Combining the techniques of taking details relating to underground utility networks in the field

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Abstract
This paper aims to present the main techniques of taking details relating to underground utility networks in the field, non-invasive techniques that complete each other. This paper is based on a job that could only be completed using all methods in the field.
The client had a requirement to accurately map the existing underground utility network within a site boundary in Carlow. The survey was largely due to developers and contractors not carrying out accurate as built surveys on underground service utilities during the construction period. The field team was contacted by the client and asked to provide a non-intrusive and accurate solution to their requirement. Therefore in obtaining a solution, the operators combined a number of survey methods together to achieve the required result. These methods included a ground penetrating radar survey incorporating a multi frequency array radar system, radio detection surveys and finally manhole surveys.

Keywords
GPR, multi frequency array radar system, radio detection.

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1. Purpose of Investigation

The objective of the survey was to locate the position and depth of all existing underground utilities using a combination of non-intrusive survey techniques. As the main investigative techniques used are largely non-destructive, the findings given in this report are based on indirect measurements and the interpretation of acoustic, electrical and electromagnetic signals. The findings represent the best professional opinions of the surveyors, based on the field team experience and the results of non-intrusive pipe location carried out elsewhere on similar materials and projects.

2. Health, Safety & Environmental

Prior to commencing work all personnel working on the project on site had passed the FAS Safe Pass Scheme (training and employment authority) and the FETAC (further education and training awards council) approved detection and location of underground services scheme. No work was undertaken in the survey zones by any personnel who have not attended these schemes.
All works were carried out in a safe manner, using only certified equipment, and the work site maintained so that it functions safely and efficiently.
All persons, except when in offices or similar accommodation wore appropriate Personal Protection Equipment:

- Safety boots
- High visibility jackets, leggings and waistcoats
- Hand Protection
- Eye Protection

Where appropriate:

- Ear Protection

3. Survey

There were no restrictions on access to the site. All access was cleared with the client and landowners prior to mobilising to site.

IDS RIS MF System	IDS Detector Duo
	
Multi Array Radar System, with 3 x600MHz and 3x 200MHz channels with cross polarization	Dual frequency GPR operating at 250+700Mhz

RD4000 + RD8000	Leica 1203 Total Station
	
Most advanced pipe and cable locators available. IP54 Rating - can operate in any environment.	General Accuracy= 1mm+1.5ppm/ typ. 2.4s Angular Accuracy= 3"(1mgon)

Fig. 1 Equipaments used on this project

The successful detection and mapping of buried utilities involves the combination of several techniques, the results of which are synthesised down to a single interpreted plot. The techniques and methodologies used will primarily depend upon the required outcome for the survey, the site conditions and the type of pipes or cables being targeted.

- Survey crew open manholes and record and photograph all details
- Radio detection survey and Sonde survey is carried out within the survey area.
- The Ground Penetrating Radar survey is carried out across the survey area.
- Survey data is post processed and analysed then crossed referenced against site service records information in office.
- All survey information is reference onto a topographical survey drawing.

4. Ground Penetrating Radar (GPR)

A number of different GPR grids were set out over the site. Data field files were collected with a multi frequency array antenna system to give maximum depth penetration whilst maintaining a high resolution at both shallow and deep depths. Full calibration was carried out at the start scan with constant quality monitoring during acquisition and frequent recalibration checks were carried out where necessary.

Depth readings from GPR rely on multiplying the measured two-way travel time by the velocity of the radio signals passing through the materials under investigation. As the surface and subsurface of the site changes, frequent recalibration of the subsurface velocities results in an accurate calculation of depths and thicknesses of located features relative to the surface.

Where possible, the whole site was covered by a tight GPR grid, using our Multi Frequency Array systems, in order to detect any sub surface utilities not located by other methods and to ascertain depths of all targets.

5. Radio Detection Survey

The radio frequency location equipment that we use on every site is the RD4000 cable locator. This has 4 modes or methods of operation that are outlined below. These methods have been developed to fit particular circumstances of locating known and unknown utilities on site. The radio frequency locator is used at the same time as our GPR system to determine the line and depth of metallic pipes and cable services i.e. Gas, Electricity, Water, Telecoms, CATV and Sewers with the aid of Sonde equipment. The way in which we use this equipment is to start from a known point on a service and trace it using one or more of the four methods.

Method 1 - Direct Connection

This is where we input a signal into a known feature i.e. a lamppost or service valve.

Method 2 - Clamp Connection

This is where we input a signal into a known pipe or cable, at access points i.e. inspection covers and manholes.

