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Subsurface Utility Engineering (SUE): Avoiding 4 Potential Pitfalls to Ensure a Successful Program

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Original Abstract

One of the biggest challenges that can arise during the design phase of an infrastructure project is achieving an accurate picture of subsurface utilities within the defined area. Often, data provided to project managers, engineers and designers is outdated, inaccurate or unavailable. As a result, projects may require costly redesign and utilities can be damaged during excavation. For this reason, the practice of Subsurface Utility Engineering (SUE) is gaining momentum across the country and abroad for infrastructure projects both big and small.

Developed and refined over the last 20 years, SUE provides a system to classify the quality of data associated with existing subsurface utilities which dramatically improves information reliability. It begins with a work plan that outlines the scope of work, project schedule, levels of service vs. risk allocation and desired delivery method.

Non-destructive geophysical methods are then leveraged to determine the presence of subsurface utilities and to mark their horizontal position on the ground surface. Vacuum excavation techniques are often employed to expose and record the precise horizontal and vertical position of the assets. This information is then typically presented in CAD format or a GIS-compatible map. A conflict matrix is also created to evaluate and compare collected utility information with project plans, identify conflicts and propose solutions.

While SUE is gaining popularity worldwide as a framework to mitigate risk associated with project redesign, construction delays and damaged utilities, many organizations struggle to implement an effective SUE program. This can threaten accountability and open municipalities, engineers and project managers to further risk. This paper would seek to demystify the SUE process and provide readers with practical information for implementing a successful SUE program. It would also:

- Provide a historical overview of the evolution of SUE and its many applications
- Describe how SUE fits into the overall design process
- Eliminate grey areas around the standards that govern SUE, including U.S. standard ASCE 38-02 and the more recent Canadian Standards Association (CSA) S250 *Mapping of Utility Infrastructure*
- Walk readers through the key elements of a successful SUE program. This includes adhering to the four quality levels outlined by ASCE 38-02, leveraging the right non-destructive technology and excavation techniques and applying best practices for collecting and mapping data
- Offer real-world case study examples of organizations including Stantec, Hatch Mott MacDonald and municipalities that have successfully implemented the SUE process on major projects

Introduction

It's been said that a good construction project requires a solid foundation. In Canada, particularly within the province of Ontario, more and more engineers and constructors are beginning to view Subsurface Utility Engineering (SUE) as integral to building this foundation.

In 2012, the Damage Information Reporting Tool (DIRT), produced annually by the Common Ground Alliance, reported a total of 232,717 incidents of underground utility damage during excavation across Canada and the U.S., which was up more than 10% from 2011.

During the design phase of an infrastructure project, it can be difficult to achieve an accurate picture of subsurface utilities, which creates unnecessary risk for project stakeholders. Utility records are often a composite of accurate records, outdated records and at times, incomplete records. In fact, a study conducted in the mid-90's revealed that existing records and visible feature surveys are typically 15-30% off the mark, and in some cases considerably worse. (Stevens and Anspach 1993).

Adding to the problem is the fact that, historically, there has existed a lack of regulation around collecting, recording and managing subsurface data. This places the burden on the constructor to deal with utility relocation in the midst of a project, which creates delays, drives up costs and exposes project stakeholders to a world of potential liability.

Subsurface Utility Engineering, a concept introduced by the American Society of Civil Engineers (ASCE) Standard 38-02 has proven especially effective at mitigating this risk. By providing a framework to evaluate the quality of data related to existing utility records, it creates a solid foundation during the development stage of a project so that there are no surprises later down the road. It essentially allows project stakeholders to leverage a benchmark which determines the integrity of utility data at the outset.

Navigating a complex landscape

Like any complex engineering practice, SUE can only add value and minimize risk if implemented correctly. When a SUE program is uncoordinated and strays from prescribed standards, the process can open project stakeholders up to further risk and liability. Furthermore, bad practices and a lack of qualifications can prevent the accurate detection of underground utilities.

