Subsurface Utility Engineering: A Proven Solution

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SUMMARY

The lack of reliable information on the location of underground utilities during construction activities can result in costly conflicts, damages, delays, utility service disruptions, redesigns, claims, injuries and, even, lost lives. While the location of subsurface utilities might be found on plans and records, experience often has shown that the utility locations are not exactly as recorded or that the records do not fully account for buried utility systems.

An engineering process known as subsurface utility engineering (SUE) has proven to be a welcome solution to providing this much-needed underground utility information. Combining geophysics, surveying, civil engineering and nondestructive excavation technologies, SUE can provide accurate three-dimensional mapping of existing underground utilities during the design phase to avoid unnecessary relocations, eliminate unexpected conflicts with utilities and enhance safety during construction.

The use of SUE services has become a routine requirement on highway and bridge design projects in the United States, and it is strongly advocated by the Federal Highway Administration (FHWA), American Society of Civil Engineering, American Association of State Highway and Transportation Officials and state departments of transportation.

A study sponsored by the FHWA found that USD$4.62 (approximately AUD$5.68) was saved on overall project costs for every dollar spent on SUE. This figure was quantified by a study of 71 projects that had a combined construction value in excess of $1 billion. Qualitative savings were not measurable, but it was clear that those savings were also significant and may have been many times more valuable than the quantifiable savings. In a similar study conducted in Canada and commissioned by the Ontario Sewer and Watermain Construction Association and the University of Toronto’s Centre for Information Systems in Infrastructure and Construction, researchers discovered an average savings of CAD$3.41 (AUD$3.79) for every dollar spent on SUE. Having been used extensively in the design of highways for 20 years, SUE is gaining strong endorsement by many other industries. The U.S. Federal Aviation Administration has developed a digital videodisk, released in early 2009, entitled, “Underground Update” to explain the benefits of SUE to the airport industry. The American Society of Civil Engineers has recognized the value of the process and developed quality level ratings to standardize the process.

With recent technological development in Geographic Information Systems (GIS) and Enterprise Asset Management software, SUE information forms the basis with which owners can greatly improve the allocation of risk, the management of assets and service to its customers.

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1. SUBSURFACE UTILITY ENGINEERING

Subsurface utility engineering is a highly efficient, nondestructive engineering practice that combines geophysics, surveying, civil engineering and asset management technologies. Used appropriately and performed correctly, SUE identifies existing subsurface utility data, maps the locations of underground utilities, and classifies the accuracy of the data based on standardized quality levels. The data allows for developing strategies and making informed design decisions to manage risks and avoid utility conflicts and delays. If a utility conflict arises, viable alternatives can be found to resolve the issue before any damage is done and almost always at a lower cost.

In 2003, the American Society of Civil Engineers (ASCE) published the *Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data.* This standard formally defines SUE and sets standard guidance for collecting and depicting underground utility information.

The ASCE standard, which has helped to elevate SUE to a new level, presents a system of classifying subsurface utility data into quality levels. Project owners, land surveyors, engineers and constructors are able to determine the quality level suitable to the needs of a particular project and at an appropriate cost in order to strategically reduce or allocate risks due to existing subsurface utilities. The standard closely follows concepts in place in the industry. Owners, engineers and surveyors can maintain their compliance with this standard through the use of SUE or through their inclusion of SUE specifications in their engineering and surveying contracts.

2. THE PROCESS

The three major activities of designating, locating and managing data can be conducted individually to meet the specific needs of a given project, but they are most advantageously employed in combination to create a complete three-dimensional mapping of a utility system. While the practice of SUE is tailored to each project, the process typically follows the following course and ASCE Quality Levels:

2.1 Quality Level D

The SUE provider gathers utility records from all available sources. These may include as-built drawings, field notes, distribution maps and, even, recollections from people who were involved in the planning, building or maintenance of the utilities in question. All the data is then compiled into a composite drawing and labeled ASCE Quality Level D.

2.2 Quality Level C

A site visit is made to find visible surface features of the existing underground utilities (e.g., manholes, pedestals, valves, etc.). This site visit may be conducted at the same time that the topographic survey is completed for the project. This information is added to the composite drawing completed during the ASCE Quality Level D record research and upgraded to ASCE Quality Level C.

2.3 Quality Level B

At this point, the project team can make an informed decision as to which utilities may have an impact on the proposed design and determine which areas may warrant further investigation. Using a variety of geophysical techniques (e.g., pipe and cable locators, or ground penetrating radar), the horizontal position of these critical utilities is determined. This information is compiled into the utility drawing, now labeled as ASCE Quality Level B data.

