VOL.
3

Technology
REPORT

Technology Advancements & Gaps in Underground Safety | 2020

CGA Common Ground Alliance

This report may be referenced as the Technology Advancements & Gaps in Underground Safety Volume 3. ©2020 Common Ground Alliance

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Contents

Introduction

With the ever-changing technology landscape in the damage prevention industry, stakeholders are forced to stay abreast of the evolving environment. Starting in 2018, the Common Ground Alliance (CGA) Technology Committee has released an annual Technology Report as a resource to help the damage prevention industry identify and understand the importance of technology used to prevent damages, protect assets, and increase overall safety.

These reports are meant to be a record of the technologies in use and under development for a specific year. The report's vision is to become a record of progress and source of inspiration for new applications of existing technologies and the development of new technologies. We include gaps in technology or “challenges to solve” that might supply a spark to help create new ideas and support for research and investment. We also hope to share the information we collect about the successful applications of technology, which may eventually lead to the adoption of new Best Practices and raise the overall level of industry knowledge. Finally, we want to provide a place for those deploying new technology to share their successes through case studies. CGA does not promote or endorse any specific products, companies, or vendors. Our focus is on the technologies and their applications to damage prevention. For this reason, the case studies are the only place where specific vendor or product names are mentioned.

Parties interested in learning more about a specific topic or about making contributions to this report are encouraged to reach out to the CGA Technology Committee for more information. Please visit http://commongroundalliance.com/about-us/commitees/technology.

Technology Committee Mission

The Committee's mission is to drive the industry to develop and utilize innovative technology that will decrease the probability or consequences of excavation damage in support of CGA’s overall mission.

Technology Committee Vision

The Committee's vision is to:

- identify opportunities to improve technology and damage prevention processes to decrease the likelihood or consequences of excavation damage; and
- provide CGA members with information on current and emerging technologies that can help prevent excavation damage.

What’s in This Report?

Now in its third year, the Technology Advancements and Gaps in Underground Safety report continues to provide CGA members a look into technologies being used in damage prevention. In this report, we identify gaps that could be filled by new or modified technologies, gaps that are in the process of being addressed by technology, and technologies currently in use.

By “modified” technologies, we have in mind technologies that may have been initially developed in other industries or applications but could be applied to damage prevention. We are also interested in improvements to existing technologies that may make them cheaper, faster, safer, more efficient, etc.

CGA's Annual (Damage Information Reporting Tool) DIRT Reports provide data on the root causes of damages. In this report, we examine some of those root causes and brainstorm ideas for how technology could be applied to address them.

Lastly, we provide case studies brought to us from select members that can be used as examples of what works now in damage prevention and/or a preview of what is being developed. The following case studies are presented:

1. <u>SeeScan—Geolocating System: A Data-Driven Solution for Locating and Mapping Buried Utilities</u>
   SeeScan applies a fully integrated, multi-sensor, utility mapping system to real-world applications. By using data instead of human interpretation, the geolocating system can determine the utility's horizontal position and depth with a high degree of accuracy.

2. <u>Pacific Gas and Electric—Water Extraction Tool Development and Testing to Aid in Legacy Cross Bore Program Sewer Lateral Inspections</u>
   Pacific Gas and Electric (PG&E) and ServPro worked together to develop and apply a new technology to extract standing water within a sewer lateral. After water is extracted, optical cameras can take imagery of the lower half of the sewer lateral, allowing for the confirmation of the presence or non-presence of a cross bore. [1]

3. <u>Leica—Democratizing Ground Penetrating Radar Technology to Non-GPR Experts for Faster, Simpler, and Reliable Detection of Underground Utilities</u>
   Leica brings new GPR utility detection technology to the field with simplified workflow, automated data processing, and high accuracy. The software guides the user on correct data collection to minimize mistakes. Users can locate underground utilities and visualize detected utilities via the onboard acquisition software.

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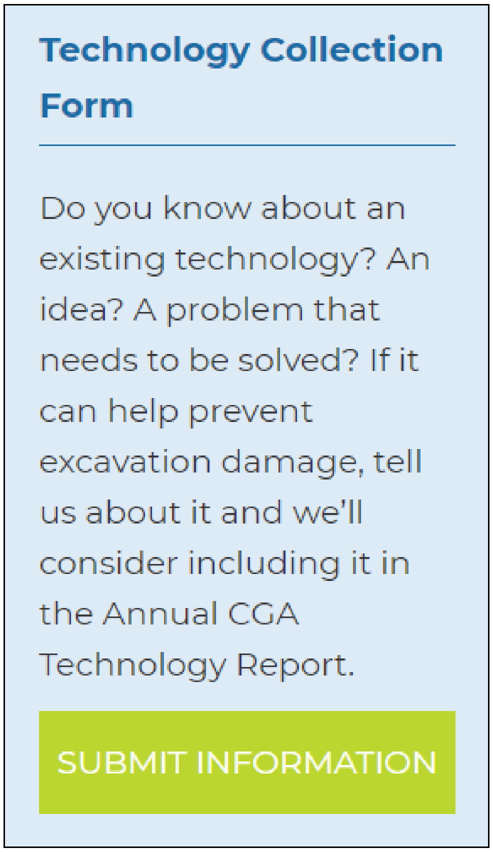
[1] The June 2018 CGA Monthly Update provides an in-depth look at cross bores, covering how they are created and the associated safety issues and mitigation strategies (https://commongroundalliance.com/media-reports/cga-monthly-update-june-2018).

New case studies are continually sought by the Technology Committee for review and possible inclusion in future reports and/or as webinar topics.[2] Parties interested in learning more about a specific topic or about making contributions to this report are encouraged to reach out to the CGA Technology Committee for more information.

To start the process, complete the short survey through the Technology Collection Form at:

https://commongroundalliance.com/programs/technology



Technology Collection Form

Do you know about an existing technology? An idea? A problem that needs to be solved? If it can help prevent excavation damage, tell us about it and we'll consider including it in the Annual CGA Technology Report.

Level of Production Guide

Where applicable, we use three "levels of production" to indicate the status of a technology:

Red – being discussed at a level to determine if the manufacture should continue

Yellow – manufacturer has determined to move forward, but is not in full production at this time

Green – in full production and available for purchase

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[2] Previously recorded webinars can be found at https://commongroundalliance.com/webinars.

Technology Opportunities aka Gaps in Damage Prevention

This section lists gaps that the CGA Technology Committee has identified from various meetings within the industry. It illustrates opportunities for technology development—a wish list of technology innovations to improve damage prevention.

Locating

- Locating non-metallic lines
- Locating and tracking abandoned facilities
- Mitigating signal bleed-over to non-target lines while using locating instruments
- Ensuring that new buried assets are locatable
- Developing locate audit tools

Excavation

- Improving excavator identification—assigning unique IDs to excavation companies
- Detecting excavation encroachment on pipelines
- Detecting excavation activity close to facilities/assets
- Developing combined systems for encroachment detection (camera + fiber optic)
- Linking the movements of excavators to utility GIS systems and creating a warning when close
- Detecting under-canopy GPS encroachment
- Using infrared wavelengths to confirm equipment activity
- Integrating imagery for proximity threat detection
- Making excavators aware of utility location without using paint on the ground

GIS = Geographic (*or Geospatial*) Information System

GPR = Ground Penetrating Radar

GPS = Global Positioning System

GPS/Digital Mapping/GIS

- Mapping near misses—collecting and enabling use of this data
- Mapping damage locations
- Providing increased locational data sharing
- Providing centralized database of mapped abandoned facilities
- Creating “open” GIS systems that provide better data sharing
- Mapping assets through mainline inspections and associating location with video
- Providing better GPS signal strength in urban canyons and under tree cover
- Providing software analysis for quality feedback about GPS coordinate collection
- Developing standards for GPS data quality

Predictive Analytics/Risk Assessment

- Providing continued analysis of root causes of damages
- Combining leading indicator tracking with patrolling and surveys; examples include:
    - Plans for construction
    - Social activities
    - Traffic patterns
- Developing risk-based standards for data collection and sharing with construction companies

Mobile Device/Mobile Data Collection

- Developing better ways to verify data and ensure data integrity
- Developing augmented reality to visualize underground utility lines through a mobile phone or tablet
- Providing visualized ticket management and processing on mobile devices
- Providing standard mark-up language for tickets and damages
- Uniquely identifying facility owners and their contact information

Education/Training

- Disseminating trenchless Best Practices on mobile apps
- Disseminating vacuum excavation Best Practices on mobile apps
- Sharing data about the pipeline location—who has access and how is that visualized/displayed?
- Training how to dig with a shovel using videos/apps

Previous Gaps That Have Graduated to a Level of Production

- Developing quality and assurance documentation following a utility locate *Green*
- Deploying a user-friendly GPR system for helping construction crews avoid utilities *Green*
- Using predictive modeling from the data that is already available *Green*
- Developing an in-field asset mapping system to map all fire hydrants, gas valves, meters, etc. *Green*
- Connecting construction training programs to existing laws using mobile apps *Green*
- Accurately mapping underground facilities *Green*
    - High-accuracy mapping of assets—less than one meter *Green*
    - Collection of Z data and depth of cover over assets *Green*
- Making GPS mapping technology more user-friendly *Green*
- Integrating GPS mapping and GIS in real time and workflow *Yellow*
- Integrating multiple sensors for facility inspection, protection, and monitoring [LIDAR (light detection and ranging), imagery, radar, etc.] *Yellow*

Summary of Current Industry Technologies

This section provides a basic identification and categorization of current technology in use.

