Remote imaging reaches beyond antiquities

A satellite-directed leak identification technology developed by Utilis has been deployed in more than 20 projects in Italy in a partnership with 2F Water Venture, a leak detection company based in Padova. **Paul Gagliardo**, Senior Technical Fellow of Utilis explains how the technology works and how utilities can employ it to reduce water loss through leakage.

Water loss management is now a higher priority for water utilities in Italy following a new rule that took effect on January 1, 2018. According to the Regulatory Authority for Energy, Networks, and the Environment (ARERA), an independent entity that promotes competition and efficiency in several utility sectors, water utilities are now required to have a program for implementing solutions to assist in meeting the quality of service levels dictated, and water conservation is one macro-indicator.

In Italy, water distribution systems average 40 percent in water loss, which accounts for approximately 3.45 billion cubic meters (m^3) of water lost per year, costing utilities US$4.74 billion or €5.5 billion in lost revenue. Water losses can originate from real physical loss from the system or from apparent losses attributed to inaccurate meter reads or unauthorized consumption.

A partnership formed by Israel-based technology company Utilis and 2F Water Venture, which has already established a successful and proven record in Italy with more than 20 completed leak detection projects (Figure 1), is likely to benefit from the government's new focus on water efficiency. Based in Padova, 2F Water Venture distributes innovative products for the integrated water utility service market focusing on leak detection in potable water mains, and the company is a part of Integrated Watercare Solutions (IWS) Group. 2F Water Venture signed an exclusive agreement with Utilis in December 2016 to resell satellite leak detection services in Italy.

Historical origins

Utilis' satellite-directed leak identification methodology uses a technology similar to what is used by antiquities analysts, but for a different purpose: to locate non-surfacing potable leaks in water pipelines.

In the 1870s, the Italian historian and doctor Giovanni Morelli published some of the first articles describing the methodology used to attribute paintings to specific artists.

Figure 1. Locations of 2F Water Venture projects carried out in the past 2 years are shown in the above figure. Cities marked with red crosses are discussed in this article.

In the 1870s, the Italian historian and doctor Giovanni Morelli published some of the first articles describing the methodology used to attribute paintings to specific artists. Using illumination with visible light positioned at a sharp angle produces shadows revealing fine surface features that can be interpreted. This approach evolved to use different wavelength radiation to inspect antiquities. When a material is illuminated by incident radiation, some of the flux is reflected and some penetrates the surface, depending on wavelength. Ultraviolet (UV) fluorescence has been used to analyze near-subsurface varnish layers. Infrared imaging methods are used to look further under the surface due to its longer wavelength to observe the paint layer highlighted from beneath. X-radiation exhibits a high ability to penetrate through materials, and this technique can also detect structural features in sculpture and painting alterations. These non-intrusive, remote sensing techniques are now being used to peer beneath the ground surface to look for leaking water pipes.

Satellite radar

In 2013, Utilis founder Lauren Guy began exploring the use of electromagnetic waves to sense different phenomena on earth including:

- Infrared spectrum for analyzing flora phenotyping
- Shortwave infrared for temperature measurement
- Multispectral sensors for air pollution monitoring.

Microwaves are the method of choice when searching for water due to its sensitivity to materials with high di-electric constants. The company developed the algorithm used to interpret the reflected images from the satellite and subsequently

Figure 2: ARERA performance levels and improvement goals chart for water resource conservation macro-indicator (M1)

Water resource conservation (M1)	M1a – Linear water losses (m³/km/day)						Goal % of annual Mla
		M1a<15	15≤M1a<25	25≤M1a<40	40≤M1a<60	M1a≥60	
M1b Water loss in total system (%)	M1b<25	A					Class A Maintain
	25≤M1b<35		B				Class B 2%
	35≤M1b<45			C			Class C 4%
	45≤M1b<55				D		Class D 5%
	M1b≥55					E	Class E

The above chart shows the performance levels and resulting improvement goals specifically dictating how much the utilities have to decrease their water losses according to the current state of the system. The system class designation is in the center of the chart, and the performance goals are in the right hand column. If a water utility has a low overall and linear water loss, it is in the A class and must maintain this score in the future. If the utility has large water losses, it must reduce the loss by 2, 4, 5, or 6 percent of the linear loss, according to the chart above.

created a commercially available product in late 2015, which has since been implemented worldwide.

