

## Summary

This paper analyzes the results and value proposition of the Utilis satellite leak detection services provided by Water Vision Technology (WVT) to the Public Authority for Water (PAW) in Oman. Two complete services were performed between January 2019 and March 2020. The satellite leak detection services will be shown to have a very high leak found rate when compared to traditional sector-by-sector field inspection. In addition, the large number of leaks found will be shown to equate to a significantly large water loss reduction and high value proposition for PAW.

- A total of 2024 leaks were found pursuant to the satellite pre-location survey program including customer side leaks and those identified by customer complaints.
- A total of 384 leaks were found on the customer side of the meter and 100 were identified through customer complaints. 29 leaks were classified as “other” having uncertain origin within private networks.
- Of the 1511 utility side leaks found 838 were non-surfacing leaks.
- The yearly value of the water loss savings is 7.26 million OMR.
- All of the POIs generated during the satellite surveys have been inspected by boots-on-the-ground (BOTG) field inspection crews.
- An average of 5.9 leaks was found per crew day and 2.9 leaks were found per kilometer inspected during the inspection program.

## Technology

Utilis provides a service consisting of a specialized RADAR signal generated from satellites to illuminate an area of interest and collect the resulting reflected signals. These signals are analyzed with a patented algorithm and processed to identify specific indicators of wet soil saturated with potable water, screening out the signal noise and other interferences. The result is a map showing likely leak locations, or Points of Interest (POI). Each POI identifies an area that is to be inspected. The inspection zone extends approximately 100 meters radially out from the center of the POI and encompasses all the pipe within that area. These results typically encompass 5% of the entire system length, so that the time and resource cost to inspect is much lower than traditional walk-the-line random inspections. Only locations where there is expected to be a leak are inspected.

## PAW - Current Conditions

Based on discussions with PAW personnel and a review of the PAW 2018 Annual Report, a compilation of current system operational data is contained in Table 1. Unaccounted for water (UFW) loss is estimated to be 61.3 million m<sup>3</sup> or 21.6% of system delivery.

**Table 1: PUBLIC AUTHORITY FOR WATER - CURRENT CONDITIONS (2018)**

Distribution System Pipelines (km)	13,680
Number of Water Service Connections	524,887
Average System Delivery (Million m <sup>3</sup> )	284
Unaccounted For Water (%)	21.6 %
Non-Revenue Water (Million m <sup>3</sup> )	61.3
Average Cost of Water (OMR/m <sup>3</sup> )	0.397

1 cubic meter = 264 gallons

1 OMR (Oman Real) = \$2.60USD

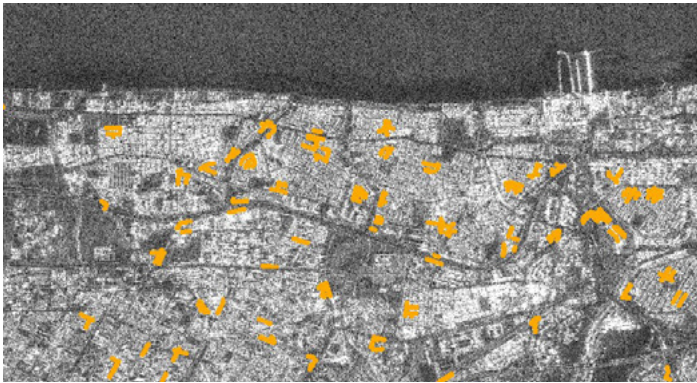
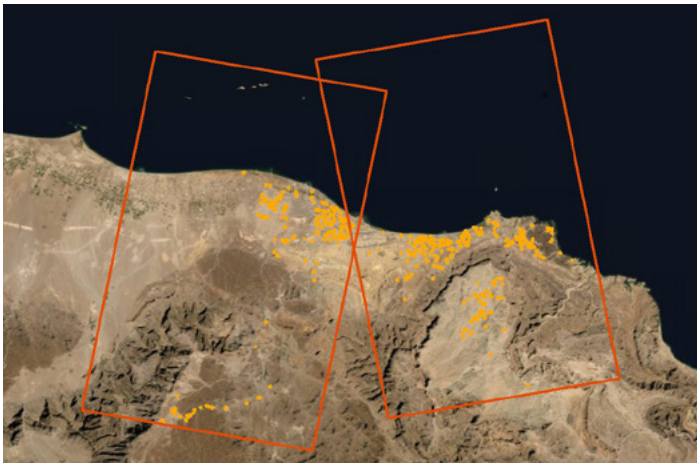
## Results

Two satellite surveys and subsequent field inspection programs have been executed thus far at PAW. The first service was performed in early 2019. Utilis collected and analyzed a satellite image of the area of interest (AOI) in January 2019 and provided the delivery of results to PAW in February 2019. WVT provided an orientation and briefing for leak detection technicians to discuss the findings, review best practices and provide one week of field support. The field boots-on-the-ground (BOTG) acoustic leak detection work began on 4 February 2019 and 9 acoustic teams were involved in the surveying. The field inspection was conducted during February, March and April 2019.

