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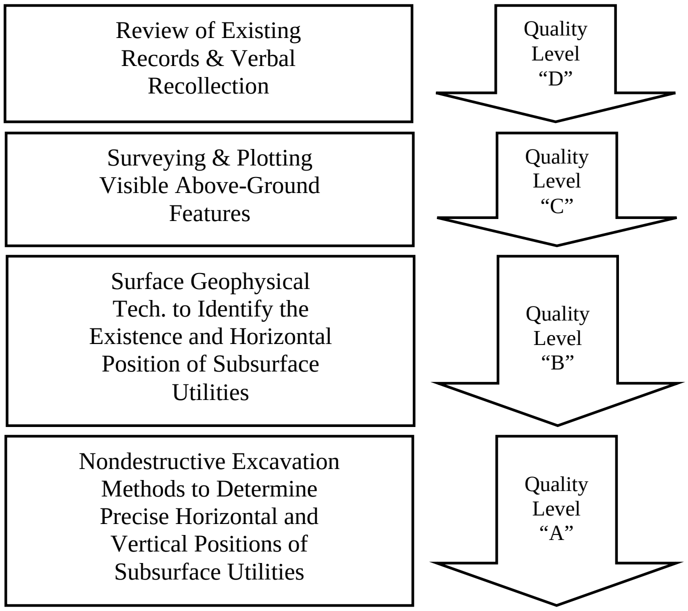

PENNDOT

SUBSURFACE UTILITY ENGINEERING MANUAL

PennDOT/MAUTC Partnership, Work Order No. 8
Research Agreement No. 510401

FINAL REPORT

August 20, 2007

By S. K. Sinha, H. R. Thomas, M. C. Wang and Y. J. Jung

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16. Abstract
This report presents the results of a 12-month study that investigated the challenges and opportunities facing SUE in PennDOT highway projects. The study took an in-depth analysis of ten SUE projects executed by PennDOT districts. Based on this analysis, a decision matrix tool to determine which projects should include SUE and the appropriate level of SUE investigation to be used has been developed. A detailed cost-benefit analysis was also performed on these ten SUE projects. All of the projects showed a strong relationship between SUE benefit-cost ratio and buried utility complexity level at the project site. The analysis clearly showed that there is no relationship between SUE benefit-cost ratio and project cost and also no relationship between buried utility complexity level and project cost. The conclusion of this research is that SUE quality levels A and B should be used based on the complexity of the buried utilities at the construction site to minimize associated risks and obtain maximum benefits.

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Submitted to

Pennsylvania Department of Transportation
Bureau of Planning and Research

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Section 1.

Executive Summary

The Pennsylvania Department of Transportation (PennDOT) contracted Penn State to study the effective use of Subsurface Utility Engineering (SUE) for highway construction projects. The PennDOT districts have considerable autonomy over the use of SUE, design, construction, procurement, and many other issues. Thus, the use of SUE is not uniform across the state, and on some projects SUE may not be effectively used. What is needed are project site-specific procedures that can be used by the Central Office to encourage all districts to make wider use of SUE and the means of conveying the details of damage prevention best practices so that the effective use of SUE can be made.

Previous studies and reports of cost savings have been performed and reported by various state DOTs, NCHRP, FHWA, University of Toronto, and Purdue University. The objective of the Penn State study was to develop a Subsurface Utility Engineering Manual for PennDOT to assist the department and consultant designers, utility relocation administrators, and others in identifying the appropriate levels of investigation needed to locate and designate existing buried utilities. The SUE Manual describes the geophysical and other technologies used to locate subsurface utilities in various geologic and ground cover conditions in Pennsylvania and identifies the most beneficial means of subsurface investigation and the cost of the investigation. Ten SUE projects were selected to be part of this study. These projects were selected randomly from a list of projects that utilized SUE. They involved a mixture of state routes in urban, suburban, and rural settings and environments. PennDOT district utility managers and engineers, consultants, utility owners, designers, and project managers were interviewed.

This report presents the results of a 12-month study that investigated the challenges and opportunities facing SUE in PennDOT highway projects. The study undertook an in-depth analysis of 10 SUE projects executed by PennDOT districts. Based on this analysis, a decision matrix tool to determine which projects should include SUE and the appropriate level of SUE investigation to be used was developed. A detailed benefit-cost analysis was also performed on these 10 SUE projects. All of the projects showed a strong relationship between SUE benefit-cost ratio and buried utility complexity level at the project site. The analysis clearly indicated that there is no relationship between SUE benefit-cost ratio and project cost and also no relationship between buried utility complexity level and project cost. The conclusion of this research is that SUE quality levels A and B should be used based on the complexity of the buried utilities at the construction site to minimize associated risks and obtain maximum benefits.

Section 2.
Introduction and Background

This section provides a better understanding of the SUE concept. The one-call system, a traditional practice for locating underground utilities, is reviewed to identify current problems, and then SUE is presented as a solution. In addition, previous research studies on SUE are reviewed.

2-1. Introduction

Nearly 20 million miles of underground pipelines, cables, and wires in the United States have been built since World War II and designed for lifetimes of 20-50 years (Sterling 2000). Increasing demand on U.S. utilities has been projected along with the deterioration of underground utilities, and larger demands for utility services have underscored the necessity of numerous utility construction projects. However, the expansion of underground infrastructure projects has resulted in damages to existing buried utilities that might cause increased construction costs, construction delays, fatal injuries or even deaths of workers, outages of facility service, and other social and environmental problems. The damage to underground utilities has been identified as one of the most dangerous problems for the construction industry. Doctor et al. (1995) reported that the number of U.S. utility damages in 1993 was more than 104,000; hits and third-party damages to gas pipelines exceeded $83 million of the total cost. Nelson and Daly (1998) stated that damages to U.S. West cable exceeded 2,000 hits in one month and averaged over 1,000 hits per month. In March 1999, a telephone utility hit cut off service for 12,000 customers in Colorado. In general, statistics of reported damages could be underreported because social and environmental costs due to utility damage are not always properly quantified. Heinrich (1996) stated that an accident cost reported as $15,000 was actually closer to $313,000, almost 20 times higher. The American Institute of Constructors (AIC) identified that damage to underground utilities was the third most important crisis for contractors (Reid 1999). Therefore, damage prevention to underground utilities is one of the most critical issues for successful projects.

The design of underground utility projects has traditionally relied on existing records or a one-call system. However, existing information on underground utilities is often incorrect, incomplete, and inadequate in as-built drawings and composite drawings, which incorporate all of the utility records for different owners. Existing records and visible-feature surveys by site visit are typically 15%-30% off the mark and sometimes considerably worse (Stevens and Anspach 1993). To overcome the limitations of using existing records, a one-call system was developed as an organized effort. The one-call system is a state-regulated program that requires utility owners to mark the location of their utility on the ground surface around any proposed excavation area; however, the information provided by the one-call system is not enough to locate underground utilities. Sterling (2000) reported that 56% of the damages to gas pipelines in 1995 were caused under the one-call system, and there are several inadequacies of current one-call systems now in use by the industry. As a more systemic damage-prevention concept for underground utilities, subsurface utility engineering (SUE) was introduced about two decades ago. SUE is an engineering process that utilizes new and existing technologies to accurately identify, characterize, and map underground utilities early in the development of a project. The employment of SUE allows not only more effective damage prevention but also more successful underground projects. The objective of this document is to present a benefit-cost analysis of SUE and a decision-making tool for appropriate selection of SUE quality level. Additionally, this report provides factors affecting the accuracy of SUE. The results can help contractors and designers plan their own subsurface projects with more accurate underground information and enable engineers to work in safer construction conditions.

2-2. One-Call System

The one-call system is a damage prevention program regulated by state law. There is at least one one-call center in every state and in the District of Columbia. The one-call system is operated by funds of members consisting of public utilities and other underground facility owners/operators. The one-call system starts with a call from a contractor, designer, or other person who is preparing a project that requires an excavation. The call usually should be made at least 2 or 3 working days before starting the excavation. After receiving a request call, the one-call center identifies potential utility conflicts and notifies facility owners/operators around the proposed site. When the facility owners/operators receive the notification from the one-call center, crews for locating the facility are sent to the site to mark the location of their underground utilities on the ground surface with above-ground APWA (American Public Works Association) color-coded markings, shown in Table 2-1 (Jeong et al. 2003). After all utilities are marked on the ground surface, the excavation can be started. The completion of locating work should be reported back to the one-call center.

The one-call system is obviously a cornerstone for damage prevention of underground utilities; however, the one-call system is not perfect. Accidents still happen. The one-call system just deals with the information on buried utilities that the members of the system provide. In other words, information on existing utilities of many non-members is not available in the one-call system. In addition, sometimes existing facility owners/operators are notified by the one-call center incorrectly or even fail to mark their utility location. Old utilities that remain active may not be discovered under the one-call system, and timing of locations relative to actual construction also can be a problem of the system. Sterling (2000) stated that many contractors do not use the one-call system because of the above-mentioned problems. Therefore, the current one-call system should be enhanced with more advanced systems for safer excavation.

Table 2-1. APWA (American Public Works Association) Color Code.

Color	**Explanation**	**Color**	**Explanation**
Red	Electric Power, Cable, Lighting	Yellow	Gas, Oil, Petroleum, Steam
Orange	Communication, Alarm, Signal	Blue	Water
Green	Sewer, Drain	Purple	Reclaimed Water, Irrigation
Pink	Temporary Survey Marking	White	Proposed Excavation

2-3. Subsurface Utility Engineering (SUE)

SUE is an engineering process that utilizes new and existing technologies to accurately identify, characterize, and map underground utilities early in the development of a project. The concept of SUE was introduced in the 1970s by Henry Stutzman to accurately locate subsurface utilities and record the underground information to increase safety and reduce economic loss in the project planning phase. The concept of SUE was developed and systematically put into professional service in the 1980s (Jeong et al. 2004). The County of Fairfax, Virginia, had a contract with So-Deep, Inc., for locating underground utilities in 1982. This was the first governmental SUE contract in the United States. In 1989, the term “subsurface utility engineering” was introduced to the world at the first National Highway/Utility Conference in Cleveland, Ohio.

The Federal Highway Administration (FHWA) and state departments of transportation (DOTs) have been promoting the use of SUE. FHWA requested proposals for educational and training materials and procurement of guidelines for SUE in 1994. The American Society of Civil Engineers (ASCE) established the first national standards for SUE. Today, SUE has been used for mitigating risks due to uncertain underground information for FHWA, state DOTs, and many agencies, as well as engineering companies. SUE is still growing as a significant tool as project owners demand higher quality levels of construction.

2-3-1. SUE Practices in Departments of Transportation

According to Jeong's research in 2004, 22 states in the United States have utilized the SUE program on their highway projects. Eight states reported that they considered a pilot project for the use of SUE in the past. The average annual budget for the SUE program in the states was about $1.5 million in 2000, $1.7 million in 2001, and $2 million in 2002. The average annual amount of budget spent on the SUE program increased as much as 135% from 2000 to 2002. No states presented a decrease in their SUE budget during this period. Texas spent more than $6 million annually as the most active state in encouraging the use of SUE for highway projects. Every highway project in Virginia, which has the longest history of the use of SUE, is required by state regulation to use SUE. Delaware, Maine, Maryland, North Carolina, Texas, and Pennsylvania have utilized SUE for all or most of their highway projects and utility projects. The other states often use SUE based on its usefulness.

The common criteria for applying SUE for projects are: (1) urban highway projects and utilities with a high potential of expected utility conflicts; (2) underground utility projects with congested utility networks and high potential of utility relocations; (3) projects with limited, narrow, and congested right-of-way; and (4) highway projects that have tight schedules. State DOTs with a SUE program have various decision-making processes to determine projects for utilizing the

SUE. A project manager and a designer can make the decision to employ SUE, or local utility agents can be involved in the decision. The central office of the state DOT can also make the decision directly.

Current qualification guidelines for selecting SUE consultants are inconsistent. A SUE consultant for projects related to utilities was typically selected with the consideration of past experience of the SUE consultant, availability of key personnel, ability to perform the project, and prior work experience with the DOT. Based on FHWA (2002), SUE consultants must be able to provide sufficient knowledge of designating, location, surveying, and data management activities, be well trained and experienced engineers, possess adequate equipment and systems for SUE activity, and have the financial capacity to provide the required services. The ability to provide the required accuracy of SUE services and adequate insurance are also important for SUE consultants (Jeong et al. 2004).

2-3-2. SUE Practices in the Private Sector

According to Jeong's research in 2004, the majority of SUE consultants had been in business less than 10 years; approximately 19% had 10 to 15 years of experience, and 14% had more than 15 years of experience. It is a relatively young industry, since SUE started to be applied for detecting underground utilities in the early 1980s. Seventy-nine percent of SUE consultants had annual sales of less than $5 million in 2001. These consultants can be characterized as small SUE companies; they employ less than 50 people, and their geographical domain is normally regional. Sixteen percent of them have annual sales of between $6 million and $10 million. Typically, among large companies involved in nationwide SUE, 5% of them have annual sales of more than $10 million and over 100 employees. The annual sales per employee increase as the size of the company increases. Small companies generate an average of $60,063 per employee in a year. In contrast, the large firms create sales of more than $100,000 per employee.

The growth rate of the SUE industry from 1997 to 2001 ranged from 115% to 276%, averaging 173%. The main reasons for the rapid growth include the benefits of cost saving and avoiding utility damage, as well as the growth of underground construction in urban areas, utility rehabilitation, and replacement (Jeong et al. 2004). In SUE consultants, technicians for fieldwork, who are in charge of designating, locating, and surveying tasks and collecting data for utility properties, comprise 69% of the total employees, and project engineers, who typically manage all the SUE projects in a specific region, comprise 16%. Other engineers for data management systems comprise 13% of SUE consultants. About 3% of employees are geophysicists who investigate underground information.

The main purpose of SUE is to provide sufficient and accurate information related to utilities for successful projects. The interpretation of different site environments, such as soil conditions, pipe material, joint type of pipe, and depth of utility requires the expertise of a geophysicist for the proper use of geophysical techniques to detect underground utilities. The low number of geophysicists employed in SUE companies is a growing concern in the industry (Jeong et al. 2004). More than half of the projects undertaken with SUE consultants are for state DOT and federal agency projects (55%). Sixteen percent of the clients are institutions and military and industrial facility projects. Engineering firms comprise 11%, and the other clients include municipalities (11%), utility companies (4%), and construction companies (3%).

For SUE projects, it is common for owners to contact SUE consultants and negotiate the terms of a contract. Even though there are some projects performed under the competitive bidding process, the bidding tends to be avoided in the SUE industry because it allows the service to fall below the necessary quality level. Strategic alliances are usually used in state DOT contracts. Under such an alliance, the owner can obtain a consistent level of underground utility information provided by a qualified SUE consultant. These alliances extend over a period of 2 or 3 years.

The most common type of contract used in the SUE industry is the cost-plus-fee contract (42%), and the daily rate contract comprises 14%. State DOTs and federal agencies, which form more than half of the SUE clients, prefer the cost-plus-fee contract since they have the resources to audit and do cost analyses. This type of contract allows SUE consultants to make a reasonable profit, but the major disadvantage of the cost-plus-fee contract and daily rate is the difficulty in proper budgeting and the provision of fewer incentives for SUE providers to work efficiently.

Unit price and lump sum contracts comprise 32% and 12% of SUE contracts, respectively. In unit price contracts, the project owners can control the budget effectively, and SUE consultants are encouraged to optimize their available resources to provide high-quality services. However, if the SUE consultants are not familiar with the site environment, this method may negatively affect the profit of SUE consultants or the quality of final deliverables. The key advantage of the lump sum contract is the ease in budgeting for project owners, but it may be difficult to obtain high-quality final deliverables (Jeong et al. 2004).

2-3-3. Quality Levels of SUE

To understand the concept of SUE, it is necessary to define the quality levels of underground information that is available to the designers, contractors, and owners (Anspach 1994). Quality levels are divided into four levels with different combinations of traditional record, site survey, geophysical technology, and air-vacuum technology. The accuracy and reliability of underground information by survey increase from quality level D to quality level A. The cost of the survey also increases from quality level D to quality level A. Quality level D is the most basic level of information. Information is obtained from the review of existing utility records and verbal accounts to determine the approximate location of existing underground utilities. Quality level D information has limitations of accuracy and comprehensiveness because utility records are usually insufficient and incorrect. Quality level C includes the information of quality level D and a site survey for surface-visible features such as fire hydrants and manholes. Professional judgment is needed to prove the estimated location of underground utilities in relation to the surveyed features. Utility information of quality level B is obtained using appropriate geophysical technologies.

