ACRP

SYNTHESIS 34

AIRPORT
COOPERATIVE
RESEARCH
PROGRAM

Subsurface Utility Engineering Information Management for Airports

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A Synthesis of Airport Practice

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Subsurface Utility Engineering Information Management for Airports

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AIRPORT COOPERATIVE RESEARCH PROGRAM

Airports are vital national resources. They serve a key role in transportation of people and goods and in regional, national, and international commerce. They are where the nation's aviation system connects with other modes of transportation and where federal responsibility for managing and regulating air traffic operations intersects with the role of state and local governments that own and operate most airports. Research is necessary to solve common operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the airport industry. The Airport Cooperative Research Program (ACRP) serves as one of the principal means by which the airport industry can develop innovative near-term solutions to meet demands placed on it.

The need for ACRP was identified in *TRB Special Report 272: Airport Research Needs: Cooperative Solutions* in 2003, based on a study sponsored by the Federal Aviation Administration (FAA). The ACRP carries out applied research on problems that are shared by airport operating agencies and are not being adequately addressed by existing federal research programs. It is modeled after the successful National Cooperative Highway Research Program and Transit Cooperative Research Program. The ACRP undertakes research and other technical activities in a variety of airport subject areas, including design, construction, maintenance, operations, safety, security, policy, planning, human resources, and administration. The ACRP provides a forum where airport operators can cooperatively address common operational problems.

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Cover figure: Jeffrey Oakley, EIT, designating utilities at Dulles International Airport. *Courtesy:* So-Deep, Inc.

FOREWORD

Airport administrators, engineers, and researchers often face problems for which information already exists, either in documented form or as undocumented experience and practice. This information may be fragmented, scattered, and unevaluated. As a consequence, full knowledge of what has been learned about a problem may not be brought to bear on its solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem.

There is information on nearly every subject of concern to the airport industry. Much of it derives from research or from the work of practitioners faced with problems in their day-to-day work. To provide a systematic means for assembling and evaluating such useful information and to make it available to the entire airport community, the Airport Cooperative Research Program authorized the Transportation Research Board to undertake a continuing project. This project, ACRP Project 11-03, "Synthesis of Information Related to Airport Practices," searches out and synthesizes useful knowledge from all available sources and prepares concise, documented reports on specific topics. Reports from this endeavor constitute an ACRP report series, *Synthesis of Airport Practice*.

This synthesis series reports on current knowledge and practice, in a compact format, without the detailed directions usually found in handbooks or design manuals. Each report in the series provides a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems.

PREFACE

By Gail R. Staba
Senior Program Officer
Transportation Research Board

This synthesis study is intended to provide airport operators, airport service providers, and utilities/infrastructure owners with ways in which information on subsurface utilities is collected, maintained, and used by airports, their consultants, and the FAA to increase the effectiveness of and enhance safety during infrastructure development programs at airports. It compares the current state of technology and effective processes from other industry sectors with what airports do today, allowing airports to consider areas for improvement.

To gather relevant information on current practices, literature was reviewed, and 16 airports were surveyed.

James H. Anspach, J.H. Anspach Consulting, Bend, Oregon, and Randy J. Murphy, Grafton Technologies, Inc., Newburyport, Massachusetts, collected and synthesized the information and wrote the report. The members of the topic panel are acknowledged on the preceding page. This synthesis is an immediately useful document that records the practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As progress in research and practice continues, new knowledge will be added to that now at hand.

CONTENTS

Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

SUBSURFACE UTILITY ENGINEERING INFORMATION MANAGEMENT FOR AIRPORTS

SUMMARY

This synthesis report identifies ways in which information on subsurface utilities is collected, maintained, and used by airports, their consultants, and the FAA to enhance safety during infrastructure development programs at airports. It compares the current state of technology and effective processes from other industry sectors with what airports do today, allowing airports to consider areas for improvement.

Airports are typically served by a network of underground utilities, not all of which are under their direct control. Many airports have unreliable and/or incomplete subsurface utility data, and as a result, utilities are often damaged during or in conflict with infrastructure development. Airports and consultants interviewed for this study indicated that the data about subsurface utilities vary greatly in quality, quantity, and access. When airport utilities are damaged or conflict with development plans, there are inevitably consequences for project schedules and budgets and sometimes significant impacts on safe and efficient airport operations.

For example, on January 10, 1996, a routine capital improvement project caused damage to an electrical cable at Newark International Airport, resulting in more than $1 billion of impacts, including hundreds of canceled and re-routed flights, disruption of travel to tens of thousands of people, and complete closure of the airport for more than 24 hours. This accident was the direct result of not knowing where the electrical cable was located. Unfortunately, this is not an isolated incident. This study found that some major airports experience almost daily utility damages caused by construction activities.

Fortunately, existing technology can identify and reliably map subsurface utilities and reduce the risks associated with utilities damage, although implementation of these processes has been slow. Some airports have embraced geographic information systems (GIS) to more efficiently store and use their utility data. Utility data are being integrated into not only airport GIS programs but asset management, computerized maintenance management, and other information technology resources. Some airports are beginning to incorporate new technologies such as mobile computers so that field personnel can instantly have access to needed utility information during construction and maintenance activities.

With greater access to improved software and hardware, airport GIS personnel report that they would like better and more comprehensive data. This study found that airport staff perceives that utility records are often inaccurate, incomplete, and not accessible to all who need them. In many cases they do not include utilities that are owned by others, such as the FAA, tenants, and local utility providers. Airports typically plan and design projects based on existing records and a small portion of the utility networks that they can see on the surface. It is the project manager's or project engineer's responsibility to identify the location of utilities during planning and design. This study found that few airports have standardized policies or procedures for how locating underground utilities is to be carried out by airport staff and/or consultants. This places an increased responsibility on the project manager and often leads to inconsistent results across an organization.

Most airports do require their consultants and tenants to provide as-built drawings; however, the quality of the information received is not standard and/or as expected, and sometimes

the information is not received at all. Although most airports have developed computer aided design and drafting (CADD) standards for as-built drawings, few have developed standards for related attributes and metadata or implemented procedures for submitting and storing these data. Contractors are sometimes willing to forego any retainage held back in lieu of delivering the as-builts an airport needs. The desire to complete projects and bring new facilities into use often eclipses the need for information necessary to efficiently operate and maintain them.

Studies have consistently shown that having accurate and comprehensive information available early in a project's life cycle leads to significant project cost savings and reduced risks. The practice of combining professional judgment with imaging, positioning, and mapping technologies for managing and coordinating the risks of existing underground utilities is called subsurface utility engineering (SUE). University and DOT studies on these technologies and practices document a significant positive return on investment ranging from 462% to 2,200% over traditional methods of researching, locating, surveying, mapping, and using underground utility information.

SUE is considered an effective practice by the FHWA, AASHTO, the American Public Works Association (APWA), the Associated General Contractors of American (AGC), the utility damage prevention community, and many other organizations more recently including the FAA.

This study found gaps in the use and understanding of SUE by many airport personnel and their consultants. Several airports have begun to use SUE as a part of planning and designing projects. Some have established separate programs or on-call contracts with SUE firms in an attempt to map all of their utilities over time regardless of the requirements of specific projects. Some of these airports have reported satisfaction with their fledgling SUE programs, but would also like to see improvements

Others forgo the use of SUE because the costs are higher than using existing records for utility depictions. Many interviewees are unaware of the studies from other industry sectors showing high return on investment. Airports that have funded SUE initiatives have done so using a variety of mechanisms. Some have used airport operating funds to conduct focused SUE projects that deliver CADD and/or GIS data depicting specific utilities or to pay for an on-call contract to make SUE services available on an as-needed basis. Airports have also initiated SUE activities as a part of construction projects or larger capital improvement programs. Many of these construction projects and programs receive funds from the FAA's Airport Improvement Program.

This study identified gaps between existing technology and processes for utility risk management in other industries with those in the airport industry. These gaps suggest that further research is needed to:

- Increase awareness and training on SUE practices
- Integrate utility mapping with geotechnical investigations
- Develop SUE prequalification criteria for airports
- Standardize scopes of work for utility mapping for airports
- Develop SUE cost guidelines for airports
- Develop a utility data model for airports
- Improve CADD–GIS interoperability
- Develop a metadata profile for airports
- Integrate utility mapping into the project development process for airports.

The study concludes that while the use of SUE on airport projects to obtain and manage data is growing, SUE is not being used as effectively in other sectors and is not always aligned with existing procedures.

CHAPTER ONE

INTRODUCTION

BACKGROUND

This chapter identifies the objective and intended audience of this report. It accentuates how critical reliable information about subsurface utilities is to airports and the risks that poor information poses to safety, operational efficiency, and infrastructure development costs. It also provides an introduction to subsurface utilities engineering (SUE) and how the processes it embodies help mitigate those risks. Finally, it summarizes the methodology for conducting this study and the contents of this report.

The objective of this synthesis report is to describe current and effective practices within the airport industry of collecting, storing, and using subsurface utility information. The intended audience for this report includes airport operators, airport service providers, the FAA, and utilities/infrastructure owners.

Airports are typically served by a network of underground utilities, some of which may be operated independently. Unreliable and/or incomplete subsurface utility data can result in damage to these utilities during development or renovation (Anspach 1998), which inevitably affects construct schedules, budget projects, and even safety (FAA 1993).

The likelihood of unintentional utility damage during airport development projects is high for two reasons. First, many airports operate somewhat autonomously from their surrounding jurisdictions. Their operating procedures are largely dictated by the FAA, which is focused on aviation safety, security, and efficiency and has no standards for underground utilities owned by airports or local entities. The FAA does have a standard for subsurface utility damage prevention (ANI1Q-QCW1342.1); however, it applies only to FAA projects (FAA 2004). There are mixed reports on whether this standard is being applied consistently among airports. Second, airports host a large volume of complex operations in a relatively small space. Supporting these operations with minimal above-ground hazard to aircraft operations requires a vast and complex network of underground utilities. In short, a large volume of buried utilities that support critical operations, combined with disparate procedures and a great deal of missing data, leads to risks that need to be mitigated (FAA 1993).

In 1994, the associate administrator for aviation safety initiated a study to review the causes and impacts of cable cuts from excavation, assess actions being taken to prevent disruptions, and provide information to FAA managers for use as a basis for decision making. The recommendations of that report were not implemented owing to FAA organizational structure and funding constraints (Nguyen 2003). Because of the continuing problem of cable cuts, the director of National Airspace System (NAS) Implementation (ANI) initiated another study in November 2001 to revisit the issue and develop improvement practices to decrease cable cuts during ANI construction projects at airports.

> The ANI Advanced Implementation Team discovered the following facts. All too often, utility damages can have catastrophic results. Even when not catastrophic, the results from damages can be significant. Being one of the many tenants at the airport, FAA owns vital underground utilities at airports. Disruptions to telecommunications or electrical power systems that support critical FAA facilities and services have a significant impact. These may include air traffic delays, increased air traffic workload, and operational and personnel safety concerns. Multimillion dollars lawsuits are increasingly common. Traditional solutions have not reduced damages to an acceptable frequency. These solutions typically made the contractor responsible for utility protection during excavation, and encouraged or required some utility owners to mark their facilities' locations on the ground surface just prior to construction. The ANI Team also discovered that the general engineering and construction industry has the same problem and is undertaking an increased effort to reduce underground utility damages during excavation. This effort includes the increased use of Subsurface Utility Engineering (SUE), and the development of a new national engineering standard ASCE 38 (Nguyen, 2003).

Other transportation sectors have also conducted extensive studies of the risks subsurface utilities can pose to safe and efficient operations and infrastructure. A large-scale study (FHWA 1999) characterized utility project risks on highways as follows:

Project delays and extra costs resulting from:

- Unnecessary utility relocations based on incorrect location information
- Unexpected utilities found during construction
- Unexpected utility configurations
- Redesign of utility or structural project elements
- Unanticipated utility relocation construction
- Utility damage repair
- Utility damage environmental mitigation
- Utility damage pavement mitigation
- Utilities at unexpected depths

- Utilities in poor condition that need replacement or repair
- Utility One-Call marks not matching up with construction plan depictions.

Initial project costs higher resulting from:

- Contractors pricing utility risk contingencies
- Investigation and processing of incomplete and inaccurate utility information

Safety risks resulting from:

- Damaged utilities affecting safe vehicle operation controls, such as traffic signalization
- Traveler inconvenience resulting from closure of surrounding highways.

The following news articles illustrate some of the potential consequences of the risks posed by incomplete information about subsurface utilities at airports.

New York Times, January 10, 1995

> Newark International Airport was crippled, then shut down, and air travel in the Eastern United States was seriously disrupted today after a construction crew driving piles for a new garage accidentally crushed high-voltage underground electrical cables serving the airport's three passenger terminals.
>
> Several hundred of Newark's passenger flights were canceled and the travel plans of tens of thousands of people were ruined after the mishap cut off electricity to the three terminals at about 8:30 a.m. Some passengers flying from Europe to Newark ended up in Bangor, Me.; others took unexpected detours on domestic trips, landing at LaGuardia and Kennedy airports and being bused here to pick up cars and meet their families.
>
> At 5 p.m., the airport's general manager, Benjamin DeCosta, ordered the airport, the nation's ninth-busiest, shut until Tuesday morning as utility crews struggled into the night to install a 100-foot loop of cable to bypass the three damaged lines and restore power to the terminals.

Minneapolis Star Tribune, August 29, 2000

> A severed cable temporarily disabled a landing system on two runways Monday morning at Minneapolis-St. Paul International Airport, delaying about 15 Northwest Airlines arrivals. Airport spokesmen said a construction crew accidentally cut a cable near the southeast end of the airport's north parallel runway about 9 a.m. That led to a 50-minute interruption in operation of the two parallel runways' instrument landing system, designed to guide arriving planes when visibility is low.

Colorado Springs Airport Website News, January 11, 2007

> At approximately 12:30 p.m., contractors working on the west side of the Colorado Springs Airport cut the primary fiber optics phone cable that serves the passenger terminal building. Airline and airport personnel have switched to back-up communications systems and it is anticipated that flight operations will continue on a normal schedule, with no impact on passengers. Maintenance crews are on site and estimate completion of the cable repair by 7:00 p.m. this evening.

The Orange County Register, June 16, 2010

> Commuters on the I-405 and 55 freeways came across some delays Wednesday morning after a gas line ruptured at a John Wayne Airport construction area. The main gas line to the airport terminal was damaged at about 7:30 a.m., said Jenny Wedge, an airport spokeswoman. It occurred at the construction site of the central utility plant, near a parking structure at the east end of the airport. Wedge said takeoffs and landings were not affected. While crews worked to shut off the gas leak, travelers were seen walking with their luggage along Michelson Drive.

Baltimore Sun, February 10, 2004

> A gas leak at Baltimore–Washington International Airport tied up vehicle traffic yesterday afternoon and prompted the temporary evacuation of three piers, airport officials said. Construction crews were working on part of the airport's $1.8 billion expansion about 11:30 a.m. when they ruptured a gas line on the lower level outside the main terminal, said a spokeswoman for BWI.

As the incidents above illustrate, utility disruptions present significant risk to airport operations, aircraft operations, and human safety. Identifying and developing strategies to mitigate them are an important part of an airport safety management system (SMS). FAA Advisory Circular 150/5200-37 defines SMS as "the formal, top-down business-like approach to managing safety risk. It includes systematic procedures, practices, and policies for the management of safety (including safety risk management, safety policy, safety assurance, and safety promotion)" (FAA 2007).

The extent and complexity of the utility networks that can impact safety in and around an airport, the types of hazards or vulnerabilities that utilities present, and methods of addressing them fall under the area of safety risk management. Airports can support the safety risk management process by accurately and comprehensively depicting the location of existing utilities, identifying the airport systems each serves, and providing important details that can help in assessing the level of risk and determining mitigation strategies. Disseminating information on subsurface utilities helps promote safety among contractors, airport maintenance staff, airline ground crews, and others that routinely come into contact with airport utilities infrastructure.

Having effective methods of achieving accurate and comprehensive subsurface utility information not only minimizes safety risks; it can limit their effect on construction project costs and schedules. Figure 1 illustrates the ability to control risks to program costs and various phases during a project development schedule. It is easier to control risks when accurate, comprehensive data are available early in the project development process (University of Texas 1986). However, airport project managers are often under pressure to deliver

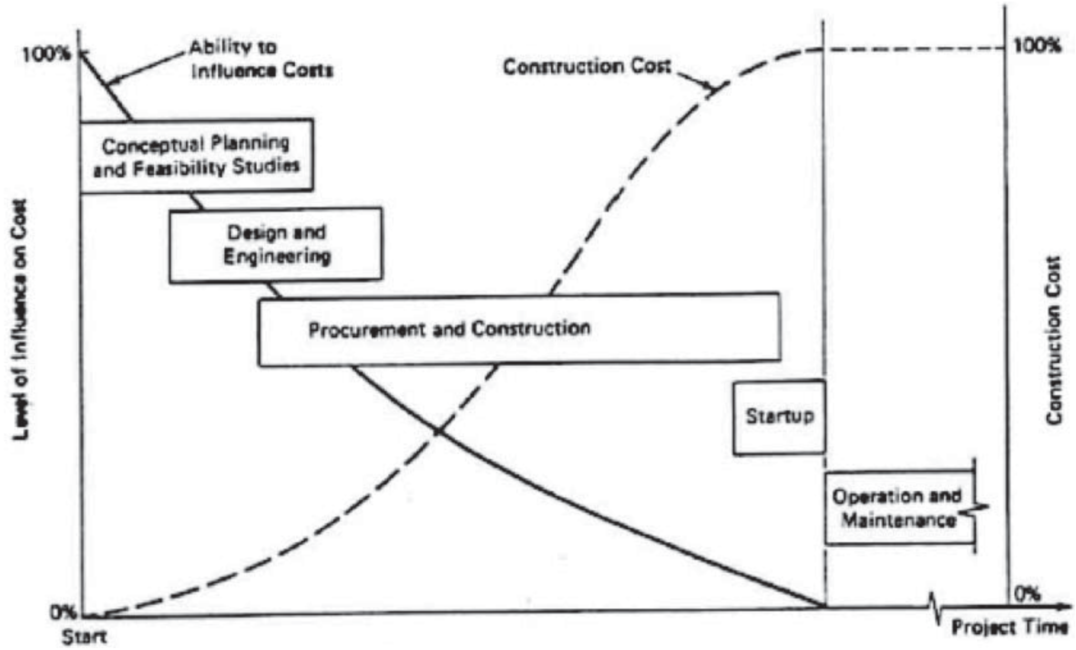

FIGURE 1 Ability to influence construction costs as a function of the project development process timeline (University of Texas 1986).

a project at the lowest possible initial cost with little thought toward future operating and maintenance costs or utility safety issues.

Developing procedures to avoid damaging utilities is not only good practice, it is a requirement. Airports that have scheduled passenger-carrying flights on aircraft with nine or more seats and unscheduled passenger-carrying flights with 31 or more seats must "Provide procedures, such as a review of all appropriate utility plans prior to construction, for avoiding damage to existing utilities, cables, wires, conduits, pipelines, or other underground facilities" according to Part 139.341 of the Code of Federal Regulations (CFR 2011). A case might be made that the phrase "appropriate utility plans" implies plans that are accurate and comprehensive.

