THE FUTURE OF PIPELINE INTEGRITY

Aaron Boettcher and Keith Chambless, Emerson, USA, discuss the evolution of digital technologies for pipeline integrity management.

Pipelines are a critical link in the oil and gas supply chain and are the safest mode of transportation to bring petroleum products to market. Despite this safety record, there have been multiple, high-profile safety incidents over the years resulting in product releases and, in some cases, loss of life. These incidents have led to an increased regulatory focus from governments and a heightened concern among the public about pipeline integrity and the environmental impacts of pipeline transportation. Most pipeline operators have integrity management programmes in place – and indeed many governments require it – but the degree of effectiveness of the programmes varies widely from operator to operator. The effectiveness of a pipeline integrity management programme depends on many factors: integrating data, identifying threats, modelling risks, and then taking the best actions to mitigate issues. These critical activities ensure companies execute such programmes and reduce systemic risk successfully.

Many operators still struggle to achieve an integrated approach using modern measurement technologies and digital management systems, which leads to a labour-intensive, slow and untargeted approach to mitigation and maintenance activities. As the oil and gas market in general begins a digital transformation journey, new technologies and solutions are available to help pipeline operators achieve a better and more efficient integrity management programme. Hence, in the not too distant future, pipeline integrity will come together with real-time measurement technologies and other digital solutions, creating a true digital twin of the pipeline. These advancements will allow integrated, real-time decision making which will significantly enhance the long-term safety, throughput and profitability of the pipeline.

Figure 1. Integration of critical activities results in a highly effective pipeline integrity management programme.

Figure 2. Operators use Emerson's GeoFields™ Facility Explorer to rapidly locate specific pipeline data.

The problem of data management

The often-disparate nature of pipeline asset- and integrity-related data and the various ways of gathering and reporting it, can make aligning and integrating data difficult (Figure 1). A field report of a leak may give its location using GPS co-ordinates, while an inline inspection (ILI) may provide the location of pipe wall corrosion using an odometer reading. A series of points in a map projection may also provide the location of the pipeline, with the as-built stationing recorded at each pipe bend. In addition, different data are often located in different parts of an organisation. The operator needs to bring these data together to perform the risk assessment and yield the proper integrity management conclusions. This process involves defining a place where data can be stored, ensuring personnel know where to locate it, using a common format, and establishing a common frame of reference to allow the location on the pipe and any applicable information to be compared across the different data sets.

A geographic information system (GIS) can accomplish alignment of data from across disparate reference systems. GIS combines a specialised database and analysis software. It is particularly beneficial for pipeline operators looking to integrate linear surveys and pipeline component data with the map data they may also have, a technique called linear referencing. This technique allows GIS to merge two common reference systems: the spatial world (GPS co-ordinates latitude-longitude and the data in map projections) and the stationing or milepost world. GIS stores the spatial pipeline data and the stationing system, and can display stored data using stationing at a spatial location. It can also integrate the stationed data into the same map containing the spatial data. A series of analysis tools scan for patterns and can, for example, establish that a leak location is coincident with corrosion predicted in the ILI run.

Modern solutions, such as Emerson's GeoFields™ software, give users the tools to comprehensively manage pipeline data, as well as build on database and GIS capabilities to provide workflows – including survey data integration, pipeline configuration changes, risk modelling and analysis, and spill modelling (Figure 2).

Modelling risk

In certain countries, including the US, operators are required to implement a risk modelling regime to understand and rank the sections of pipe that have the highest risk and could have the highest potential impact during a release.

Pipeline operators are looking to mitigate these concerns with risk modelling solutions that connect directly to the enterprise's pipeline data, eliminating the pre-processing of data and increasing accuracy, resolution and repeatability of the computations. Different types of data have different risk integration requirements, ensuring the risk factor accurately reflects the threats and consequences of the pipeline. For example, metal loss information is typically collected as points that can be translated into linear segments of varying levels of corrosion. In another example, a valve is typically represented as a point but may be buffered ±10 units to account for the exposed area around a valve location, to more easily identify potential areas of vandalism.

The ability to integrate both spatial and relational information from an enterprise database is being sought after by pipeline operators to maximise the available data sets used in the risk analysis. The ability to directly access and integrate data into the risk analysis workflow will allow for modelling to become a significantly more accurate, efficient and iterative process (Figure 3).

