PROCEDURE MANUAL

GROUND PENETRATING RADAR (GPR)

Presented By:

ORBITAL AFRICA LTD.

www.orbital.africa

VERSION v.01.22

Table of Contents

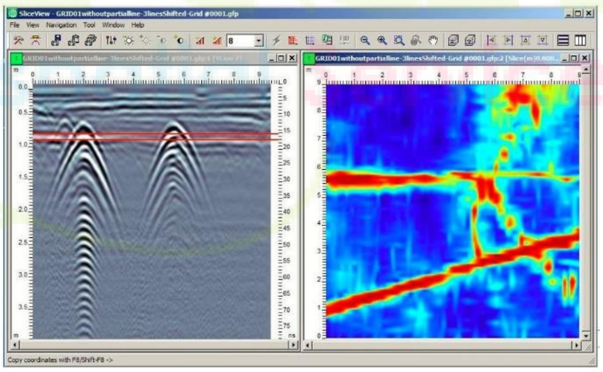
1. INTRODUCTION

1.1. Ground Penetrating Radar (GPR)

The Ground Penetrating Radar (GPR) is a geophysical method that uses radar pulses to image the subsurface. It is a non-intrusive method of surveying the sub-surface to investigate underground utilities such as concrete, asphalt, metals, pipes, cables or masonry.

GPR Technology has recently been a go-to technology when it comes to scanning and location of underground utilities. We combine the knowledge with expertise in using the latest technology, including Ground Penetrating Radar (GPR) equipment and Global Navigation Satellite System (GNSS). This non-destructive method uses electromagnetic radiation in the microwave band (UHF/VHF frequencies) of the radio spectrum, and detects the reflected signals from subsurface structures e.g. pipes, cables etc. By adopting this advanced underground survey technology incorporating the Ground Penetrating Radar and Electro-Magnetic Locators (EML), we analyze the reflected signals from structures, services, buried objects and layers beneath the ground. With statutory record plans, visual inspections of all lifted service cover on site – we often create an accurate plan of the subsurface environment in multiple formats including 3D.

1.2. Why GPR Underground Utility Scanning?



GPR, unlike more traditional EMLs, can pick up both metallic and non-metallic objects as well as utilities in a completely non-intrusive way. This unique feature makes the use of GPR for utility surveys almost mandatory in this project since there is increasing use of plastic piping on utilities.

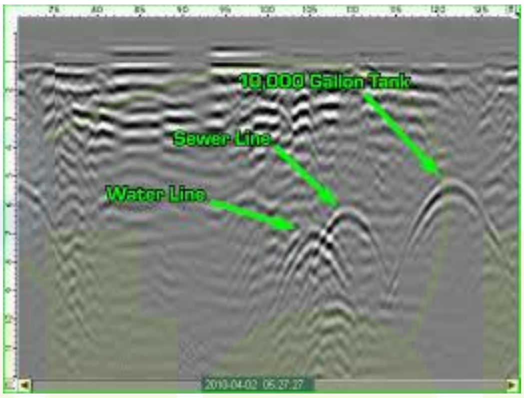
As well, GPR has more uses than just mapping utilities, with the right equipment and expertise GPR is used for the following; pavement or bridge or roadway inspection, void detection, concrete slab analysis, rebar mapping, verifying as-built information of concrete walls and floors. Using GPR prevents damage by accurately locating all buried pipes and cables prior to excavation. Ground penetrating radar can be used as part of the utility locating workflow to provide more complete locates and reduce risk.

Underground utility scanning and survey using Ground Penetration Radar with 500 MHz paired antenna provides scanning down to a depth of approximately 10 metres.

1.3. How GPR Utility Scanning Works

The Ground Penetrating Radar (GPR) equipment works by transmitting an Electro-magnetic or radio wave pulse into the ground at various frequencies, which are recorded on site using mobile device/tablet installed with GPR software. The GPR also has GNSS receiver integrated with the system. The signal is transmitted and then reflected back to the GPR unit, the quality of the signal in both directions can be dependent on the properties of the material it passes through.