SUE was developed to incorporate the disparate, inefficient, and unorganized methods of collecting and depicting utility data and establish practices to be carried out by registered professionals with expertise in geophysics, surveying, and engineering. These professionals use their judgment to select appropriate basic and advanced technologies and then use those technologies to collect and depict the location of utility infrastructure and related details about it (i.e., attributes), as well as information about the quality of these data (i.e., metadata). SUE is widely recognized as a means of both managing and mitigating risks that subsurface utilities pose to the design and construction process (Anspach 2009). SUE is officially defined by the American Society of Civil Engineers as a branch of engineering practice that involves managing certain risks associated with utility mapping at appropriate quality levels (QLs), utility coordination (UC), utility relocation design and coordination, utility condition assessment, communication of utility data to concerned parties, utility relocation cost estimates, implementation of utility accommodation policies, and utility design (ASCE 2002). An important duty of the subsurface utility engineer is effective coordination, communication, and cooperation between stakeholders, including utilities, One-Call centers, public agencies, consultants, construction contractors, and project owners (AASHTO/FHWA 2002).

The use of SUE in other transportation sectors consistently shows a significant return on investment (ROI), with the most recent study by Penn State University documenting a 2200% ROI over traditional means and methods of collecting, depicting, and using utility information (Singha 2007). Said another way, every $1 spent in using appropriate geophysics to reliably identify utilities early in the project delivery process cut costs by $22 in reduced test excavations, redesign costs, project delays, contractor change orders, bid prices, unnecessary utility relocations, and utility and environmental repairs.

In other studies that encompassed more than 100 capital improvement projects of various sizes and complexities, totaling well in excess of $1 billion worth of design and construction costs, ROI was positive in all but three projects. This led Purdue University to conclude that the use of SUE, in particular the use of geophysics as a tool for utility mapping, should be used systemically for highway projects. These studies included:

- Virginia Department of Transportation: 700% ROI (Scott 1996)
- Maryland State Highway Administration: 1800% ROI (FHWA 1995)

- Purdue University: 462% ROI (FHWA 1999)
- University of Toronto: 341% ROI (Osman 2005).

The typical way that utility information is deemed reliable is by knowing its origin, the qualifications of the persons creating it, the technology they used, and the amount of trust placed in these persons. The result is a massive amount of metadata, or information specifically about the utilities data that is required for a user to ascertain reliability. The ASCE's *Standard Guidelines for the Collection and Depiction of Existing Subsurface Utility Data,* CI/ASCE 38-02, simplifies this process by defining a utility quality level (QL) attribute that incorporates origin, qualifications, technology, and trust/accountability. QL is broken down into the following four levels:

- Utility quality level A (QLA)—Information obtained by the actual exposure (or verification of previously exposed and surveyed utilities) and subsequent direct measurement of subsurface utilities, usually at a specific point.
- Utility quality level B (QLB)—Information obtained through the application of appropriate surface geophysical methods to infer the existence and approximate horizontal position of subsurface utilities. QLB data should be reproducible by surface geophysics at any point of their depiction. The horizontal locations are surveyed to the horizontal positional accuracy requirements of the project or any required statute.
- Utility quality level C (QLC)—Information obtained by surveying and plotting visible utility features and by using professional judgment in correlating this information to quality level D information.
- Utility quality level D (QLD)—Information derived from existing records or oral recollections.

AUDIENCE

This report is primarily written for airport design and construction project managers and their counterparts in consulting organizations. These individuals are the primary parties who will decide if and how SUE practices and principles are incorporated into the projects they manage and used to manage underground utility risks. Airport engineers, computer aided design and drafting (CADD)/geographic information system (GIS) technicians, and surveyors can also benefit by understanding the technologies, practices, and policies that guide their work. Although the report is written for airport administrators and their consultants, FAA managers and staff who are involved with projects that install utilities will also find the information in this report helpful.

This report can be useful for airports of any size. While larger airports often embark on larger construction projects and have larger budgets for SUE activities, smaller airports must also manage utility networks, incorporate utilities into planning and design projects, and be aware of possible utility conflicts during construction.

METHODOLOGY

This study was carried out in three phases. First, a search for existing relevant literature was conducted and the resulting documents were reviewed for information about the state of the technology, art, or practice. Second, phone interviews were carried out with a variety of airport administrators and their consultants. A questionnaire was designed to solicit information about current practice at airports and was used to guide these interviews. Third, an e-mail survey was conducted of firms that have provided SUE services to airports. The results were combined with information identified during other studies being conducted by the investigators, as well as their experience providing SUE services to airports. All of the information gathered was synthesized into this report, a draft of which was reviewed by a panel of experts, before this final report was produced. This methodology is described in more detail here.

Literature Search

A literature search was undertaken to identify documents in the public domain that relate to subsurface utilities and airports. The literature search made use of Transportation Research International Documentation (TRID) and the Internet by means of commercial search engines. Keywords placed in the TRID search engine returned only 12 results, none more recent than 2004, and after review of the abstracts, only two pertained to this topic. Removing any keyword reference to aviation or airports produced an additional 275 results, some of which were relevant regardless of transportation or industry sector.

Internet searches were performed with various combinations of keywords such as "utilities," "subsurface utility engineering," "SUE," "airport," and "FAA," with the names of each type of utility found at airports (i.e., "fuel," "water," "storm," etc.) as well as with specific types of studies typically carried out by airports (i.e., "storm water pollution prevention plan"). This produced 1,700 results. Technical paper abstracts were reviewed for applicability. Seven were found that had not already been identified through other means. The vast majority of the documents were SUE consultant websites or articles that mentioned SUE and airports in the same document, but had no useful information for this study.

To complement electronic searches for documents and phone interviews, e-mails were sent to a sampling of airport industry consultants. Specifically, members of the Transportation Research Board's (TRB's) Airport GIS Subcommittee and attendees of American Association of Airport Executives (AAAE) conferences held over the last 14 years were contacted. They were asked for copies of or references to written procedures, standards, request for proposals, or other material that related to utilities data at airports. Finally, references furnished by this study's expert task group, and literature and documents already in the possession of this study's investigators, were also reviewed and are contained in the References.

Phone Interviews

Sixteen airports were identified at the 2011 AAAE GIS conference as having recent capital improvement projects with utility involvement. All 16 agreed to be interviewed and subsequent telephone interviews were conducted. Two airports were outside the U.S. Of the 16, eight are considered large-hub airports; that is, airports handling more than 1% of the nation's annual passenger boardings. Interviews lasted approximately 90 minutes and were structured from a questionnaire that was sent to the airports before the interview so that respondents could internally seek the answers from different departments within their organizations. The questionnaire was intended as a guide to facilitate discussion. A blank copy of the questionnaire is included in Appendix A. The answers have been aggregated to maintain confidentiality of interviewees and are included in the body of this report.

Airport interviewees suggested other sources of information, and as a result, informal interviews were also conducted with several large consulting engineering firms, FAA representatives, software and hardware vendors that supply the airport and/or public utility industries, and energy industry representatives.

E-Mail Survey

A questionnaire was developed and sent to 15 major SUE providers whose websites indicated they had experience with mapping utilities at airports. Ten firms responded, with utility mapping experience covering 44 airports. The 44 airports covered included eight for which interviews were conducted. The questionnaire provided both confirmation and differing perspectives of the procedures at these eight airports.

Figure 2 illustrates the geographic extent of North American airports for which information was gathered. In addition, two Western European airport authorities were interviewed.

Parallel Study

In addition to the interviews carried out for this project, investigators were concurrently carrying out similar research in support of other federally funded studies. Although the objectives of these studies differed from the review conducted for this project, some of the information gathered in these other studies was related to subsurface utility engineering at airports and was therefore taken into account. These studies include the Strategic Highway Research Program Projects R-01A, R-01B, and R-01C.

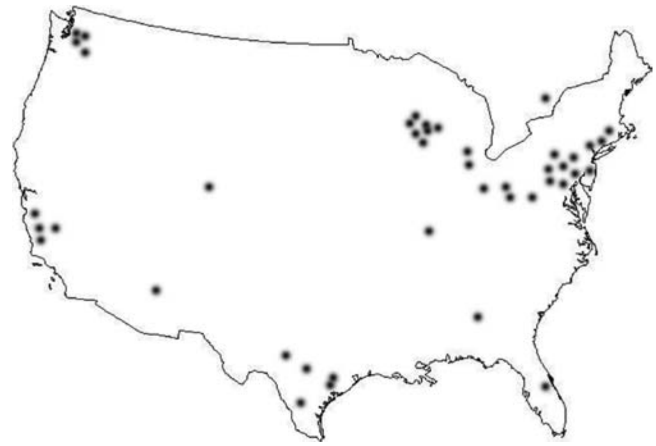

FIGURE 2 Distribution of airports for which information on this study was collected.

DOCUMENT ORGANIZATION

This document has been organized into a Summary, seven chapters, and four appendices.

- Chapter one provides an introduction stating the objectives and intended audience of this report. It identifies the problem that this report is intended to help address and identifies processes airports have used to effectively overcome it. This introduction also describes the methodology used during this study and provides an overview of the organization of this document.
- Chapter two details the existing state of the technology (SOT). It reviews current geophysical tools for imaging utilities, survey tools for both positioning the geophysical tools or for creating as-builts of exposed utilities, information storage and retrieval methods, and technology integration where the lines are blurred.
- Chapter three deals with the state of the art (SOA). It explains how property and project owners who routinely contend with utility issues integrate the available technology into a system that reduces utility risk during projects, maintenance, and operations.
- Chapter four reviews the results of the interviews and surveys. It explains how airports in general are dealing with utility data management. It can be used as a comparison between what can be done, as described in chapters two and three, and what is being done. It is a

snapshot of the state of the practice (SOP). By request, the identity of individual airports in this section is not revealed.

- Chapter five highlights what individual airports, their consultants, and SUE providers believe are effective practices being used by at least some airports and that could be considered for use by a broader audience. While at first glance this may appear like integration between SOT and SOA, it takes the perspective of users and providers into account.
- Chapter six looks at research in progress. It identifies any current research that is related to the topics addressed in this study. The purpose of this is twofold: first, to identify areas where additional information will soon be available; second, to provide suggestions that may help influence these other studies so that they provide additional benefit to the intended audience of this study.
- Chapter seven summarizes the report conclusions and identifies areas for further research.

CHAPTER TWO

STATE OF THE TECHNOLOGY

This chapter describes technologies that use geophysics to detect and interpret the location of utilities already in the ground, reference utilities to a position on the earth, and store and retrieve utility information. The detection methods detailed below are commercially available and broadly applicable. The relative merits and applicability of these technologies are described, but not the theories behind them or instructions on how to use them. (Information on theory and use can be found in many of the references in the Appendices.)

The technologies that are currently available include geophysical sensors, survey equipment, CADD and GIS software tools, portable field computers, wireless communications, Radio Frequency Identification (RFID), Global Positioning System (GPS)-enabled cameras, and software. Some of the more recent and advanced technologies are integrated with multiple sensors and survey capabilities in a single platform (Young 2010). Technologies for detecting, tracing, positioning, and depicting utilities are constantly improving. This results in an increasing number of options available to identify the location of utilities.

GEOPHYSICAL DETECTION

Geophysical detection analyzes energy fields to find anomalies with the surrounding environment that might indicate the presence of a utility. Successful detection is a function of the utility material, the way that material is connected to other portions of the same system, the way that material is connected to the ground, and properties of the ground itself. There are many types of energy available (Sterling 2000). Sometimes field engineers will apply an energy field or use one that is applied by others or occurs naturally. Some of these energies are limited in power and amplitude owing to safety and interference issues.

Some utilities can be detected by several methods, some can only be detected by one method, and some cannot be detected by any method other than exposure (Sterling 2009). A recent TRB product that assists in determining which type of geophysics is useful in a particular situation is the Selection Assistant for Utility Locating Technologies (SAULT), which can be found on the Internet at http://138.47.78.37/sault/home.asp (Sterling et al. 2011). This tool was developed in part for project owners so that they could understand the broad toolbox necessary for the utility-mapping professional.

Electromagnetic Pipe and Cable Locators

Electromagnetic pipe and cable locators (EML) have been in common use since the 1960s. Recent advances in technology make it possible to measure and display current flow direction, in addition to EML's traditional function of displaying signal amplitude. Advances also include multiple antennas and frequencies. EML devices come in a variety of available frequencies ranging from 50 HZ to 500 kHZ. The range of frequencies is essential in order to detect utilities in a variety of situations (TSA 2011).

Most EML devices allow the operator to interpret the signal as being utility-related, mark the position of that signal on the ground, and subsequently survey that mark. New devices can be equipped with mapping grade GPS capabilities. This positional data can be transmitted wirelessly to another computer or stored within the unit for later output. Most devices come with attachments that allow a signal to be better coupled to a known and exposed utility. Such attachments include cables, magnets, and inductive clamps.

EML devices are limited to the possible detection of continuously metallic structures or structures that can be made to act as if they are metallic (see Figure 3). Installation of a metal tape or "tracer wire" directly above the utility during construction is one way to allow a non-metallic utility's location to be inferred. There are also metallic insertion devices for situations where pipes or conduits, typically empty and/or out-of-service, can be accessed. Pipe diameter, material, number of bends and their proximity to one another, pipe constrictions, and check-valve placement all affect capabilities.

EML devices can also utilize sondes, or small radio transmitters, which are inserted into an accessible pipe or conduit. By detecting the sonde at numerous points as it is pushed through the pipe or conduit, the user can infer the position of the utility. Cameras can be inserted at the front of a sonde so that a video can be taken of the inside of the pipe or conduit. This can be useful for condition assessment as well as location interpretation.

Radio Frequency Identification

A type of miniature sonde, called RFID, has been employed more frequently over the last several decades (see Figure 4). RFID "tags" are installed on or near the utility during

FIGURE 3 EML device in use to designate electric lines. (Photo courtesy of Cardno.)

construction or exposure for maintenance or other purposes. Some of these devices can be programmed to include information about the utility, such as ownership, type, size, and depth. Newer RFID devices are almost unlimited in the amount of data they can contain. Some devices transmit data when "interrogated" on a particular frequency. The data can be encoded so that only proprietary devices can read them, but any device on that frequency can get a signal indicating the utility is close by. Other manufacturers are using protocols that can be read by nonproprietary devices. RFID devices that have internal batteries can be detected deeper underground than devices that have no batteries and use the energy from the above-ground receiver. One drawback for a device with batteries is that it will eventually lose power. Just as with an inserted sonde, the user can use RFIDs to infer the position of the utility by "connecting-the-dots." Another highly important use of RFID is to confirm the interpretation of a utility as a particular one, since the RFID is unique to that utility (Dziadak 2009). RFID tags have been proven to play a significant role in utility damage prevention (Anspach 2011).

FIGURE 4 A marker ball RFID/Sonde being programmed prior to emplacement. (Photo courtesy of VDOT.)

Magnetics

Magnetics (MAG) technology has not changed appreciably in decades. It is useful for finding buried steel or iron "single-point" structures such as buried manhole lids and valves. Although there are several types of MAG methods in use, the one that is most used for utility detection is a gradient-field magnetometer (see Figure 5). As with EML, once a utility has been detected with MAG technology, marks are usually placed on the ground for later survey.

Elastic Waves (Sound)

There are three separate techniques that are currently in use to trace utilities using elastic waves (additional techniques are currently in development). A pipe under mechanical stress may deform and generate noise. This noise can be measured. The noise should be loudest directly over the pipe because the elastic wave's travel distance is the shortest at this point. However, the type of surface (e.g., soil vs. concrete), the type

FIGURE 5 Gradiometer. (Photo courtesy of Schonstedt Instrument Co.)

FIGURE 6 Resonant sonics receiver. (Photo courtesy of So-Deep, Inc.)

of fill (e.g., rock vs. clay), the degree of compaction, and ground moisture may affect the noise distribution, as may other sources such as aircraft, automobiles, trains, and electrical transformers (see Figure 6). As with EML, marks are usually placed on the ground for later survey once the location has been inferred.

The following excerpt from CI/ASCE 38-02 (2002) further describes methods for using sound waves to detect subsurface utilities:

> One method involves inducing a sound onto or into a pipe. This can be accomplished by striking the pipe at an exposed point or by introducing a noise source of some kind into the pipe. This may work for metallic, nonmetallic, empty, or filled pipes. A noise source may have the advantage of moving within the pipe for some distance, thereby getting the sound closer to the detection point. By marking or measuring the loudest points, a trace of the utility may be accomplished. This method is sometimes known as 'active sonics.'
>
> A second method relies on the pipe's product being able to escape the pipe. This method is sometimes known as 'passive sonics.' For instance, water escaping a pipe at a hydrant or service petcock will vibrate the pipe. This vibration will carry along the pipe for some distance before attenuation. Factors such as product pressure, shape and size of orifice, and type of pipe material will affect the initial sound generation. Pipe material, surrounding material, compaction, and product will affect the distance the sound travels along the pipe. Factors such as those already mentioned affect the sound detection between the receiver and the pipe.
>
> The third method relies on the pipe's product containing a noncompressible fluid (water in most cases). Interfacing the fluid surface (e.g., at a hydrant) and generating a pressure wave in the fluid will in turn create vibrations in the pipe that can be detected. This method is sometimes known as 'resonant sonics.' It has the advantage of being able to tune the oscillator's frequency to one (or more) of the resonant frequencies of the pipe, usually resulting in more tracing distance. A disadvantage is the need for many different types of fluid or oscillator interfaces.

Electromagnetic Terrain Conductivity

Terrain conductivity methods create and measure eddy currents caused by differences in the average conductivity from the ground surface to an effective penetration depth of 5 m or so. Utilities (and/or the product they convey) may exhibit conductivities that are different enough from the average soil conductivity that they can be differentiated using this method. In areas of high metallic utility congestion, there is usually too much noise to interpret results. Similarly, surface metals (e.g., cars, fences, etc.) and reinforced concrete will distort results.

There are two basic antenna configurations for electromagnetic terrain conductivity (EMTC). One is long and linear; the other is square. Both instruments have the capability to store collected data for download. Each instrument has its advantages. The long linear antenna measures average conductivity in a cone-shaped space from the ground surface to a depth of about 20 feet (see Figure 7). The antenna's linearity can both augment and hinder a utility investigation. If interpretation of the data is in "real-time," the operator can view a difference in signal strength as the antenna is rotated and/or dipped. The resultant signal can give clues as to a utility's depth and direction of travel, and can also give clues as to interfering nearby structures (Geonics 2000). It is recommended that real-time interpretation be used for utility detection with this device, as using an intersection survey point grid and collecting data only at these points can result in incomplete data (ASCE 2002). Isolated metallic utilities, underground storage tanks, wells, and vault covers are usually detectable by means of this method. Under some conditions, large nonmetallic water pipes in dry soils or large nonmetallic empty and dry pipes in wet soils may be imaged. Once a utility is identified, a mark is typically placed on the ground for later survey.

FIGURE 7 Terrain conductivity device. (Photo courtesy of So-Deep, Inc.)