In a 2004 survey, SUE providers from across the U.S. were asked to assess the significance of factors that posed a challenge to their SUE projects. The factors were scored on five different scales from "extremely significant" to "not significant". The results revealed that the most significant challenge was obtaining appropriate records such as as-built drawings for a project area as well as selecting appropriate equipment for tracing utilities.

The second biggest challenge was revealed to be a general lack of understanding about SUE among clients. It was reported that many clients would confuse the process with a one-call system which is limited to benefiting the construction phase of a project by allowing project stakeholders to avoid utility hits. SUE, on the other hand, is meant to serve as a consulting service, implemented during the design stage that benefits the whole project. [1]

Here is a look at four potential pitfalls of SUE and how they can be avoided to ensure a successful program.

1. **Having an Unclear Understanding of SUE**

Though awareness of SUE has increased significantly over the past ten years, there is still a long way to go, particularly outside the province of Ontario. A lack of regulations and ongoing confusion over roles, responsibilities and expected deliverables creates a grey area that can impede the effectiveness and reliability of a SUE program.

A clear understanding of SUE on behalf of project owners is necessary to accurately define the scope of work required, estimate costs and set expectations around deliverables. What is important to point out is the fact that SUE is not just a form of locating buried utilities. On the contrary, it is an engineering process that blends civil engineering, subsurface geophysical surveying and mapping, vacuum excavation and utility asset management technologies. Though it is not yet legally mandated in Canada or the U.S., there are standards governing SUE that must be adhered to in order to ensure a "true" SUE program.

Released in 1996, the *Guideline for the Collection and Depiction of Existing Subsurface Utility Data*, ASCE Standard 38-02 essentially defined the concept of SUE. Many countries have since followed suit by creating similar standards including Malaysia, Australia and Canada which recently released CSA250: a standard which further builds upon and enhances ASCE 38-02.

An authentic SUE Program is one that adheres to the four quality levels outlined by the ASCE Standard, which are as follows:

- Quality Level D is the most basic level of information for utility locations which comes solely from existing utility records or verbal recollections. This level is primarily useful for project planning activities.
- Quality Level C involves surveying visible above ground utility facilities (e.g., maintenance hatches, telephone boxes, etc.) and correlating this information with existing utility records.
- Quality Level B involves the application of surface geophysical methods to determine the existence and horizontal position of virtually all subsurface utilities within a project's limits. Non-destructive technology including Ground Penetrating Radar and Electromagnetic (EM) tools are often leveraged at this stage to accurately detect even non-conductive underground assets including PVC pipe, sewers and assets containing broken tracer wires. Level B information is correlated with Level C & D to provide a comprehensive subsurface utility dataset that includes abandoned lines and other discrepancies, while confirming the accuracy of record data.

[1] Evaluation of an Emerging Market in Subsurface Utility Engineering, Journal of Construction Engineering and Management, Hyung Seok Jeong, Dulcy M. Abraham, Jeffrey J. Lew, Washington D.C., March/April 2004, page 233

- Quality Level A also known as "daylighting" is the highest level of accuracy presently available. It provides information on the precise vertical and horizontal positions of underground utilities along with the type, size, condition, material and other characteristics of the assets. This is usually accomplished through hydro-vacuuming or hand digging in a select area.

In order to be effective, these levels must be carried out in order, by experienced professionals that leverage the right technology, (more about that in the next section). Once collected, data should be presented in CAD format or a GIS-compatible map. A utility conflict matrix should also be created that evaluates and compares collected utility information with project plans. This allows the project engineer to identify conflicts and propose solutions.

The recently released CSA S250 standard should also be kept in mind when implementing a “true” SUE program. In 2011, The Canadian Standards Association (CSA) released Standard S250 *Mapping of Underground Utility Infrastructure* which builds upon ASCE 38-02, outlining best practices for mapping and managing underground infrastructure records.

