ASTERRA

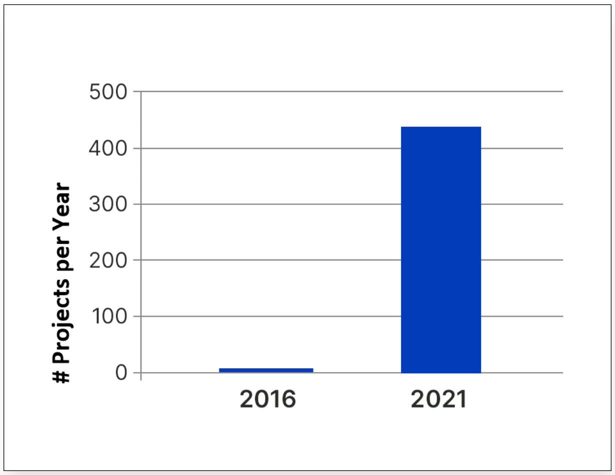
Technology by Utilis

Using Synthetic Aperture Radar for Underground Leak Detection

July 2019 / Updated August 2021

Introduction

ASTERRA uses Utilis technology and satellite data to find potable water leaks underground. This technology was developed in Israel and is now deployed worldwide as ASTERRA Recover. The process uses synthetic aperture radar data and passes it through a proprietary algorithm while applying filtering techniques. This paper will detail the thought behind the development of the technique and explore metrics that benchmark it against traditional leak detection methodology.



The Company

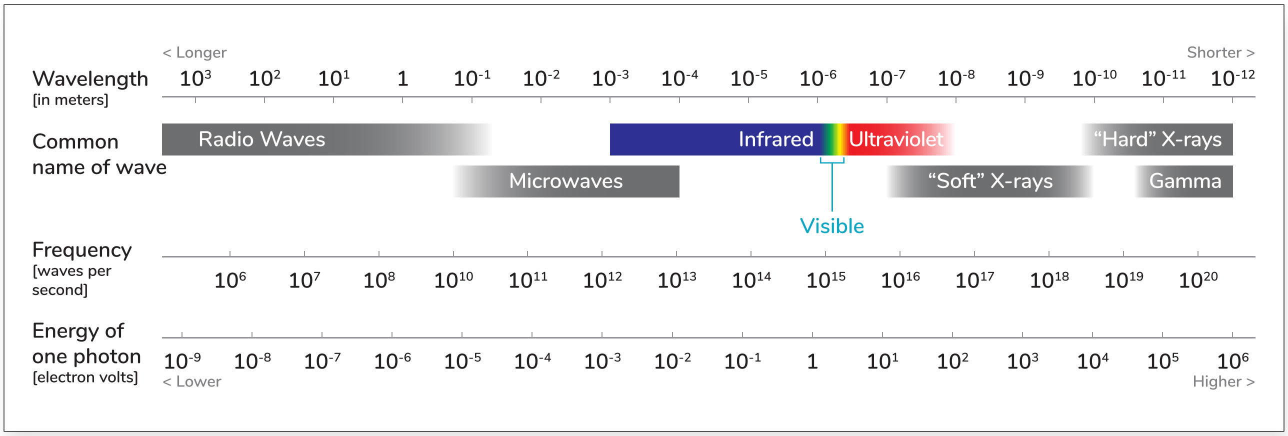
Utilis was founded in 2013 to commercialize the concept of locating subsurface, background potable water pipe leaks from space. Microwave radar is emitted from a satellite or any other airborne platform and used to detect the signature of wet soil underground with potable water indication. This technology is the same as is used to search for water on other planets such as Mars.

Commercial sales of Recover began in 2016. The number of completed projects has risen from three in 2016 to more than 430 completed projects by 2021. Over 36,000 leaks have been field verified.

We have now completed projects in 57 countries, and hold six patents related to systems and methods for underground water detection using radar. Through continuous upgrades to the product, Recover has increased the efficiency of the service time over time.