A recent advance in EMTC is the use of the square antenna (see Figure 8). This antenna shape is more efficient than the linear one and alignment of the antenna with the utility is not a factor in detection. Some technicians combine multiple antennas for a broader swath of coverage, decreasing the time spent collecting data, and increasing the density of the data returned. Improved data density allows for a more robust interpretation, and can be used to "see" utility trenches as well as the utility. The square antenna is usually coupled to some sort of survey equipment and the data are downloaded and plotted on plans without using markings on the ground. Quality control of the positioning is critical as there are no marks on the ground for correlation (Young 2010).

Ground Penetrating Radar

Ground penetrating radar (GPR) is a sub-class of electromagnetic methods. GPR is an established technology that until recently had a poor reputation. This reputation was the result of "over-selling" of GPR capabilities, difficulty of data interpretation by typical utility locating personnel, and unreliability of components. That has changed within the last decade, and GPR has become widely accepted within the subsurface utility engineering market. However, "contract locating" or One-Call providers still find the equipment too expensive and complicated for their purposes (Sterling 2007).

The main benefit of GPR is that it can detect virtually anything that contrasts with the surrounding underground environment, such as non-metallic pipes, edges of trenches, and plastic conduits. Another significant advantage is that when an image is received, its depth can be determined fairly accurately, and accuracies can be increased through calibration of the signal velocity over targets of known depths. This contrasts with EML methods, which provide a less reliable depth measurement.

GPR does have limitations. In conjunction with other technologies it can be used to interpret a very accurate picture of the subsurface environment (TSA 2011). Approximately 50% of the land area of the United States has soils that are unsuitable to obtain any meaningful data on utilities regardless of size, contrast, or depth (USDA 2009). Local use of pavement de-icing salts can also increase soil conductivities where the salt washes off, rendering GPR less reliable at the edges of paved areas in northern climates. Surface conditions such as uneven ground and physical obstacles may limit survey coverage. Additionally, the depth of penetration is inversely proportional to the size of the utility that can be imaged. This implies that small pipes and cables can be difficult or impossible to see at greater depths. Sometimes a utility can be inferred through seeing the edges of a trench, even when the utility is deep (Sterling 2009).

There are different types of GPR that involve permutations of single or multiple frequencies, numbers of antennas, orientations of antennas, types of data storage, and display capabilities. Each has its advantages and disadvantages. For the purposes of this study, we will classify them into two main groups: basic GPR and advanced GPR (Green 2006).

Basic GPR has a transducer that sends out an electromagnetic signal (see Figure 9). Electromagnetic waves are

FIGURE 8 Multiple square antenna EMTC with integrated survey. (Photo courtesy of UIT.)

FIGURE 9 Basic GPR unit. (Photo courtesy of So-Deep, Inc.)

reflected, refracted, and diffracted in the subsurface by changes in electrical conductivity and dielectric properties. Travel times of reflected, refracted, and diffracted waves are analyzed to give depths, geometry, and location information. The energy returned to the antenna is processed within the control unit and displayed on a screen. Round targets (typical of a utility) are of a distinctive shape and therefore easy to interpret. The operator usually places a mark on the ground where a target is identified, and then moves to the side and repeats the process until a series of marks can be interpreted as a probable utility. An analogy is that of a fish-finder on a boat, but instead of identifying schools of fish, the field engineer looks for long linear features. The marked utilities are then surveyed to record their location.

Advanced GPR has multiple sensors for better data density, and integrated positioning hardware to correlate the equipment's location to the data associated with that location (see Figure 10). Real-time analysis is usually not possible, and interpretation of the data is done at the office by highly skilled technicians. One advantage of advanced radar is the speed at which data can be collected, which reduces the amount of time spent on roads, aprons, taxiways, and runways. The higher data density allows better interpretation, and for some radar configurations, the multiple frequencies can increase the ability to see utilities at greater depths. Instead of the operator's stopping every few seconds to place a paint mark on the ground, he/she uses a small tow tractor. Another advantage is that the data delivered is more comprehensive than with basic GPR. A cross section through any part of the data will yield depth information at that point, rather than the interpolated depth information gained through basic radar.

Another significant advantage of advanced GPR is that other subsurface characteristics such as paving thickness, bedding thickness, voids, thrust blocks, depth to bedrock, depth to water table, soil lenses, and contamination plumes can be detected as well (see Figure 11). This increases the value of the utility mapping process. Both EMTC and GPR methods can gather this type of data (Young 2010).

FIGURE 10 Advanced GPR. (Photo courtesy of UIT.)

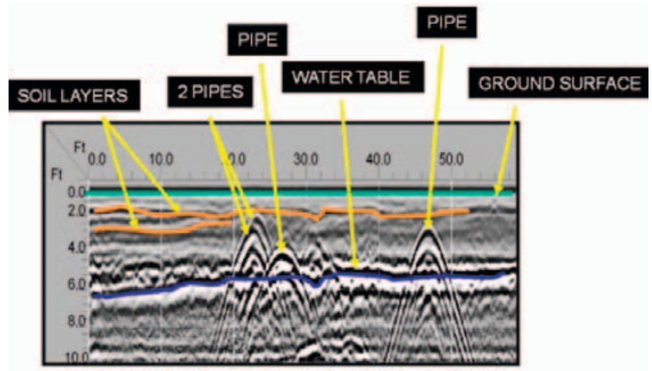

FIGURE 11 Output from an advanced GPR. (Graphic courtesy of UIT.)

POSITIONING METHODS

The state of the technology for mapping the positions of exposed or remotely sensed underground utilities is constantly and rapidly changing. Surveying methods and techniques have embraced new technologies such as total stations, spatial stations, and GPS to make it faster and cheaper to collect more accurate data.

Total Stations

Total stations can be divided into two basic types: mechanical and servo-autolock-robotic. Mechanical total stations are useful for surveying lines (paint marks representing utilities) and structures. Robotic total stations are useful for surveying the locations of advanced geophysical instruments as they are traversing a site. Total stations are oriented to known ground control points, and generally require a survey team of several persons, survey control identification, and processing of the survey data.

Spatial Stations

Spatial stations are relatively new. They combine the precision of traditional point surveying with the ability to capture shapes and details, and coordinates with integrated video and 3D scanning (see Figure 12).

Global Positioning System

GPS comes in many different forms and is rapidly changing. For the purposes of this study, GPSs are divided into mapping grade and survey grade. The differences are in cost, accuracy, and procedure. Further details on this technology can be found at many GPS manufacturers' websites.

FIGURE 12 Spatial total station. (Photo courtesy of Trimble.)

Real-Time Kinematic (RTK) GPS equipment can yield absolute positions of 1–2 cm horizontal accuracy in real time without post-processing. RTK surveys require few obstructions in the field area, ideal for airfield settings (see Figure 13).

Less accurate GPS is useful for some related utility applications. An example of this is the GPS-enabled camera, which can take a picture and associate the location of that picture with a particular geographic spot, indicate the direction the camera is pointing, and insert an icon into a CADD or GIS system that will, when clicked, bring up the photograph for viewing while you are looking at the CADD or GIS drawing (see Figure 14).

INERTIAL MAPPING

Inertial mapping methods use the same technology as submarines to track positions through the use of gyroscopes. A survey reading is taken with traditional means at the opening to a conduit or empty pipe. The inertial device (called a "smart pig" by the oil and gas industry) then travels through the pipe to either an end point or to its tethering limit and then retrieved. Its location is surveyed again and the differences between the surveyed position and the initial position are used to calculate inertial drift. If the variance is unacceptable, the distance of travel may be shortened and the process attempted again. The inertial device produces a read-out that plots its location as it travels through the pipe (Sterling 2007).

FIGURE 13 RTK GPS positioning on EMTC System at airport. (Photo courtesy of UIT.)

FIGURE 14 RTK GPS on 3-D advanced GPR array. (Photo courtesy of Cardno.)

ELECTRONIC INFORMATION STORAGE, RETRIEVAL, AND ANALYSIS

Utilities data have traditionally been recorded on engineering drawings and related documents. Years ago, these drawings were hand-drafted on parchment material, paper, or Mylar. Because these historic records can still be of significant value, they are often scanned and saved as electronic images in TIF or PDF format. Interviews with some airport staff indicated that this can amount to tens or hundreds of thousands of drawing sheets that can be stored, searched, viewed, copied, and backed up much more efficiently than their hard copy equivalents.

Electronic data about utilities can also be disseminated more easily than hard copy drawings. Advances in Internet security, the growing use of mobile computing devices, cloud computing (i.e., Internet) resources, and other advances have made it easier to exchange data with less fear of sensitive data getting into the wrong hands.

Computer Automated Design and Drafting

Over the last few decades, airport engineering drawings have been developed predominately using CADD software. Because they are produced electronically, the original drawings can be stored, backed up, retrieved, and viewed much like scanned hard copies. To reduce their file size and to prevent alteration, CADD drawings are often converted to a TIF or PDF format for archival purposes.

CADD drawings can also convey a great deal of information about components of a utilities network. Increasingly, these components are drawn accurately in 3D and in a known coordinate system so that other relevant data can be superimposed to yield a more informative map. Different types of utility components are drawn on specific layers that can be turned on or off and easily symbolized to distinguish between other types of utilities. Labels, dimensions, callouts, and other annotations provide additional textual details. More advanced CADD software allows these details to be stored in a database format that supports queries and analysis. Metadata, or information about the data itself, is stored in the drawing's title block, title/index sheets, and in letters of transmittal. Some advanced CADD software packages include or can be augmented with utility models that offer advanced analytic tools to support network capacity imaging and upstream/downstream tracing.

Geographic Information Systems

GIS has emerged over the last decade as a means to store engineering data. When GIS technology was first introduced in the 1960s it was not viewed as a precise enough tool for engineering applications. Advances in the precision of GIS data, as well as in the compatibility between GIS and CADD software, have allowed GIS to become a practical tool for engineering purposes. As a result, most utility companies and a growing number of airports are using GIS as a means of storing, retrieving and analyzing utilities data.

One of the primary benefits enjoyed with GIS is the ability to perform advanced queries and analyses of detailed locations, attributes, and metadata. Once specific utility components have been identified, linked drawings, specifications, and photos that provide further information can be easily retrieved. GIS also enables advanced models to be developed that carry information about the direction and capacity of products traveling through a utility network. These models offer additional analytic abilities such as capacity planning, what-if analyses, isolation of branches impacted by a break, and tracing the likely source of pollutants.

Building Information Modeling

Building Information Modeling (BIM) has emerged as a technology to model and depict information about the structure, utilities, furnishings, and other details of buildings. BIM enhances traditional CADD by providing sophisticated 3D models that can be used to assist facility designs and improve the efficiency of the design process. BIM also enables sophisticated analyses that can support cost estimating, material ordering, conflict detection, environmental efficiency, and other factors throughout a building's life cycle. As the use of BIM grows, new tools are being developed to aid in the planning and design of utilities networks (Ball 2011).

TECHNOLOGY INTEGRATION

The above-mentioned technologies are becoming increasingly compatible, so that the most appropriate software can be applied where and when it is most effective. International, national, or open (i.e., nonproprietary) commercial standards defining the structure and format of utilities data foster this compatibility. Many airports have defined GIS and CADD data standards that are compatible with one another so that software tools can migrate data from CADD to GIS and back again. These data standards also enable GIS and CADD data to be exchanged with other airport information systems, such as asset management and computerized maintenance management systems (CMMS). One large hub airport that has invested a great deal in CADD–GIS interoperability notes that while significant advances have been made, data exchange between CADD and GIS has plenty of room for improvement. Coordinate system transformations, differences in how GIS and CADD data are traditionally structured, and divergent user preferences are all factors that need to be taken into consideration (Reid 2003).

The benefits of exchanging data between different software applications on different hardware platforms are, however, great. For instance, it is now possible for a professional with a single hand-held device to stand at a spot on the airport property, look at a screen that has an overlay of satellite imagery, have the location shown on that imagery, look at all the utility locations, change those locations if there is better information, receive information on those utilities from RFIDs, retrieve more detailed information from records stored in a database either on site or on the Internet, and send that information immediately to almost anyone, anywhere.

Another example is combining GPS with laser scanning equipment to map utilities before they are buried. A 3D position of underground utilities constructed by open trenchless methods can be collected by a single person using integrated technologies within an accuracy of ±450 mm (±1.5 ft). Furthermore, the positional data of a 30 m (100 ft) long utility line can be collected within approximately 15 minutes, including time taken for setup (Ariatnum 2010).

CHAPTER THREE

STATE OF THE ART

This chapter describes the processes, standards, and procedures available to collect, store, and use utilities data. It describes the practical approaches that can be used, not necessarily those that are being used (the subject of the next chapter). Much of this information comes from outside the aviation industry; however, the issues, technologies, and challenges addressed are fairly universal. Some of this information comes from the interviews with airport personnel and their consultants who find these processes and procedures desirable. Some of this information comes from interviews performed by the authors as part of related utility and airport research in progress.

EXISTING UTILITY RECORDS

Existing records come in many forms and degrees of accuracy. Many times the quality of the data is not known or assumed, so the users must judge whether the accuracy and completeness of the data are sufficient for their purpose. This judgment is constrained unless all legacy data are available and indexed. The users of utility data include maintenance and operating personnel, planners, and engineers—each of whom has different needs. Some records may be pertinent to those needs, whereas others may not. Interview and survey respondents reported that knowing where records can be found, having the ability to find a specific record that includes the pertinent information, keeping those records secure and being able to access this information in a timely manner are all important.

Reported SOA procedures include:

- Having all records available electronically so that the user can access them at will from any location in a secure manner. Formats include scanned documents (e.g., PDFs and TIFs) and CADD files.
- Indexing records to indicate the area for which the record has pertinence (e.g., the entire airport property or the boundaries of a particular project); the source of the record (e.g., unknown or project as-built); and the age of the record.
- Geographically referencing utility record drawings using GIS.

UTILITY COMPOSITE RECORDS

Of all utilities on the airport property regardless of ownership, the one SOA component to have is a Utility Composite Record (UCR), with updates performed by experts in utility data development. UCRs come in two basic formats: CADD and GIS. The concept is to have a single source that shows the current best available location of all utilities with as many pertinent attributes as possible. This provides a resource that will suffice for a majority of users and eliminate the need for each user to conduct records research every time utility information is needed. Judgment on what data are considered "best" is a crucial issue. This requires a qualified expert, such as a subsurface utility engineer. UCRs are updated on a continual basis as new utility information is created from valid sources. The qualified expert must evaluate the new information against the older information to ascertain whether the UCR should be changed (CSA 2011).

Utility Network Models

Once utilities data have been consolidated into a standardized and comprehensive data set, sophisticated queries, analyses, and reports can be carried out. Information can be added to indicate the flow and capacity of individual components of a utility network. Interview and survey respondents reported that developing such utility networks enables peak demand forecasting, identification of where pollutants may have entered or exited a system, isolation of network branches in the event of a break, and other more sophisticated analyses.

As-Builts

The best way to record where utilities are located is to survey their location in three dimensions during installation and to incorporate this information into standardized drawings that depict as-built conditions. This is important for making effective risk management decisions when these utilities are involved in future construction issues (CSA 2011).

Ideally, these "as-builts" include such attributes as date of installation, type of utility, size, material, owner, and number of direct-buried cables. Metadata such as the accuracy of the survey information, the method used to collect the data, and the name of the firm or individual who collected the data are also included. These attributes and metadata are associated with the geometric features in a manner that can be easily and intuitively read by planners, engineers, maintenance technicians, and others. This can be achieved by labeling or annotating utility features on maps, applying informative symbology and an associated legend, and providing data tables that present attributes in a tabular manner. The attributes and metadata are also stored in a manner that can easily be loaded into a GIS database with minimal conversion and data re-entry (CSA 2011).

Achieving these goals requires identifying the types of data collection methods that are acceptable, methods of coordination with airport operations and security personnel as well as with contractors and other consultants, the process for submitting data to the airport, and the means by which submitted data will be evaluated for acceptance.

In addition, as-built standards define the format, layering, symbology, and annotation required. The structure of the data in terms of acceptable geometry types, attribution storage, and metadata formats are also defined. Templates that reflect this structure but do not include any data are developed and shared with consultants to make it easier for them to comply with these requirements, which may lower the costs of producing the as-builts and ensure a higher level of conformance.

Consultants are aware of the airport's procedures and standards for as-builts as a part of the bid process and at project kick-off meetings. Interview and survey respondents report that at early delivery points during a project, drawings are checked for compliance so that misunderstandings can be resolved before final as-builts are prepared and submitted.

Conformance with as-built procedures and standards can be encouraged in many ways. Enforcement mechanisms include withholding retainer fees and/or considering past as-built delivery performance during procurement. Providing past as-built data to consultants at the beginning of projects, clear and thorough as-built specifications, templates to ease the burden of as-built development, and fast evaluation and acceptance of submitted deliverables also encourages consultants to conform to an airport's standards.

Interview and survey respondents report that their practice is that if as-built procedures and/or standards are not followed, then fees can be withheld to allow airport staff and/or on-call consultants to collect the necessary information and develop the required data. This can also be done as a matter of policy on all projects, so long as the resources can be made available to provide the staff and equipment and/or outside consultant support.

Once as-built data are received and accepted by an airport (typically by the airport's project manager), the data can then quickly be entered into a document management system for archival and future retrieval. The data can also be converted and loaded into consolidated utilities drawings and, if available, a centralized GIS.

Interview and survey respondents reported that tracking as-built projects from the time the contract is awarded through to delivery and recording of data into a document management system, consolidated utilities drawings, and/or a GIS helps ensure conformance and consistency of data in the end. Spreadsheets maintained by records librarians and/or GIS managers are an effective means of tracking projects. These spreadsheets can be reviewed at periodic construction coordination meetings that many airports conduct.

While as-built procedures, standards, and enforcement mechanisms can be extensive and require ample resources, they can be scaled down so that smaller airports can apply these principles as well. National standards, data templates from the FAA, and simplified procedures can be leveraged by even the smallest airports in a manner that is proportionate to the level of construction they have planned.

DATA RELIABILITY

Reliability of data is difficult to judge. One of the reasons state governments have regulated the practice of engineering and surveying is to provide a mechanism whereby the reliability of data can be assured through training and certification. Unfortunately, utility data are often gathered, judged, and referenced by uncertified individuals. One of the prime motivators for the development of ASCE 38 was to make it easier to assess data reliability by recording a utility QL attribute. This attribute, when associated with the identity of the registered professional who assigned the QL, establishes a basis for confidence in the data. Barring a QL attribute, other information is necessary for the data user to assess the quality of the data themselves. This information may include who gathered the data, what geophysical equipment was used, when that equipment was calibrated, what survey method was used, when the survey equipment was calibrated, and the training and certifications of the person gathering the data (Noone 2004).

The SOA for data reliability is for an appropriately-registered professional to stamp record drawings that indicate the QL of the data, along with a statement of accuracy for the survey component of that data, as required by ASCE 38 (Anspach 2004).

