MAGNETIC MAPPING

The Skipper NDT team, France, explore magnetic technology for remote mapping of pipelines at river crossings.

Locations where pipelines cross rivers require special attention to ensure continued safe operation without leakage that can pollute water supplies on which local communities, livestock, and wildlife depend. Skipper NDT has developed a magnetic technology to support the pipeline industry for the inspection and monitoring of assets in complex and critical environments.

Pipeline operators have three main objectives in precisely identifying the location of their buried pipelines:

- 1. Quantify depth of cover to mitigate external interference.
- 2. Identify areas where strain on operating pipelines increases because of ground movements; for example, at river crossings, on unstable slopes, or in areas of frost heave and thaw settlement.
- 3. Update the Geographic Information System of the pipeline network.

Achieving these objectives reduces operational risks and helps to ensure pipeline reliability, energy deliverability, public safety, and environmental protection.

Skipper NDT has developed a method for accurately mapping pipelines remotely, without contacting the pipeline or interfering with the flowrate. The hardware can be installed on an Unmanned Aerial System (UAS) (Figure 1) programmed to fly along the pipeline right-of-way (ROW). Alternatively, the hardware can be mounted on a frame that is pulled by an operator or towed using a vehicle along the pipeline ROW.

The technology is based on magnetic measurements over a ROW to establish, at high precision, pipeline locations in three dimensions and to quantify its movement. The pipeline is made from steel, a ferromagnetic material, for which the total magnetic field intensity can be measured and the magnetic map in the area above the pipeline established. From that map, the magnetic signature of the pipeline is isolated, and, by using proprietary algorithms (solving the inverse problem), we infer the position of its source. Therefore, a 3-dimensional highly accurate digital twin can be created, allowing more complex calculations such as strain estimations. Using simple beam theory and characteristics of the line, the deflections from a straight line can be estimated, as well as the levels of strain in the pipeline for predictive maintenance purposes.

Figure 1. **Off-the-shelf UAS with the hardware.**

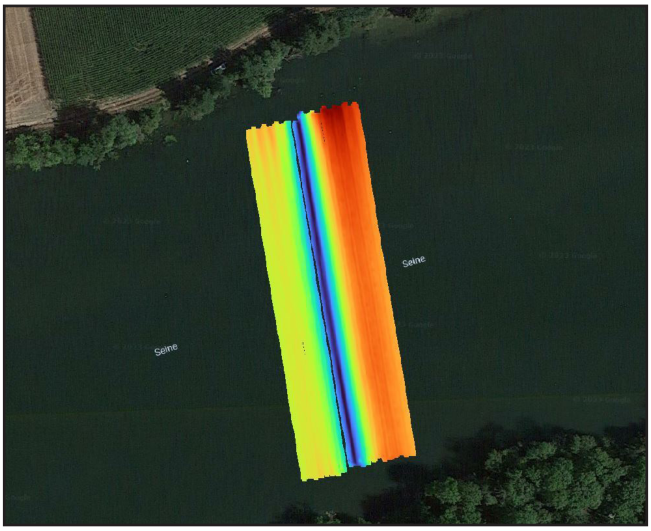

Figure 2. **Map of the magnetic field above the river crossing for the pipeline 900 mm in dia. The colour bar scale goes from 0 nanotesla (blue) to 24 nanotesla (red).**

The hardware package that Skipper NDT has developed and patented for use on a UAS or on a ground-based frame, consists of:

- Five 3-component fluxgate magnetometers.
- Real-time Global Navigation Satellite System (GNSS) receiver.
- Tactical-grade Inertial Measurement Unit (IMU).
- Remote sensor to measure distance between magnetometers and ground.
- Electronic card for data acquisition, digitalisation, and synchronisation.

Various versions of the payload are available which can be adapted to different vector configurations. The hardware weight ranges from 4.5 lbs (2 kg) to 9 lbs (4.2 kg) and its width from 2.6 ft (80 cm) to 5.2 ft (160 cm). It can be fitted under a UAS or a land-based device.

In collaboration with GRTgaz, the incumbent French gas operator managing the largest European pipeline network, three water crossings, varying from 390 ft (120 m) to 720 ft (220 m) in width and up to 39 ft (12 m) maximum water depth, were studied to establish the pipeline absolute positioning and its depth of cover. Water crossings were studied over two rivers, La Seine and La Loire. This study included pipes of three different diameters, 20, 30 and 35 in. (500, 750 and 900 mm). The crossing considered here is performed over la Seine. The map of the magnetic field, above the river crossing, of the 35 in. (900 mm) pipe is illustrated in Figure 2.

