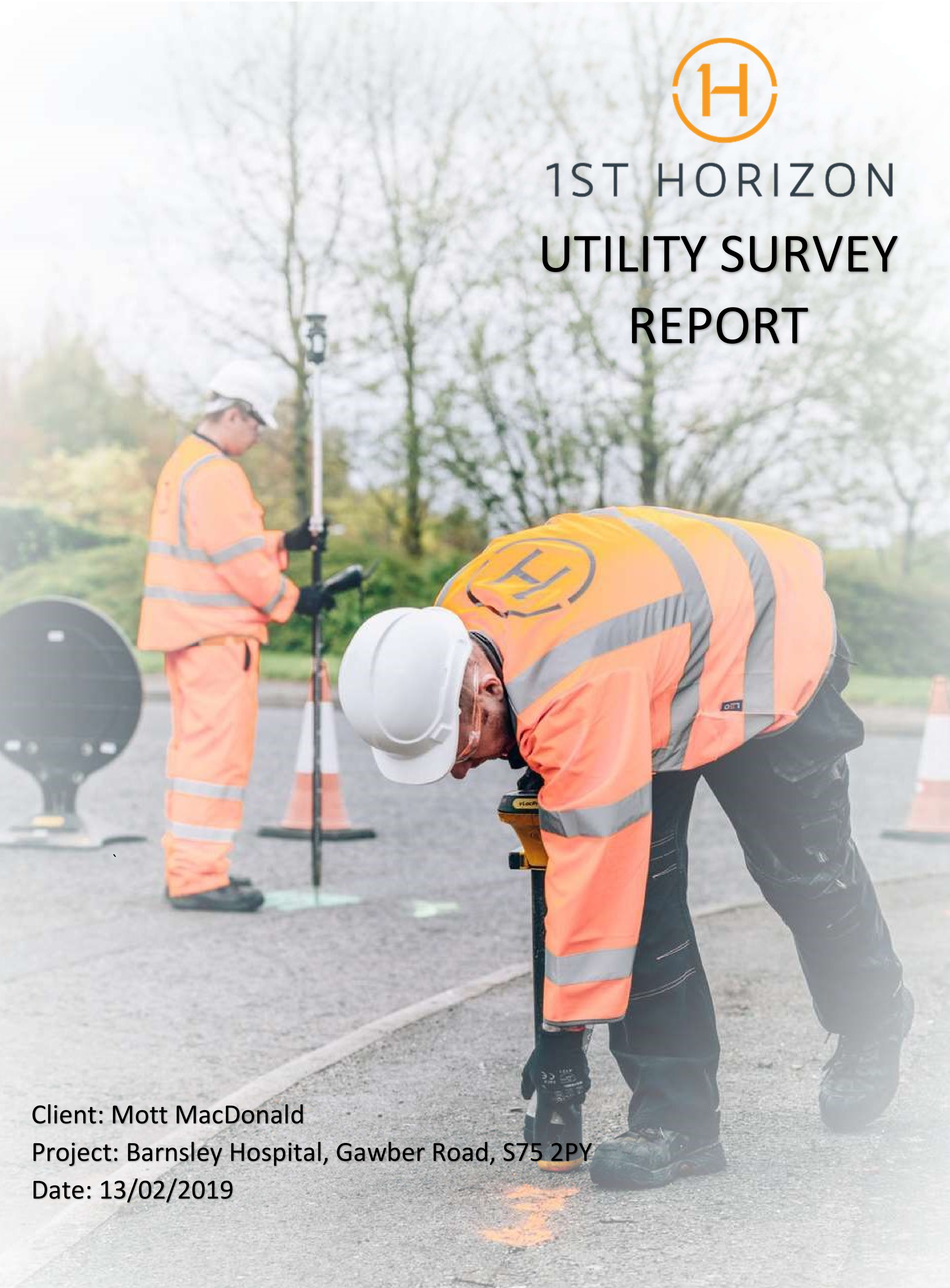

1ST HORIZON

UTILITY SURVEY REPORT

Client: Mott MacDonald

Project: Barnsley Hospital, Gawber Road, S75 2PY

Date: 13/02/2019

1ST HORIZON

<u>This report is to be read in conjunction with DWG MMB-BH5132-TS</u>

Table of Contents

1.0 - Summary

This report aims to provide details of any issues that arose during the recent survey works at Barnsley Hospital, or of any mitigating factors and circumstances that may have affected the survey works. In particular, this is related to the utility survey aspect of the overall survey works.

1.1 - Introduction

1st Horizon Surveying & Engineering Ltd recently undertook a comprehensive Topographical, Utility & 3D Laser Scanning & CCTV Survey at Barnsley Hospital, commissioned by Mott MacDonald.

The purpose of the survey was to produce a detailed CCTV report of the drainage, a detailed Utility & Topographic survey & Elevation drawings of the building for the client.

To deliver the project, 1st Horizon mobilized teams of multi-skilled operatives with a range of different expertise. These included topographical surveyors, specialist laser scanning teams, utility surveyors and GPR (Ground Penetrating Radar) operators & a CCTV survey technician.

State of the art equipment, techniques and software were used, along with extensive site experienced operatives to achieve the highest quality of survey.

1.2 – Aims & Objectives

The purpose of this document is to give the reader an overview of the complexities of utility mapping in a general sense, as well as detailing the issues specific to the recent survey at Barnsley Hospital.

The first part of this report details general utility mapping methodology and general limitations applicable to all sites. As well as this there is a tabled section detailing unique references (if any) relating to the survey at Barnsley Hospital

The second part of the report details the limitations of utility mapping in different site environments, as well as more detailed explanations on issues (if any) arisen from the survey at Barnsley Hospital.

1.3 - GPR (ground penetrating radar):