Creating a Utility Mapping Program

For facilities that have gaps in their utility records, or have unknown quality or poor quality records, utility mapping programs (UMPs) can be implemented to help fix the problem. Some important elements of such programs include:

- Prequalification criteria for SUE providers. All mapping work needs to be performed under the direct charge of a licensed professional in accordance with state statutes. Mapping generally consists of many components that are integrated into a deliverable report. These components include records research; surveying geophysical

equipment selection, use, and interpretation; and plotting and developing a map. (Examples of such prequalification criteria are provided in Appendix C.)
- SUE can be used on capital improvement projects above a certain cost threshold.
- A scope of work that includes QLB mapping of all utilities within project boundaries including a geophysical search for known and unknown utilities within that boundary.
- A plan to fill in the gaps between project boundaries over the course of time.

An SOA mapping program would contain all of the above elements.

The end result of a UMP that encompasses design and construction projects, maintenance activities, and responses to "one-call" locating requests is an increasingly more accurate and comprehensive record. At some point in the future, a utility would only need to create as-builts of new facilities and update the existing UCR as a result of abandoned or removed utilities or attribute changes. An SOA utility program continually increases the quality of data and makes certain it captures all additions and changes.

Quality Level B Utility Mapping

An SOA QLB utility mapping effort includes the use of a wide range of EML, advanced GPR (if soil conditions allow for sufficient depth of penetration), EMTC, MAG, and SOUND methods (if utility and site conditions allow). All structures on the surface or exposed during construction are photographed with GPS-enabled cameras. Where good images cannot be obtained, diagrams showing details of the utilities within the structures are developed. All empty conduits are imaged through the insertion of sondes or other conductors, if GRP did not image them. The project area is completely covered by at least two different geophysical sensors in an attempt to identify unknown or incorrectly documented utilities (TSA). Utilities of record that cannot be imaged with geophysics are portrayed at QLC or QLD (ASCE 2002).

Depth attributes on all utilities are collected where possible at valves, in vaults, in basement walls, and by indirect geophysical means. These attributes are also cross-referenced with the method of depth determination (i.e., GPR, EML, EMTC, Sonde, or as-builts) (Anspach 2010).

If advanced geophysical methods are used, raw data are retained so that the user can use it to identify other structures if desired.

The SOA for QLB utility mapping is to use all appropriate geophysics to acquire as complete a set of data on the utilities within a project area as possible (Sterling 2007).

SURVEY OF GEOPHYSICS

Because each element of the NAS is tied to a single reference framework, it is important that every utility survey conducted on an airport be accurately integrated into the National Spatial Reference System. One accepted method of doing this is to tie the survey to the Primary and Secondary Airport Control Stations (PACS/SACS) available at most airports. This can be complicated when an airport uses a locally developed grid reference system for project design and construction. To tie a local grid to a commonly recognized coordinate system, a surveyor is required to develop an accurate transformation between the coordinate systems.

The SOA for a survey is to reference all utility mapping to the PACS and SACS established at the airport. Data for x and y coordinates is integrated into North American Datum of 1983 (NAD 1983) for the airport; z values are recorded in North American Vertical Datum of 1988 (NAVD 88) datum with U.S. survey feet being the unit of measure (FAA 150 2009).

Maintenance and Repair Activities

The UCR is made available to maintenance personnel. Wireless tablet computers are made available so that technicians working in the field can instantly access and view the georeferenced UCR. When tablets are taken to the field, GPS automatically documents the user's location and provides a menu of options based on that location.

Survey-grade GPS is available to maintenance personnel. When exposing a utility for repair, an accurate x, y, z location is gathered. Menus and automated routines are available on the wireless tablet to facilitate automatic metadata and completeness of data. Interview and survey respondents reported that data are automatically submitted to the department or person responsible to update the UCR and the record is automatically archived in the central repository. Pictures are taken of the repair with a GPS-enabled camera.

Asset Management

An SOA practice among airport interviewees is to develop asset management programs. These programs seek to identify and monitor the condition of facilities, equipment, and infrastructure under the airport's control. These systems can capture not only the location and key characteristics of assets (as in a GIS) but also track condition, useful life, replacement value, and other considerations.

Damage Prevention/One-Call Activities

Interview and survey respondents reported that a staff member or consultant is retained to respond to all requests for utility locating and marking prior to construction activities. All utilities are marked or checked for completeness and accuracy if other entities did the marking. This staff member or consultant is equipped with a full range of EML devices, a mobile tablet enabled to be connected to the UCR, and survey-grade GPS. In areas where no utilities have previously been mapped, it may be necessary to supply extra personnel to assist in using the geophysical equipment properly, or to enter confined spaces. One-Call markings are surveyed and if discrepancies are found between the UCR and the field markings, they are brought to the attention of the resident utility expert, who makes judgments as to which information is likely to be more accurate. If it is determined that the One-Call mark should be part of the UCD, then it is treated as a new record.

Radio Frequency Identification Program

An SOA utility program includes RFID. Programmable RFID markers are placed on each newly installed utility at regular intervals so that during One-Call operations or maintenance activities the exact location of the utilities can be positively identified, along with other attributes that may be useful to the future contractor. RFID markers can also be placed on utilities during repair operations or anytime a utility is exposed. Specifications regarding correct installation and programming are developed. Survey respondents place survey RFID markers in the GIS or CADD UCR at their actual location.

Permitting of New Installations

An SOA is to establish a notification system that indicates when any construction may involve installing, changing, or removing utilities. A condition of receiving a construction permit is following applicable SUE policies and procedures. Upon final inspection and close-out of the permit, a contractor is required to submit accurate as-built drawings indicating the location of any utilities installed or removed.

Integrating Utility Mapping into the Project Development Process

SOA projects have a mechanism to evaluate the potential impacts that the project will have on utilities, review the quality and completeness of existing utility information, and tailor a utility mapping effort so as to reduce utility issues. Typically, this includes a QLB mapping effort within the project limits. If QLB cannot be achieved on a particular utility, an engineer reviews available utilities data and the project design so as to make recommendations on further risk reduction measures. Recommendations may include the excavation of a utility to obtain QLA data, special provisions for the contractor to follow to avoid damage, or changes in the design to avoid conflict with a suspected utility. This QLB mapping effort is performed as early in the project as possible (APWA 2007). AASHTO also states that project owners should "Ensure utilities are depicted at appropriate quality levels on all highway plans. Collect Subsurface Utility Engineering (SUE) information early in the development of all highway projects" (AASHTO 2004). Where potential conflicts with the construction and the utilities still exist, the engineers should consider the need for QLA data to determine the exact location and characteristics of the utility (Ellis 2009).

Utility Coordination

UC is the integration of tasks taken during project development to identify and resolve conflicts between the construction activities and any existing or planned utilities. It requires a commitment to communication and cooperation between the stakeholders, including utility owners (private, public, airport, tenant, and FAA), consultants, construction contractors, and others involved in the airport project development process (AASHTO/FHWA 2002). Typical tasks include but are not limited to:

- Designing to avoid conflict with existing utilities whenever possible
- Determining potential utility conflicts
- Estimating the costs of utility conflicts
- Assessing the impacts conflicts can have on project timetables
- Determining the impacts that potential conflicts can have on safety
- Identifying potential resolutions of those conflicts
- Determining cost responsibility for any utility relocations
- Determining and communicating necessary utility easements
- Determining who is responsible for any utility relocations
- Designing the utility relocation
- Coordinating the timing and execution of relocations
- Communicating safety and coordination issues to contractors.

An SOA utility coordination effort involves a written checklist of procedures and a formalized system to identify, document, resolve, and track utility conflicts (Ellis 2009). Tools are being developed through the SHRP2 R-15B project to assist project owners and engineers in this task.

CHAPTER FOUR

STATE OF THE PRACTICE

This chapter describes the degree to which airports, their consultants, and the FAA are applying state of the science technologies and SOA practices when collecting, storing, or using utilities information. In general, there is a significant gap between what airports are doing and how the SOT and SOA practices can assist in collecting, storing, and applying information on subsurface utilities.

Few airports collect utilities data using the full range of applicable technologies. Interview and survey respondents reported that because of a lack of awareness of the options, too much reliance is placed on consultant practices that vary firm by firm and sometimes even within firms. Technology gaps may also reflect limited funds. A more significant gap exists between SOA policies, procedures, standards, and organizational structures that promote the exchange of utilities data, and the practices many airports report currently using. Many airports and consultants do not follow the ASCE 38 practice of having a registered surveyor or engineer sign or stamp deliverables that contain utilities information (according to interviews and survey). Interview and survey respondents acknowledge that uncertainty as to the quality of the airport's utilities information leads to risks for the airport and other consultants who rely on this information.

Once information is collected, there is a broad range of practices for storing and retrieving it at airports. Interview and survey responses indicate that a few but growing number of airports have standards that they believe are adequate for capturing their utilities data. However fewer airports have policies and procedures in place for handling the information once it is received. Most larger airports and a growing number of medium and small airports are beginning to use consolidated CADD drawings, GIS databases, electronic document management systems, and asset management systems to store and retrieve their utilities data.

When using utilities information, many airport staff members and consultants complain about the challenging organizational and interpersonal dynamics required to find and obtain the information they need. While many accept the accuracy of the data they receive, especially if metadata are provided, most survey respondents and interviewees want more comprehensive coverage. Following are more specifics on what is currently being done, and the next chapter highlights some of the practices that could be adopted.

ORGANIZATIONAL FACTORS

Organizational factors, including awareness, organizational culture and interpersonal dynamics, policies and procedures, procurement practices, and funding sources, were highlighted in many interviews and surveys as being critical factors to the success of utilities data collection, storage and use.

Available Information

In comparison with other modes of transportation and with several other industries in general, there is relatively little literature published about collecting, storing, and using information about utilities at airports. Much of the material that is available is marketing material from private firms that provide SUE services to airports.

In addition, vague, incomplete, or in some cases erroneous interpretation of the material that is published is fairly common. Practitioners of SUE in the aviation industry have typically heard of ASCE 38-02, but interview and survey respondents reported that few have applied its specific provisions beyond the concepts of the four QLs defined within it. Although these QLs may have been achieved, they are not necessarily always differentiated on the plans nor explained to the design engineers or constructors. Many of the respondents are also aware of the Spatial Data Standards for Facilities, Infrastructure, and the Environment (SDSFIE), but few are aware of recent changes to this standard or of alternatives that exist (see the section on Data Standards in this chapter and the following chapter on Effective Practices).

Interpersonal Dynamics

One of the key factors affecting the success of utilities data collection at airports is interpersonal dynamics. At almost all airports interviewed, dynamics of this nature both helped and hindered access to the utilities data people require. Interview and survey respondents reported that different departments often hold their information close and only share it when it is in their best interests. Furthermore, consultants often withhold data they have collected on past projects to support their current work and retain a competitive advantage for future work. Some organizations also cite security. The result limits the accessibility of data to individuals who have a legitimate need to know. As data become less accessible, project costs, change orders, the likelihood of costly utility breaks, and safety risks all go up.

Many of the airports interviewed rely exclusively on design and construction project managers to implement SUE-related policies and procedures as they see fit. Many of these project managers rely primarily on the expertise of the consultants they have hired. There are advantages and disadvantages of this approach. An advantage is that it allows consultants to carry out tasks using the best technology and methods of which they are aware. It also allows them to work in ways in which their staff have been trained and become accustomed. The primary drawback of this approach is that work is carried out in a variety of ways, which can lead to inconsistent results. AASHTO, most state DOTs, and some large facility owners have overcome organizational and interpersonal constraints by establishing written programs that include standards, policies, and procedures that enforce consistency without constraining efficiency. A small but growing number of airports have also begun to establish programs of this nature.

Interview and survey respondents reported that airports schedule meetings at the beginning of and periodically during all design and construction projects. Occasionally this is also done as a part of major tenant improvement projects. Airports that conduct such meetings as a matter of policy and/or standard procedure have found that better coordination from the onset can lead to better use of available resources and better chances of receiving quality data.

Another quality of data improvement includes use of secure Internet sites to exchange data. Allowing authorized individuals to access utilities data in a secure manner over the Internet increases the accessibility of data while not compromising its security.

- Policies and Procedures—Although most airports interviewed and survey respondents reported having CADD standards that identify the format of delivered drawings, and some airports have procedures governing the use of utilities data, few airports have established procedures for collecting utilities data. They typically rely on the knowledge and experience of their outside design consultants to complete a design or data collection project. This can lead to variation in the manner in which the data are collected, which can degrade the consistency of the data once consolidated with deliverables from other consultants.
- Procurement—A few of the airports interviewed and several DOTs have prequalification requirements for SUE providers to help streamline the procurement process. A copy of some of these prequalification requirements is provided in Appendix C. FHWA has prepared a sample scope of work for SUE services (see Appendix D), which some airports and many state DOTs have modified for their use. Some state DOTs have published their own standard scope of services. These standardized descriptions ease the burden on individual project managers tasked with defining the SUE services they require.
- Airport Funded Activities—Some of the airports interviewed have allocated operational funds (as opposed to capital funds supported by FAA grants, as described below) to SUE activities. A few airports have conducted SUE projects as a means of developing comprehensive CADD and/or GIS maps of utilities in preparation for construction activities. Some airports have also selected on-call consultants that can provide SUE services on an as-needed basis. A few larger airports employ staff members who are familiar with SUE and can perform records research and field survey of utility appurtenances themselves, relying on external consultants for more equipment-intensive subsurface detection and excavation services.
- FAA Funded Projects—Many airport capital improvements are funded through federal grants or the use of passenger facility charges. These funds carry grant assurances and other requirements. Through the Airports GIS Program and other programs, the FAA is beginning to require standardized collection and submittal of geospatial data. The requirements for these submittals are defined in FAA Advisory Circulars, notably AC150/5300-16, -17 and -18, which define geodetic control, remote sensing, and GIS data collection and submittal requirements. Utilities data and references to ASCE 38 are covered in AC150/5300-18. When conducting capital improvement projects funded through FAA Airport Improvement Program (AIP) grants or projects able to utilize Passenger Facility Charges (PFCs), airport managers may be able to include subsurface utility data collection costs into their projects. Airport managers can contact the FAA Office of Airports for specific eligibility requirements.

COLLECTING SUBSURFACE UTILITIES DATA

Most airports and consultants initially, and often exclusively, rely on records research to identify the location of utilities. This research is often carried out first by searching through available record drawings and then by contacting individuals believed to have additional information. Following are the methods currently according to phone interviews and in survey responses.

- Manual Document Research—More often than not, utilities records research involves a physical search of documents kept in hard copy, CD or DVD, and/or on networked disc drives. These archives are typically accessed by indexing the project that installed or discovered a utility and then searching sheet-by-sheet for relevant details. The process is labor-intensive and subject to omissions because of lost, damaged, checked out, or misfiled documents. The process also imposes a constraint on consultants because few airports will allow them to remove needed documents from the premises.

- Electronic Document Research—At a moderate but growing number of large and medium airports, record drawings have been entered into a document management system that enables electronic search and retrieval. These systems range from custom software developed by consultants to meet an airport's specific needs to commercially available off-the-shelf (COTS) software solutions. Custom software can be expensive, but provides greater flexibility to address the specific needs, preferences, and work processes of that airport. COTS solutions range widely in price and but are developed to address more general needs.

A small but growing subset of airports utilizes document management systems that can link related documents to the geographic location of specific utility assets. These "GIS-enabled" document management systems typically provide a map display and the ability to search for documents related to a specific location. The location specified is often a generalized reference (e.g., a roughly drawn bounding area or a grouping of associated map grid cells) to the location of the project that first installed or discovered the location of the utility. Most airports that have an electronic document management system that allows authorized consultants to use it while on airport property and a few have begun to offer these capabilities through secure systems available on the Internet.

- Word-of-Mouth—Informal communication between individuals is a pervasive method used to gather airport utilities data. This method is especially prevalent and valuable when the information desired is from outside the department or organization that needs it. Although the results of such inquiries can be beneficial, success relies heavily on knowing and maintaining a friendly relationship with those who possess the information or who know someone who does. Restrictive organizational policies regarding data sharing, labor-intensive data retrieval processes, and retirement or death of individuals who are "in the know" limit the success of this method. There is also a limit to human recollection, given the rapidly growing volume of records and associated data enabled by modern CADD and GIS technology.

Once records research has been completed, some airports attempt to directly locate utilities and record specific information about them. This field work is often done in preparation for and as a part of an infrastructure development program. Following are common methods used by interview and survey respondents to collect these data.

- Remote Sensing—Remote sensing involves measuring without coming into physical contact with the subject. This method includes aerial photography and Light Detection & Ranging (LiDAR). Airports typically collect aerial photography (a few airports do so as frequently as once a year) as a means of developing GIS and/or CADD maps that can be used for planning and preliminary design purposes. Technological advances and the increasing sophistication of users of this information have fueled a trend toward higher resolution and accuracy imagery. Common resolutions include 1-ft, 6-in., and 3-in. square pixel sizes. To some degree 6-in., but especially 3-in resolution imagery can be used to identify and locate utility assets on or above the ground. The use of such imagery to locate and/or confirm the location of visible portions of the utility is growing among airports, especially as new FAA GIS requirements are prompting more aerial imagery collections at airports.

LiDAR technology is typically not used by airports or their consultants to collect utilities data, although it has been used in other industries. One limitation of LiDAR is that the assets being identified must be exposed and in the line of sight of the laser scanning device at the time the survey is conducted. This can present a logistical challenge to construction crews and equipment, as well as to project schedules. Some airports and their consultants are considering, and in a few cases applying, LiDAR as a means of supporting other non-utilities data collection efforts. FAA Standards for Using Remote Sensing Technologies in Airport Surveys (AC150/5300-17C) prescribe methods of collecting and submitting geospatial data depicting many airport features using LiDAR, although its use in collecting utilities data are currently not accepted.

- Geophysical Detection—As with aerial photography and LiDAR, subsurface detection technologies can remotely sense the location of a utility without coming into direct contact with it. GPR, EML, and RFID are examples of subsurface detection technologies that airports have used with varying degrees of success, depending on differing soil types, lack of knowledge of the limitations of the technology, and limited experience with the necessary equipment. Cost, however, appears to be the primary factor that results in GPR only being used on a limited, case-by-case basis. Often the technology is only used where critical utilities are suspected and design/construction is imminent.
- Field Surveying—Most airports have a means of collecting survey coordinates (x, y, and z) of utilities on the surface or exposed by construction. Some of the larger airports employ licensed land surveyors for utilities, properties, and other data collection requirements. Others retain on-call local consultants who can survey exposed utility locations. Several airports interviewed indicated that it was helpful to use these contracts for surveying routine utility exposures, since the advance knowledge of when a utility might be exposed and surveyed was rare.

Some airports attempt to use their on-call or in-house capabilities to survey One-Call or contract locator markings.

Although this is better than not capturing those marks, it is important to note that this does not lead to QLB information. ASCE 38 is currently under revision to clarify this point.

Survey responses indicated that airports more often contract for such survey services as a part of design projects. Increasingly lower costs, productivity improvements of newer devices, and the need for greater accuracy have favored the use of RTK GPS or total stations.

An issue that often constrains the use of these technologies is the need to come into direct physical contact with the utility. Such contact is limited by safety and security restrictions on airfield, aircraft, and ground service operations; tight construction schedules; and the cost of excavating test holes or potholes. Although this data collection method provides coordinates of the utility asset, it does not necessarily provide additional details such as the type of utility, material, condition, or invert elevations. For this reason, qualified engineers sometimes accompany surveyors in the field so that these data can be collected at the same time as the coordinates are recorded.