The Electromagnetic Spectrum

Radiation is energy that travels in the form of waves. Electromagnetic radiation (EM) can travel through empty space within the electromagnetic spectrum. Low energy EM has a long wavelength while high energy EM has short wavelength. Radio and microwaves have the longest wavelengths, and X-rays and gamma rays have the shortest wavelengths. Radar is an object detection system using EM in the microwave domain. Microwaves have a wavelength in the 0.001 to 1-meter range. Radar was developed secretly for military use before WWII. A radar system consists of a transmitter, antenna and receiver. Radar waves are sent from the transmitter and reflected off the subject object. The portion of the waves that are reflected, or backscattered, are returned to the receiver, therefore providing information about the object. Radar waves are more completely reflected by materials with high electrical conductivity including wet soil, and the reflectivity depends on the wavelength. Microwaves can penetrate ground surfaces up to 2 meters in depth, dependent on wavelength and soil type.



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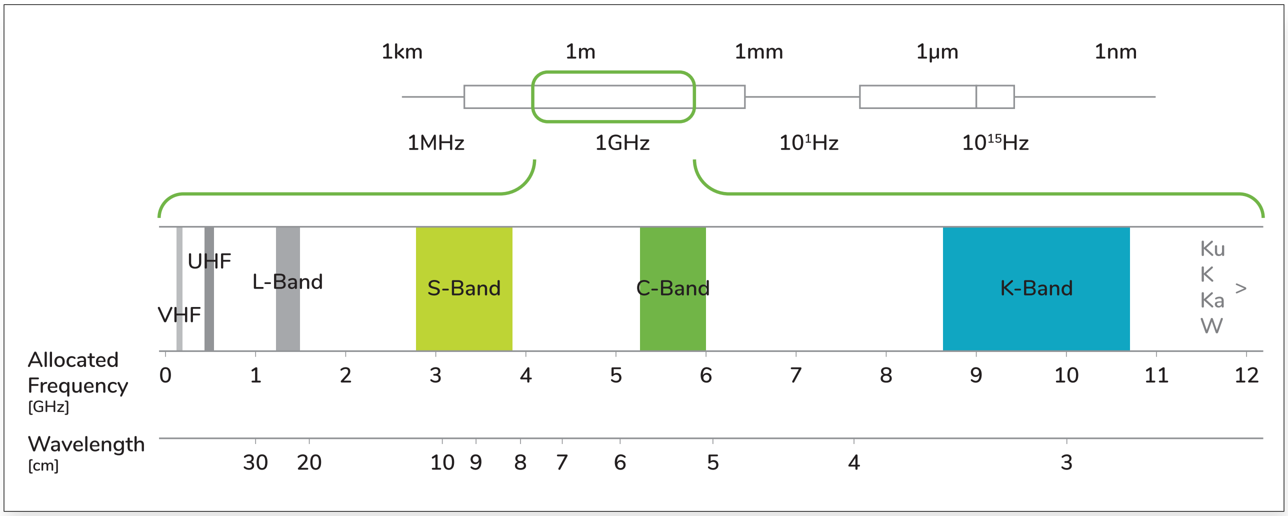
Radar

Traditional radar frequency band names originated as code-names during World War II and are still in military and aviation use throughout the world. Radars used to track ballistic missiles have over-the-horizon, foliage penetrating or ground-penetrating applications, include HF (high frequency), UHF (ultra HF) and VHF (very HF) bands with frequencies in the 3 – 1000 MHz range. Radars used in weather applications, air traffic control and missile guidance have frequencies ranging from 1 – 12 GHz and include L (long), S (short), C (compromise) and X (secret in WW II) bands. Radars in the W band (75 – 100 GHz frequency range) are used in self-driving cars. These land-based applications typically use a pulsed technique whereby an area is illuminated in short bursts and echoes are received in the quiet period in between. Doppler characteristics can determine location, velocity and direction of targets. The performance of radar systems can be gauged by their range, accuracy, ability to filter noise and ability to recognize the intended target. These are greatly impacted by transmitter power and physical size of the antenna. Other systems similar to radar make use of other parts of the EM spectrum. For example, Lidar uses ultraviolet, visible, or near infrared light from lasers rather than radio waves. Microwave imaging is a science that has evolved from older detecting/locating techniques, such as radar, in order to evaluate hidden or embedded objects in a structure or media using EM waves. Microwave imaging has a variety of applications including nondestructive testing and evaluation (NDT&E), medical imaging, concealed weapon detection at security checkpoints, structural health monitoring, and through-the-wall imaging.