Ground penetrating radar (GPR) is a geophysical method that uses radar pulses to image the subsurface. This non-intrusive method uses electromagnetic radiation waves and detects the reflected signals from subsurface structures. The GPR device is an essential tool in The Underground Detective arsenal, requiring years of experience to correctly interpret its results.

Although GPR is very useful for scanning larger area masses and for determining the location and depth of previously unknown objects or soil conditions, it does have limitations that must be taken into consideration.

GPR is used for several jobs, but the most common it is used for is locating and searching for:

- Non-metallic pipes
- Underground storage tanks (UST)
- Trenches
- Voids
- Anomalies

Since the soil does not have to be disturbed, GPR is a safe and cost-effective way to identify underground unknowns. GPR units consist of an antenna which transmits radio wave pulses which is pushed or pulled over the ground in a cart, and a visual of the readings are viewed instantly on a screen for the surveyor’s interpretation.

GPR Limitations with HIGH frequency antennas (often used for concrete scanning applications):

- Moisture – It is known that water is the most reflective material a radar pulse will encounter. Given this information it is easy to understand why moisture presence in a concrete slab would inhibit the effectiveness of GPR. Moist or ‘green’ concrete can be problematic for GPR as the presence of moisture will reflect/inhibit the passage of the radar pulse and thereby limit penetration and data quality.

- Elevated Concrete: Scanning of elevated concrete slabs is most commonly done prior to core drilling for the purpose of mapping embedded objects and reinforcing steel. It is recommended that an elevated slab be allowed to cure up to 3-4 weeks where slab thicknesses of <12" are present. Further, 6-8 weeks of curing is recommended for slabs with a thickness of >12".
- Slab-on-Grade Concrete Applications: Scanning a slab-on-grade is most commonly done prior to saw cutting or demolition for the purpose of mapping shallow utilities and electrical conduits. The same recommendations are suggested with regards to moisture presence in the concrete. Further, if moisture is present in the soils/sub-grade immediately below the concrete the radar pulses can be inhibited, and accuracy/penetration will be limited.

