by Dr David Maddison

# Underground Mapping, Leak Detection and Pipe Inspection

**As you walk along any street, you probably have no idea of the many pipes, cables, conduits, tunnels and other structures that are right under your feet. For utilities, this makes excavation difficult; a digger blade going through a gas, water or electricity mains or a major internet cable is a disaster! Technology comes to the rescue with techniques to find and map what's underground.**

**The ability to locate underground utility services** is important for several reasons:

- The location of old services might not be accurately recorded on maps, if marked at all.
- Underground service density is increasing, and in some urban areas, it has become extreme.
- While digging to add more services, there is a desire to avoid damaging existing services.
- There needs to be minimal disruption (and restoration cost) during and after such digging.
- The high and increasing population density of Australian (and other) cities requires more underground services.

The roll-out of the Australian National Broadband Network (NBN) has created a large demand for utility location services, as new cables are being installed in virtually every street. Existing services need to be accurately located; in many cases, existing Telstra conduit is used, but these are not necessarily accurately mapped.

Additional challenges are provided by the now-wide-

**Finding an underground utility the hard way! This gas pipeline was breached by a digger in Los Angeles, 2016. Image from https://youtu.be/nBBANQU4PlM**

spread use of plastic pipes for water supply, replacing traditional metal pipes. "Plastic" gas pipes generally have an aluminium layer, so are more easily detectable.

New technologies enable the location of underground services which were previously not easily locatable without digging.

Underground utility location relies on the physical properties of the services being looked for. There must be some property of the utility that contrasts with the surrounding material.

This might be due to something being carried in a pipe (gas or liquid); backfill material which is a different composition or consistency than the surrounding earth; or properties such as emission of electromagnetic radiation (eg, mains hum from power cables).

If the utility being searched for doesn't possess a suitable contrasting property, it can be enhanced. Methods to do this include energising an electrically conducting utility like a wire, cable or metal pipe with a suitable electromagnetic signal, or the insertion of a transmitter inside a pipe that transmits an electromagnetic, magnetic or acoustic signature.

In the case of a broken or shorted electrical conductor, time-domain reflectometry (TDR) can be used to find the location of the fault

In the case of fluid leaking from a pipe, visual evidence may be found at the surface, or acoustic methods can be used to find the leak. For a gas leak, the smell may give the

**Fig.1: finding a buried cable using electromagnetic induction in Germany around 1910. The search coil is wrapped around a roof truss. A very large coil was needed, as there was no convenient means of signal amplification at the time.**

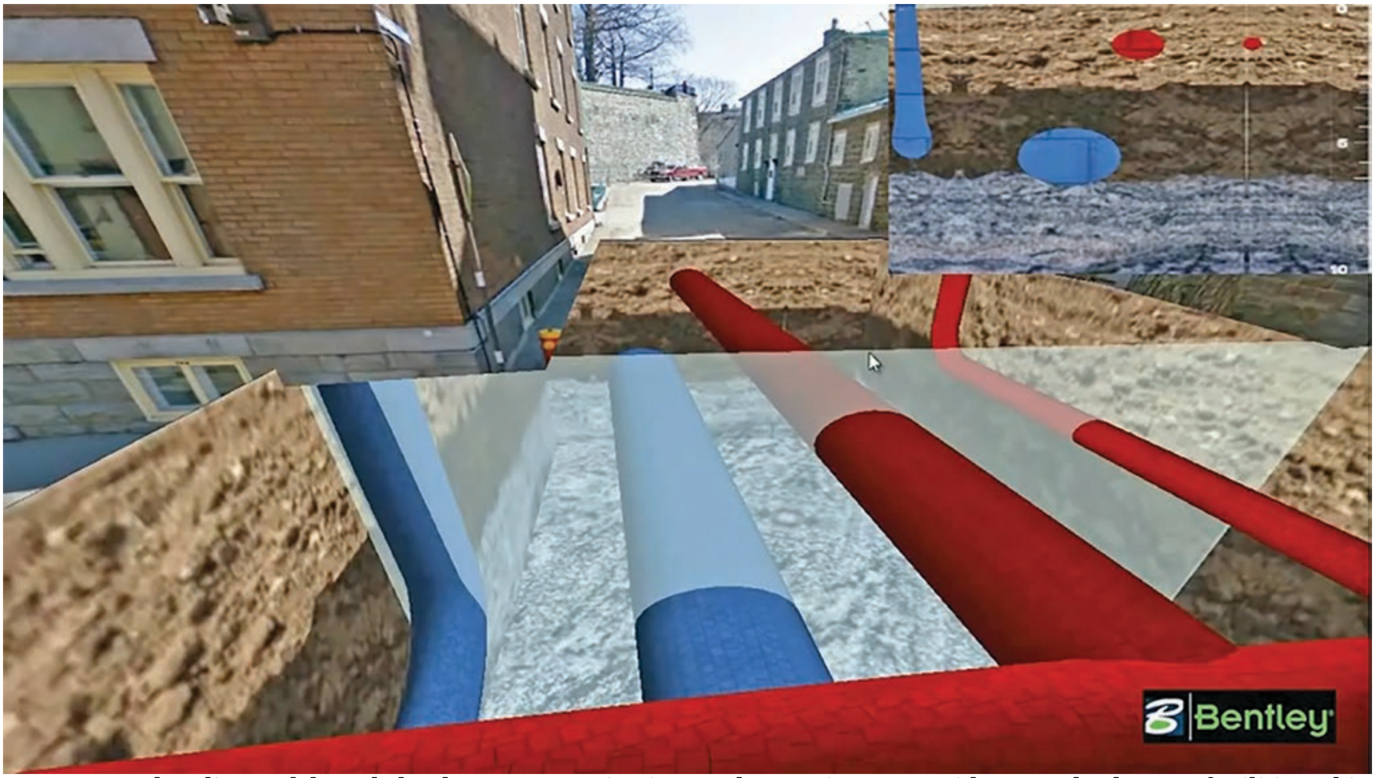
location away; chemical sensors can also be used, along with acoustic detection methods.

Technologies also exist for inspecting the interior of pipelines, some of which are described below.

It is important to note that no single instrument can detect or examine all underground utilities.

A variety of different tools are needed depending on the type of utility, its construction material and the particular local conditions.