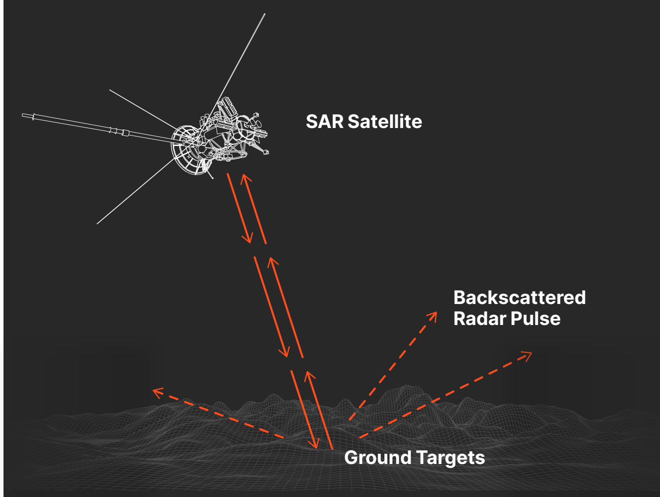
The Process

Recover mainly, amongst others, leverages the capabilities of the Japanese Advanced Land Observing Satellite (ALOS-2) which is equipped with L-band Synthetic Aperture Radar (PALSAR-2) as an observation device for detailed examination of the earth. The satellite has a polar orbit which allows it to capture data over the same swath of the earth every 14 days. It has the capability to generate a minimum image size on the scale of 30 miles wide by 40 miles long.

SAR can be used for remote detection of underground water, such as drinking water leakage from an urban water system. Water sources such as leaking pipes, lakes or swimming pools, reflect EM waves both below and above ground level. Every material has different electric properties, called the dielectric constant, creating an identifying marker that allows distinguishing between backscatter from them with SAR. Therefore, drinking water saturated soil has a specific signature in SAR data that is isolated by Recover to find water leaks.

SAR sensors placed on an elevated platform such as a satellite or an aircraft send EM waves at a known frequency towards an area and read the EM backscatter from that area. The signals are compiled into an image of the area. This includes backscatter from water sources and other landmarks such as buildings, vegetation and topographical features of the area.

For Recover to identify the water related backscatter, all other signals (e.g., EM noise reflection) are filtered or removed from the scan. Since different water sources (e.g., drinking water, sewage, seas, lakes swimming pools, etc.) have different dielectric constants, it is possible to distinguish one from the other. Unwanted targets are filtered out or removed from the scan thus leaving only the signal backscattered from pipeline water leakages (the signal from drinking water mixed with soil). The same image at different polarizations (called a quad-pole image) is used to further assist in reducing noise and identifying the desired material. The entire process by Recover and all ASTERRA products is proprietary and patented. The result is a GIS-based map showing points of interest (POI) where there are likely potable water pipe leaks. This map of POI's is then used to direct the boots-on-the-ground (BOTG) field inspections teams to confirm and pinpoint the leak location.