- Depth Penetration – The depth range of GPR is limited by the electrical conductivity of the ground, the transmitted center frequency and the radiated power. As conductivity increases, the penetration depth decreases. This is because the electromagnetic energy is more quickly dissipated into heat, causing a loss in signal strength at depth. Higher frequencies do not penetrate as far as lower frequencies but give better resolution. Good penetration is achieved in dry sandy soils or massive dry materials such as granite, limestone, and concrete

- Frequency – High frequency antennas (1000MHz – 2.6GHz) are typically able to achieve signal penetration ranging between 12"-30".

  - **Rule of Thumb: The higher the frequency the less the signal can penetrate the medium. However, higher frequency antennas will provide a higher image resolution with more data detail. This tradeoff is present across all GPR antennas.**

- Medium/Composition - The composition of both the concrete and sub-grade soils is paramount to achieving maximum signal penetration with high frequency antennas. As noted above, moisture presence will limit the depth penetration of GPR. Further, sub-grade debris and other random anomalies can reflect the radar signal before it is able to achieve maximum penetration. Lastly, the quantity of reinforcing steel present within the concrete can also reflect the signal and thereby limit its ability to penetrate the concrete.

- Size of Target – There are two main ways in which GPR is limited when discussing the size of a target.
  - Diameter of Target: GPR technology is unable to determine the size/diameter of the target being located. Ground penetrating radar is collecting a 2-Dimensional slice

through the scanned medium, such as concrete, and therefore does not detect the entire circumference of the anomaly being located.

  - Level of Detail when locating a Target: While it is possible to locate many objects with GPR there can be objects that are simply too small for the radar to find. While this limitation is more widely experienced while using low frequency antennas (which provide lower resolution data) it can be an inhibitor when scanning concrete with at high congestion of reinforcing steel or small objects buried at depths more than 10”.

- Composition of Target – It is possible for GPR to locate a target/anomaly possessing a differing electromagnetic conductivity. That being said, there are objects which are found more easily. It is true that GPR can locate empty plastic (PVC) conduits and pipes; however, it is easier to locate a highly reflective piece of metal reinforcing steel. Therefore, composition of the target can be a limitation with regards to locating. For example, it will likely be very difficult to locate a plastic conduit running below a tightly spaced grid of reinforcing steel as the rebar is a positive reaction, identified more clearly in the data, than the negative reaction of the plastic conduit. Again, it is possible to locate an object with a differing electromagnetic conductivity but there are objects which are easier to locate as their reflectivity is much higher or lower, by contrast, to the surrounding scanned medium or located anomalies.

- Quantity of Anomalies – Our GPR limitations noted above have briefly mentioned this constraint. The quantity of reflective objects found in the scanned medium (concrete or other) can have a direct impact on GPR signal penetration and the radar’s ability to locate objects at greater depths. This is a direct result of the signal not being able to penetrate (as it is reflected back to the surface) beyond the initial layer of anomalies. This is often experienced, when scanning concrete, on an elevated slab near a column.

- Concrete Conditions – The surface conditions of the concrete can also pose limiting factors to ground penetrating radar. Concrete surfaces where standing water is present are unable to be scanned as the standing water will immediately reflect the signal before it penetrates the concrete. Further, concrete surfaces that are rough or pitted can affect the antenna’s ability to directly couple with the surface and thereby limit the signals ability to penetrate the concrete. The best concrete scanning conditions are found over bare, smooth concrete where there is little to no moisture present.

GPR Limitations with LOW frequency antennas (often used for utility locating applications):

- Moisture – It is known that water is the most reflective material a radar pulse will encounter. Given this information it is easy to understand why moisture presence in the soils would inhibit the effectiveness of GPR. Wet soils encountered while conducting an underground utility search are problematic and limiting. Further, the elevation of the water table present in the soils will, likely, directly correlate to the maximum depth penetration of the radar. We do not conduct an analysis of soil composition or soil conditions.