Note: For questions about a current technology in use or to suggest additions to this catalog, please contact the Technology Committee via our web form or Contact Us page:

- *Contact Us:* https://commongroundalliance.com/about-us/contact-us
- *Web form:* https://commongroundalliance.com/technologyform

One Call

- Predictive analytics/risk assessment tools
- One call and excavator coordination software
- Enhanced positive response (provides additional information back to excavator about the performed locate)
- Ticket management and ticket processing
    - Rules-based screening software
    - Field-based

Locating Technologies

- Electromagnetic
    - Signal distortion detection
        - Evaluates measured depth accuracy
        - Indicates a measure of X/Y accuracy
    - Ambient interface management—mitigates ambient noise issues
    - High-dynamic range—removes need for gain control
- Magnetic
- Acoustic
- Ground penetrating radar (GPR)
    - Multi-frequency
    - Hand cart
    - Mobile vehicles
    - 3D radar tomography
- Radio frequency identification (RFID) markers
- Enhanced passive electromagnetic locating
- Automated flag insertion devices
- Electronic white-lining technologies

GIS/GPS Technologies

- Real time kinematic (RTK) GPS (increased resolution)
- Big data storage and analytics
- Satellite imagery
- Asset visualization
- Geofencing (virtual perimeter of geographic area)

Utility Mapping

- Subsurface utility engineering (SUE)
- Surveying
  - RTK/GNSS
  - Total stations
- LIDAR of exposed utilities
- Software to capture and manage data
- RFID markers
- Mapping vehicle carts (carts pulled behind vehicles using GPR, EM locating, LIDAR, sensors, cameras, and GNSS antennas to map underground utility positions)
- Geospatial data collection and management
- Asset features location and mapping
- Sensor fusion (combining and comparing sensor information)
  - Robotic mapping simultaneous localization and mapping (SLAM)—mapping an unknown environment while keeping track of where the mapper is spatially within that environment

EM = Electromagnetic

GNSS = Global Navigation Satellite System

LIDAR = Light Detection and Ranging

RFID = Radio Frequency Identification

RTK = Real Time Kinematic

UAV = Unmanned Aerial Vehicle

Excavation Technologies

- Vacuum excavation
  - Using air
  - Using water
- GPS encroachment devices (on the earth mover)
- Sensors on drill heads to detect potential conflicts
- Post-bore pull-back cameras
- Using routine maintenance opportunities to record asset positions
- Ground movement
  - Hazard detection—landslides onto an asset, etc.
  - Monitoring
- Software
  - Mapping
  - Workflow coordination—one party sharing costs with another by coordinating projects in the same area
- Data collection
  - Earth mover's location
  - Unique identifiers of earth movers (allows ID of who is digging and where)
  - Maintenance records
- Slot trenching (using pressurized air or water to cut a thin and accurate trench)

Imaging Technologies

- UAVs (drones with various sensors)
- Land and aerial LIDAR surveys (create accurate spatial models (point clouds) that digitize environments for computer manipulation and data storage)
- Satellite imagery
- High-resolution aerial imaging
- Synthetic aperture radar (a form of radar used to create two- or three-dimensional images or reconstructions of objects, such as landscapes)
- Aerial hyperspectral imaging (information is captured that is invisible to the human eye, e.g., gas leaks, etc.)
- Thermal imaging
- 3D radar tomography (imaging by sections)
- Data logging devices (with imagers and lasers)

Mobile Devices

- Cell phones and tablets
- Data recorders
- Handheld screens (used for showing maps)
- Augmented reality (AR) headwear

Pipeline Data Acquisition Technologies

- In-line inspections (smart pigs in the pipeline)
- External checks
    - Corrosion testers
    - Locating
    - Mapping the lines
- Field crew reports from handheld data capturing devices
    - Loggers
    - Laser distance finders
    - Cell phones and tablets
    - Digital cameras
- Environmental change detection analysis—“sees” encroachment on critical infrastructure
    - Aerial planes
    - Satellite imagery
- Encroachment analysis
    - Fiber optic sensors
    - Acoustic sensors
    - Aerial, UAV, and satellites
- Legacy data conversion to GIS
    - Paper records
    - Alignment sheets
    - Memory (human recollection)

    - Excel and Access data sheets
- Elevation and cartography data
- GPS/GIS-based data
- Mobile surveys (for methane leak detection)

Increasing Public Awareness Technologies

- Social media (e.g., Facebook, Twitter, Snapchat, LinkedIn)
- Regional CGA apps
- Web-based messaging

Technology Related to Managing and Visualizing Data

- GIS (geospatial information system)
- BIM (building information modeling)
- CAD (computer-aided design) software
- Various market-focused software (pipeline, city, construction project management)
- Artificial intelligence (AI)
- IoT (Internet of Things)
- Augmented reality (AR), virtual reality (VR), 3D visualization

How Technology Might Address DIRT Root Causes of Damages

The DIRT Report gives us a look at Root Cause analysis for damages to our infrastructure. We have taken those root causes and used imagination and forethought to apply possible answers for future technology use.

Root cause groups	Root cause	Technology that could be utilized—what is possible now	Technology that may be developed in the future
Notification Not Made	No notification made to one call (No ticket, no 811 call, no locate request)	Accurate maps of all infrastructure available to excavators	Electronic key for all large machinery. Ticket number must be entered to operate machines. GPS in the machine matches geospatial information on the 811 ticket. Each machine position must match area of existing ticket or it will not run. Swarm satellites or drones provide last-minute encroachment analysis on areas with critical underground infrastructure.
Locating Issue	Facility marked inaccurately due to abandoned facility	Accurately map all abandoned lines when discovered and store in a database Locator training on distorted signals	At time of abandonment, lines are mapped and stored in central database.
Locating Issue	Facility not marked due to locator error	Enhanced training with continuing education	Instrument compares locate to mapped database in real time and warns locator that locate activities may be incomplete.
Locating Issue	Facility marked inaccurately due to locator error	Enhanced training with continuing education	Data audits compare real time instrument sensor data against known X/Y/Z positions of subsurface facility during excavation.

Root cause groups	Root cause	Technology that could be utilized—what is possible now	Technology that may be developed in the future
Excavating Issue	Improper excavation practice not listed elsewhere	Enhanced training with continuing education including state 811 guidelines	Virtual training.
Excavating Issue	Excavator dug prior to verifying marks by test hole (pothole)	Review excavator practices, reinforce training Online/virtual education including state 811 guidelines	Artificial Intelligence compares bucket location against known X/Y/Z positions of subsurface facility during excavation.
Excavating Issue	Excavator failed to maintain clearance after verifying marks	Increased online/virtual training with continuing education including state 811 guidelines	Passive locating sensors on mechanized diggers. Body/helmet monitoring cams worn by hand tool excavation personnel.
Other Notification Issue	Excavator dug before valid start date/time	"OK to Dig" code given as an automated positive response code after all responses are complete. No code = No dig	Electronic key for all large machinery. Current ticket number must be entered each day to operate machines. Ticket number has valid dates linked. Critical site monitoring alerted by encroachment warnings tied to ticket data base.

Conclusion

Technology is an important component of damage prevention. As such it needs to be identified, evaluated, and shared so that anyone involved in protecting underground assets has an opportunity to use that technology for their own regional needs. This report shares the collective knowledge about these technologies with the goal of furthering discussions, improvements, and better ways of using them. As an almanac of underground damage prevention, the CGA Technology Committee will strive to expand upon and improve this annual report for all involved. Education is a powerful tool for change!

Case Study Overview

Case studies on damage prevention technologies are welcomed by the Technology Committee for review and possible inclusion in future reports and/or as webinar topics. The goal of the Committee is to provide information about technologies that are in different stages of development and that have good potential for making a positive change for damage prevention.

Three case studies are included on the following pages:

1. SeeScan—Geolocating System: A Data-Driven Solution for Locating and Mapping Buried Utilities
   SeeScan applies a fully integrated, multi-sensor, utility mapping system to real-world applications. By using data instead of human interpretation, the geolocating system can determine the utility's horizontal position and depth with a high degree of accuracy.

2. Pacific Gas and Electric—Water Extraction Tool Development and Testing to Aid in Legacy Cross Bore Program Sewer Lateral Inspections
   Pacific Gas and Electric (PG&E) and ServPro worked together to develop and apply a new technology to extract standing water within a sewer lateral. After water is extracted, optical cameras can take imagery of the lower half of the sewer lateral, allowing for the confirmation of the presence or non-presence of a cross bore.

3. Leica—Democratizing Ground Penetrating Radar Technology to Non-GPR Experts for Faster, Simpler, and Reliable Detection of Underground Utilities
   Leica brings new GPR utility detection technology to the field with simplified workflow, automated data processing, and high accuracy. The software guides the user on correct data collection to minimize mistakes. Users can locate underground utilities and visualize detected utilities via the onboard acquisition software.

Case Study 1: GEO® Locating System: A Data-Driven Solution for Locating and Mapping Buried Utilities

Company's Name: SeeScan, Inc.
Contact Name: Mark Whelan
Contact Email: mark.whelan@seescan.com
Area of Technology: Locating and Mapping Technology
Level of Production: Yellow

Having comprehensive maps of our underground infrastructure is one of the many ways we can reduce the risk of damaging utilities when we dig up the ground. Recent solutions have combined utility locating with mapping technology. Whether the mapping technology is supplied by a third party or is built into the locating equipment, the workflow is similar. During the locate, the operator geotags the utility's estimated position using a GPS device. The positional data is captured and can be integrated with one call software for locate and asset management. The data results in a utility map that can be maintained and shared among excavators, project planners, and asset owners.