The Skipper NDT magnetic technology was used to measure the pipeline depth below the water surface; measurements were recorded at 1.5 ft (50 cm) intervals. The

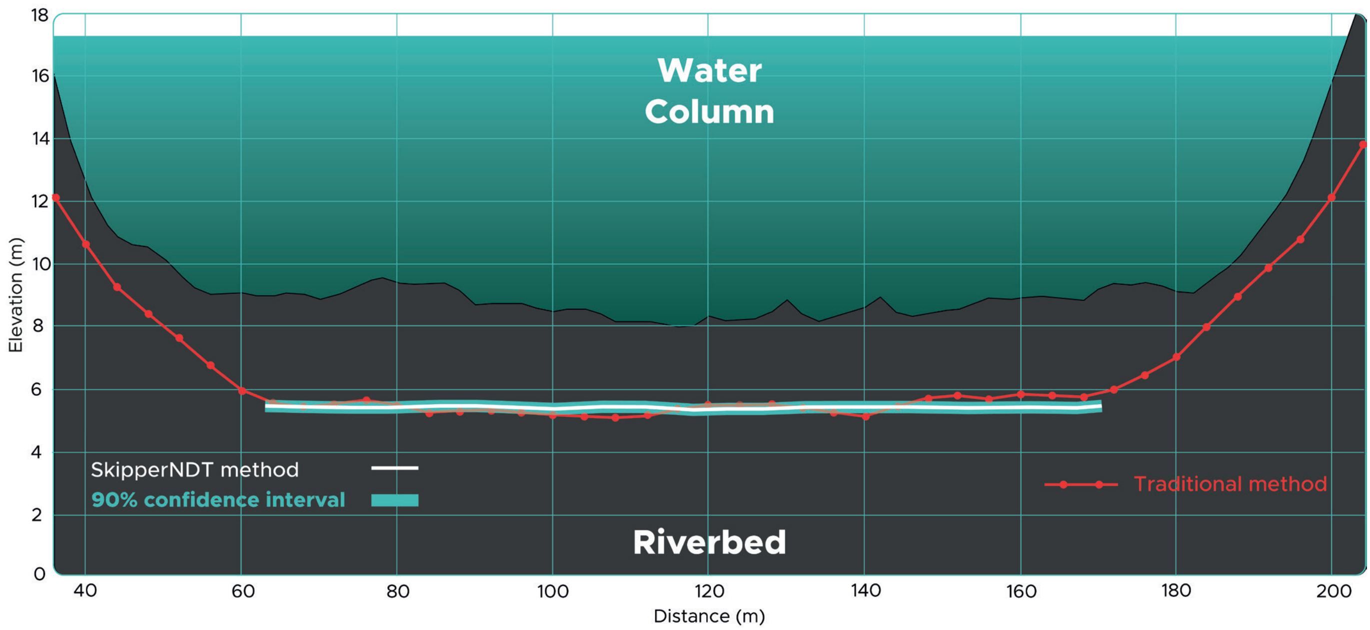

Figure 3. **The elevation profile at a river crossing, showing results from using the magnetic technology and the data from measurements by a diver.**