The GNSS captures the coordinates of the underground scan hence it's possible to produce a georeferenced map from the analyzed data. This is advantageous since it helps in determining the correct location of underground utilities on site. The recorded sections of scanned data are post-processed in the office using GPR office software. Consequently, each scan is assessed and analyzed for any possible targets (services, anomalies and voids). These are then selected using a specialist software and our highly trained GPR Surveyor.



The output from this software is integrated into the utility survey model and presented in a concise and easy to understand way such as a GIS Map or model. The underground utility surveys combine GPR, EML, visual inspection and records to produce the best subsurface mapping information possible without digging! To help complement this further, we employ a vacuum excavation service. This often enables our team to expose the utilities to provide an accurate visual data & information regarding their type, depth below the surface & location.

1.4. GPR Scanning and Survey Workflow

1.4.1. Locate and Mark

a) Real-time, in Field Locates – Simply walk the system back and forth over an area, and buried targets will appear as hyperbolas under the surface. Just backup until the red line aligns with the center of the hyperbola. This is the location of the buried pipe or the cable.

b) (Locate and Mark Traditionally "Non-Locatables" – GPR can locate both metallic and non-metallic pipes and cables. This will provide a complete picture of the underground, and helps to ensure that nothing was missed using traditional locate methods.

1.4.2. In-Field Visualization

a) MapView – When using an external GPS, you can add flags and field interpretations on targets in the GPR data and quickly visualize them using MapView. This bird's eye view helps to differentiate point targets from utilities and helps to correlate the GPR results with site drawings.

b) Grid Scan – Using a grid scan of a complex area, you can visualize linear utilities at varying depths. This helps to provide an understanding of the subsurface while still on site.

c) Visualize Complex Sites – Using a grid scan of a complex area, you can visualize linear utilities at varying depths. Even closely spaced utilities can be detected as individual lines. This example shows eight buried pipes in a relatively small area.

d) Map Abandoned Utilities – GPR can map abandoned, non-locatable utilities that may not be detected with traditional methods. In this example, the utility shown on the bottom was capped and could not be located using traditional pipe and cable locators. A grid scan was collected over the area; the depth slices identifying the abandoned, capped utility.

1.4.3. Subsurface Utility Mapping (SUM) and Subsurface Utility Engineering (SUE)

The GPR maps buried infrastructure and results can be incorporated in CAD and GIS drawings to help plan for large infrastructure projects.

a) Map Multiple utilities at different depths and made of different materials. Since GPR can locate all utilities, including metallic and non-metallic pipes, a complete picture of all buried utilities at a project site can be completed early in the project planning. This example shows a cast iron pipe and a PVC pipe at different depths in the middle of a busy intersection. This aided in future utility planning.

b) Locate utilities to plan new installations. Using GPS and interpretations, GPR can be integrated into Quality Level B SUE investigations. In this example, closely spaced utilities existed, and city planners wanted to ensure that the route of the new water lines did not interfere with existing infrastructure. The use of GPR helped them to plan the installation with minimal disruptions.

1.4.4. Create Maps and Reports

GPR data is saved and available for post-survey analysis and reporting, providing accurate records for future reference & comprehensive deliverables for your customers.

i. Georeferenced Maps and Data – Easily plot images of your data path, screen shots and interpretations in Google Earth. All information is exported seamlessly for viewing in Google Earth and other GIS platforms.

ii. Create Utility Maps in Google Earth – Plotting interpretations on GIS or aerial images and connecting them to show the utility path is a powerful way to portray your locate results.

iii. Quickly Produce Summary Reports – Take your location to the next level by providing reports of your findings. The reports can be generated instantly for instance, with the EKKO_Project software, included with the GPR system.

2. GROUND PENETRATING RADAR EQUIPMENT

We propose to use the USRADAR GPR model Q5 Series which can scan to a depth of up to 10 metres. The GPR comes with 500 MHz paired antenna for scanning and integrated with a GNSS receiver for capturing the coordinates (X,Y) of the utilities.