Several airports interviewed noted a general lack of airfield electrical information and attributed this to the difficulty in detecting an underground conduit that does not necessarily follow straight lines and the volume of wires that can run through any given conduit. To compound the matter, many electrical engineering drawings are "one-line" diagrams that show a schematic of electrical conduit and lines that is not accurately tied to a known coordinate system. Collecting electric data is particularly important because electrical lines are among those that present the highest risk to airport operations and safety.

- As-Builts—Most airports have policies that require consultants or contractors to submit as-built drawings. Seventy-five percent of airports interviewed (12 of 16) include as-built requirements in contracts. Half (8 of 16) also enforce their as-built policy by withholding a retainer fee. Despite these methods, only two of the 16 airports interviewed believed that as-builts accurately represent the installed location of utilities. Airports employees have recognized this problem, but only a few interviewed have gained management support to implement remedies (e.g., enforcement of financial penalties and/or taking nondelivery into consideration in future competition for work) or to provide funding for alternatives (e.g., staff or on-call consultants to conduct field survey and prepare sufficient as-builts). As hard as collecting as-builts from consultants can be, airports are even more challenged to collect as-builts from tenants. One approach that has worked for some airports is to provide incentives to consultants, tenants, and the FAA such as a providing greater access to the airport's data.
- Data Collection Accuracies—Most airports and consultants desire survey-grade horizontal accuracies for utility assets that are on the surface or exposed by construction or potholing. Recognizing technical limitations, and citing cost and technical limitations, they are often satisfied with less precise vertical accuracy, especially of subsurface features. Regardless of the accuracy with which data are collected, the availability of metadata is essential in allowing users of the data to judge how and when to use it. In the end, all stakeholders appear to recognize the relationship between accuracy and cost and the variations in the relative benefits and costs of more accurate data on different types of projects. For these reasons, accuracy specifications appear to not be set by universal policy, but often on a case-by-case basis by the airport project manager in charge of the design or construction effort. Many interviewees have found through experience, however, that mapping grade surveys inherently lead to utility data that is usually insufficient for design purposes.

STORING SUBSURFACE UTILITIES DATA

Data have diminished value unless stored in a manner that can be easily accessed and searched by those who need them. The manner in which utilities data are stored by airports ranges from secure, Internet-accessible databases to hand-marked drawings on the dashboard of a maintenance technician's truck. While the trend is clearly toward electronic storage and dissemination, several constraints—including time, money, and old habits—have slowed the progression. Based on the interviews, the following paragraphs describe how airports and their consultants store and access the utilities information they need.

- Record Drawing Rooms—Most large airports have record drawing rooms with some sort of paper-based cataloguing system to help staff members or authorized consultants find the drawings they need. Usually, but not always, these drawing rooms are secure and adequately protected from fire and flooding. Medium and small airports typically retain some drawings on site, but often rely on record drawings retained by the parent authority, city, or county. Some airports try to obtain and retain copies of tenant and FAA drawings, but more often than not these records are requested only when needed to support a project and then discarded when the project is complete. It is relevant to note that interviews with some airport staff members indicated that records drawings were readily available to consultants, but that consultants surveyed about those same airports indicated that they were not.
- Electronic Records—Most airports receive design and as-built drawings in electronic format on CD/DVD or through e-mail. The files submitted are typically CADD drawings in the native format of the brand of CADD software in use at the airport. In some cases, PDF or image copies of these CADD drawings are also supplied.

In most cases, airports have CADD standards that describe how the data in the CADD drawings are to be delineated on separate layers, the symbology that is to be applied, and the cover sheets and title blocks to be used. Few specify file naming, title, or page numbering conventions. At present few airports require QL attributes such as those detailed in ASCE 38. After the data are received, they are often kept on individual hard drives of the receiving project manager or consolidated onto shared network drives that others can easily access.

- Document Management Systems—Some larger airport interviewees have invested in electronic document management systems to store and retrieve record drawings and other documents. Often when they are first installed, tens or hundreds of thousands of historic hard-copy drawings and related documents are scanned and loaded into these systems. COTS document management systems range in price from a few thousand to a few hundred thousand dollars, depending on their capabilities. Some airports have opted to hire software developers to create custom document management systems tailored specifically to their needs.

Additional information about each document can be entered as the original is loaded, which can be laborious and therefore expensive. The challenge is to identify the right balance of cost versus the ease of search and retrieval that these attributes offer. Airports have entered as few as two to three attributes and as many as 22. The desire to capture additional information about utilities has often fueled the desire for more attributes.

Some airports have also tied the documents they enter into management systems to the geographic location of the facilities or assets referenced in each document. This is often most relevant when the document management system is used to search for utilities.

- Consolidated Master Utility Drawings—Many large and medium sized airports interviewed consolidate utility record and as-built drawings as they are received into UCRs that show utilities infrastructure for the entire airport. Often these records are broken down into separate drawings for each type of utility. They are typically placed on shared network drives or intranet sites for colleagues and authorized contractors to retrieve.
- Consolidated Geographic Information System Data—Some interviewed airports have converted their UCR data into a GIS database. This is the GIS equivalent to a CADD UCR. The primary difference is that GIS data are often structured to hold attributes and metadata that enable more sophisticated searches and queries to be performed.

Consolidated GIS data are sometimes stored as files on a shared network drive for airport staff and consultants to use. To open this software, they must have access to desktop GIS software that can read the GIS files. More often, especially at larger airports, these GIS data are kept in databases and made available to users through intranet web applications.

- Utility Network Models—As noted previously, once utilities information has been consolidated into a standardized and comprehensive data set, sophisticated queries, analyses, and reports can be carried out. These enable computers to understand the flow and capacity characteristics of a utility network, forecast peak demand, identify where pollutants may have entered or exited a system, isolate network branches in the event of a break, and produce other more sophisticated analyses. Few airports have taken their utilities data to this level. Most are focused on collecting a set of data that shows the location of utilities assets and a few key details.
- Data Standards—A prerequisite to consolidating CADD or GIS data are standards that identify on which layers specific types of utilities assets will appear, their geometric properties, the way in which they appear on rendered maps and drawings, attribute details, and metadata that describe the quality of the data itself. Although several standards exist, the primary details most airports and consultants require about utilities assets are type, size, material, and ownership. Currently, airports store this information in a variety of manners suited to the individual needs of their project(s). While some have adopted national or international standards, there was little consistency among the airports and consultants interviewed. Following are some of the primary standards that are currently being used, with modifications or in combination, by airports and consultants to store utilities data.
  - **Department of Defense Spatial Data Standards for Facilities Infrastructure and the Environment (SDSFIE)**—Originally developed by the Tri-Services CADD–GIS Technology Center under the U.S. Army Corps of Engineers, this standard encompasses an enormous amount of detail about utilities and other types of facilities and assets. The components of the standard are consistently defined and tools are freely available to help implement them. For these reasons, most airports that have used GIS to store utilities data have relied heavily on the SDSFIE. The key constraint airports have faced is that the volume of layers and attributes is broader than an airport typically requires and far more extensive than an airport will ever fully employ. Another constraint is that the older policy of expanding the SDSFIE to better suit non-defense applications has been reversed under new DOD leadership.
  - **U.S. National CADD Standard**—Most U.S. airports have adopted the U.S. National CADD Standard (or the corresponding American Institute of Architects CADD layering standards) and require their consultants to submit design and as-built data in this format.

- **Software Vendor Models**—A couple of software vendors have developed data standards for utilities. Although these models are extensive, they have been developed by disparate industry groups or private firms and therefore lack consistency, making them difficult for airports to implement in a uniform way. Also, because these standards were developed for broader markets, they are not perfectly matched to the typical needs of airports.
- **FAA Advisory Circular 150/5300-18B**—*General Guidance and Specifications for Submission of Aeronautical Surveys to NGS: Field Data Collection and Geographic Information System* (*GIS*) *Standards.* This document was issued in 2009 and is being rolled out nationwide as a requirement of airports using federal funding. It requires that airports collect and submit GIS data in a specified format to an FAA website. Included in this standard are a few specific (e.g., airfield lights and utility tank site) and a few generic (i.e., utility point, utility line, and utility polygon) definitions. While this utilities data structure is significantly less detailed than what airports typically require, it does provide a means for airports to share GIS data depicting utility locations with the FAA. This standard is also one of the few that mentions and encourages the use of ASCE 38-02.
- **INSPIRE**—European countries have collaborated in developing a spatial data infrastructure called INSPIRE, which includes data standards encompassing utilities. These standards are roughly analogous to the Framework Data Content Models developed by the Federal Geographic Data Committee (FGDC), under the eGovernment program. An advantage of these broad standards is that they allow software vendors to develop advanced products that can be used by those who adopt it. A disadvantage of these standards is that they are often too broad to be used as-is by a vertical market such as airports. Also, potential users who have already developed a standard sometimes face challenges when adapting their data to meet the requirements of the broader standard.
- **Metadata Standards**—Although most individuals interviewed recognize the value of metadata in conjunction with utilities, few have adopted uniform standards to represent that metadata. The FGDC's Content Standard for Digital Geospatial Metadata (CSDGM), Version 2, is broadly recognized as a defacto standard for capturing metadata, but few practitioners in the airport industry fill these data in. GIS practitioners in the energy industry have also developed a profile of the International Standards Organization (ISO) Geographic Information Metadata standard (ISO 19115). A similar profile of this standard is being developed in cooperation with the FGDC for broader use throughout North America (ANSI 2009). While this standard has a specific application for utilities and communications, and is eventually slated to become a mandate for any projects that apply federal funds to the development of geospatial data, which will include most airports, few airports currently know it exists.

  A key challenge airports face with regard to metadata that describe utilities data is the need to describe subsets of data (i.e., specific groups of features) differently. For example, it is relevant to differentiate between airfield lights collected through survey means versus digitized from a relatively old scanned as-built drawing. This increases the complexity and the burden of populating metadata about utilities.

Another very important piece of metadata is the signature or stamp of the licensed surveyor or engineer who prepared the utilities data. This signature or stamp certifies that a qualified and licensed professional is directly responsible for preparing the data to the appropriate standard of care. This conveys a certain level of trustworthiness to the recipient and future users of the data. If a deliverable was prepared in accordance with ASCE 38, the users can make decisions based on the data with a high level of confidence. Interestingly, despite its virtues, few airports interviewed require stamped or signed SUE data deliverables. The result is data that may meet an immediate need, but may not instill confidence in future users. It is also in violation of ASCE 38. Only three of the SUE firms interviewed said they stamp their airport mapping deliverables. Even the few airports interviewed that use SUE on a systematic basis to map utilities do not require their consultants to stamp their work when supplying data with a QL attribute.

USING SUBSURFACE UTILITIES DATA

The value of quality data is demonstrated when it is used to make decisions, perform analyses, avoid unintentional utility breaks, and support other activities. Quality encompasses many factors including accuracy, currency/timeliness, comprehensiveness, conformance to specifications, correctness of attribute values, and the presence of metadata (FAA 2009). Utilities data are used by many, including airport planners, designers, contractors, maintenance technicians, emergency personnel, meter readers, and others. To make use of the data, they require easy access to the subset of available information. Airports need data to be presented to them in a clear and comprehensible manner. They also need to know the quality and age of the data. With this information, they can apply responsibility and with confidence to the tasks at hand. Following are the primary ways airport interviewees are using the utilities data they collect and store.

- Design—Having quality information regarding subsurface utilities available during the early design phases of a project can help planners, architects, engineers, and others eliminate consideration of project alternatives that are unfeasible or too costly. Good data also help architects and engineers come up with optimal project designs. Planning and preliminary design can consume 5% to 15% of the cost of a typical airport construction project, 5% to 10% of which is spent on gathering information, much of it about utilities. Having quality data available at the onset of a project can therefore also provide significant saving to the project as a whole.

Designers and architects use utilities data in a variety of ways. First, they are looking for utilities that are in the way of the infrastructure to be developed and must be relocated or avoided. Second, they are looking for utilities that will need to be used to provide service to the infrastructure being developed. Lastly, they are concerned with utilities near a project site that should be avoided during the construction phase of a project.

Airport designers and architects predominantly use CADD software to do this design work. GIS is often used for analysis and the identification of possible conflicts. For architecture and design work associated with buildings, BIM is rapidly emerging as a very powerful, 3D, analytic tool that can be used to manage infrastructure need of buildings throughout their life cycle.

While most design and architecture work is carried out in an office using CADD, GIS, BIM, and other software, some utility companies have taken proposed designs into the field to confirm or check the proposed designs against existing conditions. This requires the use of powerful hand-held, tablet, or ruggedized laptops that can be brought into the field.

- Construction—Utilities data are important during construction so that workers can take the proper precautions to avoid utility breaks or risks to their personal safety. Locating and marking utilities within or near a construction area, carrying hard-copy record drawings into the field, and utilizing the utilities data present on design drawings are common methods used on airport construction projects. Less prevalent techniques include confirming the location of subsurface utilities using RFID technology, GPS-equipped construction equipment, and mobile computing devices.
- Inspection—Aside from the mandated daily airfield inspections that certificated airports (14 CFR Part 159) are required to carry out, the most frequently inspected assets at airports tend to be utilities. Having reliable data showing the location and characteristics of utilities can not only ease the inspection process, but it can ensure thorough results and protect the safety of workers. Some airports have coordinated data collection activities with utility asset inspections. While some airports have used mobile computing devices during inspections, the practice is far more pervasive in the public utility industry.
- Facilities Maintenance—Often preventative maintenance and work order requests are associated with utilities. When work orders are issued, it is often difficult to accurately identify the specific asset that requires attention, given the variety of verbal or written descriptions that are used to identify its location. In addition, details about the asset such as size, material, part numbers, etc., are often not available. Consequently, a considerable amount of time and money is wasted on repeated visits to the location, maintenance applied to the wrong asset, or maintenance applied to assets soon to be removed.

To remedy this problem, many large and medium-sized airports interviewed have implemented CMMS. These systems track work orders, maintenance labor, materials, parts and other supplies, and the cost of maintaining airport infrastructure. Some of these systems can be linked to maps containing GIS data to precisely locate facilities and assets being maintained. Whether a CMMS is map-enabled or not, it does require quality utilities information so that assets are discreetly identified and the appropriate level of detail is available. One challenge in associating data in a CMMS with utility data are that utility data that has originated from a SUE-mapping deliverable and is stored in a CADD or GIS format is typically far more specific (or granular) than data in a CMMS. Assets or facilities (particularly small, high-quantity items such as valves or lights) are often grouped into logical units in a CMMS. An example would be all valves on a certain branch of a utility network or all lights in a parking area. The result is that it is very difficult to link the individual assets (i.e., a single valve or light) with the group of items recognized by a CMMS. Airports that have had the ability to implement CMMS in parallel and in close coordination with a GIS system have often done better at establishing a link between the data in the two systems.

- Asset Management—The use of asset management practices and information systems is a growing trend in the airport industry. The term asset management, however, is being used to describe a broad variety of processes and systems. GIS, CMMS, building control and monitoring, and other tools are often included in the realm of asset management. Asset management can also include inspection and current condition data. The purest definition of asset management is financial, encompassing the cost, useful life, and replacement value information about specific assets.

Utilities assets are critical to the operation of an airport, are very large in quantity, and are typically hidden from view or easy access. Quality data about utilities is therefore a critical part of an asset management system, and one that is often difficult to develop.

- Metering—A small but by no means insignificant stream of revenue at airports comes from gas, electrical, fuel, and other meters that measure the use of product conveyed through subsurface utilities. Whether meters are read by airport staff or third parties, quality data about the location, condition, and accessibility of the meters are important for productivity, safety, and minimal impact on airport operations. Many airports rely on manual reading of meters and hard-copy records. The trend in the overall utility industry, however, is to rely more heavily on automated meter reading and mobile computing devices.

- Data Security—As a greater volume of utilities data is disseminated to a broader audience, often by means of the Internet, concerns over protecting it from mistaken or malicious acts becomes increasingly important. Airports have developed data security policies, but not necessarily at a granular level that clearly indicate how utilities data are to be protected and handled. Some airports have general data usage guidelines that must be accepted and signed. Some airports have defined Sensitive Security Information to include utilities infrastructure that directly support security activities such as closed circuit television cameras.

GROWING USE OF SUBSURFACE UTILITIES ENGINEERING AT AIRPORTS

In spite of gaps between SOT and SOA, there is an ever increasing use of SUE both on airport projects (Pillar 2001) and for complete airport facility mapping programs (Nelson 2008). Surveys of SUE consultants identified 44 airports where SUE was contracted in the past 10 years, almost exclusively limited to mapping functions.

CHAPTER FIVE

EFFECTIVE PRACTICES

This chapter identifies utility data collection, storage, and application practices that the literature review, interviews, and survey responses indicated are particularly effective at airports. In many cases, these practices are being applied. It can be noted that the practices identified here may not always be appropriate to an individual airport situation.

Using SUE effectively requires a variety of skills and coordinated work processes. Airport project managers and engineers are the primary parties responsible for carrying out effective SUE practices. However, they need to interact with airport management, GIS/CADD technicians, surveyors, public utility companies, and others as they carry out these practices. They also require support from records librarians and/or CADD/GIS program managers who can store and retrieve the utilities information produced. An effective practice referred to repeatedly in both interviews and surveys was the establishment of a single responsible department to oversee continuity of managing subsurface utility information on airports. This oversight department has the mandate to coordinate between the different stakeholders within the airport property to ensure the capture, dissemination, and management of utility information. Stakeholders identified as potentially involved in the utility process depending upon the airport structure and type of project and therefore needing coordination of activities may include:

- Airport and/or public agency project manager
- Airport and/or public agency utility design or relocation designers
- Airport and/or public agency project design engineers or their consultants
- Airport and/or public agency utility engineer
- Airport and/or public agency survey section personnel
- Airport and/or public agency property department
- Airport and/or public agency maintenance personnel
- Airport and/or public agency construction inspectors
- Airport and/or public agency consultants for construction inspection
- Airport and/or public agency roadway department
- Design or planning consultant hired by the airport and/or public agency
- Survey consultant hired by the airport and/or public agency
- State One-Call center
- Utility company records personnel
- Utility company engineering personnel
- Utility company "locators"
- Utility company "contract locators"
- Private industry "private utility locators"
- Utility company construction inspectors
- Utility company consultants for relocation design
- FAA
- Agency tenants
- U.S. military
- FHWA
- SUE consultants
- Construction personnel
- Maintenance personnel
- GIS departments
- Contracts and procurement departments
- Railroad companies.

The level of effort and therefore the number of people required to support these various positions obviously varies greatly according to the size of the airport or project. These activities can be performed as a part of existing employees' jobs on smaller projects and/or at smaller airports. More extensive construction programs at large airports may require several new staff members or consultants to fulfill these roles.

Effective SUE practices start well before and end well after (if ever) infrastructure development projects. Organizational, policy, standards, and procedural activities start in advance of a design or construction project. Project cost controls, constructability, and project safety are all better managed when accurate and complete information about utilities is available as early as possible.