Developed by a committee of industry subject matter experts, regulators and end user groups, it emerged from a recognized need by utility owners, the Federation of Canadian Municipalities, contractors and locators to improve data collection processes and clean up existing records. The standard also provides data sharing guidance for utilities that need to analyze the position of their assets versus another utility’s assets (e.g., a pipe versus a cable).

CSA S250 compliments and extends ASCE Standard 38-02 by setting out requirements for generating, storing, distributing, and using mapping records to ensure that underground utilities are readily identifiable and locatable. Accuracy levels expand upon Quality Level A, prescribing a finer level of detail to define the positional location of the infrastructure.

The standard also defines accuracy parameters for as-built records and specifies the utility attributes to be used for describing and depicting newly built underground utility infrastructure. This promotes a consistent, effective approach to data collection that ensures the quality of utility records well into the future. By encouraging a management systems approach to mapping and record keeping, municipalities and their service providers are able to increase the accuracy and reliability of their data in order to reduce potential utility damage and service interruptions.

Though relatively new, the standard has already been integrated by several authorities including the City of Toronto. Utility and right of way owners such as Union Gas and the Ontario Ministry of Transportation are also looking to improve their current records practices based on guidance provided by CSA S250. The CSA is encouraging all organizations to leverage S250 as a records management framework going forward, as it could quickly become a facet of municipal construction contracts and eventually be legislated in Canada.

2. Implementing an Unintegrated Program

Whether a road is being rehabilitated or a new building is being constructed, every project that involves excavation is replete with its own set of risks. Working with a trusted SUE provider helps to alleviate risk for the project owner who no longer needs to rely on a disclaimer that is based on outdated or incomplete records. Instead, the SUE firm with its registered geophysicists, surveyors and engineers hold up their collective hands and say "we are responsible for the utility information depicted on these plans."[2]

However, in order for a SUE project to succeed, it must be integrated and systematic so the project engineer can narrow down the geographic region where higher quality information is required, and then take full ownership over this judgment call.

Risk avoidance is one of the primary reasons it is essential to implement an integrated SUE program. When tasks within the process are outsourced or a client attempts to accomplish certain steps on their own, (such as gathering existing utility records), the margin for error increases as does the potential for liability. Not only are there more likely to be project delays, but the final deliverable can also be adversely affected. In order to produce a true composite dataset during a SUE investigation, each quality level defined under ASCE 38-02 must be compared and correlated. This correlation process is essential for identifying conflicting information from one source and planning subsequent investigations to confirm or correct data.

A municipality may wish to conduct Levels D and C on its own (collecting existing utility records and surveying above ground utilities) and then reach out to a SUE provider to perform Levels B & A. This approach is wrought with challenges. The municipality may be delayed in gathering the data and communicating information with the SUE provider. Furthermore, the data may be collected in a variety of inconsistent formats and the municipality may not have a clear understanding of the type of information that is actually required to complete these two levels.

For example, Level C does not constitute building a topographic map, as many understand it. Rather, it involves gathering information through surveying and plotting visible above-ground utility features on a simple map. Professional judgment is then required to correlate this information to Quality Level D. When the SUE process is integrated and handled entirely by a single project team, communication becomes streamlined and the margin for error, delays or added costs is minimized.

To further streamline communication, a preconstruction meeting should be held at the outset of every project where utility owners, project contractors and the project owners meet. This provides an opportunity to review existing utility data, discuss planned construction activities and outline expectations. Early on during the planning stages, the engineer involved in carrying out the SUE investigation should advise project stakeholders of potential impacts the project could have on existing subsurface utilities and recommend a scope for the utility investigation. The earlier this is started, the less risk that is involved.

Once the SUE program commences, processes should be standardized as much as possible, particularly during the data capture stage. For example, while recording field notes, templates should be leveraged that guide the data collection process such as tracing, capturing GPS points

[2] Integrating technology into Subsurface Utility Engineering projects, The Free Library, < http://www.thefreelibrary.com/Integrating+technology+into+subsurface+utility+engineering+projects.-a018676591>, James H. Aspach, 1996

and documenting field conditions. The more consistently data is collected at the outset, the more accurate the final deliverable. Outsourcing specific steps such as the GPS data capture can threaten the accuracy of this deliverable.