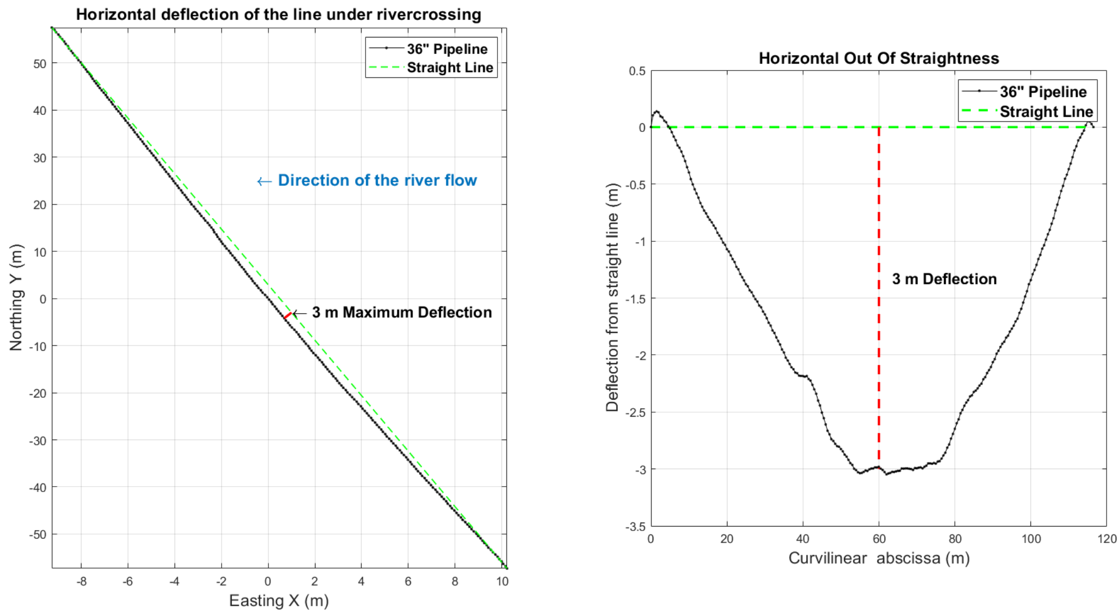

Figure 4. Results showing horizontal deflection of a pipeline at a river crossing.

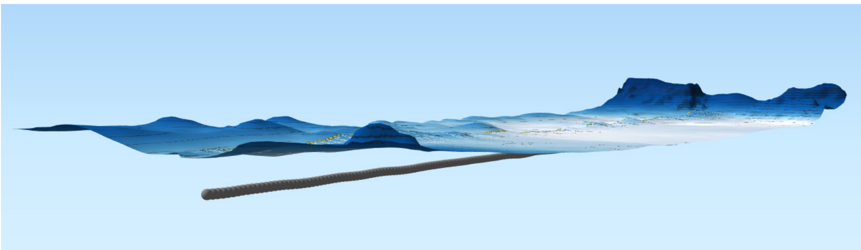

Figure 5. 3-dimensional model showing the pipeline and riverbed.

data on pipe depth obtained using the magnetic technology are illustrated in Figure 3, and the 90% confidence interval is indicated. Also shown in Figure 4 is the data from a bathymetric survey establishing the topography of the riverbed. This data was integrated with the Skipper NDT dataset using proprietary software.

Data shown in Figure 4 compares the performance of the UAS Skipper NDT solution and the traditional hand-held method. The higher density of data acquired and processed by Skipper NDT, four times more, makes it possible to assess the bending strain of the pipeline under the water crossing. Such assessment cannot be performed using the traditional hand-held methods.

Enabled by its high data density, the Skipper NDT technology is suitable to quantify pipe movement. A deflection of 10 ft (3 m) over 360 ft (110 m) was measured. That deflection does not cause a level of stress that is problematic, but illustrates the accuracy that can be obtained. In addition, given the repeatability and reproducibility of the data, the structure can be monitored to assess the need of an intervention in the future.

The 3-dimensional geolocation map generated by Skipper NDT combined with the bathymetric survey made it possible to develop an interactive digital twin of the pipeline river crossing below the riverbed. The model is supported by GIS software (QGIS, ArcGIS, etc.). A 3-dimensional model of the river crossing is illustrated in Figure 5. This type of representation is useful in establishing intervention that is required in maintaining safe operation; e.g., ensuring adequate depth of cover, appropriate sediment distribution, etc.

In summary, the advantages of the Skipper NDT technology can be summarised as follows.

Efficient and reliable data collection

- Speed of execution – large areas can be mapped rapidly, less than 30 minutes for a 300 ft water crossing inspection.
- Repeatable and reproducible datasets – the data acquisition protocol is fully automated, so that data from inspections at different times are comparable.

Enhanced operator safety

- The field work is safe and not labour-intensive – it can be carried out by one person operating the UAS, without the involvement of divers.
- Minimal logistical impact – the inspection is carried out remotely without contacting the pipeline or interfering with the flow inside the pipeline.

Robust and optimised pipeline maintenance

- Applicable on all types of metallic pipelines – the technology is equally effective regardless of the type of polymeric coating that is used on the steel pipe.
- High precision digital twin – Skipper NDT data can be used to develop interactive computer-based three-dimensional models for pipeline integrity departments to enhance risk models and to improve pipeline reliability at river crossings, unstable slopes, and other critical areas.

Autonomous and remote pipeline monitoring for complex environments

High precision digital twin enabling advanced maintenance operations

Pipeline depth of cover and bending strain assessment

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