You may remember an article on "Horizontal Drilling for Oil" in the July 2016 issue, which had a section




**An augmented reality model can help plan an excavation in an urban environment with a complex layout of utilities. This could even guide an excavator operator in real-time. See the video titled *"Augmented Reality Underground Utilities"* at https://youtu.be/KS_5OHoHHuo**

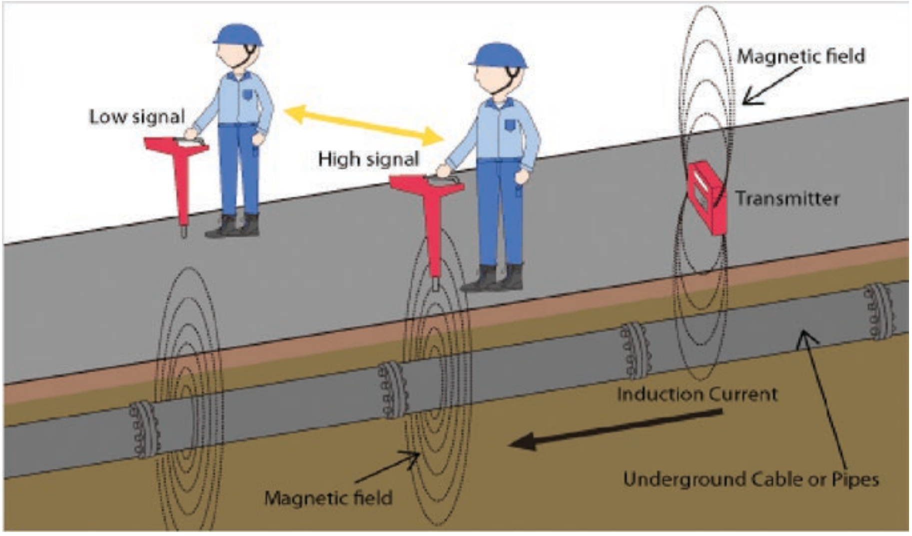



**Fig.2: the principle of passive or active electromagnetic locating. A metallic pipe or cable is energised with a low-voltage AC signal (by induction in this case), and an operator uses a detector to find the area of highest signal strength. External energising is not necessary if the cable already carries an AC signal. The signal can bleed onto other utilities when lots of cables or pipes or buried together, making detection of a specific pipe or cable difficult.**

on directional drilling for installing utility cabling and pipes. That is related to this topic, but we won't go back over that ground here.

## Earliest underground mapping

Electromagnetic induction (similar to what is used by modern metal detectors) was used from around 1910 to find buried cables.

The first patent awarded for a metal detector went to Gerhard R. Fisher in 1937 for his "Metalloscope" (US Patent 2,066,561). One of the stated uses for it was to find buried pipes.

The company he founded, Fisher Labs, is still operating today and makes utility-finding equipment among other things; see www.fisherlab.com/industrial/

## What is to be detected

The following underground objects may need to be detected or located:

- power cables (AC or DC, high or low voltage)
- telephone and other telecommunications cables including copper and optic fibre
- sewer, drinking water, stormwater or gas pipes (metal or non-metal)
- irrigation pipes
- traffic signal cables
- voids, such as tunnels or underground tanks

Unexpected objects which may be encountered during digging, besides the above, include:

- underground storage tanks
- septic systems
- old building foundations
- artefacts of archaeological interest
- buried rubbish


**Fig.3 (left): the Schonstedt RD5100H2O+ transmitter (grey box) and handheld receiver unit, for passive or active location of electrically conductive utilities.**

## Overview of location methods

There are a variety of methods that have been developed to find the above.

At the most basic level, underground services can be located visually, such as by observation of surface penetrations like access covers.

Recently-buried cables or objects may also be marked on plans which have been filed with the appropriate authority (councils, etc).

Utilities which are not found via either of these methods can be located by either passive or active means.

Passive methods of location include:

- detecting energy leakage from a cable, such as 50Hz mains hum from a power cable or RF noise from an unrelated RF source such as a low-frequency transmitter

**Fig.4 (right): the RD5100H2O+ at work, with the transmitter connected to a utility and handheld receiver unit in the background. Presumably, the Earth wire is being traced as the transmitter is connected to the body of the metal pole. The transmitter can also be used in an inductive mode, with or without a clamp.**

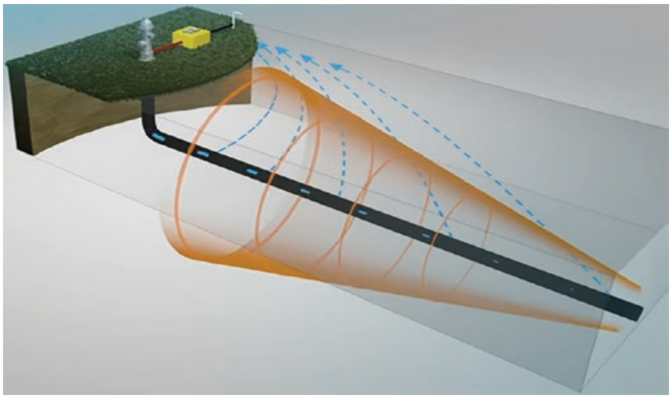


Fig.5: active location, where the yellow transmitter box is connected directly to a pipe and a ground stake provides the current return path. Image from video *"Schonstedt's Principles of Pipe & Cable Locating"* at: https://youtu.be/ACOHwbov19g

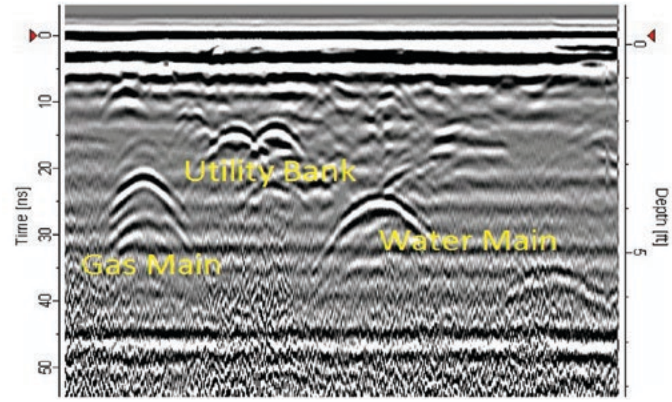



Fig.6: the result from a ground-penetrating radar showing several detected utilities. GPR scans require some interpretation. Figure courtesy of https://undergrounddetective.com

- noise from an active water or gas leak, or other noise generated by a fluid pipe such as the sound of fluid rushing through it
- perturbation of the earth's magnetic field by a buried ferrous object such as steel pipes, or the field of a magnet inserted into a non-ferrous or non-metallic pipe, or a magnet buried as a marker.

Active methods of utility finding involve injecting energy into the utility line of interest, then detecting that energy with a separate receiver. Forms of energy injected might be RF energy for an electrical conductor, sound energy for plastic water or gas pipes, or sound from a miniature transmitter on an extendable rod (rod and sonde method).

Other methods include looking at bulk soil properties such as resistivity to reveal the presence of underground structures, or to determine soil electrical properties. Sometimes dye or radioactive markers are injected into a gas or liquid line if only the outlet needs to be established, and not the route.

## Visual methods

Visual location is the most basic method of finding underground utilities. A series of access covers can indicate the path of an underground cable or pipe. The danger in this approach is that it requires the assumption that cables or pipes run in straight lines between access covers, pits and junction boxes.