In summary, a few key essentials to keep in mind in order to plan a successful, integrated SUE program are:

- Hold a preconstruction meeting as early as possible. Invite each and every project stakeholder to discuss and document project plans and expectations.
- Coordinate early and often with utility owners as to their anticipated involvement in the project.
- Consistently maintain open communication and keep everyone informed of design or timetable changes throughout the life of the project that might affect the work area and the subsurface utilities that lie beneath it.
- Where possible, trust a single team of trained professionals to carry out each step of the SUE program. Avoid service providers that outsource steps in the process such as the GPS data capture, as this may affect the value of the final deliverable.
- Ensure SUE quality levels are actioned in sequence and datasets are correlated effectively to capture discrepancies and conflicts at each stage.

3. Not Using the Right Technology to Get the Job Done

Over the past 50 years, there's been a shift towards building subsurface utilities out of durable PVC materials rather than the more traditional cast iron piping and ductile iron. These non-conductive, "non-toneable" assets are not always traceable through commonly used utility detection methods, and utility owners don't always perform the necessary steps to enable their detection such as effectively installing tracer wires.

As such, an effective SUE program generally leverages a wide intersection of technology and techniques including inductive electromagnetic instruments, Ground Penetrating Radar (GPR), GPS and vacuum excavation. This is key because there is no single technology that can locate utilities effectively for all site conditions where utility composition and depth varies.

Today, electromagnetic induction and GPR are the primary methods of finding buried utility assets, and the effectiveness of these tools is directly related to the training and experience of the field technician. As locating is a highly interpretive skill, years of experience are generally required to develop the expertise needed to identify utilities in varying conditions. When selecting a SUE provider, it is important to choose an organization that can bring a wide range of geophysical tools onsite rather than basic induction equipment only, (more on that in the next section.)

Ground Penetrating Radar (GPR) is ideal for locating non-toneable underground assets such as PVC pipes. The accuracy of the survey results is highly dependent on the operator's level of skill.

Typical equipment that might be used in a SUE project includes:

- <u>Time Domain Electromagnetic (TDE) surveys:</u> Functioning like a large powerful metal detector, TDE survey equipment is suited for locating metallic assets such as metal pipelines or assets containing a tracer wire. It pulses the ground to record the signal transmitted back to the unit from the subsurface metal.
- <u>Acoustic pipe tracers:</u> Acoustic pipe tracers, which operate based on elastic wave theory can be used to find gas or water pipes. The acoustic receiver listens for background sounds of water flowing. The results of this equipment are often limited by urban noise and a low tracing length.
- <u>Electromagnetic Induction utility locators:</u> This equipment operates by locating either a background signal or a signal introduced into the utility line using a transmitter. This is not an effective option for locating non-conductive utilities.

- <u>Ground Penetrating Radar (GPR):</u> GPR transmits high frequency radio waves into the ground or structure and analyzes the reflected velocity and energy to create a profile of the subsurface features. The reflections are caused by a contrast in the electrical properties of subsurface materials. This technology is highly effective for locating non-conductive utilities but can be affected by soil conditions.
- <u>Vacuum excavation:</u> Vacuum excavation is used to identify the precise vertical and horizontal position of underground assets to obtain 3-D data and utility properties. This process uses a vacuum in combination with high-pressure water or air to expose underground utilities. The method guarantees there will be no damage to existing utilities and the damage done to street pavement is kept to a minimum.
- <u>Global Position Satellite (GPS):</u> GPS points are captured to create a permanent record of utility locations and obtain high horizontal and vertical accuracy.

Known as the "daylighting" phase in SUE, vacuum excavation makes it possible to identify the precise vertical and horizontal positions of buried assets.