- Depth Penetration – The depth range of GPR is limited by the electrical conductivity of the ground, the transmitted center frequency and the radiated power. As conductivity increases the penetration depth decreases. This is because the electromagnetic energy is more quickly dissipated into heat, causing a loss in signal strength at depth. Higher frequencies do not penetrate as far as lower frequencies but give better resolution. Good penetration is achieved in dry sandy soils or massive dry materials such as granite, limestone, and concrete. In moist and/or clay-laden soils and soils with high electrical conductivity, penetration is limited. We do not conduct an analysis of soil composition or soil conditions.
    - Frequency – Low frequency antennas (100MHz – 900Hz) are typically able to achieve signal penetration ranging between 4'-30'.

- **Rule of Thumb: The lower the frequency of the antenna the further the signal is able to penetrate the medium. However, lower frequency antennas will provide a lower image resolution with less data detail. This tradeoff is present across all GPR antennas.**

- Medium/Composition - The composition of the soil is paramount to achieving maximum signal penetration with low frequency antennas. As noted above, moisture presence will limit the depth penetration of GPR. Further, sub-grade debris can reflect the radar signal before it is able to achieve maximum penetration. We do not conduct an analysis of soil composition or soil conditions.

- Size of Target – Low frequency antennas experience limitations regarding the size of target being located as there is a loss of resolution. There are two main ways in which GPR is limited when discussing the size of a target.
    - Diameter of Target: GPR technology is unable to determine the size/diameter of the target being located. Ground penetrating radar is collecting a 2-Dimensional slice through the scanned medium, and therefore does not detect the entire circumference of the anomaly being located.
    - Level of Detail when locating a Target: While it is possible to locate many objects with GPR there can be objects that are simply too small for the radar to find. This limitation is most frequently experienced with low frequency antennas and specifically about utility locating projects. Given the noted resolution loss, variance of soil compositions
    - and other factors the following rule is a general guideline for locating small objects with ground penetrating radar.

        - **Rule of Thumb: For every foot deep, an object is buried it will need to be at least one (1) inch in diameter. In order to locate a utility at 4' (48") deep the pipe would need to be at least 4" in diameter.**

- Quantity of Anomalies – The quantity of reflective objects found in the scanned medium, such as soil, can have a direct impact on GPR signal penetration and the radar's ability to locate objects at greater depths. This is direct result of the signal not being able to penetrate (as it is reflected back to the surface) beyond the initial layer of congestion. Areas containing a high quantity of utilities may be problematic as the radar is unable to locate smaller objects or objects buried below other existing utilities. Again, if a shallow object reflects the radar pulse back to the surface it can, in essence, eclipse the utility buried just below.

- Composition of Target – While it is possible for GPR to locate a target/anomaly possessing a differing electromagnetic conductivity there are, often, objects that are found more easily. GPR can locate empty plastic (PVC) conduits and pipes even though plastics are considered non-conductive. It is, however, easier to locate conductive anomalies, such as metal pipes, as they possess greater reflectivity. Therefore, composition of the target can be a limitation with regards to locating. For example, it will likely be very difficult to locate a small plastic conduit running below three large metal water lines in the ground. The positive reactions will likely make the plastic conduit invisible given the strength of their reaction and the way in which they reflect the GPR signal. Again, it is possible to locate an object with a differing electromagnetic conductivity but there are objects which are easier to locate as their reflectivity is much higher or lower, by contrast, to the surrounding scanned medium or located anomalies.

- Soil Composition – The composition or materials which make up the soil through which the radar pulse is attempting to travel is a limiting factor. Highly conductive soils, such as clays, can limit the penetration ability of the radar pulse. By contrast, non-conductive soils, such as sandy porous soils, can greatly increase the ability of the radar pulse to penetrate the ground. The less conductive soils offer less 'interference' or reflection of the radar pulse and thereby allow it to penetrate to greater depths. The opposite is true of highly conductive soils. This can be problematic as soil composition can change wildly across any given inspection area.