Following is a checklist of specific effective activities that span the life cycle of typical airport construction programs. Each of these is described in more detail in the sections that follow:

- Organizational structure that promotes utility data exchange
- Procedures for SUE data collection and exchange
- Data standards that promote usability
- Policies that enforce standards and procedures
- Qualified consultants
- SUE Training
- Data collection techniques
- Coordinate with construction activities

- Coordinate with maintenance activities
- Deliverables that accurately depict utilities
- Consolidate utilities data as it is received.

The following paragraphs describe in detail the SUE-related processes that airports have found most effective:

- **Organizational structure that promotes data exchange:** As noted in the chapter on state of the practice, natural divisions between departments and organizations often introduce barriers to sharing information on subsurface utilities. Project costs, the risk of utility breaks, and safety concerns all decrease as information becomes more available. To achieve this, airports are increasingly relying on documented policies and procedures to encourage awareness and information exchange among those who have a right to know.

Some airports have appointed asset managers, GIS/CADD managers, and records librarians who are empowered to seek and share data across organizational boundaries. The individuals often become a focal point for data exchange and become aware of data sources and needs throughout the airport. They are often invited to project kickoff, program coordination, and planning meetings and therefore can serve as a conduit that not only spans departments but also projects and programs within departments. Program and project managers also play an important role in the sharing of utilities data, for it is they who are often the first recipient of delivered data and/or questions from consultants seeking data.

- **Procedures for utility data collection:** There are myriad ways to collect, store, and use utilities data in an effective manner. Clearly documented procedures are important to successfully carrying out SUE-related tasks. These procedures identify the applicable standards and specifications that must be met, describe how utilities data are to be submitted to the airport and how they will be checked, and describe the ways in which utilities data can be used. The procedures also document how field utilities data collection will be coordinated with airport construction projects as well as tenant improvement inspections. Points of contact for obtaining necessary airport security badges, coordination with airfield operations, potential sources of useful information, and other relevant stakeholders are identified. Information on soil resistivity, pavement reinforcements, and other airport-specific factors that can affect the performance of geophysical detection equipment, as well as positive/negative results from past geophysical efforts, are provided to help new consultants identify which tools and methods will likely work best. Procedures are specific, but allow for some flexibility for consultants to perform work in a manner that is efficient for their company and not impede the standard of care by dictating means and methods. As procedures and related standards and policy documents are developed, consistent terminology, specifications, and references are provided (Virginia DOT).
- **Data standards for consistency and usability:** Data standards are established for the storage of utilities data. The U.S. National CADD Standard for CADD data and the DOD's SDSFIE, the FAA's AC150/5300-18B for GIS data, and the current FGDC CSDGM or ISO-19115 for metadata are adopted and adapted to meet airport-specific needs. ASCE 38 QLs are tracked within the metadata as well. Common CADD and GIS symbology are applied from sources such as the National CADD Standard or developed by the airport or its consultants. Standards such as these provide consistency, structure, and scalability to the vast and exponentially growing stores of utilities data that organizations are collecting.
- **Policies that enforce procedures and standards:** Procedures and standards for collecting, storing, and using utilities data are typically enforced through written policies that are included in airport contracts, lease agreements, and other agreements that involve utilities information. Policies establish penalties for failure to submit stamped drawings that accurately depict as-built conditions and conform to the airport's standards. In addition, funding is made available for airport staff or another consultant to develop as-builts if others do not submit them in a timely manner.
- **Qualified consultants:** Consultants involved in SUE tasks are typically pre-qualified (see sample prequalification requirements in Appendix C) and selected based on professional qualifications, although cost may often be considered as well in conformance with the airport's procurement practice. Having an on-call SUE consultant available can provide continuity and familiarity with the airport's facilities, procedures, and policies. Airports participate with and coordinate with local One-Call systems.
- **SUE training:** Project managers, engineers, and other airport staff members are trained in utilities issues, technologies, and procedures. Training is also provided to consultants and contractors on airport-specific policies and procedures.
- **Data collection techniques:** When utilities data are collected in the field, high-accuracy GPS equipment capable of horizontal accuracies of greater than ±1 ft is used. On projects where utilities are a potential factor, utilities data at the appropriate QL (often QLB) should be collected as early as possible in the project life cycle. QLB searches within the project area are conducted for both known and unknown utilities. The search for unknown utilities also has security implications (Anspach 2005). It is effective to consider the level of accuracy and/or investigation required of the not-visible underground utilities as comparable to the visible features that are included in an accurate and comprehensive topographic survey and obtain them in the same relative time frame of project development. On-call or airport staff members tasked with collecting

new or relocated utilities data in the field are in close coordination with construction crews so that utilities data can be captured before they are buried. Field survey data are tied to established airport control points such as PACS/SACS and/or the National Spatial Reference System.

- **Coordinate with construction activities:** The level of effort required for utility mapping is discussed during the planning phase of any construction project. ASCE 38 serves as a guideline for developing a scope of work for utility mapping. As design proceeds, a standardized utility conflict matrix is developed. Just prior to construction, any One-Call locating activities are coordinated with the mapping process so that discrepancies with the mapping can be resolved and potentially fixed in the mapping record (along with the appropriate metadata). During construction, abandoned utilities are removed from the ground where feasible; the utility records are adjusted accordingly. At the beginning of, and at relevant junctures throughout a construction project, CADD/GIS personnel meet with project representatives to ensure that the necessary data are being collected in a proper format. As-builts are submitted where possible at the end of major construction phases, as opposed to months after construction activity is complete. If these phased deliverables do not meet the airports data standards requirements, progress payments are withheld or other corrective measures are imposed. Utilities data are incorporated into UCR, whether they are in CADD or GIS format, so that airport staff, consultants, and others with a need to know have information that is as up-to-date as possible (SHRP2 R01).
- **Coordinate with maintenance activities:** As maintenance is performed on airport facilities and equipment, any relevant information on utilities discovered, changes in condition to known utilities, or any new utility installations is recorded. If accurate location information is needed, coordination with airport staff or on-call consultants is important so that accurate information is captured before the utility is covered. This information is submitted in a format, often by means of a CMMS, to a CADD or GIS manager who can have the data integrated into the airport's UCR.
- **Deliverables that accurately depict utilities:** Utility data research, field data collection, and utilities installed or encountered during construction are recorded on CADD drawings and/or GIS data sets that conform to the airport's data standards. A registered engineer or surveyor signs or stamps these deliverables to ensure their reliability in accordance with ASCE 38. The deliverables are formatted so that planners, designers, engineers, and contractors can easily find the information they need and so that the data can easily be merged into consolidated CADD master drawings or a GIS data repository.
- **Consolidating utilities data as it is received:** Utilities data from all available sources are consolidated into master utility CADD drawings and/or a centralized GIS database. This is done in as timely a manner as possible, especially on large-scale construction programs where each subsequent phase can benefit from up-to-date and accurate information on subsurface utilities. Close conformance to SUE standards and procedures (as mentioned earlier) will ensure that data can be integrated with existing resources in a timely and effective manner. This integrated data can then be best deployed to planners, designers, engineers and contractors working on subsequent phases.

Implementing GIS so that advanced users can employ high-powered desktop software to perform sophisticated queries and analyses, while casual users can quickly and intuitively find the information they desire, is an effective way to disseminate utilities data. Standardized metadata identifying the source of the data, the project(s) responsible for installing or relocating the utility, the date the data were collected, the method of collection, and QL as defined in ASCE 38-02 are recorded for each individual utility component or feature as opposed to the overall layer or feature class (e.g., metadata are recorded for each manhole as opposed to generalize metadata being recorded for all manholes).

To ensure consistency, the consolidation (not the collection) of utilities data is the responsibility of a single airport department and/or on-call consultant. The data management personnel that work with the data include a licensed surveyor and/or engineer who is familiar with airport utility engineering and ASCE 38, as well as CADD/GIS technicians' proficient in entering and editing the data.

Drawings are submitted in a timely manner to those responsible for data consolidation. Tenant permit applications and inspections are used as a means of tracking utility installations by tenants and others not directly under contract with the airport. Budget is set aside to help fill in the gaps in utilities data not collected under capital improvement or tenant improvement projects.

CHAPTER SIX

RESEARCH IN PROGRESS

The following research projects or programs currently underway are related to or further support the information contained in this report.

ASSET AND INFRASTRUCTURE MANAGEMENT FOR AIRPORTS (ACRP 01-16)

The objective of this ACRP project is to develop a document that will help airport managers and staff understands the components of an asset and infrastructure management program, as well as the costs and benefits of implementing one. The project will also provide a guidebook that will help airports of various sizes implement an asset and infrastructure management program that meets their needs. ACRP 01-16 and this project (i.e., ACRP S11-09-03) can be complimentary because many of the assets and infrastructure at an airport are related to utilities.

EVALUATING CMMS PRACTICES (ACRP ANTICIPATED PROJECT 09-05)

The objective of this ACRP project is to help airports select, operate, and support CMMS. The guidance developed will help airports understand the various products and options that exist, determine the appropriate level of sophistication for their specific needs, and apply the technology in the best manner possible for the airport. Because utilities are one of the primary types of assets at airports that require maintenance, the findings of this report will identify CMMS-related gaps between the state of the technology and current state of the practice.

FAA NATIONAL AIRSPACE SYSTEM ENTERPRISE ARCHITECTURE

The purpose of the FAA's NAS Enterprise Architecture (EA) is to increase the understanding of and provide a basis for modeling the evolution of the NAS. It will provide architecture information to support enterprise-level decision making about the NAS. The EA seeks to describe NAS-wide as well as program-specific elements using the Department of Defense Architecture Framework. Utilities infrastructure is an important component of the NAS. Accordingly, the NAS EA represents an opportunity to promote SUE best practices among airports and off-airport utilities that serve the NAS.

MAPPING THE UNDERWORLD

Mapping the Underworld (MTU) is a 10-year U.K. research program largely funded by the Engineering and Physical Sciences Research Council. MTU started in 2005 with four complimentary research projects covering the feasibilities of a multi-sensor location tool; mapping and position; data integration to yield a single repository for records; and RFID tags to assist future pipe location. The current project builds on this research by seeking to develop a multi-sensor device integrated with intelligent data fusion using GPR, acoustics, and electromagnetic technologies to locate all infrastructure in all ground conditions without the need for excavation.

It is a multi-disciplinary and multi-university research project bringing together experienced researchers with a range of different expertise. The project builds directly on the findings of the MTU Phase 1 feasibility study, which concluded that only the combination of the different technologies will allow for reliable detection of the buried assets and has the potential to be used for condition assessment.

STRATEGIC HIGHWAY RESEARCH PROGRAM (SHRP) R-01A: INNOVATION IN TECHNOLOGIES TO SUPPORT THE STORAGE, RETRIEVAL, AND UTILIZATION OF 3D UTILITY LOCATION DATA IN HIGHWAY RENEWAL

This project aims to identify and develop best practices for modeling, structuring, storing, retrieving and utilizing 3D utility location data. Its main goals are to reduce project delays by keeping utility mapping data current throughout the project development process, reduce the necessity for repeating complete utility mapping for the next project in the same area by tracking all utility-related changes, and reduce excavation damage to utility lines during the construction phase.

STRATEGIC HIGHWAY RESEARCH PROGRAM (SHRP) R-01B: MULTI-SENSOR PLATFORMS FOR UTILITY LOCATION & CHARACTERIZATION

This project seeks to modify and improve existing advanced GPR and EM equipment, and add the capabilities of a new type of elastic wave system based on seismic reflection and refraction techniques. The goal is to enable these instruments to work together to gather dense data sets that can interpret utility signatures better than each instrument separately. Continuous precise positioning during data collection is of paramount importance to allow these data sets to be stacked and aggregated. It is hoped that these data sets will be rich enough to be able to determine other characteristics of a utility beyond location. These new tools may have the ability to also measure characteristics of pavement, sub-base material, voids, depth to water table, and other geotechnical considerations.

STRATEGIC HIGHWAY RESEARCH PROGRAM (SHRP) R-01C: EXPANDING THE LOCATABLE ZONE FOR UNDERGROUND UTILITIES

This project is attempting to develop technology to address two specific utility detection issues, that of deep utilities beyond the capabilities of current instrumentation, and of utilities that are stacked underneath shallower ones that “hide” their presence. Technologies include seismic reflection, long-range smart tags (RFID), and electromagnetic and acoustic.

EXCAVATION ENCROACHMENT NOTIFICATION (EEN) SYSTEM

This project is under research and development, with the Gas Technology Institute in the lead role. The objective is to develop a system that utilizes GPS technology to prevent excavator encroachment. Most research and development efforts to reduce excavation damage have focused on accurately locating the pipe or detecting damage once it has occurred. Relatively limited technology development has been aimed at preventing the two primary causes of excavation damage—excavators that do not utilize the One-Call center and excavators that encroach upon locator markings. Two separate but related systems will be developed to notify utility companies of encroachment. The first system, One-Call Monitoring System, will be developed to monitor construction activity to ensure that all excavations have a valid One-Call ticket associated with the work being performed. This will be accomplished by attaching a GPS-enabled monitor onto excavation equipment. This monitor will periodically send location information from the excavation equipment to the One-Call center where it will be cross-referenced with existing tickets. If excavation activity is detected that does not have a valid One-Call ticket, an inspector will be sent to the site to investigate the reasons. The second system (an Encroachment Monitoring System) will be developed to ensure that excavation equipment does not get within the tolerance zone of markings. This will be accomplished by equipping facility locators with high-accuracy GPS equipment to record the precise location of mark-outs. This information will then be used to ensure that the excavation equipment does not get within the tolerance zone of the markings. Additionally, excavators can be continuously aware of their proximity to underground facilities, even if markings have been removed.

CHAPTER SEVEN

CONCLUSIONS

Many airports have formal programs to support utility data collection, storage, and use. Some airports are applying the basic principles of subsurface utility engineering (SUE), but not all use it effectively. Airports and their consultants may not be aware of ASCE 38 and its benefits. There are a few airports that have contracted for and received SUE mapping for individual projects, and a few have begun successful programs to integrate project data into an overall airport mapping program.

Literature clearly notes that utilities present risks to projects of all kinds, and that applying the principles of SUE is an effective way to mitigate and manage those risks. Airports possess many of the right tools to have an effective overall subsurface utility management program: geographic information system (GIS), control over activities on the airport property, adequate survey control density, and clear lines of sight to Global Positioning System (GPS) satellites. They also have personnel with experience in GIS capabilities.

A significant impediment to an effective program to manage utility data and use it effectively is a lack of SUE focus. Project managers, airport engineers, and GIS/Computer-Aided Design and Drafting (CADD)/asset managers need more information on how to effectively integrate SUE into their project development process. The following suggestions for further research and technology transfers might remedy that situation:

- **Increase awareness and training on SUE practices:** Airport staff and consultants need resources to learn about and better understand effective SUE practices and published guidelines. A guidebook may be helpful in leveraging lessons learned, research, and work completed by others.
- **Integration of utility mapping with geotechnical investigations:** Geotechnical investigations are typically conducted with a variety of surface geophysics and exploratory boreholes. Utilities interfere with these investigations by contributing to energy fields in the regions of investigation. As such, there is an attempt to eliminate utility "noise" so that interpretations are more valid. Research would helpful in describing advanced geophysics now available for the purposes of mapping utilities that may have application to airports. This research would produce significant cost savings, while at the same time increasing data quality at airports. A research project to identify applicable geotechnical factors for investigation, coupled with a trial project or two to analyze results and costs savings, might be useful.
- **Development of SUE prequalification criteria:** Many state DOTs have developed specific SUE prequalification materials. Airports may benefit from research into SUE prequalification checklists and other materials.
- **Standard scopes of work for utility mapping:** There are many standard items that can be placed in a scope of work for utility mapping. Research into a standardized scope of work for utility mapping that shows mandatory items along with optional items may be useful for airports.
- **Cost guidelines:** The Maryland State Highway Administration provides cost guidelines for SUE work per linear foot along state highways. While helpful for highway projects, metrics based on linear foot may be more conducive to linear transportation networks such as streets and highways. Research into airport cost metrics that are based on area and can be appropriately weighted to apron areas, runway and taxiway areas, and non-aircraft operating area portions of their property may be helpful to airports. Because SUE services are often required during design, the typical percentages of overall project design costs will also help airports assess the amount of money SUE services will require. Such metrics may assist airports competitively procure SUE services.
- **Development of a utility data model:** Currently, a gap exists between the overly detailed Spatial Data Standards for Facilities, Infrastructure and the Environment, inconsistent data models published by software vendors, and the simplified utilities structure in the FAA's AC 150/5300-18B. Research into development of an airport industry data model or standard that is compatible with FAA, ASCE, and other relevant guidelines may be useful to airports.
- **Improved CADD–GIS interoperability:** As a growing number of airports use GIS, it is becoming more important to exchange data between GIS and CADD software packages. Research into airport CADD–GIS exchange standards and/or nonproprietary data formats would be helpful to airports.

- **Development of a metadata profile:** Metadata are attached to CADD and/or GIS utilities data used by airports. Research into an airport metadata profile may describe the source, method of collection, quality level, date or validity of the data collected, and feature level. This may be helpful to airports describing their subsurface utilities.
- **Integrating utilities into the project development process for airports:** Other transportation sectors have developed a multitude of flow charts, coordination checklists, design criteria, utility avoidance strategies, and other items that can be incorporated into a project's planning, design, and construction process. Research into developing such an application to airports may be useful.

GLOSSARY OF TERMS, ABBREVIATIONS, AND ACRONYMS

Following is a glossary of terms used in this synthesis report, including abbreviations and acronyms commonly used is relation to SUE services performed at airports.

Abbreviation	Full Term
AAAE	American Association of Airport Executives
ACIP	Airport Capital Improvement Program
AGC	Associated General Contractors of America
AIP	Airport Improvement Program
ALP	Airport Layout Plan
APWA	American Public Works Association
BIM	Building Information Modeling
CADD	Computer Aided Design and Drafting
CD	Compact Disk
CMMS	Computerized Maintenance Management System
COTS	Commercially Available Off-the-Shelf
CSDGM	Content Standard for Digital Geospatial Metadata
DOT	Department of transportation
EA	Enterprise Architecture
EEN	Excavation Encroachment Notification
EML	Electromagnetic Pipe and Cable Locators
EMTC	Electromagnetic Terrain Conductivity
FGDC	Federal Geographic Data Committee
GIS	Geographic information system
GPR	Ground penetrating radar
GPS	Global Positioning System
IDLE	Integrated Distance Learning Environment
ISO	International Organization for Standardization
IT	Information technology
LiDAR	Light Detection and Ranging
MAG	Magnetics
MTU	Mapping the Underworld
NAD	North American Datum
NAS	National Airspace System
NAVD	North American Vertical Datum
NGS	National Geodetic Survey
PACS	Primary Airport Control Station
PDP	Project Development Process
PDF	Portable Document Format
PFC	Passenger Facility Charge
QL	Quality level
RFID	Radio Frequency Identification
ROI	Return on investment
RTK	Real-Time Kinematic
SACS	Secondary Airport Control Station
SAULT	Selection Assistant for Utility Locating Technologies
SDSFIE	Spatial Data Standards for Facilities, Infrastructure and the Environment
SMS	Safety Management System
SOA	State of the art
SOP	State of the practice
SOT	State of the technology
SUE	Subsurface utilities engineering
TIF	Tagged Image File format
UC	Utilities coordination
UCR	Utility composite record
UMP	Utility mapping program
USACE	U.S. Army Corps of Engineers

The key terms and phrases used in this report are defined here:

Attribute information is alphabetical and/or numeric information that describes particular characteristics of a geospatial feature, such as its type, dimensions, usage, occupant, etc.