Other things to look for are above-ground valves, marker posts and warning signs, kerb markings and damaged surfaces indicating that area has been dug up before. Sometimes partial excavation can also help to establish the likely path of the utility.

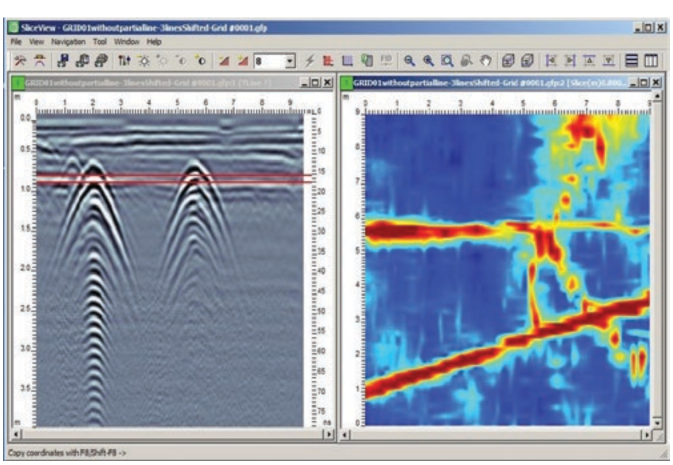
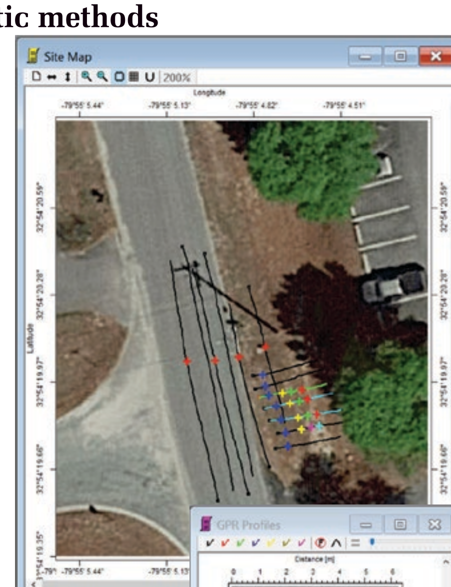


Fig.7: the Radiodetection RD-1500 GPR software can interpret a series of GPR vertical 'slices' to produce a map for a particular depth. The two red lines on the left image show the slice depth.

## Electromagnetic methods

Electromagnetic methods are the most common methods used for finding underground utilities. Of these electromagnetic methods, passive and active detection and ground-penetrating radar (GPR) are the most frequently used.

For passive or active detection, a metal utility cable or pipe is energised with an AC signal, and the radiated magnetic field from this is then detected with an appropriate receiver. Passive location can be used if the utility naturally radiates a signal.



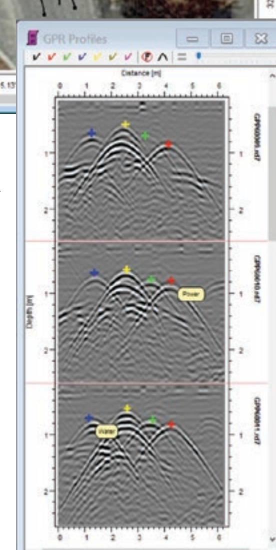




Fig.8: the MALÅ Object Mapper is a software package that can be used to plot GPR data on a Google Maps image. The black lines on the top image show the path of the GPR machine and the coloured crosses represent utilities found from the vertical slices shown at right.


**Fig.9: a typical Ground Penetrating Radar (GPR) machine in operation. It is pushed along the ground like a lawnmower, and data is recorded as a function of position.**


**Fig.10: the AML Pro uses a 2.45GHz beam and is said to be able to find plastic pipes or any buried object that has an edge, including metal pipes.**

In this case, only the receiver is needed.

## Passive electromagnetic detection

The passive method can be used when there is already an alternating current flowing through a cable. Sufficient current flow is required for the radiated signal to be detectable. Some cables also radiate signals due to coupling of long-wave or medium-wave radio stations.

One problem with this method is that the signals are liable to change without notice. Another problem is that it can be challenging to differentiate between multiple cables, since the same signals might travel in all of them.

Single-phase power cables radiate strongly at mains frequencies and related harmonics but three-phase cables radiate much less, as the phase fields tend to cancel out if the current flow is balanced.

For finding three-phase cables, lower radio frequency signals present in the environment that naturally couple into cables can be detected by many types of locating receivers (via a "radio" setting). But in this case, performance varies based on how well the cables are grounded, the soil conductivity and the line length.

The main advantages of passive detection are that it is fast, and only a receiver is required. But it can miss unexpected cables and pipes which may not be radiating anything.

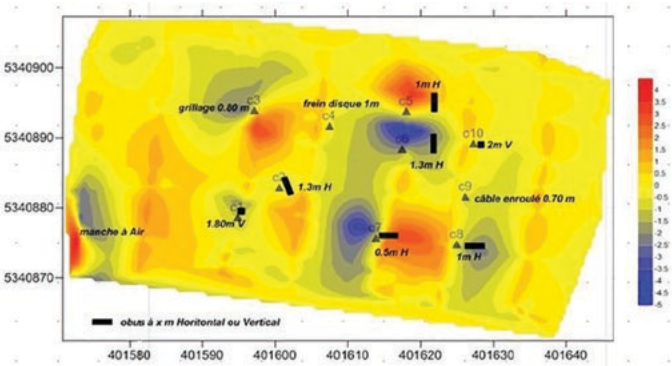



**Fig.11: a French airborne magnetic survey from a drone, looking for unexploded ordnance (UXO). The rectangles represent unexploded shells (obus) and their orientation, horizontal or vertical and dimensions. Source: ECA Group.**

## Active methods

In the active method, an AC signal from a transmitter is induced into a utility service of interest that is to be traced.

Unlike the passive method, specific lines can be positively identified and traced, which is very useful when there are many services in the same place. With some detection devices, the frequency of the injected signal can also be changed to suit conditions.

Direct injection is the best and most reliable method. The transmitter is connected via a clip to a bare metal surface of the conductor under investigation.

If that is not possible, a clamp around the pipe providing inductive coupling is the next best method. This is a similar arrangement to a current clamp meter, but operating in reverse.

If that is not possible, an induction unit can be placed on the ground above the pipe to provide inductive coupling, but the amount of coupling in this case is small, and consequently, the received signal can be weak.

This method can also be used for plastic pipes if the installer takes the small amount of trouble to install a tracer wire at the time of installation. It might also be possible to insert a metallic conductor inside an existing plastic pipe; see the section below on the "rod and sonde" method.

Multi-frequency tracer units allow you to choose a frequency appropriate for the soil and other conditions. The

**Fig.12: a handheld magnetometer, the Schonstedt GA-72Cd Magnetic Locator. This can be used to find UXO, and the military version is also used in de-mining operations in war zones. It looks for ferrous materials and does not respond to aluminium, brass or copper.**

Fig.13: a concrete slab marked with the location of rebar and conduit, found with GPR. Image from www.ladsqld.com.au/services/concrete-scanning

lower the frequency, the better it keeps to the line being located, and the less is radiated to nearby lines. However, there is also less chance of it passing through interruptions on the line such as joins and splices. It will also travel further.

