PROJECT CASE STUDY

Investigating the use of GIS and RFID/magnetic marker technologies for better underground asset management

TECHNOLOGY:

GIS + RFID + magnetic marking

INDUSTRIES:

All

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Abstract

Accurate locating and identifying of underground assets are critical for damage prevention. This research project explores how three technologies – GIS, RFID, and magnetic marking – impact the speed and reliability of finding identifying, and managing underground utilities. The 7-year study finds that multi--factor approach of connecting GIS with RFID/magnetic in-ground markers best improves underground utility management performance.

Introduction

Each year, an estimated $30 billion[1] in societal costs result from underground utility strikes. This estimate does not include additional billions of dollars lost in construction delays caused by wait times for locates, repeat locates caused by expired tickets, or excavator locate costs incurred in 're-locating' a site. These costs and related damage prevention are expected to increase as anticipated funding from the Infrastructure Investment Act and Jobs Act increases community construction projects over the next five years.

The Common Ground Alliance identifies the primary root causes for damage in its 2021 DIRT report.

> *" The vast majority of damages are caused by a limited number of issues: (1) digging without notification to the one call center/811; (2) excavators failing to pothole and failing to maintain sufficient clearance between digging equipment and buried facilities; and (3) facilities not being marked or being marked inaccurately due to locator error and/or incorrect facility records/maps.[2]"*

This study investigates a multi-factor technology solution to the root cause problem of inaccurate mapping and marking in the field.

GIS and passive UHF RFID are two of the fastest growing technologies in the world. This longitudinal study evaluates how RFID and magnetic in-field marker technologies, coupled with field connected GIS, can mitigate costs and support future underground asset management needs. Study results show that these technologies deliver fast, reliable underground asset identification and improve field to office data management while delivering the durability to meet in-ground infrastructure marking requirements.

[1] Common Ground Alliance's **2020 Damage Information Reporting Tool (DIRT) Report** analysis of more than 500,000 damages and near-miss events.
[2] Common Ground Alliance's **2021Damage Information Reporting Tool (DIRT) Report**
[3] Wang, Y., Wu, Y., Sankar, C.S., Leveraging Information Technology for Disaster Recovery: A Case Study of Radio Frequency Identification (RFID)Implementation for Facility Retrieval Journal of Information Technology Case and Application Research, 17: 41–55, 2015.

Background

This study is an extension of work conducted at Auburn University in 2012 which evaluated the feasibility, reliability, and cost of using RFID, magnets, and GPS technologies to improve underground utility locating in disaster recovery situation. In that study, the sponsors used GPS coordinates to get close to an underground utility point, underground magnetic markers to pinpoint the location, and RFID asset identification data to verify the underground asset. A cost analysis completed as part of that study showed that this process reduces the cost of recovering utility facilities buried under storm debris by 26% compared to current methods."[3]

This study extends that Auburn work in two important ways:

1. The study was conducted over a longer time-frame to assess the durability of the magnet and passive UHF RFID technologies in the field, and,
2. The study replaced GPS locating technology with the more powerful connected GIS mobile technology to assess the impact on field asset management workflows

Study Purpose and Objectives

The purpose of this longitudinal study is to determine how GIS, RFID, and magnetic marking technologies – either on their own or in combination – can deliver underground asset information that improves safety and cost and prove reliable for long-term infrastructure performance. Specific study objectives include:

- Assess the reliability and durability of buried UHF RFID magnetic markers after 7 years in the ground.
- Measure and evaluate the speed and reliability of (1) locating the underground marker, (2) positively identifying the underground marker, and (3) connecting to the GIS with a RFID interrogation.
- Assess the reliability and accuracy of producing an audit trail from a field RFID interrogation
- Assess the ease of deployment (installation) and field data collection workflows
- Identify areas for future product and process improvements or study.

Study Methodology:

Components

Staking University provided the site and underground utility locating guidance for the study. Berntsen provided the marking products, equipment, software, and labor to conduct the study.

1. **Underground RFID and magnet-enabled marking products**

   The principal underground RFID Marker (tag) used in 2015 was the InfraMarker 483 RFID Subsurface Asset Marker. The IM483 includes a magnet, passive UHF RFID tag with user memory, and is encased to optimize RFID signal strength and withstand rugged conditions.