2.4 Conflict Matrix

The Quality Level B data is then referenced with the proposed design to identify utility conflict (existing utilities crossing the path of the proposed design), and the subsurface utility engineer creates a conflict matrix. The conflict matrix identifies conflicts and allows the designers to make educated decisions regarding relocation or redesign. It is important to use the cross-sections, drainage profiles and staging plans, in addition to the basic plan views. Many times, significant conflicts will appear on these sheets, event though they were not apparent on the plan sheet.

2.5 Quality Level A

Once conflicts are identified using the conflict matrix, the final step in the data collection process is to excavate test holes at key locations where the exact size, material type, depth and orientation of the utilities are identified. The test hole information is surveyed and included in the utility drawings, which are now ASCE Quality Level A.

2.6 Decide most economical course of action

The additional data gathered from the completed test holes is added into the conflict matrix. Now, designers are able to review a complete representation of potential utility issues presented in conflict matrix and decide the most economical course of action.

When utility owners and design teams work together, mutually-beneficial strategies can be applied. In addition to significant cost savings and drastically reduced construction delays, utility owners are more likely to complete relocations when presented with a utility conflict matrix. The matrix demonstrates that all other options have been thoroughly investigated, rather than the traditional method of forcing utilities to move facilities without much apparent forethought. Cooperation is encouraged, and more desirable results are obtained.

3. HISTORY, APPLICATION AND VALUE

The term “subsurface utility engineering” was coined at the 1989 FHWA National Highway Utility Conference. The FHWA quickly accepted this term and adopted a prime advocacy position. It continues to promote the use of the SUE process in all highway and bridge design projects. Today, through the efforts of the FHWA in documenting and promoting the significant return on any dollars invested in the SUE process, over 40 State highway agencies are using SUE on their projects. In 2009, FHWA published a report of an international scan of SUE use in Canada and Australia, which studied the right-of-way and utility processes in order to streamline and integrate them with planning, environmental and design process. The findings identified the various positive aspects of each country’s system so that they possibly could be considered for application in those countries and others.

In addition to highway design, SUE is gaining strong endorsement by the Federal Highway Administration and the U.S. military for use in design of construction projects that involve congested underground utilities. Typical applications include construction of underground utilities like sanitary force mains and petroleum oil and lubricant lines, upgrades to utilities on wharves, airfield runways and taxiway repairs, new site development and utility system management.

The same technologies used in the SUE process can be, and have been, creatively applied to environmental restoration programs. For example, the surface geophysical and nondestructive vacuum excavation technologies provide an alternate means to identify, expose and, possibly, characterize buried objects, such as underground storage tanks or objects in landfills that may be a source of environmental release or explosion if disrupted by more aggressive excavation equipment. In cases where contamination is detected in subsurface holding tanks or catch basins, utility-locating technologies can be used to trace back the various pipelines entering the tank or basin to possible sources. The more precise and less invasive vacuum excavation technology also provides an alternative for the highly controlled removal of soil around buried utilities or other sensitive structures, such as security systems.

While the cost savings resulting from the avoidance of utility conflicts have been the primary factors driving the use of the SUE process in highway projects, many of the applications at military installations have realized a value in reduced construction time and in increased safety of workers and the public. There is a tremendous advantage to knowing with certainty the location of potentially impacted utilities at the planning stage, prior to contract bidding and field mobilization.

For maximum effectiveness, the SUE process should be incorporated early in the development of every project that may have an impact on underground utility facilities, particularly in built-up areas. When subsurface utilities are discovered later in the process, i.e., during the construction phase, the costs of conflict resolution and the potential for catastrophic damages are at their highest. That is why the collection and systematic depiction of reliable data for existing subsurface utilities is critical for engineers to make informed decisions and support risk management protocols regarding a project’s impact on these utilities.

4. FACING THE CHALLENGES: TIME FOR CHANGE

For decades, project owners, engineers and contractors have accepted the fact that readily available information on utility locations often was incomplete and inaccurate.

4.1 Facing the Challenges

The following scenario has been played out on many construction projects in response to this informational uncertainty and the associated risks:

4.1.1 Assign responsbility

The project owner would initially assign responsibility for utility mapping to the design engineer by including general language in the scope of work. Typically, the standard of practice for the surveyor or engineer would be to compile utility information from the utility owner, local public works files, oral recollections from people familiar with the site, and other readily available sources of such data. The surveyor or engineer then would correlate this information with the site survey for the project. This information corresponds to ASCE Quality Levels D and C.

