEE	Bureau of Safety and Environmental Enforcement
CFR	*Code of Federal Regulations*
CIS	close interval survey
CP	cathodic protection
DA	direct assessment
DCVG	direct current voltage gradient
DMA	discrete metal loss anomaly
DOC	depth of cover
ECDA	external corrosion direct assessment
ERF	estimated repair factor

EXT	external
FPR	failed pressure ratio
GIS	geographic information system
GPS	global positioning system
HCA	high consequence area
HDD	horizontal directional drill
ILI	in-line inspection
IMU	inertial mapping unit
INT	internal
IT	information technology
MAOP	maximum allowable operating pressure
MFL	magnetic flux leakage
MIC	microbiologically influenced corrosion
ML	metal loss
MOC	management of change
MOP	maximum operating pressure
MPI	magnetic particle inspection
MTR	mill test report
NAD27	North American Datum of 1927
NAD83	North American Datum of 1983
NDE	nondestructive examination
OD	outside diameter
POD	probability of detection
PODS	Pipeline Open Data Standard
POI	probability of identification
ROW	right-of-way
RPR	rupture pressure ratio
RTK	real time kinematic
SCC	stress corrosion cracking
SME	subject matter expert
SMYS	specified minimum yield strength
TDC	top dead center
TPD	third party damage
TQM	total quality management
UT	ultrasonic testing
WB	wrinkle bend
WGS84	World Geodetic System 1984

4 Benefits to an Enterprise Data Management System

Managing pipeline integrity data historically involved the rather manual process of populating data within spreadsheets or disparate databases. Transitioning to an enterprise database to manage large pipeline integrity data sets provides an operator with several advantages, including the following:

- Improved auditing and traceability: When spreadsheets are created, the logic and judgment that is applied while an individual is manipulating data is not captured, or easily understood. In most cases, this logic exists only in the mind of the individual who created the spreadsheet, which may result in compliance risk.

- Improved tracking of data corrections: Propagating corrections to data errors across multiple dependent spreadsheets, or back to the original data sources, is difficult and may potentially introduce further errors.

- Improved safeguards against human error: Databases and their associated graphical interfaces facilitate the implementation of quality rules and constraints that mitigate the potential for human error.

- Improved resource utilization: Databases may provide improved efficiency over data management that uses disparate spreadsheets.

- Improved data security: Server-based data may be more difficult to access and propagate than individual files, which can be easily transferred to local or portable drives.

- Improved scalability: Spreadsheets and small-scale databases may have size limitations that enterprise databases do not have.

5 Data Quality Oversight

5.1 General

The aspects of data quality listed in Section 5.2.3 are examples of elements an operator may consider when developing a data management system, but the extent to which they are relevant varies depending on asset complexity and organizational structure. As with any system, continuous improvement is a core principle. The system in this context is often referred to as a geographic information system (GIS) or database, but it may be a compilation of applications and databases, with a map-based visualization being just one aspect of the solution.

Data management planning considerations include the identification of key objectives to be achieved, as well as the strategies and policies that assist in achieving those objectives. A common example where source data sometimes may not be fit for purpose is risk assessment. To support the analysis associated with risk assessment, a range of numerical values are typically assigned to the inputs. However, the source of this data in many cases was not structured with this use in mind. Specific considerations would include the delineation of different pieces of information into different fields or attributes (database schema design) and defining allowable content (attribute domain). A common domain constraint is the use of code lists or controlled vocabulary to avoid saying the same thing in innumerable different ways due to spelling or the use of synonyms. Care should be taken to not overly constrain data capture so as to mask new, valid and potentially critical data. The option of “other” with an associated meta data field could support the ongoing maintenance of the domain such that it can align with evolving processes.

5.2 Objectives

5.2.1 Core Objective

The core objective of a data management system is to achieve the highest degree of data quality possible for the intended purpose, while also doing the following:

— promoting the efficient use of resources;

— providing easier access to critical information for qualified employees;

— ensuring that data is protected and preserved in accordance with business, legal, and policy requirements; and

— communicating with other systems using a common frame of reference for broader analysis capabilities.

5.2.2 Data Quality Criteria

Stakeholders should clearly define what is meant by data quality to make the data fit for purpose in supporting the intended processes. The data should meet the following criteria:

— Be defect free: Data should conform to the dimensions of data quality (outlined below), as applicable.

— Conform to specifications: Data should conform to specified metadata requirements such as type, length, value, precision, and units of measure.

5.2.3 Dimensions of Data Quality

In addition, a data quality definition could consider the following dimensions[1] of quality:

— Accuracy: The data represents reality.

— Completeness: All needed data is available.

— Consistency: The data is free of internal conflicts.

— Precision: The data is as exact as is needed.

— Granularity: The data is kept and presented at the right level of detail to meet the needs.

— Timeliness: The data is as current as needed and is retained until no longer needed.

— Integrity: The data is structurally sound. This connectivity is frequently referred to as topology within the geomatics community.

5.2.4 Strategies and Policies

Developing policies and guidelines helps create a standard set of procedures for ensuring that quality data effectively flows to and between all stakeholders.

Although data quality is a mandate for all employees, the formation of an identified team can be helpful in developing and maintaining the policies and guidelines that support standardized data quality management practices, including the following:

— Data quality audits: Data audits should occur on a periodic basis. Audits should focus on the most vulnerable/critical data. Lessons learned from data quality issues should be integrated into future audit processes.

— Data remediation processes: As audits occur, remediation prioritization should be according to the level of risk.

— Technology: Technology standards for governing data and information form part of the core system design. Data changes, including to metadata, should be governed and executed per company procedures. While spreadsheets can be used, as the breadth of the data and the organization increases it may be easier to manage data quality and data integration by utilizing database technology and GIS.

5.3 Data Governance

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[1] Standard data quality classification – TDWI (The Data Warehousing Institute)

5.3.1 General

Data governance is the discipline of creating the vision, strategy, and structures needed to deliver an integrated and coordinated approach to improving trust in data. Effective data governance ensures that data can be trusted, and that there are processes to ensure traceability and accountability for any adverse events that result from poor data management practices. The purpose in establishing this structure is to maintain a clear focus on data quality and integration initiatives within departments and projects.

The core elements of governance include the following:

— defining decision rights,

— designating responsibilities,

— assigning accountabilities,

— establishing policies,

— defining processes, and

— managing performance.

Data governance should start small and grow systematically. As better predictions and forecasting are achieved, inspections and assessments can be completed where they are most needed. The quality of integrity decisions is directly related to the quality of the data input into the many analyses performed on the integrity data (i.e. good data supports good decisions). Similarly, bad data is worse than no data, as it may drive misinformed, non-conservative decisions.

5.3.2 Data Governance Roles

The distribution of data governance across the following proposed roles can be beneficial in clearly delineating responsibilities in larger and more geographical dispersed organizations, but their applicability will vary depending on the operator's specific circumstances.

5.3.2.1 Data Owners

Data owners are individuals who are ultimately accountable for data governance implementation and execution. Specifically, they are accountable for the data quality and governance elements that the data stewards (see 5.3.2.2) are executing, and for understanding the organizational dependencies of the data. Data owners should have a working knowledge of regulations, policies, and laws regarding the data. Data owners are typically responsible for the following:

— establishing escalation points for data governance issues;

— setting the strategy for data quality, privacy, and security; and

— determining the desired accuracy or degree of data quality.

5.3.2.2 Data Stewards

Data stewards ensure data governance initiatives are successful by overseeing data inventories and work flows. Data stewards should be proficient in data management processes, and it would be beneficial for them to have a working knowledge of pipeline integrity data and its use. Data stewards are usually responsible for execution, which would include the following:

— data definitions, usage, and quality measures;

— metadata collection and recording;

— data quality review and verification;

— data policies and procedures definitions; and

— data issues and conflicts management.

5.3.2.3 Data Custodians

Data custodians work with the data on a day-to-day basis and have the technical knowledge to profile and secure data.

5.4 Data Quality Assessment

Assessing the quality of the data should become part of a continuous improvement process. This effort is in line with the principles of total quality management (TQM), which state that the quality of information and processes is the responsibility of all those who create or consume the information or processes. Data quality assessments should include the following actions:

- identification of data quality measurements,
- identification of where and when to monitor data quality,
- implementation of monitoring processes,
- completion of a baseline assessment of the data quality and intent of usage, and
- review of post-monitoring reports.

An assessment effort should be structured and prioritized based on risk.

5.4.1 Communication Strategy

5.4.1.1 General

Continuous improvements are facilitated through a communication strategy that establishes routines for when and how important communications should be conducted and could include the aspects detailed in 5.4.1.2 and 5.4.1.3.

5.4.1.2 Data-Related Alerts and Events

Create a distribution strategy to ensure that all stakeholders have access to review and update information regarding ongoing data issues.

5.4.1.3 Data Quality Measures and Metrics

Measure data quality on established metadata created for each asset. Metrics could reflect the proportion of errors by asset on each metadata element. As with any reporting of metrics, they should be prioritized and limited in order to retain relevance.

6 Transforming SME Knowledge into Data

A significant challenge for data integration is capturing and quantifying subject matter expert (SME) knowledge. This knowledge is often lost when the SME leaves their current role within the company. Given the amount of information SMEs typically process, consideration should be given to scheduling interviews with them on a pre-defined interval can help capture the information.

Determining how to turn SME knowledge into measurable data points requires careful planning. In many cases SMEs may work in different operating areas where culture, attitude, and performance may be defined and measured differently. Subjectivity can make comparing opinions across SMEs and operating divisions difficult. To minimize subjectivity, parameters and consistent data-gathering processes should be well defined. For example, rather than asking about the current condition of the right-of-way (ROW), operators should ask about the adequacy of the ROW clearing program in place, and should define adequacy in accordance with the company's ROW clearing policy and develop tools to facilitate location-specific knowledge.

During interviews, the applicable stakeholders should review with SMEs the pipeline alignment sheets with a photographic background for potential areas of concern. The interview should focus on issues that are known to exist on the pipeline, rather than the exact locations, which can be determined at a later date.

7 Data Models

Data modeling is used for assigning an overarching design to guide the database schema used for the storage of data. The intent of a data model is greater data quality and consistency, while enabling the processes that are running against the data. As such certain data models are optimized to support certain applications and vice versa.

There are varying approaches to data modeling, such as the following, that can be considered when designing a data model for pipeline integrity:

The Pipeline Open Data Standard (PODS) is an example of an industry-standard data model. There are benefits to adopting this referential data model, but due consideration should be given to how the data is utilized. The PODS data model leverages a third normal form data modeling technique, which is optimized for transactional systems where many transactional data sets are inserted and updated.

The Utility and Pipeline Data Model (UPDM) is designed primarily for the management of spatial data. Similar to PODS, this model provides a template for the management of natural gas and hazardous liquid pipe system data including provision for gathering, transmission, and distribution systems. UPDM is extensible, allowing customized schemas to address the corporate, local or national regulatory requirements or needs of the operator. Although UPDM is software (platform) agnostic.

Object-relational data modeling.

Dimensional modeling is optimized for simplified retrieval of data for the purposes of reporting and analysis. In order to improve analytical performance, consider recasting relationally modeled data into a dimensional model for this purpose.

A consideration for data models is the spatial component. There are commonly employed relational databases that meet the GIS requirements for the management and analysis of spatial data.

Depending on how the integrity data sets are to be used, these various modeling techniques can be evaluated to determine the best fit and extended as required.

8 GPS Coordinates

8.1 General

The measurement error for global positioning system (GPS) coordinates does not accumulate; each point is discretely resolved independent of previous points. The commonality between GPS coordinates is with the satellites used for resolving the coordinates and the correction factors applied to them, whether through real time kinematic (RTK) radio transmission or post processing.

The material in this section builds upon the 2008 API white paper, “Uniform Standards for GPS Submittals for One Call Purposes” (prepared in support of Common Ground Alliance Best Practices). One of the issues discussed within that white paper is the potential for introducing error into GPS coordinate locations. Reliance on GPS readings without a clear understanding of important settings and nomenclature options can lead to a false sense of security and introduce new and significant errors into the data. The four main sources of error are detailed in 8.2 through 8.5.

8.2 Coordinate Nomenclature

Coordinates stated in degrees and decimal minutes look similar to coordinates stated in decimal degrees. For example, the coordinates N 29 50.30 W 95 50.50 and N 29.5030 W 95.5050 are actually more than 30 miles apart. Unfortunately, many users of GPS instruments are unaware that the format of GPS readings is a critical aspect, and it is easy to confuse one format with another, or to not understand what format a GPS unit is using.

8.3 Datum Selection

A separate but related issue is the selection of “datum” (a theoretical model of the earth’s surface against which the GPS coordinates are referenced). Each datum is different, reflecting different models of the earth's surface, ovality, etc. There are more than 100 datums that can be selected for most GPS units, although few people are familiar with what they mean or how to select the correct one, simply using whatever default datum the unit was set to when purchased. The same GPS coordinates will identify different points on the earth when using different datums. The difference is usually rather small (dozens of feet), but this is a source of error that could be significant for integrity purposes.

These potential errors could be eliminated by imposing uniform guidelines for GPS data submittal. To maintain consistency with the National Pipeline Mapping System, it was recommended that the Common Ground Alliance adopt the North American Datum of 1983 (NAD83) and use decimal degrees (with a minimum of six decimal place digits) as the standard GPS nomenclature for one-call use. The World Geodetic System 1984 (WGS84) datum is within one meter of the NAD83 datum throughout North America and should also be accepted. This same approach would also serve North America pipeline operators for their broader integrity program. Caution should be used when utilizing offshore coordinates, such as those provided on the Bureau of Safety and Environmental Enforcement (BSEE) website, as these coordinates are typically in NAD27.

8.4 Accuracy

The accuracy of GPS readings varies due to a number of factors, including the number of satellites being tracked, the precision of the GPS unit being used, etc. The accuracy information (i.e. ±29 ft, ±58 ft, etc.) can be obtained from typical GPS units, but in many cases this is only an estimate. Different processes require varying levels of accuracy; the important consideration is that an operator understands the measurement such that they can make a determination as to its adequacy. In the absence of a uniform level of accuracy, the measurement error should be maintained as an attribute of the data to which it pertains. Any error in the GPS coordinate propagates where the coordinate is used to align other data; accordingly, benchmark surveys for inertial mapping unit (IMU) ILI runs benefit from a high degree of accuracy. The vertical measurement error in the elevation is generally 2 to 3 times that of the horizontal measurement error for GPS coordinates.

The error associated with GPS coordinates is compounded where two separate GPS points are used to derive the relative length between these points, such as resolving the length of a pipe joint. The better practice is to acquire the coordinate for one weld and then manually measure (tight chain) the length of the joint.

8.5 Base Station Elevation

A common error in the GPS survey of a pipeline centerline is that the elevation of the base station is incorrectly entered. This usually manifests as a vertical discontinuity where survey data collected on different days are immediately adjacent to each other. An example of this would be at road bores where the mainline survey was completed separately from the bore installation and tie-in.

9 Alignment for the Purpose of Pipeline Integrity

9.1 General

The approaches discussed here target integrity management objectives, of which a map-based visualization is but one aspect.

9.2 Linear Referencing

Pipelines, like railways and highways, can leverage a one-dimensional frame of reference given their linear structure. Knowing the path of the pipeline, any point on the pipeline can be uniquely defined based on a measure along the line. The genesis of this linear referencing is during the construction process (construction stationing), where a common and readily apparent measure of reporting progress and the location of events along the line is required. This stationing is typically associated with construction spreads; this frame of reference is commonly replaced by as-built stationing when the line enters service. The as-built stationing is relative to a local physical structure such as a pump or compressor station, but it may include regional or governmental boundaries. This redefinition of the spatial frame of reference creates significant challenges in accurately and efficiently utilizing original construction records in operations.

An important consideration is whether the linear reference is 2D (tight chain) or 3D (slack chain). The linear measure is typically a measure from a known point of reference, but the difference between the 2D and 3D measures quickly accumulates as the distance from the reference increases.

9.3 Weld Alignment

Using the weld tally, where present, as another framework for spatial alignment provides the benefit of a fit point (location of common alignment) where the relative error can be re-zeroed every 40 ft to 80 ft along the line. All data elements should be referenced to the nearest weld aside from any other location reference, such that a highly accurate weld alignment can be leveraged at a later date even if a weld tally does not currently exist (e.g. unpiggable lines on which a direct assessment [DA] is being conducted).

9.4 Centerline

The centerline of a pipeline is typically derived in one of the following three ways:

— line-of-sight survey,

— GPS survey, or

— inertial mapping.

A line-of-sight survey is an accumulation of relative measures whereas a GPS survey is a collection of absolute coordinates.

Inertial mapping uses a combination of inertial and odometer measurements to map the pipeline in between known GPS points at regularly spaced benchmarks. The spatial error increases based on the distance from the benchmarks. As the inertial mapping is dependent on the odometer measurements, any problem with the odometer measurements impacts the delivery of the inertial centerline.

9.5 Absolute Referencing

Data elements that are not an attribute of the pipeline commonly have a location that is defined by a GPS coordinate or polygon. The GPS points can be orthogonally projected against the centerline to resolve their position along the pipeline. In the case of a polygon, an intersection or union can be performed against the centerline to resolve the extent of interaction. In both cases, if either the centerline or external data element is moved, their relative position may need to be reassessed.

9.6 Axial Position and Extent

Regardless of the method of reference (stationing, weld offset, or GPS), attributes with a linear extent along the line are generally referenced in one of three ways:

— center and length,

— leading edge and length, or

— start and end.

The operator should understand the format used for the data deliverables received, and whether they have to be transformed to configure with the operator's data management tools, workflows, and analytics.

Another variant is where the feature can be either reported as a point or with a linear extent; valves are a common example. It is important to remain consistent in the method of reporting each type of feature (e.g. valves are all point features, sleeves are all linear features, etc.) as either point or linear features for data accuracy purposes.

9.7 Circumferential Position

Where a feature on the pipe is not fully encircling, its location around the circumference is typically referenced in one of two ways:

— center and width, or

— top edge and width.

In either case, the position can be provided as an "o'clock" orientation, or as degrees from top dead center (TDC); in both cases the convention is looking in the direction of flow (or increasing stationing in regard to bidirectional flow lines).

A special consideration for a top-edge reference is that on the back side of the pipe this reference becomes the bottom edge of the feature when standing in the ditch. This referencing convention is more prone to circumferential correlation error between in-ditch, non-destructive examination (NDE) and ILI data. Special consideration should be given to the format associated with o'clock values to ensure that this data structure is properly handled within a spreadsheet or database field (i.e. the use of a colon can create unintended issues in how the value is stored).

10 Sources of Measurement Error

10.1 Spatial Error

Spatial error can exist in a range of data inputs. ILI data, whether it is from the odometer location of a feature or from the inertial mapping data that defines the centerline, will be used here to exemplify the issue and its associated considerations. The accuracy, or conversely the measurement error, is influenced by the underlying measurement process and potentially by the relative distance from a control point as well. The spatial error may be managed by increasing the control point density (reduced), applying appropriate buffers (accounted for), or flagging the isolated occurrences where the potential for an abnormally high level of error exists (noted).

10.2 Severity Error

An ILI tool performance specification sheet shall state the tool tolerance and associated confidence interval for the depth, width, and length of an anomaly, typically based on its morphology or shape. In regards to corrosion, this is commonly expressed in terms of the Pipeline Operators Forum dimension classes (i.e. general, pitting, axial grooving, axial slotting, circumferential grooving, circumferential slotting, and pinhole). Additional limitations such as seamless pipe, girth welds, heat affected zone, bends, and fittings, can drive the measurement error beyond that stated in the specification sheet. To account for ILI tool performance error, the operator may incorporate the tool tolerance within their acceptance criteria. Increased confidence levels can be achieved through increased tolerances. Where the increased error cannot be quantified, the record can be flagged to support qualitative interpretation of the anomaly in consideration of the additional uncertainty.

10.3 Confidence Interval of the Error

Measure error is typically derived from a statistical analysis of the measurements. As such, the stated error is based on an assumed or stated level of confidence or reliability. Applying different levels of confidence to the same data set can generate significantly different measurement error ranges.

11 Management of Change

11.1 General

Management of change (MOC) is typically well defined within an operator's management system as it relates to operational controls and procedures. In regard to integrity data, the application of MOC may merit additional consideration.

11.2 New Data Relates to Old Data

The process of controlling how new data relate to historical data, in terms of representing the current threats and fitness for purpose of the pipeline, becomes increasingly important and complex as layers of data increase. The challenge is exemplified in the case of multiple ILI runs at different points in time, using different technologies, and performed on the same section of the pipeline.

Scenarios that should be addressed through documented decisions or processes and data management tools include the following:

a) A new ILI run that completely supersedes a previous run, as it identifies the same features but with better quality.

b) Additional features types relative to the previous run (e.g. cracks vs. metal loss) from a new ILI that would be added to the composite ILI dataset, but redundant features (e.g. weld and valves) would be filtered out to reduce duplication.

c) A new ILI run with missing or degraded data (e.g. experienced battery failure during the run) so that only a portion of the data supersedes the previous run.

   1) Pending a rerun, if applicable, the historical data could be grown to create an inferred population of features to fill the gap.

d) Excavation data that supersedes ILI data, as it is presumed to be more direct with less measurement error. This may not be the case with historical data, internal features, or crack features depending on the in-ditch assessment techniques.

   1) Accurate, in-ditch sized features that remain on the line (recoated or under a sleeve) may become a correlation data set for the next ILI run.

   2) Applicable records shall be maintained to substantiate in-ditch measurements and associated data.

The composite data set should be redefined in consideration of new data in order to support timely and informed interpretation by others in the organization or in the future. The superseded data sets are still maintained for reference; the challenge is ensuring that they are kept current with regard to their positioning along the centerline (i.e. updating old ILI alignments).

11.3 Accessing Historical Data

After a cut-out is performed, timely access to historical pipe attribution and defect populations may be relevant to support the investigation of cause and effect relationships, and inferring the extrapolation of these attributes beyond the extent of cut-outs, as applicable. At its simplest, this is the management of the failure history so as to avoid recurrence of the same conditions. Descriptions of repairs, pipe replacements, and inspections create a knowledge bank that can accurately summarize the events with specific information to aid future assessments and facilitate optimal decisions.

The mechanics of how this is achieved can vary significantly. Any underlying assumptions, constraints, or distortions should be clearly understood by all stakeholders who could access this data.

11.4 Rerouting (Centerline Swap)

A particularly challenging change to manage is the replacement of the entire centerline, or significant portion thereof, with a more accurate centerline trajectory. This scenario can arise when new IMU data from an ILI are more accurate than vintage centerline data within a GIS. Given the level of effort necessary to replace the centerline, the improvements and resulting benefits of a new centerline should be carefully weighed against alternatives. A more common scenario is the localized modification to the centerline.

If the source data are all in one frame of reference (e.g. GPS), translation to the new centerline can be managed in a uniform approach. Where the source data exist in several frames of reference (e.g. GPS, stationing, and weld alignment), greater effort and care may be required. If the source frame of reference is drawn upon to remove location inaccuracies that may have been induced through originally fitting the data against the previous, less accurate centerline, additional attention is required to ensure that the relative position of the various data remains aligned.

11.5 Moving Fit Points

Another common scenario is the potential repositioning of a reference point after data have been positioned relative to the point. An example would be where an intended benchmark location was surveyed before an ILI run. In this instance, during the course of the ILI run, the benchmark was repositioned onto the other side of the road due to interference from an overhead powerline at its original location. The updated location was not effectively communicated, and the ILI was imported and aligned within the corporate data management system based on the original position. If ILI data have already been leveraged in an integrity workflow, associations and dependencies may have been created against these ILI records. An update process to proportionately reposition all the impacted ILI records based on the revised location of the benchmark would be required. Such a "refit" of the data can be challenging given certain applications or data architectures. Where the new ILI data have been used to reposition previous ILI data through a weld match, the edits are even more difficult where the linkage across the ILI runs is not maintained to support cascading the update.

The process of responding to modified location data for fit points applies to any control point type (including valves, branch connections, etc.) that may have been incorrectly surveyed in the past. A variant of the preceding process is when the weld exposed in an excavation is not where it is anticipated to be based on information from the corporate data set. The challenge is how to use the accurate location of the weld to correct the corporate data set. This generally would not be resolved by simply moving the one weld, as it would corrupt the data set by significantly distorting the adjacent joint lengths. Assuming the error accumulated over a distance, as is usually the case, the error would have to be proportionately applied up to the pre-existing bounding fit points.

11.6 Data Reconciliation

When a differential analysis is conducted, such as through a data reconciliation exercise, the potential exists to identify disparities in the data. A process of resolving the hierarchy or precedence of the different data sets relative to each other is required to resolve which data is the "data of record" that flows into the subsequent integrity management analysis and decisions.

During this resolution process, an operator should consider which data sets may contain false positives, true negatives, improper identification, or outdated information. For example, magnetic ILI tools typically have high detection rates for casings. If, however, a casing is not reported by an ILI tool, an operator should not assume that the casing does not exist and remove it by default from other databases during a data reconciliation process, because non-detects are common.

12 ILI Life Cycle

12.1 General

One of the core workflows within pipeline integrity is the management of the life cycle of an in-line inspection run, extending through its integration, analysis, remediation of actionable anomalies, correlation with excavation results, and subsequent reinspection.

12.2 General Reporting Requirements

A successful ILI run depends on clear and well-documented reporting requirements that detail the underlying assumptions and clarify the expectations of the deliverables. Central to this is the pipeline questionnaire, populated by the operator. A number of questionnaire attributes are essential for determining the fitness of purpose of the ILI features, and are not otherwise discernable through the ILI data directly.

Delivery timing is highly dependent upon the length of the pipeline surveyed, the number and type of features detected on that pipeline, and the type and amount of analysis or calculations performed on the data prior to delivery (e.g. anomaly burst pressure calculations, effective area profiles, overlay with other ILI tool runs, or other integrity data, etc.).

12.3 Data Quality Letter and Preliminary Report

The data quality assurance report is issued shortly after the tool is received. This report provides the data used to determine if a re-run is required and should be available before the tool and crews demobilize from the area. These reports generally focus on the extent of coverage for the inspection in terms of percent of linear distance or pipe surface area for which the detection and sizing specifications can be met. Contributing factors could include speed excursions, debris, sensor failure, or electronics failure. Data integration considerations arise when the data is degraded but potentially usable. If data is degraded but potentially usable, then ILI data sets can be spliced together, or new metadata should be carried forward to account for location-specific uncertainties. Although these processes are not applied until later in the ILI life cycle, the decision to leverage them to accept a less than ideal run is made early.

The preliminary reporting of anomalies that require an immediate response can be challenging. There may be limited data to accurately locate the anomalies reported. Even where inertial mapping services have been run with the ILI, the data may not be available for early reporting. In order to leverage weld matching to position the preliminary features, where an historical weld tally exists (previous ILI or as-built survey) a complete weld tally should be requested as part of the preliminary reporting. Identification of welds by an ILI vendor is largely an automated process, and this deliverable may be available shortly after the run.

The following approaches can be taken regarding preliminary reporting:

— The entire run is assessed for defects beyond a certain depth or interaction with another feature (e.g. corrosion in dent) where the analysis can be quickly performed.

— Full reporting is requested, but for only a small portion of the line. Particularly beneficial when conducting crack reinspections, this approach lets the operator quickly develop an informed program based on the most probable sites, assuming an unmitigated growth such that correlation excavations could possibly be used in the refinement of the final report.

Additional critical features may be identified as the vendor works through their full analysis and review processes (presuming the operator has instructed the vendor to provide such notifications). A protocol for reporting critical features should be developed, as these features may merit a highly aggressive, limited timeframe response.

12.4 Immediate Responses

12.4.1 Pressure Reduction

Pressure limiting defects present the opportunity of instituting a pressure reduction to mitigate the associated risk where their severity would merit such a response. This requires an ILI vendor or the pipeline operator to quickly calculate the burst pressure of the suspect anomalies. In some cases, such as complex anomalies where interaction or clustering of adjacent defects is applied, this level of calculation may not always be possible in a preliminary report.

Resolving the appropriate level of pressure reduction should include a review of the recent pressure history at the location of interest.

12.4.2 Leak Detection

Where the reported depth of the feature indicates a potential for a through-wall defect, the operator should assess the location for the possible presence of a leak. The specifics of the response and the required timeliness and accuracy of the feature location would depend on the product being shipped in the pipeline and regulatory obligations, but could range from over-the-line gas detection and instrumented aerial surveillance to shutting in and sectionalizing the line with pressure monitoring.

12.5 ILI Final Report Format

The ILI final report will vary by vendor, tool technology, and operator requirements. Normal components of the ILI final report include the following:

— the hard copy binder,

— the digital version of the hard copy content,

— the pipe or features tally in a digital and queryable format, and

— the data/image files associated with the vendor's client viewer software.

The number of copies and the format of the first three deliverables is influenced by the operator's specification, but the underlying challenge is the management of change across these various representations of the data when the analysis is changed or updated. Different approaches can address this challenge depending on the circumstances and the operator's preferences. The approach should be documented and clearly understood, so that if versions become inconsistent all stakeholders understand which version is the trusted source.

12.6 Quality Assurance of Final Report before Acceptance

12.6.1 Initial Review

This first quality assurance process is focused on the ILI data as a standalone deliverable, and will consist of a review of the data to ensure that the ILI tool vendor has met the general reporting requirements specified by the operator.

12.6.2 Consideration of Historical Remediation

Before resolving the anomalies for considerations as actionable from the response criteria, historical records regarding past repairs and remediation should be considered to avoid inadvertently, and unnecessarily, excavating an anomaly.

After the aforementioned reviews are complete, any errors or omissions, if present, should be resolved before accepting the final report.

12.7 Anomaly Assessment

12.7.1 General

Although the specifics vary by jurisdiction and operator, the response criteria for anomalies is a combination of the risk posed by the features and an appropriate and timely investigation of the anomaly. Upon excavation, separate criteria would be applied to the in-ditch assessment to determine if a repair is required.

12.7.2 Establish Date of Discovery

Date of discovery occurs when an operator has sufficient information to confirm the reported anomaly from the ILI data. Depending on the notification protocols agreed upon, the date of discovery can range from prior to a preliminary report to sometime after receipt of the final ILI report. Due dates for actionable anomalies are also established at this point.

12.7.3 Review for Interaction with Risk Receptors

The potential consequences of a release are central to the integrity management of a pipeline. A prevalent example of this is the high consequence area (HCA) designation in the United States. For liquid lines, this includes both direct interaction (i.e. within the HCA) and indirect interaction (i.e. overland drainage, spill plume, and downstream transport). The extent of a pipeline interacting with HCAs is not an attribute of the pipe. If the centerline (i.e. assumed location of the pipeline) or features on the centerline are moved significantly due to improved spatial alignment, then the interaction with HCAs should be redetermined as part of the management of change process.

12.7.4 Integration of Other Data Sources

12.7.4.1 Data Sets

Operators should consider data sets that capture the pre-existing anomaly population, pipe properties, and environmental data. The data in this context are primarily leveraged to determined susceptibility to the various threats, determine current fitness for purpose of assessment results and to resolve growth or time dependent degradation to inform re-assessment intervals. Depending on the threats being actively being managed and how they are manifesting, there are numerous attributes that may be relevant in integrity management. A key consideration in the data management strategy is flexibility and agility regarding the storage, integration, and presentation of new relevant data sets as they are identified. An alignment of welds should be performed between data sets containing welds, such as ILI and excavation data. Once welds are integrated and aligned, the anomalies (such as dents, metal loss, or cracks) should be correlated and reviewed. For further information, see API RP 1160.

12.7.4.2 Interpretive and Analytic Techniques

Once the data sets are integrated and spatially normalized, multiple interpretative and differential analytic techniques can be applied to further assess the severity and potential causes of the reported anomalies. Possible considerations include the following:

- Dent anomalies from the current ILI should be reviewed to determine if they may have resulted from mechanical damage, if they are new, or if multiple dents exist within close proximity. Once identified, a review of the raw ILI data could be performed to confirm their characterization.
- Metal loss anomalies should be reviewed for potential growth. This can be done by a pit-to-pit comparison based on reported dimensions or signal to signal to reduce variabilities across the ILI runs.
- Another method may be used to compare the number of metal loss anomalies per joint. If there is a significant discrepancy in either the dimension or number of metal loss anomalies per joint, a review of the ILI data is required.
- All potential actionable anomalies should be reviewed to determine if they have been previously repaired. Depending on the circumstances, consideration may be given to the adequacy or failure of the previous repair.
- New dent anomalies should be plotted relative to known encroachments and on a map-based interface for identification of potential third-party damage sources.
- Metal loss anomalies may be analyzed for areas of highly concentrated corrosion to determine if outside factors are causing it (e.g. foreign crossing). Engagement of other stakeholders outside of the pipeline integrity department is beneficial in this “hot spot” review if other contributing factors have not been integrated into the analysis yet.
- One call density by township, section, and range could be reviewed and correlated with ILI dent indications. Aerial ROW surveillance reports could be analyzed by corresponding one call reports as a percent of the total, which may correlate with top-side dent indications. This data may also be inputted into risk assessment models and public awareness programs as well as prevention and mitigation projects. The reliability of Public Land Survey System (PLSS) mapping, and all off-the-shelf data sets used in mapping, should be subject to a data integrity review, as are all other data in the database. In regard to ground disturbance performed without one call notifications, a more general overlay of farming locations, railroads, and roadsides should be considered.