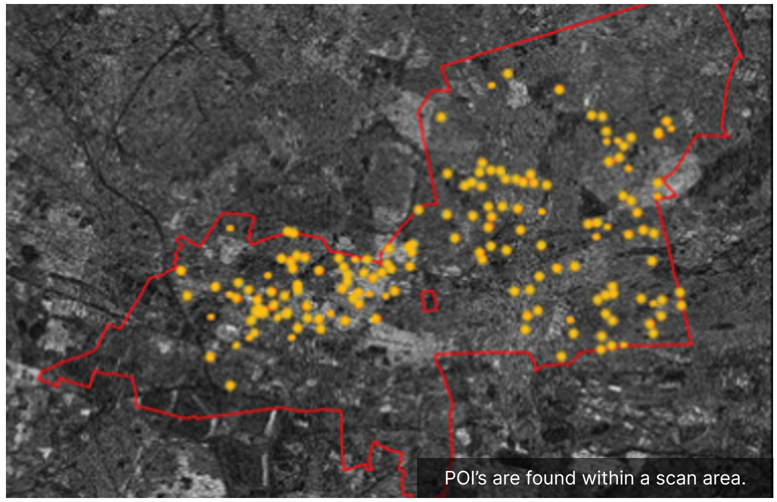


Synthetic Aperture Radar

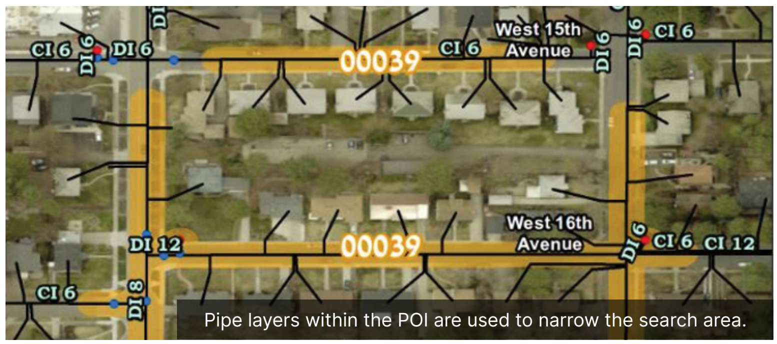
Seasat was the first earth orbiting satellite designed for earth sensing (of the ocean) using synthetic aperture radar (SAR). SAR is a form of radar that is used to capture two or 3-dimensional images of objects such as landscapes. SAR uses the motion of the radar antenna over a target region to provide finer spatial resolution than conventional radars. SAR is typically mounted on a moving platform such as an aircraft or spacecraft.

The distance the SAR device travels over a target in the time taken for the radar pulses to return to the antenna creates a large "synthetic" antenna aperture (the "size" of the antenna). The larger the aperture the higher the image resolution will be, regardless of whether the aperture is physical (a large antenna) or "synthetic" (a moving aperture). This allows SAR to create high-resolution images with comparatively small physical antennas. To create a SAR image, successive pulses of microwaves are transmitted to "illuminate" a target scene and the echo of each pulse is received and recorded. As the SAR device moves with the aircraft or spacecraft, the antenna location relative to the target changes with time. Signal processing of the successive recorded radar echoes allows combining of the recordings from these multiple antenna positions to produce a correlated image.

The ASTERRA approach to finding leaks is analogous to a doctor performing triage on a patient to determine where the most acute problems are located. The entire water system is scanned and only the most likely leak locations are identified for further BOTG field inspection. This amounts to 5 -10% of the total length of pipe. The BOTG are trained in the best practices related to looking for and pinpointing leak locations.


POI's are found within a scan area.

The POI's are the centroid of a buffer zone within which the field crews are to focus their attention. The buffer zone stretches up to 300-foot radius from the POI. All pipe within that buffer zone is inspected for leak noise using state-of-art acoustic devices. Typically all of the listening points (e.g. meters, valves, curb stops, hydrants, etc.) within that buffer zone will be accessed to search for leak noises. This can be up to 140 listening points per mile of pipeline. In some cases (e.g. where meters are located inside buildings) fewer listening points are readily available for inspection and thus the field best practices protocols are altered to maximize the number of leaks found per crew day.



Pipe layers within the POI are used to narrow the search area.

The BOTG field protocols are modified based on the conditions on the ground. The BOTG crews have a large impact on the performance of the Recover leak detection program. The better trained and the more experience they have the more leaks they find. The Recover imaging does not locate the point in the pipe that is leaking but senses the result of the leak; wet subsurface soil. Therefore the POI location is typically not the exact location of the leak. In addition, the type of pipe also impacts the success rate of the confirmation stage. PVC, or any plastic pipe, transmits sound less than metal pipe and thus it is harder to confirm by locating and pinpointing a leak.

The ASTERRA Process

- A microwave sensor onboard a satellite acquires images
- A corrected microwave image is processed
- Treated water leaks are identified using a propriety algorithm
- Data is presented graphically as a GIS data layer and within a data driven application
- Field crews on the ground receive set of POI's to locate, confirm and repair the leaks