Utilis uses L-band radar satellite imagery to identify likely leak locations. Radar, also known as radio detection and ranging, is an object-detection system that uses electromagnetic waves in the radio or microwave domain to determine the range, angle, or velocity of objects. Radar signals are strongly reflected by materials of considerable electrical conductivity – most notably by wet ground. The satellite radar signals illuminate the area of interest, and the reflected signal is bounced back and collected by the satellite. These images can be processed to omit the noise and to separate out the particular signs of potable water underground. The Utilis service detects the result of these leaks, which is wet soil, as opposed to the leak itself.

In leak detection projects deploying the Utilis methodology, the process starts when 2F Water Venture and its water management customer identify the area of interest (AOI) to be analyzed by the satellite image. The satellite travels over the same location on earth every 14 days. The image collected covers a terrestrial area of 56 kilometers (km) by 72 km. Within this AOI lies the system of water pipelines to be surveyed. The satellite image is received and analyzed in conjunction with the utility-supplied data of pipeline routes to identify likely leak locations (Figure 3). The output deliverable is a GIS-based map showing points of interest (POIs), also considered likely leak locations (Figure 4).

Boots-on-the-ground (BOTG) leak detection crews are then sent out to verify and locate the leaks through traditional acoustic and correlating methodologies. The advantage of using Utilis is that BOTG inspectors are directed to the high potential target areas, rather than inspecting the entire system.

In 2017, 2F Water Venture performed 18 projects, surveying more than 35,000 kilometers. This year, the workload is expected to double. Typically, work with a customer begins with a pilot project to demonstrate the technical efficacy and value proposition of the methodology to meet the utility goals. These are usually one or two satellite images and subsequent field inspections. Once a pilot project has shown value, the utility will enter into a long-term service agreement consisting of multiple images over a multi-year timeframe.

Projects yield positive results

The public company Azienda Cuneese Dell'Acqua SpA (ACDA) manages the integrated water network for 100 municipalities in the mountains and Piedmont region surrounding Cuneo, Italy. In order to reduce water losses, ACDA decided in March 2018 to first pilot test the Utilis technology by performing a survey of 879 km of pipe using the satellite radar methodology. ACDA reports a water loss rate of 33 percent in its 5,224-km pipe distribution network. Utilis detected 57 likely leak locations to inspect and verify. After 9 days of fieldwork with personnel from Utilis and 2F Water Venture, the internal ACDA acoustic team found 43 leaks. Twenty-eight leaks were verified and correlated. Eight locations were deemed suspect leaks but could not be correlated and verified. Seven leaks identified within the buffer zone of the POI were repaired prior to field inspection. These results reveal that 4.8 leaks per day were found, much more than the mean values with the traditional leak detection method. The team achieved an average of 0.75 leaks per site inspection.

In Italy's Tuscany region, the largest regional water utility Acquedotto del Fiora SpA (ATO) manages 55 municipalities, including all 28 in the province of Grosseto and 27 in the province of Siena. Utilis conducted a pilot test for ATO on 974 km of pipelines, which resulted in the location of 75 POIs, of which fourteen were unverifiable. Subsequently, field leak detection crews inspected 61 POIs that Utilis delivered. A total of 66

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Table 1 lists the results from the three projects reviewed.

Utility	POIs investigated	Leaks	Leaks per POI	Crew days	Leaks per crew day	POIs per day investigated
ACDA	57	43	0. 75	9	4. 8	6. 3
ATO	61	66	1. 08	9	5. 5	5. 1
Multiservizi SpA	36	26	0. 72	8	3. 25	4. 5
Combined	154	135	0. 88	26	5. 2	5. 9

leaks were found. Forty-four leaks were verified and correlated. Eleven POIs were determined to be suspect, and eleven POIs were repaired prior to project field inspection. The team found an average of 5.5 leaks per crew day. During this effort, an extraordinary 1.08 leaks per site investigation were delivered.

The public water utility Multiservizi SpA manages the integrated water system for 43 municipalities in the provinces of Ancona and Macerata. The utility supplies 28 million liters per year through a pipe network of 5,200 km to its 400,000 customers. As a pilot test, Utilis performed a survey of 596 km of Multiservizi's pipeline and delivered 57 POIs; 36 of these were inspected in 8 working days. A total of 26 leaks were found. Twenty-one leaks were verified and correlated. Three POIs were deemed to be suspect but could not be correlated. Two sites were repaired prior to project field inspection. An average of 3.25 leaks per day were found. The pilot test resulted in the discovery of an average of 0.72 leaks per site (POI) investigated.