Quality level B is called “designating” and involves the information of quality levels D and C. Underground utilities are identified by interpretation of received signals generated either actively or passively. The horizontal location can be determined and mapped by using quality level B. However, the depth of utilities is not available with quality level B. Utility information of quality level A is provided by actual exposure of underground utilities. This quality level is called “locating” and involves the information of quality levels D, C, and B. The vacuum-excavation system has been used as a leading method for quality level A because of its minimally intrusive nature. Exposing the utility at critical points provides the most accurate and reliable underground information vertically and horizontally. Visual inspection by exposing utilities can be used to verify material type of utility, depth of utility, soil condition, and other underground information and assess the condition of underground utilities. Figure 2-1 describes the quality levels of SUE.

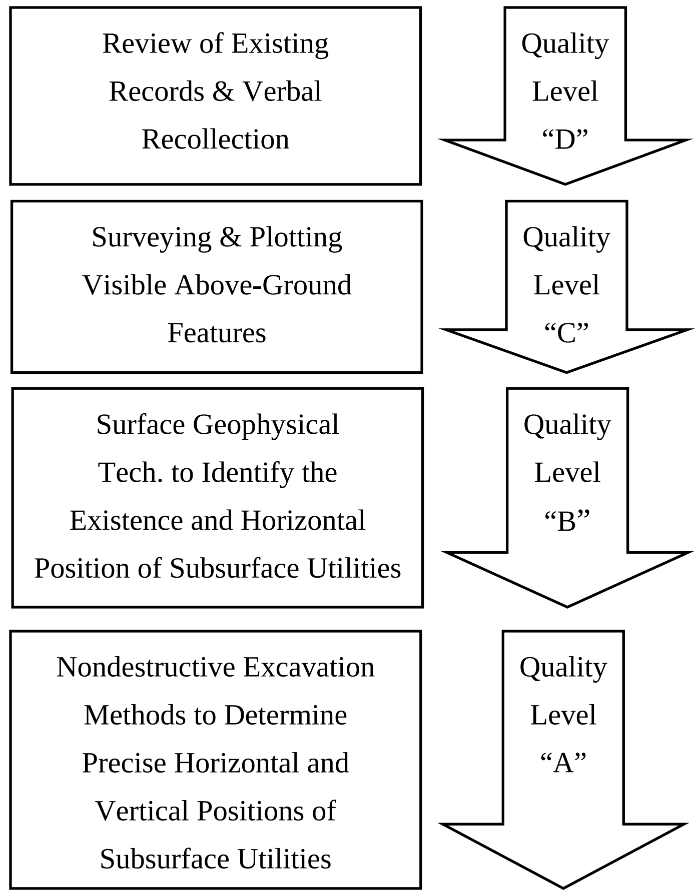

Figure 2-1. Quality Levels of SUE.

It is important to determine which quality level must be selected for a given project. If the owner wants to use lower-quality information in a congested urban area, the owner must be willing to pay for the associated costs in change order, utility damage, and other unexpected problems (Lew 2000). In contrast, the owner does not need to select expensive quality level A for a green field. Therefore, the decision and judgment for selecting the appropriate quality level for the project should be made by benefit-cost analysis with site location, sufficient knowledge of geophysical technologies, and various factors affecting the survey.

2-4. American Society of Civil Engineers (ASCE)

The ASCE published the first national standard in 2002, titled "Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data," called CI/ASCE 38-02. ASCE defines SUE as 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 polices, and utility design. The guideline was developed for use as the basis of the scope of work for utility mapping, planning, design, and construction. The guideline presents a system to classify the four quality levels of SUE according to typical tasks of engineers. The quality levels range from quality level D to quality level A. Quality level A provides the highest level of information, but the cost is also high, so the appropriate quality level for the project should be selected with input from SUE consultants. This guideline describes how subsurface information of SUE quality levels is collected and shows how the information is depicted on design plans, with three examples.

This guideline is organized with eight sections and one appendix. The sections include introduction, scope, definition, engineer and owner collection and depiction tasks, utility quality level attributes, deliverables formatting, relative costs and benefits of quality levels and information sources. The appendix identifies geophysical techniques that are used to designate subsurface utilities in quality levels A or B and describes how each geophysical technique works. This guideline allows the project owner, engineer, constructor, and utility owners to prepare plans to reduce risks with reliable subsurface information that is provided through quality levels of SUE.

2-5. American Association for State Highway and Transportation Official (AASHTO)

Right-of-Way and Utilities Guidelines and Best Practices, prepared by the Subcommittee on Right of Way and Utilities of The American Association of State and Highway Transportation Officials (AASHTO, 2004), Chapter 7, titled "Utilities," recommends that SUE be incorporated into project planning, design, and construction. The first guideline in Chapter 7 is for using current available technology to the greatest extent possible. The guideline states that utilities should be depicted at appropriate quality levels on all highway plans, and that SUE information on utilities should be collected early in the development of all highway projects. It also encourages the FHWA to continue its support of SUE. The FHWA's efforts, such as documenting cost savings of SUE, demonstrating benefits of SUE, allowing federal funds to be used for SUE, and encouraging the use of SUE, has proven helpful to state DOTs that are trying to establish and maintain SUE programs.

AASHTO recommends that state DOTs keep good records of cost and time savings because this information is often beneficial for justifying the use of SUE. For instance, the FHWA study titled "Cost Savings on Highway Projects Utilizing Subsurface Utility Engineering" (2000) is widely used to introduce and encourage the use of SUE in evaluating cost savings. AASHTO also supports the efforts of ASCE in developing a standard guideline to present a system for classifying the four quality levels of SUE. AASHTO states that all state DOTs should comply with the requirements in ASCE standard guidelines for their projects.

2-6. Federal Highway Administration (FHWA)

The FHWA expanded on AASHTO's guidelines in a 2002 FHWA report titled "Avoiding Utility Relocations." The intent of the report was to encourage highway designers to avoid unnecessary utility relocations in the design stage. The report describes the value of avoiding relocations on highway projects and the technologies that can be used to avoid relocations. It also describes the successful processes being used in the planning, design, and construction phases that support coordination and reduce conflict among owners. In this report, SUE is one of the key conclusions and recommendations for avoiding relocations because SUE can identify the presence and exact location of underground utilities, as well as other data that can be provided by exposing utilities. The report states cost and time savings of SUE by referencing other research.

Avoiding utility relocations also highlights the importance of early communication and cooperation among utilities and state DOTs. SUE allows highway designers to explore highway alignment alternatives prior to project design to avoid utility relocations. Even if a given relocation cannot be avoided, efficient relocation work can be conducted to reduce unnecessary delay through early and frequent coordination, cooperation, and communication.

The strategies for coordination, cooperation, and communication (CCC) are explained in the 2002 video available from the FHWA, *CCC: Making the Effort Works!* The video presents the efforts of such states as Georgia, Maryland, and Wisconsin to improve CCC between state DOTs and utility companies. The CCC also outlines ways that state DOTs can reduce unexpected utility conflicts, minimize costs, and increase construction productivity. The FHWA states that enhanced coordination, cooperation, and communication between state DOTs and utility companies and the utilization of accurate, comprehensive information provided by using SUE make it possible for designers to make relatively minor relocations and design around many utilities that traditionally would have been relocated.

2-7. General Accounting Office (GAO)

The General Accounting Office (GAO) developed a report in 1999 titled, *Transportation Infrastructure: Impacts of Utility Relocations on Highway and Bridge Projects*. The goal of this report was to assess the effects that utility relocations are having on the delivery and cost of highway and bridge projects. It examined the following: (1) the extent to which states are experiencing delays and the causes and impacts of the delays; (2) the number of states that are compensating construction contractors for increased costs incurred by untimely relocations of utilities; (3) available technologies, such as SUE, that are being used for project design to reduce the number or impact of delays caused by utility relocations; and (4) mitigation methods that states are using, such as incentives, penalties, and litigation, to encourage or force the cooperation of utility companies. To reach the goal, a questionnaire was sent to state DOTs and the District of Columbia. GAO states that although the FHWA recommends SUE as a means of using new and existing technologies to accurately identify, characterize, and map underground utilities, many states do not yet use the engineering process on half or more of their projects. The report describes that having SUE information early in the design process offers project designers the ability to redesign projects to avoid conflicts with existing utilities.

2-8. Purdue Study

A study titled "Cost Savings on Highway Projects utilizing Subsurface Utility Engineering," which the FHWA commissioned Purdue University to perform in order to estimate the cost savings of SUE on highway projects, was presented in 2000. Purdue University developed 21 categories to quantify the savings in terms of time, cost, and risk management after interviewing and surveying DOTs, utility owners, SUE consultants, and contractors. Table 2-2 shows categories of SUE cost savings. Four states—Virginia, North Carolina, Ohio, and Texas—were selected to provide their SUE projects. The study analyzed 71 SUE projects through studying projects in detail, interviewing personnel involved in the projects, and applying historical cost data. True qualitative costs, which may be significant to the real cost savings, are not included in the estimation.

Table 2-2. Categories of SUE Cost Savings of Purdue Study.

Number	Description
1	Reduction in unforeseen utility conflicts and relocations
2	Reduction in project delays due to utility relocates
3	Reduction in claims and change orders
4	Reduction in delays due to utility cuts
5	Reduction in project contingency fees
6	Lower project bids
7	Reduction in costs caused by conflict redesign
8	Reduction in the cost of project design
9	Reduction in travel delays during construction to the motoring public
10	Improvement in contractor productivity and quality
11	Reduction in utility companies' cost to repair damaged facilities
12	Minimization of utility customers' loss of service
13	Minimization of damage to existing pavements
14	Minimization of traffic disruption, increasing DOT public credibility
15	Improvement in working relationship between DOT and utilities
16	Increased efficiency of activities by eliminating duplicate surveys
17	Facilitation of electronic mapping accuracy
18	Minimization of the chance of environmental damage
19	Inducement of savings in risk management and insurance
20	Introduction of the concept of a comprehensive SUE process
21	Reduction in right-of-way acquisition costs

The result of this study shows a total of \$4.62 in savings for every \$1.00 spent on SUE. The range was from \$0.34 to \$206.67. The \$4.62 savings figure has been widely cited whenever the benefits of SUE are discussed. The study concluded that SUE is a viable technology that reduces project costs related to the risks caused by inaccurate underground information. It also describes that when used in a systemic manner, SUE should result in significant quantifiable and qualitative benefits and a minimum national savings of approximately \$1 billion per year.

2-9. Toronto Study

In 2005, the University of Toronto presented a study commissioned by the Ontario Sewer & Watermain Contractors Association. It investigated nine infrastructure projects that used SUE in Ontario through interviews with project owners and contractors and project case studies with drawings. This study used 11 cost-saving items, a reduction from the 21 cost-saving items identified by the Purdue study. Table 2-3 presents the 11 cost-saving items. The study's report includes detailed documentation of the qualitative or quantitative costs and benefits of using SUE in the nine projects. The study highlights the important characteristics of projects that could make the SUE investigation a worthwhile investment and encourage better understanding of SUE benefits. The result of the study shows that the average Return-on-Investment (ROI) for SUE is approximately $3.41 for each $1 spent. The ROI varied considerably across the projects, ranging from $1.98 to $6.59. This study indicates that with careful scoping of SUE services, project risks can be appropriately reduced at a reasonable cost. It concludes with possible improvements to the SUE process and recommendations indicated by various SUE project participants in Ontario, and with an industry survey that identifies how inaccurate utility information affects project outcomes.

Table 2-3. Categories of SUE Cost Savings of Toronto Study.

Number	Description
1	Design Cost
2	Utility Relocation Cost
3	Savings to Overall Construction Cost
4	Contractors Contingency Cost
5	Contractor Claims & Change Order Cost
6	Construction Personnel Injury Cost
7	Public Injury Cost
8	Utility Damage Cost
9	Travel Delay Cost
10	Business Impact Cost
11	Service Interruption Cost

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Section 3.

Scope of Work

3-1. Work Order

Subsurface Utility Engineering Manual

3-2. Problem Statement

The Pennsylvania Department of Transportation has one of the largest construction programs in the United States. Like many state DOTs, PennDOT is decentralized. This means that the situation in many respects is like dealing with 11 smaller DOTs (district offices), rather than one DOT at the central office. The districts in Pennsylvania have considerable autonomy over the use of SUE, design, construction, procurement, and many other issues. Thus, the use of SUE is not uniform across the state, and on some projects SUE may not be effectively used. What is needed are project site-specific procedures that can be used by the central office to encourage all districts to make wider use of SUE, and means of conveying the details of damage prevention best practices so that effective use of SUE can be made.

3-3. Project Objective

The objective of this project was to develop a Subsurface Utility Engineering (SUE) Manual for PennDOT to assist department and consultant designers, utility relocation administrators, and others in identifying the appropriate levels of investigation needed to locate and designate underground utilities. The SUE Manual describes the geophysical and other technologies used to locate subsurface utilities in various geologic, environmental, and ground-cover conditions in Pennsylvania and identifies the most beneficial means of subsurface investigation and the cost of the investigation. The manual also incorporates the *ASCE Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data*.

3-4. Project Tasks

In the preparation of the Subsurface Utility Engineering Manual for highway projects, the following research tasks were performed:

The first task was to quantify the benefits of SUE in the Commonwealth of Pennsylvania. In this task, 10 SUE projects executed by various PennDOT districts were selected to determine the cost savings. During the selection process, survey questionnaires were sent to districts followed by telephone interviews. The selected districts were visited to obtain the information and discuss the details of the projects with district engineers involved in the SUE projects. The collected information/data were then used to perform the benefit analysis.

The second task for this research work was to define factors that affect the accuracy of SUE. Various factors that may affect the accuracy of SUE were identified through the literature study and discussion with the district engineers. The degree of influence of each factor was evaluated based upon the experience of the personnel involved in the SUE projects.

Developing a decision matrix tool was the third task for this project. A decision matrix tool was developed to determine the utility complexity level and to determine which projects should utilize the appropriate quality level of SUE.

The fourth task was to prepare the SUE manual, which will cover the following major components:

1. Definition of SUE
2. Current standards from ASCE 38-02
3. Decision matrix tools
4. Benefit-cost analysis
5. Tables and forms for determining whether SUE is needed and the quality level of SUE

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Section 4.

Geophysical Techniques and Factors Affecting Accuracy of SUE

This section describes various geophysical techniques and non-destructive methods for locating underground utilities within the limitations of available geophysical techniques. Many factors affecting the geophysical techniques also are presented.

4-1. Geophysical Techniques

Geophysical techniques are non-invasive technologies used to image subsurface conditions in the earth through measuring, analyzing, and interpreting physical properties. Every geophysical technique depends upon the ability to identify contrasts in subsurface materials that include various properties: dielectric constants, ability to transmit acoustic energy, and other abilities (Fenning and Hansan 1993). These techniques have been applied to locating underground utilities in civil engineering. In typical applications of geophysical techniques, a form of energy is transferred into the earth, and the energy reflected from underground utilities or objects is measured, analyzed, and interpreted to identify the location of the utility (Jeong and Abraham 2004). However, no single geophysical technique can work well in all of the different site conditions and with all of the various properties of underground utilities or objects. The use of multiple techniques may yield the best possible target information.

4-2. Various Geophysical Techniques for Designating Underground Utilities

There are various geophysical techniques available for obtaining quality level B information, which is also called designation, to acquire data regarding two-dimensional locations of underground utilities. It is important for designers or engineers to be familiar with various geophysical techniques for the successful designation of underground utilities.

4-2-1. Pipe and Cable Locator

The pipe and cable locator is electromagnetic equipment that utilizes electromagnetic waves to locate buried pipes and cables. The equipment is composed of a transmitter, a receiver, and other components such as connecting cables, batteries, signal generator, and speaker, among others. Both the transmitter and the receiver are very portable. The electromagnetic energy generates the magnetic fields around the buried electrically conductive material, and the receiver captures the magnetic field, which is used to produce a visual or audible indication of the horizontal location of the utility (Jeong and Abraham 2004). Most pipe/cable locators have the ability to "induce" a signal onto an object using a transmitter, and the object must be metallic in order to conduct the signal. Pipe/cable locators typically come with a receiver and a transmitter, depending on the model. Some models come with a portable, pocket-sized transmitter with limited features, and some are equipped with standard transmitters that are built into a hard case and offer more features for varied situations.