12.7.5 Pressure Limiting Anomalies

Calculation of an anomaly's failure pressure or failure-pressure ratio depends upon attributes that may not be directly measured by the ILI tool. These would include MOP/MAOP, specified minimum yield strength (SMYS), and toughness, and could also include wall thickness depending on the inspection technology.

Given that most metal loss features that are pressure limiting are clusters of individual anomalies, the clustering rule used and its application will significantly influence the resulting pressure. Another influence on the outcome would be how shallow features (<10 %) are used in the clustering. These otherwise irrelevant features can appreciably distort the resulting pressure for long, shallow features, especially where conservative failure pressure response criteria are used. One such distortion is where shallow features are reported at the minimum detection depth specification of the tool, even though they are below that level. Although shallow anomalies are useful for delineating the shape and distribution of the metal loss in order to understand the initiation/growth mechanism, control mechanisms (filters) should be considered in regard to clustering processes.

The algorithm used to calculate the failure pressure is another variable that can influence the outcome. The selected approach should be stored as metadata for the failure pressure.

12.7.6 Growth Analysis on Anomalies

Growth analysis should be performed on all metal loss and cracking features to determine if any anomalies need to be investigated prior to the next assessment. Growth analysis can be calculated using date of construction, pit-to-pit, or standardized growth rate based on NACE or other methodologies.

12.7.7 Pipe Movement

Differential analysis of pipe movement resolved through strain measurement or slope monitoring can provide insight into time-dependent effects.

12.7.8 Validation of ILI Performance

Accuracy validation entails a differential analysis between the current ILI data and other data sources to assess the performance of the ILI system, including POD, POI and POS. This would address both the reported anomalies and applied pipe attributes, either measured by the inspection tool or provided in the pipeline questionnaire, and leveraged by the vendor in preparing the report (e.g. SMYS and MOP).

Methods for validating ILI data include, but are not limited to:

- correlation with field data from previous nonmetallic repairs or recoats for the same segment,
- correlation with field data from excavations in response to the current ILI,
- acceptable correlation with a temporarily or permanently installed spool piece that contains anomalies with known characteristics,
- correlation based on a comparison to a previously validated ILI run, or
- calibration certificate for dents that demonstrates that the pre- and post-calibration are within the published tool specification (in lieu of correlation excavations).

As detailed in API 1163, an ILI tool's performance can be validated using data from similar pipeline(s) and from historical (near-term) runs utilizing an ILI inspection tool with the same sensor technology and from the same vendor. The non-measured data, such as SMYS or MOP, that are essential variables in the vendor's assessment of defect severity, should be reviewed and confirmed for every run.

12.8 Excavation Program

12.8.1 Program

Excavation program aspects pertinent to the data integration include the following:

- validation that the correct joint is being excavated;
- extent and accuracy of NDE inspection;
- anomaly correlation;
- type and extent of remediation or repair; and
- preventive and mitigative activities performed to manage growth (from internal corrosion, external corrosion, fatigue, etc.) or recurrence.

See Section 13 regarding field data collection.

12.8.2 Anomaly Correlation

In terms of anomaly correlation, a scenario of specific interest is outlier resolution. API 1163 provides direction regarding what could constitute an outlier and what responses may be appropriate. Operators should understand the cause of the discrepancy and its significance to the remaining population of unmitigated anomalies. Where the cause of the discrepancy is systemic to some degree and attributed to ILI data as opposed to the NDE data, the remaining anomalies can be recharacterized or calibrated to compensate. This could manifest in the form of an applied bias or a modified tool tolerance specific to the circumstances associated with the outlier.

12.8.3 Differential Analysis

The differential analysis between the current ILI data and the NDE results of the excavations may involve the use of a unity plot in communicating the accuracy of the ILI tool by comparing the predicted values versus actual values. An extension of this approach is to calculate the actual tool tolerance to an equivalent level of confidence based on this data.

The timing of this analysis usually does not impact the content of the original final report (unless driven by the preliminary report). When ILI tool results deviate from the tool's published specification beyond an established amount, a request to the ILI vendor for a review of the ILI calls should be performed. Based on the results, a regrade of the ILI call outs may be necessary. The operator may establish a new date of discovery based on the regraded report. If the data cannot be sufficiently corrected through regrading, resizing, or recharacterization, the operator may have reject ILI run and have the pipeline reinspected.

12.9 Provide Correlation Results to ILI Vendor

The operator should identify which dig results to supply to the ILI vendor to utilize in calibrating their sizing algorithm. The dig feedback should include, but not be limited to, NDE reports, correlation tables, and photographs. Although generally provided once the dig program has been completed, this data may be provided incrementally when outliers are identified, or where there has been little previously available in-ditch correlation data for the ILI tool or anomaly type. In some cases, it may be beneficial to work jointly with the ILI vendor's analysts at excavation locations to resolve field NDE vs. ILI data discrepancies in sizing or characterization.

12.10 Program Closeout and Establishment of Reassessment Intervals

A review of the results should be performed and a determination made to close out the project or add additional digs. Reassessment should be established from the trap date for the ILI tool run, and be determined in consideration of prescribed regulatory intervals and risk factors, including growth modeling of the unmitigated population of anomalies.

13 Execution of Digs/Field Data Collection

13.1 Pre-dig Information

13.1.1 General

To ensure a high confidence in the location of actionable anomalies identified from ILI assessments, several physical measurements and records should be obtained prior to anomaly excavation. These parameters, when used together, minimize if not eliminate, the likelihood of excavation at an incorrect location.

13.1.2 Flow Direction

Flow direction and direction of tool travel is required to establish the order of upstream and downstream joints, as well as the orientation of the anomaly as viewed looking downstream. The anomaly orientation looking downstream should be confirmed with vendor reporting formats.

If the tool was launched in the flow direction opposite of recorded stationing, the operator should perform a calculation to correlate stationing to leverage and record station-based references.

13.1.3 Axial Position

13.1.3.1 General

The anomaly is positioned relative to the reference or target girth weld, typically the upstream weld. The target girth weld is usually the start of the excavation, as it provides the timeliest feedback in terms of the excavation's spatial accuracy. An operator could use the methods listed in 13.1.3.2 through 13.1.3.4 to determine the location of the excavation's target girth weld. Regardless of how the location of the site is resolved, alignment sheets or a GIS in addition to field staff consultations should be used to gauge the dig difficulty and whether further preparations or precautions are required for efficient and safe excavation. The legal description (e.g. state, county, etc.) of the dig site is usually required for landowner engagement for access and ground disturbance.

13.1.3.2 Relative Location

The location provided by the vendor is typically stated as a cumulative distance from tool launch. Identification of the nearest reference point (e.g. valves, casings, benchmarks, etc.) to the anomaly provided from the ILI report in the upstream and downstream direction can approximate the excavation location. Also, the operator should verify the total tool odometer reading matches the published segment length in alignment sheets, as-built drawings, surveys, or any other verified document. If the two lengths are significantly different, error may be introduced on site when locating anomaly excavation points.

Reference points should be located at regular intervals on a pipeline segment. The density of references and the resulting distance from the anomaly influence the measurement error in locating the anomaly (measuring error is reduced when reference points are closest to the intended dig location).

13.1.3.3 GPS from IMU

GPS coordinates facilitate directly resolving the excavation location and its position relative to electronic maps such as a GIS. However, the spatial error inherent in this inferred GPS is dependent on the proximity of the control points used in its derivation. To limit the typical error associated with inertial drift to a maximum of X then spacing of the control points should not exceed Y; however, any spatial error in the GPS of the control points would be additive to the inertial error of the IMU.

13.1.3.4 Weld Alignment

Joint matching at the girth weld aids the matching of previous tool data to current ILI assessment data. This avoids the need for AGM or IMU data for the current ILI in regard to alignment of the run. Weld alignment also allows a joint level comparison for anomaly growth (e.g. noting increased anomaly counts per joint and direct comparisons of identified anomalies).

13.1.4 Seam Orientation

The easiest means of validating that the correct joint has been excavated, for non-seamless pipe, is to correlate the upstream and downstream seam orientations at the target girth weld (if available). Even where the orientation may be shifted due to measurement error, the relative offset between the seams at the girth weld remains accurate. The combination of the orientations is typically more distinct than joint length and requires less excavation. For spiral pipe, resolving the orientation where the seam welds intersect the girth weld may require going beyond the pipe tally and reviewing the vendor's thematic visualization of all the data in their viewer application.

13.1.5 Joint Length

Most pipe joints are purchased and installed in random lengths; the lengths may be similar enough that they are not distinct in consideration of the ILI measurement error. When the anomaly location is in question, excavating and validating distinct joint lengths in proximity may be necessary.

13.1.6 Pipe Properties

Pipe properties to facilitate both the location validation and repair assessment include the following:

a) pipe mill,

b) pipe grade,

c) nominal wall thickness,

d) long seam type,

e) distance from upstream station, and

f) for multiple joints upstream and downstream of the target,

   1) long seam orientation,

   2) joint length, and

   3) joint number.

13.1.7 Previous Excavations in Proximity

Past excavations near proposed excavations may contain confirmed reference points and relevant pipe information. Another consideration on older lines is the minor extension of the proposed excavation in order to tie into the high integrity coating from a previous repair.

13.1.8 Deliverables for Field Execution

Table 1 lists a typical work package to support effective location and correlation of the ILI features.

Table 1—Typical Location and Correlation Work Package Contents

Fields	Description
Dig list	A complete list of all numbered, required/recommended dig locations, as well as possible and additional (provisional) dig locations, identified in the assessment segment (sorted by odometer, not dig number).
Dig sheet	An excavation sheet prepared specifically to locate the required/recommended "target" girth weld/anomaly for excavation.
Site reference	A complete pipe listing of all events reported directly upstream and downstream to aid in target joint/anomaly location and excavation.
Anomaly correlation table	A complete list of joint-to-joint (minimum) reported information for all numbered, required/recommended dig locations (as identified in the assessment segment) for field result population and recording. Given that the site may include anomalies from multiple ILI runs, referential attribution may include the following: — vendor name, — vendor project number, — vendor ILI odometer, — ILI tool type, and — ILI vendor dig sheet/anomaly number.

13.2 In-ditch Data Collection

13.2.1 General

Specific consideration should be given to the delineation of data that need to be extracted, aggregated, and integrated into the broader integrity management data set to support comprehensive and informed decisions. A further consideration is the relevance of the data recorded in the ditch and how the effort and time required relates to the benefit of the data in understanding the degradation mechanism or severity of the defect and its associated threat.

13.2.2 Location Confirmation

The means by which the location of the excavation was validated as correct should be clearly documented, along with the names of the individuals involved.

13.2.3 Foreign Structures

Any structures around dig sites should be documented. The type of structure, distance from pipeline, name of owner, and a telephone number or address should also be noted if possible. An as-built of any structure around the dig site should be drafted.

13.2.4 Pipe to Soil Readings

The operator may consider documenting cathodic protection potential readings at the pipe and ground level as applicable to the test threat being investigated. These may be taken at the time of excavation and before backfilling after a repair has been made. Both readings should be taken in a consistent polarity.

13.2.5 pH under Disbonded Coating

The pH of any water or moisture beneath the pipeline coating should be documented where relevant to the identified threats. This data can be gathered using a variety of technologies, including pH paper.

13.2.6 Soil Type

The soil type or classification at the dig location should be documented where relevant to the identified threats (e.g. class A, B, or C—along with rock, dirt, clay, sand, etc.).

13.2.7 Soil Resistivity at Pipe Depth

Consideration should be given to documenting soil resistivity readings representative of pipe depth where soil resistivity relates to the features anticipated within the excavation. Where soil resistivity can be captured, this provides the operator with an accumulating data set that may become highly relevant at a future date. If it is suspected that there are soil strata above the pipe that differ from the strata at pipe depth, resistivity readings in those differing strata may provide additional insight to the applicability of the reading taken at survey (i.e. four-pin method). All readings should be taken as close to the pipe centerline as is practicable.

13.2.8 Corrosion Status

During coating removal, the presence, type, color, hardness, and other relevant features of deposits under existing coating should be noted. Consideration can be given to the benefits of implementing the training and equipment necessary to capture the following during the excavation:

- corrosion status (i.e. active, inactive, or unknown),
- the presence of extensive (all over, random area) or localized (contained to one area) corrosion, and
- evidence of microbiologically influenced corrosion (MIC).

13.2.9 Pipe Attributes

The coating should be examined, before removal, for type and condition; sagging, cracking, wrinkling, disbondment, damage, or other attributes. NDE methods may be used to measure additional attributes such as wall thickness, with emerging technologies providing the capability to measure yield strength in the ditch.

13.2.10 Existing Repairs

Any existing repairs within the excavation should be documented and should include the following information:

- the type of repair,
- distance from known girth weld, and
- the condition of the existing repair.

13.2.11 Existing Connections or Fittings

Documenting connections or fittings by type, size, distance from known girth weld, and orientation aids in verifying the target joint and the ILI tool accuracy. Any connection or fitting should be noted on as-built drawings to ensure that the attachment is included on company alignment sheets. The wall thickness of any fitting traversed by the ILI should be validated as they are often substantially thicker than the adjacent pipe.

13.2.12 Longitudinal Seam Weld Orientation

The orientation of the long seam (o'clock or degrees) should be noted, when it can be determined visually, on the target joint and the upstream/downstream joints to aid in verifying the target joint and ILI tool accuracy.

13.2.13 Joint Length

Weld-to-weld direct measurements should be taken (with tape) to give the absolute length of pipe joints. This aids in verifying target joints and ILI tool accuracy. Distance between weld GPS points should not be used to verify joint length because of the relative error between the GPS points.

13.2.14 Excavation Site Information

As depicted in Figure 1, the following dig site information may be useful for threat management when properly documented and integrated into the overall management program.

- Excavation length is the longitudinal distance of soil that is disturbed as part of the excavation. This length is typically longer than the length of pipe that is exposed to allow for proper sloping of the excavation ditch. This can also include pipe that is exposed but does not have the coating removed.
- Exposed length is the length of pipe that is uncovered with excavation such that the pipe coating is visible.
- Remediated length is the length of pipe that has its coating removed and the surface cleaned for defect assessment and ultimately reapplication of the coating.
- NDE length is the length of the pipe that is actually assessed. Some operators choose to assess the entire exposed length of pipe while others choose to review only the target defects. This can depend on the type of defect that is being reviewed. A full joint excavation with exposed girth welds can facilitate ease of confirming location and referencing. NDE of the full joint allows an operator to assess the condition of a pipe joint beyond what was reported by the ILI tool.
- Longitudinal seam weld assessments should be documented based on the type and length of inspection that was performed. It can be helpful to understand the percentage of the total length that was assessed versus the length of pipe that was exposed when performing data integration.
- When magnetic particle inspection (MPI) or dye penetrant inspection is performed, the locations that are assessed should be documented by collecting the same area information that is collected on a corrosion feature (i.e. length, width, circumferential, and axial location).

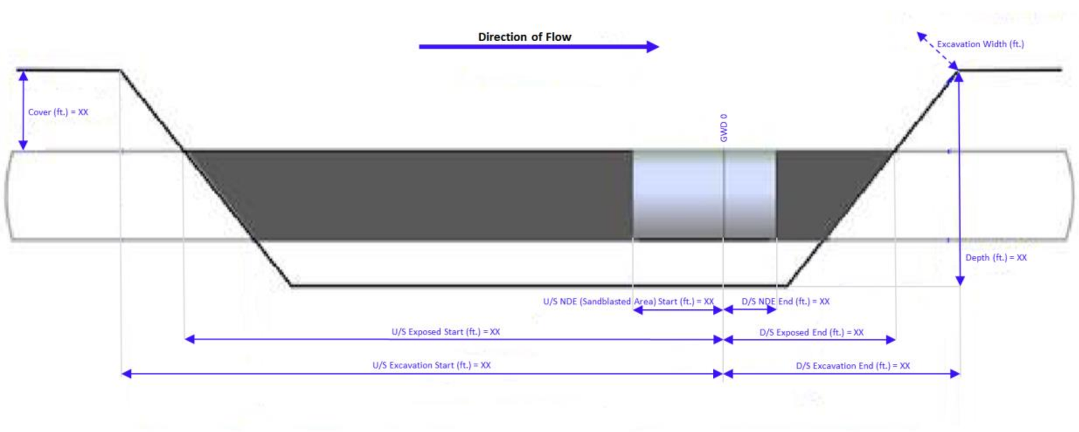

Figure 1—Schematic of Relevant Excavation Site Information

13.2.15 Site Mitigation

Appropriate axial and circumferential referencing ensure that information collected at the final stages of field NDE can be incorporated into the overall integrity management plan for a line or a specific pipe joint. For instance, ILI-reported features from subsequent ILI on previously excavated joints can be identified as active or already mitigated if the extents of historical mitigation activities are properly documented.

In addition, threat management requires the following information:

- type of repair,
- axial limits of repair type,
- extents of coating replacement,
- pipe replacement, and
- installation of new appurtenances such as CP test leads.

This information can also be provided schematically similar to Figure 1.

13.2.16 Photographs

Photographs are useful for communicating information from field personnel to personnel in the office, and can be used to validate information provided within the tables in a field NDE report. Effective photographs of the pipe surface should have a reference scale, such as a ruler with markings of the data collected during defect assessment. It is helpful to take photographs of features both on a macro level (e.g. an entire corrosion feature) and on a micro level (e.g. pits within pits to document MIC). The capabilities of field personnel and their equipment to take effective photographs should be verified.

Table 2 provides guidelines for photographs.

Table 2—Guidelines for Photographs

General Photograph Guidelines	Photograph Guidelines for Defect Assessment
— General vicinity/site overview before excavation to document ROW condition prior to disturbance — Coating condition as-seen when pipe is exposed prior to removal of coating — Soil condition — Line identifiers (e.g. number, milepost) — Flow direction — Location information (geotagging, if applicable)	— Boxed ILI callout area — Measured wall thickness — Measured depth — Measured length — Axial limits (start and stop reference locations) — Circumferential locations — Radial position — Measurement unit

13.2.17 Anomaly Assessment

13.2.17.1 General

Anomaly assessment is the process by which a feature reported by an ILI survey, or an area of interest from a DA program, is reviewed for integrity purposes. Anomaly assessment confirms or refutes the results of an integrity assessment (e.g. if an ILI survey reports a feature with a certain length, width, and depth).

13.2.17.2 Reported Versus Actual Response Time

Actionable anomalies reported in ILI assessments are assigned response times for remediation. These response times are based on regulations and the operator's procedures. Remediation of the features with a prescribed response time stops the clock, irrespective of field data collection activities that may continue past that point. Features should be documented based on when they were required to be remediated and when they actually were remediated. This ensures compliance with regulations and with corporate procedures.

13.2.17.3 Data Collected During Anomaly Assessment

All anomalies on a pipeline that are being assessed require the same basic information be gathered in order to integrate data. The key parameters are as follows:

— The length of the anomaly is the measured distance that it traverses along the length of the pipeline. It is sometimes useful to collect length information for the general anomaly being assessed and document any significant features in the anomaly (e.g. pits in a larger area of corrosion). In the case of stress corrosion cracking (SCC), it is helpful to measure both the length of the colony as a whole and the maximum interlinking length within the colony. API RP 1176 provides additional guidance in order to support meaningful correlation with ILI crack anomalies.

— Anomaly depth for metal loss and cracking is the extent through the wall thickness. This is usually measured from the surface of the pipe, internal or external, to the deepest part of the anomaly. However, for embedded planar features this could be reported as height. API RP 1176 delves further into the specific considerations of the nomenclature associated with NDE using shear wave UT. Mapping the depth profile at a pre-determined interval to create a river-bottom profile supports a more accurate failure pressure determination.

— The depth for geometry anomalies such as dents is typically captured as a percentage of pipe OD at its deepest point. Mapping the depth profile along the pipe axis at a pre-determined interval supports additional dents characterization per API 1183.

— Width is the circumferential extent of the feature being reviewed. This can be measured clockwise or counter-clockwise across the largest portion of the defect.

— Axial location measurements are taken from either an upstream or a downstream reference girth weld. The measurement is taken from the center of the girth weld to the closest extent of the feature being reviewed. It can be beneficial to measure the axial location from both upstream and downstream reference girth welds.

— For circumferential location, the top of the pipe is the 12 o'clock, or zero-degree, position. Circumferential locations are measured looking downstream of the pipe from this reference. The measurement can be taken from the top dead center of the pipe in a clockwise manner to the first instance of the feature being assessed. Alternatively, it can be to the center of the feature to align with the ILI reporting format, if applicable.

— Internal versus external radial position is determined; mid-wall defects will possibly require a quantitative measure be taken from the inner/outer surface of the pipe to the defect. Knowing whether a defect is surface breaking or not can alter the type of defect assessment to be performed.

— The measurement units should be consistent across a company's region if not the entire organization. For example, if an operator uses imperial units in the office, they should make measurements in imperial units in the field. Depth measurements should be reported with units of inch or millimeter at a minimum, and it is sometimes beneficial to also report in percent of wall thickness as well (i.e. imperial/metric, % WT).

— The identification of coincident and interacting anomalies should be addressed through the use of MPI and/or UT inspection techniques as applicable. The interaction of anomalies should be noted and accounted for in the assessment. In certain cases, (e.g. crack interacting with corrosion), successive minor buffing may be required to allow adequate characterization of the interacting anomalies. Regarding cracks in corrosion, additional characterization of the cracking as to its location in the base or sidewall or the corrosion may be beneficial.

14 As-built Asset Integration

14.1 General Data Requirements

14.1.1 Types of Data

Collecting and organizing the pipeline data in a comprehensive manner as early as possible in the pipeline's life cycle is important to managing the integrity of the pipeline. The operator should determine the data required to make integrity decisions throughout the life of the pipeline.

Before work is started, it is helpful to create a checklist of the data required to aid the lead inspector in ensuring that the requisite data is captured. Creating a template and minimum geospatial data delivery requirements (i.e. specifications) ahead of project commencement that matches the format and order of the database in which the data will be stored increases the chance of receiving usable data. An ongoing document log should be used to track documents as they are received; this document log should be followed with a project completion checklist to account for all documents.

14.1.2 Project Book

Project books, either physical or digital records/data, can be compiled during the project or upon completion. Common project books include, but are not limited to, the following:

- Department of Transportation (DOT) records,
- safety and training records,
- maps,
- CP records,
- valve listings,
- maintenance and construction records,
- pressure test records, and
- pipeline integrity records.

14.2 Data Collection

14.2.1 Receipt of Data

The operator should decide when and how to receive the data. One option is to receive the data periodically throughout the course of the project. This strategy ensures that the data can be verified for completeness and accuracy in a timely manner. The potential for future errors may be mitigated by communicating any issues that are discovered to the field personnel. Annex B provides a comprehensive example of this approach.

Another option is to receive the data at the end of the project. Project books should contain the mill test report (MTR), if available. The MTR documents the manufacturer, properties, and dimensions of the steel that was used to make the pipeline.

Determining which segments of pipe were installed in which locations is a key concern. Although MTRs, combined with the purchase order, specify the total length of pipe purchased, they do not detail whether the pipe was installed in one string or divided into multiple sections interspersed through the length of the pipeline. It is important for site inspectors and surveyors to accurately document the location of each joint of pipe and correlate the heat numbers to the correct MTR documentation.

14.2.2 GPS Survey

GPS as-built surveys require that the data format, datum, and accuracy be selected prior to performing the survey or awarding the work. Certain equipment manufacturers produce specific file types. The file types should be compatible with the structure of the data management system to better facilitate the conversion process.

Consider receiving a test sample of GPS data shortly after the project commences to validate that the data meets the requirements specified at the beginning of the project. Ongoing validation of the data is recommended, but final project completion validation is required.

In some cases, the pipe is surveyed while on skids next to the ditch. A subsequent transformation is then used to shift it to the ditch centerline. The transformation process does provide another opportunity to introduce errors into the data; where used it should be well documented and clearly understood.

The physical pipe properties and heat numbers can be noted in the GPS points for each joint of pipe. Errors can still occur because the properties will still be input manually. To counter transcription errors, radio frequency identification (RFID) tagging or bar coding can be used. A tag or bar code is affixed to each section of pipe. These tags or codes can have exact pipe properties of the steel to which they are attached. Transcription errors are eliminated with this process.

14.2.3 Review of Data Collection Requirements

After determining the company-specific requirements for the data, operators should review data collection requirements and confirm the procedures to be used by personnel gathering the data. The operator should ensure that all personnel understand the data collection methods, and the importance of the collected data, to improve the quality of the data books and the subsequent implementation of an integrity program.

14.3 Virtual Pipeline Creation

The information within a project book should be utilized for integrity decision making. Creating a virtual pipeline to map pipeline routes and depict pipe properties throughout the length of the pipeline can answer several integrity-related questions.

Loading the XYZ coordinates from the GPS survey into a computer-aided design and drafting program gives the basis for the virtual pipeline. A database template, or seed file (if established early in the process), can be utilized to streamline the data-loading process. A linear reference should be established for the pipeline; this is commonly in the form of an engineering stationing standard.

Engineering stationing is assigned to known reference locations such that stationing at intermediate points can be interpolated. All other features can be loaded and assigned a linear reference based on their positioning in relation to known reference points. Decreasing the distance between known reference points provides the most accurate linear reference representation. The accuracy of inferred engineering stationing can vary greatly when dealing with rolling landforms with significant elevation changes.

14.4 Data Storage

Data storage and archiving are key elements of the asset integration process. Project books may be received as paper copies, although converting the documents to electronic format can ensure preservation of data over time.

Whether the data is in paper format or electronic format, an index system should be created to make the data easily accessible and with improved traceability for future inquiries. The indexing strategy and metadata fields should be developed with consideration of how the records will be accessed once the pipeline enters operations.

14.5 Continuity of Linear Referencing Schema

Attention and consideration should be paid to the historical field stationing references when updating drawings and updating a station-based GIS. Maintaining this attribute ensures a common frame of reference between current and historical data, such that the historical data can be retrieved and aligned to the current ILI data with minimal effort.

14.6 Baseline In-line Inspection

14.6.1 Horizontal Directional Drilling Considerations

If performing a horizontal directional drill (HDD), the operator should consider pulling an ILI tool through the pipe both before and after installation to differentiate between manufacturing defects and construction defects, as well as to validate the use of proper construction practices. Regardless, a post-installation tool run can verify the presence of any defects injurious to the pipeline prior to starting the pipeline.

14.6.2 Pre-commissioning ILI

Considerations regarding caliper runs conducted during construction include the following:

- Where specific concerns exist regarding construction damage, running the caliper inspection before hydrotesting provides an improved assessment for mechanical damage before the pressure from the hydrotest rebounds (pops out) the associated dent.
- Running the caliper inspection prior to commissioning facilitates the original construction contractor remediating the identified dents and buckles prior to line fill.
- Where a high-resolution caliper tool is run, the vendor may require elevated back pressure to meet the specification. Where run with compressed air during construction, the pressure requirements may significantly impact logistical requirements. These pressure requirements should be identified early and communicated to all stakeholders.

14.6.3 Post-commissioning ILI

Shortly after commissioning pipelines, in-line inspections may be run to perform the following:

- detect defects from manufacturing or created during construction (and potentially correct defects under the warranty period),
- create a baseline for comparison of future tool runs, and
- validate the project book (see 14.1.2) data information (e.g. compare joint lengths and wall thickness readings, as measured by the tool, to the as-built drawings).

Incremental or expedited delivery of the survey data supports production of accurate pipeline questionnaires such that vendors can make informed proposals for the baseline inspections.

14.6.4 IMU Tools Runs

IMU tool runs can provide an additional way to map a pipeline in conjunction with the GPS survey. IMU tool data can be used to measure the radii and strain on bends, as well as confirm that any construction-related specifications were followed. Data from subsequent IMU tool runs can be used to detect any land movement issues.

14.7 Baseline Indirect Assessments

To verify that the pipeline is protected, a close interval pipe-to-soil potential survey (CIS/CIPS) can be performed to identify and locate areas where CP might not be adequate. A direct current voltage gradient (DCVG) or alternating current voltage gradient (ACVG) survey can be performed to identify and locate areas where coating defects may exist. After initial construction, it may take a year for newly backfilled soil to settle in around the pipeline such that accurate CIS and DCVG/ACVG surveys can be performed.

15 Over-the-Line Surveys (Indirect Assessments)

15.1 General

Various over-the-line surveys—such as CIS/CIPS or DCVG surveys—are performed by operators to monitor the performance of external corrosion prevention and mitigation measures. These data sets provide information only for the preventative measure (e.g. coating, CP levels) being assessed and do not directly report on the integrity of the pipe steel. An operator should align these data sets with ILI data to identify potential areas of interest where metal loss is reported on the pipeline in the same location as anomalies are found in over-the-line surveys.

15.2 Alignment

To properly align data sets collected above grade with data collected from within the pipeline through ILI, an operator should identify common features that can be detected and have a location established by both survey methods. Additionally, these points can be aligned with established locations in a GIS database to further correlate data sets. Once common features are established, locations of individual data points can be cross-referenced through GPS or linear referencing.

Figure 2 depicts some examples of how above-grade and below-grade data sets can be correlated through common features. Examples of common feature locations include the following:

— A benchmark is commonly used for tracking and establishing interpolated GPS data during ILI surveys. Benchmark locations can also be noted during over-the-line surveys using GPS equipment to facilitate data alignment.

— Corrosion control devices and equipment—such as test stations and rectifiers—are sometimes located using GPS equipment during over-the-line surveys and are typically included in spatial databases. While typically not recorded during an ILI survey, their locations can be interpolated into the ILI data set through GPS or linear referencing.

— Various pipeline features—such as above ground markers (AGMs), casings, valves, taps, bends, and repair sleeves—are often detected and recorded during ILI surveys and can be recorded during over-the-line surveys to provide additional reference points. Additional features to align ILI data could include tie-in joints of pipe that are often shorter in length or that can be identified through a detectible wall thickness change in the ILI data.