These solutions can certainly reduce the risk of utility strikes, but there is more that can be done. The industry has yet to present an end-to-end locating and mapping solution that improves the quality of the data used to create utility maps before ground is broken.

One of the key obstacles to creating accurate utility maps is the limitation of existing locating technology, which relies on human interpretation and favorable conditions to be accurate. Poorly grounded utilities, the presence of large conductors, environmental conditions, human error, and a number of other factors can all compromise locating accuracy. In fact, the CGA's 2018 DIRT Report found that 21% of reported utility damages were due to a locating issue.[3]

The GEO® Locating System

For over two decades, SeeScan has been dedicated to creating a fully integrated, multi-sensor, utility mapping system. The GEO® Locating System uses advanced signal processing to gather a substantial quantity of data about the electromagnetic signals in the locate area. The system generates a comprehensive map of utilities, backed by data gathered from the locating equipment. By using data instead of human interpretation, the GEO® Locating System is able to determine the position of the utility's horizontal position and depth with a high degree of accuracy. The system includes the following components:

- **Geo Locating Transmitter:** This transmitter applies multiple frequencies onto a target utility simultaneously. The set of frequencies is a range that includes what are considered low, medium, and high range frequencies for utility locating. Multiple transmitters can be hooked up to different utilities in the area to supply more information to the receiver.

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[3] Locating issues include a number of causes such as facility marked inaccurately due to locator error, facility marked inaccurately due to abandoned facility, site marked but incomplete, and facility not marked due to abandoned facility.

- **Geo Locating Receiver:** This multi-sensor receiver is capable of detecting all nearby electromagnetic signals at a range of frequencies simultaneously. Onboard GPS logs the receiver's position with respect to the detected signals. The receiver's visual display guides the operator over the target utility. The receiver automatically plots the utility's estimated positions at each frequency, independently of operator interpretation. The receiver captures all data in real time onto a USB for post-processing with the utility mapping platform, SubView™.
- **SubView™:** SubView is a web-based GIS platform for creating and sharing utility maps based on the data gathered from the geolocating receiver. SubView processes all data, including information about all detected actively-applied and naturally-occurring passive frequencies, as well as environmental and positional information. It then produces a complete map of utilities in the area, including each utility's estimated horizontal position and depth. Each locate is stored in the cloud, can be customized with notes and jobsite images, and is designed to be shared easily with key stakeholders.

In this series of test cases, we put the GEO® Locating System to the test to locate and map utilities within San Diego County.

Test Case 1: Dense Intersection Mapping

Overview

The geolocating receiver includes advanced motion processing that enables a user to passively[4] locate utilities while driving a vehicle. This allows for a fast way to identify multiple utilities in an area without having to disrupt traffic. Operators can mount two geolocating receivers to a custom vehicle hitch. A survey grade global navigation satellite system (GNSS) instrument between the receivers logs positional data while the vehicle is in motion.

Figure 1—Geolocating receivers mounted to a custom vehicle hitch.

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[4] Passive location involves using the locating receiver to detect signals that are already on the utility from nearby power sources, such as power lines. It does not require the use of a transmitter to energize the utility.

SeeScan performed a passive scan for utilities on May 5, 2018, at the intersection of Ruffin Road and Clairemont Mesa Boulevard. Located in the Kearny Mesa community, this busy intersection lies between two major freeways and features a number of businesses, including a new hospital at the southeast corner. Immediately prior to the locate, excavators created narrow trenches using saw cuts in preparation for the installation of a 69 kV power line.

<u>Results</u>

Multiple passes were taken through the intersection over the course of 46 minutes. The aggregated data in SubView revealed the location of electromagnetic signals at various depths throughout the intersection. The resulting map indicated multiple utility crossings, traffic loops, and utilities that run parallel to each street. One estimated utility position appeared where a power line had been recently laid in a narrow trench.

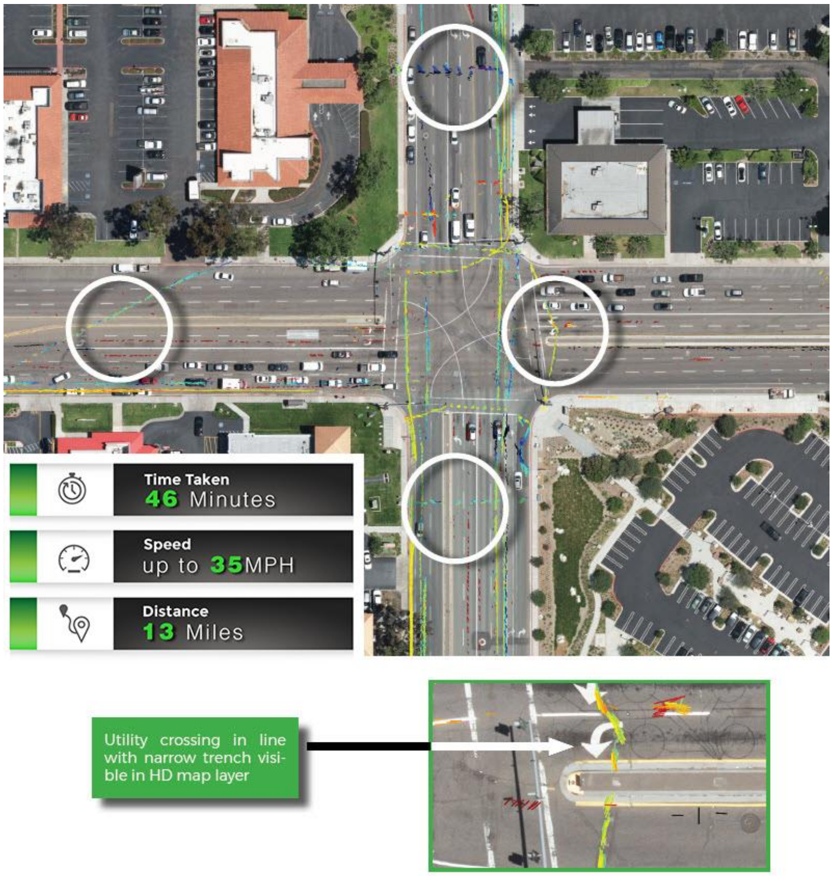

Figure 2—The intersection shows the density of signals detected at various depths, revealing the presence of multiple utilities that cross the intersection.

Test Case 2: Isolating Utilities at DeepSea Power & Light

Overview

On February 19, 2018, SeeScan located utilities buried under the parking lot at DeepSea Power & Light, a business division of SeeScan. Geolocating transmitters were used to hook up to separate utilities that serve the building.

Geolocating transmitters are capable of broadcasting multiple frequencies simultaneously. When using additional transmitters, different groups of frequencies can be applied to multiple utilities in the locate area. The geolocating receiver distinguishes these groups of frequencies, enabling one operator to effectively isolate all utilities in an area. Advanced signal processing allows the combined data gathered from all of the frequencies on a utility to reveal a more accurate map of its position.

Results

Testers walked through the parking lot over the course of about 45 minutes to gather all locate data. Using the SubView mobile app as well as the receiver's optical ground tracker, photos of asset locations were appended to the map to create a fuller picture of the locate. In the back parking lot, signal bleed coupled onto a non-targeted line running parallel to the canyon edge but not serving the building. This line was shown on the receiver's interface and in SubView after post-processing. While signal bleed is normally an obstacle, the receiver's gradient-based antenna assembly helps to distinguish utilities that are incidentally energized.

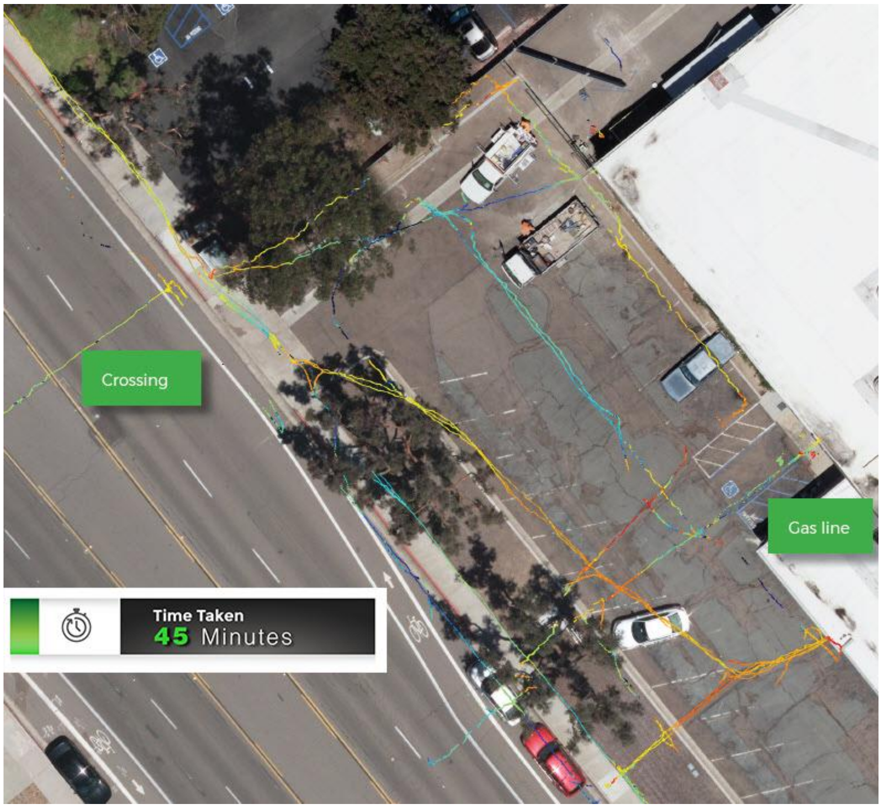

Figure 3—Zoomed in, the map data in SubView shows distinct utilities. Each line was energized with different groups of frequencies.