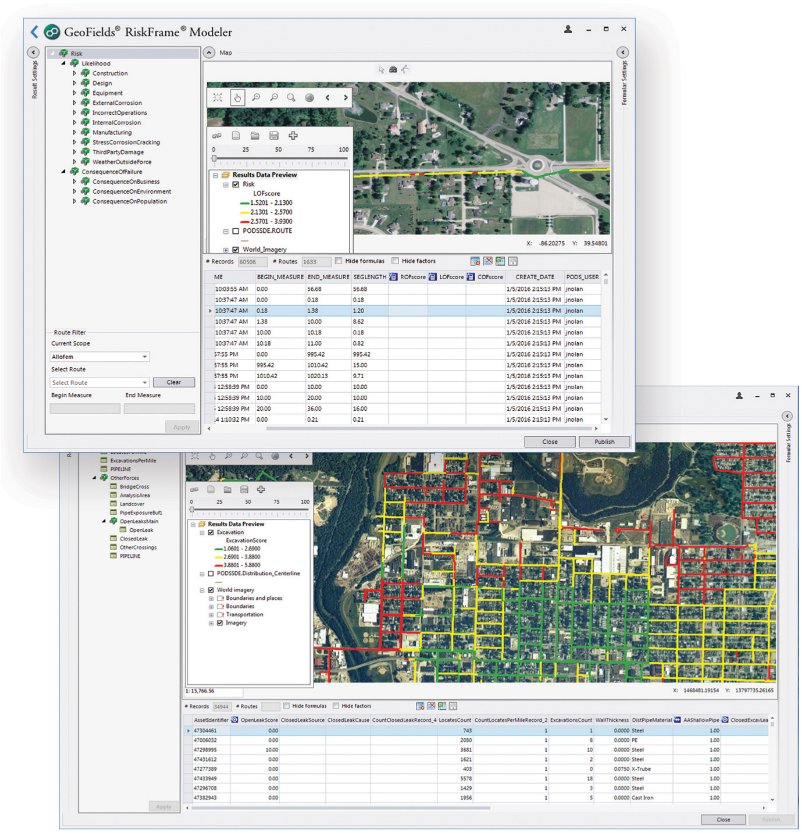

Figure 3. Advanced pipeline modelling tools generate risk scores for pipe segments and other distribution network assets.

Modelling releases

Significant input to any risk modelling activities include estimates of the impact of a potential release on high consequence areas (HCAs). There are different definitions of HCAs for both gas and liquids pipelines, and understanding risk modelling for each is significant. For gas pipelines, HCAs are fundamentally defined as populated areas where a gas pipeline explosion could result in significant damage or loss of life. In the case of liquids pipelines, there is additional complexity to understand the potential areas which are affected by the propagation of the released fluid over the ground. Potentially, the fluid may seep into waterways which could transport the released fluid further from the site of the release, increasing the risk of the impact to the environment and/or the population.

Once data sets are gathered and integrated, operators can calculate the volume that might escape the pipeline from any potential point and subsequently model the potential release – to determine where the released liquid would travel, whether over land or by water. Data sets from the pipeline operator are needed to perform this analysis, including a spatial representation of the pipeline, data on the pipeline diameter and wall thickness, and information on the valves – including valve type. Data sets necessary for this analysis from other sources include a digital elevation model (DEM) of the pipeline and

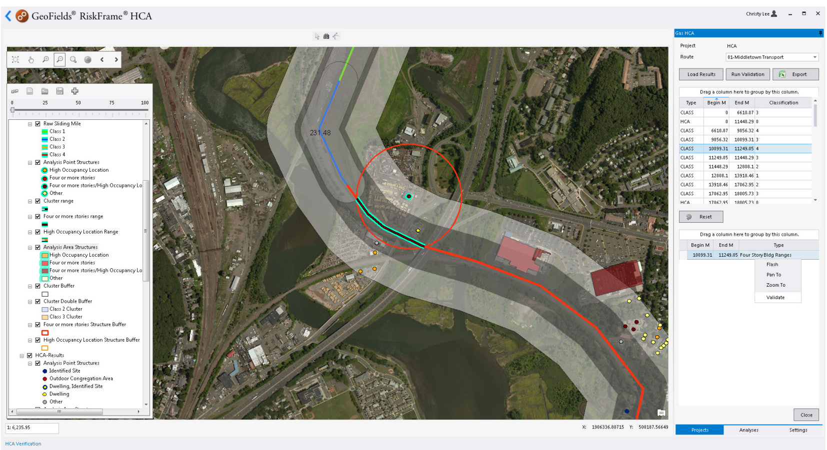

Figure 4. Spill modelling allows detailed HCA analysis, including mapping and calculation of the potential spill volume.

the surrounding area, and a stream network for the area. In addition to the data required to generate the potential release plumes, the pipeline operator should consider population and environmentally sensitive areas that may be impacted by the modelled spills.