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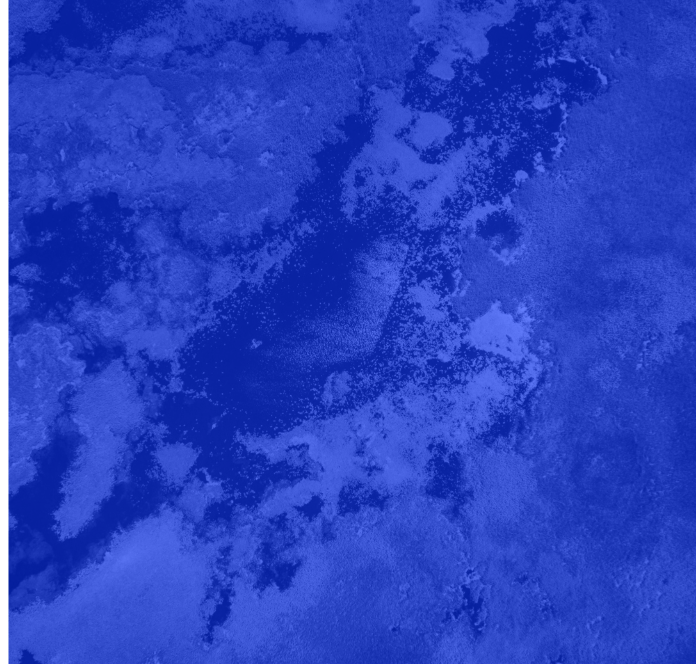
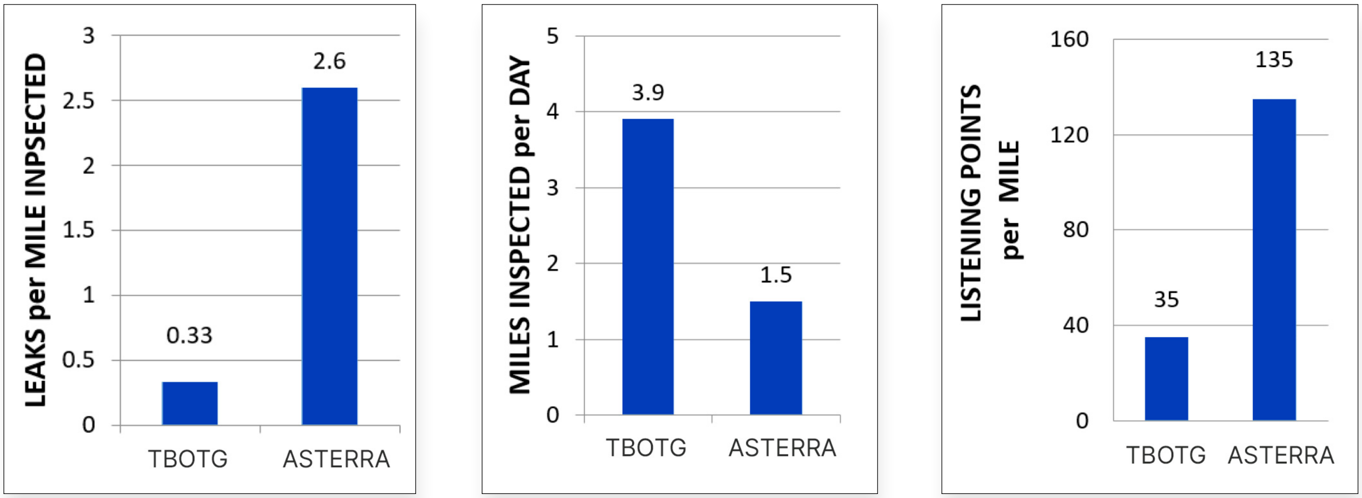
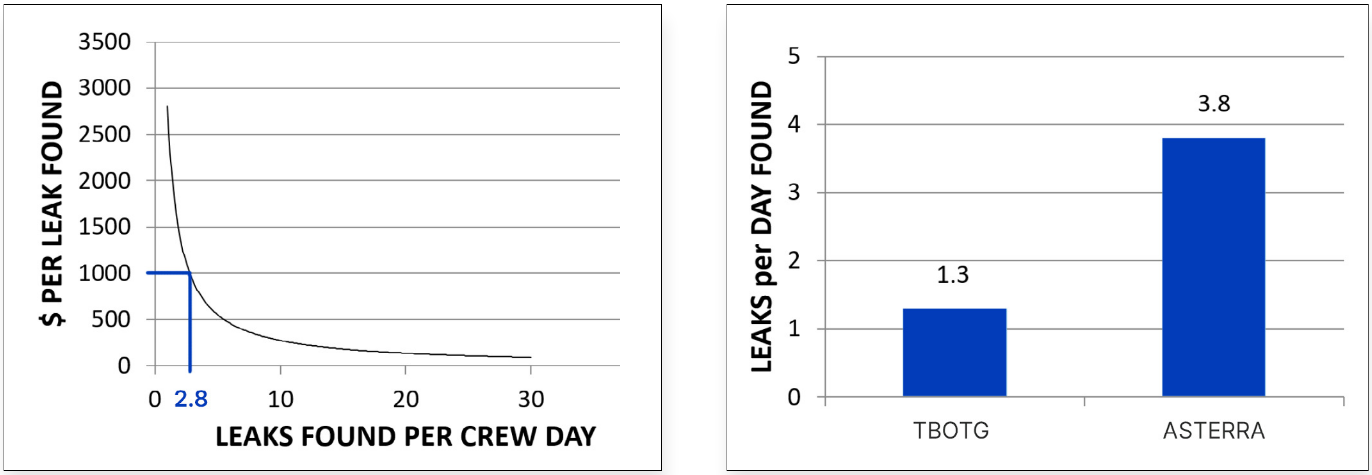
Benchmarking