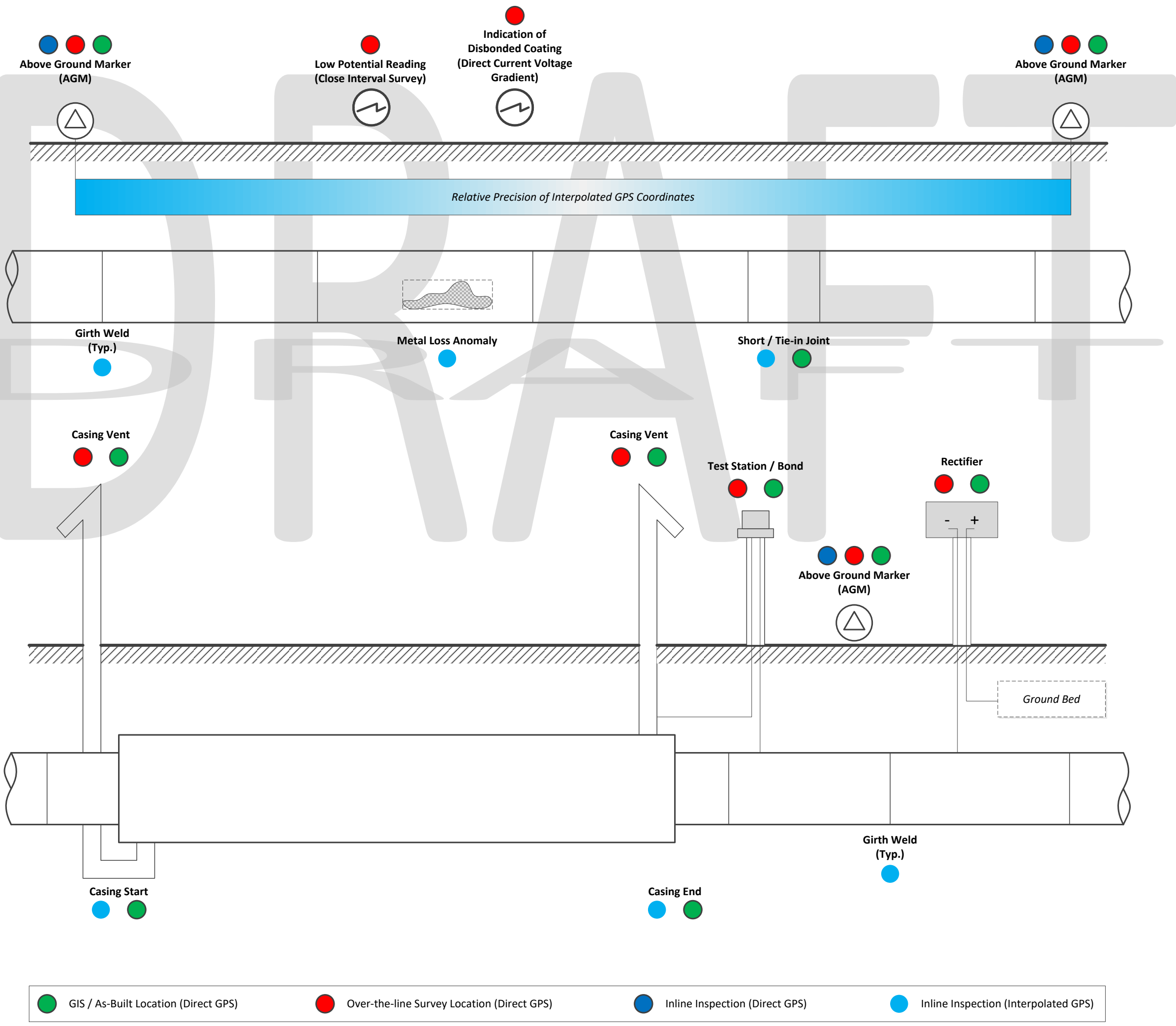

Figure 2—Examples of Common Feature Locations

16 Operational Data

When assessing threat mechanisms, it is important to delineate historical, current, and future operational conditions. In terms of understanding how the current populations of defects came to be, historical data is key. Realizing that how a line was operated decades ago may aid in the understanding of anomalies that are discovered much later (e.g. high pH SCC initiated under historical CP and temperature levels that are now environmentally dormant, though the crack continues to grow through fatigue). In regard to pressure cycling, in-depth guidance on its data management and utilization in integrity assessment is provided within API RP 1176.

17 Performance Metrics

Data-centered metrics address the quality of the inputs into integrity decisions, as opposed to the quality of the decisions or their execution. In the context of data management and integration, performance measures should be developed in consideration of the dimensions of data quality (Section 5), focused on what would materially impact integrity decisions (i.e. not all dimensions would necessarily merit associated metrics). Similarly, not all metrics benefit from performance targets; in some cases, an operator looks for variations from historical norms as opposed to absolute values. Metrics should measure what is relevant and meaningful as opposed to what is convenient.

Annex A
(informative)
Data Integration and Interpretation Report

A.1 Purpose

This survey and the reporting of its results was intended to document and consolidate the methodologies and processes used by API member companies to spatially integrate and normalize their data to support the application of comparative techniques used in interpreting the various data sets, with a focus on ILI data. These processes require careful consideration by operators regarding their application, as the brevity of responses contained here may not sufficiently reflect all relevant assumptions underlying its applicability.

A.2 Structure of the Data

The following is a list of the various data fields with a description of the intended contents.

Field	**Description**
Name	The name that the operator assigns to the process should be in consideration of the feature type(s) and the purpose of the process.
Data sources	This is a listing of the primary data types used in improving the interpretation of assessment data.
Specific attributes used	This is a listing of the specific attributes of the data types that are utilized.
Sensitivity to spatial alignment	This is an expression, where available, of the opportunity for spatial misalignment of the data used in the process and the tolerance of the analysis to spatial error. Where the operator is unsure of this field, simply enter UNKNOWN.
Criteria	This is a succinct account of the criteria that is applied to interpret the data.
Interpretive methodology	This is an explanation of how the process is applied to the interpretation of the assessment data.
QC methodology	This is an explanation of how the process is applied to the quality control of the assessment data.

A.3 Implementation and Results

Contributions to the listing were solicited in two iterations over a two-year period. Section A.4 provides a list of processes for consideration regarding additional means of leveraging and interpreting ILI data, as well as elevated engagement of the ILI vendor.

Aside from any immediate value the reference list may provide, it is envisioned that this format could be used as a framework for facilitating ongoing consolidation and redistribution of industry practices.

In the process of summarizing the results to a list of data integration processes for consideration by pipeline operators, the responses were edited in some cases to improve clarity and minimize redundancy. Variations in nomenclature still remain as an artifact of having numerous individuals and companies contribute.

Beyond the material listed in Table A.1, two broadly used QC processes are:

— Providing the NDE (excavation) results to the vendor so that the ILI assessment can be refined based on field data.

— Performing signal-to-signal analysis across different ILI runs to derive growth rates.

A.4 Threat Matrix and Interpretive Methodologies

Table A.1 provides a matrix of threats matched with relevant interpretive and QC methodologies.

Table A.1—Threat Matrix and Interpretive/QC Methodologies

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
1	Any	Threat integration	ILI tool data (deformation, magnetic flux leakage [MFL], CMFL, ultrasonic metal loss [ML], and ultrasonic crack)	All types of defects from all types of ILI data	5t × 5t	Defects from all types of ILI data	Threats are categorized as internal ML, external ML, cracking, SCC, geometry, other (laminations, inclusions, manufacturing defects, etc.). Where two or more threats overlap spatially, they are carefully analyzed. This analysis may result in an excavation.	NDE results are reviewed for verification.
2	Any	Failure pressure anomalies	Pipeline maps, GIS, operational data	Pipeline elevation data	N/A	Line elevation deviates >100 ft	Elevation data is integrated into the ILI vendor's report for all anomalies along the pipeline. After receiving the vendor report, a "local" MOP is calculated using elevation and the most conservative product weight for every item on the feature list. The estimated repair factor (ERF) is then recalculated for all anomalies between 15 % and 80 %. Vendor does not adjust ERF for elevation.	A review of the vendor's calculated failure pressures is accomplished prior to importing elevation data. This step assures the ILI vendor used the proper evaluation pressures and parameters in preparing the submitted vendor report.
3	Any	Appurtenance reconciliation	Geometry or metal loss ILI	Features list	N/A	Appurtenance	A tap, stopple, tee, sleeve, patch, weld plus end, valve, flange, or other pipeline attachment which was unknown or installed with unapproved or unknown installation methods. Compare to GIS data to determine if the appurtenance is known and if it is located within a facility. Evaluate for removal if unnecessary on the system.	N/A

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
4	Any	A change since the previous assessment	Geometry/metal loss tool	Features list	N/A	An anomaly, predicted to have changed in depth, length, width, orientation, or any injurious manner, from the previous assessment	An anomaly, predicted to have changed in depth, length, width, orientation, or any injurious manner from the previous assessment. Supplied to tool vendor to determine if there is growth since last assessment.	

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
5	Any	All ILI anomalies—sensor loss	ILI tool data (deformation or MFL, or both)	Current in-line inspection tool data	N/A—integral to ILI data	Per vendor's specification	Sensor loss occurs when a sensor is damaged/inoperative and does not function properly through portions of, or the entirety of, an in-line inspection tool run. The number of sensors on an individual ILI tool varies based upon tool size and ILI vendor. Sensor loss can affect the in-line inspection tool's ability to correctly identify and size all anomalies per specifications. Variations: The vendor must be able to meet the company-specified vendor reporting requirements, including meeting detection thresholds. One possible approach is to implement a vendor-reporting requirement that references the pipeline operators forum and ensures that the pipeline segment has been assessed. Run failure criteria: <95 % coverage, if two or more adjacent sensors fail or if multiple runs cannot be combined to reach adequate coverage.	In the event of sensor loss, a data quality certification letter facilitates a clear determination on whether the in-line inspection vendor is still able to correctly detect (i.e. minimum anomaly dimensions detectable with given sensor loss), identify, and size all anomalies in accordance with their published detection and sizing accuracy. Included in the letter would be a summary of the number of sensors damaged/inoperative and the impact on overall sensor coverage.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
6	Any	Speed excursions	Tool spec	ODO resolved speed in ft/sec	N/A—integral to ILI data	Per vendor's specification	Out-of-range speeds (typically overspeeds) are primarily associated with gas lines (incompressible liquid column mitigates the occurrence). Different tool technologies have different levels of sensitivity to speed excursions, and the effect can negatively impact POD, probability of identification (POI), and sizing.	Extrapolation of the results from correlation excavations needs to be in consideration of the tool speed at the correlation sites relative to the remainder of the line.
7	Any	Circumferential additional metal	Extra metal	Current in-line inspection tool data	N/A	Circumferential additional metal (gain) not related to previous repair or casing	ILI metal (gain) features, particularly with a circumferential extent, that are not otherwise accounted for by a casing or previous repair.	Cross examination against other sources utilizing GIS software. If metal (gain) remains unaccounted for, further investigation should be considered.
8	Any	Girth weld quality	Environmental hazard data	Pipeline maps, seismic surveys, etc.		Anomalies potentially exposed to environmental hazards	Girth welds with poor quality should be identified and reinforced or replaced if located in areas subject to ground movement, such as earthquake prone areas, near bodies of water likely to erode cover away from the pipeline, or at locations where the pipeline is exposed or suspended.	Additional anomalies could be added to the evaluation list.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
9	Any	Longitudinal seam reconciliation	Geometry or metal loss ILI	ILI log/raw data	N/A	Longitudinal seam (Y/N)	Review ILI raw data for indication of longitudinal seam or seamless pipe. Compare results to GIS and maps and records and update as needed. If previously unknown long-seam is confirmed, evaluate for long-seam threats.	The vintage of the pipe would be a key determinant when weighing the potential manufacturing threat associated with the long seam.
10	Any	All ILI anomalies—ILI tool correlation	ILI tool data (metal loss or deformation, or both)	ILI data (as-called) and remediation results (as-found)		Per vendor spec	Correlation of ILI tool data is conducted to determine tool accuracy for each ILI run by comparing actual anomaly characteristics (as found) to the predicted ILI data (as called). By correlating data for each ILI run, you can account for individual tool performance, the specified tolerance, and other conditions specific to a particular pipeline segment inspection. Graphical representation (unity plots) of anomalies is employed to help identify trends in predicted versus actual anomalies for each tool run.	If correlation results demonstrate that the data is not within the stated tool accuracy specifications, a determination regarding additional anomaly evaluations may require the regrading of data based on correlation results or continued evaluation of the assessment data based on the calculated tool accuracy and confidence level.
11	Cracking	Distance from U/S pump stations	ILI	Pump station location	N/A	Greater of 10 % of pump-to-pump segment, or 5 miles, Downstream of pump station	Focused assessment of crack ILI features. Utilize additional criteria for dig selection to account for increased potential for feature growth.	NDE results are reviewed for verification.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
12	Cracking	Girth weld cracking	MFL ILI data	Identified girth weld flaws	YES	Review of MFL and IMU ILI data to identify any areas requiring further assessment.	Reported girth weld is reviewed with regards to available strain data to determine if they are located in areas of measured strain based on IMU data. Axial strain may provide a growth mechanism for girth weld flaws.	ILI data reviewed for potential field excavation and repair.
13	Cracking	Cracks with metal loss	Two ILI data sets	Feature list location	3t × 3t	Looking for cracks that may be interacting with metal loss	Ultrasonic shear wave ILI does not detect or report metal loss. This limitation can be overcome by integrating the shear wave ultrasonic list of cracking features with the metal loss feature list of another suitable ILI technology, and reviewing for interaction (i.e. spatial proximity or coincidence) of cracks with corrosion.	Depth and remaining strength may be affected by the interaction of defects.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
14	Metal loss	Casing short	Metal loss assessment	Metal loss feature	N/A	A metal loss anomaly (external) to have greater than 20 % wall loss inside a casing	A metal loss anomaly (external) to have greater than 50 % wall loss inside a casing. Information reviewed to determine if further investigation or mitigation of the casing is required. Variations: Anomalies are evaluated with metal loss > 40 % in a casing. Metal loss in casing showing growth from prior ILI reviewed to determine if further investigation or mitigation of the casing is required.	N/A
15	Metal loss	Metal loss at foreign crossing	Metal loss ILI	Features list	±100 ft of foreign crossing	Metal loss	Metal loss within 100 ft of a foreign crossing may be an indication of third party damage. Locate anomaly and crossing in the field, and if the metal loss is within 10 ft, investigate. Variations: Anomalies are evaluated if within 50 ft of a casing or 120 ft of a foreign line crossing. Qualified with a depth criterion of ≥60 %. 50 ft interaction criteria for crossing of another pipeline.	N/A

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
16	Metal loss	Active corrosion	CP	Potential	Closer to 0.00V than -0.850V	Metal loss	A metal loss anomaly predicted by the metal loss tool to have greater than 20 % wall loss in an area with cathodic potentials closer to 0.0V than -0.850V. Variations: Any metal loss showing growth from prior ILI and in a low potential area is flagged to be addressed.	
17	Metal loss	Touching/close metal object suspect corrosion	Metal loss tool	Touching/close metal object	N/A	Touching/close metal object	A touching metal object or close metal object predicted by the metal loss tool to be located in an area with cathodic potentials closer to 0.0V than -0.850V. Variations: If any close metal object is within the same, or an adjacent, joint of pipe that contains another anomaly to be investigated, then the close metal object should be evaluated. Gains near low potential areas are investigated.	
18	Metal loss	Touching/close metal object suspect corrosion near foreign crossing	Metal loss tool	Touching/close metal object	N/A	±100 ft of foreign crossing	A touching metal object or close metal object predicted by the metal loss tool to be located within 100 ft of a foreign pipeline crossing. The foreign pipeline must be marked in the field and be within 10 ft of the staked touching metal object.	

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
19	Metal loss	Metal loss greater than 20 % of nominal wall located at a touching metal object	Metal loss tool	Touching metal object	±5 ft of touching metal object	Touching metal object within ±5 ft of touching metal object	A metal loss anomaly predicted by the metal loss tool to have greater than 20% wall loss within 5 ft of a touching metal object. Variations: Correlated new or growing metal loss is checked for nearby causes such as gains.	
20	Metal loss	Excessive metal loss in heavy wall pipe	Metal loss tool	Metal loss data	N/A	Metal loss anomaly predicted to be greater than 50 % wall loss in heavy wall pipe	A metal loss anomaly predicted to be greater than 50 % wall loss found in piping with a nominal wall thickness at least 2 nominal sizes larger than the smallest nominal wall thickness.	
21	Metal loss	Metal loss greater than 20 % of nominal wall located near girth welds in fusion-bonded epoxy (FBE) coated pipe	Metal loss tool	Metal loss data	±6 in.	A metal loss anomaly (external) predicted to be greater than 20 % wall loss of the pipe body within 6 in. of a weld	A metal loss anomaly (external) predicted to be greater than 20 % wall loss of the pipe body within 6 in. of a weld indicates possible shielding coating. Variations: Correlated growing metal loss within 1 in. of weld is addressed.	
22	Metal loss	Metal loss greater than 20 % on nominal wall located in the pipe body in FBE coated pipe	Metal loss tool	Metal loss data	N/A	A metal loss anomaly (external) predicted to be greater than 20 % wall loss of the pipe body on FBE coated pipe	A metal loss anomaly (external) predicted to be greater than 20 % wall loss of the pipe body on FBE coated pipe indicates possible shielding repair coating.	
23	Metal loss	Anomaly within close proximity of a target item	Metal loss tool	Metal loss	±5 ft	An anomaly predicted to be within 5 ft of a targeted item	An anomaly predicted to be within 5 ft of another investigation.	

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
24	Metal loss	Coating damage	Close interval surveys	On or off	±50 ft	Depression not meeting company criteria	Excluding foreign crossing interference, localized depressions in the CP (be it on or off) would be indicative of a significant coating holiday (i.e. current drain). Assuming the presence of a nonshielding coating, this is a potential validation parameter for the presence of active external corrosion. This is dependent on information known about existing coating, bare pipe areas, etc.	N/A
25	Metal loss	Internal metal loss—data review	Corrosion coupon/probes data, operational data, product history, frequency of operation, use of inhibitors, validation sites, ILI comparisons	Data sources integrated with ILI data		Compare reported internal metal loss with known information	ILI-reported internal metal loss is reviewed against past reports (if available). The potential for growth is also determined by reviewing the data sources to see if there have been verifiable calculated growth rates. Periodic UT scans of validation sites can be used to determine if there is actual growth or if the "growth" is due to tool deviation where coupons, history, etc., do not indicate growth.	As-found data is forwarded to ILI vendors for fine tuning of the ILI results on internal metal loss calls.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
26	Metal loss	Active corrosion	Close Interval Surveys	Off or polarization shift	±50 ft	Per NACE SP0169	Assuming the presence of a nonshielding coating, and ignoring geometry effects, this is a direct measure of the polarization level of the pipe (assumed to be at the defect) and can be used to evaluate active vs. non-active corrosion. This technique is particularly valuable in terms of older lines where the CP has been significantly remediated or upgraded recently. This impacts growth-based modeling for reinspection intervals.	N/A
27	Metal loss	Complex corrosion	Metal loss tool	Metal loss boxes	N/A	Group all clusters within a specified circumferential extent (e.g. 2 hr span) position	Identify large groups of axially aligned anomalies (i.e. at common clock position). Complete list of groups based on the 2 hr span interaction with and a sublist of those groups with a peak depth ≥50 % and a length greater than 6 in. Variations: Pits are grouped based on interaction rule: 1 in. axial and 6t circumferential.	Groups provided to tool vendor for a secondary review of the feature interaction.
28	Metal loss	Complex corrosion	Metal loss tool	Metal loss boxes	N/A	Clusters that have three or more ML boxes with depth ≥50 %, within 3t × 3t of each other	Identify sub-clusters of metal loss boxes with depth ≥50 % to see if there is overlapping signal or underlying metal loss signal response. Variations: Pits are grouped based on interaction rule: 1 in. axial and 6t circumferential.	Clusters provided to tool vendor to manually verify clustering and failure pressure, or sizing needs revision.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
29	Metal loss	Complex corrosion	Metal loss tool	Metal loss boxes	N/A	Groups of 6t × 6t grouping with failed pressure ratio (FPR) ≤1.25	Identify potentially more severe anomalies (i.e. determine if there are any missed metal loss boxes that would join existing clusters). Variations: Pits are grouped based on interaction rule: 1 in. axial and 6t circumferential.	Groups provided to tool vendor for review to see if bridging ML box was missed.
30	Metal loss	External metal loss—coating review	CIS data, historic drawings, documents, and photos	Pipeline stationing of reconditioned areas	Some errors integrating field measured PL station numbers to station number interpolated through GIS mapping	Compare CIS measurements against anticipated coatings based on drawings and historic data	Review CIS data and compare to boundaries of anticipated coated, painted, or potentially bare pipe. This gives a better understanding of why some CP measures may be lower than others. Assists in determining if pipe originally laid bare has been recoated as part of reconditioning projects. Reviews of past integrity digs in the area can also be used to verify overall coating condition.	Reviews of ILI data may also show signs of reconditioning, such as puddle welds, patches, sleeves, etc. Historically, joints that were reconditioned were also coated upon completion of the reconditioning work. Intact and well-bonded coating at external corrosion features excludes these features from growth analysis. In joints where coating is noted to be well bonded and active corrosion is not likely, ILI data comparisons are used to assess report deviations from run to run.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
31	Metal loss	Metal loss validation of past repairs	ILI data, repair records	Reported metal losses under composite repairs	N/A	Pre-remediation measurement vs. current measurement.	The ILI vendors are instructed to report metal losses beneath composite repairs. Past ILI data, repair locations, and sizings are provided to the vendors for integration into the ILI reports. The vendor is to also use the known data to assist applying their sizing algorithms. Other known sizings (recoated anomalies) are reviewed to validate accuracy once the vendor data is received. This report validation is dependent on the presence of past findings.	This process assists in determining the ability of the ILI vendor to accurately size anomalies in the ILI reports. It also speeds up the time needed to validate a new ILI report since numerous new digs are not necessarily required.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
32	Metal loss	Corrosion growth	ILI metal loss	Metal loss features from multiple ILI runs	Joint alignment across the various ILI runs	Variances in max. depth, number, and volume of metal loss with a joint	This process leverages the definitive method of weld alignment to facilitate a course run-to-run comparison to highlight joints that merit additional scrutiny in terms of corrosion growth or feature characterization. The use of the volume of metal loss is a means to account for differing interaction rules that result in artificial variances in anomaly populations. Additional caution needs to be exercised where there are potentially highly variable corrosion growth rates within a single joint (e.g. MIC). Variations: For dig programs with suspected excessive corrosion growth, ensure the next assessment is performed using the same technology from the same vendor to accurately compare any metal loss growth, thus eliminating tool tolerance between different vendors with different tools. Calculate and plot joint corrosion volume. Identify anomalies for possible investigation where the maximum depth has increased by more than twice the tool tolerance.	Internal and external metal loss handled separately, but then compared to identify ID/OD mischaracterization.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
33	Metal loss	Metal loss in proximity of long seam	Metal loss ILI tool	Metal loss and deformation anomalies from previous tool runs	N/A	All anomalies	Existing anomalies are reviewed when new physical information obtained from subsequent tool runs is available.	Compare previous tool run data with current ILI data to identify if anomalies can be reclassified since the previous assessment. For example, if the current tool run identifies pipe seam orientation (when it was not known previously), anomalies are reexamined to determine if anomalies can be reclassified (e.g. a previously identified dent could be reclassified as a dent on a long seam).

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
34	Metal loss	Life cycle corrosion analysis	Metal loss ILI tool	Metal loss data	Joint alignment across the various ILI runs, engineering stationing of anomalies and other data streams	All anomalies	Graphical alignment of the following data by engineering stationing: a) ILI anomaly information as follows: 1) Individual anomaly depth (multiple runs identified with different colors) 2) Cumulative corrosion normalized to 1 over segment length b) Previous repair information	The analysis is used to seek areas where corrosion damage (that does not require repair based on regulatory or company criteria) appears to be increasing in depth, extent, or density, or where existing damage is NOT increasing in depth, extent, or density. It can be used to identify areas of suspect shielding coatings, coating damage/failure, and to prioritize areas for addition of cathodic protection, enhanced dig programs, reconditioning, or replacement.
35	Metal loss	Metal loss anomaly dimension	Metal loss ILI tool	Metal loss data		ML features that are greater than 5× in length than width	Perform a comparison of ILI data to other corrosion anomalies at the same o'clock position on the joint that might be an indication of selective seam corrosion, especially if it is in the bottom half of the pipeline orientation.	Could add anomalies to be evaluated in consideration of the possibility of selective seam corrosion.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
36	Metal loss	Alternating current (A/C) corrosion from HVAC power lines	ILI and PODS close interval survey, A/C survey, corrosion coupon survey for current density calculations	Metal loss from multiple ILI compared to A/C power corridors		Looking for change in metal loss in proximity to HVAC power lines, high A/C volts, and current density	Pipeline sections entering, leaving, and crossing at angles to HVAC power corridors are at a higher risk of increased corrosion rates, especially on FBE coated lines or coatings with high dielectric strength.	Use close interval survey data, A/C survey, corrosion coupons, and ILI metal loss data to determine if further A/C modeling is necessary.
37	Metal loss	Internal metal loss—data review	ILI, centerline, and operational data	Metal loss feature density, elevation, flow rate, corrosivity, pigging frequency, and chemical treatments	Joint alignment across the various ILI runs	Internal metal loss located in low areas	Review concentration of internal metal loss features in consideration of the supporting mechanism. This would typically be in close proximity to low lying areas, but contributing factors would be laminar flow and product corrosivity as well as mitigating measures such as cleaning runs and chemical treatment.	
38	Metal loss	External metal loss	ILI and CIS	Metal loss density and depth and CP on/off	Joint alignment across the various ILI runs	Metal loss change in areas of lower potentials	Review areas of increased corrosion activity that are in close proximity to lower potential levels indicated on the CIS although they may still meet criteria.	

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
39	Metal loss	External metal loss	ILI data, hydrotest data, repair records, CP data, leak history, pipe data, coating data, MAOP data, foreign line crossings	ILI features, pipe-to-soil potentials, close interval surveys, condition of coating, previous reconditioning/repairs, corrosion rates, soil conditions	±50 ft	Significant growth between ILI tool runs, P/S potentials below –850 mV, disbonded or shielded coating areas, corrosion preferential to a seam or girth weld	External ML can be reviewed in combination with other data such that active corrosion could meet repair criteria prior to the next scheduled in-line inspection.	ILI data is overlaid with other corrosion data (P/S surveys and CIS data) to look for localized hot spots and areas where corrosion protection systems may need enhancements. Coating data and historical excavation data are reviewed to see if an area may need reconditioning to arrest active corrosion.
40	Metal loss	Internal metal loss	ILI data, hydrotest data, repair records, product specifications, pigging return corrosivity tests, corrosion coupon tests, corrosion inhibitor records, leak history, pipe data, MAOP data	ILI features, previous reconditioning/repairs, corrosion rates, pipe elevation data	±50 ft	Significant growth between ILI tool runs, pipe-to-soil potentials below –850 mV, disbonded or shielded coating areas, corrosion preferential to a seam or girth weld	Internal ML can be reviewed in combination with other data such that active corrosion could meet repair criteria prior to the next scheduled in-line inspection.	ILI data is overlaid with other data (low-elevation spots, areas of likely water hold up, seam orientation, girth weld proximity) to look for localized hot spots and areas where internal corrosion protection systems may need enhancements (more frequent maintenance pigging, different types of cleaning pigs, corrosion inhibitor enhancements, etc.).

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
41	Metal loss	External metal loss—in a casing	ILI data, hydrotest data, repair records, CP data, leak history, pipe data, coating data, MAOP data, casing data	External metal loss ILI features, casing records, pipe-to-soil and casing to soil potentials, and record of filling casing/carrier annulus with dielectric filler	within cased crossing	100 mV separation between pipe and casing to soil potentials	Validating that casing and carrier pipes are electrically isolated.	ILI data is overlaid with other data to look for localized hot spots and areas where external corrosion protection systems may need enhancements (casing filling).
42	Metal loss	Corrosion growth	ILI metal loss	Metal loss features from consecutive ILI	5t × 5t	Variance in max. depth and rupture pressure ratio	Three levels depending upon whether consecutive inspections are available. Level 1 (single ILI) presumed growth from historical experience or environmental data, level 2 (back-to-back ILI): feature matching at joint level, level 3 (signal matching): possible if back-to-back ILI are from the same vendor.	
43	Metal loss	External metal loss—FBE coated pipelines	ILI metal loss, AC/CIS/ACVG/DCVG survey	Feature listing	N/A	Metal loss features identified by ILI integrated with AC/CIS/ACVG/DCVG surveys to identify potential coating, CP, or AC issues	ILI metal loss features are overlaid with the survey data. Features are prioritized for excavations/verifications based on the depth and suspected interference from the field data. Additional scope is added to verify the corrosion mechanism and further mitigation methods are considered at other suspect locations. Remaining features are identified for continuous monitoring in subsequent inspections.	NDE results are reviewed for verification.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
44	Metal loss	Orientation graphs	ILI metal loss, elevation, station data, HCA, CP survey	Feature listing	Elevation data	Internal and external metal loss trending	The data from the different sources are plotted against the stationing data to identify any trend in the external and internal metal loss distribution. Trending from subsequent inspections is also compared to see any significant change in trends from one inspection to other. The results of the analysis are used to identify and implement preventative measures.	N/A
45	Metal loss	Internal corrosion susceptibility	Flow rates and products characteristics	Historical operations	N/A	Develop Internal corrosion susceptibility threshold where additional monitoring or mitigation would be warranted	A semi-quantitative threat score is calculated using flow conditions and product characteristics. The results of the analysis are low, medium, or high susceptibility. Mitigation strategies are planned and implemented depending upon the susceptibility scores. The age and historical operations of the pipeline in conjunction with ILI data may trigger the mitigation or monitoring of the pipeline as well.	N/A
46	Metal loss	Internal corrosion mitigation effectiveness	ILI metal loss, orientation graphs, corrosion monitors	Back-to-back ILI corrosion growth rates	Elevation Data	Effectiveness of mitigation program: growth in depth or number of internal ml features.	The effectiveness of the mitigation program is judged by integrating and evaluating the data from different sources, including back-to-back inspections.	N/A

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
47	Metal loss	Internal corrosion susceptibility	ILI, IMU/construction records	Elevation	N/A	N/A	Elevation data and internal ML data are overlaid and analyzed. Particular attention is paid to overbends and underbends.	N/A
48	Metal loss	Back-to-back integration	ILI	Feature lists	Yes	Features matched at two different points in time or between two different types of metal loss inspections MFL/UT/CMFL	Metal loss feature lists are integrated with the previous inspections or other metal loss technologies to identify major discrepancies. These discrepancies are required to be reconciled and have identified tool errors/limitations/strengths, ILI processing errors, ILI analyst errors, and high corrosion growth rates.	All major discrepancies are reviewed internally and by the ILI vendor (as required) to ensure accuracy.
49	Metal loss	Air to ground interface corrosion	ILI	Bends		Corrosion falls just downstream of a bend, growth	Metal loss features downstream of, and in proximity to, a bend undergo additional scrutiny. It could be indicative of coating failure at ground/air interface.	
50	Metal loss	Metal loss change from external to internal	Current and prior ILI	Metal loss attribute		External (EXT) to Internal (INT) change, growth	The change from external to internal from one ILI to the next warrants further scrutiny as a possible through-wall event. True depth of pinhole size pit can escape the detection of tool.	