IM483 RFID Subsurface Asset Marker

2. **RFID Readers and Magnetic Locators**

   The TSL 1128 mobile RFID interrogator was used to write and read the underground markers. The TSL 1128 was selected for its RFID antenna performance, ease of use in the field, and connectivity to the mobile device running the data collection apps.

TSL 1128 Bluetooth® UHF RFID Reader

3. **Schonstedt MAGGIE Magnetic Locator**

   The Schonstedt MAGGIE magnetic locator was used to detect and pinpoint the magnetic signal emitted by the IM362 underground marker. The MAGGIE was selected for its strong sensitivity performance, ease of use in the field, and audio/visual feedback for polarity and signal strength.

Schonstedt MAGGIE Magnetic Locator

4. **GIS and RFID Connecting Software.**

   For the installation process in 2015, Berntsen used its own proprietary InfraMarker software platform to provide GIS functionality (mapping, photos, forms building, data collection) and the capability to control the TSL RFID interrogator and exchange data between the underground RFID marker and the software.

   For the 2022 read interrogation, Berntsen used ESRI's ArcGIS as the GIS platform and ESRI's Survey123 for ArcGIS and ArcGIS Field Maps for ArcGIS mobile data collection software enhanced with the InfraMarker RFID app to conduct field RFID interrogations. The InfraMarker RFID app performs the same TSL RFID interrogation functionality with independent cloud data capture for RFID interrogations and with data exchange to the ArcGIS platform.

   The change to the world's largest GIS platform was made possible by the 2022 introduction of InfraMarker RFID for the ArcGIS mobile software tools. The update provides the same functionality and better matches the GIS platform in use by utilities and governments throughout the world.

[3] Wang, Y., Wu, Y., Sankar, C.S., Leveraging Information Technology for Disaster Recovery: A Case Study of Radio Frequency Identification (RFID) Implementation for Facility Retrieval Journal of Information Technology Case and Application Research, 17: 41–55, 2015.

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Installation and Setup (2015)

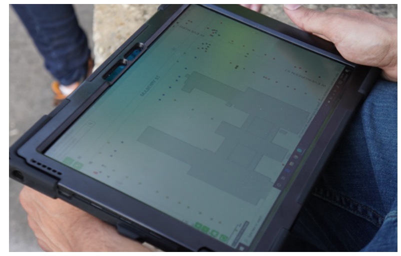
In the summer of 2015, the study team placed 174 underground InfraMarker RFID tags (IM483) in the ground above previously identified utility gas, water, electric, and telecom lines at the Staking University site in Manteno, Illinois using the following process:

Pre-placement: The Berntsen InfraMarker team loaded the InfraMarker RFID software on an Apple iPad(s) and created the forms to write data to the underground RFID markers.

1. Each underground RFID marker was 'written' in the field at the point of placement using InfraMarker mobile software and a connecting TSL RFID reader. The data written to each marker included the specific utility location coordinates taken from the mobile device settings, owner name, and asset or point description. This information supplemented the unique EPC (serial number) already on the tag.
2. Once written at the site, each RFID marker was placed level 12-24 inches below the surface, above or adjacent to the specific utility point.

InfraMarker underground tag placed in trench over water pipe

InfraMarker underground tag placed over water pipe near a catch basin

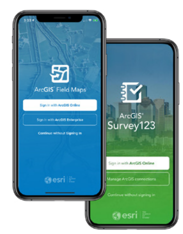


All Utilities depicted in InfraMarker software after installation in 2015

3. After placement in the hole, additional information (photo, video, date/time stamp, and/or notes) was collected using the GIS mobile software. The additional information collected as well as the data written to the InfraMarker RFID tag were saved to the GIS record of that asset or point.
4. Berntsen maintained the Staking University site map in its GIS and provided periodic location checks over the next six years.

A screen capture from the data collection workflow in the InfraMarker app, used for the installation of RFID Markers in 2015.

A screen capture from the asset location map in the InfraMarker app, used for the installation of RFID Markers in 2015.



Intro screens of the InfraMarker add-in for ArcGIS Field Maps and Survey123 used in 2022 to read the RFID Markers installed in 2015.