The pipe and cable locator is the most widely used method for quality level B of SUE. At least 70% of utility-designating data have been created from pipe and cable locators, with other methods used to verify the information or for situations where the pipe and cable locator provides poor information (Noone 2004). Frequencies from 50 to 480 kHz are usually used for successful utility searches. As the frequency becomes higher, the range available for utility designation decreases, but relatively smaller objects can be found with high frequency within an effective range.

In general, the available depth of this method is 15 ft (ASCE 2002). The pipe and cable locator works well for metallic utilities, utilities that have tracing materials installed above the utility, and utilities that have spaces for a metallic conductor or transmitter inserted into the utility. The major shortcoming is that non-metallic utilities without the aforementioned condition cannot be detected with this method. A crew size of 1 or 2 people can locate underground utilities with the pipe and cable locator.

4-2-2. Ground Penetrating Radar (GPR)

GPR is an electromagnetic method that detects interfaces between subsurface materials with differing dielectric constants (Anderson et al. 2003). Microwave pulses are transmitted into the ground from an antenna, and any incoming reflections are monitored at the receiver and passed on to a computer to depict a continuous graphic profile of the subsurface strata. Reflecting surfaces appear as bands on the profile. The result of the GPR survey is affected by the frequency of the microwave (10 to 1,000 MHz), dielectric constants, and conductivity of the soil (ASCE 2002). Depth of the GPR survey is highly site specific and is limited by signal attenuation, which is dependent on the electrical conductivity of the subsurface materials. Signal attenuation is greatest in soils with high electrical conductivity such as clays, saturated sands, and tidal areas where salt is prevalent because the high conductivity transforms the electromagnetic energy into heat. On the contrary, the signal attenuation is lowest in soils with relatively low electrical conductivity, such as unsaturated sand or rock.

In general, the maximum penetration depth of a GPR signal in clay is less than 3 ft. Survey depth is also dependent on antenna frequency. The depth increases with decreasing frequency, and while the higher frequency cannot penetrate as deep into the earth as the lower frequency, the higher frequency can detect utilities with smaller diameters and provide high spatial resolution and target definition. The main benefit of GPR is its ability to image metallic and non-metallic utilities since the signal is reflected from any changes in all three electromagnetic characteristics of dielectric constant, conductivity, and magnetic permeability. GPR also provides subsurface information while rapidly surveying large areas with minimum interference to traffic. The major shortcoming of GPR is its highly limited usability. Restricted applicable soil conditions and low penetration depth restrict the use of GPR. Even in ideal conditions such as dry sand, GPR is not effective in detecting utilities at depths greater than 15 ft (ASCE 2002).

4-2-3. Terrain Conductivity Survey

A terrain conductivity survey uses the difference in conductivity between buried underground utilities and the surrounding soil. The transmitter of a terrain conductivity system introduces eddy current into the ground, and the eddy current is reflected once it meets underground utilities that have different conductivities from the surrounding soil. The receiver measures and analyzes the reflected currents to detect underground utilities. In general, buried metallic utilities have lower conductivity than the surrounding soil (Jeong and Abraham 2004).

This method is not useful in utility-congested areas because there is too much noise to interpret the result. Discrete metallic utilities, storage tanks, wells, and vault covers are usually detectable with this method. Under some ideal conditions, terrain conductivity surveys can detect large non-metallic pipelines. This method works well in conductive areas, and the effective maximum depth is 15 ft (ASCE 2002).

4-2-4. Resistivity Survey

The resistivity survey works by introducing DC current into the ground through two or more electrodes and measuring the resulting voltage difference between another pair of electrodes. The electrode pairs are moved along a surveyed line, and the electrical measurements result in a horizontal profile of apparent resistivity. The subsurface resistivity is calculated by knowing the electrode separation and geometry of the electrode position, applied current, and measured voltage. Different electrode spacings change the effective depth of measurement. The length of electrodes is about 10 times the depth of the measurement.

Resistivity methods may be useful for a utility search but not a utility trace (ASCE 2002). This method works well in resistive areas. In general, most soils are electrical insulators (highly resistive), but they become less resistive as moisture or water content in soils increases.

4-2-5. Metal Detector

A metal detector starts by transmitting an AC magnetic field, which induces eddy currents in nearby metallic utilities within instrument range. These eddy currents produce a secondary field in the metallic utilities, which interacts with the primary field. The search coil in the receiver captures the difference in the magnetic fields. The most important factors influencing the result of the metal detector include the properties of the target, properties of the soil, target size, and depth. Most metal detectors are limited to depths near the ground surface. In general, the effective depth is only 2 ft for utility designation (Jeong and Abraham 2004); however, some metal detectors are better than pipe and cable locators for detecting small-diameter metallic utilities within the effective depth. Metal detectors sensitively respond to both ferrous and non-ferrous metal objects such that noise can be caused by nearby fences, vehicles, buildings, concrete reinforcement rebar, metallic debris, etc. In addition, metal detectors may react to high concentrations of natural iron-bearing minerals, salt water, acids, and other highly conductive fluids. These may result in ground noise and a false signal reading by the metal detector.

4-2-6. Magnetic Survey

Magnetometers can be used to detect buried ferrous metallic objects such as pipelines and tanks with contrasting magnetite content. By detecting anomalies in the earth's magnetic field caused by ferrous metallic utilities, the magnetometer provides underground information for utility designation. The response is proportional to the mass of the buried ferrous metallic utilities. In general, the effective maximum depth is 10 ft. The intensity of the magnetic field can change on a daily basis in response to solar magnetic storms and ionospheric conditions.

Two basic types of magnetometers are commonly used: a proton magnetometer for total field measurement and a fluxgate magnetometer for gradiometric measurement. In the proton magnetometer, an excitation voltage is applied to a coil around a container filled with a proton-rich fluid such as kerosene. The field reorients the protons in the fluid, allowing for measurement of a nuclear precession frequency, which is proportional to the strength of the field. The proton magnetometer measures the earth's total field intensity, which reveals the existence of ferrous metallic utilities. It can be useful for utility designation in wide areas, but power lines, railroads, vehicles, etc., can interfere with the total field measurement. In the fluxgate magnetometer, the different intensities of the magnetic field are captured by two sensors separated in a known distance. The sensors consist of an iron core that undergoes changes in magnetic saturation in response to variations in the earth's magnetic field.

The fluxgate magnetometer is easier to use and more useful for utility designation than the proton magnetometer. In addition, this reduces interference from solar magnetic storms and regional magnetic changes. It is typically effective to detect isolated shallow ferrous metallic utilities, underground storage tanks, wells, and vault covers, and magnetized non-metallic fiber optic cables and cast iron pipes also can be detected with this magnetometer (Jeong and Abraham 2004).

4-2-7. Acoustic Survey

The acoustic survey generally works through capture of utility noises by the receiver. The noises are loudest directly over the utilities because the noise travel distance is the shortest. However, utility noises are often interfered with by existing noises such as aircraft, vehicles, trains, electrical transformers, and so forth. In addition, the type of ground surface, soil compaction, moisture, and utility material affect the noise distribution.

Typically, there are three types of acoustic emissions: active sonics, passive sonics, and resonant sonics. In the active sonic method, a transducer, which is connected to the surface appurtenance of the underground utility, introduces sound waves (typically 132 to 210 Hz) into the utility (Jeong and Abraham 2004). The sound waves travel along the utility and reach the ground surface before attenuation. The receivers, such as geophones or accelerometers, detect the sound waves, and the underground utility can be traced by measuring and marking the loudest point. The need for prior knowledge about the surface appurtenance of the target utility limits this method only to utility tracing. The passive sonic method relies on the utility’s product. For instance, water at a hydrant or service petcock makes some vibrations that travel along the utility and are captured by the receiver before attenuation. The sources of noise in this method are affected by product pressure, shape and size of orifice, and type of utility material. The resonant sonic method relies on the utility's product, which contains a non-compressible fluid. The vibration is created by interfacing the fluid surface and generating a pressure wave in the fluid, which is detected by the receiver (ASCE 2002). These acoustic surveys are typically useful for plastic water pipelines (6.5 ft of effective depth) and gas pipelines (8 ft of effective depth) (Jeong and Abraham 2004).

4-2-8. Thermal Survey (Infrared Method)

In the thermal survey, anomalies of the temperature field are used to identify underground utilities that disturb the normal ground temperature field due to the function of utilities such as steam pipelines or utilities that have different thermal characteristics than the surrounding ground (Sterling 2000). In general, this method detects and measures the heat flux emitted from some utilities such as steam systems, high-voltage power lines, and sanitary sewers. This method is useful for insulated steam systems or other high heat flux systems. Changes in solar radiation transferred to the ground surface or air temperature variations may cause sufficient changes in the thermal field for shallow buried utilities. Thermal noise also includes topography, variations in thermal conductivity, and intrinsic endothermic and exothermic sources (Hoover et al. 1996).

4-2-9. Gravity Survey

Gravity surveys can be used to detect underground utilities or objects that exhibit density variations from surrounding areas. Since the changes in gravitational field are very small, a microgravity method should be utilized for utility designation (Anspach 1994). Gravity is the attraction between masses. The strength of gravitational force is a result of the mass and distance separating the objects. Gravity anomalies are captured by differences in density due to the presence of underground utilities or objects. For instance, if an empty utility is buried at the target point, a lower gravitational force is measured than surrounding areas that are filled with soils. This method is relatively expensive and slow and limited to identifying utilities of great mass differentials from their surrounding areas.

4-2-10. Seismic Survey

A seismic survey can be used to detect underground utilities. Seismic waves are introduced into the ground using hammers or explosives. Once the seismic waves meet discontinuities such as utilities, the reflected and refracted waves are returned back and captured by the receiver, such as geophones, which are emplaced at the ground surface at various distances from the wave source. Seismic waves travel at different velocities in different materials. In general, solid, denser, and water-saturated materials tend to display higher-velocity waves, so the time-distance relationships measured in this survey may indicate the presence of underground utilities or other objects. This method is useful where field conditions are extremely limited due to signal/noise ratio problems, but it is relatively expensive and difficult to interpret the results (Anspach 1994).

4-3. Factors Affecting Accuracy of SUE

Every geophysical technique has its own limitations. Until now, there has been no single geophysical technique that could be used for every type of utility, soil type and site. Many factors, including characteristics of expected underground utilities, geological conditions at the site, and other environmental and social factors should be considered as criteria for the appropriate selection of geophysical techniques. Information about the factors can be obtained from existing documents, as-built drawings, utility companies, site visits, and other sources.

4-3-1. Type of Utility

There are many types of utilities that provide various services: gas lines, sewer lines, water mains, electric cables, communication cables, etc.; however, certain techniques are not available or very useful for the detection of specific types of utilities. In general, the passive sonics method and the resonant method of acoustic surveys are used only for water and gas pipelines to create vibrations that can be captured by a receiver. The thermal survey is also available only for warm utilities such as sanitary sewers and high-voltage power lines, detecting anomalies in the temperature field from the surrounding ground.

4-3-2. Material of Utility

Various materials have been used for underground utilities: iron, steel, plastic, concrete, clay, etc.; however, some techniques are limited or more effective for specific materials. For instance, the magnetic survey is not applicable to non-ferrous metallic materials such as copper, plastic, and concrete materials but is applicable to ferrous metallic materials, including steel, cast iron, and ductile iron. Some electromagnetic methods such as GPR or the terrain-conductive survey have great benefits that can image both metallic and non-metallic materials.

4-3-3. Depth of Utility

The depth of underground utilities is very diverse. In general, while a sanitary sewer is buried at a depth of 7 ft, a communication cable is buried at a depth of 18 inches. Hence, the penetration limitation of the signal each technique uses is an important factor for the selection of techniques. For instance, some metal detectors are more effective than a pipe and cable locator to detect metallic utilities; however, the applicable depth of metal detectors is less than 2 ft, while that of pipe and cable locators is up to 15 ft. The applicable depth of passive and resonant acoustic surveys varies in relation to target utilities. The depth is 6.5 ft for water pipelines but 8 ft for gas pipelines.

4-3-4. Type of Soil

The input signal penetrations of some geophysical techniques depend on the properties of the soil. For example, the higher the water content in the soil, the higher will be the conductivity of the soil, which causes dissemination of some signal penetrations. High conductivity in clays or highly saturated sand causes rapid dissemination of GPR signals so that the penetration of the GPR signal is reduced to less than 3 ft. The loss of GPR penetration depth is significant in comparison with 6 ft in low-conductivity soil. A terrain-conductive method is more effective in highly conductive soils, while a resistivity method works well in highly resistive soils.

4-3-5. Ground Surface Condition

Ground surface condition refers to a covering on the ground affecting the input signal of geophysical techniques. Many underground utilities are buried under surface pavements with asphalt or reinforced concrete. These ground conditions cause disturbances to specific techniques. For instance, reinforced concrete pavement may impede the introduction of electromagnetic signals into the ground. Acoustic surveys and thermal surveys also may have some difficulty capturing vibration and heat flux, respectively, emitted from utilities with such a pavement.

4-3-6. Access Point of Utility

Access point of utility means the presence of a surface access point connected to the underground utility in the vicinity. The access point also is an important factor for selecting appropriate geophysical techniques. For instance, in the active sonics method of the acoustic survey, prior knowledge about the surface appurtenance of the target utility is necessary because the transducer introduces sound waves into the utility through the surface appurtenance. A hydrant is a good example of an access point of utility.

4-3-7. Internal Condition of Utility

The internal condition of utilities refers to the filled level in empty utilities. Some techniques work better depending on the internal condition of utilities. For instance, the acoustic survey is more applicable when the pipeline is filled with water or gas because the method is based on the pressure transporting the sound wave. The internal conditions of utilities also affect the density anomalies of the gravity survey. The gravity survey detects different densities due to the presence of underground pipelines from surrounding areas. For the gravity survey, an empty water pipeline is more detectable than a filled water pipeline because of the density difference between the air and surrounding soils.

4-3-8. Density of Utility

Density of utility ultimately means how many utilities or buried objects are present around the target utility. In general, congested utilities and nearby buried objects may interfere with and confuse the interpretation of survey results. Thus, surveys for the site with high utility density are required to use more reliable and sophisticated techniques to avoid such an interference and confusion. In addition, high utility density increases the possibility of accidents due to hitting the utilities, and the results from such accidents can be more serious. In general, urban areas and commercial areas have more congested utilities.

4-3-9. Special Materials for Detecting Non-Metallic Utilities

In general, the detection of non-metallic utilities is more difficult than that of metallic utilities due to their own characteristics, and only a few geophysical techniques are available for non-metallic utilities. The installation of special materials on or above the utilities during construction can help to detect non-metallic utilities. The presence of such materials allows geophysical techniques to work better and more geophysical techniques to be applied for non-metallic materials. Special materials include metallic marking tapes, tracing wires, and electronic markers.

4-3-10. Qualified SUE Consultants

Qualified SUE consultants that are familiar with all geophysical techniques are necessary for surveying underground utilities and interpreting the results of the surveys. Unqualified SUE consultants can result in the need for another survey and create serious problems for projects.

4-3-11. Other Factors

Rebar, wire mesh, guard rail post, asbestos, wooden water pipeline, and other factors can disturb the appropriate use of geophysical techniques.

4-4. Non-Destructive Methods for Locating Underground Utilities

Non-destructive methods provide the highest level of accurate underground information. The use of non-destructive methods eliminates damage to underground utilities by pinpointing exactly where the utilities are positioned in three dimensions. In addition, information such as the properties of utilities, pavements, and soils that can be obtained through non-destructive methods assists the designer and owner in making important decisions. The air-vacuum excavation system is the predominant leader of non-destructive methods. The process starts with digging an approximately 1-ft-by-1-ft hole at the horizontal location provided during the designating stage with geophysical techniques. This system proceeds with the simultaneous action of compressed air jets to loosen soil and vacuum extraction of the resulting debris (Sterling 2000). The process continues until the utility is exposed. The utility type, material, size, depth, three-dimensional location, condition, soil type, water table, contamination, and other properties of the soil are provided with this system. Until recently, air was the primary source of digging power, but high-pressure water systems are beginning to be used for excavation because of their lower price compared to air systems. A water system also is more effective in wet soils, heavy clays, and caliches than an air system. However, the use of water excavation is limited to the supply of water in the holding tank, and wet debris is more difficult to handle than the dry material produced by an air system. In addition, improper operation of a water system has the potential of damaging the utilities being exposed. The appropriate selection of the vacuum excavation system should be made for the successful utility location considering target soil and utility properties.