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
51	Metal loss	Metal loss—anomaly density	ILI metal loss	Number of metal loss anomalies per joint		All reported metal loss per type (internal, external) within a joint	Evaluating and plotting anomaly densities may provide indication of disbonded coating or identify higher priority evaluation areas. Integrating the anomaly density areas to CP readings and elevation profiles may identify causal factors. Utilizing anomaly depth categories (10 % – 19 %, 20 % – 29 %, etc.) is beneficial in identifying higher priority areas.	Remediation results can validate tool accuracy
52	Metal loss	Metal loss—casing evaluation	ILI metal loss and features	Metal loss and features located in a casing		Metal loss located in a casing that coincides with casing features in contact with the pipe	Evaluate metal loss that coincides with a feature in a casing (metal casing spacer that is identified in the ILI data or at the end of the casing indicating interaction with a link seal or casing boot). Interaction of pipe with casing feature may affect pipe coating and the discrimination or accuracy of the ILI data. Casing features not identified in the ILI run may be detected by the pattern of metal loss. Evaluation of metal loss from subsequent runs may be used to determine growth of metal loss features.	Remediation results can validate tool accuracy

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
53	Metal loss	Internal metal loss—ILI data review	Metal loss tool	Internal metal loss data	N/A	All internal metal loss	In regards to gas service, assess the density of internal metal loss indications in the 4- to 7-o'clock position over a standard unit distance. Although this threshold would vary between lines, a general threshold rule for elevated scrutiny is 10 per 80 ft.	Data of concern are reviewed by engineering, verified by tool vendor if needed and used for integration with other IC data
54	Stress corrosion cracking	Stress corrosion cracking	ILI data, hydrotest data, operating stress, operating temperature, year of pipe manufacture, proximity to compressor or pump station, type and condition of coating, leak history, excavation data	Pipelines operating above 60 % of SMYS, above 100 °F, within 20 miles of a compressor or pump station, more than 10 years old, coated with other than FBE, are more likely to develop SCC.	N/A	If conditions are more likely that SCC can develop, additional activities are added during routine inspections at likely locations of external corrosion or localized stress in order to detect SCC.	If “noteworthy” SCC is ever experienced on a pipeline segment, then that segment is subjected to additional integrity assessments, such as with crack detection ILI tools (capable of detecting SCC) or hydrotesting to detect any ongoing SCC.	ILI data is overlaid with other data (external corrosion, dents, field bends, CP data) to look for common conditions where undetected SCC may be probable.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
55	Excavation damage	Mechanical damage—dents in close proximity	ILI dents	Deformations within an ILI run	N/A	Axially aligned, on top side, within 1 ft of one another	ILI data is reviewed for potential dents in close proximity. The data is used to assist in identifying areas with potential gouges/stress concentrators within dents that may not have been categorized by the ILI vendors. Compare current ILI data sets to past ILI data sets to determine if the indications have appeared since the previous ILI which could indicate "new" mechanical damage. This comparison can be dependent on the past reporting criteria or ability to view raw signal data. Locations of possible damage are also mapped to determine if they occur at "suspect" areas such as road crossings, utility crossings/corridors, farm lands, etc.	The results of assessments are fed back to the MFL vendors to have the raw data reassessed to see if further categorizations could have been made, or if the tool failed to see the gouges/stressors, within dents.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
56	Excavation damage	Dent with metal loss screening on reconditioned lines	Historic drawings, reconditioning specs, ILI data	Dent features within ILI data on reconditioned pipe and as-found dig findings	N/A	Examine ILI data for signs of previous reconditioning repairs	Review current ILI data versus past ILI data to determine if reported deformations are “new” since the previous ILI. Review vendor data to determine if the pipe joint has been previously reconditioned (presence of puddle welds, patches, sleeves, etc.). Compare this data and the reported metal losses to the alignment drawings to understand if the line had corrosion prior to the installation of coating or CP, or both. Review findings at excavations and note if vendor-reported "dents with metal loss" were actually due to mechanical damage, a corrosion cell specifically "attacking" a dent due to coating loss, or if it was minor corrosion coincidental to a dent.	Past and current findings are reviewed with MFL vendors. The intent is for the ILI vendors to utilize the data to assist in better categorizing mechanical dents w/ metal loss versus old reconditioned dents with minor coincidental corrosion for prioritization purposes.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
57	Excavation damage	Bottom side deformation	Dent feature from geometry assessment	Dent features within a single ILI	N/A	Axially aligned	Deformation located on the bottom of the pipeline (below 4- and 8- o'clock position) with a depth greater than 2 % of the nominal diameter (greater than 0.250 in. depth for a pipeline diameter less than nominal pipe size [NPS] 12). Variations: bottom dents <2 % (or 0.25 for <12 in. pipe) are correlated to prior runs and all are put on pending dig list.	Deformations missed by the ILI are fed back to the tool vendor to determine lack of reporting.
58	Excavation damage	Mechanical damage—deformation(s) within close proximity to pipeline crossings, roads, or farmland	ILI tool data (deformation and metal loss)	Current and previous ILI tool data	Placement of centerline within geospatial data	A topside dent that does not meet repair criteria identified in the current ILI tool run, that was not identified in the previous ILI tool run as a dent (i.e. a “newly reported” dent indication), which is located in close proximity to a pipeline crossing, road, or farmland	Identifying “newly reported” dent indications that do not meet repair criteria (i.e. does not have indication of metal loss because a dent with metal loss would meet repair criteria) which are located in areas with the potential to contain road construction/maintenance, pipeline construction/maintenance, or farming activities, can be more successful at the identification of metal loss within dents than simply depending on ILI tool and vendor capabilities.	If a dent with metal loss is found, findings including field measurements are communicated to the ILI vendor. The ILI vendor should be requested to perform a root cause analysis for the missed calls. Lessons learned (if any) should be applied to improve the analysis processes.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
59	Excavation damage	Comparison on the number of deformation reported on two successive ILI runs	Deformation	Deformation indications from multiple ILI run	N/A	New topside dents >1 %	Review of new topside dents >1 % when comparing current deformation results to previous deformation results. May be an indication of excavation damage or damage resulting from previous maintenance work performed on or nearby the top of pipe.	If such conditions exist, dig will be performed, check with one call for any reported events, etc.
60	Excavation damage	Depth of cover and coating type	Pipeline maps and surveys	Burial depth and coating type data		Depth less than 12 in. anywhere; greater than or equal to 12 in. and less than 24 in. in road residential areas, ROWs, or cultivated fields	Perform a depth-of-cover survey to identify shallow burial depths and coating type to determine higher risk of third party damage	Could possibly add additional anomalies to be evaluated. Concrete coating or ditch shields may be identified in coating type which could explain shallower than normal depths.
61	Excavation damage	Failure of topside dents	ILI deformation tool	Current in-line inspection tool data		All top-sided dents that were not evaluated during prior dig programs located 10 ft from known foreign line crossings	Perform surface evaluation of all top-sided deformations not evaluated in previous dig programs to determine if third party damage would be likely. Aggressiveness of the pressure cycles should be considered when decisions are made whether or not to excavate to evaluate the anomaly.	Additional anomalies could be added to the evaluation list.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
62	Excavation damage	Dents at foreign crossing	Dent ILI and PODS	Features list	±100 ft of foreign crossing	Dents	Dents within 100 ft of a foreign crossing may be an indication of third-party damage. Review orientation of the pipe crossing and compare to dent orientation. Ground truth and confirm locations of the anomaly and crossing.	N/A
63	Excavation damage	Dents and depth of cover	ILI data, depth of cover, and one call density	Graphs	Topside dents per joint or orientation graph with depth of cover as a secondary axis.	Undug dents on top of pipe located in shallow cover in areas of high one call density may need to be investigated.	Topside dents located on shallow pipe may be indicative of dents with metal loss even if the ILI tool did not interpret the dent to have metal loss.	Ground truthing may be needed to verify location of dents and shallow pipe.
64	Excavation damage	Dents, dents with metal loss	ILI Data, repair records, depth-of-cover surveys, land surface use, one call, aerial patrols, CP data	Smooth top dents >1% of OD, any top dent with any indication of metal loss	±50 ft	< 2 ft DOC, dent repairs in area, cultivated fields, aerial patrols indicating surface activity, CP data indicating coating damage	Dent indications with other data that indicate probability of excavation damage would elevate the dent indications to likely excavation damage and be considered for possible excavation or additional preventive and mitigative activities, such as increased patrolling, additional signage, increased public awareness activities, possible lowering of the pipeline in place, and contact with land users.	Site visits and alignment of data that places possible excavation damage indications in the same field as shallow DOC data, aerial patrols indicating ongoing surface activity, damaged coating, crossings, or one call activity in the area

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
65	Excavation damage	Off-axis dent	Geometry ILI data	Geometry feature shape	N/A	Denotes whether or not the longitudinal axis of a geometry feature varies more than 15° from the longitudinal or transverse axis of the pipeline	Geometry features oriented off-axis can be an indication of mechanical damage resulting from line strikes. Features identified as off-axis are reviewed in additional detail to determine if additional assessment is required.	ILI data, location data are reviewed for potential additional assessment requirements.
66	Excavation damage	Multi-apex dent	Geometry ILI data	Geometry feature shape data	N/A	Denotes whether or not the geometry of a dent has a singular or multiple apex points	Multi-apex dents may have been an indication of complex or increased stress/strain. Features are reviewed in more detail to assess for the identification of stress concentrators reported by ILI data.	ILI data review
67	Weather and outside force	Global pipeline strain	ILI	Reported locations of strain	Yes	Reported areas of calculated strain based on IMU data are reviewed for potential mitigation	Areas of strain are monitored for change and to ensure that measured strain is within acceptable limits.	ILI data review is supplemented with ROW information to identify areas requiring mitigation or additional monitoring.
68	Construction threat	Wrinkle bend threats	ILI deformation and metal loss	Wrinkle bends with seam and anomalies	N/A	Wrinkle bends reflecting weld seam running through wrinkles, or indications of gouges or DMAs on wrinkles	Compare in ILI data tally the orientation of wrinkle bends to the orientation of long seam. Data search for possible ML on or within 3 in. of wrinkle.	For suspect features consider a more in-depth review by the ILI vendor and possible field investigation.

Annex B
(informative)

Pipeline Construction Data Collection Requirements

This Annex provides a distilled version of a specification that defines requirements for construction survey as-built data collection. The intent of this example process is to facilitate a complete, accurate and consistent data set that is available to all stakeholders in a timely manner (i.e. before line fill).

Following this approach, the corrected as-built dataset in consideration of Pipe Integrity (PI) feedback based on incremental and post backfill flat file deliverables would be the basis of the alignment sheets and final deliverable to PI.

B.1 Deliverable process

GENERAL REQUIREMENTS

Staged Deliverables

Facilitation of a complete, accurate and consistent as-built data set in a timely manner will be achieved by creating a data deliverable that is incremented as the project advances and data become available. The incremental data deliverable interval is defined on a project specific basis and is defined in the Project Specific Data Implementation Plan document.

The staged deliverables are:

- Field Collected – incremental
- Field Collected – Post Backfill
- Attribute Augmented – as to whether the project or PI resolves this additional data and attribution will be determined on a project specific basis and documented in a Project Specific Data Implementation Plan.

The following data deliverables should be available prior to line fill.

- As-built Survey Data (unchained and chained)
- Supporting Data – caliper, cutouts (part of the final as-built data).

The Project Records Deliverables will typically follow after line fill.

The data provided for the Field Collected Incremental deliverables will contain the Construction 2D (IFC – Issued for Construction) chainage. A 3D chainage is not required for these deliverables.

The final as-built 3D Chainage will not be defined until the last increment of the deliverable at which time the as-built alignment sheets will be generated at the direction of the project.

All chainages are to be recorded in Imperial Units in the US and Metric Units in Canada, with a precision of three decimal places.

The Field Collected Post Backfill flat file deliverable will encompass the additional datasets that are scheduled to be collected after backfill has been completed; Top of Pipe (T.O.P) DOC, Fence lines, Signs, Markers, Testleads. All other data points with the exception of the T.O.P. DOC data can be included in the Field Collected Incremental deliverables, if available at that time or alternatively can be added to the Field Collected Post Backfill deliverable.

General Data Acceptance and Delivery Requirements

The incremental field collection datasets shall be delivered to the Liquid data steward in the specified flat file format at predetermined intervals during the project for timely review and feedback.

- Determination of the data delivery interval frequency will be unique to each project and relative to the overall size and scope of the project. At a minimum the data is expected to be delivered in multiple increments per construction spread.
- This data delivery distribution interval is to be determined by the Liquid Data Steward and Project representative and communicated to the Contractor and agreed upon before the start of the project.
- Any deviation to the data requirements will need to be documented and submitted to the data steward for approval and added as an acceptable data deliverable to the project; otherwise the data will be sent back to the contractor for corrective measures and resubmittal.
- The Liquid data steward shall administer any variances to the template and the associated datasets.
- As part of the final data deliverable; the Contractor will supply a Project Summary Report detailing the data quality control methodology, and statement of data accuracy.

B.2 Field Collected Data

This dataset will be comprised of all information captured in the field by the construction survey vendor, except for Horizontal Directional Drills (HDD's) and fabricated assemblies. The integration of the HDD's, typically installed before the mainline survey, into the common format shall be included in this deliverable. In terms of fabricated assemblies along the path of the pipeline (e.g. elbow, valves, tees etc.), the minimum data that assures traceability of the components shall be captured (i.e. manufacturer, PO, and serial/heat/pipe number/tag number).

FIELD DATA ACCEPTANCE AND DELIVERY REQUIREMENTS

All relevant Survey Notes/Sketches, drawings and redlines are required to be submitted as part of the incremental data deliverables.

FIELD COLLECTED SPATIAL REFERENCING REQUIREMENTS

While the data may be originally collected in another data projection and datum; the data supplied in the flat file template must adhere to the spatial parameters specified below.

Coordinate format -shall be provided in Northing, Easting, Universal Transverse Mercator (UTM) Zone, Datum and Elevation. However the provision of the equivalent Latitude, Longitude coordinates would be appreciated.

i. UTM Northings/Eastings and UTM Zone
ii. Optional Geographic Coordinate System: Latitude and Longitude coordinates (X,Y) are to be provided in decimal degrees with a precision of 7 decimals.
iii. Datum: NAD83 UTM/WGS 84 Latitude and Longitude.
iv. Spheroid Model
v. Elevation (Z) values to be recorded in feet in the US; with a precision of 3 decimals.

GPS accuracy of the data must meet the Company's accuracy tolerances. The allowable relative positional accuracy for As-built Survey measurements is 0.16 feet (or 5 cm).

B.3 Data Requirements

The required data elements and associated attribution would include:

BENDS/ELBOWS

- All Bends require sufficient survey points to define the bend mid points

- Required attribution includes: type of bend, bend direction and radius, horizontal and vertical degrees, Manufacturer, PO and Serial Number.

BUOYANCY CONTROL

- All Buoyancy Control records require sufficient survey points to define each individual weight point features and their associated 2D chainage. A linear event is to be added where applicable. A Linear event is defined by a spanning distance or a start and end location where by two or more point features of the same weight type are present.
- Required data attribution to be recorded includes the type of weight, and the count of individual weights contained within each linear weight section.

CASINGS

- All Casings are linear records and require sufficient survey points to define the start and end locations of each casing.
- Required data attribution includes: Grade, Insulator Type, Outside Diameter

COATING INFORMATION

- All changes in coating information must be tied to the corresponding weld records and populated only where the coating value changes.
- Required data attribution includes: Line Coating Type & Brand

CATHODIC PROTECTION

- Sufficient survey points are required to define the location of anodes, rectifiers and testleads
- Required data attribution for Testleads includes: TestleadID.

CROSSINGS

- All Crossings require sufficient survey points to define at a minimum, the centerline of the crossing. Additional survey points are required to define the Start and End locations of any Road, Railway, and water crossing.
- Required data attribution will vary by the crossing type.

HDD'S/BORE LOCATIONS

- Survey measurements and as-built information of the HDD pipeline section shall be obtained prior to pullback installation activities. Sufficient survey points shall be obtained at the HDD pipeline section entry and exit points to cross-reference pipeline as-built survey data and incorporate the HDD Contractor's drill logs and as-built data.
- Tie-in welds must be collected and recorded for both the entry and exit points of each Bore and HDD location, maintaining references to the initial survey Point IDs and Construction Chainages.
- Chainages must be recorded in ascending order with direction of flow.

PIPE INFORMATION

- All changes in pipe information at a minimum must be tied to the corresponding weld records and populated where the pipe value changes.
- Required data attribution includes: Up and Downstream Heat & Pipe Numbers, Manufacturer, Wall Thickness, Outside Diameter, Specification and grade.

PIPE PROTECTION

- All Pipe Protection records are linear and require sufficient survey points to define the type and start and end locations.
- The type is defined by code list in the data collection template.

VALVES/FITTINGS

- All valves and fittings must be located by survey points at the centerline of the features, and has to include the isolation valves on the launcher and receiver barrel assemblies.
- Required data attribution to be recorded includes, but not limited to:
  a) VALVES - Size, Type, Serial Number, and Manufacturer
  b) FITTINGS - Serial Number

WELDS

- All welds must be located by survey points; maintaining a unique spatial location (Northing, Easting) and 2D Chainage value, no duplicates will be acceptable.
- Weld Numbering will be generated by NDE and must adhere to the Weld numbering syntax the Pipeline Construction Specification
- Required data attribution to be recorded includes: GW Type & Process, Weld Date, Up and downstream Pipe, Joint, Heat, NDE Numbers (Double Joint Number).

B.4 Attribution Augmented

This dataset will be comprised of datasets that are required to achieve full traceability of any pipe, facility, asset or fitting that is traversed by an In-Line Inspection tool.

This data may not be accessible in the field at the time the survey data collection is performed. Certain data attributes may be captured during different phases of the project; nominal pipe wall can be captured during the field data survey while the elbow wall thickness data may have to be obtained from the fabrication spool drawings or MTR's.

The scope and allocation of this work is to be assessed by PI and the Project and defined well before the start of the new construction project and documented in a Project Specific Data Implementation Plan. This work scope can be completed in whole by either the Vendor, other project staff or by PI; or alternatively a combined effort by all parties to complete.

Examples of the required supporting documentation include but are not limited to:

- Pipe Mill Records (MTRs)
- Valve & Fitting – Fabrication Shop Records
- Facility Pipe and Spool Drawings
- Pipe Coating Reports (Above Ground) – Shop and Field
- Pipe Coating Reports (Below Ground) – Shop and Field (incl. Weld Coating, Tie-in Coating, Multi-Liquid Coating Inspections/Checklist, Fabrication)
- Weld – NDT Log

B.5 As-Built

GENERAL REQUIREMENTS

i. A fully spanning as-built survey dataset for the project, acceptable to the data steward, shall be completed prior to line fill.
ii. The as-built survey data upon completion will be comprised of Pipeline Routes spanning Launcher to Receiver barrel.
iii. The generation of the alignment sheets deliverables are outside of this scope and will remain with the project team to oversee and manage.

PIPELINE ROUTE REQUIREMENTS – AS-BUILT

i. A Pipeline route is defined by a designated facility to facility delineation (typically at pump stations and/or barrel launch and receive sites). The start point of each pipeline route is defined as the reducer connection/weld to the Launcher Barrel, and ends at the reducer connection/weld to the Receiver Barrel; where all route measures are recorded in ascending order, coinciding with the direction of flow from start to end.

ii. Route 3D chainage is to be recorded in Imperial Units in the US and Metric Units within Canada with a precision of 3 decimal places.

- A Route will be bound by the starting and ending points as defined above and will consist of multiple Station Series, where each section chainage will re-zero.
- In cases where there is an absence of barrels, such as a non-piggable segment (ie: Interconnect); an agreement between the project and Pipeline Integrity will be required to define the pipeline route delineation prior to construction.
- Pump Station Suction and Discharge routes are not to be included in the mainline as-built dataset, but are to be provided in a separate tab with the Pump Station Name and Suction (S) /Discharge (D) clearly delineated. The common branch connection location is to be identified and included in both the Mainline and Pump Station Routes.

HYDROTEST RECORDS INCLUDING CUTOUTS

- The hydrotests must be aligned to their final start and end tie-in welds.

RECONCILIATION WITH ALIGNMENT SHEETS

- The finalized and approved as-built dataset will become the master dataset from which the alignment sheets will be generated from, where applicable. All subsequent edits in content shall occur in the master dataset which would cascade to the alignment sheets. A detailed update listing of changes shall accompany the updated master dataset.

B.6 Supporting Data – (Post Construction Delivery)

CALIPER DATA

- The caliper feature listing is to be provided by the project and should include a complete and continuous weld tally.

EXCAVATION DATA

- All excavations arising from the caliper ILI shall be tied back to a specific weld within the caliper listing and the as-built dataset

DIRECT CURRENT VOLTAGE GRADIENT (DCVG) DATA

- Survey used to identify pipeline coating holidays based upon a measured voltage gradient through the soil (quantified as a %IR). A DCVG survey shall be conducted prior to the baseline assessment.

CHALLENGING CONSTRUCTION

- Identification of any challenging conditions encountered along the pipeline during construction must be documented and defined by a start and end location; and should be readily tied back to survey notes and any associated NCR documentation.
- Examples include: rock ditch, excessively wet or muddy conditions, and excessively cold conditions

B.7 Project Record Deliverables

The following is the scope of documentation that is required from the project for the handover of the asset to operations. This listing should be used as a reference to identify and generate a comprehensive and robust project specific project turnover plan.

- Materials: Manifests
  - Bill of Lading Reports (Railway reports to trace pipe transportation and loading) (incl. Elbows and Fittings)

- Materials: Welding

- Weld Log Book / Welding Binder (Senior Welder Acceptance)
- Welding Inspections / Compliance Reports
- Weld Procedure / Parameters
- Welder's Qualification Certificates
- Transition / Counterbore Reports
- Mainline Welding Reports (incl. Parameters & Inspections) - (Pipelines only)
- Poorboy Welding Reports (incl. Parameters & Inspections) - (Pipelines only)
- Tie In Welding Reports (incl. Parameters & Inspections) - (Pipelines only)
- Fabrication Records

- Materials: Corrosion Control
  - Pipe Coating Reports (Above Ground) – Shop and Field
  - Pipe Coating Reports (Below Ground) – Shop and Field (incl. Weld Coating, Tie-in Coating, Multi-Liquid Coating Inspections/Checklist, Fabrication)
  - Plant Applied Coating Inspection (External and internal coating Inspection, Holiday Tests, Jeeping)
  - Engineering & Construction Civil
  - Rock Blasting Report (if applicable)
  - Footing Inspection / Compaction Test Report - (Facilities Only)
- Engineering and Construction – Piping
  - Stress Analysis Report
- Engineering & Construction Planning
  - Design Basis Memorandum (DBM)
  - Project Execution Plan (PEP)
  - Project Variance for Construction Specs
  - Project Master Punchlist (Construction, Commissioning Punchlists)
- Pre-Commissioning and Commissioning
  - Commissioning - Data Books - (Facilities Only)
- Vendor Documentation
  - Vendor Equipment Manuals O&M (Facilities Only)
- Construction Drawings & Data
  - Facility Pipe and Spool Drawings:
  - Red Marked as-built Drawings

  - CP Installation Records
  - CP design and construction documents
  - CP Surveys
  - Test Lead Installation Records
  - Crossing Reports and as-built drawings
  - Launcher/Receiver Site Plans
  - Schematics & Isometric Drawings, P&IDs, Facility Plot Plans including Pump Stations.
  - Vendor and Subcontractor Supplied Drawings,
  - As-built Survey Report
  - Construction Alignment Sheets
  - As-Built Alignment Sheets
  - Survey Notes/sketches/field books
  - Bending Reports
  - Bore/HDD As-Built Profile drawings, Final survey tie-in locations
  - Valve Schematic drawings
- Engineering & Construction Status Reporting
  - Lessons Learned Log "
  - Construction Daily Progress Reports/Activites (Crew Daily Reports)"
  - Photographs of (Fabrication/Construction/Installation) of pressure containment components"
  - Inspector Daily Reports
  - Backfill Reports
- Pipe Integrity - Materials: Non-Destructive Testing (NDT)
  - Radiograph Films / Ultrasonic Data (AUT)"
  - NDE Records Magnetic Particle Inspection Reports
  - Qualifications of the NDE Technicians
  - Radiographic Testing / Ultrasonic Reports
  - Weld Map Drawings
  - Weld - NDT Log
  - Audit Reports (From Materials Engineering)
- Pipeline Maintenance
  - Caliper In-line Inspection reports including a list of AGM Locations

  - Excavation report (Dents & Ovality Investigative Digs)

- Pipe Integrity - Materials: Quality Management
  - Pipe Mill listings (electronic version for all new ordered Pipe, ie. Excel or access)
  - Coating & Fabrication Mill listings
  - Pipe, Facility, Launcher/Receiver Material Test Reports and Mill Test Certificates
  - Pipe Production Inspection Reports (inspection done in the mill)
  - Purchase Orders
  - Non-conformance Reports (NCRs)
  - Soil profile logs from deep anode beds
- Hydrostatic Test Documentation
  - Construction Hydrotest Summary Records
  - Schematic drawing and sketch of Hydrotest sections with final tie-in welds identified (after test).
  - Test Head Documentation
  - Regulatory Reporting Leave to Open (LTO) Package Completed, Signed and Filed
- Consequence Modelling
  - All HCA polygons within 40 mile buffer (.gdb)
  - HCA, CPS, Flowpath GIS Files (.kmz, .gdb, .shp)
  - HCA tabular listing (excel file)
  - CPS tabular listing (excel file)
  - HCA-CPS cross reference listing (excel file)
  - HCA/CPS Final Report (.pdf)
  - Worst Case Discharge Volumes (excel file)
  - Worst Case Discharge Volume Reports (.pdf)
  - Worst Case Discharge Volume input parameters (excel file)

Bibliography

[1] The Data Warehousing Institute, information available at https://tdwi.org/home.aspx

[2] API White Paper, Uniform Standards for GPS Submittals for One Call Purposes, August 4, 2008

[3] NACE SP0169, *Control of External Corrosion on Underground or Submerged Metallic Piping Systems*

Integrity Data Management and Integration

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Integrity Data Management and Integration

1 Scope

This bulletin provides a compendium of methodologies and considerations for integrating the underlying data used to support integrity management. Any one approach, let alone the entirety of the document, may not be appropriate or applicable in all circumstances. The document reviews possible approaches for consideration by operators in the context of their specific circumstances.

The primary focus of this bulletin is the methodologies and processes used to spatially integrate and normalize the data to support the application of comparative techniques used in interpreting integrity data, with particular emphasis on in-line inspection (ILI) data. The document begins with a discussion of general data-quality processes, goals, and considerations such that data quality approaches can be considered in the context of the data integration processes.

An impediment to informed integrity decisions is the inability to efficiently review a broad spectrum of data in a format that has been normalized and spatially aligned. With the variations in organizational structures, integrity management programs, and technologies used across the pipeline sector, individual operators design data integration procedures that are customized to their organizational structure, processes, and pipeline systems.

Properly managed and integrated data ~~support~~supports agile analytics to integrate new data as they become available and to recognize coincident events and patterns. The data source may be from within an organization, or may be external to the company, as in the case of representative data based on industry experience or manufacturing processes. The intent is to empower operators to efficiently analyze and integrate threat- and integrity-related data to support their integrity management programs.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document applies (including any addenda/errata).

~~API RP 1160, *Managing System Integrity for Hazardous Liquid Pipelines*~~

API RP 1163, *In-Line Inspection Systems Qualification*

~~API RP 1173, *Pipeline Safety Management Systems*~~

API RP 1176, *Recommended Practice for Assessment and Management of Cracking in Pipelines*

3 Abbreviations

AC	alternating current
ACVG	alternating current voltage gradient
BSEE	Bureau of Safety and Environmental Enforcement
CFR	*Code of Federal Regulations*
CIS	close interval survey
CP	cathodic protection
DA	direct assessment
DCVG	direct current voltage gradient
DMA	discrete metal loss anomaly
DOC	depth of cover

ECDA external corrosion direct assessment

ERF estimated repair factor

EXT external

FPR failed pressure ratio

GIS geographic information system

GPS global positioning system

HCA high consequence area

HDD horizontal directional drill

ILI in-line inspection

IMU inertial mapping unit

INT internal

IT information technology

MAOP maximum allowable operating pressure

MFL magnetic flux leakage

MIC microbiologically influenced corrosion

ML metal loss

MOC management of change

MOP maximum operating pressure

MPI magnetic particle inspection

MTR mill test report

NAD27 North American Datum of 1927

NAD83 North American Datum of 1983

NDE nondestructive examination

OD outside diameter

POD probability of detection

PODS Pipeline Open Data Standard

POI probability of identification

ROW right-of-way

RPR rupture pressure ratio

RTK real time kinematic

SCC stress corrosion cracking

SME subject matter expert

SMYS specified minimum yield strength

TDC top dead center

TPD third party damage

TQM total quality management

UT ultrasonic testing

WB wrinkle bend

WGS84 World Geodetic System 1984

4 Benefits to an Enterprise Data Management System

Managing pipeline integrity data historically involved the rather manual process of populating data within spreadsheets or disparate databases. Transitioning to an enterprise database to manage large pipeline integrity data sets provides an operator with several advantages, including the following:

— Improved auditing and traceability: When spreadsheets are created, the logic and judgment that is applied while an individual is manipulating data is not captured, or easily understood. In most cases, this logic exists only in the mind of the individual who created the spreadsheet, which may result in compliance risk.

— Improved tracking of data corrections: Propagating corrections to data errors across multiple dependent spreadsheets, or back to the original data sources, is difficult and may potentially introduce further errors.

— Improved safeguards against human error: ~~Human errors, such as versioning errors and corruption errors, can compromise the integrity of data entry.~~ Databases and their associated graphical interfaces facilitate the implementation of quality rules and constraints that mitigate the potential for human error.

— Improved resource utilization: Databases may provide improved efficiency over data management that uses disparate spreadsheets.

— Improved data security: Server-based data may be more difficult to access and propagate than individual files, which can be easily transferred to local or portable drives.

— Improved scalability: Spreadsheets and small-scale databases may have size limitations that enterprise databases do not have.

5 Data Quality Oversight

5.1 General

The aspects of data quality listed in Section 5.2.3 are examples of elements an operator may consider when developing a data management system, but the extent to which they are relevant varies depending on asset complexity and organizational structure. As with any system, continuous improvement is a core ~~principal~~principle. The system in this context is often referred to as a geographic information system (GIS) or database, but it may be a compilation of applications and databases, with a map-based visualization being just one aspect of the solution.

Data management planning considerations include the identification of key objectives to be achieved, as well as the strategies and policies that assist in achieving those objectives. A common example where source data sometimes may not be fit for purpose is risk assessment. To support the analysis associated with risk assessment, a range of numerical values are typically assigned to the inputs. However, the source of this data in many cases was not structured with this use in mind. Specific considerations would include the delineation of different pieces of information into different fields or attributes (database schema design) and defining allowable content (attribute domain). A common domain constraint is the use of code lists or controlled vocabulary to avoid saying the same thing in innumerable different ways due to spelling or the use of synonyms. Care should be taken to not overly constrain data capture so as to mask new, valid and potentially critical data. The option of “other” with an associated meta data field could support the ongoing maintenance of the domain such that it can align with evolving processes.

5.2 Objectives

5.2.1 Core Objective

The core objective of a data management system is to achieve the highest degree of data quality possible for the intended purpose, while also doing the following:

— promoting the efficient use of resources;

— providing easier access to critical information for qualified employees;

— ensuring that data is protected and preserved in accordance with business, legal, and policy requirements; and

— communicating with other systems using a common frame of reference for broader analysis capabilities.

5.2.2 Data Quality Criteria

Stakeholders should clearly define what is meant by data quality to make the data fit for purpose in supporting the intended processes. The data should meet the following criteria:

— Be defect free: Data should conform to the dimensions of data quality (outlined below), as applicable.

— Conform to specifications: Data should conform to specified metadata requirements such as type, length, value, precision, and units of measure.

5.2.3 Dimensions of Data Quality

In addition, a data quality definition could consider the following dimensions[1] of quality:

— Accuracy: The data represents reality.

— Completeness: All needed data is available.

— Consistency: The data is free of internal conflicts.

— Precision: The data is as exact as is needed.

— Granularity: The data is kept and presented at the right level of detail to meet the needs.

— Timeliness: The data is as current as needed and is retained until no longer needed.

— Integrity: The data is structurally sound. This connectivity is frequently referred to as topology within the geomatics community.

5.2.4 Strategies and Policies

Developing policies and guidelines helps create a standard set of procedures for ensuring that quality data effectively flows to and between all stakeholders.

Although data quality is a mandate for all employees, the formation of an identified team can be helpful in developing and maintaining the policies and guidelines that support standardized data quality management practices, including the following:

— Data quality audits: Data audits should occur on a periodic basis. Audits should focus on the most vulnerable/critical data. Lessons learned from data quality issues should be integrated into future audit processes.

— Data remediation processes: As audits occur, remediation prioritization should be according to the level of risk.

— Technology: Technology standards for governing data and information form part of the core system design. Data changes, ~~such as~~including to metadata, should be governed and executed per company procedures. While spreadsheets can be used, as the breadth of the data and the

[1] Standard data quality classification – TDWI (The Data Warehousing Institute)

organization increases it may be easier to manage data quality and data integration by utilizing database technology and~~/or~~ GIS~~, or both~~.

5.3 Data Governance

5.3.1 General

Data governance is the discipline of creating the vision, strategy, and structures needed to deliver an integrated and coordinated approach to improving trust in data. Effective data governance ensures that data can be trusted, and that there are processes to ensure traceability and accountability for any adverse events that result from poor data management practices. The purpose in establishing this structure is to maintain a clear focus on data quality and integration initiatives within departments and projects.

The core elements of governance include the following:

- defining decision rights,
- designating responsibilities,
- assigning accountabilities,
- establishing policies,
- defining processes, and
- managing performance.

Data governance should start small and grow systematically. As better predictions and forecasting are achieved, inspections and assessments can be completed where they are most needed. ~~Consequently, the financial burden of reacting to unforeseen incidents may also be reduced.~~ The quality of integrity decisions is directly related to the quality of the data input into the many analyses performed on the integrity data (i.e. good data supports good decisions). Similarly, bad data is worse than no data, as it may drive misinformed, non-conservative decisions.

5.3.2 Data Governance Roles

The distribution of data governance across the following proposed roles can be beneficial in clearly delineating responsibilities in larger and more geographical dispersed organizations, but their applicability will vary depending on the operator's specific circumstances.

5.3.2.1 Data Owners

Data owners are individuals who are ultimately accountable for data governance implementation and execution. Specifically, they are accountable for the data quality and governance elements that the data stewards (see 5.3.2.2) are executing, and for understanding the organizational dependencies of the data. Data owners should have a working knowledge of regulations, policies, and laws regarding the data. Data owners are typically responsible for the following:

- establishing escalation points for data governance issues;
- setting the strategy for data quality, privacy, and security; and
- determining the desired accuracy or degree of data quality.

5.3.2.2 Data Stewards

Data stewards ensure data governance initiatives are successful by overseeing data inventories and work flows. Data stewards should be proficient in data management processes, and it would be beneficial for them to have a working knowledge of pipeline integrity data and its use. Data stewards are usually responsible for execution, which would include the following:

- data definitions, usage, and quality measures;
- metadata collection and recording;
- data quality review and verification;

— data policies and procedures definitions; and

— data issues and conflicts management.