Engineering information includes hard copy and electric drawings, maps, imagery, operations and maintenance manuals, survey data, and many other forms of technical data.

An **Enterprise GIS** is a collection of geographic information, GIS applications, and business processes built upon a common framework to support collaborative decision-making across divisions and among management, staff, and consultants.

Geographic features are depictions of natural or manmade elements that occupy a specific location. Examples include a runway, building, river, or underground pipe. Geospatial features or a particular type (i.e., all runways) are often referred to as a feature type, data set, or layer of spatial data.

Geographic information is data that depict geographic features on a map, drawing, or photo. It includes hard copy and electric engineering drawings, maps, aerial imagery, and survey data.

Metadata are information about the data themselves such as source, accuracy, dates for which the data are valid, and security classification. Metadata are essential in helping users determine the extent to which they can rely on a given datum to make decisions.

Profile is an extension or adaptation of a standard to meet a specific industry's requirements.

Subsurface utilities engineering is a branch of engineering practice that involves managing certain risks associated with utility mapping at appropriate quality levels, utility coordination, utility relocation design and coordination, utility condition assessment, communication of utility data to concerned parties, utility relocation cost estimates, implementation of utility accommodation policies, and utility design (ASCE 2002).

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APPENDIX A

Interview Questionnaire

Following is a brief questionnaire intended to identify how airports and other organizations collect, store, and use information about subsurface utilities. We will use these questions as a guide during a phone interview. Answers to these questions from a variety of airports will be consolidated to identify industry best practices, technological trends, and opportunities for further research that will benefit airports and utility providers. These findings and recommendations will be published in an Airport Cooperative Research Program synthesis report. The specific information you provide will not be publicly available in a manner that can be associated with you or your airport. Consolidated statistics, which combine results from many airports, will be published in the final report.

Participant Name: ____

Contact Information: ____

Qualifying Questions

- Are you willing to participate? Yes. No
- Do you have experience with collecting or using utilities information? Yes. No
- Do you have 30–45 minutes for a phone interview? Yes. No. Later ____________

General

- What airport (or organization) do you work for? _________
- What is the organizational structure of your airport?
  - ☐ Part of an authority that operates an airport(s)
  - ☐ Part of the city
  - ☐ Part of the county
  - ☐ Other: __________________________
- In what department do you work (please indicate closest match)?
  - ☐ Planning
  - ☐ Engineering
  - ☐ Property management
  - ☐ Maintenance
  - ☐ Operations
  - ☐ Other: ______________________

Collecting Information About Utilities

- What sources of subsurface utilities information do you use (check all that apply)?
  - ☐ Record drawings from completed projects
  - ☐ Maintenance shop drawings
  - ☐ Consolidated utility drawings (CADD)
  - ☐ Use a spatially-enabled database (GIS) to pull up utility information
  - ☐ Consolidated utility model (GIS)
- Which utilities cause more problems from a data collection standpoint than others? Why?

- Do you use Subsurface Utility Engineering (SUE)? Yes. No
  If yes, describe your use of SUE:

- Has your organization contracted with a consultant/contractor within the last 3 years to provide SUE services? If so, were these services contracted via:
  - ☐ No, we have not contracted for subsurface utilities engineering services
  - ☐ Within the scope of design contract(s)
  - ☐ Within the scope of construction contract(s)
  - ☐ Separate subsurface utilities engineering contract(s)
  - ☐ On-call subsurface utilities engineering contract(s)
- Other: ______________________________
- Do you require your consultants to use SUE? Yes. No

- Do you use SUE on a project by project basis? Yes. No
- Do you use SUE to globally map airport utilities to improve the base utility information? Yes. No
- Do you have a pre-qualification process for SUE consultants?
- Do you procure SUE on a qualifications-based selection or low-bid?
- On what percentage of CIP projects do you use the following field data collection techniques?
  ___ % Airport or consultant survey of one-call marks
  ___ % QLB (marks and survey by same company and stamped as QLB)
  ___ % Aerial or field survey of utility structures and use records to fill in the gaps
  ___ % Pothole/no survey
  ___ % Test holes leading to QLA data (survey of exposed utility stamped)
  ___ % Other: ________________
- On what percentage of projects do you use the following technologies?
  ___ % RFID Marker Balls
  ___ % GPS-enabled cameras
  ___ % 3-D multi-channel radar
  ___ % 2-D single channel radar
  ___ % other advanced geophysics (i.e., not standard pipe and cable locators)
  ___ % lidar survey for exposed utilities
  ___ % other advanced survey techniques for exposed utilities
  ___ % Field tablet comparison of observations vs. utilities in GIS with corrections as necessary
  ____ Other:
- Do you record and/or require metadata (i.e., information about the data such as who collected it, how, and when) about your utilities information? Yes. No. Unsure
- Do you currently have access to information on the location of utilities installed by the FAA (i.e., electrical or telecommunications lines to control tower and navigational aids) at your airport?
- Does the FAA have access or request any utility information from you before their projects?

As-Built or Record Drawings

- For what percent of construction projects that involve utilities do you request "as-built" drawings?
  ☐ 75%–100%
  ☐ 50%–75%
  ☐ 25%–50%
  ☐ Less than 25%
- For what percent of construction projects that involve utilities do you receive "as-built" drawings?
  ☐ 75%–100%
  ☐ 50%–75%
  ☐ 25%–50%
  ☐ Less than 25%
- Are these "as-builts" typically
  ☐ Annotations to design documents
  ☐ CADD documents updated to accurately depict as-built conditions
  ☐ GIS data deliverables
  ☐ Other: ____________________________
- Are the "as-builts" you received stamped by a surveyor or engineer? Yes. No
- How long does it take to receive "as-built" drawings from consultants/contractors after a project is completed?
  ☐ Within 30 days
  ☐ 30–90 days
  ☐ More than 90 days
  ☐ Never
- Do you have written standards for "as-builts"? Yes. No. If Yes, what do these standards cover (e.g., layering, format, accuracies)?

- Do the "as-builts" you receive meet your needs? Please explain.

- What methods do you use to enforce or incent your consultants, tenants, FAA, or others to supply "as-builts" according to your standards?
- Do you incorporate "as-built" drawings into master utility drawings and/or a central GIS database? Yes. No
  ☐ If so, describe the process and the groups involved. How long does it take to get as-built drawings into the GIS database and make them accessible?
- Do you require maintenance personnel to supply utility information during routine maintenance dig-ups if it doesn't agree with records and to what degree of accuracy?

Storage of Utilities Information

- Where is the utilities information you use kept (please check all that apply)?
  ☐ Document management system
  ☐ Central GIS database

- ☐ Record documents physically stored in a central place
- ☐ Tenants keep their own, airport retrieves as required
- ☐ FAA keeps their own
- ☐ Other: ____

- Are utilities record drawings kept in a central document management system? Yes. No
  - ☐ How far back are historical records available?
  - ☐ What is the process for entering new records drawings into the system?
  - ☐ Are documents geo-referenced and searchable using a map? Is it GIS capable?
  - ☐ Do consultants have access to these records? If so, what is the procedure for gaining access?
- Is there or was there a military presence at your airport? If so, how did or do you get information on utilities installed by the military?
- Is utility information readily available to everyone who needs it in a timely fashion?
- Do you require that your utilities data be kept in compliance with standards? If so, which standards do you use?
  - ☐ ASCE 38 for collection and depiction
  - ☐ SDSFIE
  - ☐ National CADD Standards
  - ☐ FAA Airports GIS
  - ☐ Utility models from GIS/CADD software vendors
  - ☐ Internally developed
  - ☐ Other:
- Do there need to be better standards developed? If so, describe.
- Are there any problems with how the utility information is presented in the output you receive?

Use of Utilities Information

- Which departments in your airport use utilities data on a regular basis (please check all that apply)?
  - ☐ Planning
  - ☐ Engineering
  - ☐ Property management
  - ☐ Maintenance
  - ☐ Operations
  - ☐ Other: ________________________
- How important are accurate utilities information viewed by the rest of your colleagues who use utility data?
- Do you feel your colleagues get the maximum value out of the utilities data you already have?
- How often do external stakeholders (i.e., consultants, tenants, FAA, utility companies, city/county, etc.) require utilities data from the airport?
  - ☐ Which department is responsible for providing this information to them?
  - ☐ Do you have any written agreements that govern the use of these data?
- Which utilities cause more problems from a design and construction standpoint than others? Why?
- How many change orders do you typically get per year/or on a project? __________
  - ☐ On average, what percentage of those is due to utilities? ________________
  - ☐ Approximately what percentage of these change orders could have been avoided with better utilities information? ____________%
  - ☐ What are the causes of the change orders that could not have been avoided with better information?
- Approximately, how many unintentional utility breaks have occurred at your airport over the past five years? (confidential) _____________________
- What percentages of CI projects use these procedures to manage utility data?
  ____% Utility meeting at start of project
  ____% Utility meetings during project in some periodic fashion
  ____% Utility Conflict Matrix
  ____% Utility relocation cost estimates
  ____% Database of historical utility relocation costs
  ____% Appointed project utility coordinator
  ____% Formal/standard utility data-gathering and use flowchart/procedures
- How and when do you communicate capital improvement project information to affected utility owners?
- Do you allow your consultants to choose how and when they will map utilities or does the airport mandate the process?
- Are Design+Build projects handled any differently than when design is contracted separately from construction?
- What organization/department is the official "One Call" responder for airport-owned utilities on airport property?
- Do one-call responders use airport utility records? Yes. No
  - ☐ What kind?
- Do One-Call responders notify anyone if the records disagree with their field findings?
- Do you have a formalized Buried Asset Management Program? Buried Asset Management is a standardized program within an organization that can address all aspects of its underground infrastructure including but not limited to inventory, location, condition, 3R (replacement, renewal, and repair) decisions, capacity, data management and dissemination, operation and maintenance, and output display. Its objective is to maximize the value derived from an asset stock over the whole life cycle, within the context of delivering appropriate levels of service to customers, communities and the environment, and at an acceptable level of risk.

If so, briefly describe.

- Does your airport use the following types of software in conjunction with utilities information?
  - ☐ Desktop GIS ________________________
  - ☐ Desktop CADD _______________________
  - ☐ Enterprise/web GIS ____________________
  - ☐ Asset or financial management systems ____________
  - ☐ Mobile applications on cell phones or PDAs _____________
- Describe some of your utility conflicts "horror stories." (confidential)

Quality of Utilities Information

Please indicate below the relative quality of your utilities information. Please consider quality as encompassing accuracy, timeliness, comprehensiveness, and availability of the data.

	Strongly Agree	Agree	Not Sure	Disagree	Strongly Disagree
Meets my needs					
Meets my colleagues' needs					
Is better than it was 5 years ago					
Is better than other airports					
Is better than our city/county					

On a scale from 1–10, where 1 is no data and 10 is sufficiently accurate, timely, and comprehensive utilities data, where does your utilities data currently fall?______

Please indicate below the positional accuracy you typically require of your utilities data

	<3 in.	3–12 in.	1–3 ft	3–10 ft	>10 ft
Horizontal location of appurtenances					
Vertical location of appurtenances					
Horizontal location of subsurface features					
Vertical location of subsurface features					

- What improvements would you want to make to the quality of your utilities information?

Best Practices (again, this information will be kept in confidence).

- Do you feel your airport collects, maintains, and uses utilities information in the best manner possible? Yes. No. If no, please indicate what improvements could be made?
- Which airports (if any) collect, maintain, and use utilities information better than your airport (this information will be held in confidence)?
- Which organizations or types of organizations (other than airports) collect, maintain, and use utilities information better than airports?

Additional Comments

APPENDIX B

SUE Consultant Survey

Following is the survey questions that were e-mailed to a variety of consultants who have performed SUE services for airports.

Name of Firm

Name of Interviewee

Are you aware of airport mapping requests at airports that you did not get or pursue?

Why did you not pursue them?

Have you performed utility mapping on airports?

Which ones?

Did the airport hire you directly?

If so, which department?

Did the airport's program manager hire you?

Did you work for a consultant?

Which department at the airport did you primarily interact with?

How many departments did you have to interact directly with?

Was the work related to a CIP or general layout?

Were records available?

Were they all in one place?

Were they adequate for your needs?

Do they meet your needs better or worse than record drawings available from non-airport clients?

Did the airport have record drawings in a searchable document management system?

If so, could the drawings be searched by location either using a map or textual descriptions of location?

Did your firm have direct access to this document management system on-site at the airport or via the Internet?

Did the airport have utilities data in a GIS?

Did your firm have direct access to this GIS on-site at the airport or via the Internet?

Were you asked to stamp deliverables in accordance with ASCE 38?

Was your hiring based upon qualifications or low bid?

Were any utility systems more difficult to map than others?

Why?

Did you employ any advanced geophysics?

GPR

3-D GPR

Terrain Conductivity

Were your deliverables in CADD?

Have you ever been required by an airport to provide data in a GIS format?

If so, were standards used to define the required format? If so, which standards were used?

Did the airports or AE firms specify formatting?

What would you recommend to airports as a best practice regarding utility mapping?

APPENDIX C

SUE Prequalification Criteria

GEORGIA DOT SUE PREQUALIFICATION REQUIREMENTS

The state of Georgia Department of Transportation defines the following prequalification requirements for SUE (Area Class 5.08), which can be found in the "Consultant Prequalification Manual" (http://www.dot.state.ga.us/doingbusiness/consultants/Documents/Consultant%20Prequalification%20Manual11509.pdf).

Class 5.08—Subsurface Utility Engineering (SUE)

This class of work is defined as the engineering processes that involve managing certain risks associated with accurately and comprehensively identifying, characterizing, and mapping overhead and underground utility facilities. The major activities include utility records research, mapping, designating, utility impact analysis, locating, and data management. Other activities associated with this class of work are utility relocation design, coordination, and training. These activities, when coordinated with utility owners, Department personnel, and surveyors, provide high quality utility information for use during project development, design, and construction. These activities should conform to standards and guidelines as described in FHWA and ASCE Subsurface Utility Engineering publications in conjunction with the Department's current standards, guidelines, and processes and SUE scope of services.

(1) Professional Status

Registration as a Professional Engineer with the Georgia State Board of Professional Engineers and Land Surveyors and proven proficiency in the field of Civil Engineering with emphasis on transportation and utility design.

Registration as a Land Surveyor with the Georgia State Board of Professional Engineers and Land Surveyors and proven proficiency in the field of route surveying with emphasis on designating utilities.

(2) Adequacy of Personnel

At least two professionals, one of each as stated in item one (1) above are required. One of the professionals is required to perform independent checks of data, calculations, plans, and reports of the other.

At least two designators are required.

At least one key personnel must demonstrate a strong working knowledge of the Department's current Plans Development Process (PDP).

Must have sufficient personnel to prepare engineering plans, reports and specifications to the Department's current Electronic Data Guidelines and SUE Standards.

Must demonstrate to have sufficient personnel to accommodate multiple projects simultaneously.

The number of professional and technical support personnel must be recorded and updated.

(3) Equipment

Must have adequate equipment to demonstrate the ability to designate both metallic and non-metallic types of underground utility facilities in accordance with the current ASCE standard CI/ASCE 38-02 "Standard Guidelines for the Depiction of Existing Subsurface Utility Data."

Must have adequate equipment to demonstrate the ability to locate underground utility facilities in a minimally intrusive manner.

Must have adequate equipment to demonstrate the ability to accurately and efficiently survey and reduce field information.

Must have adequate equipment to prepare engineering plans, reports and specifications to the Department's current Electronic Data Guidelines and SUE Standards.

(4) Past Record, Experience, and Capability

Satisfactory experience must be demonstrated in the activities required by this class by the individual(s) who are bona fide employees for the firm thereof.

IOWA DOT SUE PREQUALIFICATION REQUIREMENTS

Description: This category of work is defined as an engineering process for accurately identifying subsurface utility facility locations. The firm should be able to precisely identify, locate, and map the horizontal and vertical position of underground utilities, as well as the type, size, condition, material, and other characteristics. These services shall be performed by using existing utility records, survey, surface geophysical techniques, and nondestructive digging methods. Firms should able to present this information in CADD and tie it into project plans. Work in this category includes:

- Mapping at designated quality levels
- Utility coordination
- Utility relocation design and coordination
- Utility condition and assessment
- Communication of utility data to concerned parties
- Utility relocation cost estimates
- Implementation of utility accommodation policies
- Utility design for highway plans during the development of a highway project.

Minimum Qualification Standards

MQS: Statement B or Statement C. Also, the project manager should have been involved in the management of at least three SUE projects.

Statement B. Professional status in the category of work shall be demonstrated on Form 102113 by reference to at least one person registered by the Iowa Engineering and Land Surveying Examining Board as a professional engineer. Resumes of personnel so referenced shall indicate the extent and nature of experience in the category of work. Other personnel supporting prequalification in the category shall be referenced on Form 102113. Satisfactory experience in the category shall be demonstrated on Form 102113 by reference to completed projects.

Firms may designate one or more individuals, holding a certificate of registration granted by the Iowa Engineering and Land Surveying Examining Board as a professional engineer, as responsible for the practice of engineering in Iowa by the firm. The designated individual or individuals shall have full authority to make all final engineering decisions on behalf of the firm with respect to the work performed by the firm. This designation shall not relieve the firm of any responsibility or liability imposed upon it by law or by contract.

Statement C. All requirements expressed in Statement "B" above shall apply with the exception that in lieu of registration as a professional engineer, registration as a land surveyor is required.

APPENDIX D

SUE Sample Scope of Work

The FHWA has prepared the following "Sample SUE & Utility Coordination Scope of Work for Consultant Services."

SUBSURFACE UTILITY ENGINEERING AND UTILITY COORDINATION SERVICES NON-PROJECT-SPECIFIC

I. GENERAL

A. Definitions and Terms.

1. *CI/ASCE 38-02*: "Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data," American Society of Civil Engineers, 2003.
2. *DOT*: State Department of Transportation and/or its authorized representative(s), as the context implies.
3. *Consultant*: The individual or firm directly, or indirectly through sub-consultants, providing engineering and design-related services as a party to the contract.
4. *Contract Manager*: The designated DOT representative responsible to coordinate, authorize, and monitor the status of task orders issued pursuant to the contract.
5. *Project Manager*: The designated DOT representative, typically from the involved DOT region, responsible on a specific project to evaluate and prescribe SUE needs, and to monitor the performance of approved tasks.
6. *R.S.*: Revised Statutes, as amended [Replace this reference with the name of applicable State statute].
7. *MUTCD*: "Manual on Uniform Traffic Control Devices," U.S. Department of Transportation, Millennium Edition, December 2000.
8. *QL A*: Utility Quality Level A as further described herein. Generally, QL A indicates the precise horizontal and vertical location of utilities obtained by the actual exposure (or verification of previously exposed and surveyed utilities) and subsequent measurement of subsurface utilities, usually at a specific point.
9. *QL B*: Utility Quality Level B as further described herein. Generally, QL B indicates information obtained through the application of appropriate surface geophysical methods to determine the existence and approximate horizontal position of subsurface utilities.
10. *QL C*: Utility Quality Level C as further described herein. Generally, QL C indicates information obtained by surveying and plotting visible above-ground utility features and by using professional judgment in correlating such information to QL D information.
11. *QL D*: Utility Quality Level D as further described herein. Generally, QL D indicates information derived from existing records and oral recollections.
12. *Subsurface Utility Engineering, or SUE*: A branch of engineering practice that involves managing certain risks associated with utility mapping at appropriate quality levels, utility coordination, utility relocation design and coordination, utility condition assessment, communication of utility data to concerned parties, utility relocation cost estimates, implementation of utility accommodation policies, and utility design.
13. *UNC*: Utility Notification Center.
14. *Utility Quality Level*: A professional opinion of the quality and reliability of utility information. Such reliability is determined by the means and methods of the professional.