Section 5.
Utility Impact Rating

5-1. Introduction

This section explains utility impact rating, which refers to the utility complexity for a given project, section, or location. Although quality level A of SUE provides the most reliable underground information, not all projects need to use quality level A, which requires the highest cost. The utility impact rating form is designed to recommend appropriate quality levels of SUE based on a utility impact score. The Georgia Department of Transportation (Georgia DOT) and Washington State Department of Transportation (Washington State DOT) have developed different types of utility impact forms. The Georgia DOT form seeks to know how many influences related to utility issues exist on a project through 10 questions, and the Washington State DOT applies 6 criteria to identify whether a DOT project qualifies as a SUE project. However, both of these are too limited to provide a meaningful measure of utility impact on a project, and neither addresses appropriate quality levels of SUE, which would be helpful for project owners, designers, and contractors. The utility impact form developed in this study consists of three steps. Step 1 and Step 2 are screening processes for possible SUE projects, and Step 3 is an evaluation of projects passing Step 1 and Step 2 to select appropriate quality levels of SUE. All questions, complexity factors, and designs of steps in the form have been determined through literature reviews and interviews with utility engineers of the Pennsylvania Department of Transportation (PennDOT). Appendix A provides the utility impact rating form and detailed descriptions of the utility complexity factors for highway project analysis.

5-2. Step 1

Project information such as title, cost, description (general summary), and scope (actual work scope) should be filled out before beginning Step 1. If the scope of the project is changed, the utility impact rating analysis should be done again for that project. Step 1 determines whether SUE (Quality levels A & B) should be utilized for a project. Table 5-1 shows the process for Step 1.

Table 5-1. Step 1 for Utility Impact Rating.

No.	QUESTIONS	Column 1		Column 2	
1	Is there evidence of underground utilities in the project area? (based on information from SUE Quality levels D&C)	☐	NO	☐	YES or Unknown
2	Does the project require any excavation "regardless of depth"? Note: This includes any TCE or other easements.	☐	NO	☐	YES or Unknown

The questions in Step 1 can be answered with traditional utility information (Quality levels C & D) provided by a one-call system, utility companies, site visits, etc. If there are no boxes checked in Column 2, then it is generally not practical to perform a SUE Quality levels A & B investigation. If any boxes in Column 2 are checked, the utility impact rating analysis proceeds to Step 2 to conduct further analysis of the project.

5-3. Step 2

Step 2 further analyzes and determines whether SUE (Quality levels A & B) should be utilized for a project. Table 5-2 shows five questions involved in Step 2. The questions can be answered with traditional utility information (Quality levels C & D) provided by a one-call system, utility companies, site visits, etc. If there are no boxes checked in Column 2, then it is generally not practical to perform a SUE Quality levels A and B investigation. If any boxes in Column 2 are checked, the utility impact rating analysis proceeds to Step 3 to calculate a utility impact score and determine the appropriate SUE quality levels.

Table 5-2. Step 2 for Utility Impact Rating.

No.	QUESTIONS	Column 1		Column 2	
1	What is the depth of project excavation? Note: This includes any TCE or other easements.	☐	≤ 18”	☐	> 18”
2	Do you feel that the utility owners in the project area will be able to accommodate the project’s schedule in regard to accurately showing the location of their utility facilities on PennDOT plans?	☐	Confident	☐	Doubtful
3	What is the likelihood that the project will have an impact on the existing utilities?	☐	No Impact	☐	Impact
4	How often have the utility owners in the project area provided timely/accurate utility information, if any?	☐	Always	☐	Seldom
5	How would you rate the reliability of the designer to provide accurate design-construction related information?	☐	Good	☐	Poor

5-4. Step 3

Step 3 determines which SUE quality levels should be selected for a project/section/location. Title, cost, description (general summary), and scope (actual work scope) should be filled out before answering the questions. The Step 3 questions are answered for a project, a section, or a location, while all questions in Step 1 and Step 2 are for a project. One project can have several sections or locations that have different utility impacts. Step 3 should be conducted for each section or location so that SUE quality levels can be selected for each section or location. Table 5-3 shows 17 complexity factors involved in Step 3.

Table 5-3. Step 3 for Utility Impact Rating.

No.	Complexity Factors	Column 1		Column 2		Column 3	
1	Density of Utilities (number)	☐	1	☐	2 or 3	☐	> 3
2	Type of Utilities	☐	Less Critical	☐	Sub Critical	☐	Critical
3	Pattern of Utilities (number)	☐	1 Parallel or Crossing	☐	2 Parallel or Crossing	☐	> 2 Parallel or Crossing
4	Material of Utilities	☐	Rigid	☐	Flexible	☐	Brittle
5	Access to Utilities	☐	Easy	☐	Medium	☐	Restricted
6	Age of Utilities (years)	☐	≤ 10 years	☐	> 10 years, ≤ 25 years	☐	> 25 years
7	Estimated Utility Relocation Costs (% of total project cost)	☐	≤ 2%	☐	> 2, ≤ 5%	☐	> 5%
8	Estimated Project Traffic Volume (ADT per lane)	☐	≤ 1,500	☐	> 1,500, ≤ 6,000	☐	> 6,000
9	Project Time Sensitivity	☐	Low	☐	Medium	☐	High
10	Project Area Description	☐	Rural	☐	Suburban	☐	Urban
11	Type of Project/Section/Location	☐	Simple	☐	Moderate	☐	Complicated
12	Quality of Utility Record	☐	Good	☐	Fair	☐	Poor
13	Excavation Depth within Highway Right-of-Way, including Easement (inches)	☐	≤ 18”	☐	> 18”, < 24”	☐	≥ 24”
14	Estimated Business Impact	☐	Low	☐	Moderate	☐	High
15	Estimated Environmental Impact	☐	Low	☐	Moderate	☐	High
16	Estimated Safety Impact	☐	Low	☐	Moderate	☐	High
17	Other Impact (Specify):	☐	Low	☐	Moderate	☐	High

Note: Detailed descriptions of complexity factors are presented in section 5-5.

The utility impact rating to the right that best fits the analyst's opinion of the issue is checked based on traditional utility information (Quality levels C & D) provided by the one-call system, utility companies, site visits, etc. If the answer for the complexity factor is unknown, Column 3 should always be checked. If the number of checked boxes for each column is known after checking for all complexity factors, the utility impact score is calculated with following equation.

$$UIS = \{(1 \times \text{Sum of Column 1}) + (2 \times \text{Sum of Column 2}) + (3 \times \text{Sum of Column 3})\} / n \quad \text{Eq. 5-1.}$$

Where UIS = Utility Impact Score
n = Number of the complexity factors considered/checked

Based on the utility impact score, the utility impact rating form recommends appropriate SUE quality levels and shows risk levels related to other quality levels for a project/section/location. Table 5-4 shows the project complexity levels, recommended SUE quality levels to be used, relative costs of using SUE quality level, and project risk levels based on the utility impact score. Relative cost of using SUE quality level is calculated based on the typical unit price of the different quality level costs. The cost of using SUE quality level A is almost twice the cost of using SUE quality level B/A and almost four times the cost of using SUE level B.

Table 5-4. Utility Impact Score, Complexity Levels, recommended SUE Quality Levels, Relative Cost Levels, and Project Risk Levels.

Utility Impact Score	1.00 – 1.31	1.32 – 1.71	1.72 - 2.11	2.12 – 2.51	2.52 – 3.00
Complexity Levels	(1)	(2)	(3)	(4)	(5)
SUE Quality Levels	D&C	C/B	B	B/A	A
Relative Cost	1	6.67	16.67	33.33	66.67
Project Risk Levels	Low (L)	Fair (F)	Medium (M)	High (H)	Extreme (E)

Although this utility impact rating form recommends appropriate SUE quality levels, in some cases, the project owner or designer must use his/her discretion for selecting appropriate SUE quality levels. This form also presents project risk levels of SUE quality levels that the project owner or designer selects.

Table 5-5. Complexity Level, SUE Quality Level, Project Risk Level, and SUE Benefits Level.

SUE Decision Matrix for Highway Projects

Utility Related Risk Level	**80-100**	**SUE Quality Level C&D**					**0-20**	**SUE Benefits Level (Positive)**
	60-80	**SUE Quality Level B/C**	**SUE Quality Level C&D**				**20-40**	
	40-60	**SUE Quality Level B**	**SUE Quality Level B/C**	**SUE Quality Level C&D**			**40-60**	
	20-40	**SUE Quality Level A/B**	**SUE Quality Level B**	**SUE Quality Level B/C**	**SUE Quality Level C&D**		**60-80**	
	0-20	**SUE Quality Level A**	**SUE Quality Level A/B**	**SUE Quality Level B**	**SUE Quality Level B/C**	**SUE Quality Level C&D**	**80-100**	
Utility Complexity Level		**5**	**4**	**3**	**2**	**1**	**Utility Complexity Level**	
Utility Related Risk Level	**0-20**		**SUE Quality Level A**	**SUE Quality Level A/B**	**SUE Quality Level B**	**SUE Quality Level B/C**	**0-20**	**SUE Benefits Level (Negative)**
	0-20			**SUE Quality Level A**	**SUE Quality Level A/B**	**SUE Quality Level B**	**20-40**	
	0-20				**SUE Quality Level A**	**SUE Quality Level A/B**	**40-60**	
	0-20					**SUE Quality Level A**	**60-80**	
	0-20						**80-100**	

Table 5-5 shows the SUE decision matrix for highway projects. This table is used to illustrate the interrelationship among Utility Complexity Level, recommended SUE Quality Level, Utility Related Risk Level, and SUE Benefits Level (positive and negative). For instance, if the utility complexity level is 5 based on utility impact analysis, then the recommended SUE quality level should be A (low project risk level [0-20] and high SUE benefits level [80-100]), as shown in Table 5-5. However, if a project engineer selects SUE quality level B/C for utility complexity level 5, then the project risk level becomes high [60-80] and the SUE benefits level becomes low [20-40]. This means that if the project engineer wants to use lower quality levels than the recommended quality levels for the given utility complexity level, the engineer must be willing to take more risks on the project and pay for the associated cost in change orders, utility damage, and other unexpected problems that may be caused by increased risks. Also, if the utility complexity level is 2 based on utility impact analysis, then the recommended SUE quality level should be B/C (low project risk level [0-20] and high SUE benefits level [80-100]), as shown in Table 5-5. However, if a project engineer selects SUE quality level A for utility complexity level 2, then the SUE benefits level becomes negative [40-60] and the project risk level remains the same [0-20]. This means that using a higher SUE quality level than the recommended SUE level for the given utility complexity level will derive negative benefits of SUE.

5-5. Complexity Factors

In order to properly evaluate the utility impact rating in Step 3, this section presents a detailed description of each complexity factor.

5-5-1. Density of Utilities

Density of utilities refers to the number of buried utilities per roadway cross-section that can be expected to be encountered on the project. If there are many utilities expected to be buried at the project site, more reliable data/information will be required to successfully locate those utilities. A higher density of utilities means more utility complexity, which requires getting better information related to underground utilities on the project.

Low : One pipe/roadway cross-section
Medium : Two or three pipes/roadway cross-section
High : More than three pipes/roadway cross-section and unknown pipes

5-5-2. Type of Utilities

Type of utilities refers to the various service types of buried utilities that can be expected to be encountered on the project. Utilities can be broadly divided into three different categories: (1) municipal, (2) energy, and (3) communication. Critical utilities such as fiber-optic lines are buried at a more shallow level than other types of utilities, so the possibility of accidentally hitting these lines is high. In addition, hitting gas or high-voltage lines can have serious results. Therefore, critical utilities generally require a greater level of data/information than other underground utilities on the project site.

Less-Critical : Water, forced sewer main, storm water
Sub-Critical : Telephone, electric, television cable, gravity sewer
Critical : Fiber-optic cable, gas, oil, petroleum, high-voltage line, unknowns

5-5-3. Pattern of Utilities

Pattern of utilities refers to the configuration of buried utilities that can be expected to be encountered on the project. Some areas may have a simple pattern that consists of a few parallel or crossing utilities, while other areas may have a complex pattern that consists of numerous parallel and crossing utilities. For instance, an intersection in a downtown location may have a more complex pattern of utilities than other areas. A more complex pattern of utilities requires more reliable information.

Simple : One parallel and/or one crossing utility
Medium : Two parallel and/or two crossing utilities
Complex : More than two parallel and/or crossing utilities

5-5-4. Material of Utilities

Material of utilities refers to the material types of buried utilities that can be expected to be encountered on the project. This factor is divided into three different categories: (1) rigid, (2) flexible, and (3) brittle. Brittle material requires higher quality levels of SUE than other materials. Some utility materials are more susceptible to damage than others.

Rigid : Concrete, cast iron, ductile iron
Flexible : PVC, HDPE
Brittle : Clay, unknowns

5-5-5. Access to Utilities

Access to utilities refers to the difficulty or ease of access to buried utilities that may be encountered on the project. If access to buried utilities is restricted, it will be more difficult to get accurate information on these buried utilities than in areas where access to utilities is easy. It is recommended that higher quality levels of SUE be used when access to utilities is more restricted.

Easy : Open land
Medium : Few light structures, pavements, medians
Restricted : Bridge pier, other large structures

5-5-6. Age of Utilities

Age of utilities may reveal the type of utility material and the physical condition of the utility. Older pipes may have deteriorated extensively and become more easily damaged by an accidental hit during construction activity. In addition, existing records on older utilities may be less reliable.

New : $\leq$ 10 years
Medium : > 10 and $\leq$ 25 years
Old : > 25 years

5-5-7. Estimated Total Utility Relocation Costs

When higher utility relocation costs (including PennDOT and utilities costs) are expected for the project, more accurate underground information is required to reduce the risks of increased project cost or project schedule delays. SUE quality level A and B investigations can reduce project costs where wrong or poor utility information requires relocating some utilities on the project.

Low : ≤ 2% of total project cost (Design & Construction Cost)
Medium : > 2 and ≤ 5% of total project cost (Design & Construction Cost)
High : > 5% of total project cost (Design & Construction Cost)

5-5-8. Estimated Project Traffic Volume

Project traffic volume is the Average Daily Traffic (ADT) volume for the project per lane. Any delay in the project in areas with higher traffic volume will result in greater travel delays to the public. Therefore, a higher level of SUE is required to minimize unnecessary project delays due to encountering unexpected buried utilities at the project site.

Low : ≤ 1,500 ADT per lane
Moderate : > 1,500 and ≤ 6,000 ADT per lane
High : > 6,000 ADT per lane

5-5-9. Project Time Sensitivity

Project time sensitivity pertains to the project schedule. Accurate utility information can reduce unnecessary project delays that can result from inaccurate design. Therefore, more reliable information is required in the design stage for projects that have tight schedules. Higher project time sensitivity means tighter schedules, which require avoiding project delays.

Low : Project is not time sensitive
Medium : Some flexibility in schedule
High : Very tight schedule – no time extension

5-5-10. Project Area Description

Project area description refers to the location or nature of the project. This factor is separated into three categories: (1) rural, (2) suburban, and (3) urban. In general, urban areas have more complex and congested utilities because of higher building and infrastructure density. Therefore, an urban area means more congested utilities, so higher quality levels are recommended.

Rural : Rural areas with lots of open land
Suburban : Suburban areas with few businesses and residences
Urban : Urban areas with numerous businesses and residences

5-5-11. Type of Project/Section/Location

The type of project/section/location quite often may indicate whether SUE is needed. As an example, a pavement resurfacing project that generally requires work only on the pavement surface will not need SUE. Project location and, specifically, the section at which the construction work will take place may reveal traffic volume, accessibility, and potential consequences of accidentally damaging the buried utilities. This factor is separated into three different categories: (1) without excavation, (2) shallow excavation, and (3) deep excavation.

Simple : Without excavation, i.e., widening, and/or other minor construction work

Moderate : Shallow excavation, i.e., guide rail, low-depth pipe replacement, traffic light post, shoulder cutting, and/or minor drainage

Complicate : Deep excavation, i.e., new construction, full-depth reconstruction, bridge foundation, deep-depth pipe replacement, etc.

5-5-12. Quality of Utility Record

Quality of utility record indicates the reliability of existing records on buried utilities. The availability of accurate historical utility records for the project can significantly reduce the potential for encountering unexpected underground utilities. This factor is divided into three different categories: (1) good, (2) fair, and (3) poor. A poor quality of utility records requires higher quality levels of SUE.

Good : Very accurate record of utilities
Fair : Not very good record of utilities
Poor : Utilities information/data are not accurate

5-5-13. Depth of Excavation within Highway Right-of-Way

The depth of excavation within a highway right-of-way quite often may indicate whether or not SUE quality level A or B is needed. Note: This includes TCE or other easements. The accurate location of buried utilities at the project site should be determined to save project cost and time together with associated benefits. This depth factor can be separated into three categories.

Low : ≤ 18”
Medium : > 18” and < 24”
High : ≥ 24”

5-5-14. Estimated Business Impact

Business impact is concerned with the income and property loss for local businesses resulting from the accidental hitting of unexpected buried utilities. At areas near or surrounding high business density, the quality level A of SUE is essential. User impact, access to business, and length of service interruption should also be taken into consideration.

Low : Very low business impact in the project area
Moderate : Possibility of some business impact in the project area
High : Great business impact in the project area

5-5-15. Estimated Environmental Impact

Potential environmental problems caused by accidentally hitting an in-service utility, such as a gas explosion, oil spill, and/or water flooding, need to be assessed. Project areas with a high potential of environmental impact require a high quality level of SUE.

Low : Very low environmental impact in the project area
Moderate : Possibility of some environmental impact in the project area
High : Great environmental impact in the project area

5-5-16. Estimated Safety Impact

Safety impact is concerned with possible injury to people caused by accidentally hitting an in-service utility. Projects located in densely populated areas require a high quality level of SUE to minimize such an impact.

Low : Very low safety impact in the project area
Moderate : Possibility of some safety impact in the project area
High : Great safety impact in the project area

5-5-17. Other Factors (Specify)

Projects with a high potential of other impact factors require a high quality level of SUE to avoid or reduce project risks (e.g., blasting of rocks, other utilities relocation, etc.).

Low : Very low impact in the project area

Moderate : Possibility of some impact in the project area

High : Great impact in the project area

5-6. Case Studies

Three case studies have been presented in this section to demonstrate Steps 1, 2, and 3 for Utility Impact Rating analysis of a highway construction project.

5-6-1. A Project that Stops at Step 1

Project Title : Crack Seal, Various Sections (Bradford)

District : District 3 – Montoursville

Total Project Cost : $75,000

Design Cost : $2,500

Project Scope : Seal Cracks

Project Description :

The objective of this project was to seal cracks in various roadway sections in Bradford County. Since there was no evidence of underground utilities in the project area and the project did not require any excavation, there was no need to consider underground utility impacts analysis. Therefore, this project should be stopped at Step 1 of the utility impact rating form because it is not practical to perform a SUE quality levels A and B investigation on this project.

Utility Impact Score : N/A (Stop at Step 1)

i. Step 1

No.	QUESTIONS	Column 1		Column 2	
1	Is there evidence of underground utilities in the project area? (based on information from SUE quality level D&C)	X	NO		YES or Unknown
2	Does the project require any excavation "regardless of depth?" Note: This includes any TCE or other easements.	X	NO		YES or Unknown

5-6-2. A Project that Stops at Step 2

Project Title : Concrete patching, SR 1012-MC2 (Blair)

District : District 9 – Hollidaysburg

Total Project Cost : $550,000

Design Cost : $50,000

Project Scope : Patch SR 1012 and ramps from I-99 into Tyrone

Project Description :

This project involved patching of a concrete road. There was evidence of underground utilities in the project area, and the project did require excavation. However, the depth of excavation was less than 18 inches, which is not extensive enough to use SUE quality level A and/or B; utility owners were able to show the location of their utilities in time, utility impact was not expected, and the designer was reliable in providing accurate design-construction related information. Therefore, there was no need to consider underground utility impact, and this project should be stopped at Step 2 of the utility impact rating form because it is not practical to perform SUE quality levels A and B investigation on this project.

Utility Impact Score : N/A (Stop at Step 2)

i. Step 1

No.	QUESTIONS	Column 1		Column 2	
1	Is there evidence of underground utilities in the project area? (based on information from SUE quality level D&C)		NO	X	YES or Unknown
2	Does the project require any excavation "regardless of depth"? Note: This includes any TCE or other easements.		NO	X	YES or Unknown

ii. Step 2

No.	QUESTIONS	Column 1		Column 2	
1	What is the depth of project excavation? Note: This includes any TCE or other easements.	X	≤ 18”		> 18”
2	Do you feel that the utility owners in the project area will be able to accommodate the project’s schedule in regard to accurately showing the location of their utility facilities on PennDOT plans?	X	Confident		Doubtful
3	What is the likelihood that this project will have an impact on the existing utilities?	X	No Impact		Impact
4	How often have the utility owners in the project area provided timely/accurate utility information, if any?	X	Always		Seldom
5	How would you rate the reliability of the designer to provide accurate design-construction related information?	X	Good		Poor

5-6-3. A Project that Stops at Step 3

Project Title : Bellwood Road and Bridge, SR 0865-002 (Blair)

District : District 9 – Hollidaysburg

Total Project Cost : $3.1 Million

Project Scope : Build new structure and realign road

Project Description :

The focus of this project was to realign Bellwood Bridge and Road. There was evidence of underground utilities in the project area, and the project did require excavation. In addition, the depth of excavation was more than 18 inches, utility impact was expected, and the designer was not able to provide accurate design-construction related information. Therefore, it was necessary to consider underground utility impact, and this project should proceed to Step 3 of the utility impact rating form to determine the appropriate quality levels of SUE. In Step 3, the utility impact score of this project is calculated as 1.80, and quality level B is recommended. Therefore, if quality level D or C were used for this project, the project risk became high, but if quality level B were selected, the project risk became low.

Utility Impact Score : 1.80

Complexity Level : 3

SUE Quality Level : B

i. Step 1

No.	QUESTIONS	Column 1		Column 2	
1	Is there evidence of underground utilities in the project area? (based on information from SUE quality level D&C)		NO	**X**	YES or Unknown
2	Does the project require any excavation "regardless of depth"? Note: This includes any TCE or other easements.		NO	**X**	YES or Unknown

ii. Step 2

No.	QUESTIONS	Column 1		Column 2	
1	What is the depth of project excavation? Note: This includes any TCE or other easements.		≤ 18"	**X**	> 18"
2	Do you feel that the utility owners in the project area will be able to accommodate the project's schedule in regard to accurately showing the location of their utility facilities on PennDOT plans?	**X**	Confident		Doubtful
3	What is the likelihood that the project will have an impact on the existing utilities?		No Impact	**X**	Impact
4	How often have the utility owners in the project area provided timely/accurate utility information, if any?		Always	**X**	Seldom
5	How would you rate the reliability of the designer to provide accurate design-construction related information?		Good	**X**	Poor

iii. Step 3

No.	Complexity Factors	Column 1		Column 2		Column 3	
1	Density of Utilities (number)		1	**X**	2 or 3		> 3
2	Type of Utilities		Less Critical	**X**	Sub Critical		Critical
3	Pattern of Utilities (number)		1 parallel or crossing	**X**	2 parallel or crossing		> 2 parallel or crossing
4	Material of Utilities		Rigid	**X**	Flexible		Brittle
5	Access to Utilities	**X**	Easy		Medium		Restricted
6	Age of Utilities (years)		≤ 10 years	**X**	> 10 years, ≤ 25 years		> 25 years
7	Estimated Utility Relocation Costs (% of total project cost)		≤ 2%		> 2%, ≤ 5%	**X**	> 5%
8	Estimated Project Traffic Volume (ADT per lane)		≤ 1,500	**X**	> 1,500, ≤ 6,000		> 6,000
9	Project Time Sensitivity	**X**	Low		Medium		High
10	Project Area Description		Rural	**X**	Suburban		Urban
11	Type of Project/Section/Location		Simple	**X**	Moderate		Complicated
12	Quality of Utility Record		Good	**X**	Fair		Poor
13	Excavation Depth with Highway Right-of-Way, including Easement (inches)		≤ 18”		> 18”, < 24”	**X**	≥ 24”
14	Estimated Business Impact	**X**	Low		Moderate		High
15	Estimated Environmental Impact	**X**	Low		Moderate		High
16	Estimated Safety Impact	**X**	Low		Moderate		High
17	Other Impact (Specify):	-	Low	-	Moderate	-	High

5-6-4. Other SUE Projects that Go through Steps 1, 2, and 3

Appendix B provides detailed information related to nine other SUE projects for Utility Impact Rating analysis of a highway construction project.

Section 6.

SUE Benefit-Cost Analysis

6-1. Introduction

SUE benefits are important to project owners, designers, contractors, DOTs, and utility companies. SUE reduces unnecessary utility relocations, unexpected damages to existing utilities, mislocations of utilities, change orders and claims, personnel injuries, negative factors for productivity, social and environmental damages, and other problems related to utilities through accurate underground information. The benefits are combined with subsequent savings in time and cost for whole projects. Stevens (1993) presents cost savings in various forms for the taxpayer, the ratepayer, and the owners on projects utilizing SUE, as shown in Table 6-1. Administrative cost savings would be 2% of overall project costs because projects completed up to 20% faster enable financing to be paid more quickly. Costs for insurance, bonding, and change orders also may be less. Engineering cost savings yield 0.5% because SUE techniques may save time by using digital transfer of survey data into CADD. Construction costs realize savings of 2.25% because construction bids may be lowered due to fewer utility conflicts as a result of more accurate underground information. Liability of identification of utilities is also transferred from contractors to the SUE companies. Overrun costs realize savings of 5%. The overrun saving may be derived from reduced delay claims, reduced engineering reworks, and reduced utility damages. Utility relocation cost savings yield 5% of overall project costs. Designers using accurate underground information may eliminate underground utility relocations before construction. The results of this research show that, in comparison with projects not utilizing SUE, the total cost savings of SUE project may range from 10% to 15% on a typical project.

Table 6-1**.** Cost Savings Rate on Projects utilizing SUE.

Cost	Expenditure on Typical Projects	Saving Rates	Savings on Overall Projects
Administrative Cost	20%	10%	2%
Engineering Cost	10%	5%	0.5%
Construction Cost	45%	5%	2.25%
Overrun Cost	15%	33%	5%
Utility Relocation Cost	10%	50%	5%
Total	100%	-	14.75%

Anspach (1994) summarizes SUE savings that were derived by various parties. In his paper, FHWA reports that applying SUE nationwide would have cost savings exceeding $100 million per year for highway work alone. A state utility engineer of the Virginia DOT states that $700,000 worth of utility conflicts was eliminated, with less than $100,000 spent on SUE in a Richmond project. Anspach's paper also deals with other SUE savings relative to relocation costs, construction delay claims, project completion time, construction bids, and other issues. Brown and Mckim (2002) also describe cost savings attributed to the use of SUE. According to their study, Virginia DOT indicates a cost savings of $7.00 for every $1.00 spent on SUE. The Society of American Value Engineers (SAVE) shows a 10:1 return rate, and Maryland DOT shows an 18:1 savings. However, these studies are underestimated because they use a limited number of projects to produce results. Jeong et al. (2004) modified the result of a Purdue study (2000) after re-analyzing the same data, including 71 projects. In their paper, the ratio of the cost of SUE to the total construction cost ranged from 0.02% to 10.76%, and the average ratio was 1.39%. The average $12.23 in savings for every $1.00 spent on SUE is quantified by SUE project analysis. Jeong et al. (2004) also carried out a cost savings analysis of each individual category. A reduced number of utility relocations is analyzed as the most outstanding source of cost savings, with 37.1% in SUE cost savings. Reduced claims and change orders (19.3%), reduced accidents and injuries (11.6%), and reduced project delays (9.6%) are also ranked as significant contributors to cost savings. Other cost savings that together comprise 22.3% include reduced right-of-way acquisition costs (3.5%), induced savings in risk management and insurance (3.3%), and other categories (15.5%). Lew (2000) shows a total of $4.62 in savings for every $1.00 spent on SUE in the Purdue study, with ranges from $0.34 to $206.67, and Osman and El-Diraby (2005) state in a Toronto study that average return-on-investment (ROI) for SUE is approximately $3.41 for each $1 spent, with ranges from $1.98 to $6.59. Considerable previous research has shown that using SUE can save money on projects involving underground utilities. This section describes a benefit-cost analysis (BCA) that quantifies the cost savings of SUE with projects developed in Pennsylvania. The BCA identifies how much money can be saved per dollar spent on SUE. This study uses both SUE projects and non-SUE projects to quantify the cost savings of SUE, while previous research used only SUE projects. This approach can increase the possibility of having more realistic numbers through cost-benefit analysis.

6-2. Benefit-Cost Analysis

Benefit-cost analysis is an approach that is preferred for proving the effectiveness of new systems or techniques. Benefit-cost analysis estimates and totals up the equivalent money value of the benefits and costs of projects to establish whether they are worthwhile. The benefit-cost analysis of SUE is conducted with SUE projects and non-SUE projects that have problems related to underground utilities. B (Benefit)/C (Cost) is the fundamental equation of benefit-cost analysis. When B/C > 1, utilizing SUE can be beneficial and very effective. All projects in this study were collected from different districts of PennDOT. Estimated benefits/costs were investigated by conducting interviews with PennDOT utility engineers who were involved in the projects, analysis of historical data, and review of individual project studies and actual benefits/costs derived from direct costs of projects.

6-2-1. Benefit-Cost Analysis of SUE Projects

In SUE projects, benefits are estimated costs that are derived from utility engineer's feedback, historical data, and individual project studies. The benefits are determined from the differences in underground utility information before and after using SUE. SUE costs are obtained form direct costs of using SUE in the projects. Thus, the Benefit-Cost Ratio (BCR) of SUE projects is

$$(BCR)_{SUE} = \frac{B_{SUE}}{C_{SUE}} \qquad \text{Eq. 6-1.}$$

Where	$(BCR)_{SUE}$	=	Benefit-cost ratio of SUE projects
	B_{SUE}	=	Estimated benefits of SUE projects
	C_{SUE}	=	Actual SUE costs of SUE projects

6-2-2. Benefit-Cost Analysis of Non-SUE Projects

Previous research efforts utilized only SUE projects to quantify cost savings of SUE. Those studies inferred estimated costs as SUE benefits from utility conflicts that were revealed by SUE. However, as the Toronto study (2005) mentioned, the mere identification of utility conflicts does not necessarily result in a cost being incurred. In this study, non-SUE projects with problems are also used to determine the cost savings of SUE because they can provide direct costs incurred by problems related to utilities as SUE benefits. SUE costs of non-SUE projects should be inferred, since SUE was not used. The SUE costs are estimated costs that are determined with input from PennDOT utility engineers, historical data, and individual project studies. Eq. 6-2 shows the equation of the benefit-cost ratio of non-SUE projects.

$$(BCR)_{NON\text{-}SUE} = \frac{B_{NON-SUE}}{C_{NON-SUE}} \qquad \text{Eq. 6-2.}$$

Where $(BCR)_{NON\text{-}SUE}$ = Benefit-cost ratio of non-SUE projects
$B_{NON\text{-}SUE}$ = Actual benefits of quality level A of non-SUE projects
$C_{NON\text{-}SUE}$ = Estimated SUE costs of non-SUE projects

6-2-3. Benefit Factors of SUE

There are a number of benefits associated with utilizing SUE for highway projects. In this study, 11 main benefit factors are identified to conduct benefit-cost analysis of SUE. Main benefit factors involve detail factors. Some benefits can be quantified in a precise manner, while others are difficult to quantify.

6-2-3-1. Utility Relocation Cost

Utility relocation is the adjustment, replacement, or relocation of utility facilities as required by a highway construction project, such as removing and reinstalling the facility, acquiring necessary right-of-way, moving or rearranging existing facilities, changing the type of facility, and any necessary safety and protective measures. It also means constructing a replacement facility that is functionally equal to the existing facility, where necessary for continuous operation of the utility service, the project economy, or sequence of highway construction, according to PennDOT Utility Manual 2004.

Utility relocation cost includes costs incurred due to a change of proposal, contractor as well as designer. It may also include the cost of claims that involves the administrative direct cost. Meanwhile, the costs due to schedule or completion delay plus user costs may also be included. By using SUE in the design stage, the designer will be able to avoid costs incurred by unnecessary utility relocation and by discovering unexpected utilities or objects that are in conflict. For example, a design shows a utility line that must be relocated to avoid conflicts with the proposed utility, so the contractor starts to dig for the utility relocation. However, if the utility that was expected to be found does not actually exist, the contractor will identify the mistake in the design immediately after digging. Construction would be shut down or delayed to address the problem and redesign the project with more accurate information. Sometimes the discovery of unexpected utilities or objects happens during construction. If there is an unknown utility that is in conflict and is not identified in the design, it also takes time to uncover the problems and redesign the project. However, SUE allows the designer to identify exact locations of utilities so that unnecessary utility relocation design and unexpected utility conflicts would be avoided at the design stage. To identify SUE benefits related to utility relocation cost, SUE reports and interviews are used for SUE projects, and direct costs are used for non-SUE projects.

6-2-3-2. Utility Damage Cost

Utility damage cost includes person injury costs, equipment damage costs, and third-party damage costs. By using SUE, the designer provides a better design to avoid costs incurred by utility damages. If a contractor does not know the existence or exact location of buried utilities, utility-damaging accidents are likely to happen. These accidents can lead to person injuries, equipment damages, and third-party damages. However, SUE allows the designer and the contractor to reduce the costs incurred by utility damages. For SUE projects, interviews and historical data are used for benefit-cost analysis. For non-SUE projects, direct costs spent on person injuries, equipment damage, and third-party damages are used for BCA.

6-2-3-3. Emergency Restoration Cost

Emergency restoration cost includes utility restoration costs and project delay costs by the emergency. The use of SUE allows avoiding emergency restoration costs incurred by utility damages. If the contractor conducts excavation work without accurate information, utility-damaging accidents are likely to happen, leading to utility damage and project delays. However, SUE allows the designer to have accurate underground information around construction sites so that costs incurred by utility damage would be reduced. For SUE projects, interviews and historical data are used for BCA. For non-SUE projects, direct costs spent on utility restoration and project delays resulting from the emergency are used for BCA.

6-2-3-4. Traffic Delay Cost

Traffic delay cost is primarily the user's time delay cost. The delay may include traffic speed delay and queuing delay. Such a delay cost incurred by hitting utilities can be saved by using SUE. If the designer and the contractor are not aware of the existence or exact location of utilities around target sites, utility-hitting accidents can easily happen. Hitting utilities can cause leakage of products such as water or gas and necessitate more work, leading to additional traffic delays; however, these traffic delays could be reduced by using SUE because the SUE can reduce utility accidents. It is very difficult to estimate traffic delay cost in SUE projects that do not have actual damages; therefore, traffic delay cost is not analyzed for BCA in SUE projects but, rather, in non-SUE projects. Interviews are used for the analysis in non-SUE projects.

6-2-3-5. Business Impact Cost

Business impact cost is the cost incurred by business enterprises resulting from loss of business activity. Business impact cost may occur due to accidentally hitting existing utilities. It may involve the cost due to hindering business access, damage to business such as inventory loss to flooding or fire, and others. SUE enables the avoidance or reduction of business impact costs incurred by hitting utilities. Hitting utilities caused by inaccurate information can cause leaking of products such as water or gas and necessitate additional work, thus increasing the impact on businesses near construction sites. However, SUE allows for a more efficient design that reduces business impact costs caused by hitting utilities. Because it is difficult to estimate the business impact cost in SUE projects that do not have actual damages, business impact cost is not analyzed for BCA in SUE projects. For non-SUE projects, business impact costs are estimated through interviews with personnel involved in the projects.

6-2-3-6. User Service Cost

User service cost refers to the monetary value for users' inconveniences incurred by loss/delay of service (for example, loss/delay of internet, gas, cable, telephone, water, etc.). Sometimes utility hits result in service loss, so that service users cannot use the services until the restoration is completed. However, SUE allows the designer to identify the exact information for all utilities so that user service losses caused by hitting utilities are reduced. It is very difficult to estimate user service cost in SUE projects that do not have actual damages; therefore, user service cost is not analyzed for BCA in SUE projects. For non-SUE projects, user service costs are considered with interviews and historical data.

6-2-3-7. Environmental Impact Cost

Environmental impact cost is the cost to restore/remediate the impacted environment. An example is the cost for cleaning contaminated ground. By using SUE reports in the design stage, the designer designs efficiently and accurately and avoids environmental impact costs that could be incurred by hitting utilities. Hitting utilities can cause leakage of products such as water or gas and necessitate additional work as well as lead to environmental problems. However, by using SUE, environmental costs caused by hitting utilities would be reduced. It is very difficult to estimate the environmental impact cost of resolving environmental problems in SUE projects; therefore, environmental impact cost is not analyzed for BCA in SUE projects. The direct costs are used for BCA in non-SUE projects.

6-2-3-8. Information Gathering and Verification Cost

Information gathering and verification cost is the cost for gathering and verifying utility information without using SUE. Traditional costs for gathering and verifying related utility information can be avoided by using SUE in the design stage. SUE provides all related information so that the designer does not need to spend money and time to gather and verify information. For BCA, interviews are used for SUE projects, and the direct costs of gathering and verifying underground information are used for non-SUE projects.

6-2-3-9. Legal and Litigation Cost

Legal and litigation cost is money spent on the negotiation, arbitration, legal and litigation process to resolve disputes. SUE can reduce legal and litigation costs. Accurate utility information provided by SUE can reduce unexpected problems resulting from claims, change orders, or other reasons so that legal and litigation costs would be reduced. The savings in legal and litigation cost can then be considered a benefit of SUE. For SUE projects, interviews are used for BCA, and for non-SUE projects, direct costs of projects are used.

6-2-3-10. Efficient Utility Design

Efficient utility design means that the design can minimize conflicts and can result in reductions in the amount of time spent for redesign and design change orders. By using reliable underground information, the designer saves time in designing and makes a design for one time only to avoid or minimize costs incurred by unnecessary work. For example, if the proposed utility is designed to detour around a utility that is expected to have existed but does not actually exist, the design can cause construction delay and cost increases. Using SUE allows the designer to identify the existence and exact locations of all utilities so that unnecessary work would be avoided in the design stage. For SUE projects, discrepancies between quality levels A&B and quality levels C&D can provide information for identifying and estimating unnecessary work. Also, interviews with personnel who are involved in projects are used to estimate cost savings and time savings for design and construction for BCA. For non-SUE projects, direct costs of projects are used for BCA. Efficient utility design leads to cost savings in both design and construction.

6-2-3-11. Other Utility Related Costs and Benefits

Other utility related costs and benefits are the factors that are not described in previous items. Examples include savings in risk management and insurance, digital mapping accuracy, comprehensive utility management systems, etc. For other utility-related costs and benefits, interviews are used with personnel who are involved in SUE projects.

6-2-4. Cost Factors of SUE

In SUE, there are two kinds of costs. One is the designation cost that is involved in quality level A or B, and the other is the location cost involved in quality level A. Designation cost is for the use of geophysical techniques to designate the horizontal position of underground utilities/objects, and location cost is for the use of vacuum excavation systems to locate horizontal and vertical position as well as finding out other utility information and soil information. For SUE projects, the SUE costs are obtained from direct costs of projects, while for non-SUE projects the SUE costs should be derived from interviews, historical data, and individual project studies.

6-3. A Case Study of Benefit-Cost Analysis of SUE Project

Project Title	:	Bellwood Road and Bridge, SR 0865-002 (Blair County)
District	:	District 9 – Hollidaysburg
Total Project Cost	:	$3.1 million
Design Cost	:	$330,000
SUE Cost	:	$20,000 (Designating: $10,000; Locating: $10,000)
Project Scope	:	Build new structure and realign road
Project Description	:	

The project involved relocation of a roadway and reconstruction of a bridge in the rural area of Bellwood. The SUE was used on the roadway portion to design drainage facilities. In the early project stage, there was some information on a gas line on one side of the existing road and a waterline on the other side at the project site. The technology used for SUE quality level B included basic electro-magnetic equipment such as the pipe and cable locator and metal detector. For SUE quality level A, the vacuum excavation method was used at 15 different locations. Based on the results of SUE investigation, the decision was made to place the drainage facilities on the side of the road where the waterline was located. On that side of the road, there was less impact length and more room for relocation; additionally, work could be done by the Department contractor.

Cost Savings by SUE

Utility relocation cost	:	$5,000
Design and construction cost	:	$50,000
Information gathering and verification cost	:	$10,000
Total Savings	:	$65,000
B/C Ratio	:	$65,000 / $20,000 = 3.25

Note: Detailed information related to benefit-cost analysis of nine other SUE projects analyzed for this study is presented in Appendix C.

Section 7.

Research Results

This section describes utility impact rating and benefit-cost analysis of 10 SUE highway projects from different PennDOT districts. The case studies were investigated by conducting interviews with utility engineers, SUE consultants, and project engineers. Site visits, analyses of project data, and detailed individual studies of the 10 SUE highway projects were also performed for this research.

Ten SUE projects from Hollidaysburg and Montoursville districts were examined in detail. These projects were selected randomly from a list of projects that utilized SUE quality level A and/or B. The projects investigated in this study involved road construction and bridge replacement in urban, suburban, and rural areas. PennDOT project managers and engineers, utility owners, SUE consultants, designers, and contractors were interviewed.

Table 7-1 summarizes general information on the 10 SUE projects, and Table 7-2 shows a summary of cost savings for the projects. Note that in Table 7-1, total project cost involves both design and construction cost, and in Table 7-2, delay cost by the emergency is the construction delay costs for restoration work incurred by the emergency, such as hitting existing utilities. A detailed benefit-cost analysis of all 10 SUE projects is shown in Table 7-3. Statistical analyses of the 10 SUE highway projects and statistical analyses based on utility complexity level for benefit-cost analysis are shown in Tables 7-4 and 7-5, respectively. Graphical analyses and results of all 10 SUE projects for benefit-cost analysis are shown in Figures 7-1, 7-2, and 7-3.

A savings of $22.21 for every $1.00 spent on SUE was quantified from a total of the 10 projects. These projects had a total project cost in excess of $120 million. The costs of obtaining SUE quality level A and/or B data on these 10 projects were less than 0.6 percent of the total project costs, and this resulted in a cost savings of 15% over traditional quality level C and/or D utility-related data.

Table 7-1 presents general information on the 10 SUE projects. Projects of various sizes were analyzed, with project costs ranging from $2 million to $63 million. The quality of the utility records for the projects was poor or fair. A summary of the SUE cost savings itemized according to the benefit-cost analysis is presented in Table 7-2. As shown in Table 7-3, the expenditure for using SUE ranged from $20,000 to $141,000 for the SUE projects. The ratio of SUE cost to the total project cost ranged from 0.22% to 2.8%, with an average of 1.15%. The SUE projects showed cost savings that ranged from $65,000 to $4.5 million. The benefit-cost ratio ranged from 3.25 to 33.93, with an average of 22.21, as shown in Table 7-4. This means that $22.21 can be saved for every $1 spent on SUE. The costs of obtaining SUE information on these 10 projects were less than 0.6 percent of the total project cost.

Utility complexity levels were dependent on utility impact scores, which were estimated using the utility impact rating form. The utility impact rating form includes 17 complexity factors consisting of various properties of existing buried utilities, characteristics of project areas, and other social issues. The utility impact scores ranged from 1.80 to 2.94 and complexity levels 3, 4, and 5 were analyzed for the SUE projects, as shown in Table 7-3.

Figure 7-1 is a plot of SUE benefit-cost ratio and the total project cost. As shown in Figure 7-1, there is absolutely no relationship between SUE benefit-cost and the total project cost. SUE benefits are high even if the total project cost is low. Figure 7-2 is a plot of utility complexity level and the total project cost. As shown in Figure 7-2, there is also absolutely no relationship between utility complexity level and the total project cost. Utility complexity level is high even if the total project cost is low. Figure 7-3 is plot of SUE benefit-cost ratio and the utility complexity level. As shown in Figure 7-3, there is a strong relationship between SUE benefit-cost and utility complexity level. The benefit-cost of SUE increases as the utility complexity level of the project increases.

Table 7-1. General Information related to SUE Projects.

Project No.	Description	Total Project Cost*	Design Cost	Project Area	Quality of Utility Record
District 9 – Hollidaysburg					
SR 0865-002	Roadway Con.	$3,100,000	$330,000	Urban	Fair
SR 2014-04M	Roadway Con.	$2,400,000	$710,000	Suburban	Fair
SR 0022-024	Bridge Replace.	$2,600,000	$600,000	Urban	Fair
SR 4013-002	Bridge Replace.	$11,600,000	$2,000,000	Urban	Fair
SR 0036-25M	Roadway Con.	$1,600,000	$200,000	Urban	Fair
District 3 - Montoursville					
SR 0061-079	Bridge Replace.	$9,000,000	$1,000,000	Suburban	Poor
SR 6006-001/002	Roadway Con.	$13,000,000	$1,000,000	Rural	Poor
SR 0054-014	Bridge Replace.	$9,000,000	$1,000,000	Urban	Poor
SR 0015-077	Bridge Replace.	$63,000,000	$10,000,000	Urban	Poor
SR 0049-50M	Roadway Con.	$5,200,000	$700,000	Urban	Poor

* Total project cost includes design and construction cost.

Table 7-2. Summary of Cost Savings for SUE Projects.

Project No.	Project relocation cost ($)	Delay cost by relocation ($)	Redesign cost ($)	Change order & claim cost ($)	Restoration cost ($)	Delay cost by the emergency ($)*	Design & construction cost ($)**	Information gathering & verification cost ($)	Total Cost Savings ($)
District 9 – Hollidaysburg									
SR 0865-002	5,000						50,000	10,000	65,000
SR 2014-04M	5,050						150,000	10,000	165,050
SR 0022-024	150,000						100,000	15,000	265,000
SR 4013-002	500,000						1,000,000	15,000	1,515,000
SR 0036-25M	275,000	50,000	75,000				1,100,000	15,000	1,515,000
District 3 – Montoursville									
SR 0061-079	250,000		1,000,000		50,000		200,000		1,500,000
SR 6006-001/002	1,500,000	100,000		75,000	35,000	1,500,000	1,000,000		4,210,000
SR 0054-014	1,000,000						1,650,000		2,650,000
SR 0015-077	3,000,000		500,000				1,000,000		4,500,000
SR 0049-50M	1,800,000						100,000		1,900,000
Total	8,485,050	150,000	1,575,000	75,000	85,000	1,500,000	6,350,000	65,000	18,285,050
% of Total Saving	46.40	0.82	8.61	0.41	0.46	8.20	34.73	0.36	100.00

* Project delay cost of $1.5 million was estimated for closure or delay of construction due to accidental damages to underground utilities.

** Total project cost includes design and construction cost.

Table 7-3. Benefit-Cost Analysis and Utility Impact Score for SUE Projects.

Project No.	Project Cost	SUE Cost (C)	Cost Saving (B)	B/C	SUE % of Total Project Cost*	Cost Saving % of Total Project Cost*	Impact Score	Complexity Level
District 9 – Hollidaysburg								
SR 0865-002	$3,100,000	$20,000	$65,000	3.25	0.65	2.10	1.80	3
SR 2014-04M	$2,400,000	$34,243	$165,050	4.82	1.43	6.88	2.37	4
SR 0022-024	$2,600,000	$50,000	$265,000	5.30	1.92	10.19	2.50	4
SR 4013-002	$11,600,000	$50,000	$1,515,000	30.30	0.43	13.06	2.69	5
SR 0036-25M	$1,600,000	$44,804	$1,515,000	33.81	2.80	94.69	2.81	5
District 3 - Montoursville								
SR 0061-079	$9,000,000	$66,000	$1,500,000	22.72	0.73	16.67	2.24	4
SR 6006-001/002	$13,000,000	$141,000	$4,210,000	29.86	1.08	32.38	2.44	4
SR 0054-014	$9,000,000	$101,000	$2,650,000	26.23	1.12	29.44	2.24	4
SR 0015-077	$63,000,000	$141,000	$4.500,000	31.91	0.22	7.14	2.94	5
SR 0049-50M	$5,200,000	$56,000	$1,900,000	33.93	1.08	36.54	2.94	5
TOTAL	$120,500,000	$704,047	$18,285,050					

* Total project cost includes design and construction cost.

Table 7-4. Statistical Analysis of all the (10) SUE Projects for Benefit-Cost Analysis.

Highway Projects	Benefit-Cost Analysis					Total Project Cost	SUE Cost % Total Project Cost*	SUE Saving % Total Project Cost*
	Min.	Max.	Avg.	Std.	Med.			
SUE	3.25	33.92	22.213	12.711	28.045	$120.50 Million	0.584	15.17

* Total project cost includes design and construction cost.

Table 7-5. Statistical Analysis based on Utility Complexity Level for Benefit-Cost Analysis.