4. Lacking the Necessary Expertise

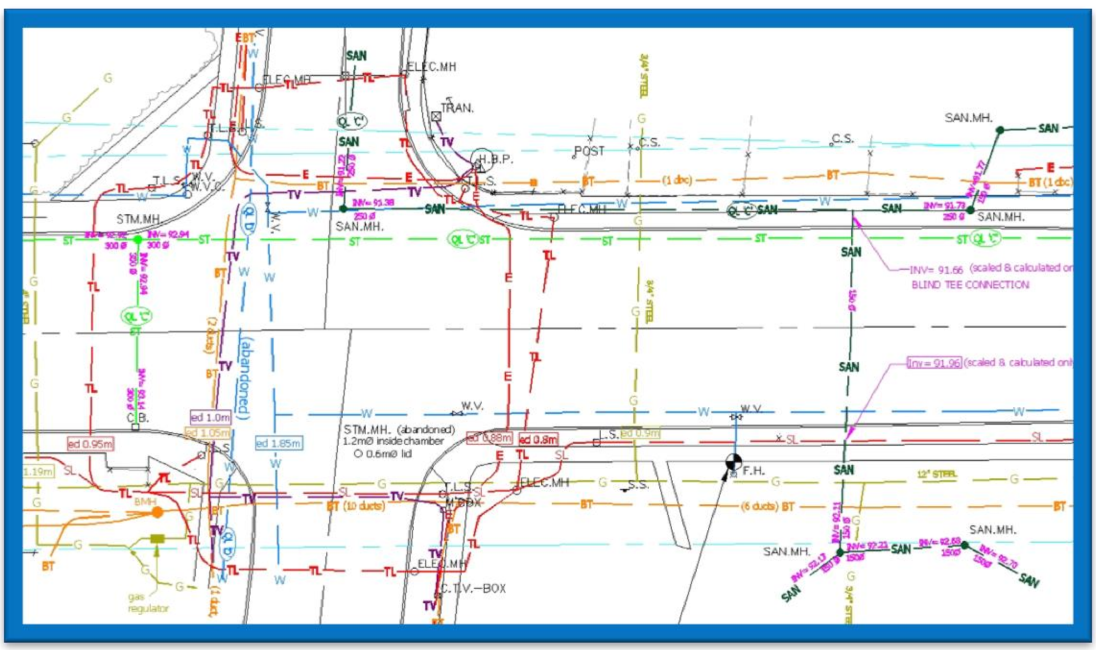
Subsurface Utility Engineering is more than a sum of its parts. Beyond vacuum excavating, locating, surveying and mapping, it is an engineering process that can only be carried out by those with the necessary geophysical skills. As a multifaceted discipline, SUE requires solid project management, sound judgment, and sharp analysis skills capable of interpreting data from a variety of sources, identifying utility conflicts and planning relocation where necessary.

Moreover, a SUE provider must be familiar with a range of geophysical techniques so they're able to select the appropriate geophysical methods for the project at hand. Without the ability to select the right tools, additional surveys may be required which can cause major project delays. This is especially true of high profile projects such as a highway rehabilitation which might contain extensive underground utility congestion consisting of underground gas, water, telecommunications and electrical utilities. If any of these utilities are missed due to the wrong equipment or a lack of expertise, the main objective of the SUE program, which is to mitigate risk, will not be fulfilled.

In selecting a SUE provider, it's always important to ensure technicians are highly trained and well versed in using non-destructive technologies including Ground Penetrating Radar (GPR) and other electromagnetic tools to accurately determine the existence and horizontal positioning of subsurface utilities. A high level of technical knowledge coupled with systemized data collection procedures and a Quality Management System is required to implement these techniques safely and effectively.

SUE technicians must also be trained and qualified to research and analyze utility records such as system sketches, red-lined as-builts from the utility owner and actual survey as-builts that were completed as the utility was being installed. As a second step, they must be skilled at taking these records to the field and finding and marking the various system lines such as water, electric, telephone, cable TV, fibre optic, natural gas, steam, chilled water and other unique systems.