Data Collection (2022)

In June 2022, Berntsen's InfraMarker team returned to the Staking University site to test the location, verification, and inspection workflow for each of the 174 underground markers. The follow-up study process involved five steps:

1. The locate team was provided an iPad with the ArcGIS InfraMarker project, a TSL Reader, a Schonstedt magnetic locator, and two hours of training on use of the equipment and study process.
2. Locate marker workflow. The locator used the map of the site and supporting photos to travel to the proximate marker location on the campus. Once close, the locator used a magnetic locator sweep to pinpoint the surface location of the underground marker. A successful locate occurred when a strong, negative polarity signal displayed on the magnetic locator.
3. Identify marker workflow. The second step was to positively identify the underground asset to verify the underground marker matched the digital representation on the map. The locator used the TSL1128 to 'read' the tag through the ground at the point where the maximum magnetic signal was returned. A successful asset identification occurred when the information from the underground tag was returned and displayed on the iPad.
4. Connect to GIS workflow. After a successful identification, the locator would select the RFID data displayed on the iPad and launch the related GIS inspection form associated with that underground asset. The locator would then complete and submit the inspection form. A successful workflow operation occurred when the inspection form was complete and added as a record to the asset data in the GIS.

The team documented the number of underground markers located with GPS and magnetic locating, number of markers that returned successful RFID identification (positive asset verification), and the number of inspection forms completed. Time measurements were also taken for each process.

Random Asset point locating speed:

In addition to testing the location and verification of 174 assets, the team selected fifty markers at random to simulate the action of finding and conducting an action at a particular point. In this test, the locator was assigned a point at random and instructed to locate, identify, and update that point.

Ease of use feedback:

Locators were interviewed during and after the study to qualitatively learn about their user experience with the hardware and software.

Audit and Compliance Performance

Every RFID interrogation conducted in the field using the InfraMarker RFID app incorporates a date/time stamp to verify presence and record the time when the marker interrogation occurred. The final step in the study was to produce an audit trail file of the two-day project.

Study Results

Reliability and Durability of Subsurface Magnet and RFID markers

Total Number of underground RFID markers buried at Staking University	174
Locating Performance	
Number of underground RFID tags located with GIS and magnetic locator	162
Number of underground RFID tags NOT located with GIS and magnetic locator*	12
Percentage of underground markers located after 7 years* (162 of 174)	93%
Asset Identification Performance	
Number of located underground RFID tags that produced a successful RFID read (all tag data read and displayed in the field)	158
Number of located underground RFID tags that returned no data	4
Percentage of located underground markers that also produced a successful RFID identification (158 of 162)	97.5%
Field Connected GIS Workflow Performance	
Number of RFID identified markers with a completed inspection form launched by the RFID interrogation	158
Percentage of identified markers with a completed GIS inspection record	100%

*Staking University is a training site and is continually being excavated. Two RFID tags been confimed to have been dug up or destroyed during unrelated training or demonstration sessions. It is likely several others have also had a similar fate.

Location and identification performance (full campus)

The two locators completed the locating, identification, and workflow process of 174 underground markers in 16 hours of total FTE time. The process for using the map, conducting a magnetic location and RFID read, and completing a basic form in the field GIS took an average of 5 minutes per locate.

Random assignment asset locating and identification performance (50 points)

Fifty assets were selected at random for verification, simulating the efforts required to find a buried valve or splice for inspection. The 50 assets were located and verified with a RFID interrogation within two hours (including walking time).

Audit and Compliance Performance

Each RFID interrogation was captured in the simulating the audit requirement of proving a technician was proximate to the asset at a specific date/time. Each RIFD interrogation was captured in the InfraMarker RFID Cloud.

Study Findings

1. **Magnetic Markers are durable and effective for pinpoint locating.**

   93% of the markers were magnetically located after seven years in the ground.

   *Note: that the area where the RFID markers were installed is continually under excavation for training purposes. Two of the missing 12 missing markers were confirmed to have been excavated and removed during other training sessions at Staking University.