Fig 1: USRadar Q5 Ground Penetrating Radar (GPR)

Simply put, the Q5 is a workhorse when it comes to locating buried utilities. Its easy-to-use interface can also be expanded and configured for other applications as needed. Not only is this system incredibly versatile, but it is the most powerful ground penetrating radar for locating utilities up to 5-10 metres deep at high resolution.

2.1. Hardware and Software

2.1.1. Featured Q5 Hardware Technologies

- SmartGain2
- Folding Rough Terrain Cart
- Self-Calibrating

Featured Q5 Software Technologies

- SmartStack
- StreetSmart Real-Time Processing
- Auto Config
- Depth Calibration etc.

2.2. Applications for the Q5

The Q5's versatility allows it to be put to use across many different applications. Some of these include, but are not limited to:

Utility Locating
- Non-metallic pipes; Metallic pipes and Fibre optics
- Water boxes; Missing valves; Conduit etc

2.2.1. Environmental

- Buried drums and tanks
- Voids and landfill limits

2.2.2. Law Enforcement

- Forensic investigation
- Illegal connections

2.2.3. Archaeological

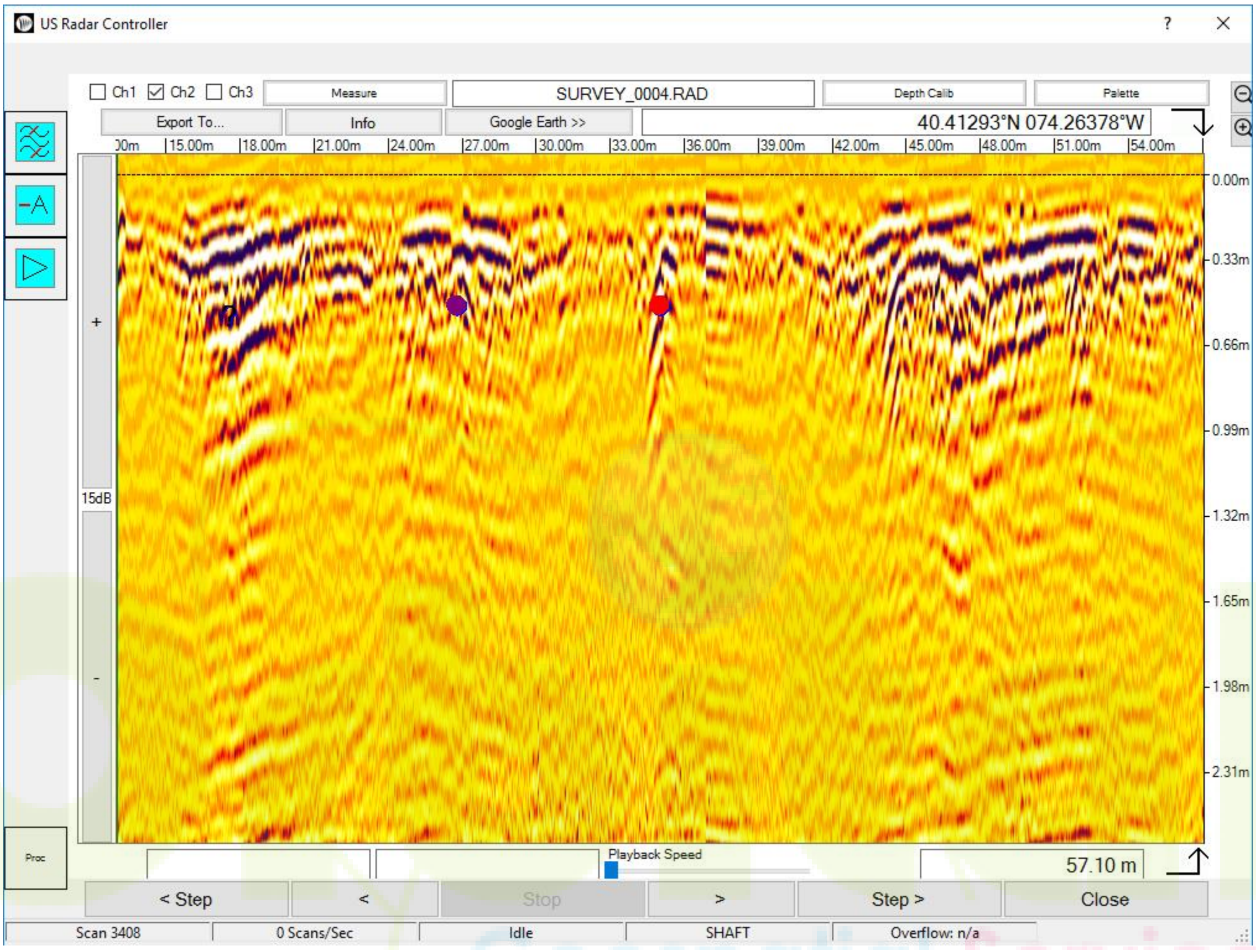
- Artefacts
- Graves etc.

2.3. Q5 Features

- ❖ Durable, Glare-Resistant Tablet Interface
- ❖ Daylight readable, weatherproof Getac tablet interface
- ❖ High performance CPU enables real-time data processing
- ❖ Built-in 3D view capability
- ❖ Wi-Fi, USB, Ethernet, HDMI and Audio ports supported

Fig 2: USRadar Q5 Data Collector

2.4. GPR Software



2.5. Acquisition Software

- ❖ Easy to use out of the box
- ❖ Perfect for on-the-go locating
- ❖ Auto-Calibrates Antenna

2.6. Q5 Technical Specifications

a. Radar Controller Computer

Getac F110

- Operating System: Windows 7 or 10 64-bit
- Third-generation Intel® Core™ i5vPro™ Processor
- Durability: MIL-STD-810G, 4-foot drop and all-weather IP65 dust and water-resistant design
- Display: 11.6-inch, HD daylight-readable, ten-point multi touch + digitizer
- I/O Interface: Ethernet Port, DC Power Port, 1 USB 3.0 Port, HDMI Port, Wi-Fi and Bluetooth
- Expansion Options: MicroSD or second USB 2.0 port, RJ45 Ethernet, Dedicated GPS
- Communications: Wi-Fi, Bluetooth® and optional 4G LTE or 3G Gobi™

b. Software

- Microsoft Windows
- US Radar Control Software Including:
  - System Configuration
  - A Scan Display (Oscilloscope Mode)
  - B Scan Display (Cross Sectional View)
  - C Scan Display (3D) (Optional)
  - Real Time Signal Processing
  - Data Storage and Playback

c. System Scan Modes

- Maximum typical logging scan rate of 390 traces per second
- Trigger Modes: Free run, timed interval, shaft encoder, GPS, manual
- Nominal Sampling Rate: 650,000,000 samples per second
- Maximum Resolution: 100 Gigasamples per second
- Hardware Time Varying Gain: 45dB
- Software Time Varying Gain: 60dB
- Software Flat Gain: 60dB

d. System Environmental Specifications

- Temperature: -11 deg. To 50 deg. C
- Moisture and dust resistance: IP 65

e. Radar Hardware Specifications

- Total System Dynamic Range: >130 dB
- Receiver Dynamic Range: >90 dB
- Sampling Interval: 10 ps-6.4 ns
- Time Range Adjustment Interval: 10 ps
- Pulse Repetition Frequency: 0.1-4 MHz-adjustable
- Samples per Trace: 2-8192, Adjustable
- Effective Bandwidth (typ.): >4 GHz
- Stacking: Automatic
- Transmitter: Stepped Ultra-Wideband Single Frequency

3. GPR SCANNING METHODOLOGY

The proposed methodology for GPR Scanning and survey will focus on primary (field) data collection by GPR operator.