4.1.2 Recognize underground utilities will be missed

Recognizing the likelihood that utilities would either be missed or erroneously located through this process, the surveyor or engineer would include a disclaimer on the plans. In essence, the disclaimer would pass the responsibility for underground utilities on to the construction contractor. Either the project owner or the contractor would rarely challenge such disclaimers, and, thus, the design engineer would incur minimal risk for any errors related to utility depictions on the design plans.

4.1.3 Contractor forced to assume utility information is complete

Facing a bid competition and recognizing that project owners are typically held responsible for delays and costs associated with unknown or differing site conditions, contractors would have no option other than to assume that the utility depictions on the plans were complete and accurate.

At the start of construction, the dial before you dig contractors often do not have accurate asbuilts or they mark expected utility locations in the field just prior to digging, with a 2-foot range of accuracy horizontally and no indication vertically. These locations may or may not have coincided with the design plans.

4.1.4 Project owner faced with difficult situation

As a result, the project owner would often face a situation in which: (a) the initial construction bids would likely have a contingency built into account for the informational uncertainty surrounding underground utilities and the likelihood that claims, and extended schedule, would have to be developed and negotiated; (b) the contractor would secure a preferable position, since any additional work would be negotiated and performed outside of a bid situation; (c) the financial risk would be magnified by the potential costs of construction downtime, schedule delays, redesign and utility relocation; and (d) a worst-case scenario could develop that may involve utility damage, service outages, consequential damages and injury to workers or the public.

4.2 Time for Change

Over the years, four events began to change this scenario. They are:

4.2.1 New equipment and computer technology

The convergence of new equipment and data-processing technologies allowed for the cost-effective collection, depiction and management of existing utility information. These technologies encompass surface geophysics, surveying techniques, computer-aided design and drafting and geographic information systems and minimally intrusive excavation techniques.

4.2.2 Competition allows shift of liability

Competition in the marketplace has allowed project owners to shift more responsibility and liability to the design engineers and contractors.

4.2.3 Growning litigious culture

There has been an overall growth in the litigious nature of society and the associated increase in risk to all parties involved in design and construction projects.

4.2.4 Subsurface utility engineering rises to professional stature

The birth of subsurface utility engineering became a distinct professional service in the 1980s. The subsurface utility engineer rose to a professional status requiring appropriate training, expertise and tools to characterize the nature of utility conflicts before work begins in the field, to coordinate utility relocations and easements, to allow construction activities to be planned away from high risk utilities, when possible, and to develop complete and accurate as-built utility plans.

5. BUILDING FOR CAPACITY: NEW TECHNOLOGY

Recent technological developments in Geographic Information Systems (GIS) and Enterprise Asset Management (EAM) have catapulted the value of SUE data to other aspects of managing a municipality or business. By incorporating precise underground utility data into GIS and EAM programs, departments responsible for accounting and finance, work management and inventory control benefit greatly. Using subsurface utility information and other collateral materials, infrastructure assets are placed in the GIS database, describing the structure by size, material, specifications, date of installation, and geographic coordinates. The GIS data can then be merged into the EAM system, which provides a workflow platform to automate customer service requests, generate work orders, institute a preventative maintenance program and track multiple warehouse inventory and facility assets. With data presented in a visual format, technicians are able to make more intuitive and strategic decisions.

Relationships between data become more apparent; increasing the value of the information collected, maintained and relied upon to proactively manage business. With reliable data in hand, budget forecasting and regulatory agency reporting are streamlined.

With the information stored graphically and digitally, application developers can set up filters and sorting capabilities. Aspects of the system can provide information to others through a connection to an internal Intranet or external Internet web site, providing a higher level of customer service while potentially reducing administration costs. Exchange times via wireless modem can take as little as ten minutes from field to server to the staff member or public.

6. CONCLUSION

The technology is now available to achieve a complete and precise three-dimensional mapping of subsurface utilities prior to or during the design phase of a project. If Quality Level A information is collected through the full use of the SUE process, the project owner, engineer, land surveyor and contractor can proceed with confidence that utilities have been identified and categorized as to their horizontal location, depth, size, composition and condition. The use of the SUE process will continue to grow as project owners request higher quality levels of utility information to reduce and better manage their risks. In the end, the use of SUE will shift the risk of inaccurate or incomplete information to the party most capable of handling that risk – the subsurface utility engineer.

Related cost analyses have shown that the use of the SUE process provides a significant return on investment. In general, the SUE process costs about 10 percent of the total preliminary engineering cost, or about one percent of the total project cost. These costs are small when compared to the overall savings on projects where the SUE process is used.

The GIS/EAM solution pulls in field data, record drawings, asset inventory and work order details to present a dynamic picture for query and analysis. Its web-based functionality allows access for intelligent, real-time decision-making. Budget forecasting and capital improvement program development is easier. Public needs are satisfied responsively and reporting requirements are met. System performance improves, and costs are reduced.

In this era of partnerships, SUE represents a new way of doing business, in which the past adversarial relationship among project owners, design engineers, utility companies and contractors has been replaced by a cooperative effort to reach an appropriate balance between the risk of informational uncertainty.

REFERENCES

Several studies have been conducted and are often cited as proof of the true value of subsurface utility engineering. Two of the most often cited are:

1. University of Toronto Study: *Evaluating the use of Subsurface Utility Engineering in Canada*

In Ontario, the market for SUE has seen fairly rapid growth especially on large-scale municipal projects. The University of Toronto conducted a 12-month study taking an in-depth look at 9 large municipal and highway reconstruction projects that utilized SUE. A cost model for SUE utilization was developed that takes into account both tangible and intangible benefits. The data from the study was applied to the model to determine the cost savings due to SUE utilization on these nine projects. All projects showed a positive return-on-investment (ROI) that ranged from CAD$2.05 to CAD$6.59 for every dollar spent on SUE. Although these ROI figures should not be considered universal, they indicate that with careful scoping of SUE services, project risks can be appropriately reduced at reasonable cost.

2. Purdue University Study: *Cost Savings on Highway Projects Utilizing Subsurface Utility Engineering*

Purdue University's study was published and distributed in 2000. A total of 71 projects in Virginia, North Carolina, Texas and Ohio were studied. These projects involved a mix of interstate, arterial, and collector roads in urban, suburban and rural settings. Two broad categories of savings emerged: quantifiable savings and qualitative savings. An average of US$4.62 in avoided costs for every dollar spent on SUE was quantified. Qualitative savings, were non-measurable, but it was clear to the researchers that those savings were also significant and were possibly many times more valuable than the quantifiable savings. It was concluded that SUE was a viable practice that reduced project costs related to the risks associated with existing subsurface utilities and should be used in a systemic manner.

BIOGRAPHICAL NOTES

Nicholas Zembillas is Senior Vice President of Cardno TBE's Utilities Division and oversees global operations, which includes more than 20 offices on three continents. Cardno TBE provides subsurface utility engineering, three-dimensional underground imaging, professional utility coordination and surveying and mapping services to public and private-sector clients throughout the United States, Canada and the United Kingdom.

Mr. Zembillas joined Cardno TBE in 1993 as Director of Utility Engineering. He soon established a separate Utilities Division within Cardno TBE and introduced clients to Subsurface Utility Engineering. Under his guidance, Cardno TBE is now recognized as a leader in subsurface utility engineering, professional utility coordination and design by the Federal Highway Administration and most Departments of Transportation throughout the

United States. Mr. Zembillas is recognized globally for his expert knowledge of subsurface utility engineering, and is often a speaker on subsurface utility engineering technology at conferences and seminars worldwide.

Since joining Cardno TBE, Mr. Zembillas has helped implement subsurface utility engineering programs for over 40 state DOTs and many other federal/state agencies.

Mr. Zembillas is an original member of the American Society of Civil Engineers (ASCE), Standards Committee for Collection and Depiction Guidelines for Existing Utility Data (ASCE 38-02) on Design and Construction Documents. He is a board member of National Utility Locating Contractors Association and the National Highway and Utility Committee. He is a past member of the National Damage Prevention Advisory Board and a past director of the FDOT D7 Utilities Coordination Committee.

Prior to Cardno TBE, Mr. Zembillas worked for the Florida Department of Transportation (FDOT) as a District Utility Engineer for District 7. During his 17-year tenure, he administered state and federal utility accommodation policies and procedures, served as the FDOT liaison with the utility industry and helped to introduce subsurface utility engineering to FDOT and the utility industry. He also assisted in establishing the Joint Project Agreement, a program recognized throughout the United States and currently used by many DOTs.

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