A higher frequency travels over joins better but does not travel as far along the utility.

Generally, it is better to use a lower frequency if possible. As an example of frequencies available, the Schondstedt RD5100H2O+ detector has options for 4kHz, 8kHz, 9.8kHz, 33kHz, 65kHz, 83kHz, 131kHz and 200kHz. When it is using a sonde (see below), frequencies of 512Hz, 640Hz, 8KHz and 33kHz can be used.

## Ground-penetrating radar

In ground-penetrating radar (GPR), the beam is directed downward into the soil to find buried objects. The frequencies used are in the range of 10MHz to 2.6GHz. Buried objects have a different electrical permittivity to the surrounding soil, so radar signals are reflected, refracted or scattered back to the surface.

GPR uses include finding pipes (including plastic types), cables, underground voids and tanks, underground structures like old building foundations, buried pits, valves and tree roots.

The performance of GPR is strongly dependent upon soil conductivity; higher conductivity soils attenuate the radar signal more. Lower-frequency signals penetrate soil further but offer a reduced resolution. GPR performance is consequently a compromise between resolution and soil penetration.


Fig.14 (above): the MIRA Tomographer.

### DIY pipe, conduit and leak locating

You can make your own device to locate non-conductive pipes such as PVC. You push a wire up the pipe, which is attached to a signal generator. The signal is detected with an AM radio at approximately 760kHz. See the YouTube video titled *"Homemade Electronic Plastic Pipe Locating Device(Circuit)"* at https://youtu.be/NtI4ZPjsKqM

It is claimed to work for pipes buried under concrete slabs as well, but it does not work on metallic pipes. Note that we haven't tested this device.

You can also use an acoustic method to detect a water leaks from a pressurised water pipe. This involves a length of PVC pipe as an acoustic waveguide, a foam cup and a stethoscope. See the video titled *"DIY water leak detector"* at: https://youtu.be/wfitM1KT8BM

You can use a DIY method to trace a metal pipe or conduit, using a fixed frequency oscillator IC such as the MCO-1510A, and a transistor radio. This is shown in the video titled *"DIY Wire/Conduit Tracer"* at: https://youtu.be/Ss6BWOsXiW8

GPR penetration through ice is excellent; ground can be detected several kilometres beneath the ice in Antarctica, compared to just a few centimetres of penetration in highly conducting soils.

In Australia, GPR is said to be popular in WA due to favourable (dry, low conductivity) soil conditions but less popular in Victoria due to less favourable (moist, higher conductivity) soil conditions.

The AML Pro series of underground utility locators (www.ssilocators.com/products/AML-PRO) use 2.45GHz beams to look for density differences in the subsurface. These are said to be able to locate plastic pipes or any other underground object with an edge. It is said not to suffer from the deficiencies of ground-penetrating radar and will work in clay, wet soil, snow or even standing water.

For more on the AML Pro, see the video titled *"change in densities"* at https://youtu.be/U-Z0JgdIvMk

## Magnetometry

Buried objects can be weakly magnetic, or cause perturbations in the earth's magnetic field. These can be picked up by a sensitive magnetometer. Apart from archaeology and mineral surveys, magnetometry can be used to find buried

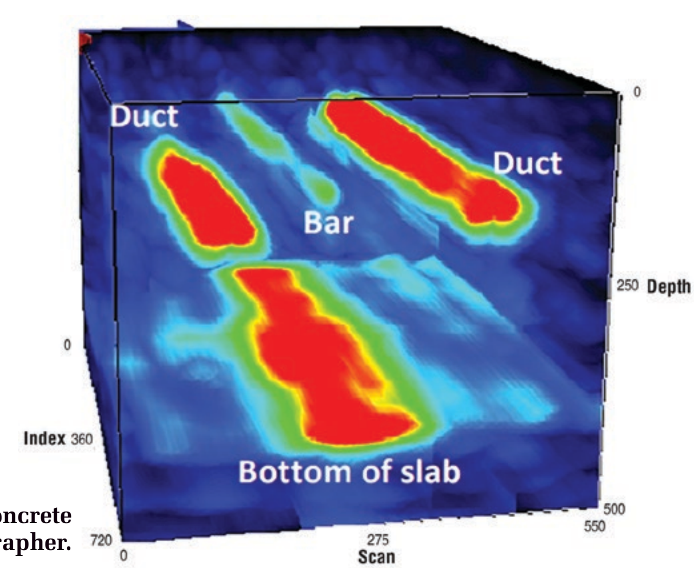



Fig.15 (right): a 3D tomographic view of a concrete structure made with the MIRA Tomographer.

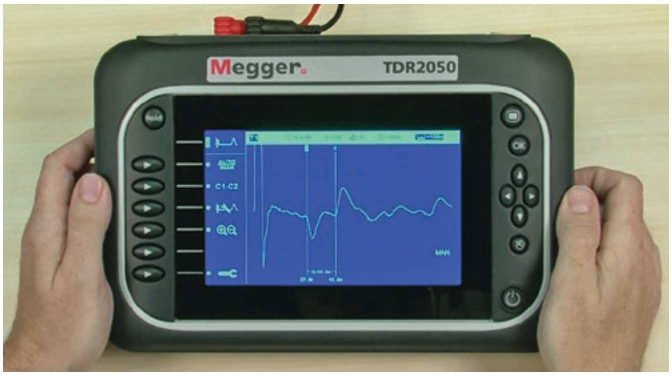



**Fig.16: a Megger TDR2050 TDR in use. See the video titled *"TDR2050 introduction, function and operation"* at https://youtu.be/SjAonwhZqVk**

ferrous objects such as utility pipes.

This technique can also be used to find valve boxes, steel enclosures, manhole covers, marker magnets (see below), reinforced concrete septic tanks and well casings. A video on the use of magnetic location titled *"Principles of Underground Magnetic Locating"* can be seen at https://youtu.be/sTFIUyL0-Ow

Magnetometry can also be used to survey archeological sites and in mineral exploration. Plus it is commonly used to find unexploded ordnance such as on old bomb practice ranges or former war zones.

## Concrete scanning

Services such as water and power are sometimes buried in concrete. It's important to know where it is safe to penetrate a concrete structure, to avoid rebar and post-tension cables etc. Methods used to achieve this include x-rays and ground-penetrating radar.

Ultrasonic tomography is an alternate means of examining the inside of a concrete structure for rebar, ducts and conduits. This uses ultrasound with a pulse-echo method. One instrument which does this is the MIRA Tomographer (http://germann.org/).