Complexity Level	Benefit-Cost Analysis					Total Project Cost*	SUE Cost % Total Project Cost*
	Min.	Max.	Avg.	Std.	Med.		
1	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2	n/a	n/a	n/a	n/a	n/a	n/a	n/a
3	3.25	3.25	3.25	0	3.25	$3,100,000	0.65
4	4.82	29.86	17.79	11.89	22.72	$36,000,000	1.25
5	30.3	33.93	32.49	1.73	32.86	$81,400,000	1.13

* Total project cost includes design and construction cost.

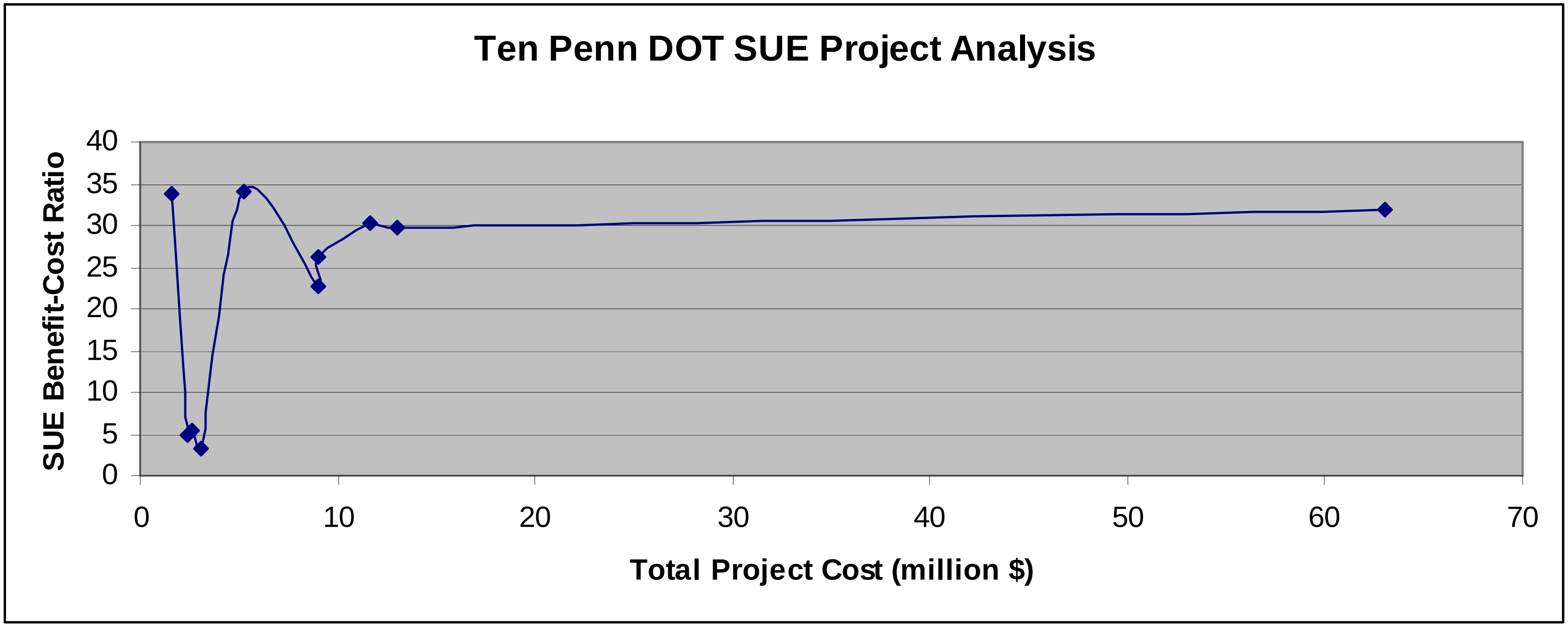

Figure 7-1. SUE Benefit-Cost Ratio vs. Total Project Cost Shows No Relationship.

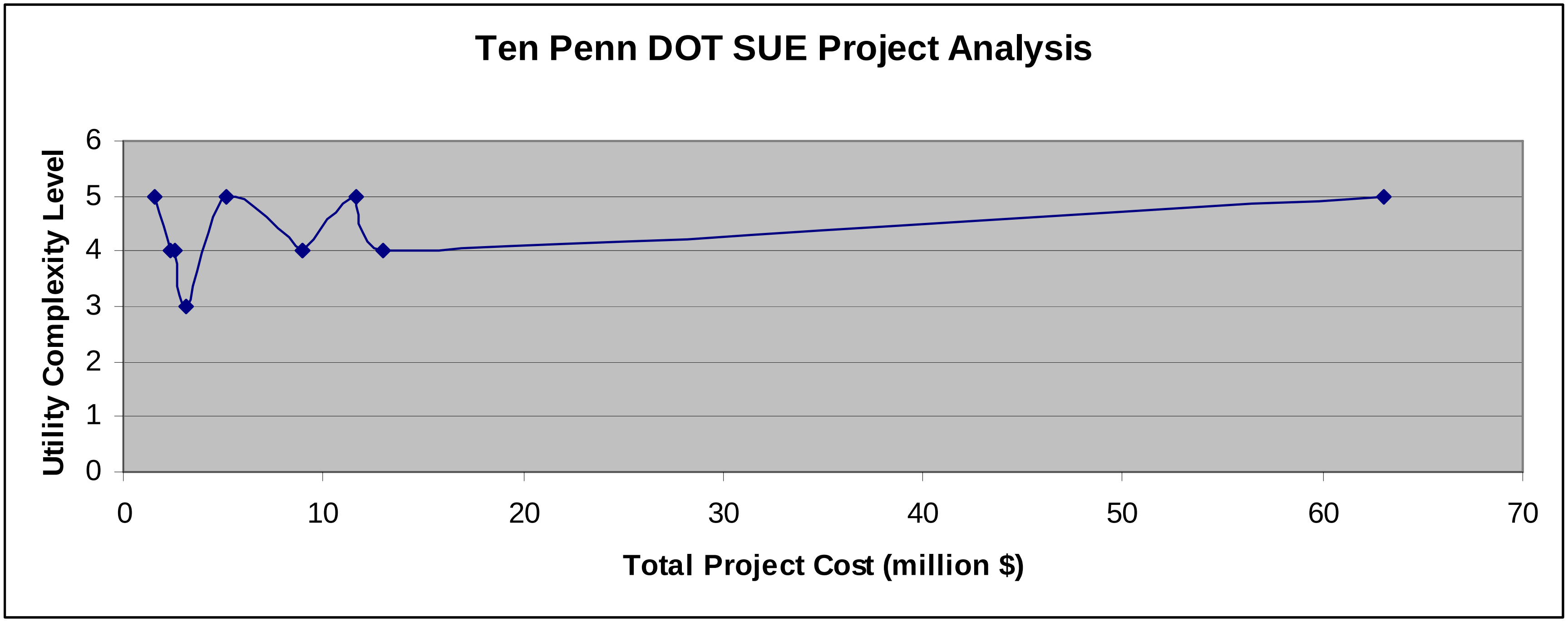

Figure 7-2. Utility Complexity Level vs. Total Project Cost Shows No Relationship.

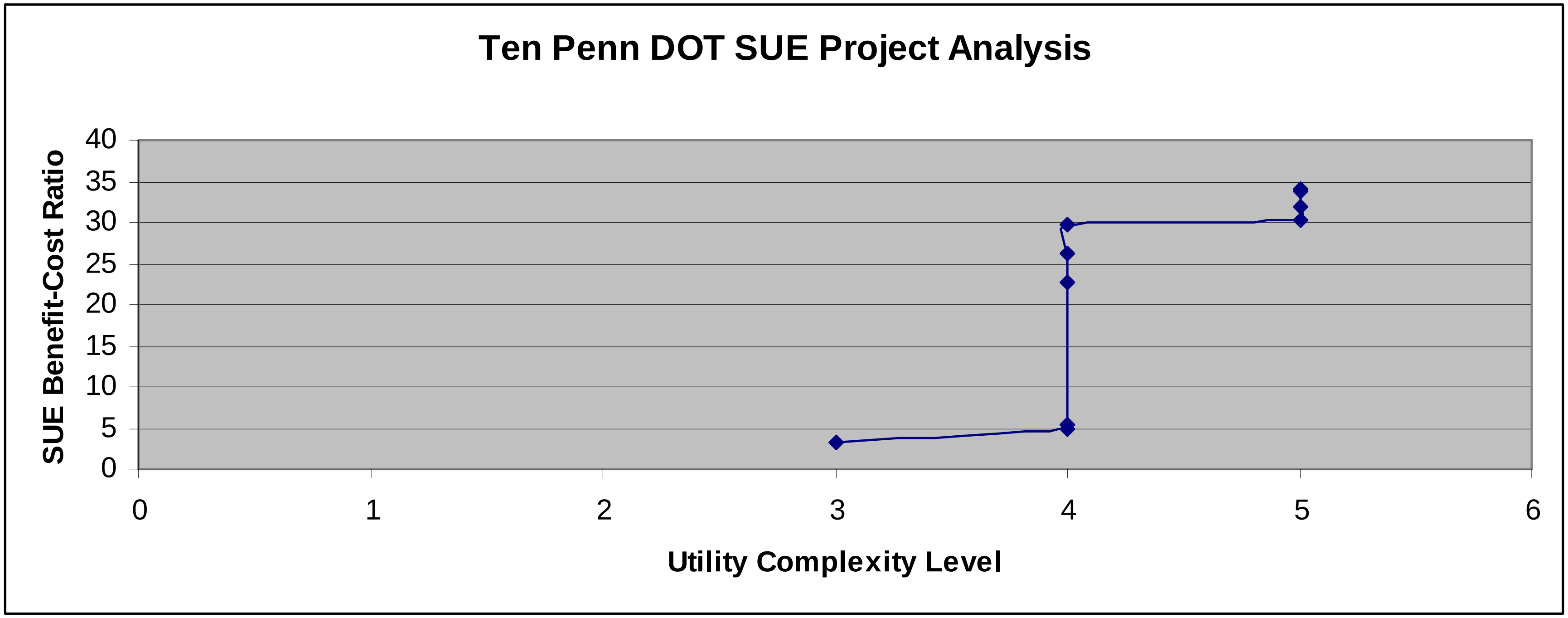

Figure 7-3. SUE Benefit-Cost Ratio vs. Utility Complexity Level Shows Strong Relationship.

Section 8.

Conclusions

Based on this research, it was concluded that most PennDOT districts have an inconsistent process for utilizing SUE quality levels A and B to reduce risks and obtain maximum SUE benefits. The districts in Pennsylvania have considerable autonomy over the use of SUE, design, construction, procurement, and many other issues. Thus, the use of SUE is inconsistent across the state, and on some projects SUE may not be effectively used. A decision matrix tool has been developed to determine which projects should include SUE and what the appropriate level of SUE investigation should be, based on the complexity of buried utilities at the construction site.

From a study of 10 SUE projects from different PennDOT districts, the results indicate that there is a strong relationship between the SUE benefits-cost ratio and the complexity of the buried utilities at the construction site. The greater the complexity of utility level, the higher the SUE benefits. This study also showed that there is no relationship between the SUE benefit-cost ratio and the total project cost.

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Section 9.

Recommendations

Several recommendations for PennDOT subsurface utility engineering programs can be justified based upon the following factors:

1. A review of FHWA, ASCE, and state DOT utility manuals;
2. Discussion with district utility managers and engineers, designers, and consultants; and
3. A review of recent journals, conference papers, and technical reports.

These recommendations are:

1. Each district's utility engineer and project manager should use a decision matrix tool developed in this study to determine which projects should include SUE and what the appropriate level of investigation should be to obtain maximum benefits and reduce risk.
2. Consider utilizing SUE quality levels A and B for all projects/sections/locations that have a complexity level of 2 or higher in Step 3 of a decision matrix tool.
3. Develop a program of continuing education for district managers and engineers on SUE.

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APPENDIX A

SUE Utility Impact Form

SUE UTILITY IMPACT FORM

Project Title : ______________________________

County: **SR:** **Section:**

Project Cost : ______________________________

Design Cost: **Construction Cost:**

Project Description : ______________________________
(General Summary)

____

Project Scope : ______________________________
(Actual Work Scope)

____

Note: If the scope of the project changes, it is recommended that utility impact analysis be done again.

Date of Analysis: _______________ Analysis Done By:____________________
Revised Analysis Date: _____________ Analysis Done By:_________________

Note: Steps 1&2 are screening processes and Step 3 is an evaluation of the project passing Steps 1&2.

SUE UTILITY IMPACT FORM – STEP 1

Table 1. STEP 1 determines whether SUE (quality levels A & B) should be utilized for a project or not. For each question, check the box that best describes the project conditions.

No.	QUESTIONS	Column 1		Column 2	
1	Is there evidence of underground utilities in the project area? (based on information from SUE quality level D&C)	☐	NO	☐	YES or Unknown
2	Does the project require any excavation “regardless of depth”? Note: This includes any TCE or other easements.	☐	NO	☐	YES or Unknown

STEP 1: If there are no boxes in Column 2 checked, then it is generally not practicable to perform a SUE quality levels A and B investigation.

STEP 1: If one or both boxes in Column 2 are checked, please proceed to STEP 2 to conduct further analysis.

SUE UTILITY IMPACT FORM – STEP 2

Table 2. STEP 2 further analyzes whether SUE (quality levels A & B) should be utilized for a project. For each question, check the box that best describes the project conditions.

No.	QUESTIONS	Column 1		Column 2	
1	What is the depth of project excavation? Note: This includes any TCE or other easements.	☐	≤ 18”	☐	> 18”
2	Do you feel that the utility owners in the project area will be able to accommodate the project’s schedule in regard to accurately showing the location of their utility facilities on Penn DOT plans?	☐	Confident	☐	Doubtful
3	What is the likelihood that project will have impact on the existing utilities?	☐	No Impact	☐	Impact
4	How often have the utility owners in the project area provided timely/accurate utility information, if any?	☐	Always	☐	Seldom
5	How would you rate the reliability of the designer to provide accurate design-construction related information?	☐	Good	☐	Poor

STEP 2: If there are no boxes checked in Column 2, then it is generally not practicable to perform a SUE quality levels A and B investigation.

STEP 2: If any boxes in Column 2 are checked, please proceed to STEP 3 to calculate utility impact score and determine the appropriate SUE quality levels.

SUE UTILITY IMPACT FORM – STEP 3

STEP 3 determines which SUE quality level should be selected for a project/section/location.

Project/Section/Location : ____________________

County: **SR:** **Section:**

Project/Section/Location Description & Scope : ____________________

____

____

____

____

Utility Impact Score : ____________________

Table 3. Please check the utility impact rating to the right that best fits your opinion of the issue. If the answer for the complexity factor is unknown, <u>always check Column 3.</u> Please refer to page A-6 for a detailed description of the complexity factors.

No.	Complexity Factors	Column 1		Column 2		Column 3	
1	Density of Utilities (number)	☐	1	☐	2 or 3	☐	> 3
2	Type of Utilities	☐	Less Critical	☐	Sub Critical	☐	Critical
3	Pattern of Utilities (number)	☐	1 Parallel or Crossing	☐	2 Parallel or Crossing	☐	> 2 Parallel or Crossing
4	Material of Utilities	☐	Rigid	☐	Flexible	☐	Brittle
5	Access to Utilities	☐	Easy	☐	Medium	☐	Restricted
6	Age of Utilities (year)	☐	≤ 10 years	☐	> 10 years, ≤ 25 years	☐	> 25 years
7	Estimated Utility Relocation Costs (% of total project cost)	☐	≤ 2 %	☐	> 2, ≤ 5 %	☐	> 5 %
8	Estimated Project Traffic Volume (ADT per lane)	☐	≤ 1,500	☐	> 1,500, ≤ 6,000	☐	> 6,000

9	Project Time Sensitivity	☐	Low	☐	Medium	☐	High
10	Project Area Description	☐	Rural	☐	Suburban	☐	Urban
11	Type of Project/Section/Location	☐	Simple	☐	Moderate	☐	Complicated
12	Quality of Utility Record	☐	Good	☐	Fair	☐	Poor
13	Excavation Depth with Highway Right-of-Way, including Easement (inches)	☐	≤ 18”	☐	> 18”, < 24”	☐	≥ 24”
14	Estimated Business Impact	☐	Low	☐	Moderate	☐	High
15	Estimated Environmental Impact	☐	Low	☐	Moderate	☐	High
16	Estimated Safety Impact	☐	Low	☐	Moderate	☐	High
17	Other Impact-Specify:	☐	Low	☐	Moderate	☐	High

Table 4. Process for calculating the utility impact score based on response from Table 3.