5.3.2.3 Data Custodians

Data custodians work with the data on a day-to-day basis and have the technical knowledge to profile and secure data.

5.4 Data Quality Assessment

Assessing the quality of the data should become part of a continuous improvement process. This effort is in line with the principles of total quality management (TQM), which state that the quality of information and processes is the responsibility of all those who create or consume the information or processes. Data quality assessments should include the following actions:

— identification of data quality measurements,

— identification of where and when to monitor data quality,

— implementation of monitoring processes,

— completion of a baseline assessment of the data quality and intent of usage, and

— review of post-monitoring reports.

An assessment effort should be structured and prioritized based on risk.

5.4.1 Communication Strategy

5.4.1.1 General

Continuous improvements are facilitated through a communication strategy that establishes routines for when and how important communications should be conducted and could include the aspects detailed in 5.4.1.2 and 5.4.1.3.

5.4.1.2 Data-Related Alerts and Events

Create a distribution strategy to ensure that all stakeholders have access to review and update information regarding ongoing data issues.

5.4.1.3 Data Quality Measures and Metrics

Measure data quality on established metadata created for each asset. Metrics could reflect the proportion of errors by asset on each metadata element. As with any reporting of metrics, they should be prioritized and limited in order to retain relevance.

6 Transforming SME Knowledge into Data

A significant challenge for data integration is capturing and quantifying subject matter expert (SME) knowledge. This knowledge is often lost when the SME leaves their current role within the company. Given the amount of information SMEs typically process, consideration should be given to scheduling interviews with them on a pre-defined interval can help capture the information.

Determining how to turn SME knowledge into measurable data points requires careful planning. In many cases SMEs may work in different operating areas where culture, attitude, and performance may be defined and measured differently. Subjectivity can make comparing opinions across SMEs and operating divisions difficult. To minimize subjectivity, parameters and consistent data-gathering processes should be well defined. For example, rather than asking about the current condition of the right-of-way (ROW), operators should ask about the adequacy of the ROW clearing program in place, and should define adequacy in accordance with the company's ROW clearing policy and develop tools to facilitate location-specific knowledge.

During interviews, the applicable stakeholders should review with SMEs the pipeline alignment sheets with a photographic background for potential areas of concern. The interview should focus on issues that are known to exist on the pipeline, rather than the exact locations, which can be determined at a later date. ~~After the interview is complete, the applicable stakeholders should determine the required pipeline integrity decisions based on the pre-defined parameters and the actions that are triggered by these parameters.~~

7 Data Models

Data modeling is used for assigning an overarching design to guide the database schema used for the storage of data. The intent of a data model is greater data quality and consistency, while enabling the processes that are running against the data. As such certain data models are optimized to support certain applications and vice versa.

There are varying approaches to data modeling, such as the following, that can be considered when designing a data model for pipeline integrity:

- The Pipeline Open Data Standard (PODS) is an example of an industry-standard data model. There are benefits to adopting this referential data model, but due consideration should be given to how the data is utilized. The PODS data model leverages a third normal form data modeling technique, which is optimized for transactional systems where many transactional data sets are inserted and updated.
- The Utility and Pipeline Data Model (UPDM) is designed primarily for the management of spatial data. Similar to PODS, this model provides a template for the management of natural gas and hazardous liquid pipe system data including provision for gathering, transmission, and distribution systems. UPDM is extensible, allowing customized schemas to address the corporate, local or national regulatory requirements or needs of the operator. Although UPDM is software (platform) agnostic.
- Object-relational data modeling.
- Dimensional modeling is optimized for simplified retrieval of data for the purposes of reporting and analysis. In order to improve analytical performance, consider recasting relationally modeled data into a dimensional model for this purpose.

A consideration for data models is the spatial component. There are commonly employed relational databases that meet the GIS requirements for the management and analysis of spatial data.~~:~~

Depending on how the integrity data sets are to be used, these various modeling techniques can be evaluated to determine the best fit and extended as required.~~Data modeling is used to assign a structure for the storage of integrity data. When designed correctly, the data model ensures that the stored data sets have structural integrity, which assists in ensuring a high degree of data quality.~~

~~There are varying approaches to data modeling, such as the following, that can be considered when designing a data model for pipeline integrity:~~

~~The Pipeline Open Data Standard (PODS) is an example of an industry-standard data model. There are benefits to adopting this referential data model, but due consideration should be given to how the data is utilized. The PODS data model leverages a third normal form data modeling technique, which is optimized for transactional systems where many transactional data sets are inserted and updated.~~

~~Object-relational data modeling.~~

~~Dimensional modeling is optimized for simplified retrieval of data for the purposes of reporting and analysis. In order to improve analytical performance, consider recasting relationally modeled data into a dimensional model for this purpose.~~

~~Depending on how the integrity data sets are to be used, these various modeling techniques can be evaluated to determine the best fit.~~

8 GPS Coordinates

8.1 General

The measurement error for global positioning system (GPS) coordinates does not accumulate; each point is discretely resolved independent of previous points. The commonality between GPS coordinates is with the satellites used for resolving the coordinates and the correction factors applied to them, whether through real time kinematic (RTK) radio transmission or post processing.

The material in this section builds upon the 2008 API white paper, “Uniform Standards for GPS Submittals for One Call Purposes” (prepared in support of Common Ground Alliance Best Practices). One of the issues discussed within that white paper is the potential for introducing error into GPS coordinate locations. Reliance on GPS readings without a clear understanding of important settings and nomenclature options can lead to a false sense of security and introduce new and significant errors into the data. The four main sources of error are detailed in 8.2 through 8.5.

8.2 Coordinate Nomenclature

Coordinates stated in degrees and decimal minutes look similar to coordinates stated in decimal degrees. For example, the coordinates N 29 50.30 W 95 50.50 and N 29.5030 W 95.5050 are actually more than 30 miles apart. Unfortunately, many users of GPS instruments are unaware that the format of GPS readings is a critical aspect, and it is easy to confuse one format with another, or to not understand what format a GPS unit is using.

8.3 Datum Selection

A separate but related issue is the selection of “datum” (a theoretical model of the earth’s surface against which the GPS coordinates are referenced). Each datum is different, reflecting different models of the earth’s surface, ovality, etc. There are more than 100 datums that can be selected for most GPS units, although few people are familiar with what they mean or how to select the correct one, simply using whatever default datum the unit was set to when purchased. The same GPS coordinates will identify different points on the earth when using different datums. The difference is usually rather small (dozens of feet), but this is a source of error that could be significant for integrity purposes.

These potential errors could be eliminated by imposing uniform guidelines for GPS data submittal. To maintain consistency with the National Pipeline Mapping System, it was recommended that the Common Ground Alliance adopt the North American Datum of 1983 (NAD83) and use decimal degrees (with a minimum of six decimal place digits) as the standard GPS nomenclature for one-call use. The World Geodetic System 1984 (WGS84) datum is within one meter of the NAD83 datum throughout North America and should also be accepted. This same approach would also serve North America pipeline operators for their broader integrity program. Caution should be used when utilizing offshore coordinates, such as those provided on the Bureau of Safety and Environmental Enforcement (BSEE) website, as these coordinates are typically in NAD27.

8.4 Accuracy

The accuracy of GPS readings varies due to a number of factors, including the number of satellites being tracked, the precision of the GPS unit being used, etc. The accuracy information (i.e. ±29 ft, ±58 ft, etc.) can be obtained from typical GPS units, but in many cases this is only an estimate. Different processes require varying levels of accuracy; the important consideration is that an operator understands the measurement such that they can make a determination as to its adequacy. In the absence of a uniform level of accuracy, the measurement error should be maintained as an attribute of the data to which it pertains. Any error in the GPS coordinate propagates where the coordinate is used to align other data; accordingly, benchmark surveys for inertial mapping unit (IMU) ILI runs benefit from a high degree of accuracy. The vertical measurement error in the elevation is generally 2 to 3~~×~~ times that of the horizontal measurement error for GPS coordinates.

The error associated with GPS coordinates is compounded where two separate GPS points are used to derive the relative length between these points, such as resolving the length of a pipe joint. The better practice is to acquire the coordinate for one weld and then manually measure (tight chain) the length of the joint.

8.5 Base Station Elevation

A common error in the GPS survey of a pipeline centerline is that the elevation of the base station is incorrectly entered. This usually manifests as a vertical discontinuity where survey data collected on different days are immediately adjacent to each other. An example of this would be at road bores where the mainline survey was completed separately from the bore installation and tie-in.

9 Alignment for the Purpose of Pipeline Integrity

9.1 General

The approaches discussed here target integrity management objectives, of which a map-based visualization is but one aspect.

9.2 Linear Referencing

Pipelines, like railways and highways, can leverage a one-dimensional frame of reference given their linear structure. Knowing the path of the pipeline, any point on the pipeline can be uniquely defined based on a measure along the line. The genesis of this linear referencing is during the construction process (construction stationing), where a common and readily apparent measure of reporting progress and the location of events along the line is required. This stationing is typically associated with construction spreads; this frame of reference is commonly replaced by as-built stationing when the line enters service. The as-built stationing is relative to a local physical structure such as a pump or compressor station, but it may include regional or governmental boundaries. This redefinition of the spatial frame of reference creates significant challenges in accurately and efficiently utilizing original construction records in operations.

An important consideration is whether the linear reference is 2D (tight chain) or 3D (slack chain). The linear measure is typically a measure from a known point of reference, but the difference between the 2D and 3D measures quickly accumulates as the distance from the reference increases.

9.3 Weld Alignment

Using the weld tally, where present, as another framework for spatial alignment provides the benefit of a fit point (location of common alignment) where the relative error can be re-zeroed every 40 ft to 80 ft along the line. All data elements should be referenced to the nearest weld aside from any other location reference, such that a highly accurate weld alignment can be leveraged at a later date even if a weld tally does not currently exist (e.g. unpiggable lines on which a direct assessment [DA] is being conducted).

9.4 Centerline

The centerline of a pipeline is typically derived in one of the following three ways:

- line-of-sight survey,
- GPS survey, or
- inertial mapping.

A line-of-sight survey is an accumulation of relative measures whereas a GPS survey is a collection of absolute coordinates.

Inertial mapping uses a combination of inertial and odometer measurements to map the pipeline in between known GPS points at regularly spaced benchmarks. The spatial error increases based on the distance from the benchmarks. As the inertial mapping is dependent on the odometer measurements, any problem with the odometer measurements impacts the delivery of the inertial centerline.

9.5 Absolute Referencing

Data elements that are not an attribute of the pipeline commonly have a location that is defined by a GPS coordinate or polygon. The GPS points can be orthogonally projected against the centerline to resolve their position along the pipeline. In the case of a polygon, an intersection or union can be performed against the centerline to resolve the extent of interaction. In both cases, if either the centerline or external data element is moved, their relative position may need to be reassessed.

9.6 Axial Position and Extent

Regardless of the method of reference (stationing, weld offset, or GPS), attributes with a linear extent along the line are generally referenced in one of three ways:

— center and length,

— leading edge and length, or

— start and end.

The operator should understand the format used for the data deliverables received, and whether they have to be transformed to configure with the operator's data management tools, workflows, and analytics.

Another variant is where the feature can be either reported as a point or with a linear extent; valves are a common example. It is important to remain consistent in the method of reporting each type of feature (e.g. valves are all point features, sleeves are all linear features, etc.) as either point or linear features for data accuracy purposes.

9.7 Circumferential Position

Where a feature on the pipe is not fully encircling, its location around the circumference is typically referenced in one of two ways:

— center and width, or

— top edge and width.

In either case, the position can be provided as an "o'clock" orientation, or as degrees from top dead center (TDC); in both cases the convention is looking in the direction of flow (or increasing stationing in regard~~s~~ to bidirectional flow lines).

A special consideration for a top-edge reference is that on the back side of the pipe this reference becomes the bottom edge of the feature when standing in the ditch. This referencing convention is more prone to circumferential correlation error between in-ditch, non-destructive examination (NDE) and ILI data. Special consideration should be given to the format associated with o'clock values to ensure that this data structure is properly handled within a spreadsheet or database field (i.e. the use of a colon can create unintended issues in how the value is stored).

10 Sources of Measurement Error

10.1 Spatial Error

Spatial error can exist in a range of data inputs. ILI data, whether it is from the odometer location of a feature or from the inertial mapping data that defines the centerline, will be used here to exemplify the issue and its associated considerations. The accuracy, or conversely the measurement error, is influenced by the underlying measurement process and potentially by the relative distance from a control point as well. The spatial error may be managed by increasing the control point density (reduced), applying appropriate buffers (accounted for), or flagging the isolated occurrences where the potential for an abnormally high level of error exists (noted).

10.2 Severity Error

An ILI tool performance specification sheet shall state the tool tolerance and associated confidence interval for the depth, width, and length of an anomaly, typically based on its morphology or shape. In regards to corrosion, this is commonly expressed in terms of the Pipeline Operators Forum dimension classes (i.e. general, pitting, axial grooving, axial slotting, circumferential grooving, circumferential slotting, and pinhole). Additional limitations such as seamless pipe, girth welds, heat affected zone, bends, and fittings, can drive the measurement error beyond that stated in the specification sheet. To account for ILI tool performance error, the operator may incorporate the tool tolerance within their acceptance criteria. Increased confidence levels can be achieved through increased tolerances. Where the increased error cannot be quantified, the record can be flagged to support qualitative interpretation of the anomaly in consideration of the additional uncertainty.

10.3 Confidence Interval of the Error

Measure error is typically derived from a statistical analysis of the measurements. As such, the stated error is based on an assumed or stated level of confidence or reliability. Applying different levels of confidence to the same data set can generate significantly different measurement error ranges.

11 Management of Change

11.1 General

Management of change (MOC) is typically well defined within an operator's management system as it relates to operational controls and procedures. In regard to integrity data, the application of MOC may merit additional consideration.

11.2 New Data Relates to Old Data

The process of controlling how new data relate to historical data, in terms of representing the current threats and fitness for purpose of the pipeline, becomes increasingly important and complex as layers of data increase. The challenge is exemplified in the case of multiple ILI runs at different points in time, using different technologies, and performed on the same section of the pipeline.

Scenarios that should be addressed through documented decisions or processes and data management tools include the following:

a) A new ILI run that completely supersedes a previous run, as it identifies the same features but with better quality.

b) Additional features types relative to the previous run (e.g. cracks vs. metal loss) from a new ILI that would be added to the composite ILI dataset, but redundant features (e.g. weld and valves) would be filtered out to reduce duplication.

c) A new ILI run with missing or degraded data (e.g. experienced battery failure during the run) so that only a portion of the data supersedes the previous run.

    1) Pending a rerun, if applicable, the historical data could be grown to create an inferred population of features to fill the gap.

d) Excavation data that supersedes ILI data, as it is presumed to be more direct with less measurement error. This may not be the case with historical data, internal features, or crack features depending on the in-ditch assessment techniques.

    1) Accurate, in-ditch sized features that remain on the line (recoated or under a sleeve) may become a correlation data set for the next ILI run.

    2) Applicable records shall be maintained to substantiate in-ditch measurements and associated data.

The composite data set should be redefined in consideration of new data in order to support timely and informed interpretation by others in the organization or in the future. The superseded data sets are still maintained for reference; the challenge is ensuring that they are kept current with regard to their positioning along the centerline (i.e. updating old ILI alignments).

11.3 Accessing Historical Data

After a cut-out is performed, timely access to historical pipe attribution and defect populations may be relevant to support the investigation of cause and effect relationships, and inferring the extrapolation of these attributes beyond the extent of cut-outs, as applicable. At its simplest, this is the management of the failure history so as to avoid recurrence of the same conditions. Descriptions of repairs, pipe replacements, and inspections create a knowledge bank that can accurately summarize the events with specific information to aid future assessments and facilitate optimal decisions.

The mechanics of how this is achieved can vary significantly. Any underlying assumptions, constraints, or distortions should be clearly understood by all stakeholders who could access this data.

11.4 Rerouting (Centerline Swap)

A particularly challenging change to manage is the replacement of the entire centerline, or significant portion thereof, with a more accurate centerline trajectory. This scenario can arise when new IMU data from an ILI are more accurate than vintage centerline data within a GIS. Given the level of effort necessary to replace the centerline, the improvements and resulting benefits of a new centerline should be carefully weighed against alternatives. A more common scenario is the localized modification to the centerline.

If the source data are all in one frame of reference (e.g. GPS), translation to the new centerline can be managed in a uniform approach. Where the source data exist in several frames of reference (e.g. GPS, stationing, and weld alignment), greater effort and care may be required. If the source frame of reference is drawn upon to remove location inaccuracies that may have been induced through originally fitting the data against the previous, less accurate centerline, additional attention is required to ensure that the relative position of the various data remains aligned.

11.5 Moving Fit Points

Another common scenario is the potential repositioning of a reference point after data have been positioned relative to the point. An example would be where an intended benchmark location was surveyed before an ILI run. In this instance, during the course of the ILI run, the benchmark was repositioned onto the other side of the road due to interference from an overhead powerline at its original location. The updated location was not effectively communicated, and the ILI was imported and aligned within the corporate data management system based on the original position. If ILI data have already been leveraged in an integrity workflow, associations and dependencies may have been created against these ILI records. An update process to proportionately reposition all the impacted ILI records based on the revised location of the benchmark would be required. Such a "refit" of the data can be challenging given certain applications or data architectures. Where the new ILI data have been used to reposition previous ILI data through a weld match, the edits are even more difficult where the linkage across the ILI runs is not maintained to support cascading the update.

The process of responding to modified location data for fit points applies to any control point type (including valves, branch connections, etc.) that may have been incorrectly surveyed in the past. A variant of the preceding process is when the weld exposed in an excavation is not where it is anticipated to be based on information from the corporate data set. The challenge is how to use the accurate location of the weld to correct the corporate data set. This generally would not be resolved by simply moving the one weld, as it would corrupt the data set by significantly distorting the adjacent joint lengths. Assuming the error accumulated over a distance, as is usually the case, the error would have to be proportionately applied up to the pre-existing bounding fit points.

11.6 Data Reconciliation

When a differential analysis is conducted, such as through a data reconciliation exercise, the potential exists to identify disparities in the data. A process of resolving the hierarchy or precedence of the different data sets relative to each other is required to resolve which data is the "data of record" that flows into the subsequent integrity management analysis and decisions.

During this resolution process, an operator should consider which data sets may contain false positives, true negatives, improper identification, or outdated information. For example, magnetic ILI tools typically have high detection rates for casings. If, however, a casing is not reported by an ILI tool, an operator should not assume that the casing does not exist and remove it by default from other databases during a data reconciliation process, because non-detects are common.

12 ILI Life Cycle

12.1 General

One of the core workflows within pipeline integrity is the management of the life cycle of an in-line inspection run, extending through its integration, analysis, remediation of actionable anomalies, correlation with excavation results, and subsequent reinspection.

12.2 General Reporting Requirements

A successful ILI run depends on clear and well-documented reporting requirements that detail the underlying assumptions and clarify the expectations of the deliverables. Central to this is the pipeline questionnaire, populated by the operator. A number of questionnaire attributes are essential for determining the fitness of purpose of the ILI features, and are not otherwise discernable through the ILI data directly.

Delivery timing is highly dependent upon the length of the pipeline surveyed, the number and type of features detected on that pipeline, and the type and amount of analysis or calculations performed on the data prior to delivery (e.g. anomaly burst pressure calculations, effective area profiles, overlay with other ILI tool runs, or other integrity data, etc.).

12.3 Data Quality Letter and Preliminary Report

The data quality assurance report is issued shortly after the tool is received. This report provides the data used to determine if a re-run is required and should be available before the tool and crews demobilize from the area. These reports generally focus on the extent of coverage for the inspection in terms of percent of linear distance or pipe surface area for which the detection and sizing specifications can be met. Contributing factors could include speed excursions, debris, sensor failure, or electronics failure. Data integration considerations arise when the data is degraded but potentially usable. If data is degraded but potentially usable, then ILI data sets can be spliced together, or new metadata should be carried forward to account for location-specific uncertainties. Although these processes are not applied until later in the ILI life cycle, the decision to leverage them to accept a less than ideal run is made early.

The preliminary reporting of anomalies that require an immediate response can be challenging. There may be limited data to accurately locate the anomalies reported. Even where inertial mapping services have been run with the ILI, the data may not be available for early reporting. In order to leverage weld matching to position the preliminary features, where an historical weld tally exists (previous ILI or as-built survey) a complete weld tally should be requested as part of the preliminary reporting. Identification of welds by an ILI vendor is largely an automated process, and this deliverable may be available shortly after the run.

The following approaches can be taken regarding preliminary reporting:

— The entire run is assessed for defects beyond a certain depth or interaction with another feature (e.g. corrosion in dent) where the analysis can be quickly performed.

— Full reporting is requested, but for only a small portion of the line. Particularly beneficial when conducting crack reinspections, this approach lets the operator quickly develop an informed program based on the most probable sites, assuming an unmitigated growth such that correlation excavations could possibly be used in the refinement of the final report.

Additional critical features may be identified ~~during the analysis~~ as the vendor works through ~~detailed~~ their full analysis and review processes (presuming the operator has instructed the vendor to provide such notifications). A protocol for reporting critical features should be developed, as these features ~~should be reacted to in~~may merit a highly aggressive, limited timeframe ~~once discovered~~response.

~~Part of the preliminary report is the data quality assurance report that is issued shortly after the tool is received. This report provides the data used to determine if a re-run is required and should be available before the tool and crews demobilize from the area. These reports generally focus on the extent of coverage for the inspection in terms of percent of linear distance or pipe surface area for which the detection and sizing specifications can be met. Contributing factors could include speed excursions,~~

~~debris, sensor failure, or electronics failure. Data integration considerations arise when the data is degraded but potentially usable. If data is degraded but potentially usable, then ILI data sets can be spliced together, or new metadata should be carried forward to account for location-specific uncertainties. Although these processes are not applied until later in the ILI life cycle, the decision to leverage them to accept a less than ideal run is made early.~~

12.4 Immediate Responses

12.4.1 Pressure Reduction

Pressure limiting defects present the opportunity of instituting a pressure reduction to mitigate the associated risk where their severity would merit such a response. This requires an ILI vendor or the pipeline operator to quickly calculate the burst pressure ~~and safe operating pressure of every~~of the suspect anomal~~y~~ies. In some cases, such as complex anomalies where interaction or clustering of adjacent defects is applied, this level of calculation may not always be possible in a preliminary report.

Resolving the appropriate level of pressure reduction ~~shall~~ should include a review of the recent pressure history at the location of interest~~, in consideration of the feature's safe working pressure~~.

12.4.2 Leak Detection

Where the reported depth of the feature indicates a potential for a through-wall defect, the operator should assess the location for the possible presence of a leak. The specifics of the response and the required timeliness and accuracy of the feature location would depend on the product being shipped in the pipeline and regulatory obligations, but could range from over-the-line gas detection and instrumented aerial surveillance to shutting in and sectionalizing the line with pressure monitoring.

12.5 ILI Final Report Format

The ILI final report will vary by vendor, tool technology, and operator requirements. Normal components of the ILI final report include the following:

- the hard copy binder,
- the digital version of the hard copy content,
- the pipe or features tally in a digital and queryable format, and
- the data/image files associated with the vendor's client viewer software.

The number of copies and the format of the first three deliverables is influenced by the operator's specification, but the underlying challenge is the management of change across these various representations of the data when the analysis is changed or updated. Different approaches can address this challenge depending on the circumstances and the operator's preferences. The approach should be documented and clearly understood, so that if versions become inconsistent all stakeholders understand which version is the trusted source.

12.6 Quality Assurance of Final Report before Acceptance

12.6.1 Initial Review

This first quality assurance process is focused on the ILI data as a standalone deliverable, and will consist of a review of the data to ensure that the ILI tool vendor has met the general reporting requirements specified by the operator.

12.6.2 Consideration of Historical Remediation

Before resolving the anomalies for considerations as actionable from the response criteria, historical records regarding past repairs and remediation should be considered to avoid inadvertently, and unnecessarily, excavating an anomaly.

After the aforementioned reviews are complete, any errors or omissions, if present, should be resolved before accepting the final report.

12.7 Anomaly Assessment

12.7.1 General

Although the specifics vary by jurisdiction and operator, the response criteria for anomalies is a combination of the risk posed by the features and an appropriate and timely investigation of the anomaly. Upon excavation, separate criteria would be applied to the in-ditch assessment to determine if a repair is required.

12.7.2 Establish Date of Discovery

Date of discovery occurs when an operator has sufficient information to confirm the reported anomaly from the ILI data. Depending on the notification protocols agreed upon, the ~~D~~date of discovery ~~can occur at any time once an ILI report is received. This~~ can range from prior to a preliminary report to sometime after receipt of the final ILI report. Due dates for actionable anomalies are also established at this point.

12.7.3 Review for Interaction with Risk Receptors

The potential consequences of a release are central to the integrity management of a pipeline. A prevalent example of this is the high consequence area (HCA) designation in the United States. ~~In regards to~~For liquid lines, this includes both direct interaction (i.e. within the HCA) and indirect interaction (i.e. overland drainage, spill plume, and downstream transport). The extent of a pipeline interacting with HCAs is not an attribute of the pipe. ~~In this regard, i~~If the centerline (i.e. assumed location of the pipeline) or features on the centerline are moved significantly due to improved spatial alignment, then the interaction with HCAs should be redetermined as part of the management of change process.

12.7.4 Integration of Other Data Sources

12.7.4.1 Data Sets

Operators should consider data sets that capture the pre-existing anomaly population, pipe properties, and environmental data. ~~Such data sets could include the following:~~

- ~~pipe diameter, wall thickness, grade, and seam type;~~
- ~~pipe coating, including girth weld coating;~~
- ~~maximum operating pressure (MOP)/maximum allowable operating pressure (MAOP);~~
- ~~hydrotest pressures;~~
- ~~girth weld type;~~
- ~~previous ILI runs;~~
- ~~excavation results;~~
- ~~alignment maps;~~
- ~~cathodic protection (CP) surveys;~~
- ~~interference surveys;~~
- ~~historical repairs;~~
- ~~previous failures (either in service or hydrostatic test);~~
- ~~unauthorized encroachments;~~
- ~~depth of cover;~~
- ~~soil information;~~
- ~~weather and outside forces considerations (e.g. seismicity, slope stability, scour);~~
- ~~cleaning pig usage;~~
- ~~internal corrosion inhibition;~~
- ~~foreign line crossings; and~~

~~one call density.~~The data in this context are primarily leveraged to determined susceptibility to the various threats, ~~calculate~~determine current fitness for purpose of assessment results and to resolve growth or time dependent degradation to inform re-assessment intervals. ~~Annex B pertaining to the PHMSA prescribed data sets provides an example of the spectrum of data an operator could leverage.~~ Depending on the threats being actively being managed and how they are manifesting, there are numerous attributes that may be relevant in integrity management. A key consideration in the data management strategy is flexibility and agility regarding the storage, integration, and presentation of new relevant data sets as they are identified.

An alignment of welds should be performed between data sets containing welds, such as ILI and excavation data. Once welds are integrated and aligned, the anomalies (~~e.g.~~such as dents, metal loss, or cracks~~, etc.~~) should be correlated and reviewed. For further information, see API RP 1160.

12.7.4.2 Interpretive and Analytic Techniques

Once the data sets are integrated and spatially normalized, multiple interpretative and differential analytic techniques can be applied to further assess the severity and potential causes of the reported anomalies. Possible considerations include the following ~~(see Annex A for a more detailed discussion)~~:

- Dent anomalies from the current ILI should be reviewed to determine if they may have resulted from mechanical damage, if they are new, or if multiple dents exist within close proximity. Once identified, a review of the raw ILI data could be performed to confirm their characterization.
- Metal loss anomalies should be reviewed for potential growth. This can be done by a pit-to-pit comparison based on reported dimensions ~~(i.e. depth, length, width, orientation).~~or signal to signal to reduce variabilities across the ILI runs.
- Another method may be used to compare the number of metal loss anomalies per joint. If there is a significant discrepancy in either the dimension or number of metal loss anomalies per joint, a review of the ILI data is required.
- All potential actionable anomalies should be reviewed to ~~confirm that they have not~~determine if they have been previously repaired ~~(e.g. unbanded composite [clock springs] or recoats)~~. Depending on the circumstances, consideration may be given to the adequacy or failure of the previous repair.
- New ~~D~~dent anomalies should be plotted relative to known encroachments and on a map-based interface ~~or alignment sheet and reviewed for a~~for identification of potential third-party damage sources.
- Metal loss anomalies may be ~~plotted on a map-based interface or alignment sheet and~~ analyzed for areas of highly concentrated corrosion to determine if outside factors are causing it (e.g. foreign crossing). Engagement of other stakeholders outside of the pipeline integrity department is beneficial in this “hot spot” review if other contributing factors have not been integrated into the analysis yet.
- One call density by township, section, and range could be reviewed and correlated with ILI dent indications. ~~Pilot~~ Aerial ROW surveillance reports could be analyzed by corresponding one call reports as a percent of the total, which may correlate with top-side dent indications. This data may also be inputted into risk assessment models and public awareness programs as well as prevention and mitigation projects. The reliability of Public Land Survey System (PLSS) mapping, and all off-the-shelf data sets used in mapping, should be subject to a data integrity review, as are all other data in the database. In regard~~s~~ to ground disturbance performed without one call notifications, a more general overlay of farming locations, railroads, and roadsides should be considered.

12.7.5 Pressure Limiting Anomalies

Calculation of an anomaly's failure pressure or failure-pressure ratio depends upon attributes that may not be directly measured by the ILI tool. These would include MOP/MAOP, specified minimum yield strength (SMYS), and toughness, and could also include wall thickness depending on the inspection technology.

Given that most metal loss features that are pressure limiting are clusters of individual anomalies, the clustering rule used and its application will significantly influence the resulting pressure. Another influence on the outcome would be how shallow features (<10 %) are used in the clustering. These otherwise irrelevant features can appreciably distort the resulting pressure for long, shallow features, especially where conservative failure pressure response criteria are used. One such distortion is where shallow features are reported at the minimum detection depth specification of the tool, even though they are below that level. Although shallow anomalies are useful for delineating the shape and distribution of the metal loss in order to understand the initiation/growth mechanism, control mechanisms (filters) should be considered in regard~~s~~ to clustering processes.

The algorithm used to calculate the failure pressure is another variable that can influence the outcome. The selected approach should be stored as metadata for the failure pressure.

12.7.6 Growth Analysis on Anomalies

Growth analysis should be performed on all metal loss and cracking features to determine if any anomalies need to be investigated prior to the next assessment. Growth analysis can be calculated using date of construction, pit-to-pit, or standardized growth rate based on NACE or other methodologies.

12.7.7 Pipe Movement

Differential analysis of pipe movement resolved through strain measurement or slope monitoring can provide insight into time-dependent effects.

12.7.8 Validation of ~~Accuracy~~ILI Performance

Accuracy validation entails a differential analysis between the current ILI data and other data sources to assess the ~~accuracy of the report~~performance of the ILI system, including POD, POI and POS. This would address both the reported anomalies and applied pipe attributes, either measured by the inspection tool or provided in the pipeline questionnaire, and leveraged by the vendor in preparing the report (e.g. SMYS and MOP).

Methods for ~~V~~validating~~on of~~ ILI data ~~can be derived by, but not limited to, one or more of the following~~include, but are not limited to~~ methods~~:

- correlation with field data from previous nonmetallic repairs or recoats for the same segment,
- correlation with field data from excavations in response to the current ILI,
- acceptable correlation with a temporarily or permanently installed spool piece that contains anomalies with known characteristics,
- correlation based on a comparison to a previously validated ILI run, or
- calibration certificate for dents that demonstrates that the pre- and post-calibration are within the published tool specification (in lieu of correlation excavations).

As detailed in API 1163, an ILI tool's performance can be validated using data from similar pipeline(s) and from historical (near-term) runs utilizing an ILI inspection tool with the same sensor technology and from the same vendor. The non-measured data, such as SMYS or MOP, that are essential variables in the vendor's assessment of defect severity, should be reviewed and confirmed for every run.

12.8 Excavation Program

12.8.1 Program

Excavation program aspects pertinent to the data integration include the following:

- validation that the correct joint is being excavated;
- extent and accuracy of NDE inspection;
- anomaly correlation;
- type and extent of remediation or repair; and

— preventive and mitigative activities performed to manage growth (from internal corrosion, external corrosion, fatigue, etc.) or recurrence.

See Section 13 regarding field data collection.