New technologies must always be benchmarked against existing ones to determine technical efficacy and value proposition. Performance metrics can be used to perform an apples-to-apples comparison. The best metric to measure technical efficacy of satellite leak detection is leaks found per mile physically inspected. This shows how well the ASTERRA satellite triage can reduce the area inspected and focus BOTG to the most likely leak locations. A meta-analysis of over 1600 traditional BOTG projects over ten years was undertaken, showing an average of 0.33 leaks found per mile versus 2.6 leaks per mile using Recover.

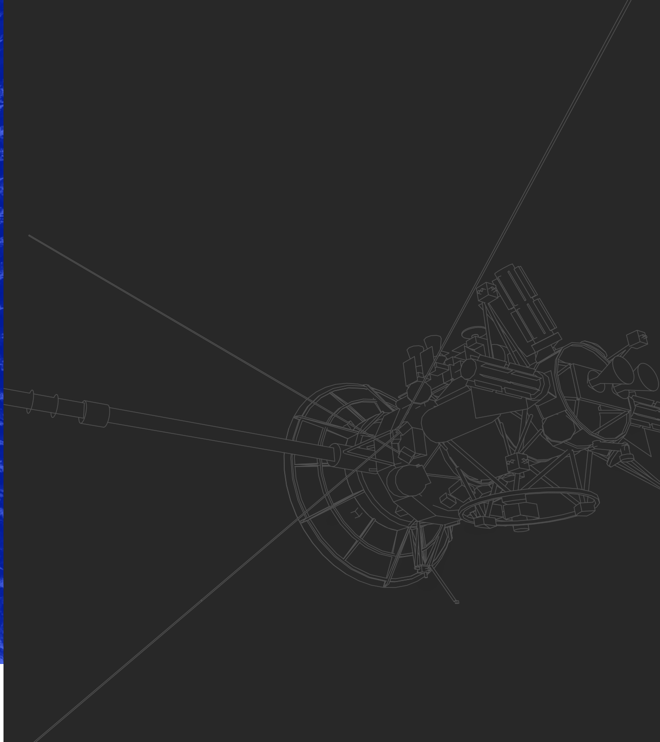




Traditional boots-on-the-ground (TBOTG) vs. ASTERRA method.



The breakeven point between TBOTG and ASTERRA is 2.8 leaks per crew day. Above that, ASTERRA is more cost effective.



Conclusions

Value proposition can best be conveyed using the metric of leaks found per crew day. The more leaks found per day, the lower the unit cost of finding a leak since the major cost of pinpointing a leak is the BOTG labor resources. The ASTERRA program currently identifies 3.8 leaks per crew day (and growing every day) versus the traditional BOTG services finding an average of 1.3 leaks per day. Using average performance results, satellite survey and BOTG crew pricing, a value metric of dollars per leak found can be calculated. A typical Recover project will result in a cost per leak found of less than $1000.

Highlights of Satellite Imagery

- Efficient and accurate survey of a large area, covering an entire water system in a single screening.
- Using the Recover triage methodology field leak detection crews verify almost 4 leaks per day, resulting in significant reductions in non-revenue water.
- Small leaks down to 0.1 liters per minute are detectable.
- Information generated can be used in any GIS system; the data output can be overlaid with any other data layer.
- There are no installation or capital costs associated with the Recover program. No changes to existing infrastructure are required. Totally remote solution.
- Knowledge provided via data output is readily accessible and does not require external expertise to interpret.
- ASTERRA's Recover is the most effective at reducing NRW, both economically and logistically.