A spill model release consists of terrestrial flow and hydrologic flow. When a plume originates over land, the exact shape of a release plume is determined by considering flow between grid cells (or LiDAR points) in the digital elevation data. After the initial release, volume is distributed to adjacent cells, modelling wave fronts that move across the terrain. Volume may also pool in low areas as well as spread out in more than one direction (Figure 4).

Should a terrestrial plume intersect a hydrographic network, or should an identified potential release point originate over water, the potential hydrographic plume will flow downstream through the network until the pipeline operator can take necessary measures to contain the release and stop the flow downstream. This time is determined by a stream flow calculation and the time limit to take mitigation measures – as defined by the pipeline operator based on local knowledge.

Using results from a terrestrial spill model (potential impact plumes which intersect high consequence areas), an operator can identify the start and end of each pipeline segment that could potentially impact a HCA. This is a critical step towards building a comprehensive integrity management programme which targets maintenance and mitigation activities in an effort to limit the impacts to the surrounding population and environment.

Moving pipeline integrity into the real-time world with new technologies

Much of pipeline integrity management and the digital technologies that have evolved to date have been focused on analysing and managing disparate data sources, where data is provided at different times and at different rates into a common system for data management, risk analysis and spill modelling. As measurement technologies and techniques have improved, the ability to measure internal pipe corrosion and erosion directly has also improved, providing a significant new data source for risk modelling. This data allows better management using real-time knowledge of pipeline integrity which can be fed directly into the integrity data management system.

In addition to new real-time technologies for sensing corrosion and erosion, many pipeline operators today are utilising real-time transient models for leak detection and operations management. For instance, Emerson's PipelineManager™ pipeline monitoring software takes in real-time data from a supervisory control and data acquisition (SCADA) system and then performs real-time transient modelling using a fully thermodynamic, first principles physical model (a digital twin of the pipeline) to determine if a leak has occurred. The transient modelling capability also allows for many innovative uses of the software, including look-ahead modelling: forecasting operation of the pipeline in the future based on the current operating state of the pipeline. This allows operators to derive predictive intelligence that indicates if an unsafe operational regime will be entered in the future, based on how the pipeline is operating today. The API 1130: Computational Pipeline Monitoring standard recommends the use of real-time transient modelling as the most accurate and reliable method for leak detection.

The digital twin of the pipeline is nearly here

A true digital twin of the pipeline opens significant opportunities for enhanced decision making and operational performance that could bring pipeline operators new levels of safety and profitability. Solutions providers to the midstream oil and gas industry, such as Emerson, are already working on ways to create a digital twin of the pipeline, leveraging the expertise and capability from existing disparate software applications for pipeline integrity management, leak detection, pipeline modelling, scheduling and commercial management.

Operators will be able to integrate their operational and commercial management and decision making process into a common software platform that offers integrated workflows. Dashboards and mobile applications will streamline nominations and help optimise the process, expedite decisions with the best available data, and turn accepted nominations into completed movements. The greatest value is derived from the vast computing power available and the ability to create a digital twin to simulate thousands of operational scenarios based on existing real-time data, with the results used to quickly optimise the daily operational plan and schedule. This allows longer term business goals to be achieved, such as reducing energy consumption, maximising throughput of the pipeline, and maximising profitability of the pipeline asset.

Being able to optimise the operational strategy, not only based on capacity but also considering the real-time and future integrity of the pipeline, when modelling operational scenarios is a powerful concept. Accepting that extra nomination or taking on a new customer may not be the best long-term financial decision if it is going to reduce the useful life of the pipeline asset or create additional risk of failures in HCAs, since the pipeline may need to be operated at a higher pressure for longer periods of time.

There is even the possibility that with the advent of useful machine learning and analytics engines, the pipeline will be able to virtually run itself – with the operator acting more as an airline pilot when the airplane is at cruise altitude, monitoring the process and only taking intervention and control during more complex operating scenarios, such as startup and shutdowns (takeoffs and landings).

This type of future is closer than many people in the industry may realise, and some automation and solution providers, such as Emerson, are looking to make this vision a reality. Pipeline operators who are thinking about this future and moving in that direction will realise clear competitive advantage for themselves in the marketplace in the near term.