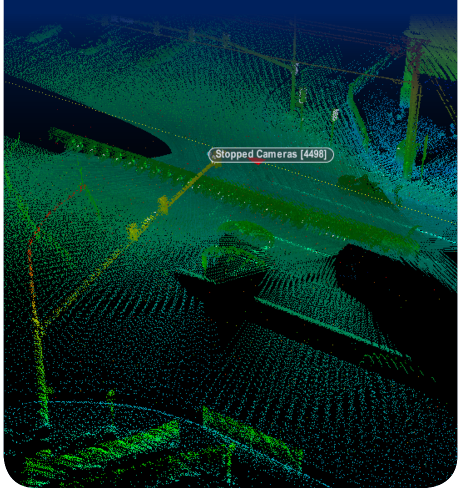
3D Engineered Models:
Schedule, Cost and Post-Construction

PROGRAM CASE STUDY

This case study highlights a Comparison of New Programmatic Approaches in Virginia and Michigan to improving underground utility mapping to better support design, construction, and asset management.



As-Built Utility Surveys: A Tale of Two State Transportation Departments

Documenting the location and other important characteristics of newly installed utilities is an important component of right-of-way (ROW) management, especially considering those utilities will be in place, hidden from view, and operational for many years. Most state departments of transportation (DOTs) do not own most of the buried utilities, yet these structures affect current and future DOT projects, including ongoing maintenance and operational functions. The best opportunity for agencies to capture accurate utility positional information for future use in design, construction, and asset management is, in fact, during construction when the utility is exposed.

Both the Virginia and Michigan DOTs have initiated processes that lead to accurate utility location and related information for asset management and project safety during utility installation and/or project development. Virginia is capitalizing on radio frequency identification (RFID) tagging systems, which use radio waves to capture and read information stored on tags attached to newly installed utilities and to existing utilities as they are uncovered. Michigan's data exchange initiative is improving the awareness and quality of underground utility information. This case study presents key aspects of these programs to encourage similar utility location efforts.

> "Because the public transportation right-of-way is where nearly all buried utility systems are located, the planning, design, construction, maintenance, rehabilitation, and renewal of both transportation systems and utility systems are closely connected. Better information sharing and coordination between the owners of these two systems could accomplish a great deal."
>
> *– Transportation Research Board SHRP2 Report S2-R01-RW: Encouraging Innovation in Locating and Characterizing Underground Utilities*

Virginia's GPS/RFID Program

The Virginia DOT's (VDOT's) Northern Virginia District regularly constructs large, complex projects and experiences problems during construction with utility information being outdated. Although they provide a thorough utility investigations map early in the project (at the 10% stage) for the benefit of their designers and in accordance with ASCE 38-02, the American Society of Civil Engineers' *Standard Guidelines for the Collection and Depiction of Existing Subsurface Utility Data*, the utility locations continue to change, and new utilities are constructed, during the life of the project.

Invariably, utility relocations happen before and during project construction, and during the three- to five-year design time, utility owners may need to install new utilities in the project area as a course of their normal business. VDOT also installs its own utilities during this process.

In addition to the mapping being out-of-date, significant errors and omissions in One-Call markings were occurring during project construction. This was causing delays and other associated problems.

Figure 1. Marker balls give a robust point-to-point picture of newly installed utilities and allow personnel to "connect-the-dots" with fairly accurate results using readily available RFID software technology.

There are many reasons these errors can occur, including the following:

- One-Call responders, who mark the location and route of utilities present at a work site, typically work unaccompanied with no traffic control measures other than a safety vest. This means transmitters cannot be placed in traffic, where they may need to be; vaults cannot be opened and utilities individually clamped and traced; and heavy traffic and tired, angry commuters tend to make One-Call responders justifiably preoccupied with their safety while working in the roadway.
- Utility owner records may not be updated and available to the One-Call responders, resulting in a lack of current spatial and system information, or even the wrong information, on the new facilities.
- The approximately 30 utility owners in the district do not all use the same One-Call responders, which allows known mismarks to go uncorrected.
- Some utilities cannot be detected with standard pipe and cable locating tools.

To address these issues, the Northern Virginia District developed a pilot program that uses an RFID tagging system combined with Global Positioning System (GPS) data. This combined use of RFID, GPS, and mapping software is providing real solutions to long-standing utility problems.