B. Work Locations.

1. Potential projects on which SUE may be required are at undetermined locations statewide. The specific projects will be as determined by DOT.
2. Work under this contract will be authorized by means of task orders specific to the applicable project. The Consultant is reminded that this contract does not guarantee the amount of work, if any, available under the contract.

C. Range of Services.

1. The work to be performed will be only as specified in individual task orders, and may include any or all of the activities described herein.
2. The intent of this contract is twofold: (a) to achieve accuracy and economy in project-driven utility inventories, conflict assessment, and relocations, through the application of SUE techniques that are not otherwise readily available to DOT; and (b) to enable DOT to assign various tasks (such as utility coordination, utility relocation design, cost estimating, agreement development, etc.) that DOT may otherwise perform in-house.
3. However, the primary services anticipated to be rendered hereunder are QL A and QL B mapping.

D. Work Inspections.

1. The Consultant shall make reasonable provision for DOT representatives to observe the Consultant's work in progress.

E. DOT Assistance.

DOT will furnish the following at no cost to the Consultant:

1. Copies of applicable manuals, policies and procedures, forms, or other standard documentation.
2. Copies of applicable "as constructed" plans showing information pertinent to the work.
3. Information, if known, on involved utilities, such as owner name, contact person, permit records, or utility maps; provided, however, that DOT does not warrant the accuracy or completeness of such information.
4. Prints or electronic files of project plans, profiles, cross sections, details, or correspondence pertinent to the work.
5. Alignment, centerline, profile, and survey control data.
6. Liaison with utility owners and property owners as necessary to facilitate the Consultant's access to pertinent records or property.

F. Work Standards.

1. Except as may be modified or specified herein, or otherwise approved by DOT, the collection and depiction of information, and any required submittals, shall conform to the applicable provisions of CI/ASCE 38-02, “Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data.” A copy of CI/ASCE 38-02 is available for inspection by contacting the DOT Contract Manager; or may be ordered from the American Society of Civil Engineers at www.asce.org.
2. It is intended that this Scope of Work be construed harmoniously with CI/ASCE 38-02; however, in the event of conflict, the provisions of this Scope of Work shall take precedence.

G. Submittals.

1. All required reports, documentation, studies, field notes and sketches, plan drawings, and electronic data shall be submitted for review and acceptance by the Project Manager.
2. When applicable, the Consultant shall submit an example of an original plan sheet and obtain approval from DOT prior to drafting plans.
3. Final submittals shall incorporate any corrections or revisions resulting from DOT’s review.

H. Certification.

1. The Consultant’s Professional Engineer or Professional Land Surveyor in responsible charge of the work shall perform a final review of, seal, and sign all applicable submittals, including but not limited to original field notes and sketches (or copies of same if approved by DOT), hard copies of electronic data, and plan drawings.

I. Plan Drawings.

1. Plan drawings shall conform to the requirements set forth in the DOT Drafting Manual, or as otherwise directed or approved by DOT.
2. Drawings with colors shall be reproducible by all printing or duplication media in black-and-white.
3. Drafting and lettering shall be of proper density and legibility for a 50% reduction during reproduction.
4. The depiction of attributes such as line type, material type, age, condition, ownership, status (e.g., in-service, out-of-service, active, abandoned), number of conduits or direct buried cables, or other required information, shall not be eliminated, obliterated, or obscured by the manner of reproduction or by 50% reduction in size.
5. Final drawings for reproduction shall have all drafting work and image on one side of the sheet.
6. The Consultant shall replace, at no cost to DOT, plan sheets that do not comply with the above criteria.

J. Electronic Data.

1. The Consultant’s selected hardware and software, methodology, and format for deliverables, shall conform to the applicable requirements of the DOT Survey and/or Drafting Manuals, or shall be as otherwise directed or approved by DOT.
2. The Consultant shall contact the Project Manager, prior to creating any electronic data, to verify the current collection and submission requirements.
3. The Consultant shall identify each unit of magnetic media submitted, with adhesive labels affixed to the media and containing identifying and archival information prescribed by the Project Manager.
4. A letter must accompany the magnetic media and shall contain the same information as required to be affixed to the media, and shall also contain a description of the software utilized.

II. MISCELLANEOUS TASKS

A. Training and Orientation.

1. Assist DOT in conducting training and orientation sessions for interested parties. A training session will cover such items as available services, detection and excavation technology, project deliverables, and task order development.

B. Scoping Assistance for Task Orders.

1. Assist DOT in developing the scope of work for a subsequent task order by assessing project SUE needs, generating alternatives, and/or making recommendations.

C. Work Plan and Schedule.

1. Develop a detailed work plan and schedule of activities showing conformance to the work requirements and time constraints imposed by the task order; and obtain DOT’s approval of said work plan prior to commencing work.

D. Mobilization.

1. Deploy necessary personnel, equipment, and supplies from the Consultant’s central location to the work site, in preparation for the work.
2. Unless otherwise approved by DOT, the Consultant shall not be compensated for more than one mobilization per task.

E. Traffic Control.

1. Whenever the work will affect the movement of traffic or traffic safety, provide traffic control and utilize traffic control devices in conformance with the MUTCD, and [if applicable, the State supplement thereto adopted pursuant to State Statute].
2. Traffic Control shall be directed by a worksite traffic supervisor certified by the American Traffic Safety Services Association (ATSSA), or the [State] Contractors Association (CCA).
3. The Consultant’s Traffic Control Plan (TCP) and Method(s) of Handling Traffic (MHT(s)) shall be subject to acceptance by DOT prior to commencing work.

F. Permits and Rights of Entry.

1. Obtain all necessary permits from DOT and/or local jurisdictions to allow the Consultant to work within public rights of way.
2. If work must be performed on private property, the Consultant shall obtain written permission from the property owner for the Consultant and DOT to enter the premises, including names and telephone numbers of contact persons should notification prior to entry be necessary.

3. Work on DOT rights of way may require a Special Use Permit or similar authorization, which will prescribe necessary conditions and controls. The DOT Project Manager will provide liaison between the Consultant and the involved DOT permit office.

G. Condition Assessments.

1. Perform interior pipewall inspections and/or thickness tests of existing buried utility lines, utilizing video, ultrasonic, and/or visual techniques as appropriate.

H. Aerial or Ground-Mounted Utility Facilities.

1. If specified by DOT, Quality Level D or C services as further described herein shall include records research, identification, surveying, correlation, and/or depiction of aerial or ground-mounted utilities, notwithstanding that such surface features may not be associated with an existing subsurface utility line or system.

I. Unknown Lines.

1. If, when performing an assigned task, the Consultant detects line(s) of unknown function, status, or ownership, the Consultant shall obtain, record, and depict information on such line(s) to a quality level that is commensurate with that of the original assigned task.

III. PROJECT UTILITY COORDINATION/DESIGN TASKS

A. Project Meetings, Site Reviews.

1. Attend project meetings and/or site reviews with DOT staff and/or other involved parties.
2. Record and report on proceedings.

B. Preconstruction Utility Coordination.

Coordination activities include but are not limited to:

1. Implement and comply with established DOT project utility coordination procedures.
2. Notify and furnish preliminary project data to involved utility owners.
3. Provide liaison among DOT, utility owners, and other involved parties.
4. Schedule and conduct coordination meetings and field reviews with utility owners.
5. Identify and coordinate the resolution or mitigation of utility conflicts.
6. Determine financial responsibility for utility relocation costs.
7. Negotiate and secure utility relocation agreements, owner commitments, or sign-offs.
8. Facilitate the incorporation of existing/proposed utility facility information into project plans.
9. Prepare project contract documents describing utility activities and utility/contractor coordination requirements.
10. Prepare project utility clearance documents certifying that all utility work has been completed, or that all necessary arrangements have been made for the work to be properly coordinated with the highway construction project.

C. Conflict Assessment, Development of Alternatives, Cost Estimates.

1. Work with DOT and utility owners to determine conflict points between planned construction and existing or planned utility facilities.
2. Develop and make recommendations on relocation alternatives, with emphasis on cost effectiveness and on minimizing conflicts.
3. Develop or facilitate comparative cost estimates.

D. Utility Design.

1. Subject to owners' approval, design and prepare plans and specifications for utility facilities to be relocated or installed on the DOT project.
2. Incorporate utility design information into project plans and furnish documentation to DOT and/or utility owners as needed.
3. Comply with applicable DOT and/or utility design standards and DOT utility accommodation policies.

E. Construction Coordination and Monitoring.

1. Provide liaison among DOT, construction contractors, and utility owners in the coordination, scheduling, and performance of utility work.
2. Monitor and report on utility relocation or installation work.
3. Determine and ensure compliance with construction plans, specifications, and schedules.
4. Negotiate field changes as conditions warrant.
5. Prepare as-built documentation and quantities.

IV. QUALITY LEVEL D TASKS

Tasks leading to QL D include:

A. Records and Information Research.

1. Conduct appropriate investigations (e.g., owner records, DOT records, UNCL records, County records, personal interviews, visual inspections, etc.), to help identify utility owners that may have facilities within the project limits or that may be affected by the project.

B. Records Collection.

1. Collect applicable records (e.g., utility owner base maps, "as built" or record drawings, permit records, field notes, geographic information system data, oral histories, etc.) on the existence and approximate location of existing involved utilities.

C. Records Review.

1. Review records for: evidence or indication of additional available records; duplicate or conflicting information; need for clarification.

D. Aerial or Ground-Mounted Facilities.

1. Include records research, identification, and depiction of aerial or ground-mounted utility facilities in QL D tasks if specified (see "Miscellaneous Tasks").

E. Compilation and Presentation of Data.

1. Transfer information on all involved utilities to appropriate plan sheets, electronic files, and/or other documents as required or directed by DOT.
2. Exercise professional judgment to resolve conflicting information.
3. For information depicted, indicate: utility type and ownership; date of depiction; quality level(s); end points of any utility data; line status (e.g., active, abandoned, out of service); line size and condition; number of jointly buried cables; and encasement.

V. QUALITY LEVEL C TASKS

Tasks leading to QL C include:

A. Inclusive of QL D Tasks.

1. Perform tasks as described for QL D. There is no prescribed order in which QL D and C tasks must be performed.

B. Identification of Surface Utility Features.

1. Identify surface features, from project topographic data (if available) and from field observations that are surface appurtenances of subsurface utilities.

C. Aerial or Ground-Mounted Facilities.

1. Include survey and correlation of aerial or ground-mounted utility facilities in QL C tasks if specified (see "Miscellaneous Tasks").

D. Surveys.

1. Survey surface features of subsurface utility facilities or systems, if such features have not already been surveyed by a registered professional. If previously surveyed, check survey data for accuracy and completeness.
2. The survey shall also include (in addition to subsurface utility features visible at the ground surface): determination of invert elevations of any manholes and vaults; sketches showing interior dimensions and line connections of such manholes and vaults; any surface markings denoting subsurface utilities, furnished by utility owners for design purposes.

E. Confined Space Procedures.

1. Whenever the work requires the entry of personnel into confined spaces (including but not limited to manholes, vaults, and pipes), comply with applicable OSHA (Occupational Safety and Health Administration, U.S. Department of Labor) procedures and requirements.

F. Correlation, Interpretation, and Presentation of Data; Resolution of Discrepancies.

1. Exercise professional judgment to correlate data from different sources, and to resolve conflicting information.
2. Update (or prepare) plan sheets, electronic files, and/or other documents to reflect the integration of QL D and QL C information.
3. Recommend follow-up investigations (e.g., additional surveys, consultation with utility owners, etc.) as may be needed to further resolve discrepancies.
4. As appropriate, amend the indicated quality level of depicted information.

VI. QUALITY LEVEL B TASKS

Tasks leading to QL B include:

A. Inclusive of QL C Tasks.

1. Perform tasks as described for QL C. There is no prescribed order in which QL C and B tasks must be performed.

B. Line Detection and Marking.

1. Select and apply appropriate surface geophysical method(s) to search for and detect subsurface utilities within the project limits, and/or to trace a particular utility line or system.
2. Based on an interpretation of data, mark the indications of utilities on the ground surface, for subsequent survey. Utilize paint or other method acceptable to DOT for marking of lines.
3. Utilize the uniform color code of the American Public Works Association for marking of utilities.
4. Unless otherwise directed, mark centerline of single-conduit lines, and outside edges of multi-conduit systems.
5. Unless otherwise approved, maintain horizontal accuracy of ±1.5 feet (450 mm) in the marking of lines.
6. As an alternative to the physical marking of lines, the Consultant may, with DOT's approval, utilize other means of data collection, storage, retrieval, and reduction, that enable the correlation of surface geophysical data to the project's survey control.

D. Surveys.

1. Survey all markings that indicate the presence of a subsurface utility.
2. Perform surveys to a horizontal accuracy consistent with applicable DOT survey standards. Reference surveys to the project's survey control.
3. If requested, record depth information as may be indicated by the particular detection method used.

E. Correlation, Interpretation, and Presentation of Data; Resolution of Discrepancies.

1. Exercise professional judgment to correlate data from different sources, and to resolve conflicting information.
2. Update (or prepare) plan sheets, electronic files, and/or other documents to reflect the integration of QL D, QL C, and QL B information.
3. Recommend follow-up investigations (e.g., additional surveys, consultation with utility owners, etc.) as may be needed to further resolve discrepancies.
4. As appropriate, amend the indicated quality level of depicted information.

VII. QUALITY LEVEL A TASKS

Tasks leading to QL A include:

A. Inclusive of QL B Tasks.

1. Perform tasks as described for QL B. There is no prescribed order in which QL B and A tasks must be performed.

B. Selection of Test Locations.

1. DOT may require QL A data where the precise horizontal and vertical location of utilities, obtained by exposure and survey of the utility at specific points, is needed for conflict assessment/resolution purposes.
2. The Consultant may recommend test locations based on the requirements of the project and on existing subsurface utility information.

C. Selection of Method.

1. When available, verifiable information on previously exposed and surveyed utilities (such as survey records during utility line construction) shall be furnished in lieu of new excavation, exposure, and survey at that same point, or at a suitable nearby point.
2. Otherwise, when utility lines must be exposed and surveyed at specified locations, the Consultant shall use minimally intrusive excavation techniques, acceptable to DOT, that ensure the safety of the excavation, the integrity of the utility line to be measured, and that of other lines which may be encountered during excavation.
3. DOT intends that excavation shall be by means of air- or water-assisted vacuum excavation equipment manufactured specifically for the purpose, provided, however, that approval of water-assisted vacuum excavation may be subject to additional findings by DOT that such method poses minimal risk of damage to the highway facility or utility lines.

D. Compliance with UNCL Requirements.

1. The Consultant shall comply with all applicable provisions of [State Law] when planning or performing excavations at utility test hole sites.
2. Compliance actions include, but are not limited to: notify owners or operators of underground utility facilities at least two (2) business days prior (not including the day of actual notice) to making or beginning excavations in the vicinity of such facilities; call the UNCL at ____________ for the marking of member utilities; contact non-member utilities directly; coordinate with utility owner representatives as required for inspection or other on-site assistance; immediately cease excavation work and report any resultant utility line damage to owner.

E. Excavation of Test Holes.

1. Clear the test hole area of surface debris.
2. In paved areas, neatly cut and remove existing pavement, which cut shall not exceed 225 square inches (0.15 square meters) unless otherwise approved.
3. Excavate the test hole by the method(s) acceptable to DOT and to the standards set forth herein (see also "Selection of Method" above). The nominal diameter of the test hole shall not exceed 15 inches (375 mm) unless otherwise approved.
4. Expose the utility only to the extent required for identification and data collection purposes.
5. Avoid damage to lines, wrappings, coatings, cathodic protection, or other protective coverings and features.
6. Hand-dig as needed to supplement mechanical excavation and to ensure safety.
7. Revise the test hole location as necessary to positively expose the utility.
8. Store excavated material for re-use or disposal, as appropriate.

F. Collection, Recording, and Presentation of Data.

Measure and/or record the following information on an appropriately formatted test hole data sheet that has been sealed and dated by the Consultant:

1. Elevation of top and/or bottom of the utility tied to the project datum, to a vertical accuracy of ±0.05 feet (15 mm).
2. Elevation of existing grade over utility at test hole.
3. Horizontal location referenced to project coordinate datum, to a horizontal accuracy consistent with applicable DOT survey standards.
4. Field sketch showing horizontal location referenced to a minimum of three (3) swing ties to physical structures existing in the field and shown on the project plans.
5. Approximate centerline bearing of utility line.
6. Outside diameter of pipe, width of duct banks, and configuration of non-encased multi-conduit systems.
7. Utility structure material composition, when reasonably ascertainable.
8. Identity of benchmarks used to determine elevations.
9. Utility facility condition.
10. Pavement thickness and type when applicable.
11. Soil type and site conditions.
12. Identity of utility owner/operator.
13. Other pertinent information as is reasonably ascertainable from test hole.

G. Site Restoration.

1. Replace bedding material around exposed utility lines in accordance with owner's specifications or as otherwise directed or approved.
2. Backfill and compact the excavation in a manner acceptable to DOT. If approved, re-use excavated material with appropriate moisture/density control.
3. Install color-coded warning ribbon within the backfill area and directly above the utility line.
4. As applicable, provide permanent pavement restoration within the limits of the original cut using materials, compaction, and pavement thickness acceptable to DOT.
5. Repair or replace backfill or pavement that fails (i.e., subsidence and/or loss of pavement material) within two (2) years of the original restoration work.
6. For excavations in unpaved areas, restore disturbed area as nearly as practicable to pre-existing conditions.
7. Furnish and install permanent surface marker (e.g., P.K. nail, peg, steel pin, or hub) directly above the centerline of the structure and record the elevation of the marker.

Interpretation of Data and Resolution of Discrepancies.

1. Exercise professional judgment to correlate data from different sources, and to resolve conflicting information.
2. Update plan/profile sheets, electronic files, and/or other documents to reflect the integration of QL D, QL C, QL B, and QL A information.
3. Recommend follow-up investigations (e.g., additional surveys, consultation with utility owners, etc.) as may be needed to further resolve discrepancies.
4. As appropriate, amend the indicated quality level of depicted information.

Abbreviations used without definitions in TRB publications:

AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation