Subsurface Utility Engineering for Drinking Water and Wastewater Utilities

Berk Uslu, Sunil K. Sinha
Virginia Polytechnic Institute and State University, Blacksburg, United States
Corresponding Email: berkuslu@vt.edu

Abstract:Buried utility locating practices are an integral part of condition assessment, renewal engineering, and damage prevention programs for drinking water and wastewater utilities. An extensive literature review was conducted to determine the underground utility practices, locating technologies, data management practice, as well as education and outreach programs. This literature review synthesized the practices form other industries. The practices from water and wastewater utilities were determined by the help of participation utilities to the WATERiD Database. Case studies in locating technology applications and locating practice application was written to capture these practices. These case studies were also supplemented by phone interviews with various utilities. Comparison between the literature and utility practice indicated various gaps in the utility practice. Recommendations are offered to fill these gaps for an effective use of underground utility practices by water and wastewater utilities. These recommendation include adaptation and implementation of specific best practices of transportation industry by the water and wastewater utilities. Specifically, adaptations of; standards, decision support tools for data quality levels and locating technologies, data standardization and integration, as well as participation on education and outreach programs are discussed.

Keywords: Subsurface Utility Engineering, Underground Utility Locating, Infrastructure Management, Condition Assessment, Renewal Engineering, Water Industry.
Article Classification: Reviewpaper

Introduction

Keys to implementing infrastructure asset management strategies are a comprehensive understanding of the asset condition, and how asset condition and performance changes over time. Current condition and its likely rate of deterioration of an asset are important information in developing a proactive maintenance schedule in the most cost effective manner. The starting point of condition assessment is to first locate the location of the underground assets and the relative locations of the defects observed in these infrastructure (Rogers et al., 2012a). Thus, underground utility locating practices and technologies are an integral part of the condition assessment practice (Hao et al., 2012).

This paper reviews the state of locating practices and make recommendations for best practices for water and wastewater utilities in US. This review starts with the synthesis of literature for the utility locating practices, technologies, locating data management, and locating education and outreach. This literature review is followed by locating practice review of water and wastewater utilities. The buried utility locating practices followed, technologies used, data management, and education and outreach activities of water and wastewater utilities are synthesized through case studies and phone interviews. This synthesis identifies the gaps in the practice. Recommendations to fill the gaps in utility practice is also provided in this paper. Detailed findings of this study can be found on this database and the related synthesis report published (Uslu et al. 2014).It builds on the information regarding underground utility locating technologies and practices accumulated in the Water Infrastructure Database (WATERiD). WATERiD is a national, web based interactive database for water infrastructure systems, and was developed in order to provide a standard platform through which institutional knowledge can be shared (Sinha and Graf, 2012).

Background

Buried utility locating is also an important process ensuring the sustainability of utility service networks in water and wastewater infrastructure (Canto-Perello and Curiel-Esparza, 2013; Curiel-Esparza and Canto-Perello, 2013). Infrastructure management decision making is inherently an integrated process that requires the assimilation of a multitude of data, processes, and software systems (Elsawah et al, 2014). There is a broad consensus in the industry that adopting integrated multidisciplinary approaches is a key requirement for implementing efficient, sustainable, and proactive asset management programs (Halfawy, 2008; Hafskjold, 2010).The starting point of a proper asset management program is to first locate the location of the underground assets and the relative locations of the defects observed in these infrastructure (Grigg, 2006; Costello et al., 2007; Rogers et al., 2012a; Hao et al., 2012; Davis et al., 2013; Atef and Mosegli, 2014).

Condition assessment surveys were historically carried out by sending out inspectors to evaluate the defects inside those accessible pipes along the network. This method suffers from inefficiency in terms of manpower, and it is impractical for the majority of pipes and cables that make up the network (Hao et al., 2013). The fact that water and wastewater pipes are buried significantly restricts the accessibility of these assets for condition assessment and renewal engineering (Rogers et al. 2012a). Various technologies has been develop to remotely access these infrastructure for condition assessment and renewal engineering (Thuruthy, 2013a, 2013b; Liu and Kleiner, 2013; Hao et al. 2012; Steiner et al. 2011). The use of these remote access technologies results in the need to accurately locate the underground assets and their defects (Chapman et al., 2007).

LITERATURE REVIEW

The literature review was conducted to collect information with respect to underground utility locating for water and wastewater infrastructure, as well as other infrastructure systems such as the roads, bridges, energy, oil and gas, telecommunication, and airports. Figure 1 represents the scope of the literature review on buried utility locating.