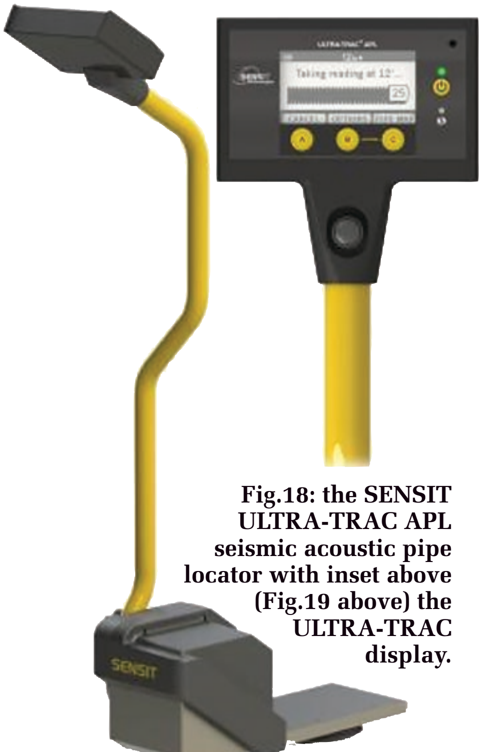



**Fig.18: the SENSIT ULTRA-TRAC APL seismic acoustic pipe locator with inset above (Fig.19 above) the ULTRA-TRAC display.**

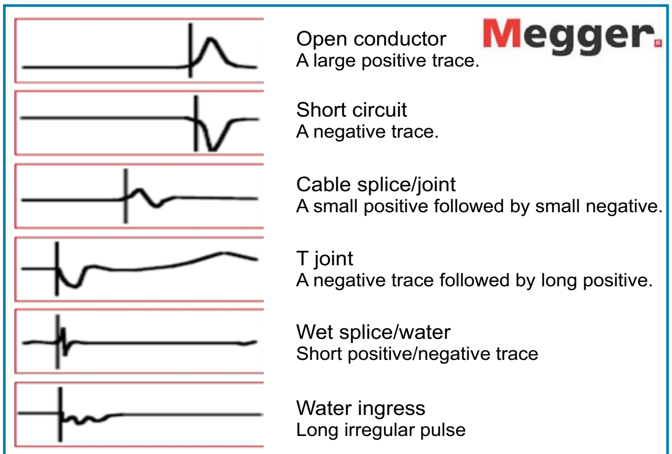



**Fig.17: example traces from a TDR. Signal strength is on the vertical axis and time along the horizontal axis. The distance to the discontinuity in the cable to be determined from the time delay. The velocity factor (relative to the speed of light) varies from 0.45-0.57 for an EPR power cable to 0.82-0.98 for coaxial cable.**

## Time-domain reflectometry

A time-domain reflectometer (TDR) emits a signal on a conductor (eg, a power or telecom cable) and then 'listens' for reflections. These indicate the presence of a break or other discontinuity such as a short circuit or bad cable splice. It functions similarly to radar, but in one dimension, along the cable.

TDR accuracy can be affected by twists and bends in the cable and also not knowing the precise speed of light in the particular cable under test. For best results, the cable should be tested from both ends, in which case the transmission speed is not critical.

We published a DIY TDR design in our December 2014 issue (siliconchip.com.au/Article/8121).

## Acoustic methods

Acoustic methods can be used to find non-metallic objects and are especially useful if an object like a sonde, metal-


**Fig.20: the Leaktronics PG-2 pulse wave generator connected to a domestic water pipe.**

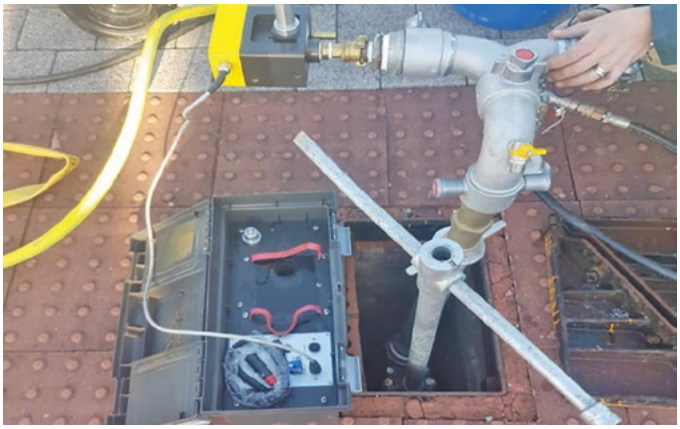


**Fig.21: a pulse wave generator or 'thumper' attached to a water main. The device is self-powered by water pressure being released through the device (via the yellow hose), although in this case is electronically controlled for frequency and intensity. Image credit: SES Water Management.**

**Fig.22 (right): a Sewerin "Knocker" which attaches to the outside of a plastic or other pipe with a chain and makes a knocking sound of adjustable frequency and intensity. This is conducted along the pipe and can be detected above ground. No water is released.**

cored rod or magnet cannot be inserted into a pipe. These methods include seismic, acoustic emission, active sonics, passive sonics and resonant sonics. Sonic methods can also be used to locate metal pipes.

The seismic method is a relatively new technique, and applicable to depths of 5-10 metres. A sound wave is injected into the ground, and a reflection from the buried utility is listened for. It is similar to SONAR.

With the SENSIT ULTRA-TRAC APL device, a series of soundings are made in the form of "pings", five in a row

Fig.23 (left): a SubSurface Leak Detection (www.subsurfaceleak.com) LD-12 instrument in use. Such equipment is also used to trace utility pipes when a pulse wave generator device is connected.

Fig.24 (below): the relatively inexpensive V18 water leak detector (http://etowos.com/). See the videos titled *"Acoustic Water Pipe Leak Detector +905414883700"* at https://youtu.be/QCaoX3Bfu2w and *"V18 Water Leak Detector"* at https://youtu.be/_wxJkkjt1hc


with a minimum of three rows. Software then constructs an image from the reflections created by an impedance mismatch of the buried object with the surrounding soil. See the video titled *"Locating with the ULTRA-TRAC® APL"* at https://youtu.be/YNvi5-Dx46Y

Three methods utilise acoustic emission: active, passive and resonant. Acoustic emission, as the name implies, involves using a transducer such as a microphone on the surface listening for noises generated by a pipe.

The premise used is that the noise will be loudest when the transducer is above the pipe, so this is the presumed location of the pipe. The emissions that can be heard are strongly dependent on surface type (eg, soil, concrete or bitumen), fill type and condition of fill, such as how compacted it is, plus the moisture level.

Active sonics involves creating a sound on or within a pipe. A simple example is striking a metal pipe with a hammer at an exposed point and listening for the radiated noise at points along the ground, to trace its source. Also, if there are multiple pipes, a pipe of interest can be struck at one end and the pipe that makes the most noise elsewhere can be assumed to be the same pipe.


Fig.25: part of the Adelaide CBD street plan, showing acoustic emissions over several days and the location of a leak indicated by this data.