The second service was performed in late 2019. Utilis collected and analyzed a satellite image of the area of interest (AOI) in November 2019 and provided the delivery of results to PAW in December 2019. The BOTG acoustic leak detection work started on 9 December 2019 and 12 acoustic teams were involved in the surveying. The field inspection was conducted during December 2019, January, February and March 2020.

The results of the two services are listed in Table 2. A total of 6,030 kilometers were surveyed and 738 points of interest (POI) were identified in the first service. Of the 742 leaks identified in this service, 61 were found on pipe mains and 514 were found on service lines. 103 of the leaks found were on the customer side of the meter and 41 were found via customer complaints. 23 leaks were classified as “other”, which are leaks where the origin is uncertain due to the fact they are located within private networks.

In the second service a total of 7,650 kilometers was surveyed and 984 points of interest (POI) were identified. Of the 1282 leaks identified in this service, 84 were found on main lines and 852 were found on service lines. 281 of the leaks found were on the customer side of the meter and 59 were found via customer complaints. 6 leaks were classified as “other”.



\*Example of the Area of interest (AOI), with yellow lines showing the Points of Interest (POI)

This table shows all the leaks identified pursuant to the satellite surveys including customer side leaks. Those leaks identified and pinpointed pursuant to customer generated complaints are not included in the BOTG performance metrics. These leaks reported by customers were within a POI generated by the satellite analysis and not found through satellite directed BOTG inspections. They would have been found even if the satellite survey had not been performed. Thus, to be conservative, they are not included in the performance metrics analysis. The leaks classified as “other” are included in this metric because they were found pursuant to satellite directed inspections even though they are of uncertain location and on private networks. These outcomes result in a performance metric of 5.9 leaks being found per crew day and 2.9 leaks found per kilometer physically inspected. The performance across the two services is very consistent. It is important to note that only 677 km of pipe was physically inspected out of 13,680 km that comprises the PAW system. This is about 5% of the total system.

**Table 2: PAW RESULTS**

	Leaks	Crewday	Leak/day	Kilometers	Leak/km
Service 1	701	119	5.9	277	2.5
Service 2	1223	208	5.9	390	3.1
<b>Total</b>	<b>1924</b>	<b>327</b>	<b>5.9</b>	<b>667</b>	<b>2.9</b>

These results can be compared with historical benchmarks from over 200 satellite directed projects and over 1800 traditional Boots-on-the-Ground (BOTG) point-to-point inspection projects conducted by a leak detection contractor over a period of ten years. The data is listed in Table 3. Satellite directed programs historically have achieved a result of 3.8 leaks per day and 1.6 leaks per km. Traditional BOTG projects have resulted in benchmarks of 1.3 leaks per day and 0.2 leaks per km found. The PAW results are significantly better than both of these benchmarks.

**Table 3: PAW RESULTS COMPARED TO BENCHMARKS**

	Leaks/day	Leaks/km
Traditional botg benchmark	1.3	0.2
Satellite average	3.8	1.6
PAW	5.9	2.9

The leaks per day metric show the capability and efficiency of the BOTG field leak crews in finding leaks. It is a measure of the ability of the field crews. In this case it shows how well the PAW crews are performing their functions. The leaks per kilometer found show the efficacy of the satellite imagery algorithm in identifying where leaks are located. It is a measure of the efficacy of the technology. The satellite imagery technology performed exceedingly well in this situation.

It is also informative to note that many true positive POIs exhibited more than one leak per site. In other projects it has been found that multiple POIs exhibit multiple leaks. This clustering effect is commonplace. The best practices for the BOTG field leak inspectors require that the entire POI be investigated even if a singular leak is found. Each POI identifies an area encompassing approximately 400 meters of pipeline where field teams are to inspect. In the case of the PAW work 43.5% of the POIs where leaks were found had more than one leak. See Table 4. This does not include leaks found via customer complaints. This result reinforces the need for field crews to follow the Best Practices when searching for leaks pursuant to a POI list.

**Table 4: PAW RESULTS - POI > 1 LEAK**

	Leaks	Poi > 1 leak	% > 1 Leak
Service 1	701	327	46.6%
Service 2	1223	511	41.8%
<b>Total</b>	<b>1924</b>	<b>838</b>	<b>43.5%</b>

## Value Proposition

The following analysis will utilize only the number of leaks found on main and service lines, as these are the utility side

leaks that contribute to lost revenue. This cohort of leaks will be used to calculate the value proposition of the work, including water loss reduction and avoided cost.