Figure 4—The map data in SubView shows multiple distinct utilities throughout the front and back parking lots. A line running along the canyon edge reveals a separate utility energized via signal bleed.

Test Case 3: Locating 30-in. Gas Pipeline

Overview

How a signal appears is profoundly a function of its frequency. Applying a range of multiple frequencies to a utility at once provides a more complete picture of the target utility, as well as nearby utilities in the area.[5]

With the GEO® Locating System, the alternating current flowing on a pipeline will have both a frequency high enough to energize the pipeline and a frequency low enough to continue traveling on the pipeline. Since the receiver is able to distinguish frequencies independently and at various depths, any bleed off that energizes a nearby conductor—for example, a shallow telecommunications cable with tracer wire—adds to the complete picture of the local buried infrastructure. This has significant potential for identifying utilities that cross over pipelines.

SeeScan passively located a 30-in. San Diego Gas & Electric (SDG&E) gas pipeline on November 13, 2019. According to a publicly available high-pressure gas pipeline map on SDG&E's website, the pipeline travels under a parking lot off Balboa Avenue near SeeScan's campus. SeeScan testers mounted two geolocating receivers and a survey-grade GPS to the vehicle hitch and drove through the parking lot to gather locate data on the pipeline.

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[5] The American Society for Civil Engineers (ASCE) confirms the need for using multiple frequencies when locating utilities, stating: *"A wide range of available frequencies is necessary to search for utilities. In general, frequencies from 50 Hz to 480 kHz can be successful. It is usually prudent to have this complete range available during a utility locate. For example, a relatively shallow cast iron pipe with rubber or other nonmetallic jointing material **might only be found using the high 480-kHz frequency, whereas a deep steel pipeline may need the 8-kHz frequency to find it and the 1-kHz frequency to trace it for any length of distance."***[Emphasis added]
From the Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data." *American Society of Civil Engineers* Reston, VA: 2003. Pg. 15.

Results

The locate map in SubView reveals the location of the SDG&E transmission pipeline at 7.8 ft (2.4 m) west from its indicated position on the pipeline map, well outside of the utility's tolerance zone.[6] The depth is approximately 7 ft (2.1 m); no depth information is available on the pipeline map. The utility's estimated position in SubView lines up with paint markings in the street from a locate performed by SDG&E.

Data gathered from the receiver shows an additional buried utility that crosses over the pipeline, which terminates at an electrical box, indicating an electrical line.

Figure 5—The map in SubView reveals a shallow electrical line that crosses over the pipeline (1). The transmission pipeline lies approximately 7.8 ft to the west of the position in the SDG&E map (2). The pipeline's location lines up with paint markings in the street from a recent locate (3).

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[6] Pipeline map information gathered from https://www.sdge.com/safety/gas-safety/pipeline-map. According to the website, the accuracy of pipeline locations varies +/- 500 feet.

Conclusion

With a congested utility network and new utilities being buried every year, it is crucial that we improve our visibility into the underground. There are many challenges to making that visibility possible, but technological advancements and a shared commitment to safety can help. The GEO® Locating System is a fully integrated mapping solution and in the near future will offer key stakeholders with easily shareable, data-driven utility maps to protect their underground assets.

Case Study 2: Water Extraction Tool Development and Testing to Aid in Legacy Cross Bore Program Sewer Lateral Inspections

Company's Name:	Pacific Gas and Electric Company (PG&E) and ServPro Industries, LLC.
Contact Name:	Aaron Rezendez, PG&E, and Ivan Espinal, ServPro
Contact Email:	aaron.rezendez@pge.com and iespinal9542@sbcglobal.net
Area of Technology:	Cross bore prevention and identification
Level of Production:	*Green*

Pacific Gas and Electric Company (PG&E) has a cross bore inspection program to identify and remediate gas cross bores and a public outreach program that provides safety information to PG&E customers, sewer districts, and public works agencies. The program uses video camera inspections to verify that no damage has occurred to sewer lines when using trenchless construction methods on new construction projects.

The goal of the program is to identify cross bores by completing inspections of potential conflict locations and repairing all occurrences as they are discovered. PG&E completed approximately 46,045 inspections in 2018 (bringing the total to 181,430 inspections since 2013). In 2018, PG&E found approximately 1 cross bore per 1,000 inspections.

PG&E's R&D and Innovation Department partnered with their Cross Bore Program to identify new technologies that may support efforts to access Unable to Access (UTA) sewer laterals as part of its legacy cross bore inspection efforts. R&D was asked to focus its efforts on San Francisco and, specifically, developing technology to extract standing water within a sewer lateral.

Water obstructions (Figure 6) generally occur when there are sags or small obstructions within the sewer lateral. The ability to see below the water line is required to confirm that no cross bore is present. If the water could be extracted, then the optical cameras would be able to take imagery of the lower half of the sewer lateral, allowing for confirmation of the presence or non-presence of a cross bore.

Figure 6—Example of water at the base of the interior of a sewer lateral as viewed by an inspection crew's camera.

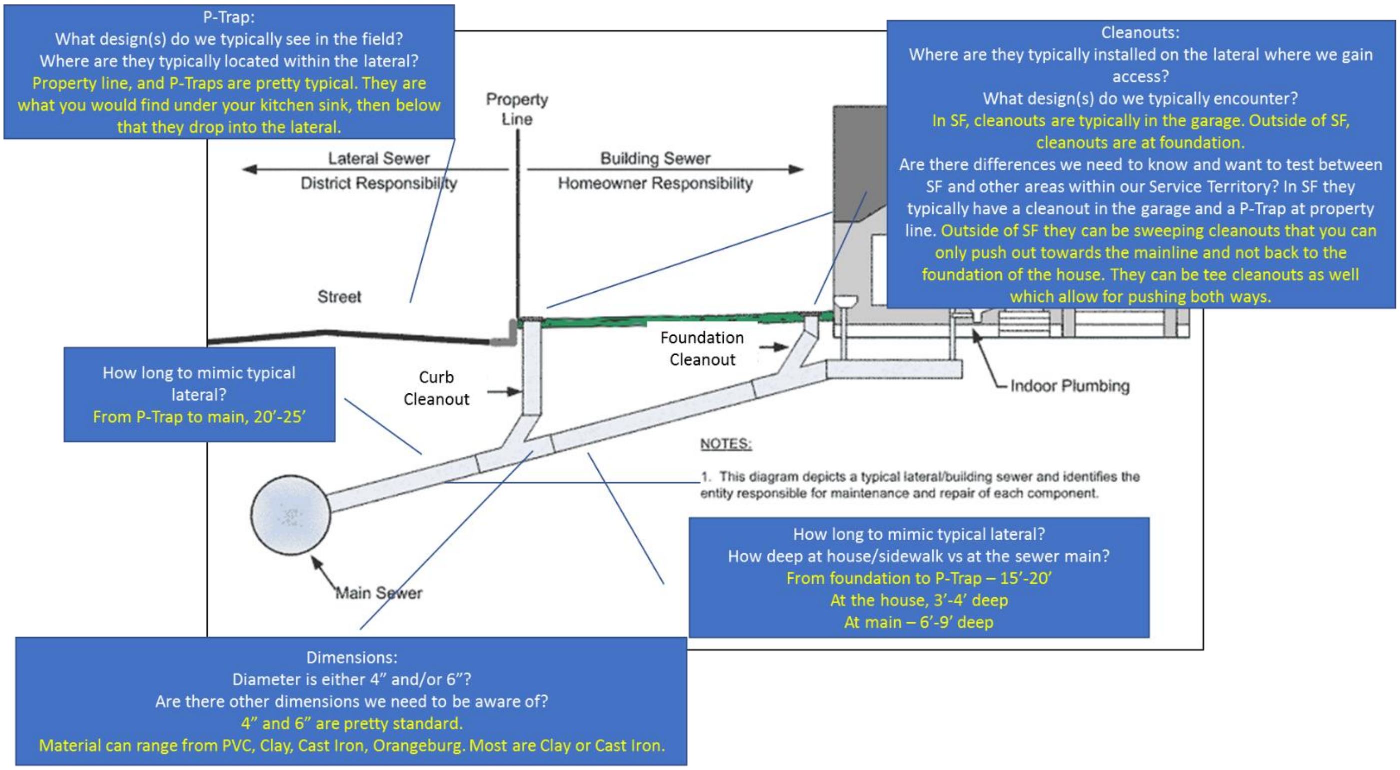
The project included the following objectives:

(1) Build a testing facility that mirrors installed sewer later configurations.
(2) Build a water extraction system that in the lab can consistently navigate the sewer lateral prop and sufficiently extract water such that inspections of the bottom half of the sewer lateral may be successfully completed.
(3) Demonstrate at actual UTA locations that the water extraction system can consistently navigate the sewer lateral and sufficiently extract water such that inspections of the sewer lateral may be successfully completed.
(4) Be able to dispose of extracted water in compliance with all applicable regulatory and legal requirements.

Tool Development and Testing

ServPro was selected to build and test a water extraction tool (WET). ServPro is a professional disaster recovery and restoration company with franchises across the United States. In addition to a variety of post-disaster services, ServPro provides specialty services related to wastewater removal, referred to as 'black water,' and disposes of the material at authorized waste disposal facilities in compliance with state and federal handling and disposal requirements. WET would be a new business for ServPro, so it required a thorough understanding of sewer lateral inspections, the nature of issues encountered in the field, and the tools used within the industry.

ServPro's leadership and tool design personnel met with PG&E's contract inspection crews in September 2018 to understand sewer lateral configuration and discuss the technology involved in sewer inspection. Critical to ServPro was gaining a deeper understanding of the requirements for current technology used in sewer lateral inspections, including needed flexibility balanced with rigidity, surface texture to avoid snagging, and maximum allowable diameter to manage small spaces. In addition to field visits, ServPro solicited information from PG&E's Cross Bore Program personnel (Figure 7).



P-Trap:
What design(s) do we typically see in the field?
Where are they typically located within the lateral?
Property line, and P-Traps are pretty typical. They are what you would find under your kitchen sink, then below that they drop into the lateral.

Cleanouts:
Where are they typically installed on the lateral where we gain access?
What design(s) do we typically encounter?
In SF, cleanouts are typically in the garage. Outside of SF, cleanouts are at foundation.
Are there differences we need to know and want to test between SF and other areas within our Service Territory? In SF they typically have a cleanout in the garage and a P-Trap at property line. Outside of SF they can be sweeping cleanouts that you can only push out towards the mainline and not back to the foundation of the house. They can be tee cleanouts as well which allow for pushing both ways.

How long to mimic typical lateral?
From P-Trap to main, 20'-25'

How long to mimic typical lateral?
How deep at house/sidewalk vs at the sewer main?
From foundation to P-Trap – 15'-20'
At the house, 3'-4' deep
At main – 6'-9' deep

Dimensions:
Diameter is either 4" and/or 6"?
Are there other dimensions we need to be aware of?
4" and 6" are pretty standard.
Material can range from PVC, Clay, Cast Iron, Orangeburg. Most are Clay or Cast Iron.

Figure 7—Generalized sewer lateral with questions (white text) and Cross Bore Program responses (yellow text).

ServPro built a sewer lateral prop for testing the WET at its local headquarters in Cotati, CA. The testing prop was constructed of 4-in.-diameter PVC and was 53 ft in length. The testing prop included foundation and curb clean outs, a sag, and a branch. Water was fed into the system to simulate partial or fully flooded water obstruction (Figure 8).

Figure 8 (clockwise)— Foundation access.
Branch in sewer lateral.
Curb access with p-trap.
Sag in sewer lateral using clear PVC for viewing water extraction in progress.

Water Extraction Tool (WET) Design

ServPro already has existing pumping capabilities built into its fleet vehicles to support its core business. Additionally, ServPro has existing arrangements for disposal of waste (black) water per state and federal requirements. The project utilized their existing system installed into a standard van (Figure 9).

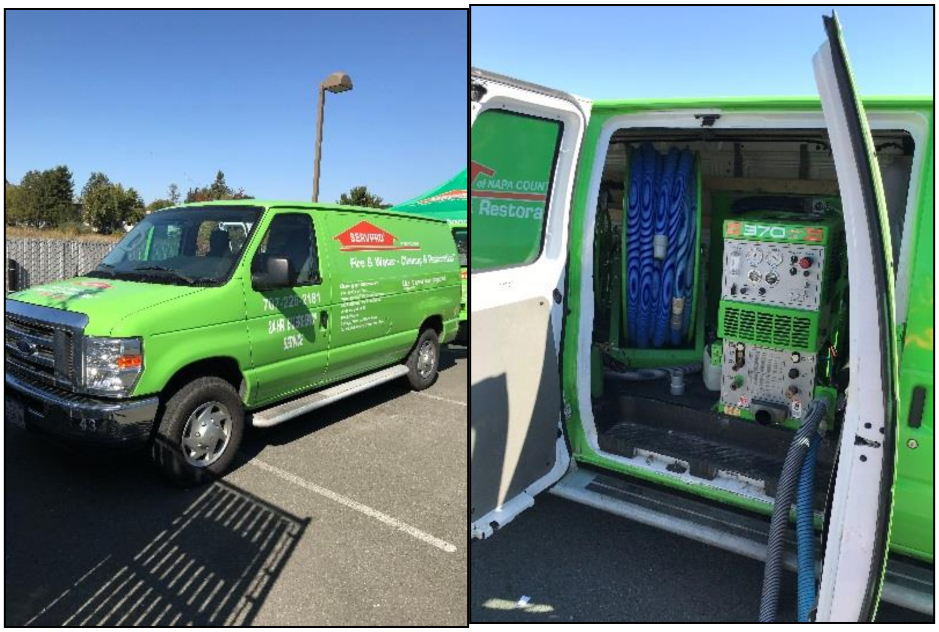


Figure 9 (left-right)—ServPro van and the interior showing vacuum hose and pumping system. Water storage tank (not pictured) is directly behind the pump.

A variety of hose types, sizes, and tips were developed and tested. Hose sizes included 1-in., 1.25-in., and 1.5-in. diameter. All hoses were 50 ft in length and could be connected if longer distances were required. Hoses were perforated to allow water to be extracted while the hose lay on the inside surface of a sewer lateral. Tips were designed to prevent larger objects such as rocks and gravel from clogging the hose. Figure 10 shows the hoses and tips.

Figure 10—Hoses and tips used during initial testing. Perforations can be seen on the hoses.

Initial Testing

Testing of the system occurred on October 19, 2018, at ServPro's Cotati HQ. The test was broadcast live via WebEx. Participants included PG&E's R&D and Innovation team, representatives from PG&E's Cross Bore Program, and leadership from the Distribution Integrity Management Program (DIMP).

Water was introduced and the sewer lateral was tested partially filled and completely flooded. The hose easily navigated the sag and branches. Testing demonstrated water extraction was sufficient such that a successful camera inspection would be possible (Figure 11).

Figure 11 (left-right)—Extraction hose within flooded sewer lateral prop.
Water partially extracted from sewer lateral prop.
Close-up of sewer lateral prop following extraction with no remaining water, allowing for successful camera inspection.

Following the success of the initial testing, it was decided to conduct additional testing in San Francisco at identified water obstruction locations.

WET Testing in San Francisco

Testing occurred at a total of 36 locations in San Francisco during November 2018 and March 2019. The ServPro crew worked in tandem with a PG&E sewer inspection crew. Testing using the following process was generally followed:

1. Sewer inspection crew performs an initial inspection of the sewer lateral, providing the following:
    a. Depth from access point to sewer lateral line
    b. Distance from access point to main and/or foundation
    c. Location in feet from access point to water, length of sewer lateral affected, if possible, and approximate depth of water within sewer lateral
2. ServPro technician chooses proper WET configuration and performs water extractions as many times as needed to successfully inspect the sewer lateral. Roots, hardened construction materials, and/or grease build-ups are not able to be extracted with WET.
3. Inspection crew re-inspects the sewer lateral following water extraction.

Selected highlights from field testing are provided below.

In late 2018, field tests were conducted at four locations in San Francisco's Potrero Hill neighborhood, where water-related obstructions within sewer laterals were common. Of the four locations, three sewer laterals were inaccessible due to roots, debris, or a collapse of the lateral, and no testing was possible. These challenges were not unexpected.

The single, accessible location proved invaluable as a first testing of the WET. The site consisted of a sewer lateral with two accessible cleanouts, one at the property’s foundation and another located at the curb. The sewer inspection crew inserted its optical camera at the curb location and confirmed the presence of water within the sewer lateral going back toward the property’s foundation. While the optical inspection camera remained in the sewer lateral, the ServPro crew inserted its WET at the foundation cleanout, feeding it into the sewer lateral toward the street. With the optical camera, real-time imagery was captured of the WET extracting water (Figure 12). Once the water was fully extracted, the crew successfully completed its inspection, confirming no cross bore present at this location.

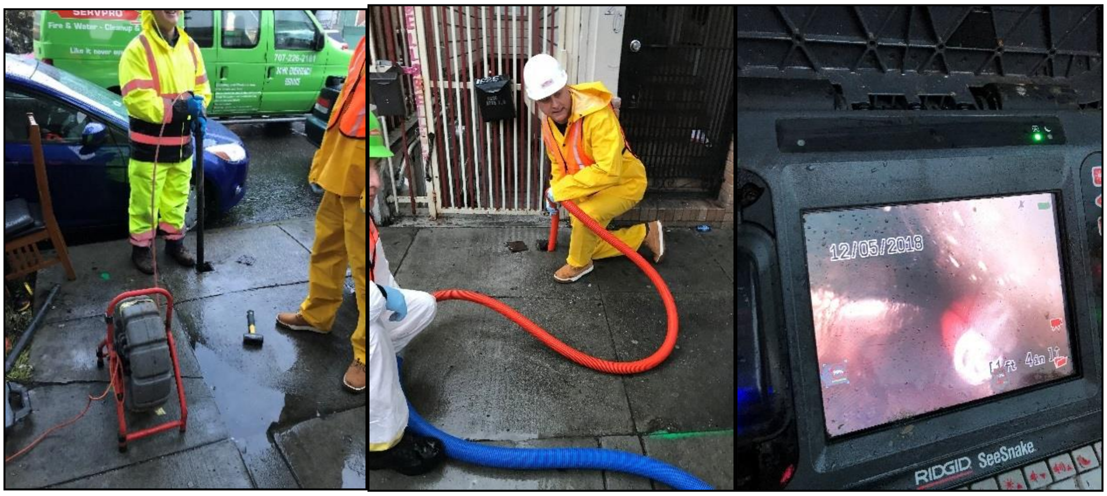


Figure 12 (left-right)—Inspection crew inserts optical camera at curb cleanout.
ServPro crew inserts WET at property line cleanout.
Real-time view of optical camera screen showing water being extracted.

San Francisco has a combined sewer/water runoff collection system, which prohibited testing during the rainy season. Testing was continued in March 2019, following the rainy season. During March 2019, an additional 32 locations were selected, of which 19 deployments of the WET were performed.

Generally, the WET navigated the p-trap with little or minimal effort. Following testing at its Cotati HQ and from prior field experience, ServPro had developed an adaptation of the hose that included the assistance of a plumbing snake (Figure 13). This adaptation was developed to assist with navigation of the p-trap. Additionally, during testing the snake was able to gently loosen sand and gravel that had accumulated within the sewer lateral, making extraction possible and increasing the utility of WET. In two instances, the WET was used to extract water simultaneously while conducting the camera inspection. In one such instance at a multifamily complex, the water needed to be extracted continuously because water usage in the building was continuous and obscured the inspection camera (Figure 13). Ultimately, the sewer lateral inspector conducted a successful inspection of the sewer lateral and determined no cross bore was present.

***Figure** 13 (left-right)— Plumber's snake modification to the hose to assist with p-trap navigation. Water extraction and camera inspection occurring simultaneously at a multi-family complex.*

Summary of All Water Extraction Tool (WET) Deployments

A total of 20 WET deployments occurred during testing (Figure 14). At four of the deployments, the WET was unable to extract the water due to

1. Inability to navigate the p-trap at two locations
2. Significant sand and gravel within sewer lateral
3. Sewer lateral clogged with wet wipes

WET successfully extracted water at 16 locations. Of these, three locations were not successfully inspected by the crew due to a combination of obstructions, including:

1. Unknown obstruction
2. Combination of hardened grease and gravel
3. Broken sewer lateral

Thirteen WET deployments resulted in successful sewer lateral inspections, none of which contained a cross bore. Figure 14 shows the performance of WET when deployed.

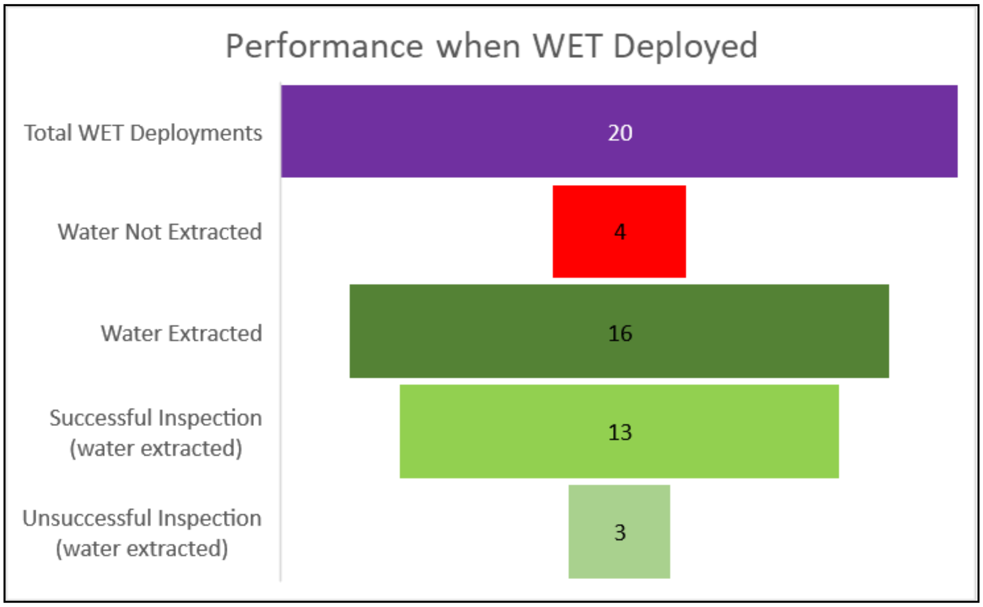


Figure 14—Performance when WET was deployed.

ServPro has an existing Wastehauler Discharge Permit issued by the City of Santa Rosa Water. Water collected during testing was disposed of pursuant to the requirements of the permit. Future activities would follow the same process.

Conclusion

ServPro successfully designed, built, and tested a water extraction tool (WET) that consistently navigated sewer laterals in the field and sufficiently extracted water within the sewer lateral such that inspections of the bottom half of the sewer lateral were successfully completed. A variety of hose types, sizes, and tips were developed and tested. Hose sizes included 1-in., 1.25-in., and 1.5-in. diameter. The 1.25-in.-diameter hose proved the most effective and easy to use. All hoses were 50 ft in length and could be connected if longer distances were required. Hoses were perforated to allow water to be extracted while the hose lay on the inside surface of a sewer lateral. Tips were designed to prevent larger objects such as rocks and gravel from clogging the hose. Lastly, to assist with navigation of the p-trap, a plumber's snake was incorporated into the design (Figure 15).

Figure 15—Final 1.25-in.-diameter hose configuration with plumber's snake.

Thirty-six San Francisco sites were visited during testing, at which the WET was deployed 20 times. WET was successful in 80% of the deployments, with 81% of those being successfully inspected by the sewer inspection crew.

The WET tool proved to be an invaluable addition to the portfolio of tools used in sewer lateral inspections. PG&E is moving forward with incorporation of the service into its inspection processes. Savings in San Francisco alone are estimated to be $2,000,000 in avoided excavation costs.

Case Study 3: Democratizing Ground Penetrating Radar Technology to Non-GPR Experts for Faster, Simpler, and Reliable Detection of Underground Utilities

Company's Name: Leica Geosystems
Contact Name: Simon Pedley
Contact Email: simon.pedley@hexagon.com
Area of Technology: Locating Device—Ground Penetrating Radar (GPR)
Level of Production: Green

Since the 1970s, ground penetrating radar (GPR) technology has been used primarily by highly skilled and experienced professionals trained to interpret difficult radar grams for detecting and mapping underground utilities. Achieving high-skilled interpretation can be an issue because achieving the best results requires a high degree of training and experience on the equipment. This article discusses new cutting-edge GPR technology that allows unskilled GPR users to locate, avoid, and map underground utilities in a simple, fast, and reliable way in the field. By opening the world of GPR to those with limited GPR knowledge, the new technology provides for safer excavation practices and leads to fewer utility strikes.

What is GPR?

GPR is a geophysical method that uses electromagnetic energy to create an image of the subsurface. This nondestructive method uses high frequency, pulsed electromagnetic waves (from 25 MHz to 3,000 MHz) to acquire information by the reflected energy from subsurface structures.

GPR transmits a very short pulse of electromagnetic (EM) energy into the material through a transmitting antenna. Energy reflected by discontinuities is captured by a receiving antenna. Depth range and resolution are related to the radar frequency, transmitted power, host material EM properties, and the shape and characteristics of the targets.

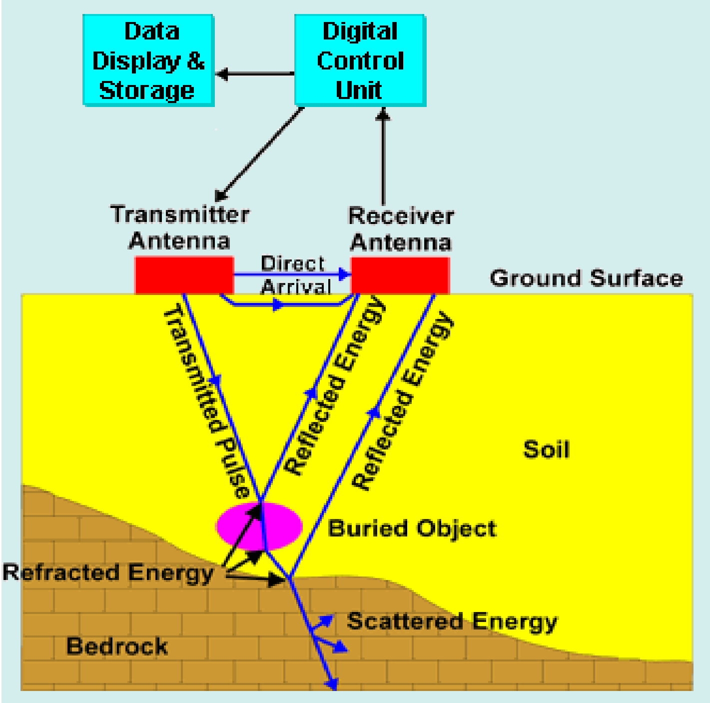


Figure 16—Overview diagram of how GPR works.

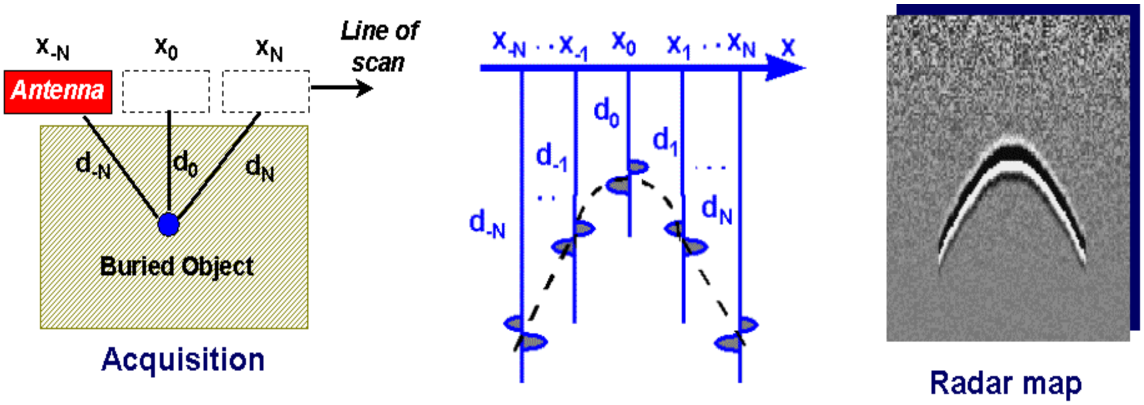


Figure 17—Visualization of how a hyperbola is formed

GPR Radar Grams

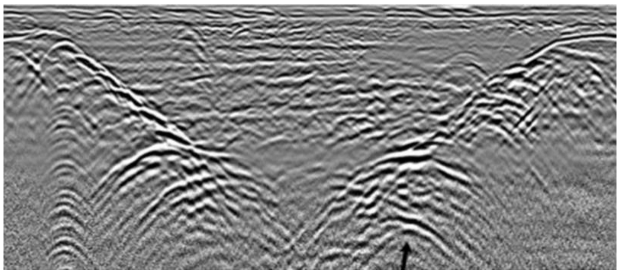


Figure *18—Radar gram.*

Once a GPR scan has been completed, we are able to view a radar gram that, to the untrained eye, may look like a contemporary black and white painting. This is where skill, experience, and training are key to utilizing the current technology. A GPR professional will be able to take various pieces of information from a radar gram and understand the locations of trenches and if there is a pipe in that trench. They will also be able to see the difference in material changes of the subsurface and how these differ from the path of the utilities. A lot of information can be taken but this only comes with a high amount of training and years of experience using these tools.

Recent Innovations

In recent years, the use of C-scans has been increasingly used in archeology and utility investigations to aid in the visualization of GPR data. C-scans use multiple GPR radar grams that are generated with each data swath collected. To produce such a scan, an area must be crossed methodically in two directions. Once the data has been collected, the process of creating a C-scan may begin. Algorithms are used to interpolate the data into a top-down view of the subsurface. For such visualization to be generated, the data must be post-processed, which takes the data collected and saved on site for review and interpretation in the office using separate computer and software packages. Post-processing is a time-consuming process. Currently a day's worth of data collection takes up to two days to process.

It is now possible to create a C-scan in the field. This helps to visualize the subsurface and allows an operator to quickly understand the approximate location of utilities or areas of interest. To mark and identify these in the files, or even start to map these utilities, the users still must interact with the radar gram.

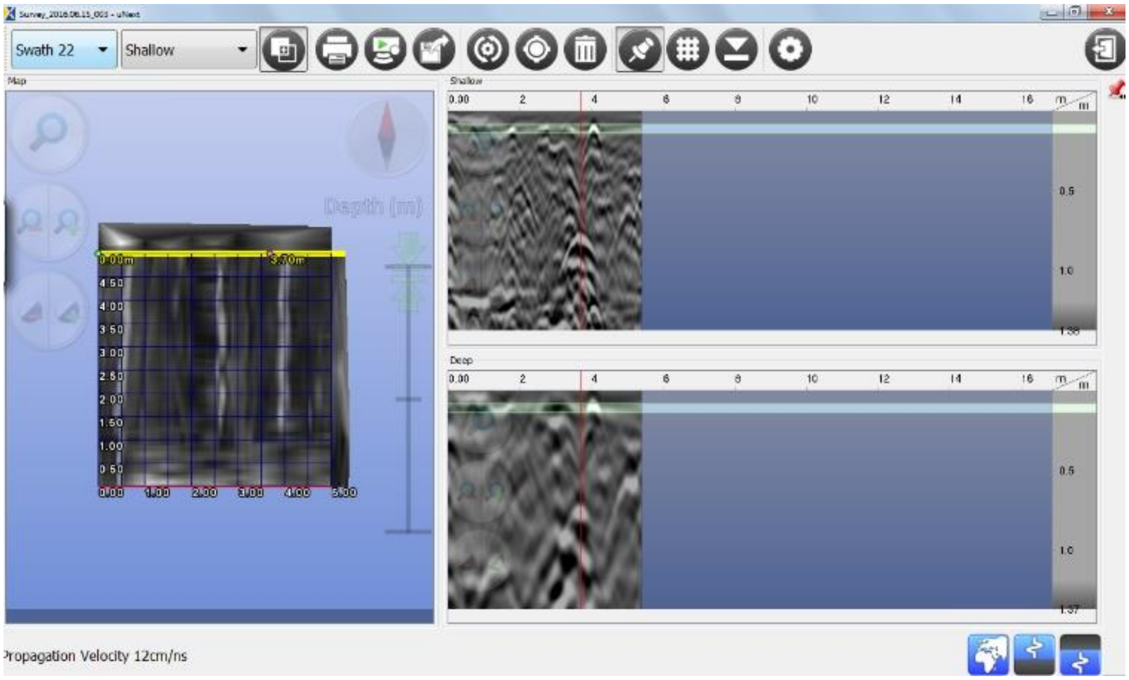


Figure 19—Graphical image of current in field C-scan. C-scan displays the topographical view, and utility identification is conducted on the radar grams.

New Technology

Leica Geosystems has introduced a new GPR called the DSX, a portable utility detection solution designed to bring non-skilled GPR users the latest developments in utility detection with simplified workflow, automated data processing, and high accuracy. Users can now easily locate underground utilities and clearly visualize detected utilities via the onboard acquisition software called DXplore, which is very intuitive to use. Users have the flexibility to easily interface with various positioning systems while performing utility verification immediately on site. This solution combines the latest GPR technology with the best-in-class positioning accuracy from Leica Geosystems' GNSS[7]/GPS or TPS[8] devices.

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[7] Global Navigation Satellite System

[8] Total Position System

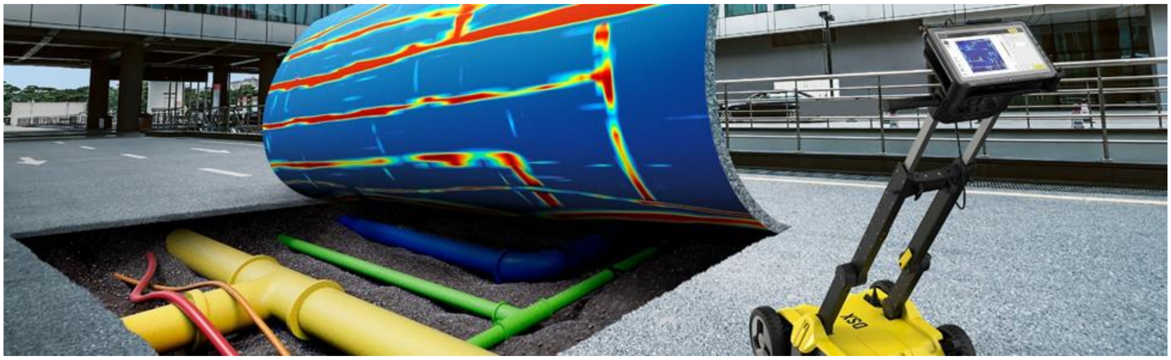
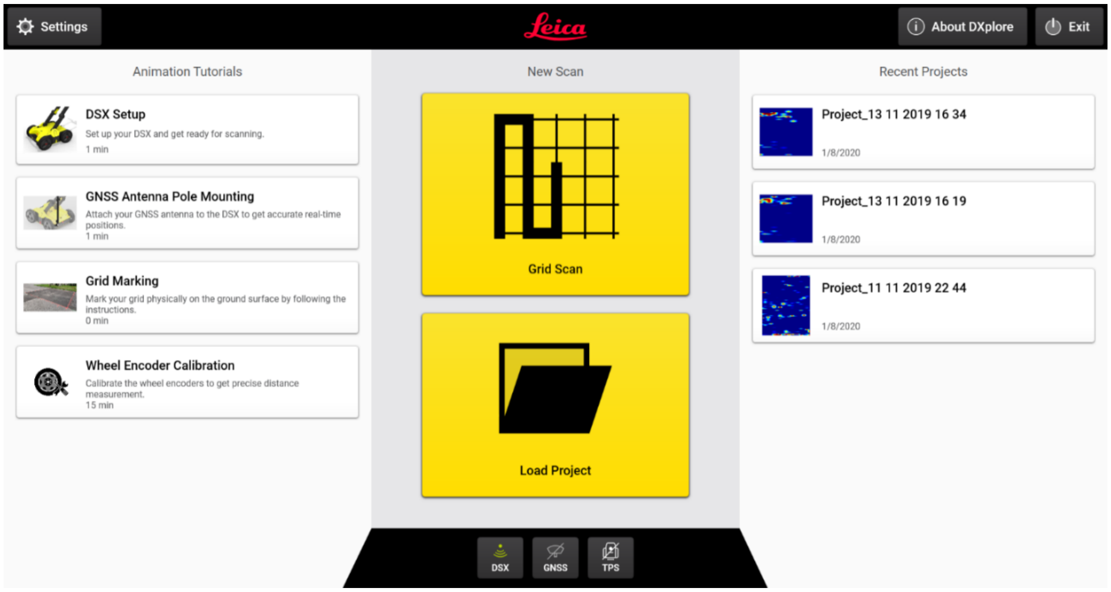


Figure 20—Visualization of captured vs real-world data

The software's easy-to-use tutorials cover the main aspects of using and collecting data with the GPR system. The user will have confidence to set the system up, connect a GNSS/GPS antenna to the controller, and correctly mark the acquisition grid for accurate and reliable data collection. Training time has been dramatically reduced with this software.