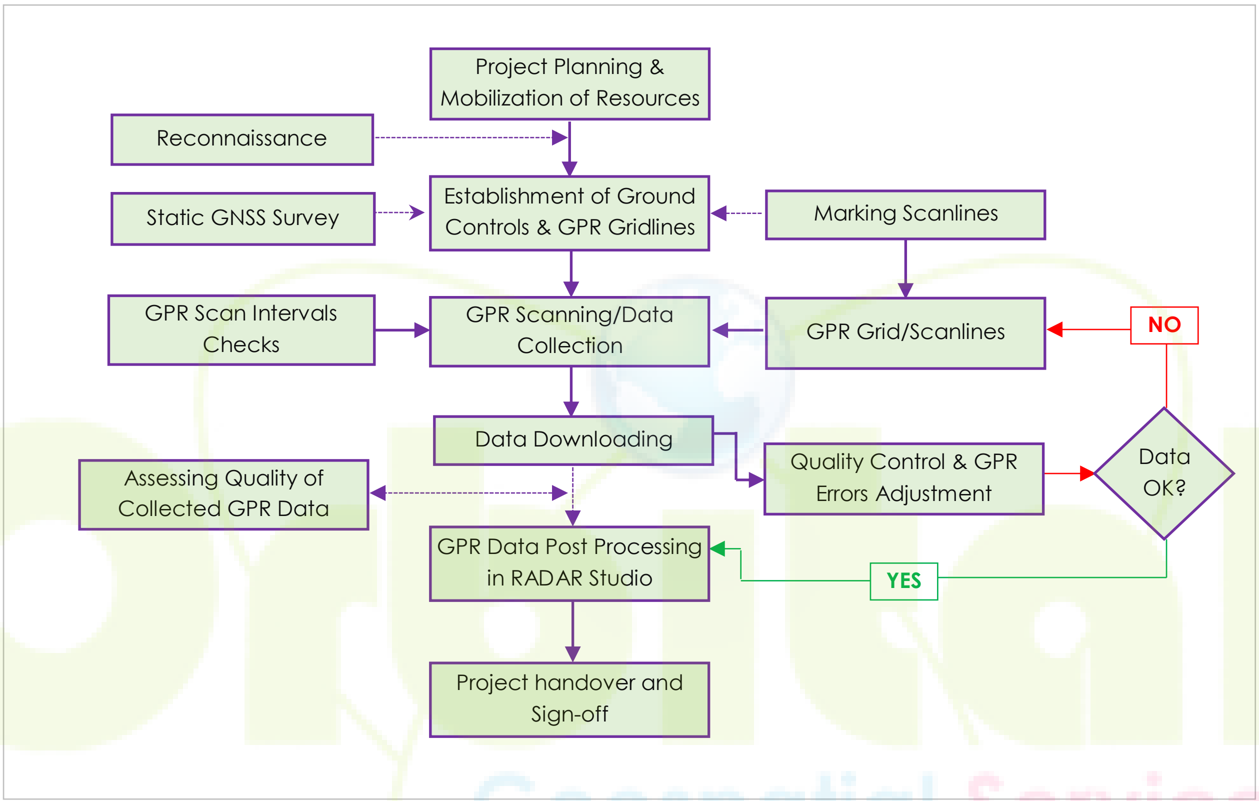


Fig 3: Overview of GPR Underground Utility Scanning and Survey

3.1. Field Survey & Data Collection

Ground Penetrating Radar survey is a non-destructive geophysical method that produces a continuous cross-sectional profile or record of subsurface features, without drilling, probing, or digging. A GPR operates by transmitting pulses of ultra-high frequency radio waves (microwave electromagnetic energy) down into the ground through a transducer (also called an antenna). The transmitted energy is reflected from various buried objects or distinct contacts between different earth materials. The GPR antenna then receives the reflected waves and stores them in the digital control unit. USRADAR GPR model Q5 Series, was used for the survey along with 500 MHz paired antenna for scanning down to depth of 10m. We carried out our scanning by using GPR then we positioned the utilities using the RTK/GNSS.

The data collection process begins by preliminary scanning to ensure that the survey parameters were okay. This is then followed by the actual survey. The scans are done across (cross-sectional) and along (longitudinal) the area being scanned using one axis starting from same baseline and later on the perpendicular axis starting on baseline of the starting point. This allows the collection of data for utilities running across and those located along the scan zone as shown by the radargrams below.