RFID tags identify the specific utility and record valuable information about the facility. This information can then be obtained in the field or in the office via the as-built records. GPS coordinates are established at each point, and, using mapping software, the running line of the utility is established on an electronic mapping layer. This layer can be overlaid on the design files as well as on Google Earth.

For each relocated utility, VDOT is installing a programmable 3M™ marker ball at a depth of 3 feet

> "Trying to locate a fixed-location object by repeatedly employing various detection methods is clearly inefficient… However, rapid developments in utility marking and radio frequency tagging systems (RFID) and new technologies involving global positioning systems (GPS) and three-dimensional (3D) geographical information systems (GIS) have changed what is technically possible in this regard. Together, these technologies allow for the development of accurate 3D databases for newly installed utilities and for the rapid capture of accurate positional information when existing utilities are exposed."
>
> *– Transportation Research Board SHRP2 Report S2-R01-RW: Encouraging Innovation in Locating and Characterizing Underground Utilities*

"The current RFID program has proven very beneficial to the entire northern Virginia construction industry by providing a utility as-built that has sub-foot accuracy and has promoted safety with utility damage prevention by providing our contractors a tool for finding valuable information pertaining to the utility infrastructure in the field. Time and time again this process has provided a safer working environment for our contractors and has reduced the risk of possible injury to the traveling public."

– Shea Ridings, Utility Construction Program Manager–Project Controls, Northern Virginia District, Virginia DOT

within the utility backfill, directly above the centerline of the utility, in accordance with the following protocol:

- every 25 feet on straight installations (for both metallic and non-metallic utilities)
- at every tee fitting
- at crossings of other utilities
- at service connections
- at horizontal and vertical changes of significance (greater than 1-foot change)
- at the endpoints of any abandoned facilities when they are encountered or uncovered in the field

The marker balls give a robust point-to-point picture of the newly installed utility and allow field and office personnel to "connect-the-dots" with fairly accurate results using readily available RFID field and office software technology.

The marker balls include retrievable information on the utility owner, type and size of utility, elevation/depth, GPS horizontal coordinates, and reason for the marker (e.g., tee, service connection, change in direction). They are programmed in the field primarily through laptop connections, although in certain situations some basic information can also be programmed with the field instrument. With a unique identification number for each ball, additional as-built information important to each utility owner can be referenced and stored in a secure database.

VDOT's workflow process is as follows:

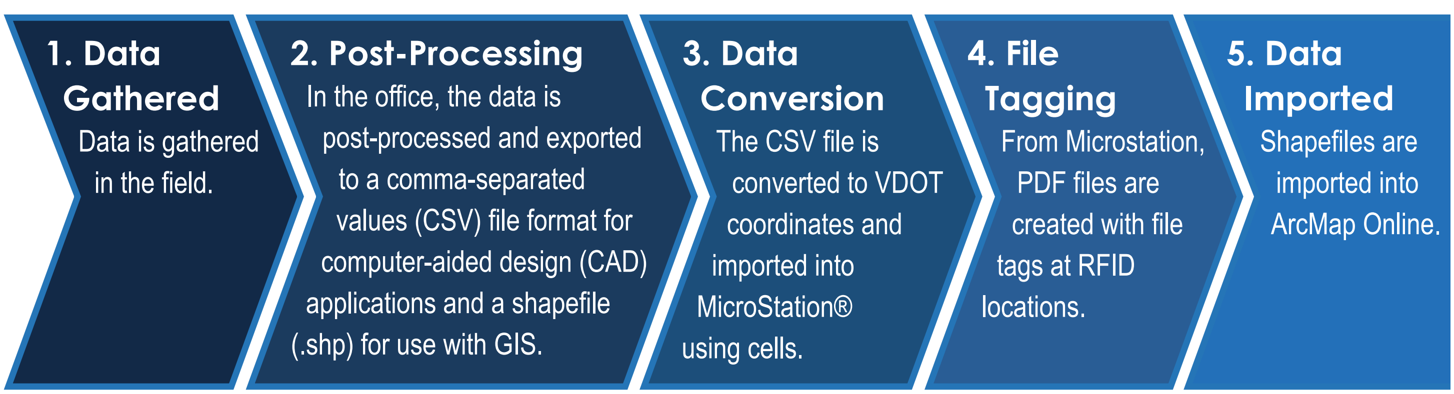


Figure 2. Virginia DOT RFID tagging system workflow process.

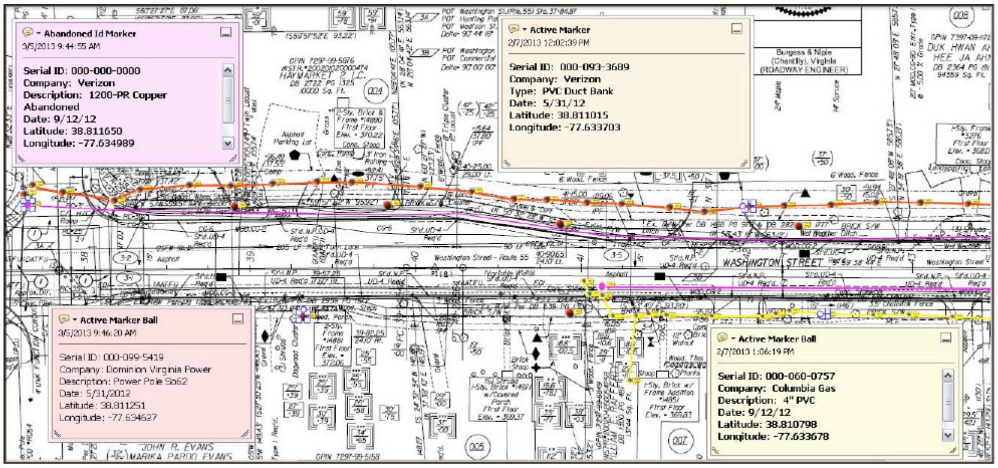


Figure 3. Utility information valuable to the project is also stored on VDOT's construction plans in an interactive PDF file with popup windows. This as-built information is furnished to the utility owners on a monthly basis so that they can update their records in a timely manner.

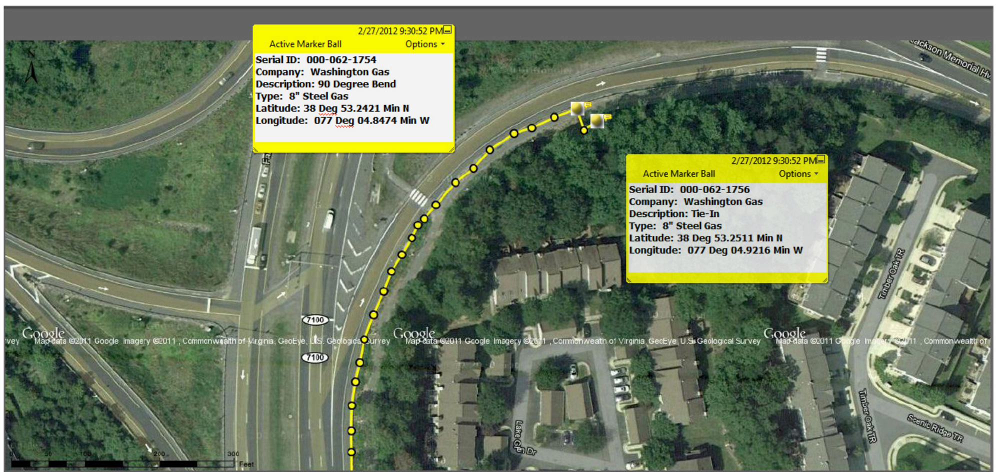


Figure 4. RFID information and connecting lines displayed within Google Earth.

At this time, VDOT is retaining control of the marker ball installation and program functions so that quality can be assured for project risk management purposes. VDOT construction personnel survey the utility installations, program and install the marker balls, and place the as-built data into a database compatible with their CAD platform and Google Earth. This may change in the future as quality control and assurances are developed to allow others (e.g., utility companies, contractors) to do so.

Although the accuracy of the GPS location data will only be mapping grade, the value of this system is really for the damage prevention and construction industries. When returning to the site, utility locators will be able to use a single, one-piece instrument and GPS coordinates to get close to the marker ball, and then the instrument can zero in on the accurate location—typically within inches since there are no interferences with that frequency in the immediate vicinity when installation protocols are followed. It allows absolute positive identification of the facility, rather than seeing a combined signal or 10 different nearby signals that leave multiple interpretations up to the One-Call responder.

The costs of the marker balls are small in bulk purchases, and utility owners are onboard in purchasing them. When VDOT's program started, companies within the district were not yet using these marker balls for locating purposes. This lag in use allowed VDOT the opportunity to catalog hundreds of feet of mismarks as One-Call responded to actual requests for markings. VDOT has been able to review marks in the field quickly, check them with their 3M locator wand, and see the mistakes in minutes in a safe manner with unambiguous results.