12.8.2 Anomaly Correlation

In terms of anomaly correlation, a scenario of specific interest is outlier resolution. API 1163 provides direction regarding what could constitute an outlier and what responses may be appropriate. Operators should understand the cause of the discrepancy and its significance to the remaining population of unmitigated anomalies. Where the cause of the discrepancy is systemic to some ~~degree, and~~degree and attributed to ILI data as opposed to the NDE data, the remaining anomalies can be recharacterized or calibrated to compensate. This could manifest in the form of an applied bias or a modified tool tolerance specific to the circumstances associated with the outlier.

12.8.3 Differential Analysis

The differential analysis between the current ILI data and the NDE results of the excavations may involve the use of a unity plot in communicating the accuracy of the ILI tool by comparing the predicted values versus actual values. An extension of this approach is to calculate the actual tool tolerance to an equivalent level of confidence based on this data.

~~This process supports the identification of outliers. The operator should understand what contributed to the outlying correlation and its applicability and influence on the remaining population of the unmitigated anomalies.~~

The timing of this analysis usually does not impact the content of the original final report (unless driven by the preliminary report). When ILI tool results deviate from the tool's published specification beyond an established amount, a request to the ILI vendor for a review of the ILI calls should be performed. Based on the results, a regrade of the ILI call outs may be necessary. The operator may establish a new date of discovery based on the regraded report. If the data cannot be sufficiently corrected through regrading, resizing, or recharacterization ~~to acceptable levels~~, the operator ~~ILI data~~ may have ~~to be completely~~ reject~~ed~~ ILI run and have the pipeline reinspected.

12.9 Provide Correlation Results to ILI Vendor

The operator should identify which dig results to supply to the ILI vendor to utilize in calibrating their sizing algorithm. The dig feedback should include, but not be limited to, ~~all~~ NDE reports, correlation tables, and photographs. Although generally provided once the dig program has been completed, this data may be provided incrementally when outliers are identified, or where there has been little previously available in-ditch correlation data for the ILI tool or anomaly type. In some cases, it may be beneficial to work jointly with the ILI vendor's analysts at excavation locations to resolve field NDE vs. ILI data discrepancies in sizing or characterization.

12.10 Program Closeout and Establishment of Reassessment Intervals

A review of the results ~~shall~~ should be performed and a determination made to close out the project or add additional digs ~~shall be made~~. Reassessment ~~shall~~ should be established from the trap date ~~from~~ for the ILI tool run, and ~~shall~~ be determined in consideration of prescribed regulatory intervals and risk factors, including growth modeling of the unmitigated population of anomalies.

13 Execution of Digs/Field Data Collection

13.1 Pre-dig Information

13.1.1 General

To ensure ~~the~~ a high~~est~~ confidence in the location of actionable anomalies identified from ILI assessments ~~are excavated at the correct location~~, several physical measurements and records should be obtained prior to anomaly excavation. These parameters, when used together, minimize if not eliminate, ~~provide a high degree of confidence that anomaly excavation occurs at the joint of interest. As~~

~~a result,~~ the likelihood of excavation at ~~the~~ an incorrect location ~~is minimized, if not eliminated, with confirmation of each parameter~~.

13.1.2 Flow Direction

Flow direction and direction of tool travel is required to establish the order of upstream and downstream joints, as well as the orientation of the anomaly as viewed looking downstream. The anomaly orientation looking downstream should be confirmed with vendor reporting formats.

If the tool was launched in the flow direction opposite of recorded stationing, the operator should perform a calculation to correlate stationing to leverage and record station-based references.

13.1.3 Axial Position

13.1.3.1 General

The anomaly is positioned relative to the reference or target girth weld, typically the upstream weld. The target girth weld is usually the start of the excavation, as it provides the timeliest feedback in terms of the excavation's spatial accuracy. An operator could use the methods listed in 13.1.3.2 through 13.1.3.4 to determine the location of the excavation's target girth weld. Regardless of how the location of the site is resolved, alignment sheets or a GIS in addition to field staff consultations should be used to gauge the dig difficulty and whether further preparations or precautions are required for efficient and safe excavation. The legal description (e.g. state, county, etc.) of the dig site ~~will be~~ is usually required for landowner engagement for access and ground disturbance.

13.1.3.2 Relative Location

The location provided by the vendor is typically stated as a cumulative distance from tool launch. Identification of the nearest reference point (e.g. valves, casings, benchmarks, etc.) to the anomaly provided from the ILI report in the upstream and downstream direction can approximate ~~locate~~ the excavation location ~~with reduced error~~. Also, the operator should verify the total tool odometer reading matches the published segment length in alignment sheets, as-built drawings, surveys, or any other verified document. If the two lengths are significantly different, error may be introduced on site when locating anomaly excavation points.

Reference points should be located at regular intervals on a pipeline segment. The density of references and the resulting distance from the anomaly influence the measurement error in locating the anomaly (measuring error is reduced when reference points are closest to the intended dig location). ~~In the absence of weld alignment, the reference points are useful in aligning past and future ILI data allowing accurate data comparisons between tool runs.~~

13.1.3.3 GPS from IMU

GPS coordinates facilitate directly resolving the excavation location and its position relative to ~~creating mapping files that can be overlaid onto~~ electronic maps such as a GIS. However, the spatial error inherent in this inferred GPS is dependent on the proximity of the control points used in its derivation. To limit the typical error associated with inertial drift to a maximum of X then spacing of the control points should not exceed Y; however, any spatial error in the GPS of the control points would be additive to the inertial error of the IMU.~~.~~

13.1.3.4 Weld Alignment

Joint matching at the girth weld aids the matching of previous tool data to current ILI assessment data. This avoids the need for AGM or IMU data for the current ~~run~~ ILI in regard~~s~~ to alignment of the run. ~~IMU data can be useful for other purposes.~~ Weld alignment also allows a joint level comparison for anomaly growth (e.g. noting increased anomaly counts per joint and direct comparisons of identified anomalies).

13.1.4 Seam Orientation

The easiest means of validating that the correct joint has been excavated, for non-seamless pipe, is to correlate the upstream and downstream seam orientations at the target girth weld (if available). Even where the orientation may be shifted due to measurement error, the relative offset between the seams at the girth weld remains accurate. The combination of the orientations is typically more distinct than joint length and requires less excavation. For spiral pipe, resolving the orientation where the seam welds intersect the girth weld may require going beyond the pipe tally and reviewing the vendor's thematic visualization of all the data in their viewer application.

13.1.5 Joint Length

~~The joint length of several joints, both upstream and downstream of the joint containing the anomaly of interest, is required.~~ Most pipe joints are purchased and installed in random lengths; the lengths may be similar enough that they are not distinct in consideration of the ILI measurement error. When the ~~correct~~ anomaly location is in question, excavating and ~~measuring~~ validating distinct joint lengths in proximity ~~additional upstream and downstream joints is recommended~~may be necessary~~. Matching the excavated joint lengths and order to verify ILI joint length data or historical records, or both, will validate the excavation location~~.

13.1.6 Pipe Properties

Pipe properties to facilitate both the location validation and repair assessment include the following:

a) pipe mill,

b) pipe grade,

c) nominal wall thickness,

d) long seam type,

e) distance from upstream station, and

f) for multiple joints upstream and downstream of the target,

  1) long seam orientation,

  2) joint length, and

  3) joint number.

13.1.7 ~~Additional Information~~Previous Excavations in Proximity

~~Additional information useful for successful excavations includes previous repair records of nearby digs.~~ Past ~~repair records for an activity~~excavations near proposed excavations ~~should~~ may contain confirmed ~~benchmarks or other~~reference points ~~of reference~~ and relevant pipe information~~ applicable to future excavations~~. Another consideration on older lines is the minor extension of the proposed excavation in order to tie into the high integrity coating from a previous repair.~~Other ILI information can include the following:~~

~~joint number,~~

~~relative and radial positions,~~

~~depth,~~

~~feature type,~~

~~orientation,~~

~~length,~~

~~width,~~

~~additional comments from ILI vendor, and~~

~~feature identifier.~~

13.1.8 Deliverables for Field Execution

Table 1 lists a typical work package to support effective location and correlation of the ILI features.

Table 1—Typical Location and Correlation Work Package Contents

Fields	Description
Dig list	A complete list of all numbered, required/recommended dig locations, as well as possible and additional (provisional) dig locations, identified in the assessment segment (sorted by odometer, not dig number).
Dig sheet	An excavation sheet prepared specifically to locate the required/recommended "target" girth weld/anomaly for excavation.
Site reference	A complete pipe listing of all events reported directly upstream and downstream to aid in target joint/anomaly location and excavation.
Anomaly correlation table	A complete list of joint-to-joint (minimum) reported information for all numbered, required/recommended dig locations (as identified in the assessment segment) for field result population and recording. Given that the site may include anomalies from multiple ILI runs, referential attribution may include the following: — vendor name, — vendor project number, — vendor ILI odometer, — ILI tool type, and — ILI vendor dig sheet/anomaly number.

13.2 In-ditch Data Collection

13.2.1 General

Specific consideration should be given to the delineation of data that need to be extracted, aggregated, and integrated into the broader integrity management data set to support comprehensive and informed decisions. A further consideration is the relevance of the data recorded in the ditch and how the effort and time required relates to the benefit of the data in understanding the degradation mechanism or severity of the defect and its associated threat.

13.2.2 Location Confirmation

~~The facility or system, or both, name should be documented on all reports. The legal description (e.g. state, county, etc.) of the dig location should also be noted. Providing GPS coordinates will give a sufficiently accurate location of the dig site, subject to the considerations outlined in Section 8. Any above ground structures (e.g. pipe, valves, station, etc.) may aid in measurements to correct pipe joint locations if measured with tape or wheel using the odometer count from the above ground structure~~The means by which the location of the excavation was validated as correct should be clearly ~~document~~documented, along with the names of the individuals involved.

13.2.3 Foreign Structures

Any structures around dig sites should be documented. The type of structure, distance from pipeline, name of owner, and a telephone number or address should also be noted if possible. An as-built of any structure around the dig site should be drafted.

13.2.4 Pipe to Soil Readings

The operator may consider documenting cathodic protection potential readings at the pipe and ground level as applicable to the threat being investigated. These may be taken at the time of excavation and before backfilling after a repair has been made. Both readings should be taken in a consistent polarity.

13.2.5 pH under Disbonded Coating

The pH of any water or moisture beneath the pipeline coating should be documented where relevant to the identified threats. This data can be gathered using a variety of technologies, including pH paper.

13.2.6 Soil Type

The soil type or classification at the dig location should be documented where relevant to the identified threats (e.g. class A, B, or C—along with rock, dirt, clay, sand, etc.).

13.2.7 Soil Resistivity at Pipe Depth

Consideration should be given to documenting soil resistivity readings representative of pipe depth where soil resistivity relates to the features anticipated within the excavation. Where soil resistivity can be captured, this provides the operator with an accumulating data set that may become highly relevant at a future date. If it is suspected that there are soil strata above the pipe that differ from the strata at pipe depth, resistivity readings in those differing strata may provide additional insight to the applicability of the reading taken at survey (i.e. four-pin method). All readings should be taken as close to the pipe centerline as is practicable.

13.2.8 Corrosion Status

~~Coating should be examined, before removal, for sagging, cracking, wrinkling, disbondment, damage, etc.~~ During coating removal, the presence, type, color, hardness, and other relevant features of deposits under existing coating should be noted. Consideration can be given to the benefits of implementing the training and equipment ~~The following should be determined and documented on the dig report~~necessary to capture the following during the excavation:

- corrosion status (i.e. active, inactive, or unknown),
- the presence of extensive (all over, random area) or localized (contained to one area) corrosion, and
- evidence of microbiologically influenced corrosion (MIC).

13.2.9 Pipe Attributes

The coating should be examined, before removal, for type and condition; sagging, cracking, wrinkling, disbondment, damage, ~~etc~~or other attributes. ~~The type of existing coating should be documented as well as the condition in which it was found. A list of coating types should be provided on dig reports. Types of coating conditions should also be provided on dig reports.~~ NDE methods may be used to measure additional attributes such as wall thickness, with emerging technologies providing the capability to measure yield strength in the ditch.

13.2.10 Existing Repairs

Any existing repairs within the excavation should be documented ~~on the dig report~~ and should include the following information:

- the type of repair,
- distance from known girth weld, and
- the condition of the existing repair.

~~All existing repairs should be noted on as-built documentation.~~

~~1.1.1 Pipe Damage~~

~~The operator should document the following information regarding any discovered pipe damage:~~

- ~~type of damage,~~
- ~~distance from known girth weld, and~~
- ~~orientation.~~

13.2.11 Existing Connections or Fittings

Documenting connections or fittings by type, size, distance from known girth weld, and orientation aids in verifying the target joint and the ILI tool accuracy. Any connection or fitting should be noted on as-built drawings to ensure that the attachment is included on company alignment sheets. The wall thickness of any fitting traversed by the ILI should be validated as they are often substantially thicker than the adjacent pipe.

13.2.12 Longitudinal Seam Weld Orientation

The orientation of the long seam (o'clock or degrees) should be noted, when it can be determined visually, on the target joint and the upstream/downstream joints to aid in verifying the target joint and ILI tool accuracy.

13.2.13 Joint Length

Weld-to-weld direct measurements should be taken (with tape) to give the absolute length of pipe joints. This aids in verifying target joints and ILI tool accuracy. Distance between weld GPS points should not be used to verify joint length because ~~the GPS points are not exact~~of the relative error between the GPS points.

13.2.14 Excavation Site Information

As depicted in Figure 1, the following dig site information may be useful for threat management when properly documented and integrated into the overall management program.

- Excavation length is the longitudinal distance of soil that is disturbed as part of the excavation. This length is typically longer than the length of pipe that is exposed to allow for proper sloping of the excavation ditch. This can also include pipe that is exposed but does not have the coating removed.
- Exposed length is the length of pipe that is uncovered with excavation such that the pipe coating is visible.
- Remediated length is the length of pipe that has its coating removed and the surface cleaned for defect assessment and ultimately reapplication of the coating.
- NDE length is the length of the pipe that is actually assessed. Some operators choose to assess the entire exposed length of pipe while others choose to review only the target defects. This can depend on the type of defect that is being reviewed. A full joint excavation with exposed girth welds can facilitate ease of confirming location and referencing. NDE of the full joint allows an operator to assess the condition of a pipe joint beyond what was reported by the ILI tool.
- Longitudinal seam weld assessments should be documented based on the type and length of inspection that was performed. It can be helpful to understand the percentage of the total length that was assessed versus the length of pipe that was exposed when performing data integration.
- When magnetic particle inspection (MPI) or dye penetrant inspection is performed, the locations that are assessed should be documented by collecting the same area information that is collected on a corrosion feature (i.e. length, width, circumferential, and axial location).

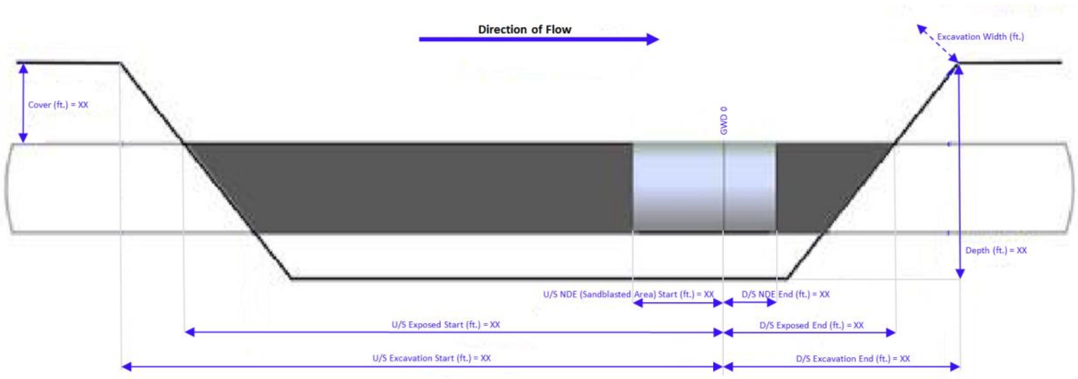

Figure 1—Schematic of Relevant Excavation Site Information

13.2.15 Site Mitigation

Appropriate axial and circumferential referencing ~~ensures~~ensure that information collected at the final stages of field NDE can be incorporated into the overall integrity management plan for a line or a specific pipe joint. For instance, ILI-reported features from subsequent ILI on previously excavated joints can be identified as active or already mitigated if the extents of historical mitigation activities are properly documented.

In addition, threat management requires the following information:

— type of repair,

— axial limits of repair type,

— extents of coating replacement,

— pipe replacement, and

— installation of new appurtenances such as CP test leads.

This information can also be provided schematically similar to Figure 1.

13.2.16 Photographs

Photographs are useful for communicating information from field personnel to personnel in the office, and can be used to ~~verify~~ validate information provided within the tables in a field NDE report. Effective photographs of the pipe surface should have a reference scale, such as a ruler with markings of the data collected during defect assessment. It is helpful to take photographs of features both on a macro level (e.g. an entire corrosion feature) and on a micro level (e.g. pits within pits to document MIC). The capabilities of field personnel and their equipment to take effective photographs should be verified.

Table 2 provides guidelines for photographs.

Table 2—Guidelines for Photographs

General Photograph Guidelines	Photograph Guidelines for Defect Assessment
— General vicinity/site overview before excavation to document ROW condition prior to disturbance — Coating condition as-seen when pipe is exposed prior to removal of coating — Soil condition — Line identifiers (e.g. number, milepost) — Flow direction — Location information (geotagging, if applicable)	— Boxed ILI callout area — Measured wall thickness — Measured depth — Measured length — Axial limits (start and stop reference locations) — Circumferential locations — Radial position — Measurement unit

13.2.17 ~~Defect~~ Anomaly Assessment

13.2.17.1 General

~~Defect~~ Anomaly assessment is the process by which a feature reported by an ILI survey, or an area of interest from a DA program, is reviewed for integrity purposes. ~~Defect~~ Anomaly assessment confirms or refutes the results of an integrity assessment (e.g. if an ILI survey reports a feature with a certain length, width, and depth)~~. The true characterization of the feature cannot be confirmed until the defect assessment is complete. Accurate defect assessment allows for the determination of the quality of the integrity assessment~~.

13.2.17.2 Reported Versus Actual Response Time

Actionable ~~Features~~ anomalies reported in ILI ~~surveys~~ assessments are assigned response times for remediation. These response times are based on regulations and the operator's procedures. Remediation of the features with a prescribed response time stops the clock, irrespective of field data collection activities that may continue past that point. Features should be documented based on when they were required to be remediated and when they actually were remediated. This ensures compliance with regulations and with corporate procedures.

13.2.17.3 Data Collected During ~~Defect~~ Anomaly Assessment

All ~~defects~~ anomalies on a pipeline that are being assessed require the same basic information be gathered in order to integrate data. The key parameters are as follows:

— The length of the anomaly is the measured distance that it ~~a defect~~ traverses along the length of the pipeline. It is sometimes useful to collect length information for the general ~~defect~~ anomaly being assessed and document any significant features in the ~~defect~~ anomaly (e.g. pits in a larger area of corrosion). In the case of stress corrosion cracking (SCC), it is helpful to measure both the length of the colony as a whole and the maximum interlinking length within the colony. API RP 1176 provides additional guidance in order to support meaningful correlation with ILI crack anomalies.

— ~~Defect~~ Anomaly depth for metal loss and cracking is the ~~amount of~~extent through the wall thickness ~~that the defect occupies on the pipe joint~~. This is usually measured from the surface of the pipe, internal or external, to the deepest part of the ~~defect~~anomaly. However, for embedded planar features this could be reported as height. API RP 1176 delves further into the specific considerations of the nomenclature associated with NDE using shear wave UT. Mapping the depth profile at a pre-determined interval to create a river-bottom profile supports a more accurate failure pressure determination.

— The depth for geometry anomalies such as dents is typically captured as a percentage of pipe OD at its deepest point. Mapping the depth profile along the pipe axis at a pre-determined interval supports additional dents characterization per API 1183.

— Width is the circumferential extent of the ~~defect~~ feature being reviewed. This can be measured clockwise or counter-clockwise across the largest ~~section~~ portion of the defect.

— Axial location measurements are taken from either an upstream or a downstream reference girth weld. The measurement is taken from the center of the girth weld to the closest extent of the feature being reviewed. It can be beneficial to measure the axial location from both upstream and downstream reference girth welds.

— For circumferential location, the top of the pipe is the 12 o'clock, or zero-degree, position. Circumferential locations are measured looking downstream of the pipe from this reference. The measurement ~~should~~ can be taken from the top dead center of the pipe in a clockwise manner to the first instance of the ~~defect~~ feature being assessed. Alternatively, it can be to the center of the feature to align with the ILI reporting format, if applicable.

— Internal versus external radial position is determined; mid-wall defects will possibly require a quantitative measure be taken from the inner/outer surface of the pipe to the defect. Knowing whether a defect is surface breaking or not can alter the type of defect assessment to be performed.

— The measurement units should be consistent across a company's region if not the entire organization. For example, if an operator uses imperial units in the office, they should make measurements in imperial units in the field. Depth measurements should be reported with units of inch or millimeter at a minimum, and it is sometimes beneficial to also report in percent of wall thickness as well (i.e. imperial/metric, % ~~/wt~~WT).

— The identification of coincident and interacting anomalies should be addressed through the use of MPI and/or UT inspection techniques as applicable. The interaction of anomalies should be noted and accounted for in the assessment. In certain cases, (e.g. crack interacting with corrosion), successive minor buffing may be required to allow adequate characterization of the interacting anomalies. Regarding cracks in corrosion, additional characterization of the cracking as to its location in the base or sidewall or the corrosion may be beneficial.

~~1.1.1.1 External and Internal Corrosion Assessment Methods~~

~~The operator should perform the following measurements to support external and internal corrosion assessments.~~

- ~~Create a box outline for the feature based on ILI dimensions and any other corrosion defect not reported by the ILI tool.~~
- ~~Verify depth using one or more measurement techniques (e.g. pit gauge, manual ultrasonic, automated ultrasonic, phased array, laser scan, etc.).~~
- ~~Record axial limits relative to the reference point (e.g. girth weld) to provide the length of indication.~~
- ~~Record circumferential limits (i.e. orientation) relative to a reference point and correlated to ILI data.~~
- ~~Map the flaw depth profile at a pre-determined interval to create a river-bottom profile needed to estimate the rupture pressure ratio (RPR) if required.~~
- ~~Use ultrasonic testing (UT) to determine the presence of internal metal loss.~~

~~1.1.1.2 Crack, Lamination, and Lack of Fusion Assessment Methods~~

~~API 1176 provides details for sizing crack-like anomalies. Considerations pertaining to data integration include the following:~~

- ~~Create a box outline for the feature based on ILI dimensions and any other crack-related or lamination defect not reported by the ILI tool.~~
- ~~Verify depth using one or more measurement techniques (e.g. manual shear wave ultrasonic, automated shear wave ultrasonic, phased array, grinding, etc.).~~
- ~~Record axial limits relative to the reference point (e.g. girth weld) to provide the length of indication.~~
- ~~Record circumferential limits (i.e. orientation) relative to a reference point and correlated to ILI data.~~
- ~~Map the flaw depth profile at a predetermined interval to create a river-bottom profile needed to estimate RPR if required.~~
- ~~Use shear wave UT to determine presence of coincident internal cracks where applicable to the cracking mechanism.~~

~~1.1.1.3 Mechanical Damage Assessment Methods~~

~~The operator should perform the following measurements to support mechanical damage assessments:~~

- ~~Create a box outline for the feature based on ILI dimensions or any other mechanical damage not reported by the ILI tool.~~

- ~~Record axial limits relative to the reference point (e.g. girth weld) to provide the length of indication.~~
- ~~Record circumferential limits (e.g. orientation) relative to a reference point and correlated to ILI data.~~
- ~~Use MPI or UT to determine the presence of external or internal secondary defects such as corrosion, cracks, or gouges.~~

~~1.1.1.4 Interacting Defect Assessment~~

~~An assessment of interacting defects should follow guidelines provided for the individual defects when applicable. In certain cases, (e.g. crack interacting with corrosion), successive minor buffing may be required to allow adequate characterization of the interacting defects.~~

~~The operator should perform the following steps to support interacting-defect assessments:~~

~~a) Create a box outline for the feature based on ILI dimensions and any other interacting defects not reported by the ILI tool.~~

~~b) Record axial limits for each defect relative to the reference point (e.g. girth weld) to provide length of indication.~~

~~c) Record circumferential limits (i.e. orientation) for each defect relative to a reference point and correlated to ILI data.~~

~~d) Measure the depths of individual defects.~~

~~e) Determine the mode of interaction, such as the following:~~

~~1) Is the crack located at the bottom of a corrosion pit?~~

~~2) Is the crack located at the side wall of the corrosion?~~

~~3) Is the crack located within a dent anomaly?~~

14 As-built Asset Integration

14.1 General Data Requirements

14.1.1 Types of Data

Collecting and organizing the pipeline data in a comprehensive manner as early as possible in the pipeline's life cycle is important to managing the integrity of the pipeline. The operator should determine the data required to make integrity decisions throughout the life of the pipeline. ~~The operator should collect a variety of data that includes but is not limited to the following:~~

~~a detailed listing of the pipe specifications,~~

~~type of coating,~~

~~elevation profiles,~~

~~pipeline drawings, and~~

~~hydrostatic test records.~~

Before work is started, it is helpful to create a checklist of the data required to aid the lead inspector in ensuring that the requisite data is captured. ~~An ongoing document log should be used to track documents~~

~~as they are received; this document log should be followed with a project completion checklist to account for all documents.~~ Creating a template and minimum geospatial data delivery requirements (i.e. specifications) ahead of project commencement that matches the format and order of the database in which the data will be stored increases the chance of receiving usable data. An ongoing document log should be used to track documents as they are received; this document log should be followed with a project completion checklist to account for all documents.

14.1.2 Project Book

Project books, either physical or digital records/data, can be compiled during the project or upon completion. Common project books include, but are not limited to, the following:

- Department of Transportation (DOT) records,
- safety and training records,
- maps,
- CP records,
- valve listings,
- maintenance and construction records,
- pressure test records, and
- pipeline integrity records.

~~1.2 GPS Survey~~

~~GPS as-built surveys require that the data format, datum, and accuracy be selected prior to performing the survey or awarding the work. Certain equipment manufacturers produce specific file types. The file types should be compatible with the structure of the data management system to better facilitate the conversion process.~~

~~Consider receiving a test sample of GPS data shortly after the project commences to validate that the data meets the requirements specified at the beginning of the project. Ongoing validation of the data is recommended, but final project completion validation is required.~~

14.2 Data Collection

14.2.1 Receipt of Data

The operator should decide when and how to receive the data. One option is to receive the data periodically throughout the course of the project. This strategy ensures that the data can be verified for completeness and accuracy in a timely manner. ~~Also, t~~The potential for future errors may be mitigated by communicating any issues that are discovered to the field personnel. ~~The final project book might not be organized efficiently, however, due to multiple receipt dates.~~Annex B provides a comprehensive example of this approach.

Another option is to receive the data at the end of the project~~, when all work is completed~~. ~~Remediation of the features with a prescribed response time stops the clock, irrespective of field data collection activities that may continue past that point.~~ Project books should contain the mill test report (MTR), if available. The MTR documents the manufacturer, properties, and dimensions of the steel that was used to make the pipeline.

Determining which segments of pipe were installed in which locations is a key concern. Although MTRs, combined with the purchase order, specify the total length of pipe purchased, they do not detail whether the pipe was installed in one string or divided into multiple sections interspersed through the length of the pipeline. It is important for site inspectors and surveyors to accurately document the location of each joint of pipe and correlate the heat numbers to the correct MTR documentation.

14.2.2 GPS Survey

GPS as-built surveys require that the data format, datum, and accuracy be selected prior to performing the survey or awarding the work. Certain equipment manufacturers produce specific file types. The file types should be compatible with the structure of the data management system to better facilitate the conversion process.

Consider receiving a test sample of GPS data shortly after the project commences to validate that the data meets the requirements specified at the beginning of the project. Ongoing validation of the data is recommended, but final project completion validation is required.

~~A GPS survey of the transition points between pipe sections with differing pipe properties should be conducted on new construction. Capturing the GPS location of every weld on the pipeline provides a detailed view of the pipeline.~~

In some cases, the pipe is surveyed while on skids next to the ditch. A subsequent transformation is then used to shift it to the ditch centerline. The transformation process does provide another opportunity to introduce ~~error~~errors into the data; where used it should be well documented and clearly understood.

The physical pipe properties and heat numbers can be noted in the GPS points for each joint of pipe. Errors can still occur because the properties will still be input manually. To counter transcription errors, radio frequency identification (RFID) tagging or bar coding can be used. A tag or bar code is affixed to each section of pipe. These tags or codes can have exact ~~location and~~ pipe properties of the steel to which they are attached. Transcription errors are eliminated with this process~~, but; cost can be a significant deterrent to implementing this technology~~.

14.2.3 Review of Data Collection Requirements

After determining the company-specific requirements for the data, operators should review data collection requirements and confirm the procedures to be used by personnel gathering the data. The operator should ensure that all personnel understand the data collection methods, and the importance of the collected data, ~~in order to~~to improve the quality of the data books and the subsequent implementation of an integrity program.

14.3 Virtual Pipeline Creation

The information within a project book should be utilized for integrity decision making. Creating a virtual pipeline to map pipeline routes and depict pipe properties throughout the length of the pipeline can answer ~~a number of~~several integrity-related questions.

Loading the XYZ coordinates from the GPS survey into a computer-aided design and drafting program gives the basis for the virtual pipeline. A database template, or seed file (if established early in the process), can be utilized to streamline the data-loading process. A linear reference should be established for the pipeline; this is commonly in the form of an engineering stationing standard.

~~An engineering~~Engineering stationing is assigned to known reference locations such that stationing at intermediate points can be interpolated. All other features can be loaded and assigned a linear reference based on their positioning in relation to known reference points. Decreasing the distance between known reference points provides the most accurate linear reference representation. The accuracy of inferred engineering stationing~~s~~ can vary greatly when dealing with rolling landforms with significant elevation changes.

14.4 Data Storage

Data storage and archiving are key elements of the asset integration process. Project books may be received as paper copies, although converting the documents to electronic format can ensure preservation of data over time.

Whether the data is in paper format or electronic format, an index system should be created to make the data easily accessible and with improved traceability for future inquiries. The indexing strategy and metadata fields should be developed with consideration of how the records will be accessed once the pipeline enters operations.

14.5 Continuity of Linear Referencing Schema

Attention and consideration should be paid to the historical field stationing references when updating drawings and updating a station-based GIS. Maintaining this attribute ensures a common frame of reference between current and historical data, such that the historical data can be retrieved and aligned to the current ILI data with minimal effort.

14.6 Baseline In-line Inspection

14.6.1 Horizontal Directional Drilling Considerations

If performing a horizontal directional drill (HDD), the operator should consider pulling an ILI tool through the pipe both before and after installation to differentiate between manufacturing defects and construction defects, as well as to validate the use of proper construction practices. Regardless, a post-installation tool run can verify the presence of any defects injurious to the pipeline prior to starting the pipeline.

14.6.2 Pre-commissioning ILI

Considerations regarding caliper runs conducted during construction include the following:

— Where specific concerns exist regarding construction damage, running the caliper inspection before hydrotesting provides an improved assessment for mechanical damage before the pressure from the hydrotest rebounds (pops out) the associated dent.

— Running the caliper inspection prior to commissioning facilitates the original construction contractor remediating the identified dents and buckles prior to line fill.

~~—~~ Where a high-resolution caliper tool is run, the vendor may require elevated back pressure to meet the specification.

— _Where ~~the tool is~~ run with compressed air during construction, the pressure requirements may significantly impact ~~costs and~~ logistical requirements. These pressure requirements should be identified early and communicated to all stakeholders.

14.6.3 Post-commissioning ILI

Shortly after commissioning pipelines, in-line inspections may be run to perform the following:

— detect defects from manufacturing or created during construction (and potentially correct defects under the warranty period),

— create a baseline for comparison of future tool runs, and

— validate the project book (see 14.1.2) data information (e.g. compare joint lengths and wall thickness readings, as measured by the tool, to the as-built drawings).

Incremental or expedited delivery of the survey data supports production of accurate pipeline questionnaires such that vendors can make informed proposals for the baseline inspections.

14.6.4 IMU Tools Runs

IMU tool runs can provide an additional way to map a pipeline in conjunction with the GPS survey. IMU tool data can be used to measure the radii and strain on ~~any~~ bends ~~installed~~, ~~verify the radii of the bends,~~ as well as ~~and~~ confirm that any construction-related specifications were followed. Data from subsequent IMU tool runs can be used to detect any land movement issues.

14.7 Baseline Indirect Assessments

To verify that the pipeline is protected, a close interval pipe-to-soil potential survey (CIS/CIPS) can be performed to identify and locate areas where CP might not be adequate. A direct current voltage gradient (DCVG) or alternating current voltage gradient (ACVG) survey can be performed to identify and locate areas where coating defects may exist. After initial construction, it may take a year for newly backfilled soil to settle in around the pipeline such that accurate CIS and DCVG/ACVG surveys can be performed.

15 Over-the-Line Surveys (Indirect Assessments)

15.1 General

Various over-the-line surveys—such as CIS/CIPS or DCVG surveys—are performed by operators to monitor the performance of external corrosion prevention and mitigation measures. These data sets provide information only for the ~~mitigation~~ preventative measure (e.g. coating, CP levels) being assessed and do not directly report on the integrity of the pipe steel. An operator should align these data sets with ILI data ~~in order to~~to identify potential areas of interest where metal loss is reported on the pipeline in the same location as anomalies are found in over-the-line surveys.

15.2 Alignment

To properly align data sets collected above grade with data collected from within the pipeline through ILI, an operator should identify common features that can be detected and have a location established by both survey methods. Additionally, these points can be aligned with established locations in a GIS database to further correlate data sets. Once common features are established, locations of individual data points can be cross-referenced through GPS or linear referencing.

Figure 2 depicts some examples of how above-grade and below-grade data sets can be correlated through common features. Examples of common feature locations include the following:

— A benchmark is commonly used for tracking and establishing interpolated GPS data during ILI surveys. Benchmark locations can also be ~~entered into a GIS database and recorded~~noted during over-the-line surveys using GPS equipment to facilitate data alignment.

— Corrosion control devices and equipment—such as test stations and rectifiers—are sometimes located using GPS equipment during over-the-line surveys and are typically included in ~~GIS~~ spatial databases. While typically not recorded during an ILI survey, their locations can be interpolated into the ILI data set through GPS or linear referencing.

— Various pipeline features—such as above ground markers (AGMs), casings, valves, taps, bends, and repair sleeves—are often detected and recorded during ILI surveys and can be recorded during over-the-line surveys to provide additional reference points. Additional features to align ILI data ~~to the GIS database~~ could include tie-in joints of pipe that are often shorter in length or that can be identified through a detectible wall thickness change in the ILI data.

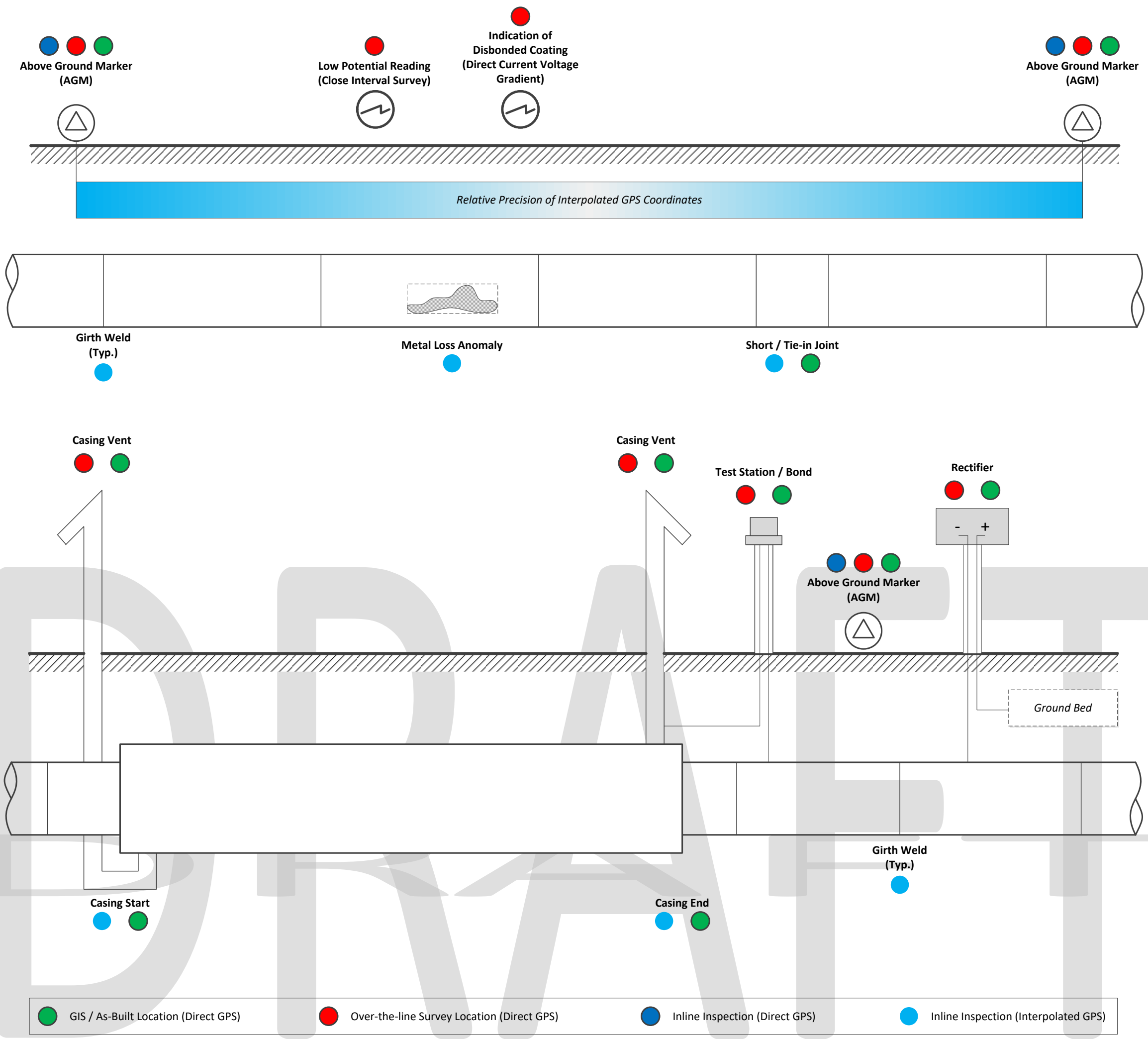

Figure 2—Examples of Common Feature Locations

16 Operational Data

When assessing threat mechanisms, it is important to delineate historical, current, and future operational conditions. In terms of understanding how the current populations of defects came to be, historical data is key. Realizing that how a line was operated decades ago may aid in the understanding of ~~defects~~ anomalies that are discovered much later (e.g. high pH SCC initiated under historical CP and temperature levels that are now environmentally dormant, though the crack continues to grow through fatigue). ~~In regards to~~In regard to pressure cycling, in-depth guidance on its data management and utilization in integrity assessment is provided within API RP 1176.

~~2 Reporting and Data Mining~~

~~2.1 General~~

~~Different types of data may be required for different types of integrity and risk analysis. The Integrity Management Program (IMP) may determine whether the data can be gathered from existing sources/databases or whether there is a need to collect new information through other means. When using existing data, it is important to know how the data was collected so that the limitations of the generalizability of results may be determined and the proper analyses may be performed. Annex B provides a representative listing of data elements typically used within the integrity management process.~~

~~2.2 Data Integration/Analysis~~

~~2.2.1 Growth Analysis~~

~~There are multiple ways for an operator to complete a growth analysis. The operator may choose from, but is not limited to, the following growth analysis types:~~

- ~~a predicted growth rate assigned to the entire pipeline segment,~~
- ~~a predicted growth rate assigned on a joint-by-joint basis,~~
- ~~a predicted growth rate based on a localized mechanism (e.g. shielding field joint coating or crack growth from pressure cycling), or~~
- ~~a comparison of predicted anomalies from subsequent inspections (cluster-to-cluster, pit-to-pit, or colony-to-colony).~~

~~2.2.2 Risk Analysis~~

~~Risk analysis is the process by which the operator evaluates pipeline and facility risk. To determine risk, the operator may evaluate both the probability of an event or condition that leads to a release and the consequences of that release. The risk results are leveraged to identify the opportunity and applicability of additional prevention and mitigation measures. The risk evaluation process includes, but is not limited to, the following components:~~

~~annual data acquisition;~~

~~baseline CP survey,~~

~~annual CP survey data,~~

~~rectifier and bond readings,~~

~~casing assessments,~~

~~close interval survey,~~

~~coating assessment survey,~~

~~ACVG,~~

~~DCVG,~~

~~in-line inspection survey data,~~

~~one call and aerial patrol reports,~~

~~HCA evaluation,~~

~~leak surveys, and~~

~~growth rates, including site-specific considerations (e.g. shielding field joint coating);~~

~~understanding data quality;~~

~~risk analysis execution;~~

~~risk results review and validation;~~

~~risk algorithm reviews; and~~

~~facility risk assessment.~~

~~2.3 Data Integration and Analysis Output~~

~~Data integration and analysis output includes the following:~~

- ~~data validation and correlation,~~
- ~~nonregulatory criteria digs,~~

- ~~determination of monitoring requirements,~~
- ~~determination of preventive and mitigative measures,~~
- ~~determination of reassessment method, and~~
- ~~determination of reassessment schedule.~~

17 ~~Integrity~~ Performance Metrics

Data-centered metrics address the quality of the inputs into integrity decisions, as opposed to the quality of the decisions or their execution. In the context of data management and integration, performance measures should be developed in consideration of the dimensions of data quality (Section 5), focused on what would materially impact integrity decisions (i.e. not all dimensions would necessarily merit associated metrics). Similarly, not all metrics benefit from performance targets; in some cases, an operator looks for variations from historical norms as opposed to absolute values. Metrics should measure what is relevant and meaningful as opposed to what is convenient.

Annex A
(informative)
Data Integration and Interpretation Report

A.1 Purpose

This survey and the reporting of its results was intended to document and consolidate the methodologies and processes used by API member companies to spatially integrate and normalize their data to support the application of comparative techniques used in interpreting the various data sets, with a focus on ILI data. These processes require careful consideration by operators regarding their application, as the brevity of responses contained here may not sufficiently reflect all relevant assumptions underlying its applicability.

A.2 Structure of the Data

The following is a list of the various data fields with a description of the intended contents.

Field	**Description**
Name	The name that the operator assigns to the process should be in consideration of the feature type(s) and the purpose of the process.
Data sources	This is a listing of the primary data types used in improving the interpretation of assessment data.
Specific attributes used	This is a listing of the specific attributes of the data types that are utilized.
Sensitivity to spatial alignment	This is an expression, where available, of the opportunity for spatial misalignment of the data used in the process and the tolerance of the analysis to spatial error. Where the operator is unsure of this field, simply enter UNKNOWN.
Criteria	This is a succinct account of the criteria that is applied to interpret the data.
Interpretive methodology	This is an explanation of how the process is applied to the interpretation of the assessment data.
QC methodology	This is an explanation of how the process is applied to the quality control of the assessment data.

A.3 Implementation and Results

Contributions to the listing were solicited in two iterations over a two-year period. Section A.4 provides a list of processes for consideration regarding additional means of leveraging and interpreting ILI data, as well as elevated engagement of the ILI vendor.

Aside from any immediate value the reference list may provide, it is envisioned that this format could be used as a framework for facilitating ongoing consolidation and redistribution of industry practices.

In the process of summarizing the results to a list of data integration processes for consideration by pipeline operators, the responses were edited in some cases to improve clarity and minimize redundancy. Variations in nomenclature still remain as an artifact of having numerous individuals and companies contribute.

Beyond the material listed in Table A.1, two broadly used QC processes are:

— Providing the NDE (excavation) results to the vendor so that the ILI assessment can be refined based on field data.

— Performing signal-to-signal analysis across different ILI runs ~~in order to~~to derive growth rates.

A.4 Threat Matrix and Interpretive Methodologies

Table A.1 provides a matrix of threats matched with relevant interpretive and QC methodologies.

Table A.1—Threat Matrix and Interpretive/QC Methodologies

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
1	Any	Threat integration	ILI tool data (deformation, magnetic flux leakage [MFL], CMFL, ultrasonic metal loss [ML], and ultrasonic crack)	All types of defects from all types of ILI data	5t × 5t	Defects from all types of ILI data	Threats are categorized as internal ML, external ML, cracking, SCC, geometry, other (laminations, inclusions, manufacturing defects, etc.). Where two or more threats overlap spatially, they are carefully analyzed. This analysis may result in an excavation.	NDE results are reviewed for verification.
2	Any	Failure pressure anomalies	Pipeline maps, GIS, operational data	Pipeline elevation data	N/A	Line elevation deviates >100 ft	Elevation data is integrated into the ILI vendor's report for all anomalies along the pipeline. After receiving the vendor report, a "local" MOP is calculated using elevation and the most conservative product weight for every item on the feature list. The estimated repair factor (ERF) is then recalculated for all anomalies between 15 % and 80 %. Vendor does not adjust ERF for elevation.	A review of the vendor's calculated failure pressures is accomplished prior to importing elevation data. This step assures the ILI vendor used the proper evaluation pressures and parameters in preparing the submitted vendor report.
3	Any	Appurtenance reconciliation	Geometry or metal loss ILI	Features list	N/A	Appurtenance	A tap, stopple, tee, sleeve, patch, weld plus end, valve, flange, or other pipeline attachment which was unknown or installed with unapproved or unknown installation methods. Compare to GIS data to determine if the appurtenance is known and if it is located within a facility. Evaluate for removal if unnecessary on the system.	N/A

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
4	Any	A change since the previous assessment	Geometry/metal loss tool	Features list	N/A	An anomaly, predicted to have changed in depth, length, width, orientation, or any injurious manner, from the previous assessment	An anomaly, predicted to have changed in depth, length, width, orientation, or any injurious manner from the previous assessment. Supplied to tool vendor to determine if there is growth since last assessment.	

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
5	Any	All ILI anomalies—sensor loss	ILI tool data (deformation or MFL, or both)	Current in-line inspection tool data	N/A—integral to ILI data	Per vendor's specification	Sensor loss occurs when a sensor is damaged/inoperative and does not function properly through portions of, or the entirety of, an in-line inspection tool run. The number of sensors on an individual ILI tool varies based upon tool size and ILI vendor. Sensor loss can affect the in-line inspection tool's ability to correctly identify and size all anomalies per specifications. Variations: The vendor must be able to meet the company-specified vendor reporting requirements, including meeting detection thresholds. One possible approach is to implement a vendor-reporting requirement that references the pipeline operators forum and ensures that the pipeline segment has been assessed. Run failure criteria: <95 % coverage, if two or more adjacent sensors fail or if multiple runs cannot be combined to reach adequate coverage.	In the event of sensor loss, a data quality certification letter facilitates a clear determination on whether the in-line inspection vendor is still able to correctly detect (i.e. minimum anomaly dimensions detectable with given sensor loss), identify, and size all anomalies in accordance with their published detection and sizing accuracy. Included in the letter would be a summary of the number of sensors damaged/inoperative and the impact on overall sensor coverage.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
6	Any	Speed excursions	Tool spec	ODO resolved speed in ft/sec	N/A—integral to ILI data	Per vendor's specification	Out-of-range speeds (typically overspeeds) are primarily associated with gas lines (incompressible liquid column mitigates the occurrence). Different tool technologies have different levels of sensitivity to speed excursions, and the effect can negatively impact POD, probability of identification (POI), and sizing.	Extrapolation of the results from correlation excavations needs to be in consideration of the tool speed at the correlation sites relative to the remainder of the line.
7	Any	Circumferential additional metal	Extra metal	Current in-line inspection tool data	N/A	Circumferential additional metal (gain) not related to previous repair or casing	ILI metal (gain) features, particularly with a circumferential extent, that are not otherwise accounted for by a casing or previous repair.	Cross examination against other sources utilizing GIS software. If metal (gain) remains unaccounted for, further investigation should be considered.
8	Any	Girth weld quality	Environmental hazard data	Pipeline maps, seismic surveys, etc.		Anomalies potentially exposed to environmental hazards	Girth welds with poor quality should be identified and reinforced or replaced if located in areas subject to ground movement, such as earthquake prone areas, near bodies of water likely to erode cover away from the pipeline, or at locations where the pipeline is exposed or suspended.	Additional anomalies could be added to the evaluation list.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
9	Any	Longitudinal seam reconciliation	Geometry or metal loss ILI	ILI log/raw data	N/A	Longitudinal seam (Y/N)	Review ILI raw data for indication of longitudinal seam or seamless pipe. Compare results to GIS and maps and records and update as needed. If previously unknown long-seam is confirmed, evaluate for long-seam threats.	The vintage of the pipe would be a key determinant when weighing the potential manufacturing threat associated with the long seam.
10	Any	All ILI anomalies—ILI tool correlation	ILI tool data (metal loss or deformation, or both)	ILI data (as-called) and remediation results (as-found)		Per vendor spec	Correlation of ILI tool data is conducted to determine tool accuracy for each ILI run by comparing actual anomaly characteristics (as found) to the predicted ILI data (as called). By correlating data for each ILI run, you can account for individual tool performance, the specified tolerance, and other conditions specific to a particular pipeline segment inspection. Graphical representation (unity plots) of anomalies is employed to help identify trends in predicted versus actual anomalies for each tool run.	If correlation results demonstrate that the data is not within the stated tool accuracy specifications, a determination regarding additional anomaly evaluations may require the regrading of data based on correlation results or continued evaluation of the assessment data based on the calculated tool accuracy and confidence level.
11	Cracking	Distance from U/S pump stations	ILI	Pump station location	N/A	Greater of 10 % of pump-to-pump segment, or 5 miles, Downstream of pump station	Focused assessment of crack ILI features. Utilize additional criteria for dig selection to account for increased potential for feature growth.	NDE results are reviewed for verification.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
12	Cracking	Girth weld cracking	MFL ILI data	Identified girth weld flaws	YES	Review of MFL and IMU ILI data to identify any areas requiring further assessment.	Reported girth weld is reviewed with regards to available strain data to determine if they are located in areas of measured strain based on IMU data. Axial strain may provide a growth mechanism for girth weld flaws.	ILI data reviewed for potential field excavation and repair.
13	Cracking	Cracks with metal loss	Two ILI data sets	Feature list location	3t × 3t	Looking for cracks that may be interacting with metal loss	Ultrasonic shear wave ILI does not detect or report metal loss. This limitation can be overcome by integrating the shear wave ultrasonic list of cracking features with the metal loss feature list of another suitable ILI technology, and reviewing for interaction (i.e. spatial proximity or coincidence) of cracks with corrosion.	Depth and remaining strength may be affected by the interaction of defects.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
14	Metal loss	Casing short	Metal loss assessment	Metal loss feature	N/A	A metal loss anomaly (external) to have greater than 20 % wall loss inside a casing	A metal loss anomaly (external) to have greater than 50 % wall loss inside a casing. Information reviewed to determine if further investigation or mitigation of the casing is required. Variations: Anomalies are evaluated with metal loss > 40 % in a casing. Metal loss in casing showing growth from prior ILI reviewed to determine if further investigation or mitigation of the casing is required.	N/A
15	Metal loss	Metal loss at foreign crossing	Metal loss ILI	Features list	±100 ft of foreign crossing	Metal loss	Metal loss within 100 ft of a foreign crossing may be an indication of third party damage. Locate anomaly and crossing in the field, and if the metal loss is within 10 ft, investigate. Variations: Anomalies are evaluated if within 50 ft of a casing or 120 ft of a foreign line crossing. Qualified with a depth criterion of ≥60 %. 50 ft interaction criteria for crossing of another pipeline.	N/A

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
16	Metal loss	Active corrosion	CP	Potential	Closer to 0.00V than -0.850V	Metal loss	A metal loss anomaly predicted by the metal loss tool to have greater than 20 % wall loss in an area with cathodic potentials closer to 0.0V than -0.850V. Variations: Any metal loss showing growth from prior ILI and in a low potential area is flagged to be addressed.	
17	Metal loss	Touching/close metal object suspect corrosion	Metal loss tool	Touching/close metal object	N/A	Touching/close metal object	A touching metal object or close metal object predicted by the metal loss tool to be located in an area with cathodic potentials closer to 0.0V than -0.850V. Variations: If any close metal object is within the same, or an adjacent, joint of pipe that contains another anomaly to be investigated, then the close metal object should be evaluated. Gains near low potential areas are investigated.	
18	Metal loss	Touching/close metal object suspect corrosion near foreign crossing	Metal loss tool	Touching/close metal object	N/A	±100 ft of foreign crossing	A touching metal object or close metal object predicted by the metal loss tool to be located within 100 ft of a foreign pipeline crossing. The foreign pipeline must be marked in the field and be within 10 ft of the staked touching metal object.	

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
19	Metal loss	Metal loss greater than 20 % of nominal wall located at a touching metal object	Metal loss tool	Touching metal object	±5 ft of touching metal object	Touching metal object within ±5 ft of touching metal object	A metal loss anomaly predicted by the metal loss tool to have greater than 20% wall loss within 5 ft of a touching metal object. Variations: Correlated new or growing metal loss is checked for nearby causes such as gains.	
20	Metal loss	Excessive metal loss in heavy wall pipe	Metal loss tool	Metal loss data	N/A	Metal loss anomaly predicted to be greater than 50 % wall loss in heavy wall pipe	A metal loss anomaly predicted to be greater than 50 % wall loss found in piping with a nominal wall thickness at least 2 nominal sizes larger than the smallest nominal wall thickness.	
21	Metal loss	Metal loss greater than 20 % of nominal wall located near girth welds in fusion-bonded epoxy (FBE) coated pipe	Metal loss tool	Metal loss data	±6 in.	A metal loss anomaly (external) predicted to be greater than 20 % wall loss of the pipe body within 6 in. of a weld	A metal loss anomaly (external) predicted to be greater than 20 % wall loss of the pipe body within 6 in. of a weld indicates possible shielding coating. Variations: Correlated growing metal loss within 1 in. of weld is addressed.	
22	Metal loss	Metal loss greater than 20 % on nominal wall located in the pipe body in FBE coated pipe	Metal loss tool	Metal loss data	N/A	A metal loss anomaly (external) predicted to be greater than 20 % wall loss of the pipe body on FBE coated pipe	A metal loss anomaly (external) predicted to be greater than 20 % wall loss of the pipe body on FBE coated pipe indicates possible shielding repair coating.	
23	Metal loss	Anomaly within close proximity of a target item	Metal loss tool	Metal loss	±5 ft	An anomaly predicted to be within 5 ft of a targeted item	An anomaly predicted to be within 5 ft of another investigation.	

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
24	Metal loss	Coating damage	Close interval surveys	On or off	±50 ft	Depression not meeting company criteria	Excluding foreign crossing interference, localized depressions in the CP (be it on or off) would be indicative of a significant coating holiday (i.e. current drain). Assuming the presence of a nonshielding coating, this is a potential validation parameter for the presence of active external corrosion. This is dependent on information known about existing coating, bare pipe areas, etc.	N/A
25	Metal loss	Internal metal loss—data review	Corrosion coupon/probes data, operational data, product history, frequency of operation, use of inhibitors, validation sites, ILI comparisons	Data sources integrated with ILI data		Compare reported internal metal loss with known information	ILI-reported internal metal loss is reviewed against past reports (if available). The potential for growth is also determined by reviewing the data sources to see if there have been verifiable calculated growth rates. Periodic UT scans of validation sites can be used to determine if there is actual growth or if the "growth" is due to tool deviation where coupons, history, etc., do not indicate growth.	As-found data is forwarded to ILI vendors for fine tuning of the ILI results on internal metal loss calls.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
26	Metal loss	Active corrosion	Close Interval Surveys	Off or polarization shift	±50 ft	Per NACE SP0169	Assuming the presence of a nonshielding coating, and ignoring geometry effects, this is a direct measure of the polarization level of the pipe (assumed to be at the defect) and can be used to evaluate active vs. non-active corrosion. This technique is particularly valuable in terms of older lines where the CP has been significantly remediated or upgraded recently. This impacts growth-based modeling for reinspection intervals.	N/A
27	Metal loss	Complex corrosion	Metal loss tool	Metal loss boxes	N/A	Group all clusters within a specified circumferential extent (e.g. 2 hr span) position	Identify large groups of axially aligned anomalies (i.e. at common clock position). Complete list of groups based on the 2 hr span interaction with and a sublist of those groups with a peak depth ≥50 % and a length greater than 6 in. Variations: Pits are grouped based on interaction rule: 1 in. axial and 6t circumferential.	Groups provided to tool vendor for a secondary review of the feature interaction.
28	Metal loss	Complex corrosion	Metal loss tool	Metal loss boxes	N/A	Clusters that have three or more ML boxes with depth ≥50 %, within 3t × 3t of each other	Identify sub-clusters of metal loss boxes with depth ≥50 % to see if there is overlapping signal or underlying metal loss signal response. Variations: Pits are grouped based on interaction rule: 1 in. axial and 6t circumferential.	Clusters provided to tool vendor to manually verify clustering and failure pressure, or sizing needs revision.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
29	Metal loss	Complex corrosion	Metal loss tool	Metal loss boxes	N/A	Groups of 6t × 6t grouping with failed pressure ratio (FPR) ≤1.25	Identify potentially more severe anomalies (i.e. determine if there are any missed metal loss boxes that would join existing clusters). Variations: Pits are grouped based on interaction rule: 1 in. axial and 6t circumferential.	Groups provided to tool vendor for review to see if bridging ML box was missed.
30	Metal loss	External metal loss—coating review	CIS data, historic drawings, documents, and photos	Pipeline stationing of reconditioned areas	Some errors integrating field measured PL station numbers to station number interpolated through GIS mapping	Compare CIS measurements against anticipated coatings based on drawings and historic data	Review CIS data and compare to boundaries of anticipated coated, painted, or potentially bare pipe. This gives a better understanding of why some CP measures may be lower than others. Assists in determining if pipe originally laid bare has been recoated as part of reconditioning projects. Reviews of past integrity digs in the area can also be used to verify overall coating condition.	Reviews of ILI data may also show signs of reconditioning, such as puddle welds, patches, sleeves, etc. Historically, joints that were reconditioned were also coated upon completion of the reconditioning work. Intact and well-bonded coating at external corrosion features excludes these features from growth analysis. In joints where coating is noted to be well bonded and active corrosion is not likely, ILI data comparisons are used to assess report deviations from run to run.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
31	Metal loss	Metal loss validation of past repairs	ILI data, repair records	Reported metal losses under composite repairs	N/A	Pre-remediation measurement vs. current measurement.	The ILI vendors are instructed to report metal losses beneath composite repairs. Past ILI data, repair locations, and sizings are provided to the vendors for integration into the ILI reports. The vendor is to also use the known data to assist applying their sizing algorithms. Other known sizings (recoated anomalies) are reviewed to validate accuracy once the vendor data is received. This report validation is dependent on the presence of past findings.	This process assists in determining the ability of the ILI vendor to accurately size anomalies in the ILI reports. It also speeds up the time needed to validate a new ILI report since numerous new digs are not necessarily required.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
32	Metal loss	Corrosion growth	ILI metal loss	Metal loss features from multiple ILI runs	Joint alignment across the various ILI runs	Variances in max. depth, number, and volume of metal loss with a joint	This process leverages the definitive method of weld alignment to facilitate a course run-to-run comparison to highlight joints that merit additional scrutiny in terms of corrosion growth or feature characterization. The use of the volume of metal loss is a means to account for differing interaction rules that result in artificial variances in anomaly populations. Additional caution needs to be exercised where there are potentially highly variable corrosion growth rates within a single joint (e.g. MIC). Variations: For dig programs with suspected excessive corrosion growth, ensure the next assessment is performed using the same technology from the same vendor to accurately compare any metal loss growth, thus eliminating tool tolerance between different vendors with different tools. Calculate and plot joint corrosion volume. Identify anomalies for possible investigation where the maximum depth has increased by more than twice the tool tolerance.	Internal and external metal loss handled separately, but then compared to identify ID/OD mischaracterization.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
33	Metal loss	Metal loss in proximity of long seam	Metal loss ILI tool	Metal loss and deformation anomalies from previous tool runs	N/A	All anomalies	Existing anomalies are reviewed when new physical information obtained from subsequent tool runs is available.	Compare previous tool run data with current ILI data to identify if anomalies can be reclassified since the previous assessment. For example, if the current tool run identifies pipe seam orientation (when it was not known previously), anomalies are reexamined to determine if anomalies can be reclassified (e.g. a previously identified dent could be reclassified as a dent on a long seam).

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
34	Metal loss	Life cycle corrosion analysis	Metal loss ILI tool	Metal loss data	Joint alignment across the various ILI runs, engineering stationing of anomalies and other data streams	All anomalies	Graphical alignment of the following data by engineering stationing: a) ILI anomaly information as follows: 1) Individual anomaly depth (multiple runs identified with different colors) 2) Cumulative corrosion normalized to 1 over segment length b) Previous repair information	The analysis is used to seek areas where corrosion damage (that does not require repair based on regulatory or company criteria) appears to be increasing in depth, extent, or density, or where existing damage is NOT increasing in depth, extent, or density. It can be used to identify areas of suspect shielding coatings, coating damage/failure, and to prioritize areas for addition of cathodic protection, enhanced dig programs, reconditioning, or replacement.
35	Metal loss	Metal loss anomaly dimension	Metal loss ILI tool	Metal loss data		ML features that are greater than 5× in length than width	Perform a comparison of ILI data to other corrosion anomalies at the same o'clock position on the joint that might be an indication of selective seam corrosion, especially if it is in the bottom half of the pipeline orientation.	Could add anomalies to be evaluated in consideration of the possibility of selective seam corrosion.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
36	Metal loss	Alternating current (A/C) corrosion from HVAC power lines	ILI and PODS close interval survey, A/C survey, corrosion coupon survey for current density calculations	Metal loss from multiple ILI compared to A/C power corridors		Looking for change in metal loss in proximity to HVAC power lines, high A/C volts, and current density	Pipeline sections entering, leaving, and crossing at angles to HVAC power corridors are at a higher risk of increased corrosion rates, especially on FBE coated lines or coatings with high dielectric strength.	Use close interval survey data, A/C survey, corrosion coupons, and ILI metal loss data to determine if further A/C modeling is necessary.
37	Metal loss	Internal metal loss—data review	ILI, centerline, and operational data	Metal loss feature density, elevation, flow rate, corrosivity, pigging frequency, and chemical treatments	Joint alignment across the various ILI runs	Internal metal loss located in low areas	Review concentration of internal metal loss features in consideration of the supporting mechanism. This would typically be in close proximity to low lying areas, but contributing factors would be laminar flow and product corrosivity as well as mitigating measures such as cleaning runs and chemical treatment.	
38	Metal loss	External metal loss	ILI and CIS	Metal loss density and depth and CP on/off	Joint alignment across the various ILI runs	Metal loss change in areas of lower potentials	Review areas of increased corrosion activity that are in close proximity to lower potential levels indicated on the CIS although they may still meet criteria.	

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
39	Metal loss	External metal loss	ILI data, hydrotest data, repair records, CP data, leak history, pipe data, coating data, MAOP data, foreign line crossings	ILI features, pipe-to-soil potentials, close interval surveys, condition of coating, previous reconditioning/repairs, corrosion rates, soil conditions	±50 ft	Significant growth between ILI tool runs, P/S potentials below –850 mV, disbonded or shielded coating areas, corrosion preferential to a seam or girth weld	External ML can be reviewed in combination with other data such that active corrosion could meet repair criteria prior to the next scheduled in-line inspection.	ILI data is overlaid with other corrosion data (P/S surveys and CIS data) to look for localized hot spots and areas where corrosion protection systems may need enhancements. Coating data and historical excavation data are reviewed to see if an area may need reconditioning to arrest active corrosion.
40	Metal loss	Internal metal loss	ILI data, hydrotest data, repair records, product specifications, pigging return corrosivity tests, corrosion coupon tests, corrosion inhibitor records, leak history, pipe data, MAOP data	ILI features, previous reconditioning/repairs, corrosion rates, pipe elevation data	±50 ft	Significant growth between ILI tool runs, pipe-to-soil potentials below –850 mV, disbonded or shielded coating areas, corrosion preferential to a seam or girth weld	Internal ML can be reviewed in combination with other data such that active corrosion could meet repair criteria prior to the next scheduled in-line inspection.	ILI data is overlaid with other data (low-elevation spots, areas of likely water hold up, seam orientation, girth weld proximity) to look for localized hot spots and areas where internal corrosion protection systems may need enhancements (more frequent maintenance pigging, different types of cleaning pigs, corrosion inhibitor enhancements, etc.).