Transactions

Filter: Date From: 06/09/2022 Through: 06/11/2022 Apply

Asset Name	Asset Owner	InfraMarker ID	Action	Date	Latitude	Longitude
GAS 2	Staking	2013060184470100010100032	read	06-09-2022 03:36:38 pm	41.23008229	-87.80867473
WTR 27	Staking	201209108521030001020018A	read	06-09-2022 03:33:50 pm	41.23000174	-87.80866425
3M TEL 2	Staking	20120918852004000104001E2	read	06-09-2022 03:20:53 pm	41.22991023	-87.80834013
TEL 26	Staking	20120910852103000101002CE	read	06-09-2022 03:15:17 pm	41.22990996	-87.80854798
TEL 27	Staking	2012091085210300010100247	read	06-09-2022 03:13:51 pm	41.22990914	-87.80859649
		20120910852004000104000B1	read	06-09-2022 03:05:17 pm		
GAS 43	Staking	201209108520040001040014D	read	06-09-2022 03:03:46 pm	41.2298808	-87.80854514
		2012091085200400010400249	read	06-09-2022 03:02:15 pm		
		201807201212 1A0510300572	read	06-09-2022 02:44:58 pm		
GAS 34	Staking	201209108520040001050028B	read	06-09-2022 02:38:58 pm	41.22988442	-87.80773262
		20120910852004000104001D6	read	06-09-2022 02:37:06 pm		
Gas33	Staking University	20120910852004000104001D6	write	06-09-2022 02:36:42 pm	41.22992636	-87.8076588

2. **RFID asset identification performance is reliable.**

   Nearly 98% of the located underground markers returned RFID information that had been written to the tag in 2015.

3. **Field RFID interrogation connectivity to GIS worked in all instances**

   Every RFID read from a 'found' marker connected to the GIS, launched the related inspection record, and captured a date/time stamp that contributed to a full audit record of marker interrogation.

   There were zero errors in matching the marker in the field to the associated asset record in the GIS.

4. **GIS complements in-field locating and identification.**

   While GIS alone is not sufficient for precision locating, it is invaluable as a tool to accelerate locating and field asset management workflows. The power of the GIS map with accompanying photos and notes, significantly reduced the time to get close to the underground marker and minimize the use of the magnetic locator for precision locating. GIS, tied to an RFID asset identifier, eliminates the human error of field to office data transcription and minimized time for launching the related inspection form.

5. **Field use improvements should be implemented to reduce steps and minimize equipment requirements in the field.**

   The equipment performed well but the technicians found use of the equipment cumbersome when carrying the iPad, magnetic locator, and RFID reader.

Preliminary Conclusions

While the sponsors will continue to conduct further testing, we are confident enough in these study findings and our work to date to offer the following conclusions:

- GIS is an essential tool for better, safer, underground asset locating and management. The future of underground utility management is better when the power of GIS is available to field locators. GIS is the foundation for underground utility location and identification data sharing across organizations.
- GIS delivers best results when coupled with in-field verification of a physical asset such as an RFID identifier. That two-factor verification approach mirrors standard verification practices in place across the digital world.
- Magnetic marking is a reliable utility agnostic tool for point and line marking. Magnetic marking, coupled with GIS mapping, is a low-cost, reliable solution for underground infrastructure locating.
- RFID has been referred to as the "serial number of IoT" and is shown in this study to be a reliable unique identifier for underground assets (e.g. valves) or points (e.g. conflicts, weld points, splices). The technology's capability to act as a digital connector to the GIS or Asset Management System reduces human error and increases the value of the technology for underground infrastructure management.

Next Steps

The sponsors will continue to conduct periodic reviews of Staking installed marking products as well as installing new marking products to test updated technology capabilities in a wider variety of installations. In addition, planned next steps include:

- Demonstrate technology capabilities with Common Ground Alliance Next Practices and locating events to highlight results and obtain expert feedback.
- Conduct a pilot installation with a new construction project using customer GIS and staff.
- Work with existing equipment RFID and magnet locator manufacturers to optimize field workflow design and process.
- Demonstrate standards for GIS data sharing across multiple organizations.

Study Sponsors

Berntsen International is a leader in the manufacture and sale of survey and utility marking products. It developed the unique combination of RFID hardware and software that includes RFID / magnetic markers and readers, mobile apps and geographic information system (GIS) software that is undergoing continual study at Staking University's training campus.

Since 1999, Staking University has worked to prevent utility damage by providing hands-on training and certification programs focused on underground utility locating techniques. Its flagship site is located on a 16 city-block campus of the former Manteno State Hospital in Manteno, Illinois. This site offers 'real world' testing of utility locating practices with its unique mix of old, new and abandoned-in-place infrastructure.

For more information about the study, email info@inframarker.com.

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