At each stage of a SUE investigation, expertise is required for effective data analysis and interpretation. A utility conflict matrix requires the project engineer to consolidate and compare all information and identify discrepancies in record data versus the results of the Quality Level C and B field surveys. CAD expertise is also required to map the utilities and create a digital utility composite.



Of the many types of expertise required to carry out a SUE project, CAD experience is needed to map captured data and create a digital utility composite of the project work area.

Utility	Location/Intersection	Proposed Work	Comments	Conflict	Resolution
Sanitary sewer	Crossing St. Andrews Blvd. on the east of Kipling intersection	Road reconstruction	South-east side of intersection, in front of 93 St. Andrews	N	No conflicts
Watermain	Crossing St. Andrews Blvd. on the east of Kipling intersection	Road construction	East side of intersection, behind curb	N	No conflicts
Encased telephone	Crossing St. Andrews Blvd. at 15,17,19,22,24 & 24a St. Andrews Blvd.	Road resurfacing	Potential conflict with subgrade cut, facility is 43" deep	Y	Modify facility if cut is 40" or greater.
Gas line	Crossing St. Andrews Blvd. at 6.9 metres east of 92 St. Andrews Blvd.	Road reconstruction	Potential conflict with subgrade cut.	Y	Use caution if cut is 40" or greater.
Copper telephone	Crossing St. Andrews Blvd. at 8.4 metres west of 92 St. Andrews Blvd.	Sewer reconstruction	Assumption: sewer will be below telephone.	N	Use caution with sewer construction.

Where applicable, the final deliverable should include a utility conflict matrix. This requires the project engineer to consolidate and compare all information and identify discrepancies in record data versus the results of the Quality Level C and B field surveys.

<u>Canadian SUE Success Stories</u>

As the concept of SUE gains popularity both nationally and worldwide as a framework to mitigate risk and project delays, it has been integrated into many major construction projects across the country with great success.

For example, the process has played an integral role in the Union Station Revitalization which is set to bring many new enhancements to riders such as a roof and glass atrium over passenger platforms and railway tracks, new staircases, additional vertical access points, and an overhaul of the platforms and station concourses. GO Transit is also expanding its services and infrastructure with a goal to increase ridership, enhance speed and anticipate growing demand. This includes the reconfiguration of track between the Don River and Strachan Avenue where existing tracks will be interconnected to various platforms, allowing more riders to access trains.

Because the track had been subject to change and resurveyed multiple times over the years, concerns arose over the accuracy of existing data particularly for subsurface assets, "We're dealing with infrastructure that is 50-70 years old," said Florin Doru Merauta, Senior Project Engineer – Electrical Lead, Hatch Mott MacDonald. "We were uncertain of the location of underground utilities and were working with disparate datasets that were scattered across multiple platforms. Adding to the challenge was the fact that Go Transit's interlocking track system is considered one of the most complex in North America."

The SUE process was implemented to get an accurate depiction of all existing public and privately owned utility services including gas, hydro, water, fibre optics, telecommunications and signal cabling. Non-destructive geophysical inspection methods including Ground Penetrating Radar (GPR) and Electromagnetic Induction (EM) were leveraged to detect buried cables and utilities that crossed the corridor. The vertical and horizontal positions of subsurface assets were then confirmed through vacuum excavation. Collected data was referenced against existing maps to reveal anomalies, and information was then stored in a central database.

Property boundary and topographic data was also gathered and overlaid on a map, to generate a 3D topographic survey. The study resulted in a documented understanding of the Union Station Rail Corridor (USRC) ownership and easements, detailed knowledge of surface infrastructure and the spatial position of all underground utilities targeted by the investigation.

“We used to rely on older records and would need to resurvey a project area every time there was a change, which would drive up costs,” said Florin. “Surveyors would bring their own tools and data would be stored disparately after every survey. We now have a consistent database of accurate information that conforms to Go Transit standards and can be leveraged by contractors for years to come.”

Traditional survey techniques were also combined with LiDAR data to model the corridor in 3D, providing an accurate perspective of corridor dimensions. Explains Florin: “Trains are protected by a clearance envelope through a very narrow tunnel. 3D modelling provides a detailed perspective and better line of sight, allowing us to make more accurate measurements for corridor routes.”

During the Go Transit expansion, non-destructive geophysical methods were leveraged to detect buried cables and utilities that crossed the corridor. Collected data was then verified and stored in a database to be used by contractors for years to come.

SUE was also leveraged to identify underground utilities during the QEW Credit River Environmental Assessment (EA) Study. The study was completed to inform a long-term strategy for addressing the rehabilitation needs of the QEW Credit River Bridge. Future requirements for the stretch of the QEW that runs from Mississauga Road to the west of Hurontario Street were also considered.

During the environmental assessment and the preliminary design stage, Quality Levels A & B were implemented to identify potential impediments to the design and construction of underground installations. Using Ground Penetrating Radar (GPR) and Electromagnetic Induction, underground utilities were targeted for further investigation.

Quality level A was then carried out through a vacuum excavation study to establish the precise vertical and horizontal positions of select buried utilities. This allowed for better design and utility coordination while minimizing the potential for conflict. All revealed information was then captured in a subsequent survey.

"This type of investigation is typically not completed during the preliminary design stages," said Dana Glofcheskie**,** Project Engineer, Transportation Planning, MMM Group Limited. "However, SUE provides a much better level of accuracy than plans from utility companies coupled with aerial photos, allowing us to more confidently identify utility conflicts and develop a more detailed utility relocation plan. This in turn reduces risk for our client during future phases of the project."[3]

Conclusion

Few would argue that when implemented systematically by experienced technical experts, SUE provides an extremely effective framework to mitigate risk and cut costs. A study conducted by Purdue University for the American Federal Highway Administration (FHWA) showed that out of 71 projects studied across the U.S., an average project savings of $4.62 was achieved for every dollar spent on SUE. In total, the projects showed a combined savings of more than $1 billion. Moreover, the research demonstrated that obtaining Quality Level B or A on these projects added less than 0.5 % to the total construction costs and represented a savings in construction costs of almost 2%.[4]

However, despite growing awareness of SUE, there is little doubt there is still a long way to go within Canada. The same 2012 DIRT Report that revealed more than 200,000 occurrences of damaged utilities across Canada and the U.S. also uncovered that 60,000 of these projects had not involved a locate prior to excavation. With greater awareness, more than a quarter of these events could have been avoided within the year. [5]

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[3] What Lies Beneath, ReNew Canada Magazine, Kevin Vine, March/April 2014, Pg. 24

[4] Cost Savings On Highway Projects Utilizing Subsurface Utility Engineering, Purdue University Department of Building Construction Management, Prepared for the U.S. Department of Transportation Federal Highway Administration < https://www.fhwa.dot.gov/programadmin/pus.cfm>, July 2011

[5] Subsurface Utility Engineering's Reputation is Growing, Construction Comment Magazine, James Raiswell, September 2005, Page 18

As SUE is not yet mandated within the country and still remains highly unregulated, a challenge lies in the fact that to some extent, it's meaning remains open to interpretation. However, as awareness is beginning to spread, changes are occurring and many organizations have begun to champion for more clearly defined regulations around SUE. This includes talks of potentially developing accredited SUE training programs. The introduction of CSA S250 was also a big step in the right direction, reinforcing the importance of effective utility data collection and record keeping, north of the border.

Over the next several years, as discussion around SUE continues to amplify and more and more organizations become aware of the ROI achieved on major construction projects, misinterpretation will begin to be replaced by knowledge. This will allow the SUE process to be implemented as intended, yielding optimal engineering design results and reducing incidents of damaged utilities across the country.

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