VDOT is seeing tremendous value in this program. The average cost to install a 24" water main is approximately $145.00 per linear foot. The cost to install RFID tags at a rate of four marker balls per 100 linear feet of that same pipe increases the cost per linear foot by 60 cents. The potential for reducing delays, damages, and roadway

> “GUIDE creates a mature and sustainable approach to data collection, management, and dissemination of 3D geospatial data on underground utility infrastructure by capturing accurate XYZ information at the time of installation and organizing it in a spatial database format for secure, highly accessible use by downstream stakeholders.”
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> *– John P. Lobbestael, P.S., Manager, Survey Support Unit, Bureau of Development–Design, Michigan DOT*

tie-ups is immense. VDOT has documented several cases where they are certain major construction accidents would have occurred if not for the marker balls.

Utility owners are seeing value, too. What used to take hours in a congested intersection—scanning, identifying, and marking an individual utility with no guarantee of accuracy or completeness—can now be done in minutes with assurance that the marks are correct.

As RFIDs are put in place during routine maintenance excavations, test holes, and other exposures of utilities, VDOT will begin to build a more complete picture of the ROW underground infrastructure, increasing safety while decreasing costs. New and improved RFID capabilities are being developed that will make things even easier in the future. Incorporating RFID readers into construction equipment (already underway with Caterpillar and John Deere) will only enhance damage prevention efforts.[1]

Michigan’s GUIDE Program

The Michigan DOT (MDOT) used State Transportation Innovation Council (STIC) incentive funds from the Federal Highway Administration to document a pilot statewide utility as-built program. The program is called GUIDE (Geospatial Utility Infrastructure Data Exchange).

In the spring of 2014, the Michigan Utility Coordination Committee, which includes representatives from MDOT, Consumers Energy, DTE Energy, and AT&T, set out to acquire accurate three-dimensional (3D) geospatial information during utility installation on seven pilot projects. The pilot projects consisted of new, permitted utility installations located within existing MDOT right-of-way. Accurate survey data was acquired on the installed utilities for all seven projects according to a GUIDE requirements document.[2]

Figure 5. Michigan DOT utility crew surveying inside cardboard tubes after backfill.

1 “VDOT’s Successful RFID Experiment,” Damage Prevention Professional, by Jim Anspach and Matt McLaughlin, Fall 2011.

2 GUIDE Report, prepared by Eric Barden, P.S., Spicer Group, March 2015. *https://www.michigan.gov/documents/mdot/GUIDE2014_510082_7.pdf*

At the 2014 GUIDE Pilot kickoff meeting, the three utility companies identified the projects they were going to include in the pilot project. The following summary details these projects and their respective owners.

Consumers Energy

- 1,340 feet of 6" gas distribution main relocation along M-21 in Shiawassee County
- 4,398 feet of installation of 8" steel, high-pressure gas main and 19 feet of 1" steel, high-pressure gas main along M-43 in Eaton County
- 4,021 feet of installation of 6" plastic, medium-pressure gas main and 70 feet of 2" plastic, medium-pressure gas service on M-20 in Isabella County

AT&T

- 2 miles of 1.25" high-density polyethylene (HDPE) (fiber optic) installation along M-61 in Gladwin County
- 2,100 feet of communication duct bank relocation, horizontal directional drilling (HDD) under I-75 at the University Drive Interchange in Oakland County
- 125 feet of 1.25" HDPE (fiber optic) installation along M-17 in Washtenaw County

DTE Energy

- 100 feet of 12" high-pressure gas main relocation at M-85 (Fort Street) and Gibraltar Road in Wayne County
- 2.96 miles of gas main renewal. 3" and 4" medium-density plastic main inserted into existing 6" cast iron mains along M-5 (Grand River Avenue) in Wayne County

"Another important topic … is the issue of utility as-builts, particularly underground utilities. The Michigan Utility Coordination Committee is developing the Geospatial Utility Infrastructure Data Exchange initiative. GUIDE is set to radically change the 3D spatial awareness and spatial quality of underground utility information in Michigan. This should be a national standard."

– Gene V. Roe, Ph.D., P.E., PLS; Founder of Lidar News

Figure 6. Gas Main exposed through Vacuum Excavation.