Method 3 - Induction

This method is used to trace a known service where there are no access points to use. The transmitter puts a signal (frequency MHz) into the ground which travels in both directions down the service. The surveyor will then pick up the transmitted signal with the receiver. As with all signals, they will only travel for a certain distance before they fade, it is very much dependent on the condition of the pipe or cable and how the material that it is made from, conducts the signal. When the signal fades, the surveyor will move the transmitter to the last detected point, then continue to trace the service through the survey area. As he goes along the service, he will take

depth readings and mark them on the ground.
Method 4 – Induction and Find Sweeps
Once the investigation has been completed and the Team Leader has confirmed with his team that all known services and any additional unknown service have been detected and pick up by our land surveyor, there is one last procedure that is carried out, this is called our final sweeps.

6.Chamber/Manhole Inspection Survey

Each manhole/ inspection cover within the survey area was opened and the contents documented. These measurements are recorded on a digital manhole description sheet. The manholes were individually numbered. All depths recorded inside the chamber were by disto, measuring tape or leveling staff,. Details included:

- Cover Levels
- Invert levels
- Service Type
- Service Material
- Pipe sizes
- Chamber dimensions
- Direction of flow
- Photographs

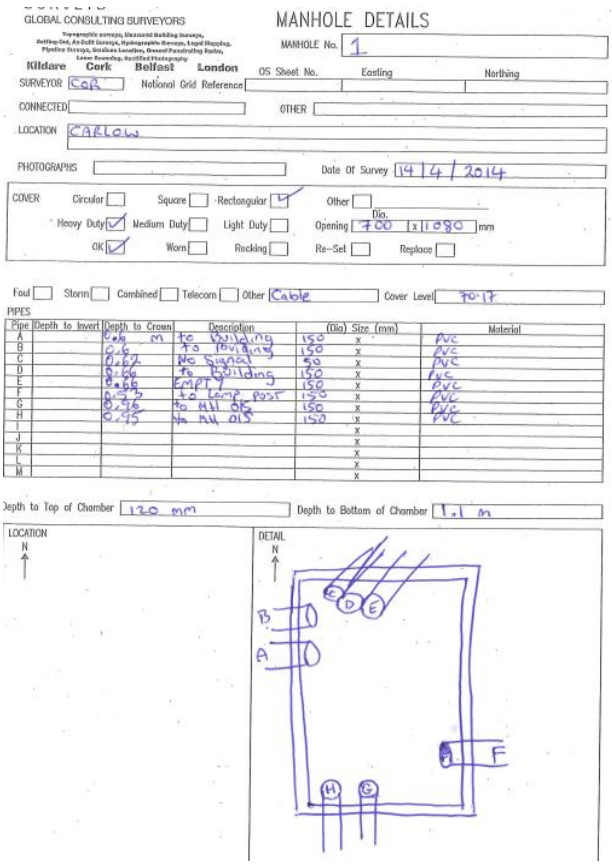

Fig. 2: Manhole Inspection Sheet

7. General GPR Limitations

GPR surveying is limited by the following guidelines		Minimizing GPR Limitations
Depth and size of Utility	In good ground conditions and within the depth range of two metres the ability to detect a utility will reduce in diameter by 1mm for each 10mm of depth. i.e. a 200mm pipe can be detected at 2m and a 50mm pipe at 0.5m but a 25mm plastic water service pipe to a house cannot be detected at 1.2m with radar	The field team incorporated Radio Detection surveys in areas where GPR was found to be ineffective.
Shadowing	This can happen where shallow buried utilities hide or mask deeper buried utilities below.	The staff used mutli frequency radar systems to reduce the effect of shadowing.
Soil Condition	GPR surveying operates best within high resistivity material. Clay overburden can impair GPR surveying. The depth penetration and quality of the data depends on the ground conditions on site. Poor data maybe a result of areas with high conductivity	The team calibrate our GPR Systems for varying soil types on each project.
Plan Accuracies	Plan accuracies of the order of + or – 150mm maybe achieved but this figure will depend on the depth of the service below ground level.	The field crew incorporated Radio Detection surveys in areas where GPR was found to be ineffective.