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
41	Metal loss	External metal loss—in a casing	ILI data, hydrotest data, repair records, CP data, leak history, pipe data, coating data, MAOP data, casing data	External metal loss ILI features, casing records, pipe-to-soil and casing to soil potentials, and record of filling casing/carrier annulus with dielectric filler	within cased crossing	100 mV separation between pipe and casing to soil potentials	Validating that casing and carrier pipes are electrically isolated.	ILI data is overlaid with other data to look for localized hot spots and areas where external corrosion protection systems may need enhancements (casing filling).
42	Metal loss	Corrosion growth	ILI metal loss	Metal loss features from consecutive ILI	5t × 5t	Variance in max. depth and rupture pressure ratio	Three levels depending upon whether consecutive inspections are available. Level 1 (single ILI) presumed growth from historical experience or environmental data, level 2 (back-to-back ILI): feature matching at joint level, level 3 (signal matching): possible if back-to-back ILI are from the same vendor.	
43	Metal loss	External metal loss—FBE coated pipelines	ILI metal loss, AC/CIS/ACVG/DCVG survey	Feature listing	N/A	Metal loss features identified by ILI integrated with AC/CIS/ACVG/DCVG surveys to identify potential coating, CP, or AC issues	ILI metal loss features are overlaid with the survey data. Features are prioritized for excavations/verifications based on the depth and suspected interference from the field data. Additional scope is added to verify the corrosion mechanism and further mitigation methods are considered at other suspect locations. Remaining features are identified for continuous monitoring in subsequent inspections.	NDE results are reviewed for verification.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
44	Metal loss	Orientation graphs	ILI metal loss, elevation, station data, HCA, CP survey	Feature listing	Elevation data	Internal and external metal loss trending	The data from the different sources are plotted against the stationing data to identify any ~~particular trend~~trend in the external and internal metal loss distribution. Trending from subsequent inspections is also compared to see any significant change in trends from one inspection to other. The results of the analysis are used to identify and implement preventative measures.	N/A
45	Metal loss	Internal corrosion susceptibility	Flow rates and products characteristics	Historical operations	N/A	Develop Internal corrosion susceptibility threshold where additional monitoring or mitigation would be warranted	A semi-quantitative threat score is calculated using flow conditions and product characteristics. The results of the analysis are low, medium, or high susceptibility. Mitigation strategies are planned and implemented depending upon the susceptibility scores. The age and historical operations of the pipeline in conjunction with ILI data may trigger the mitigation or monitoring of the pipeline as well.	N/A
46	Metal loss	Internal corrosion mitigation effectiveness	ILI metal loss, orientation graphs, corrosion monitors	Back-to-back ILI corrosion growth rates	Elevation Data	Effectiveness of mitigation program: growth in depth or number of internal ml features.	The effectiveness of the mitigation program is judged by integrating and evaluating the data from different sources, including back-to-back inspections.	N/A

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
47	Metal loss	Internal corrosion susceptibility	ILI, IMU/construction records	Elevation	N/A	N/A	Elevation data and internal ML data are overlaid and analyzed. Particular attention is paid to overbends and underbends.	N/A
48	Metal loss	Back-to-back integration	ILI	Feature lists	Yes	Features matched at two different points in time or between two different types of metal loss inspections MFL/UT/CMFL	Metal loss feature lists are integrated with the previous inspections or other metal loss technologies to identify major discrepancies. These discrepancies are required to be reconciled and have identified tool errors/limitations/strengths, ILI processing errors, ILI analyst errors, and high corrosion growth rates.	All major discrepancies are reviewed internally and by the ILI vendor (as required) to ensure accuracy.
49	Metal loss	Air to ground interface corrosion	ILI	Bends		Corrosion falls just downstream of a bend, growth	Metal loss features downstream of, and in proximity to, a bend undergo additional scrutiny. It could be indicative of coating failure at ground/air interface.	
50	Metal loss	Metal loss change from external to internal	Current and prior ILI	Metal loss attribute		External (EXT) to Internal (INT) change, growth	The change from external to internal from one ILI to the next warrants further scrutiny as a possible through-wall event. True depth of pinhole size pit can escape the detection of tool.	

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
51	Metal loss	Metal loss—anomaly density	ILI metal loss	Number of metal loss anomalies per joint		All reported metal loss per type (internal, external) within a joint	Evaluating and plotting anomaly densities may provide indication of disbonded coating or identify higher priority evaluation areas. Integrating the anomaly density areas to CP readings and elevation profiles may identify causal factors. Utilizing anomaly depth categories (10 % – 19 %, 20 % – 29 %, etc.) is beneficial in identifying higher priority areas.	Remediation results can validate tool accuracy
52	Metal loss	Metal loss—casing evaluation	ILI metal loss and features	Metal loss and features located in a casing		Metal loss located in a casing that coincides with casing features in contact with the pipe	Evaluate metal loss that coincides with a feature in a casing (metal casing spacer that is identified in the ILI data or at the end of the casing indicating interaction with a link seal or casing boot). Interaction of pipe with casing feature may affect pipe coating and the discrimination or accuracy of the ILI data. Casing features not identified in the ILI run may be detected by the pattern of metal loss. Evaluation of metal loss from subsequent runs may be used to determine growth of metal loss features.	Remediation results can validate tool accuracy

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
53	Metal loss	Internal metal loss—ILI data review	Metal loss tool	Internal metal loss data	N/A	All internal metal loss	In regards to gas service, assess the density of internal metal loss indications in the 4- to 7-o'clock position over a standard unit distance. Although this threshold would vary between lines, a general threshold rule for elevated scrutiny is 10 per 80 ft.	Data of concern are reviewed by engineering, verified by tool vendor if needed and used for integration with other IC data
54	Stress corrosion cracking	Stress corrosion cracking	ILI data, hydrotest data, operating stress, operating temperature, year of pipe manufacture, proximity to compressor or pump station, type and condition of coating, leak history, excavation data	Pipelines operating above 60 % of SMYS, above 100 °F, within 20 miles of a compressor or pump station, more than 10 years old, coated with other than FBE, are more likely to develop SCC.	N/A	If conditions are more likely that SCC can develop, additional activities are added during routine inspections at likely locations of external corrosion or localized stress in order to detect SCC.	If “noteworthy” SCC is ever experienced on a pipeline segment, then that segment is subjected to additional integrity assessments, such as with crack detection ILI tools (capable of detecting SCC) or hydrotesting to detect any ongoing SCC.	ILI data is overlaid with other data (external corrosion, dents, field bends, CP data) to look for common conditions where undetected SCC may be probable.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
55	Excavation damage	Mechanical damage—dents in close proximity	ILI dents	Deformations within an ILI run	N/A	Axially aligned, on top side, within 1 ft of one another	ILI data is reviewed for potential dents in close proximity. The data is used to assist in identifying areas with potential gouges/stress concentrators within dents that may not have been categorized by the ILI vendors. Compare current ILI data sets to past ILI data sets to determine if the indications have appeared since the previous ILI which could indicate "new" mechanical damage. This comparison can be dependent on the past reporting criteria or ability to view raw signal data. Locations of possible damage are also mapped to determine if they occur at "suspect" areas such as road crossings, utility crossings/corridors, farm lands, etc.	The results of assessments are fed back to the MFL vendors to have the raw data reassessed to see if further categorizations could have been made, or if the tool failed to see the gouges/stressors, within dents.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
56	Excavation damage	Dent with metal loss screening on reconditioned lines	Historic drawings, reconditioning specs, ILI data	Dent features within ILI data on reconditioned pipe and as-found dig findings	N/A	Examine ILI data for signs of previous reconditioning repairs	Review current ILI data versus past ILI data to determine if reported deformations are “new” since the previous ILI. Review vendor data to determine if the pipe joint has been previously reconditioned (presence of puddle welds, patches, sleeves, etc.). Compare this data and the reported metal losses to the alignment drawings to understand if the line had corrosion prior to the installation of coating or CP, or both. Review findings at excavations and note if vendor-reported "dents with metal loss" were actually due to mechanical damage, a corrosion cell specifically "attacking" a dent due to coating loss, or if it was minor corrosion coincidental to a dent.	Past and current findings are reviewed with MFL vendors. The intent is for the ILI vendors to utilize the data to assist in better categorizing mechanical dents w/ metal loss versus old reconditioned dents with minor coincidental corrosion for prioritization purposes.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
57	Excavation damage	Bottom side deformation	Dent feature from geometry assessment	Dent features within a single ILI	N/A	Axially aligned	Deformation located on the bottom of the pipeline (below 4- and 8- o'clock position) with a depth greater than 2 % of the nominal diameter (greater than 0.250 in. depth for a pipeline diameter less than nominal pipe size [NPS] 12). Variations: bottom dents <2 % (or 0.25 for <12 in. pipe) are correlated to prior runs and all are put on pending dig list.	Deformations missed by the ILI are fed back to the tool vendor to determine lack of reporting.
58	Excavation damage	Mechanical damage—deformation(s) within close proximity to pipeline crossings, roads, or farmland	ILI tool data (deformation and metal loss)	Current and previous ILI tool data	Placement of centerline within geospatial data	A topside dent that does not meet repair criteria identified in the current ILI tool run, that was not identified in the previous ILI tool run as a dent (i.e. a “newly reported” dent indication), which is located in close proximity to a pipeline crossing, road, or farmland	Identifying “newly reported” dent indications that do not meet repair criteria (i.e. does not have indication of metal loss because a dent with metal loss would meet repair criteria) which are located in areas with the potential to contain road construction/maintenance, pipeline construction/maintenance, or farming activities, can be more successful at the identification of metal loss within dents than simply depending on ILI tool and vendor capabilities.	If a dent with metal loss is found, findings including field measurements are communicated to the ILI vendor. The ILI vendor should be requested to perform a root cause analysis for the missed calls. Lessons learned (if any) should be applied to improve the analysis processes.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
59	Excavation damage	Comparison on the number of deformation reported on two successive ILI runs	Deformation	Deformation indications from multiple ILI run	N/A	New topside dents >1 %	Review of new topside dents >1 % when comparing current deformation results to previous deformation results. May be an indication of excavation damage or damage resulting from previous maintenance work performed on or nearby the top of pipe.	If such conditions exist, dig will be performed, check with one call for any reported events, etc.
60	Excavation damage	Depth of cover and coating type	Pipeline maps and surveys	Burial depth and coating type data		Depth less than 12 in. anywhere; greater than or equal to 12 in. and less than 24 in. in road residential areas, ROWs, or cultivated fields	Perform a depth-of-cover survey to identify shallow burial depths and coating type to determine higher risk of third party damage	Could possibly add additional anomalies to be evaluated. Concrete coating or ditch shields may be identified in coating type which could explain shallower than normal depths.
61	Excavation damage	Failure of topside dents	ILI deformation tool	Current in-line inspection tool data		All top-sided dents that were not evaluated during prior dig programs located 10 ft from known foreign line crossings	Perform surface evaluation of all top-sided deformations not evaluated in previous dig programs to determine if third party damage would be likely. Aggressiveness of the pressure cycles should be considered when decisions are made whether or not to excavate to evaluate the anomaly.	Additional anomalies could be added to the evaluation list.

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
62	Excavation damage	Dents at foreign crossing	Dent ILI and PODS	Features list	±100 ft of foreign crossing	Dents	Dents within 100 ft of a foreign crossing may be an indication of ~~third party~~third-party damage. Review orientation of the pipe crossing and compare to dent orientation. Ground truth and confirm locations of the anomaly and crossing.	N/A
63	Excavation damage	Dents and depth of cover	ILI data, depth of cover, and one call density	Graphs	Topside dents per joint or orientation graph with depth of cover as a secondary axis.	Undug dents on top of pipe located in shallow cover in areas of high one call density may need to be investigated.	Topside dents located on shallow pipe may be indicative of dents with metal loss even if the ILI tool did not interpret the dent to have metal loss.	Ground truthing may be needed to verify location of dents and shallow pipe.
64	Excavation damage	Dents, dents with metal loss	ILI Data, repair records, depth-of-cover surveys, land surface use, one call, aerial patrols, CP data	Smooth top dents >1% of OD, any top dent with any indication of metal loss	±50 ft	< 2 ft DOC, dent repairs in area, cultivated fields, aerial patrols indicating surface activity, CP data indicating coating damage	Dent indications with other data that indicate probability of excavation damage would elevate the dent indications to likely excavation damage and be considered for possible excavation or additional preventive and mitigative activities, such as increased patrolling, additional signage, increased public awareness activities, possible lowering of the pipeline in place, and contact with land users.	Site visits and alignment of data that places possible excavation damage indications in the same field as shallow DOC data, aerial patrols indicating ongoing surface activity, damaged coating, crossings, or one call activity in the area

ID	Threat	Description	Data Source	Specific Attributes Used	Sensitivity to Spatial Alignment	Criteria	Interpretive Methodology	QC Methodology
65	Excavation damage	Off-axis dent	Geometry ILI data	Geometry feature shape	N/A	Denotes whether or not the longitudinal axis of a geometry feature varies more than 15° from the longitudinal or transverse axis of the pipeline	Geometry features oriented off-axis can be an indication of mechanical damage resulting from line strikes. Features identified as off-axis are reviewed in additional detail to determine if additional assessment is required.	ILI data, location data are reviewed for potential additional assessment requirements.
66	Excavation damage	Multi-apex dent	Geometry ILI data	Geometry feature shape data	N/A	Denotes whether or not the geometry of a dent has a singular or multiple apex points	Multi-apex dents may have been an indication of complex or increased stress/strain. Features are reviewed in more detail to assess for the identification of stress concentrators reported by ILI data.	ILI data review
67	Weather and outside force	Global pipeline strain	ILI	Reported locations of strain	Yes	Reported areas of calculated strain based on IMU data are reviewed for potential mitigation	Areas of strain are monitored for change and to ensure that measured strain is within acceptable limits.	ILI data review is supplemented with ROW information to identify areas requiring mitigation or additional monitoring.
68	Construction threat	Wrinkle bend threats	ILI deformation and metal loss	Wrinkle bends with seam and anomalies	N/A	Wrinkle bends reflecting weld seam running through wrinkles, or indications of gouges or DMAs on wrinkles	Compare in ILI data tally the orientation of wrinkle bends to the orientation of long seam. Data search for possible ML on or within 3 in. of wrinkle.	For suspect features consider a more in-depth review by the ILI vendor and possible field investigation.

~~Annex B~~
~~(informative)~~

~~Representative Data Listing~~

~~The data collection process includes, but is not limited to, the following components collected together for pipe reference and data analysis:~~

~~B.1 Construction Records~~

~~a) GIS Data~~

~~1) Alignment Sheets~~

~~i) Foreign Line Crossings~~

~~2) As-builts~~

~~i) Coating Data~~

~~I) Joint Coating Specs~~

~~ii) Material Specs~~

~~3) X-Ray Records~~

~~4) Centerline GPS Survey~~

~~5) HCA Identification~~

~~b) Baseline Assessment~~

~~1) Hydro Records (Establish MOP),~~

~~2) Caliper.~~

~~B.2 Cathodic Protection~~

~~a) CP Installation Records,~~

~~b) Compliance Driven Assessments~~

~~1) Baseline Survey,~~

~~2) Annual Survey,~~

~~3) Rectifier/Bond Readings,~~

~~4) Casing Assessments,~~

~~5) Close Interval Survey,~~

~~6) Coating Assessment Survey,~~

~~i) ACVG,~~

~~ii) DCVG,~~

~~7) Other.~~

~~B.3 Hydrostatic Test (Reassessment)~~

~~a) Test Data~~

~~1) Pressure (MOP),~~

~~2) Failure Records,~~

~~3) Spike Test.~~

~~B.4 External Corrosion Direct Assessment (ECDA)~~

~~a) Pre-Assessment~~

~~b) Indirect Assessment~~

~~c) Direct Assessment~~

~~d) Post Assessment~~

~~B.5 In-line Inspection~~

~~a) Final Report~~

~~b) Dig Selection (Criteria)~~

~~c) Tool Correlation Plots (Dig Feedback)~~

~~d) Growth Analysis~~

~~e) Anomaly Density Plots~~

~~f) Direct Examination Documentation~~

~~g) Other~~

~~B.6 Risk~~

~~a) Risk Model Results~~

~~1) Risk Model Validation~~

~~i) ILI~~

~~ii) ECDA~~

~~iii) Dig Feedback~~

~~2) Dynamic Segmentation~~

~~i) HCA~~

~~3) Threat Analysis~~

~~i) Dig Feedback~~

~~4) Consequence Analysis~~

~~5) Historical Records~~

~~Annex C~~Annex B
(informative)

Pipeline Construction Data Collection Requirements

This Annex provides a distilled version of a specification that defines requirements for construction survey as-built data collection. The intent of this example process is to facilitate a complete, accurate and consistent data set that is available to all stakeholders in a timely manner (i.e. before line fill).

Following this approach, the corrected as-built dataset in consideration of Pipe Integrity (PI) feedback based on incremental and post backfill flat file deliverables would be the basis of the alignment sheets and final deliverable to PI.

~~C.1~~B.1 Deliverable process

GENERAL REQUIREMENTS

Staged Deliverables

Facilitation of a complete, accurate and consistent as-built data set in a timely manner will be achieved by creating a data deliverable that is incremented as the project advances and data become available. The incremental data deliverable interval is defined on a project specific basis and is defined in the Project Specific Data Implementation Plan document.

The staged deliverables are:

- Field Collected – incremental
- Field Collected – Post Backfill
- Attribute Augmented – as to whether the project or PI resolves this additional data and attribution will be determined on a project specific basis and documented in a Project Specific Data Implementation Plan.

The following data deliverables should be available prior to line fill.

- As-built Survey Data (unchained and chained)
- Supporting Data – caliper, cutouts (part of the final as-built data).

The Project Records Deliverables will typically follow after line fill.

The data provided for the Field Collected Incremental deliverables will contain the Construction 2D (IFC – Issued for Construction) chainage. A 3D chainage is not required for these deliverables.

The final as-built 3D Chainage will not be defined until the last increment of the deliverable at which time the as-built alignment sheets will be generated at the direction of the project.

All chainages are to be recorded in Imperial Units in the US and Metric Units in Canada, with a precision of three decimal places.

The Field Collected Post Backfill flat file deliverable will encompass the additional datasets that are scheduled to be collected after backfill has been completed; Top of Pipe (T.O.P) DOC, Fence lines, Signs, Markers, Testleads. All other data points with the exception of the T.O.P. DOC data can be included in the Field Collected Incremental deliverables, if available at that time or alternatively can be added to the Field Collected Post Backfill deliverable.

General Data Acceptance and Delivery Requirements

The incremental field collection datasets shall be delivered to the Liquid data steward in the specified flat file format at predetermined intervals during the project for timely review and feedback.

- Determination of the data delivery interval frequency will be unique to each project and relative to the overall size and scope of the project. At a minimum the data is expected to be delivered in multiple increments per construction spread.
- This data delivery distribution interval is to be determined by the Liquid Data Steward and Project representative and communicated to the Contractor and agreed upon before the start of the project.
- Any deviation to the data requirements will need to be documented and submitted to the data steward for approval and added as an acceptable data deliverable to the project; otherwise the data will be sent back to the contractor for corrective measures and resubmittal.
- The Liquid data steward shall administer any variances to the template and the associated datasets.
- As part of the final data deliverable; the Contractor will supply a Project Summary Report detailing the data quality control methodology, and statement of data accuracy.

~~C.2~~B.2 Field Collected Data

This dataset will be comprised of all information captured in the field by the construction survey vendor, except for Horizontal Directional Drills (HDD's) and fabricated assemblies. The integration of the HDD's, typically installed before the mainline survey, into the common format shall be included in this deliverable. In terms of fabricated assemblies along the path of the pipeline (e.g. elbow, valves, tees etc.), the minimum data that assures traceability of the components shall be captured (i.e. manufacturer, PO, and serial/heat/pipe number/tag number).

FIELD DATA ACCEPTANCE AND DELIVERY REQUIREMENTS

All relevant Survey Notes/Sketches, drawings and redlines are required to be submitted as part of the incremental data deliverables.

FIELD COLLECTED SPATIAL REFERENCING REQUIREMENTS

While the data may be originally collected in another data projection and datum; the data supplied in the flat file template must adhere to the spatial parameters specified below.

Coordinate format -shall be provided in Northing, Easting, Universal Transverse Mercator (UTM) Zone, Datum and Elevation. However the provision of the equivalent Latitude, Longitude coordinates would be appreciated.

i. UTM Northings/Eastings and UTM Zone
ii. Optional Geographic Coordinate System: Latitude and Longitude coordinates (X,Y) are to be provided in decimal degrees with a precision of 7 decimals.
iii. Datum: NAD83 UTM/WGS 84 Latitude and Longitude.
iv. Spheroid Model
v. Elevation (Z) values to be recorded in feet in the US; with a precision of 3 decimals.

GPS accuracy of the data must meet the Company's accuracy tolerances. The allowable relative positional accuracy for As-built Survey measurements is 0.16 feet (or 5 cm).

~~C.3~~B.3 Data Requirements

The required data elements and associated attribution would include:

BENDS/ELBOWS

- All Bends require sufficient survey points to define the bend mid points
- Required attribution includes: type of bend, bend direction and radius, horizontal and vertical degrees, Manufacturer, PO and Serial Number.

BUOYANCY CONTROL

- All Buoyancy Control records require sufficient survey points to define each individual weight point features and their associated 2D chainage. A linear event is to be added where applicable. A Linear event is defined by a spanning distance or a start and end location where by two or more point features of the same weight type are present.
- Required data attribution to be recorded includes the type of weight, and the count of individual weights contained within each linear weight section.

CASINGS

- All Casings are linear records and require sufficient survey points to define the start and end locations of each casing.
- Required data attribution includes: Grade, Insulator Type, Outside Diameter

COATING INFORMATION

- All changes in coating information must be tied to the corresponding weld records and populated only where the coating value changes.
- Required data attribution includes: Line Coating Type & Brand

CATHODIC PROTECTION

- Sufficient survey points are required to define the location of anodes, rectifiers and testleads
- Required data attribution for Testleads includes: TestleadID.

CROSSINGS

- All Crossings require sufficient survey points to define at a minimum, the centerline of the crossing. Additional survey points are required to define the Start and End locations of any Road, Railway, and water crossing.
- Required data attribution will vary by the crossing type.

HDD'S/BORE LOCATIONS

- Survey measurements and as-built information of the HDD pipeline section shall be obtained prior to pullback installation activities. Sufficient survey points shall be obtained at the HDD pipeline section entry and exit points to cross-reference pipeline as-built survey data and incorporate the HDD Contractor's drill logs and as-built data.
- Tie-in welds must be collected and recorded for both the entry and exit points of each Bore and HDD location, maintaining references to the initial survey Point IDs and Construction Chainages.
- Chainages must be recorded in ascending order with direction of flow.

PIPE INFORMATION

- All changes in pipe information at a minimum must be tied to the corresponding weld records and populated where the pipe value changes.
- Required data attribution includes: Up and Downstream Heat & Pipe Numbers, Manufacturer, Wall Thickness, Outside Diameter, Specification and grade.

PIPE PROTECTION

- All Pipe Protection records are linear and require sufficient survey points to define the type and start and end locations.
- The type is defined by code list in the data collection template.

VALVES/FITTINGS

- All valves and fittings must be located by survey points at the centerline of the features, and has to include the isolation valves on the launcher and receiver barrel assemblies.
- Required data attribution to be recorded includes, but not limited to:
  a) VALVES - Size, Type, Serial Number, and Manufacturer
  b) FITTINGS - Serial Number

WELDS

- All welds must be located by survey points; maintaining a unique spatial location (Northing, Easting) and 2D Chainage value, no duplicates will be acceptable.
- Weld Numbering will be generated by NDE and must adhere to the Weld numbering syntax the Pipeline Construction Specification
- Required data attribution to be recorded includes: GW Type & Process, Weld Date, Up and downstream Pipe, Joint, Heat, NDE Numbers (Double Joint Number).

~~C.4~~B.4 Attribution Augmented

This dataset will be comprised of ~~any and all~~ datasets that are required to achieve full traceability of any pipe, facility, asset or fitting that is traversed by an In-Line Inspection tool.

This data may not be accessible in the field at the time the survey data collection is performed. Certain data attributes may be captured during different phases of the project; nominal pipe wall can be captured during the field data survey while the elbow wall thickness data may have to be obtained from the fabrication spool drawings or MTR's.

The scope and allocation of this work is to be assessed by PI and the Project and defined well before the start of the new construction project and documented in a Project Specific Data Implementation Plan. This work scope can be completed in whole by either the Vendor, other project staff or by PI; or alternatively a combined effort by all parties to complete.

Examples of the required supporting documentation include but are not limited to:

- Pipe Mill Records (MTRs)
- Valve & Fitting – Fabrication Shop Records
- Facility Pipe and Spool Drawings
- Pipe Coating Reports (Above Ground) – Shop and Field
- Pipe Coating Reports (Below Ground) – Shop and Field (incl. Weld Coating, Tie-in Coating, Multi-Liquid Coating Inspections/Checklist, Fabrication)
- Weld – NDT Log

~~C.5~~B.5 As-Built

GENERAL REQUIREMENTS

i. A fully spanning as-built survey dataset for the project, acceptable to the data steward, shall be completed prior to line fill.
ii. The as-built survey data upon completion will be comprised of Pipeline Routes spanning Launcher to Receiver barrel.
iii. The generation of the alignment sheets deliverables are outside of this scope and will remain with the project team to oversee and manage.

PIPELINE ROUTE REQUIREMENTS – AS-BUILT

i. A Pipeline route is defined by a designated facility to facility delineation (typically at pump stations and/or barrel launch and receive sites). The start point of each pipeline route is defined as the reducer connection/weld to the Launcher Barrel, and ends at the reducer connection/weld to the Receiver Barrel; where all route measures are recorded in ascending order, coinciding with the direction of flow from start to end.

ii. Route 3D chainage is to be recorded in Imperial Units in the US and Metric Units within Canada with a precision of 3 decimal places.

- A Route will be bound by the starting and ending points as defined above and will consist of multiple Station Series, where each section chainage will re-zero.
- In cases where there is an absence of barrels, such as a non-piggable segment (ie: Interconnect); an agreement between the project and Pipeline Integrity will be required to define the pipeline route delineation prior to construction.
- Pump Station Suction and Discharge routes are not to be included in the mainline as-built dataset, but are to be provided in a separate tab with the Pump Station Name and Suction (S) /Discharge (D) clearly delineated. The common branch connection location is to be identified and included in both the Mainline and Pump Station Routes.

HYDROTEST RECORDS INCLUDING CUTOUTS

- The hydrotests must be aligned to their final start and end tie-in welds.

RECONCILIATION WITH ALIGNMENT SHEETS

- The finalized and approved as-built dataset will become the master dataset from which the alignment sheets will be generated from, where applicable. All subsequent edits in content shall occur in the master dataset which would cascade to the alignment sheets. A detailed update listing of changes shall accompany the updated master dataset.

~~C.6~~B.6 Supporting Data – (Post Construction Delivery)

CALIPER DATA

- The caliper feature listing is to be provided by the project and ~~must~~ should include a complete and continuous weld tally.

EXCAVATION DATA

- All excavations arising from the caliper ILI shall be tied back to a specific weld within the caliper listing and the as-built dataset

DIRECT CURRENT VOLTAGE GRADIENT (DCVG) DATA

- Survey used to identify pipeline coating holidays based upon a measured voltage gradient through the soil (quantified as a %IR). A DCVG survey ~~and~~ shall be conducted prior to the baseline assessment.

CHALLENGING CONSTRUCTION

- Identification of any challenging conditions encountered along the pipeline during construction must be documented and defined by a start and end location; and should be readily tied back to survey notes and any associated NCR documentation.
- Examples include: ~~Rock~~ rock ~~Ditch~~ditch, ~~Excessively~~ excessively ~~Wet~~wet or ~~/M~~muddy ~~Conditions~~conditions, and ~~Excessively~~ excessively ~~Cold~~ cold ~~Conditions~~conditions

~~C.7~~B.7 Project Record Deliverables

The following is the scope of documentation that is required from the project for the handover of the asset to operations. This listing should be used as a reference to identify and generate a comprehensive and robust project specific project turnover plan.

- Materials: Manifests

  - Bill of Lading Reports (Railway reports to trace pipe transportation and loading) (incl. Elbows and Fittings)

- Materials: Welding
  - Weld Log Book / Welding Binder (Senior Welder Acceptance)
  - Welding Inspections / Compliance Reports
  - Weld Procedure / Parameters
  - Welder's Qualification Certificates
  - Transition / Counterbore Reports
  - Mainline Welding Reports (incl. Parameters & Inspections) - (Pipelines only)
  - Poorboy Welding Reports (incl. Parameters & Inspections) - (Pipelines only)
  - Tie In Welding Reports (incl. Parameters & Inspections) - (Pipelines only)
  - Fabrication Records
- Materials: Corrosion Control
  - Pipe Coating Reports (Above Ground) – Shop and Field
  - Pipe Coating Reports (Below Ground) – Shop and Field (incl. Weld Coating, Tie-in Coating, Multi-Liquid Coating Inspections/Checklist, Fabrication)
  - Plant Applied Coating Inspection (External and internal coating Inspection, Holiday Tests, Jeeping)
  - Engineering & Construction Civil
  - Rock Blasting Report (if applicable)
  - Footing Inspection / Compaction Test Report - (Facilities Only)
- Engineering and Construction – Piping
  - Stress Analysis Report
- Engineering & Construction Planning
  - Design Basis Memorandum (DBM)
  - Project Execution Plan (PEP)
  - Project Variance for Construction Specs
  - Project Master Punchlist (Construction, Commissioning Punchlists)
- Pre-Commissioning and Commissioning
  - Commissioning - Data Books - (Facilities Only)
- Vendor Documentation
  - Vendor Equipment Manuals O&M (Facilities Only)
- Construction Drawings & Data

- Facility Pipe and Spool Drawings:
- Red Marked as-built Drawings
- CP Installation Records
- CP design and construction documents
- CP Surveys
- Test Lead Installation Records
- Crossing Reports and as-built drawings
- Launcher/Receiver Site Plans
- Schematics & Isometric Drawings, P&IDs, Facility Plot Plans including Pump Stations.
- Vendor and Subcontractor Supplied Drawings,
- As-built Survey Report
- Construction Alignment Sheets
- As-Built Alignment Sheets
- Survey Notes/sketches/field books
- Bending Reports
- Bore/HDD As-Built Profile drawings, Final survey tie-in locations
- Valve Schematic drawings

- Engineering & Construction Status Reporting
  - Lessons Learned Log "
  - Construction Daily Progress Reports/Activites (Crew Daily Reports)"
  - Photographs of (Fabrication/Construction/Installation) of pressure containment components"
  - Inspector Daily Reports
  - Backfill Reports
- Pipe Integrity - Materials: Non-Destructive Testing (NDT)
  - Radiograph Films / Ultrasonic Data (AUT)"
  - NDE Records Magnetic Particle Inspection Reports
  - Qualifications of the NDE Technicians
  - Radiographic Testing / Ultrasonic Reports
  - Weld Map Drawings
  - Weld - NDT Log
  - Audit Reports (From Materials Engineering)

- Pipeline Maintenance
    - Caliper In-line Inspection reports including a list of AGM Locations
    - Excavation report (Dents & Ovality Investigative Digs)
- Pipe Integrity - Materials: Quality Management
    - Pipe Mill listings (electronic version for all new ordered Pipe, ie. Excel or access)
    - Coating & Fabrication Mill listings
    - Pipe, Facility, Launcher/Receiver Material Test Reports and Mill Test Certificates
    - Pipe Production Inspection Reports (inspection done in the mill)
    - Purchase Orders
    - Non-conformance Reports (NCRs)
    - Soil profile logs from deep anode beds
- Hydrostatic Test Documentation
    - Construction Hydrotest Summary Records
    - Schematic drawing and sketch of Hydrotest sections with final tie-in welds identified (after test).
    - Test Head Documentation
    - Regulatory Reporting Leave to Open (LTO) Package Completed, Signed and Filed
- Consequence Modelling
    - All HCA polygons within 40 mile buffer (.gdb)
    - HCA, CPS, Flowpath GIS Files (.kmz, .gdb, .shp)
    - HCA tabular listing (excel file)
    - CPS tabular listing (excel file)
    - HCA-CPS cross reference listing (excel file)
    - HCA/CPS Final Report (.pdf)
    - Worst Case Discharge Volumes (excel file)
    - Worst Case Discharge Volume Reports (.pdf)
    - Worst Case Discharge Volume input parameters (excel file)

Bibliography

[1] The Data Warehousing Institute, information available at https://tdwi.org/home.aspx

[2] API White Paper, Uniform Standards for GPS Submittals for One Call Purposes, August 4, 2008

[3] NACE SP0169, *Control of External Corrosion on Underground or Submerged Metallic Piping Systems*