Fig.26: a Hydro-Lok hydrogen leak detector (siliconchip.com.au/link/aaxf) in use. Hydrogen is an excellent tracer gas as it is cheap, there is a low natural concentration in air, it is relatively easy to detect, it is non-toxic (so it can be used in drinking water pipes) and it passes through tiny cracks.

Fig.27: the Cues MPlus XL Push System for visual pipeline inspection (siliconchip.com.au/link/aaxe).

A ‘thumper’ or pulse-wave generator is a device connected to a water pipe that causes a thumping sound when water is released through it. This sound is traced with above-ground listening equipment to trace the pipe. See the video titled *“The Pulse Generator PG-2 by Leaktronics - For Locating Pipes and Plumbing Lines”* at https://youtu.be/QqICLgDK8k4

Devices can also be attached directly to the outside of a pipe to knock the pipe, similarly to hitting it with a hammer. These methods are suitable for plastic pipes.

It is also possible to listen for noises created by a pipe when deliberately releasing water from an outlet such as a tap or hydrant. The noise carries along the pipe, and it can be listened for to locate the pipe.

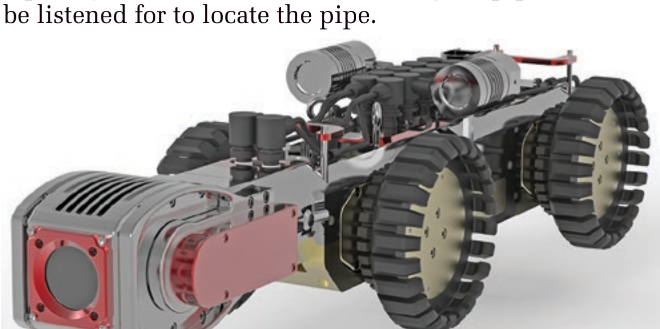


Fig.28: the Ryonic (www.ryonic.io/) Mini RMIS Crawler for inspection of 180-450mm diameter pipes.


Fig.29: a variety of sondes available from Radiodetection.

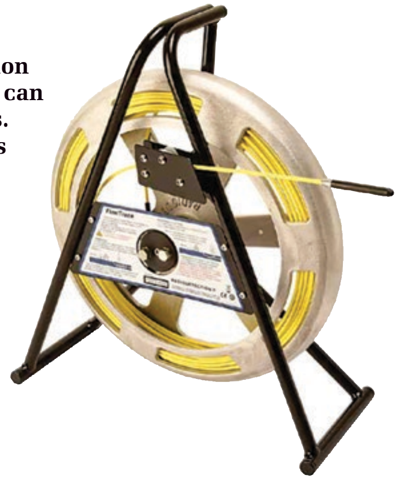


Fig.30: the Radiodetection Flexitrace, a rod which can be used to insert sondes. It is stored as a coil, has an integral conductor and can itself be energised along with the sonde. Energising the sonde only allows a pipe blockage to be detected; energising the entire rod enables a pipe to be traced.

The area of active and passive sonics also overlaps with the area of leak detection, whereby sounds generated by a leak are listened for. The equipment for hearing the sound is the same in both cases. Some devices therefore combine the functions of acoustic pipe location along with leak detection.

Part of the Gen-Ear equipment package (https://drainbrain.com/en/home-page/) includes a device to inject compressed air into the pipe system to enhance the sound of the leak. We have also read about a method of setting up resonance in a pipe to aid in its location in the literature, but we could find no current commercial device using this principle.

You can hear examples of various leak sounds, plus sounds from a hydraulic pulse wave generator at: https://leaktronics.com/leak-sounds/

Also see the video titled *"Gen-Ear LE Water Leak Locator - How-to Video"* at https://youtu.be/JYMT7WNADcA

## Real-time acoustic leak detection

The Adelaide CBD water network includes permanent, real-time acoustic emission monitoring to detect leaks. This comprises 305 acoustic accelerometers and associated communications, data logging and analysis equipment. There are also flow and pressure sensors installed.

The purpose of this is to detect small leaks before they become much larger leaks. You can read more about this at: http://siliconchip.com.au/link/aaxc

## Underground leak detection using hydrogen

Hydrogen can be used as a tracer gas when locating leaks in underground pipes using a gas sniffing device. Hydrogen is ordinarily flammable and explosive when mixed with oxygen, but a 5% hydrogen and 95% nitrogen mix is safe.

It is used as a tracer gas because the molecule is so small it will pass through any crack.

## Push cameras and robotic inspection

A push camera can be used for internal pipeline inspection. This is a camera attached to a long, flexible rod which is pushed along the pipeline of interest. The information obtained can augment above-ground detection.

A remote-controlled or robotic crawler can also be inserted into larger pipeline systems, to conduct a visual inspection to confirm the condition of the pipe and other information not determined by above-ground detection.

## Rod and sonde methods

Many underground services are made of non-conductive materials such as plastic or clay, and have been installed without the foresight of a metal wire or detectable marker tape to enable them to be located.

Ground-penetrating radar or acoustic methods could possibly detect such pipes if conditions are right, or they can be traced by a "rod and sonde" method. In the latter case, you need to know that they exist and have an access point to insert equipment.

The sonde is an instrument that transmits a signal. It is attached to the end of a tracer rod, which is pushed along the pipe. The signal from the sonde is detected by receiving equipment above ground, which is the same as used for passive or active detection.

In some instances, no sonde is used, but the rod has a metallic core which can be traced from above ground when inserted into non-metallic pipes.

Examples of services that can be traced are plastic conduits containing optic fibre (if there is room for a rod or sonde), plastic or clay pipes as used for sewer or stormwater, concrete pipes, plastic water pipes (if depressurised to allow insertion of a rod and sonde) etc.

As an example, sonde products from Radiodetection (www.radiodetection.com/en-au) operate at frequencies of 512Hz, 8kHz and 33kHz with sonde diameters from 6.4mm to 64mm, and stated detection depths are up to 15m.

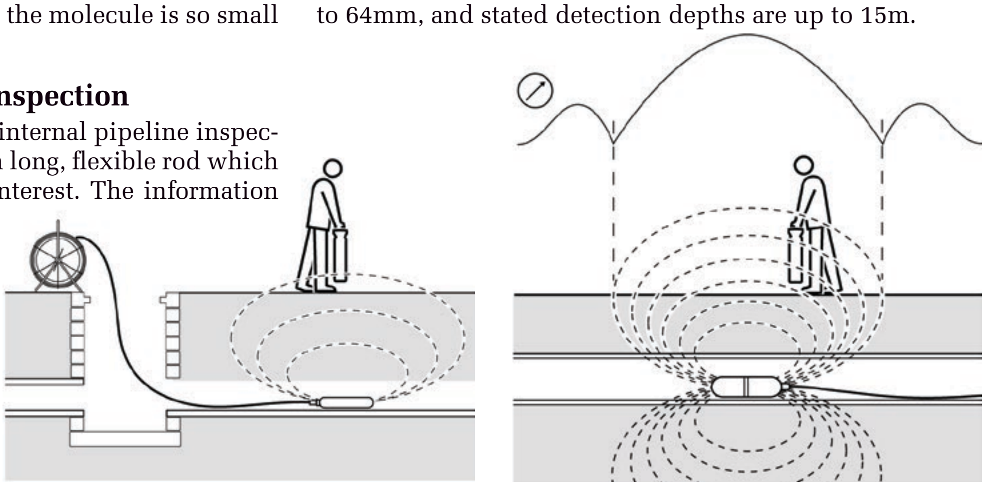


Fig.31: the rod and sonde detection method. An electromagnetic signal from the sonde is picked up at the surface.