The results achieved by 2F Water Venture in these three projects, summarized in Table 1, compare very favorably to other projects around the world. Utilis has completed more than 100 projects worldwide since 2016. Field leak detection crews using the Utilis-directed leak surveys are typically able to find 2-3 leaks per day, as compared to the 5.2 leaks per day found in this cohort.

Traditional BOTG linear leak inspection protocols produce approximately 1 leak per crew day. 2F Water Venture achieved terrific results based on this performance metric, more than 2 times the improvement from average Utilis-directed leak detection and more than 5 times the improvement over traditional BOTG. On average, Utilis-directed crews find approximately 0.6 leaks per site investigation. Some POIs yield no leaks, and some POIs identify clusters of leaks. In about 10 percent of the sites identified by Utilis, more than one leak is found within the buffer zone of the POI. In this study group, a high level of performance was exhibited as 2F Water Venture found almost 0.9 leaks per site visit. This result is 50 percent higher than the typical rate found at other Utilis-directed projects.

The Utilis-directed protocol is a combination of the satellite image POIs and the leak detection field crew's ability to acoustically identify and correlate the leak. The POI map allows the BOTG field inspectors to focus their time and energy on less than 5 percent of the total system length, which minimizes time in the field and maximizes leaks found. This fact generates the positive value proposition. It costs the same to fix a leak no matter how it is found. Lowering the cost and time to find leaks reduces the overall cost of non-revenue water loss reduction.

A critical component of the Utilis-directed protocol is for the BOTG to follow a leak inspection protocol focusing on best practices. Training of leak inspectors is very important, as is experience using the equipment. As field inspectors have more experience with the Utilis POI map and the field listening equipment, the success at finding leaks rises. Since 2016, 2F Water Venture's performance in these types of projects has improved from 0.4 leaks per site investigated in 2016 to 0.8 leaks per POI investigated thus far in 2018.

Sometimes finding leaks is more art than science.

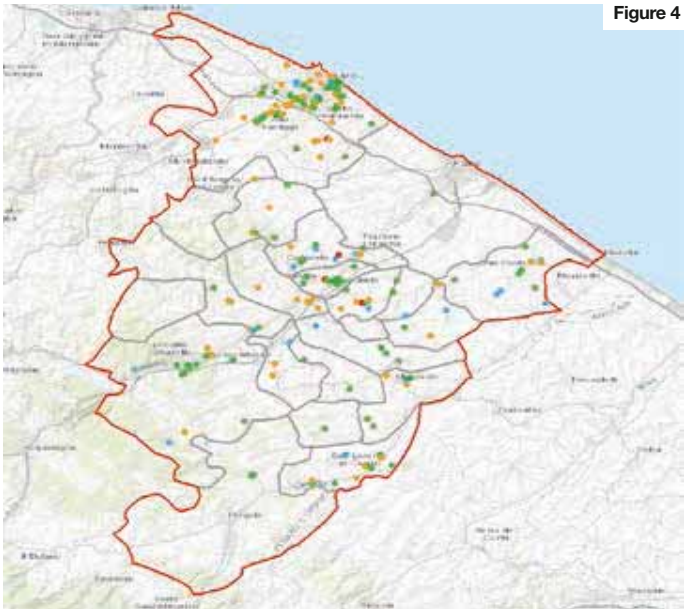
The public water utility Multiservizi SpA manages the integrated water system for 43 municipalities in the provinces of Ancona and Macerata.

Author's Note

Paul Gagliardo is the Senior Technical Fellow at Utilis Corp, an Israel-based tech company. Utilis maintains offices in San Diego, California, United States, and has channel partners in Asia, European Union, and South America. The company has won multiple innovation challenges and contests in the past 2 years, including the Aquatech Innovation Award in 2017 in Amsterdam; Imagine H2O 2017 Water Data Challenge; and the 2018 winner of the WaterFirst! Initiative. Utilis holds a US patent for a System and Method of Underground Water Detection.

Figure 3

Figure 4



Utilis-supplied data of pipeline routes are used in conjunction with the satellite imagery (Figure 3) to indicate points of interest (POIs) that are likely leak locations (Figure 4). Images supplied by 2F Water Venture