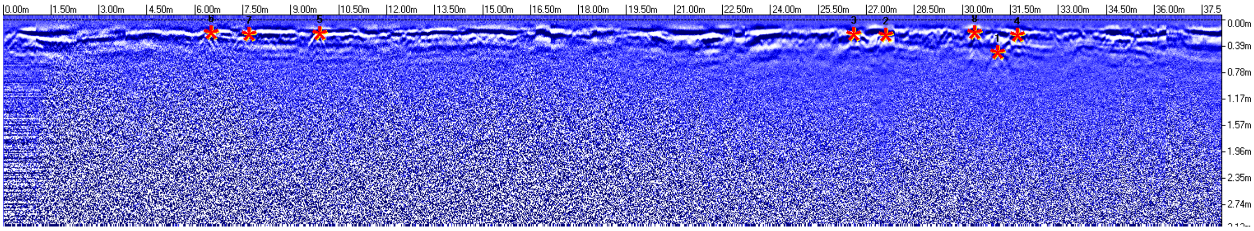


Fig 4: Sample Radargram for a Road Interchange

Our team will use the latest technology with expert methods to explore detectable features underground. We shall combine the knowledge with expertise in using the latest technology, including Ground Penetrating Radar (GPR) equipment. This non-destructive method uses electromagnetic radiation in the microwave band (UHF/VHF frequencies) of the radio spectrum, and detects the reflected signals from subsurface structures e.g. pipes, cables etc.

By adopting this advanced underground survey technology i.e. incorporating the Ground Penetrating Radar and Electro-Magnetic Locators (EML), we shall analyse reflected signals from structures, services, buried objects and layers beneath the ground. With statutory record plans, visual inspections of all lifted service cover on site – we shall create an accurate plan of the subsurface environment in multiple formats including 3D. A Utility Mapping Survey will provide the client with the confidence to progress with the project and ensure there are 'no-surprises'. Adhering to all health and safety regulations thus ensuring that survey best practices are employed.

3.2. GPR Data Post-Processing

GPR, unlike more traditional EMLs, can pick up both metallic and non-metallic objects as well as utilities in a completely non-intrusive way. This unique feature makes the use of GPR for utility surveys almost mandatory in this project since there is increasing use of plastic piping on utilities. As well, GPR has more uses than just mapping utilities, with the right equipment and expertise it can be used for pavement/bridge/roadway inspection, void detection, concrete slab analysis, rebar mapping, verifying as-built information of concrete walls and floors.

Normally, the Ground Penetrating Radar (GPR) equipment works by transmitting an Electro-magnetic or radio wave pulse into the ground at various frequencies, which are recorded on site using mobile device/tablet installed with GPR software. The GPR also has GNSS receiver integrated with the system. The signal is transmitted and then reflected back to the GPR unit, the quality of the signal in both directions can be dependent on the properties of the material it passes through. The GNSS captures the coordinates of the underground scan hence it's possible to produce a georeferenced map from the analysed data. This is advantageous since it helps in determining the correct location of underground utilities on site.

The recorded sections of scanned data (pictured above) shall be post-processed in the office using GPR office software. Consequently, each scan shall be assessed and analysed for any possible targets (services, anomalies and voids). These are then selected using a specialist software and our highly trained GPR Surveyor. The output from this software shall be integrated into the utility survey model and presented in a concise and easy to understand way such as a GIS Map or model. The underground utility surveys combine GPR, EML, visual inspection and records to produce the best subsurface mapping information possible without digging! To help complement this further, we shall employ a vacuum excavation service. This will enable our team to expose the utilities to provide an accurate visual of their type, depth as well as position.