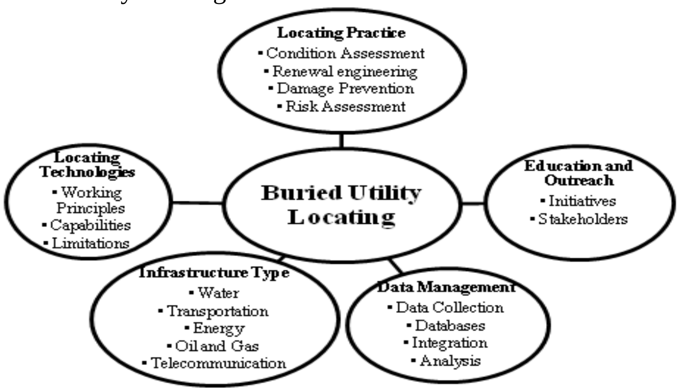

Figure 1. Scope of Literature Review.

A supporting committee was formed by industry experts from diverse backgrounds (1 technology provider, 1 service provider, 1 water utility, and 1 wastewater representative). The breakdown for the reviewed document types and years published is summarized in figure 2. The complete list of reviewed literature is provided as references.

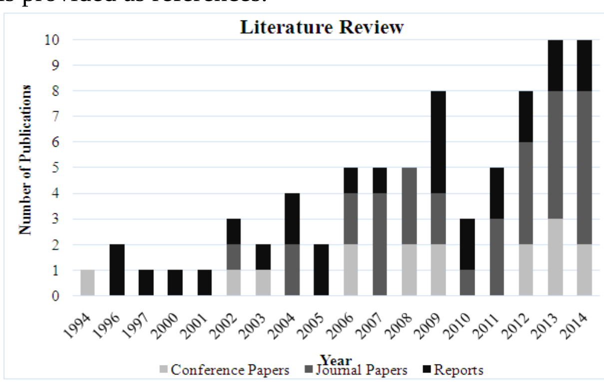

Figure 2. Literature Review

Synthesis of Literature Review

The reviewed literature is synthesized in the following section following the goals of the literature review effort.

Locating Practices

The underground utility locating surveys has traditionally relied on existing records or a one-call system (Anspach, 1994). However, existing information on underground utilities is often incorrect, incomplete, and inadequate in as-built drawings and composite drawings, which incorporate all of the utility records for different owners (AASHTO, 1996; APWA, 1997; ATIS 1997). Existing records and visible-feature surveys by site visit are typically 15%-30% off the mark and sometimes considerably worse (ASCE 2002). To overcome the limitations of using existing records, a one-call system was developed as an organized effort (APWA, 2001). However, the information provided by the one-call system is not enough to locate underground utilities in many cases (Lanka et al., 2001, Jeong et al. 2003). American Association of State Highway and Transportation Officials (AASHTO) reported that 56% of the damages to gas pipelineswere caused under the one-call system (AASHTO, 2004). There are many inadequacies of current one-call systems that are not yet addressed industry (Anspach, 2013). Although this system is state mandated to prevent utility damages, it is not a viable substitute for underground locating practices (Noone, 2002).

Various data collection standards has been developed in order to guide practitioners on the quality of the data needed for an underground utility locating survey (ASCE, 2002; CSA, 2011; BSI 2014). These standards are expected to address issues such as (1) how underground utility information should be obtained, and to what accuracy and level of quality (2) what engineering practices and technologies should be used to obtain that information, and (3) how that information should be conveyed to the information users (Jung, 2012).

There are numerous standards of practices developed to efficiently select the quality level of data needed for underground utility locating surveys. Standardizedof practices are developed by Pennsylvania Department of Transportation (PennDOT), Georgia Department of Transportation (GDOT), Texas Department of Transportation (TxDOT), and Washington Department of Transportation (WSDOT) to determine the quality of the information needed for a specific project to minimize the risk (Jeonget al., 2004; AASHTO, 2005a; AASHTO 2005b; Goodrum et al., 2008; Kraus et al., 2008; Sinha et al., 2008; Campbell et al., 2009: Jung, 2009; Quiroga et al., 2012).These standards of practice include matrices such as the utility impact score to determine the overall risk of a project and suggest required data collection levels.

Many agencies conduct benefit/cost ration analysis for underground utility locating projects.These benefits are quantified in order to calculate and document benefits of underground utility locating projects (Lew 2000, FHWA 2003, Osman and El-Diraby, 2005, Jung 2012). These quantified benefits give agencies the opportunity to effectively represent the benefits of the underground utility programs to their stakeholders and extend these programs for the advantage of agencies (Anspach 2013).

Locating Technologies

Every locating technology depends upon the ability to identify contrasts in underground utilities that include various properties: dielectric constants, ability to transmit acoustic energy, and other abilities (Llopis et al., 2014). A paper published as the part of the United Kingdom based Mapping-of-the-Underworld project (Rogers et al. 2012b) provide the review of the locating and condition assessment technologies for underground utilities. A counterpart report published in United States by Strategic Highway Research Program (SHRP) (Sterling et. al, 2009) provides the review of the underground utility locating technologies as well. The use of multiple techniques may yield the best possible target information (Rashed and Al-Garni, 2013).