The satellite directed work in PAW organized the leak types by five categories: mains, services, customer reported, customer side and other. This data is contained in Table 5. Customer side leaks, customer reported found leaks and leaks classified as other are reported in the table but will not be included in the analysis. Of the 2024 leaks detected by Utilis 1924 were found by satellite image directed field inspection and 100 were found within the POIs through customer complaints. Of the 1924 found by satellite directed inspections 384 were on the customer side of the meter and 29 were classified as other. Therefore there are 1511 leaks on the utility side of the meter, mains and service lines, and will thus be considered non-revenue water leaks. Of these 1511 leaks 145 were on a main line and 1366 leaks were on service lines.

**Table 5: PAW RESULTS - LEAK LOCATIONS**

	Mains	Service	Customer	WO	Customer Reported	Total
Service 1	61	514	103	41	23	742
Service 2	84	852	281	59	6	1282
<b>Total</b>	<b>145</b>	<b>1366</b>	<b>384</b>	<b>100</b>	<b>29</b>	<b>2024</b>

Utilis found a total of 1511 utility side leaks via the satellite directed field inspection work within the confines of this study period, of which 838 were hidden, or, had not surfaced and would not have been identified if not for a physical inspection of the specific area. 55.5% of the utility side leaks identified by Utilis were non-surfacing. Finding hidden, or non-surfacing leaks, is one of the hallmarks of the satellite survey technique. These are leaks that have a long life and contribute significantly to non-revenue water.

## Cost Benefit Analysis

It is notoriously difficult to estimate the rate and duration of leakage from mains and service lines. Both of these factors weigh heavily on the value proposition, ROI and simple payback value metrics. In AWWA Manual M36, Water Audits and Loss Control Programs, main line leaks are estimated to be 2.4 m<sup>3</sup>/hr and service line leaks are estimated to be 1.2 m<sup>3</sup>/hr. A data set from 1800 traditional BOTG field leak inspection projects was compiled to determine leak sizes based on type of leak. Using data from the cohort of these projects the average main line leak was estimated to be 2.1 m<sup>3</sup>/hr and the average service line leak was estimated to be 0.74 m<sup>3</sup>/hr. A data set was compiled for PAW calculating the Service 1 quantified water savings from a DMA analysis. A number of leak volume loss rates were verified and a number were estimated. Using the verified and estimated data, main line leaks are calculated to have a loss rate of 3.1

m<sup>3</sup>/hr and service line leaks are calculated to have a loss rate of 1.2m<sup>3</sup>/hr. These three data sets are listed in Table 6.

**Table 6: LEAK LOSS RATE (m<sup>3</sup>/hr)**

	Main	Service
AWWA M36	2.4	1.20
TBOTG database	2.1	0.74
Paw DMA analysis	3.1	1.20

When actual or field estimated leak flow rates are not available it is necessary to use either the M36 or TBOTG Traditional database values when calculating total water loss. In this case PAW has estimated and calculated leak flow rates, so those values will be used in the analysis. As can be seen from Table 6 the values identified by PAW are similar to those benchmark values. The PAW DMA leak loss rate values were calculated based on the Service 1 program. Those values will be applied to both services to calculate the total water loss identified in the satellite survey program.

A total of 145 main line leaks and 1366 service line leaks were discovered by the satellite imagery program during the first two services. Based on the PAW DMA data the main line leaks total 449.5 m<sup>3</sup>/hr and the service line leaks total 1639.2 m<sup>3</sup>/hr. This equates to a total real water loss of 2088.7 m<sup>3</sup>/hr. Table 7 shows the volume of real water loss identified by various time periods. Identifying and repairing these leaks in the PAW system would result in a lowering of the UFW from 21.6% to 16.2%. This is a 25% reduction in total UFW volume.

**Table 7: TOTAL REAL WATER LOSS REDUCTION - m<sup>3</sup>**

Daily	Monthly	Quarterly	Yearly
<b>50,130</b>	<b>1,504,000</b>	<b>4,512,000</b>	<b>18,300,000</b>

The PAW average cost of water production is listed as 0.397 OMR/m<sup>3</sup> from the 2018 PAW Annual Report. This is the avoided cost, or value proposition, of the water loss reduction. This equates to a value proposition of 19,900 OMR per day due to this leak detection and repair program. Based on a yearly total real water loss reduction of 18.3 million m<sup>3</sup> this equates to a yearly value proposition to PAW of 7.26 million OMR.

## About the author



Paul Gagliardo has more than 25 years of experience in the water utility business and most recently worked for American Water as the Innovation Director.