1.4 - Utility locating (tracing)

Utility location is the process of identifying and labeling public utility mains that are underground using an electromagnetic field locator (EML). An electromagnetic locator, or pipe and cable locator is used for tracing utility lines and metallic pipes and clearing excavation and drilling locations as well as for future developments and proposed works. These utility locators consist of two main parts, a transmitter and a receiver. The transmitter emits a frequency selected by the surveyor that induces onto nearby pipes and cables. The receiver detects these radio frequencies, and the surveyor is able to accurately locate and trace the pipes and cables. Underground utility locating requires the use of a few different methods to accurately mark buried lines. These mains may include lines for telecommunication, electricity distribution, natural gas, cable television, fibre optics, traffic lights, street lights, storm drains, water mains and wastewater pipes. In some locations, major oil and gas pipelines, national defence communication lines, rail and road tunnels also compete for space underground.

Public utility systems are often run underground; some by the very nature of their function, others for convenience or aesthetics.

Radiolocation is the process of using radio waves to find the location of something. Electromagnetic equipment is often used, consisting of a transmitter and a receiver. Electromagnetic signals are often emitted from metal pipes and cables which are detected by the receiver. These signals can be generated by the transmitter and placed on the pipe or it can be naturally occurring low frequency radio waves and electrical noise.

Electromagnetic Location

This method of locating buried pipes, cables and sewers has become almost universal. Its main shortcoming is that it will not locate non-metallic lines such as plastic pipes. However, utilities taking the small amount of trouble to lay tracer wires with plastic pipes are not affected by this shortcoming. The technology has many advantages.

Electromagnetic location combines many advantages and facilities for obtaining information from the sub-surface underground that are not available from any other technique or combination of techniques.

- It can search an area from the surface to locate buried lines.
- It can trace and identify a target line.
- It can trace and identify sewers or other non-metallic ducts or pipes to which there is access; it can locate blockages and collapses.
- It can measure depth from the surface.
- It can monitor the progress of 'No Dig' tools and instruments.
- The technology can be used to provide data to steer equipment or tools both above ground and below ground, or on the sea bed.
- It can find some types of cable fault, monitor pipeline coating condition and locate water leaks in plastic pipes.
- The equipment is portable.
- The equipment is easily handled and is successfully used by workers.
- The technique works in all soil conditions; even underwater.
- The component parts of the technology are low cost. Sufficiently low cost to be purchased by small contractors or issued on a large scale by regional or national organisations.
- The technology exists today.

The wide variety of functions and applications requires just three basic building blocks:

- a signal generator or transmitter to apply a signal to a buried line.
- a small self-contained transmitter suitable for inserting in drains or ducts.
- a handheld receiver to locate the signals from the transmitters or to locate signals occurring 'naturally' on buried lines.

1.5 - Utility locating methods:

Direct Connection (Conduction)

This is the preferred method for locating metallic utility lines. It is the most accurate method providing the most options for the surveyor locating a buried utility line.

- The transmitter is placed next to an access point for the target line being traced (typically a valve, utility furniture, lamppost, or other point where direct contact with line can be made). A connection lead from the transmitter is connected to the target line and a second lead is connected to ground.
- The transmitter is adjusted for frequency and power output to match the properties of the target line being traced, surrounding soil and other utilities nearby. Application of the correct frequency is essential to prevent electromagnetic coupling or bleed off to other metallic utilities or objects.
- The receiver is then set to the same frequency as the transmitter, gain control adjusted accordingly, and the signal which is sent from the transmitter through the target line is traced and marked on the surface.

<u>Ring Clamp (Induction):</u>

Ring Clamp Induction is used to induce a signal onto a metallic cable or conduit where direct connection is not an option.