The initial thought was to document the utilities continuously as they were being installed, but also have a mechanism to document existing utilities if they were encountered and exposed. However, each utility wanted to try different approaches and techniques for capturing data that would meet the accuracy goals of the requirements.

These approaches included installation of cardboard tubes in the backfill for subsequent survey and tube removal; re-exposure of installed utilities via vacuum excavation (similar techniques but slightly different accuracy requirements for obtaining quality level A (QLA) data via ASCE 38-02, since ASCE 38 is a project-based standard); and continuous survey during installation.

Each approach required that the data be obtained either by or under the direct responsible charge of, and sealed by, a registered surveyor to a high degree of accuracy — horizontal 5 cm (0.16 feet) and vertical 10 cm (0.33 feet). As in Virginia, there was a specified, required minimum spacing for survey points (every 100 feet) and at every significant change in direction, vault structure, or service tie-in. In this pilot project, the utility companies were charged with the survey task and costs.

Figure 6. Survey crew obtaining positional data on exposed utility.

At the start of the GUIDE Pilot, no defined process existed for utility companies to submit their data files once the data was acquired and checked internally. MDOT set up a Microsoft Office 365 SharePoint website and granted user access to the GUIDE committee members when the project began. This website was set up as a simple location to upload and share files associated with the GUIDE Pilot, including data files collected for each project. Going forward, it is evident that a conditioned and well-defined process needs to be developed for utility companies to submit data collected, have data checked by MDOT, pass a set of defined criteria for final acceptance, and be uploaded to some kind of central GIS repository.

During the 2014 GUIDE Pilot, it became apparent that coordinating efforts between surveying staff and construction staff was the single biggest challenge each utility company faced. However, with some creative thinking, there are several ways to successfully coordinate the acquisition of the required geospatial data that depend on the utility installation method, depth of installation, soil conditions, and several other factors. Having surveying staff and construction staff coordinate surveying activities on a daily basis is not always required. More likely, each project will be coordinated using multiple techniques, as warranted by installation methods and other varying conditions.

Although there are many issues remaining to be addressed, the pilot project was deemed successful enough to continue developing a larger, statewide program, incorporating lessons learned from the pilot. This phase is currently underway. It will include developing a comprehensive set of collection standards as well as other necessary informational materials to continue advancing GUIDE.

GUIDE is one of many initiatives underway at MDOT to advance 3D engineered models to the next level. The agency's ultimate goal is to rely on 3D geospatial data to manage state transportation assets.

Comparison of VDOT and MDOT Pilot Programs

Collecting accurate survey data on the location and character of utilities during installation intuitively seems constructive in knowing where the utilities are after they are covered and backfilled. This was rarely the historical practice for numerous reasons. As underground space becomes more congested and valuable, traditional practices must change.

The Virginia and Michigan DOTs took differing but similar approaches in addressing these practices within their rights-of-way. Costs and savings are being evaluated. Policies and procedures are being evaluated and modified as more experience is gathered.

Comparison of VDOT and MDOT Pilot Programs

	Who Collects Data	Data Accuracy	RFID Installed	Data Collected	Data Governance
VDOT	**VDOT**	Mapping Grade (not sealed)	yes	Points not exceeding every 25 feet	Retained by VDOT, shared with Utilities
MDOT	**Utility Owners**	Survey Grade (sealed)	no	Points not exceeding every 100 feet	Retained for now by MDOT, shared with Utilities

Both state programs have input into a new national ASCE engineering standard under development: Standard for the Collection, Administration, and Exchange of Newly Installed Utility Infrastructure. Both states are already using ASCE 38-02. Combining these two standards into everyday project development practice gives stakeholders a complete picture of the certainty and uncertainty of the existing underground utility environment.

Both programs store utility information with an elevation (GUIDE) or depth (VDOT) attribute at points along a line and with an absolute horizontal referencing datum. The accurate geospatial location obtained during the time of installation can be incorporated into future 3D geospatial data models.

In the future, this geospatial data can also be tied to the agency's enterprise asset management databases, which may include 3D and condition information for other assets such as bridge clearances and drainage structures. Future project development staff will be able to use current models confidently and add data during the design process, but in the meantime, the format is easy for the field and office personnel to collect and use.

For additional information about this EDC Initiative, please contact:

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U.S. Department of Transportation
Federal Highway Administration

FHWA-HIF-16-016