Utility ocation	Although all reasonable steps have been taken to locate all features, there is no guarantee that all will be shown on the drawing as some above ground features may have obstructed the survey.	The utility surveyors are all qualified and certified to locate underground services.
Existing Utility Records	Existing record information showing underground services is often incomplete and unknown accuracy; therefore it should be regarded only as an indication.	It is always our intention to use the Utility provider's details, if supplied prior to survey commencement, as a guide for locationpurposes. However, should we not be able to locate those guided services we shall not be held responsible for the accuracy, or otherwise, of the location of that service, as issued by the utility provider and therefore shown "Taken From Records" on the drawing and we are not liable for any loss that may arise due to the lack of accuracy in the guided information.
Loss of Signal	It is not always possible to trace the entire length of each underground service.	The processors indicated on the drawing if a service trace is lost.
Utility Congestion	Where similar services run on close proximity, separation maybe impossible.	The team incorporated Radio Detection surveys in areas where GPR was found to be ineffective.
Pipe Material	Successful tracing of nonmetallic pipes maybe limited due to material construction of the pipe.	The field crew incorporate Radio Detection/ Manhole& PWG surveys in areas where GPR was found to be ineffective.

Tab. 1 General GPR Limitations and solutions

8.Accuracies

Estimated Detection Rate		
Depth Range	Utilities buried within this range	Estimated Confidence
0 to 800mm below surface	65%	Approx 90%- 98% of Utilities Detected.
800mm to 1500mm below surface	20%	Approx 80%- 95% of Utilities Detected.
1500mm to 2200mm below surface	12%	Approx 70%- 92% of Utilities Detected.
2200mm+	3%	Unknown
The American Society of Civil Engineers in their 'Standard Guidance for the collection and depiction of existing subsurface utility data' has a useful rule of thumb for GPR which in, metric values, can be summarised as: 'In good ground conditions and within the depth range of two metres the ability to detect a utility will reduce in diameter by 1mm for each 10mm of depth. i.e. a 200mm pipe can be detected at 2m and a 50mm pipe at 0.5m but a 25mm plastic water service pipe to a house cannot be detected at 1.2m with radar'.		

Tab. 2 Accuracies

9. Findings

Detected Utilities	
Gas	No evidence of Gas plant was detected within survey area. The site service records show the gas pipe connecting the buildings within survey area. No signal was detected of those pipes and GPR results were inconclusive due to the presence of concrete slab found on GPR scan and due to the signal being absorbed by the pipe material rather than reflected back to the radar antenna. The gas main lines drafted and marked as taken from records.

Cables-Electric	ESB cables were located and mapped within survey area. It was not possible to verify the depths on every ESB line. Where it was not possible to verify the ESB lines as per records service drawing, those lines were drafted and marked as taken from records.
Telecoms	Telecom cables were located and mapped. Where it was not possible to verify the Telecom lines as per records service drawing, those lines were drafted and marked as taken from records.
Lighting	Lighting cables were located and mapped. Where it was not possible to verify the public lighting lines as per records service drawing, those lines were drafted and marked as taken from records.
Water main	Water main pipes are untraceable with radio detection methods. There was no signal detected of the sluice valve nearby some manholes or other valves/hydrants located nearby survey boundary possible due to non-metallic nature of the pipes. There were a number of inspection chambers with disconnected water pipes. No signal was detected of that disconnected pipes. Due to the signal being absorbed by the pipe material rather than reflected back to the radar antenna the GPR results were inconclusive. The water main lines were drafted and marked as taken from records.
CCTV/ CATV	No evidence of BT (Esat) or UPC (NTL) lines were detected within survey area.
Fibre Optic	SMART telecom lines were untraceable with radio detection methods possible due to the fibre optic nature of those cables. SMART telecom was drafted and marked as taken from records.
Drainage	Storm water, foul and combined sewer pipes were located and mapped.
GPR Anomalies	As well as all the confirmed utility services, there are a number of unidentified features shown as Unidentified GPR Anomalies within survey area. These features may be the result of services which are running through the sites but couldn't be detected with radio detection methods i.e. due to the non-metallic nature of the pipes, abandoned services, natural geological features or land drains amongst other things. The particular concrete slabs were marked as hatched areas.

Tab. 3 Findings

10. Conclusion

The data collected from the utility survey has ranged from reasonable to a high quality from the various methods used across the site.

Although 100% detection of all utilities was not achieved using ground penetrating radar, the correlation using the combined methods of the radio detection survey and the GPR survey yielded a very accurate set of results as opposed to carrying out each method independently or carrying out a desktop study only. However, due to the limitations based on site conditions, a 100% guarantee cannot be offered.

Every effort has been made to ensure that all results are accurate and reliable. Ground Penetrating Radar is a well-established technique to determine subsurface utilities, voids and anomalies.

It is recommended to carry out a slit trenching works to investigate route, depth and diameter of water main and gas main pipes which were untraceable with radio detection methods.

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