- A ring clamp is connected to the transmitter in place of connection leads and then clamped around desired metallic pipe or cable. Signal travels from transmitter to a coil within the clamp and onto the target line.
- The receiver is set to the same frequency as the transmitter as with direct connection and the target line is traced and marked on the surface.

<u>Induction:</u>

Induction is used when there is no surface access to the target line. Induction is the least desirable method of locating due to the massive amount of electromagnetic coupling or bleed off that is created. Induction method, when used properly is an invaluable locate method.

- The transmitter is placed on the surface, and over the point where the target line is thought to run.

- Once the target line is located, it is then traced with the receiver using the same method as direct connection.
- This method can also be used to perform an inductive search to locate unknown or abandoned lines.

Sonde:

A locating sonde is used when there is surface access to a buried pipe, but the pipe is non-metallic and not capable of carrying an EM signal. The sonde is a beacon that radiates its own set frequency which can be traced by a receiver. Applications include empty ducts, ducted non-metallic services, drains and sewers.

Detectable Duct Rod:

A Duct Rod is a flexible, detectable line that is pushed into drains, conduits and sewer lines which carries a signal from the transmitter using the direct connection method. The duct rod can be used together with a sonde attached to it.

- The sonde is pushed or pulled through the pipe, duct or sewer line with a duct rod and then traced using the direct connection method.

1.6 - Limitations of Utility Surveys:

Different site environments all provide their own unique difficulties and limitations and some may be simpler than others. Whilst employing every traditional underground survey methodology, using competent, experienced surveyors to carry out the survey, unfortunately, 100% coverage can never be guaranteed. Listed below are some of the most common problems the surveyor may face when mapping utilities in different environments:

Provision of Statutory authority plans, Service Records, Service Drawings.

Before commencing a utility mapping survey, it should be a recognised requirement and considered best practice to provide the utility survey team with any available utility stats or service records/drawings from providers understood to own assets or apparatus within the specified site. It is rare that this is the case, and subsequently it is left to the utility surveyor to attempt to source service records whilst on site, against the time/cost constraints of the job as well as on site deadlines. This will typically involve finding a drawing room and sifting through multiple drawings searching for anything applicable to the site. The provision of or access to service records is rarely forthcoming from site owners/reps and it is a time-consuming process to attempt to source records ourselves. Depending on the working hours of the job or a pre-agreed deadline to be off site, you may appreciate that in some cases there may not be time to look for records. Furthermore, there is every chance that not all underground services are documented on service records, drawings, as-laid, as-builts etc.

Access to Buildings, Plant, Kiosks, Pumping Stations, Drywells, Control Rooms, Electrical/gas buildings, Tanks etc.

The preferred method for inducing a signal onto a service is via means of direct connection. This is done using positive and negative connection leads and clipping onto a metallic valve or pipe risers etc. To use this method, the survey team may need to gain access to plant rooms, Kiosks, pumping stations, Drywells or any other building or room which may enable access to services. These areas may require some form of authorisation to gain access or may be classed as a confined space. Therefore, it is not always time-effective or cost-effective to gain access to these areas to attempt to trace services, or it simply may not be possible to gain any access at the time of survey, due to lack of authorisation. Where theses areas cannot be accessed other none intrusive methods are utilised to locate services.

On-site marking of services 'Taken from records'

Once all traditional survey methods have been exhausted; namely RFL (Radiofrequency Location) and EML (Electromagnetic Location) or GPR (Ground Penetrating Radar), the utility surveyor on site will perform a site walkover and cross reference any utility statutory authority plans, service records/drawings, as laid/as built drawings which have been made available at the time of survey. The purpose of this process is a quality control to establish the services mapped on site using RFL, EML and GPR techniques relate to services shown on utility records.