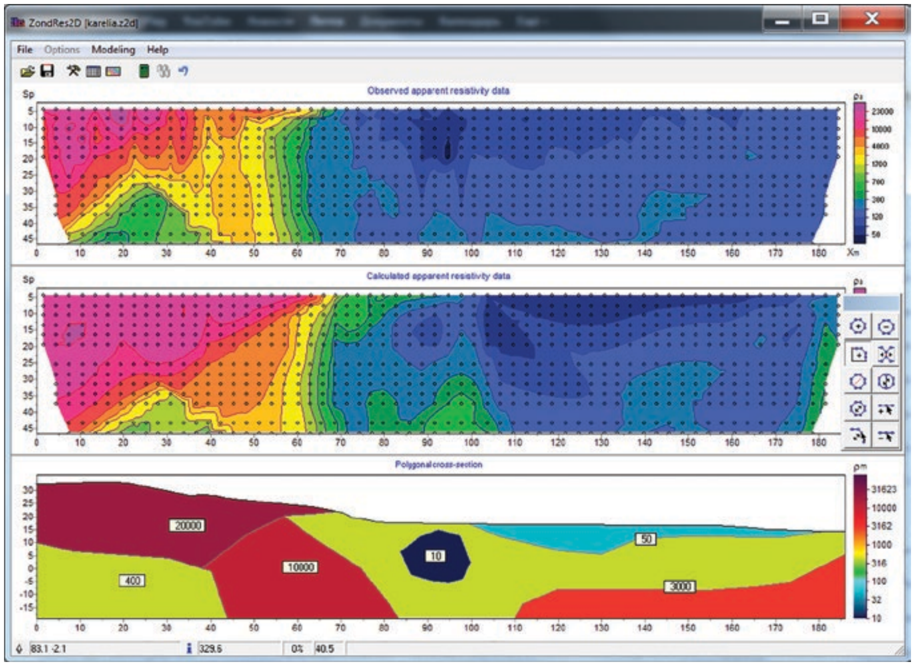



**Fig.32: an electrical resistivity imaging plot from the ZondRes2D software (siliconchip.com.au/link/aaxg). Surface data (top two plots) is used to generate a cross-section of soil resistivity at the bottom, across a particular transect of the surface data.**

## Electrical resistivity imaging

Electrical resistivity imaging is not generally used to find utilities as it is a time-consuming method. It is used for Earthing design for major electrical infrastructure such as power lines and substations.

A two-wire method is used to measure soil resistivity horizontally, while a four-wire method is used for vertical resistivity soundings. In the latter case, a constant current is applied across the outer electrodes and the potential difference measured across the inner ones.

## Frequency and time-domain electromagnetic methods

These methods are mainly used to examine major subsurface features.

In frequency domain electromagnetics, the transmitter current is varied sinusoidally at a fixed frequency, and the magnitude and phase of the induced current are measured to provide a measurement of subsurface electrical conductivity. This can indicate subsurface features, include metallic objects such as pipes.

In time-domain electromagnetics, pulsed current is sent into the ground, and a secondary magnetic field is established. The decay rate of that field is used to determine the subsurface electrical conductivity. It can map many types of subsurface features, including ferrous and non-ferrous metals.

## Utility 'potholing'

Potholing is a non-destructive excavation method to confirm the exact location of utility services in the vicinity of proposed construction works.

Air and hydro vacuum excavators are used to create a loose spoil that can be vacuumed away, to expose utility services and other underground structures. After work, the holes created can be filled in with that spoil or other fill.

Unlike a digging implement such as a shovel or backhoe, there is much less likelihood of damaging utilities with this method.

This method is important because it confirms the exact location of utilities which have been found by other methods. This method can also be used to excavate utilities to effect repairs.

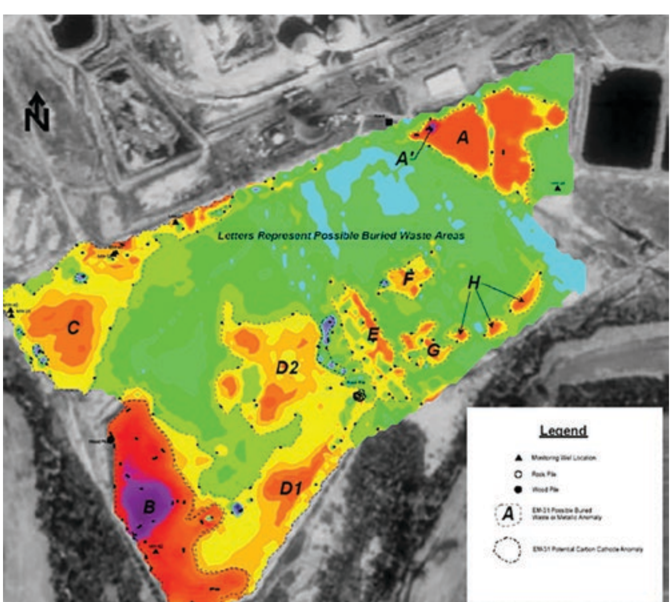



**Fig.33: a ground plot from the Geonics EM-31 frequency domain ground conductivity meter, showing various subsurface features. Source: Mundell & Associates, Inc.**

**Fig.34: a Geonics EM31-MK2 ground conductivity meter, which operates at 10kHz. Source: GeoView Inc. Compare this with the build-it-yourself "Incredibly Sensitive Magnetometer" which we published in the December 2018 issue (siliconchip.com.au/Article/11331).**

Fig.35: a Geonics EM-61 time domain metal detector. Note the GPS antenna. Source: GeoView Inc.

Fig.36: a 'potholed' site showing tree roots and utility cables. Potholing can be done to either locate services with certainty, or to make repairs once a leak or break has been located. Image source: Core Engineering, Inc.