Animation Tutorials

DSX Setup
Set up your DSX and get ready for scanning.
1 min

GNSS Antenna Pole Mounting
Attach your GNSS antenna to the DSX to get accurate real-time positions.
1 min

Grid Marking
Mark your grid physically on the ground surface by following the instructions.
0 min

Wheel Encoder Calibration
Calibrate the wheel encoders to get precise distance measurement.
15 min

Recent Projects

Project_13 11 2019 16 34
1/8/2020

Project_13 11 2019 16 19
1/8/2020

Project_11 11 2019 22 44
1/8/2020

Figure 21—Home screen of the DXplore.

The DSX utility detection solution improves post-processing time by detecting every type of utility and immediately generating an intuitive and easy-to-understand 3D utility map in the field.

Users no longer must interpret a radar gram nor wait for post processing. The DSX immediately displays the results with automated GPR post processing and data analysis right in the field. A digital utility map is generated within minutes. This utility detection solution brings a more efficient, robust, and easy-to-use GPR system to contractors and users by detecting utilities on site and easily checking data quality in real time.

Prior to operating the DSX, users may upload utility maps of the designated work area. These maps can help identify located utilities and correct utility maps if inaccuracies are discovered. Users can also add additional information in the form of POIs (Points of Interest), which include physical markings such as valves, post-construction evidence, or marks laid by electromagnetic locators prior to using the GPR.

When using the system in the field, the operator collects data in two directions, transversal and longitudinal, within the defined excavation area. The software guides the user on correct data collection to minimize mistakes. Upon completion of data collection, the data is analyzed, and the user can work and interact with the tomographic view.

To determine if a utility is present, the operator simply uses their finger to swipe across the screen where they believe the software should show an indication of a utility (Figure 22). At this point, a unique software algorithm determines if the path drawn is a utility. If the software confirms a utility, it draws it on the map. Additionally, the software also confirms the actual path of the utility, not necessarily where the operator drew it. The software alerts the operator if it does not confirm that a utility is identified.

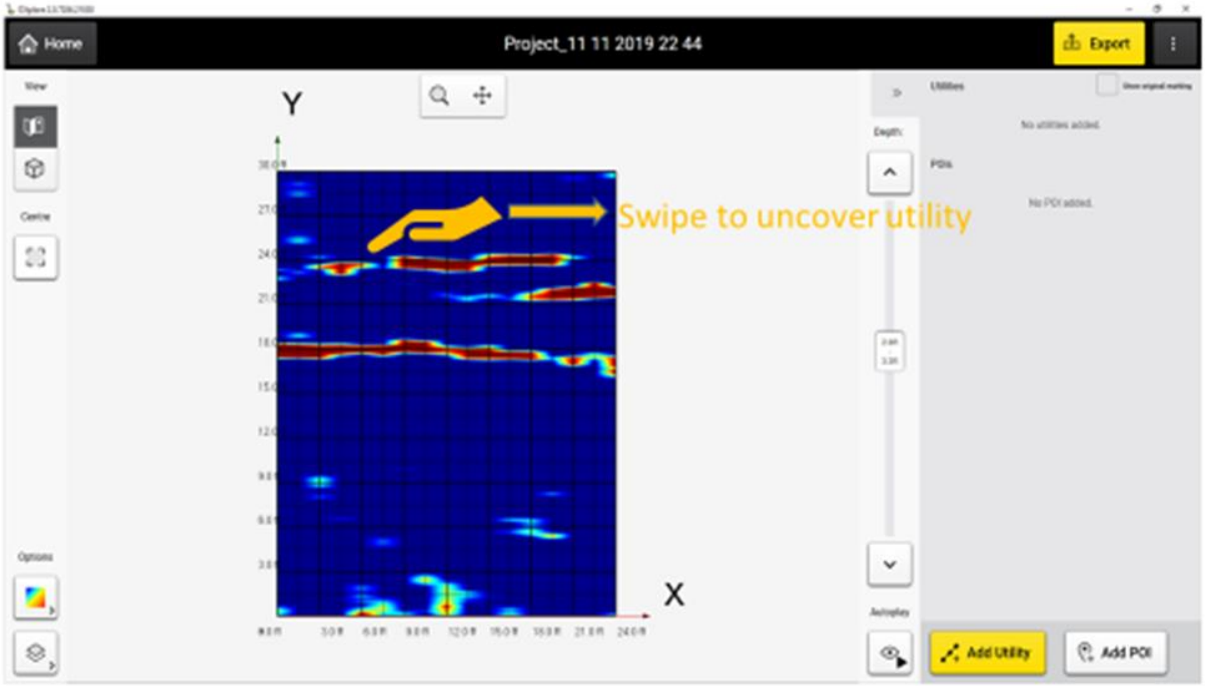


Figure 22—Screen shot of finger swipe to identify utility.

Once all utilities have been drawn, the utility line can be viewed in a 3D space. The software displays each utility's GNSS/GPS or TPS position and the calculated depth. This allows the operator to see how the utility tracks and interacts with other utilities in the subsurface.

Once the utility map is produced by the DSX, the data can be used in multiple ways:

- Exported so that third-party software applications can utilize the DXF file format.

- Transferred to Leica Geosystems' MC1 software. The MC1 is the one-for-all software solution platform to guide and automate all heavy construction machines. The data will be georeferenced in the current building model that is being used, and the identified utilities will automatically have an avoidance zone placed around them. The avoidance zone works in real time to alert the excavator driver when they are in close proximity of a utility.

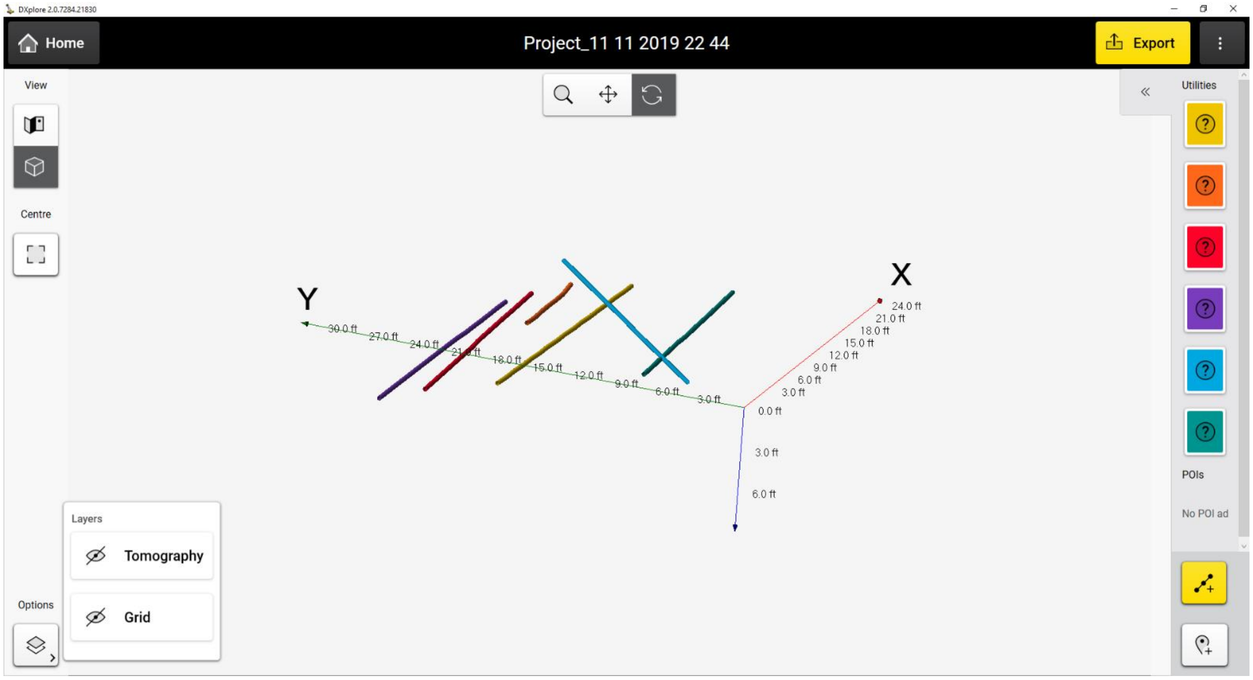


Figure 23—3D view of detected utilities.

Conclusion

New technology, such as the intuitive software on the Leica DSX ground penetrating radar, can provide better access to all users interested in GPR to locate metallic and non-metallic utilities or to confirm that excavation areas are clear of utilities. When the DSX is used in conjunction with Leica Geosystems MC1 machine control software, the chances of utility damage are reduced. Excavator operators are provided visual models of the underground infrastructure while aboard the machine. Safer excavation practices and improved damage prevention are the goals.