Any service lines remaining on utility stats/records, which could not be located or mapped on site using the traditional RFL, EML, GPR methods will be marked on site by the lead utility surveyor using the relevant utility drawing and will be annotated as 'Taken from records' or 'TFR'. In the case of 'as-built/as-laid drawings, if there are accurate dimensions and references on the utility drawing, the utility surveyor shall use these measurements and transfer them to on-site markings as accurately as possible using a tape measure.

In the case that no such measurements or dimensions exist on the utility stats/service drawings, the utility surveyor shall transfer the service lines from drawing to on-site to best-fit as possible, taking into account hard features such as building lines and kerbs, as well as associated street furniture, such as street lighting columns, sluice valves, wash-outs, manholes etc and their relative distances to the utility service line.

This can be done retrospectively in a digital format, although it has been more beneficial in the past to mark up and record all services on site, whether they have been mapped or unmapped, and annotate them accordingly. This reduces the chance of a service line or utility record being omitted altogether because it has not been marked up on site. All utility lines on site recorded as they normally would be using a robotic Total Station.

Ultimately, the recorded position of a 'TFR' utility line may still be inaccurate and/or erroneous. However, once the survey process has been exhausted, and every method has been utilised, and a service line still cannot be located and mapped, its onsite marking using a utility drawing, is the most accurate way to record it, without trial digging and confirmation, which is neither cost or time effective.

Site Walkover

Once all traditional survey methods have been exhausted; namely RFL (Radiofrequency Location) and EML (Electromagnetic Location) or GPR (Ground Penetrating Radar), the utility surveyor on site will perform a site walkover and cross reference any utility stats, service records/drawings, as laid/ as built drawings which have been made available at the time of survey. The purpose of this is a quality control procedure is to try and ensure the services mapped on site using RFL, EML and GPR techniques relate in some way to services shown on utility records.

Conclusion

It should be noted that in any event, the survey team will carry out a comprehensive survey process and methodology to attempt to map all underground services initially as per their site-specific RAMS. Survey techniques and methodology include but are not limited to: lifting/inspection of inspection chambers, sonding, sound-testing, dye-testing, direct connection, induction, capacitive coupling, passive and active modes, power & radio sweeps, GPR grids and on-site mark out, site walkovers, site handovers etc.

Our aim is to provide the highest level of service with without compromise.

If some of the above items are not achieved before and throughout a utility survey, then the integrity of the survey could suffer. It is imperative that all associated information and access points are obtained.

1.7 - Where services and their depth information are obtained:

Point of detection on a metallic pipe or cable. Tolerance depth of + / - 15%

Point of detection using means of drainage tracing, also where invert levels are taken from.

Point of detection when locating using GPR, accuracy dependent on ground conditions. Tolerance depth of + / -15%

1.8 - Equipment used on site to conduct a utility survey:

- Vivax Vloc pro3 (RFL/EML) consisting of Transmitter and receiver, direct connection leads and ring clamp.
- Leica/IDS DS2000 GPR (ground penetrating radar).
- Small cobra flexi trace (to locate small tight angled drainage i.e. Gullies, fibre optic routes and empty ducts).
- Medium cobra flexi trace (to locate drainage, fibre optic routes and empty ducts.
- Large cobra push rod with sonde attachment (to locate deeper drainage up to 2.5m, and in areas where utilities are congested).
- Hydraulic manhole lifter (to aid safe lifting techniques)
- Metal detector (to locate buried manholes and inspection covers.
- Selection of hand tools.

1.9 – Abbreviations

EML	**Electromagnetic Location**
RFL	**Radio Frequency Locator**
GPR	**Ground Penetrating Radar**
TFR	**Taken From Records**
AR	**Assumed Route**
UTL	**Unable To Lift**
UTT	**Unable to Trace**
UTS	**Unable to Sonde**
WWTW	**Wastewater Treatment Works**
STW	**Sewage Treatment Works**
SWD	**Surface Water Drain**
FWD	**Foul Water Drain**
CWD	**Combined Water Drain**