Site conditions determine the effectiveness of underground utility locating technologies (Jung, 2007). Soil, ground conditions, accessibility, and density of underground utilities are factors to be evaluated when selecting the appropriate technologies (Hutchins and Sinha, 2009). There are numerous decision support systems developed to aid the selection of appropriate underground utility locating technologies for specific site conditions (Lanka et al., 2001; Jeong and Abraham, 2004; Hutchins and Sinha, 2009; Sterling et al., 2011).

The technological advancements are accelerating rapidly in the underground utility locating domain, the data capturing and management is becoming more sophisticated and capable.One of the recent advancements is the newly developed technologies that allow the collection and accumulation of 3D underground data (Young et al. 2009). Another advancement in underground utility locating is the application of the Radio Frequency Identification (RFID) Tags. RFID tags are applied during the construction stage at the underground utility trench (North, 2010). These RFID tags are used to locate the underground pipes after the projects are delivered and trenches are closed.

DataManagement

Maintaining accurate and complete records for existing utilities is essential to locate those utilities in the future (FHWA, 2003). There were varying standards on how the underground utility location is recorded (Sterling, 2009). Tabular format, GIS and CAD databases are used to record and maintain underground utility location data. Integrated and standardized databases are being developed to effectively manage and share underground utility location data. Such integrated system for underground utility location has been developed for TxDOT for underground utility projects (Kraus et al. 2009). This integrated data management system determined the standardized data exchange protocols between departments of a utility and other stakeholders. This system utilize 2-D GIS capabilities for visual interaction of the data. However, with the new advancements in locating technologies, migration to 3D data management systems has become possible (Zlatanova et al.,2002; Du and Zlatanova, 2006; Döner et al. 2010;).

Education and Outreach

On a recent survey conducted among DOT’s, it is determined that one of the major barriers in implementing successful underground utility locating programs is education and outreach for new initiatives (Anspach, 2010). Federal Highway Administration (FHWA) started the “Every Day Counts” program.Every Day Counts (EDC) is designed to focus on a finite set of initiatives. Teams from the Federal Highway Administration works with state, local, and industry partners to deploy the initiatives and to develop performance measures to gauge their success. Likewise, local communities formed to better share their knowledge and experiences. Tampa Bay Excavation Task Force formed in the Tampa Bay area in Florida is a good example of this practice (Jensen et al. 2013).

PRACTICE REVIEW

The first step of the practice review was to write case studies determine the utility practices. Various water and wastewater utilities were contacted in order to provide data to write case studies on underground utility locating practice and technology use. Second step in the practice review was to conduct interviews with various utilities to capture underground utility locating practices.

Water and Wastewater Underground Utility Locating Case Studies

A total of 55 case studies were written for the WATERiD Project in the domain of underground utility locating. Among these case studies, 21 was written to capture advanced DOT practices for the reference of water and wastewater utilities. 29 captures the underground utility technology applications. Remaining 5 (1 international) captures the water and wastewater utility practices on underground utility locating. Figure 4 represents the topic breakdown of case studies in the WATERiD Database. Following section synthesize the key lessons learned by these case studies.

Utility Phone Surveys

In order to supplement the case studies in order to get full coverage, phone interviews was conducted with representatives from various utilities Table 3represents the number of utilities contacted to fill the gaps in geographical synthesis.

Table 3. Geographical Coverage Overview.

EPA Region	Utilities for phone interviews
1	City of Dover, NH; Massachusetts Water Resources Authority, MA
2	Ocean County Utilities Authority, NJ
3	City of Virginia Beach, VA; City of Blacksburg, VA
4	Tallahassee, FL
5	Montgomery County, OH; City of Worthington, OH; City of Jacksonville, IN
7	City of Des Moines, IA
8	Salt Lake City, UT
9	City of Los Angeles, CA
10	City of Redmont, OR

The questions asked during the phone interviews are as follows;

1. How is the data quality needed for an underground utility locating survey determined?
2. What type of locating technologies are being used by the utility?
3. How does the utility keep their location data?
4. Is the utility a part of any local, state or federal community to share information and experiences?

Results of the Phone Interviews

Question 1 –How is the data quality needed for an underground utility locating survey determined?

The use of the one call system is very common among the survey participants. All participants indicated that their utility uses one-call system to locate pipes and it is state mandated. However, 9 out of 13 utilities indicate that the location information gathered through one-call system is supplemented by the use of locating technologies when needed. Only 3 out of 13 indicated that there is an established standard followed to determine the quality level needed. 2 out of 13 utilities indicate that employed utility locating contractors determine the data quality level needed.

Question 2 - What type of locating technologies are being used by the utility?