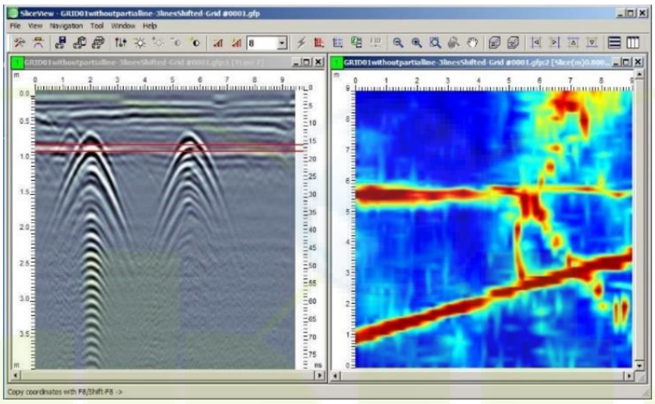


Fig 5: Sample GPR Post-processed Data

From the radargrams obtained, we are able to visualize several hyperbolas (inverted U shapes), all situated about 0.2m - 0.7m in the subsurface. This can be seen from Figure 4 above. When we identify a hyperbola in our GPR data, we know that there is an object in the subsurface, and by moving to the top of the hyperbola we can pinpoint the position of the object which would be collected by the GNSS/RTK. This allows us to establish the presence of several underground pipes.

We shall then carry out data processing to find out the number of utilities that will be identified at a scan depth of about 0m - 10m which include but not limited to:

i. Metallic utility which may correspond to water pipe line.
ii. Nonmetallic utility which very well corresponds to power cable.
iii. A bunch of cables as identified at a depth of 0.20m
iv. Sewer utilities at a depth of about 0.5m – 1m etc.

The raw scans were then processed removing the noise and enhancing the contrasts using processing software called 'RADAN'. These images are then converted to raster images that could be read and edited using Microsoft Paint or even AutoCAD for digitizing the interface. At the post-processing stage, we are able to plot the underground utilities identified during the fieldwork.

4. SOFTWARE AND HARDWARE

4.1. GPR Software

- ArcGIS Desktop – Used to produce and analyse vector data and creation of cartographic maps.
- AutoCAD Civil 3D – For drafting and processing of topographical data. Used to produce topographical maps.
- MS Office Suite – MS word & Excel will be used for report writing, data analysis respectively.
- GPR Radar Studio – Used to analyze/process the GPR data during postprocessing phase.

4.2. GPR Hardware

i. GNSS/RTK/Geodetic GPS

In survey process using RTK based GNSS receivers, the elevation points are taken at evenly spaced distances (i.e. 25 m) along transects stratified from high to low elevations. To navigate to each measurement point, the surveyor uses the CAD gridline file uploaded to the RTK GPS map to aid in identifying the stakeout points. The Stonex S800A can be configured with the radio and cellular modem that best fits the project needs. We can choose from Digital UHF, CORS or Spread Spectrum radio for sending corrections to the rover.

ii. Ground Penetrating Radar (GPR)

The GPR high frequency ground penetrating radar we are able to interrogate structures or material layers in pavements. A GPR is a geophysical method that uses radar pulses to image the subsurface. This non-destructive method uses electromagnetic radiation in the microwave band (UHF/VHF frequencies) of the radio spectrum, and detects the reflected signals from subsurface structures. A GPR system is made up of three main components:

- Control unit,
- An Antenna and
- Power Supply

The Q5 GPR equipment can be run with a variety of power supplies ranging from small rechargeable batteries to vehicle batteries and normal 110/220-volts. The connectors and adapters are available for each power source type. The unit in the photo above can run from a small internal rechargeable battery or external power.

5. SAMPLE GPR PHOTOS

6. WORK PLAN

ACTIVITIES	WEEKS AND DAYS																				
DESCRIPTION OF ACTIVITY	WEEK 1							WEEK 2							WEEK 3						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	15	17	18	19	20	21
1. Site Reconnaissance																					
2. Negotiation and Contract Signing																					
MILESTONE 1: SITE PREVISIT, PROPOSAL SUBMISSION AND CONTRACT SIGNING																					
3. Site & GPR Survey Needs Assessment																					
4. Creation GPR Grid/Scanlines																					
5. GPR Survey & Field Data Collection																					
MILESTONE 2: SITE ASSESSMENT AND COLLECTED GPR FIELD DATA																					
6. GPR Data Download and Assessment																					
7. Data Post-Processing and Analysis																					
8. GPR Outputs and Radargrams																					
MILESTONE 3: PROCESSED DATA AND PRESENTATION OF ALL DELIVERABLES																					
9. Preparation of Project Report																					
10. Submission of Report & Closure																					
MILESTONE 4: PRESENTATION OF FINAL PROJECT REPORT																					