## Dial before you dig!

Free information is available from public records in Australia on known locations of utility services. You can dial 1100 for the "Dial Before You Dig" service or visit the website at [www.1100.com.au/](www.1100.com.au/)

An equivalent free service is available in New Zealand by phoning 0800 B4UDIG (248344) or visiting [www.beforeudig.co.nz/nz/home/](www.beforeudig.co.nz/nz/home/)

## Location accuracy

For surveyors and excavators, the location accuracy of utilities recorded on plans or maps are rated according to the following Quality Level (QL) scores, based on Australian Standard AS5488:

- QL-A: sighted (eg, observed via pothole)
- QL-B: traced typical accuracy of ±300mm horizontally and ±500mm vertically)
- QL-C: aligned from surface features (low accuracy)
- QL-D: any other method

## RFID pipe tagging

An RFID tag can be affixed to a buried pipe to aid in later identification. One type from ELIOT Innovative Solutions ([siliconchip.com.au/link/aaxd](siliconchip.com.au/link/aaxd)) can be detected at a depth of 1.5m. See the video titled *"RYB ELIOT"* at: [https://youtu.be/MoUww2cIatY](https://youtu.be/MoUww2cIatY)

A tag does not have to be attached directly to a pipeline if it is deeper than 1.5m; a warning mesh with tags embedded in it can be buried above the pipeline at a detectable depth.

Some tags are said to be detectable at depths to 7m, presumably in favourable soil conditions. Figures are hard to

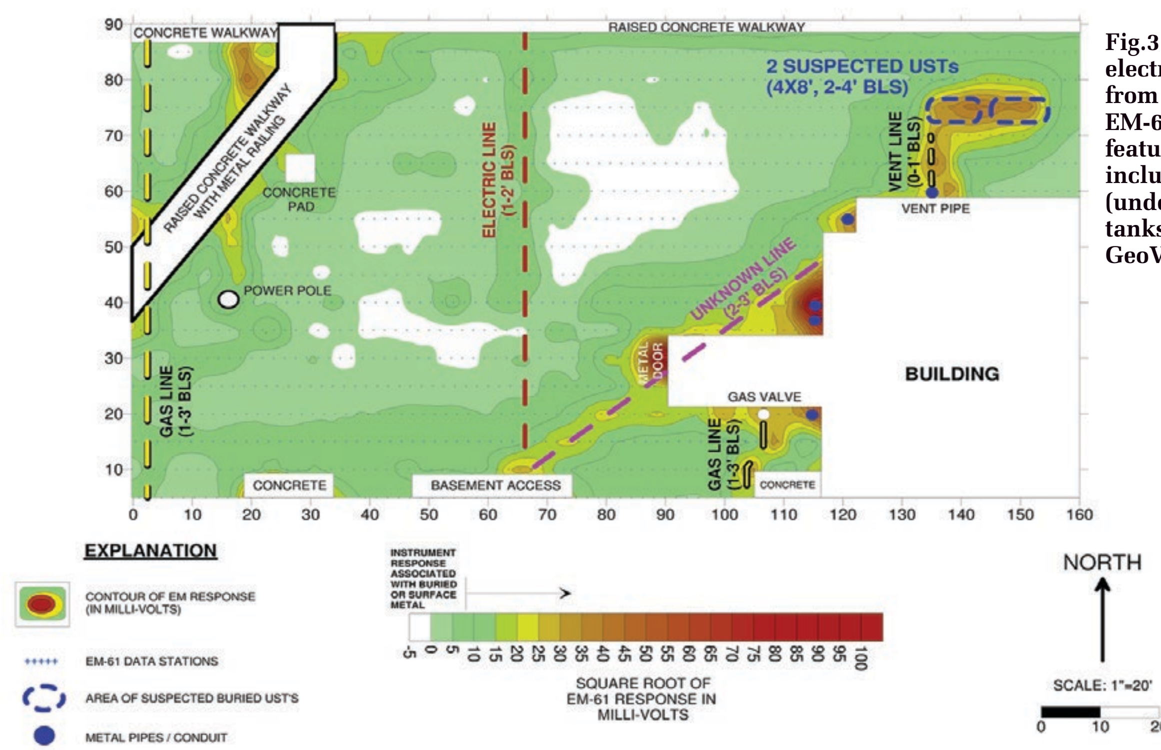



Fig.37: a time-domain electromagnetics plot from the Geonics EM-61. Various features are identified, including two USTs (underground storage tanks). Source: GeoView Inc.

**Fig.39: ELIOT Innovative solutions RFID tags on plastic (HDPE) gas pipe.**

come by, but we've seen a price quoted for tags at US$15 each and about 375 are needed per km. Much information can be loaded onto the tags.

## Marker tapes and magnets

It is good practice (or compulsory in some instances) to bury a marker tape in the trench above a utility service, to ensure there is a visual warning for future excavators. Some such tapes are also electronically detectable.

Magnets can be buried at the same time as a utility to aid in later finding. See the video titled *"DEEP-1 Video - Underground Magnets for Utility Marking"* at: **https://youtu.be/N6GVP3LqD8Q**

Non-detectable marking tapes are covered by Australian and New Zealand Standards AS/NZS 2648.1 1995 and AS/NZS 4275 Part 0 1995. Marker tapes for electrical services should comply with AS/NZS 3000 : 2007 clause 3.11.4.5, and should be located about halfway between the service and the surface.

Once an underground utility service is located, it needs to be marked. This is commonly done with coloured spray paint on the ground, or flags pushed into the ground where

**Fig.42: these marker tapes have an embedded stainless steel wire to make detection easier. Non-detectable tapes are also available but only provide a visual warning as a digger comes close to an underground utility AND if the tape is spotted!**

**Fig.41: warning mesh with embedded RFID tags from ELIOT Innovative Solutions.**


**Fig.40: the detecting device for ELIOT RFID tags.**

possible. The marking colours are specified by Australian Standard AS5488.

## The digital urban model

By combining data from a variety of sources, it is possible to create a "digital urban model". This is a system where the location of utilities, buildings and all other structures are accurately recorded in a geographic coordinate system. This can also form part of an augmented reality model.

This information can also be utilised by excavation equipment to automatically avoid buried objects during the digging process. SC

### Leak detection professionals don't always get it right…

I had a mains water leak under my home's concrete slab. A professional leak detector was called in, who used listening equipment to find the leak.

Unfortunately, after plumbers had dug through a tiled floor and 150mm of reinforced concrete, the leak was nowhere to be found. They eventually found it about two metres away, requiring further slab excavation work...

A colleague reported exactly the same thing – in his case on a steep, reinforced concrete driveway. A significant mains leak was reported to the water board and they turned up with some very professional-looking equipment to find the source.

When the first hole they jackhammered didn't show water, they tried again again about three metres away – and even the second attempt was out by another metre or so, resulting in an even larger hole in the driveway (and, he reports, a very botched "repair").

Underground utility finding is based upon firm scientific principles, but different techniques apply to different conditions. Underground utility finding requires a good amount of skill, plus plenty of experience to interpret the results, especially when multiple utility services are located close to each other.

### Utility locating as a career

If looking for a new career, this might be worth investigating. I have quite a bit of experience with utility locating firms, and one thing that I found quite consistent is that their fees are substantial!