6 out of 13 utilities indicate the use of underground locating technology by in-house crews. These technologies include pipe and cable locators and GPR. 3 out of 13 utilities indicate that any other technologies are deployed by the recommendation of underground utility locating contractors.

Question 3 – How does the utility keep their location data?
All utilities indicate that there is an asset inventory sheet which the locations are recorded in tabular format. However they had indicated that the quality of these records vary greatly. 12 out of 13 utilities indicate that the location data for the pipes are managed through GIS systems. No utility indicated a 3D system utilized.

Question 4 - Is the utility a part of any local, state or federal community to share information and experiences?
Only 3 utility out of 13 indicated an involvement with such community.

Synthesis of the Practice Review

Locating Practices

Utilities use the underground location information to avoid utility conflicts for new construction or renewal projects. As case studies indicate, there are instances during construction where high quality underground location information is needed for pipes, defects, and other underground features surrounding pipes.

Phone interviews indicated that utilities have been using underground utility locating practices in a limited and unstructured way. The practice review indicate that utilities are relying on the state and federal mandated one-call systems regardless of the detail of information needed (13 out of 13). The quality of the location data is determined in needs basis as covered in the example case studies or utilities tend to rely on utility locating consultant recommendations. However, without a standard practices developed by utilities to evaluate the consultant recommendations, utilities are not getting full benefits.

Locating Technologies (vertical and horizontal data)

The case studies indicate that water and wastewater utilities use various underground utility locating technologies. Technology application case studies indicate a frequently use of GPR, pipe and cable locators. Case studies summarized at Figure 5 indicate that of the 28 technology application cases evaluated, 20 of them are GPR applications and 4 were pipe and cable applications. This finding on the technology use is supported by the phone survey results. Utilities indicate the use of GPR and pipe and cable locators by in-house crews. Although some application of the other technologies are recorded (Figure 5), these technologies are employed with the recommendation of the consultants. There are some hesitations among utilities to employ some of the emerging technologies because of the lack of experience and proven track record.

Data Management (Collection, Reporting, Integration)

Utilities indicate through phone interviews that there are no integrated databases forthe locating surveys which contain various data like the consultants, cost, technology used, and surrounding utilities. Although these data exist in various utility records, there are no integrated databases to capture this data in a standardized format. Underground utility locations are used to supplement asset inventory sheets by the utilities. The horizontal locations and the depths of the pipes are noted at the utility databases in tabular format. These location information is usually integrated with a GIS system to visualize the pipes on maps. Some of the utilities use CAD drawings in order to record or update the as-build information exist on their infrastructure. However, utilities have indicated that accuracy of the CAD databases have been unreliable because of the reliance on design data rather than as-build data in order to create these drawings as demonstrated in case studies.

Education and Outreach

Very limited number of phone interview participants indicate that their utility is a part of an education or an outreach program regarding utility underground practices.

Recommendations

This section provides recommendations for water and wastewater utilities to improve their underground utility practices.

Locating Practices

Although there are decision support systems exist for the damage prevention, there are no such decision support systems exist for utility locating for condition assessment and renewal engineering for water and wastewater pipelines.

Locating Technologies

There are various decision support tools exist in literature for effective selection of locating technologies. These decision support tools are created for damage prevention purposes for transportation industry. Similar to the decision support tools for data quality levels, these tools can be updated and tailored to fit water and wastewater utility needs. Specifically, the applications of locating technologies for condition assessment and renewal engineering need to be further researched. Table 5 summarize a list of parameters which can be used for such decision support tool. This list of parameters are augmented with the parameters needed for condition assessment and renewal engineering projects. Further research is needed to determine the parameters needed and develop the algorithm for the suggested decision support tool.

Table 5. Parameters for Data Quality Selection Decision Support System

Parameter	Unit
Soil types present	Type
Rock is present	Yes/No
Average daily traffic (ADT)	ADT
Groundwater levels	feet
Ground cover (if unpaved)	Type
Types of utilities present	Type
Environmental conditions	Good-Bad
Density of utilities	Low-High
Proximity of nearby structures	Feet
Type of nearby structures	Type
Depth of Utilities	Feet
Type of CA Technology	Type
Type of RE Technology	Type
Data Quality Needed	Data Quality

Development of Proper Data Keeping and Data Management Techniques

Having a standard set of data to collect at the project close will help to ensure proper data keeping for the future reference. There should be at least, a basic set of required information readily available for every project completed. The recommended standard data collection parameters discussed below could provide utilities with a basic set of information to collect at project close to ensure proper data keeping.

Table 6. Suggested Project Data

Project Location	Pipeline Type
Work Start Date	Consultant
Work End Date	Contractor
Project Cost	Technology
Pipeline Material	Data Quality Level
Internal Diameter	Comments

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