UTILITY IMPACT SCORE: Column 1 – (1), Column 2 – (2), Column 3 – (3)				
1	**Total Box Checked**	**Sum of Column 1**	**Sum of Column 2**	**Sum of Column 3**
2	**Utility Impact Score**	**[(1 x Sum of Column 1) + (2 x Sum of Column 2) + (3 x Sum of Column 3)] / *n****		

n = Number of the complexity factors considered/checked

Table 5. Demonstrates the project complexity level, recommended SUE level to be used and relative cost of using SUE quality level, and project risk level based on the utility impact score from Table 4.

Utility Impact Score	**1.00 – 1.31**	**1.32 – 1.71**	**1.72 - 2.11**	**2.12 – 2.51**	**2.52 – 3.00**
Complexity Levels	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
SUE Quality Levels	**D&C**	**C/B**	**B**	**B/A**	**A**
Relative Cost Factors	1	6.67	16.67	33.33	66.67
Project Risk Levels	**Low (L)**	**Fair (F)**	**Medium (M)**	**High (H)**	**Extreme (E)**

COMPLEXITY FACTORS

In order to properly evaluate the utility impact rating to the right that best fits your opinion of the issue in STEP 3, this section presents detailed descriptions of each complexity factor.

1. Density of Utilities

Density of utilities indicates the number of buried utilities per roadway cross-section that can be expected to be encountered on the project. If there are many utilities expected to be buried within the project, more reliable data/information will be required to successfully locate the utilities. A higher density of utilities means more utility complexity, which requires getting better information related to underground utilities on the project.

Low : One pipe/roadway cross-section
Medium : 2 or 3 pipes/roadway cross-section
High : More than 3 pipes/roadway cross-section and unknown pipes

2. Type of Utilities

Type of utilities indicates service types of buried utilities that can be expected to be encountered on the project. Utilities can be broadly divided into three different categories: (1) municipal, (2) energy, and (3) communication. Critical utilities, such as fiber-optic lines, are buried at a more shallow depth than other types of utilities, so the possibility of accidentally hitting these lines is high. In addition, hitting gas or high voltage lines can have serious impacts. Therefore, critical utilities generally require a greater level of data/information than other underground utilities on the project site.

Less-Critical : Water, forced sewer main, storm water
Sub-Critical : Telephone, electric, television cable, gravity sewer
Critical : Fiber-optic cable, gas, oil, petroleum, high-voltage line, unknowns

3. Pattern of Utilities

Pattern of utilities indicates configuration of buried utilities that can be expected to be encountered on the project. Some areas may have a simple pattern that consists of a few parallel or crossing utilities, while some areas may have a complex pattern that consists of many parallel and crossing utilities. For instance, an intersection in a downtown area may have a more complex pattern of utilities than other areas. A more complex pattern of utilities requires more reliable information.

Simple : One parallel and/or one crossing utility
Medium : 2 parallel and/or 2 crossing utilities
Complex : More than 2 parallel and/or crossing utilities

4. Material of Utilities

Material of utilities indicates the material types of buried utilities that can be expected to be encountered on the project. This factor is separated into three different categories: (1) rigid, (2) flexible, and (3) brittle. Brittle material requires higher quality levels of SUE than other materials. Some utility materials are more susceptible to damage than others.

Rigid : Concrete, cast iron, ductile iron
Flexible : PVC, HDPE
Brittle : Clay, unknowns

5. Access to Utilities

Access to utilities indicates the difficulty or ease of access to buried utilities that may be encountered on the project. If access to buried utilities is restricted, it will be more difficult to get accurate information on these buried utilities than in areas where access to utilities is easy. It is recommended that higher quality levels of SUE be used when access to utilities is more restricted.

Easy : Open land
Medium : Few light structures, pavement, median
Restricted : Bridge pier, other big structures

6. Age of Utilities

Age of utilities may reveal the type of utility material and the physical condition of the utility. Older pipes may have deteriorated extensively and become more easily damaged by an accidental hit during construction activity. In addition, existing records of old utilities may be less reliable.

New : ≤ 10 years
Medium : > 10 and ≤ 25 years
Old : > 25 years

7. Estimated Total Utility Relocation Costs

When higher utility relocation costs (including PennDOT and utilities costs) are expected for the project, more accurate underground information is required to reduce the risks of increased project cost or project schedule delays. SUE quality level A and B investigations can reduce project costs where wrong or poor utility information requires relocating some utilities on the project.

Low : ≤ 2 % of total project cost (Design & Construction Cost)
Medium : > 2 and ≤ 5 % of total project cost (Design & Construction Cost)
High : > 5 % of total project cost (Design & Construction Cost)

8. Estimated Project Traffic Volume

Project traffic volume is the Average Daily Traffic (ADT) volume for the project per lane. Any delay in the project in areas with higher traffic volume will result in greater travel delays to the public. Therefore, a higher level of SUE is required to minimize unnecessary project delays due to encountering unexpected buried utilities at the project site.

Low : ≤ 1,500 ADT per lane
Moderate : > 1,500 and ≤ 6,000 ADT per lane
High : > 6,000 ADT per lane

9. Project Time Sensitivity

Project time sensitivity indicates the project schedule. Accurate utility information can reduce unnecessary project delays that can result from inaccurate design; therefore, more reliable information is required in the design stage for projects that have tight schedules. Higher project time sensitivity means tighter schedules that require avoiding project delays.

Low	:	Project is not time sensitive
Medium	:	Some flexibility in schedule
High	:	Very tight schedule – no time extension

10. Project Area Description

Project area description indicates the location or nature of the project. This factor is separated into three different categories: (1) rural, (2) suburban, and (3) urban. In general, urban areas have more complex and congested utilities because of higher building and infrastructure density. Therefore, an urban area usually means more congested utilities, so higher quality levels are recommended.

Rural	:	Rural areas with lots of open land
Suburban	:	Suburban areas with few businesses and residences
Urban	:	Urban areas with many businesses and residences

11. Type of Project/Section/Location

Type of project quite often may indicate whether SUE is need. As an example, a pavement resurfacing project that generally requires work only on the pavement surface will not need SUE. Project location and, specifically, the section at which the construction work will take place may reveal traffic volume, accessibility, and potential consequences of accidentally damaging the buried utilities. This factor is separated into three different categories: (1) without excavation, (2) shallow excavation, and (3) deep excavation.

Simple	:	Without excavation, i.e., widening, other minor construction work
Moderate	:	Shallow excavation, i.e., guide rail, low depth pipe replacement, traffic light post, shoulder cutting, minor drainage
Complicate	:	Deep excavation, i.e., new construction, full-depth reconstruction, bridge foundation, deep-depth pipe replacement, etc.

12. Quality of Utility Record

Quality of utility record indicates the reliability of existing records on buried utilities. The availability of accurate historical utility records for the project will be able to reduce the potential for accidentally hitting unexpected underground utilities. This factor is separated into three different categories: (1) good, (2) fair, and (3) poor. A poor quality of utility records requires higher quality levels of SUE.

Good : Very accurate record of utilities
Fair : Not very good record of utilities
Poor : Utilities information/data are not accurate

13. Depth of Excavation within Highway Right-of-Way

Depth of excavation within a highway right-of-way often may indicate whether SUE quality level A or B is needed. Note: This includes TCE or other easements. The accurate location of buried utilities at the project site should be determined to save project costs and time together with associated benefits. This depth factor can be separated into three categories.

Low : ≤ 18”
Medium : > 18” and < 24”
High : ≥ 24”

14. Estimated Business Impact

Business impact is concerned with the income and property loss of local businesses resulting from accidents due to hitting unexpected buried utilities. At areas near or surrounding high business density, the quality level A of SUE is essential. User impact, access to business, and length of service interruption should also be taken into consideration.

Low : Very low business impact in the project area
Moderate : Possibility of some business impact in the project area
High : Great business impact in the project area

15. Estimated Environmental Impact

Potential environmental problems caused by accidentally hitting an in-service utility, such as a gas explosion, oil spill, and/or water flooding, need to be assessed. Project areas with a high potential of environmental impact require a high quality level of SUE.

Low	:	Very low environmental impact in the project area
Moderate	:	Possibility of some environmental impact in the project area
High	:	Great environmental impact in the project area

16. Estimated Safety Impact

Safety impact is concerned with possible injury to people caused by accidentally hitting an in-service utility. Projects located in densely populated areas require a high quality level of SUE to minimize the likelihood of such an impact.

Low	:	Very low safety impact in the project area
Moderate	:	Possibility of some safety impact in the project area
High	:	Great safety impact in the project area

17. Other Factors-Specify

Projects having a high potential of other impact factors require a high quality level of SUE to avoid or reduce project risks, i.e., blasting of rocks, relocation of other utilities, etc.

Low	:	Very low impact in the project area
Moderate	:	Possibility of some impact in the project area
High	:	Greater impact in the project area

Relevant Comments:

APPENDIX – B

Utility Impact Rating – Case Studies

1. **Project 1 – SR 4013-002**

Project Title : 7^{th} St. Bridge

County : Blair **SR :** 4013 **Section :** 002

Project Cost : $11.6 million

Design Cost : $2.0 million **Construction Cost :** $9.6 million

Project Description : Replace bridge
(General Summary)

Project Scope : Replace sidewalks, place lighting, narrow road to provide parking
(Actual Work Scope**)** Replace bridge, remove 2 bridges, and realign road

STEP 1

No.	QUESTIONS	Column 1		Column 2	
1	Is there evidence of underground utilities in the project area? (based on information from SUE quality level D&C)		NO	**X**	YES or Unknown
2	Does the project require any excavation "regardless of depth"? Note: This includes any TCE or other easements.		NO	**X**	YES or Unknown

STEP 2

No.	QUESTIONS	Column 1		Column 2	
1	What is the depth of project excavation? Note: This includes any TCE or other easements.		≤ 18"	**X**	> 18"
2	Do you feel that the utility owners in the project area will be able to accommodate the project's schedule in regard to accurately showing the location of their utility facilities on Penn DOT plans?		Confident	**X**	Doubtful
3	What is the likelihood that project will have impact on the existing utilities?		No Impact	**X**	Impact
4	How often have the utility owners in the project area provided timely/accurate utility information, if any?		Always	**X**	Seldom
5	How would you rate the reliability of the designer to provide accurate design-construction related information?		Good	**X**	Poor

STEP 3

No.	Complexity Factors	Column 1		Column 2		Column 3	
1	Density of Utilities (number)		1		2 or 3	**X**	> 3
2	Type of Utilities		Less Critical		Sub Critical	**X**	Critical
3	Pattern of Utilities (number)		1 parallel or crossing		2 parallel or crossing	**X**	> 2 parallel or crossing
4	Material of Utilities		Rigid		Flexible	**X**	Brittle
5	Access to Utilities		Easy	**X**	Medium		Restricted
6	Age of Utilities (year)		≤ 10 years		> 10 years, ≤ 25 years	**X**	> 25 years
7	Estimated Utility Relocation Costs (% of total project cost)		≤ 2 %		> 2, ≤ 5 %	**X**	> 5 %
8	Estimated Project Traffic Volume (ADT per lane)		≤ 1,500		> 1,500, ≤ 6,000	**X**	> 6,000
9	Project Time Sensitivity		Low		Medium	**X**	High
10	Project Area Description		Rural		Suburban	**X**	Urban
11	Type of Project/Section/Location		Simple	**X**	Moderate		Complicated
12	Quality of Utility Record		Good	**X**	Fair		Poor
13	Excavation Depth with Highway Right-of-Way, including Easement (inches)		≤ 18”		> 18”, < 24”	**X**	≥ 24”
14	Estimated Business Impact		Low		Moderate	**X**	High
15	Estimated Environmental Impact		Low	**X**	Moderate		High
16	Estimated Safety Impact		Low	**X**	Moderate		High
17	Other Impact-Specify:		Low		Moderate		High

Utility Impact Score : **2.69**

Recommended Quality Level of SUE : **Quality Level A**

2. Project 2 – SR 0022-024

Project Title	:	Third Ave. Bridge
		County : Blair **SR :** 0022 **Section :** 024
Project Cost	:	$2.6 million
		Design Cost : $600,000 **Construction Cost :** $2.0 million
Project Description (General Summary)	:	Replace SR 22 Third Ave. Br. in Duncansville
Project Scope (Actual Work Scope)	:	Bridge Replacement

STEP 1

No.	QUESTIONS	Column 1		Column 2	
1	Is there evidence of underground utilities in the project area? (based on information from SUE quality level D&C)		NO	X	YES or Unknown
2	Does the project require any excavation "regardless of depth"? Note: This includes any TCE or other easements.		NO	X	YES or Unknown

STEP 2

No.	QUESTIONS	Column 1		Column 2	
1	What is the depth of project excavation? Note: This includes any TCE or other easements.		≤ 18"	X	> 18"
2	Do you feel that the utility owners in the project area will be able to accommodate the project's schedule in regard to accurately showing the location of their utility facilities on PennDOT plans?	X	Confident		Doubtful
3	What is the likelihood that project will have impact on the existing utilities?		No Impact	X	Impact
4	How often have the utility owners in the project area provided timely/accurate utility information, if any?		Always	X	Seldom
5	How would you rate the reliability of the designer to provide accurate design-construction related information?	X	Good		Poor

STEP 3

No.	Complexity Factors	Column 1		Column 2		Column 3	
1	Density of Utilities (number)		1		2 or 3	**X**	> 3
2	Type of Utilities		Less Critical		Sub Critical	**X**	Critical
3	Pattern of Utilities (number)		1 parallel or crossing		2 parallel or crossing	**X**	> 2 parallel or crossing
4	Material of Utilities		Rigid		Flexible	**X**	Brittle
5	Access to Utilities		Easy	**X**	Medium		Restricted
6	Age of Utilities (year)		≤ 10 years		> 10 years, ≤ 25 years	**X**	> 25 years
7	Estimated Utility Relocation Costs (% of total project cost)		≤ 2 %		> 2, ≤ 5 %	**X**	> 5 %
8	Estimated Project Traffic Volume (ADT per lane)		≤ 1,500	**X**	> 1,500, ≤ 6,000		> 6,000
9	Project Time Sensitivity		Low		Medium	**X**	High
10	Project Area Description		Rural		Suburban	**X**	Urban
11	Type of Project/Section/Location		Simple		Moderate	**X**	Complicated
12	Quality of Utility Record		Good	**X**	Fair		Poor
13	Excavation Depth with Highway Right-of-Way, including Easement (inches)		≤ 18”		> 18”, < 24”	**X**	≥ 24”
14	Estimated Business Impact		Low	**X**	Moderate		High
15	Estimated Environmental Impact	**X**	Low		Moderate		High
16	Estimated Safety Impact	**X**	Low		Moderate		High
17	Other Impact-Specify:		Low		Moderate		High

Utility Impact Score : 2.50

Recommended Quality Level of SUE : Quality Level B or A

3. Project 3 – SR 0036-25M

Project Title : 18th St. Culvert

County : Blair **SR :** 0036 **Section :** 025

Project Cost : $1.6 million

Design Cost : $200,000 **Construction Cost :** $1.4 million

Project Description (General Summary) : Lower pavement under RR Culvert to gain OH clearance

Project Scope (Actual Work Scope**)** : Lower road, install drainage

STEP 1

No.	QUESTIONS	Column 1		Column 2	
1	Is there evidence of underground utilities in the project area? (based on information from SUE quality level D&C)		NO	X	YES or Unknown
2	Does the project require any excavation "regardless of depth"? Note: This includes any TCE or other easements.		NO	X	YES or Unknown

STEP 2

No.	QUESTIONS	Column 1		Column 2	
1	What is the depth of project excavation? Note: This includes any TCE or other easements.		≤ 18"	X	> 18"
2	Do you feel that the utility owners in the project area will be able to accommodate the project's schedule in regard to accurately showing the location of their utility facilities on Penn DOT plans?	X	Confident		Doubtful
3	What is the likelihood that project will have impact on the existing utilities?		No Impact	X	Impact
4	How often have the utility owners in the project area provided timely/accurate utility information, if any?	X	Always		Seldom
5	How would you rate the reliability of the designer to provide accurate design-construction related information?	X	Good		Poor

STEP 3

No.	Complexity Factors	Column 1		Column 2		Column 3	
1	Density of Utilities (number)		1		2 or 3	X	> 3
2	Type of Utilities		Less Critical		Sub Critical	X	Critical
3	Pattern of Utilities (number)		1 parallel or crossing		2 parallel or crossing	X	> 2 parallel or crossing
4	Material of Utilities		Rigid		Flexible	X	Brittle
5	Access to Utilities		Easy		Medium	X	Restricted
6	Age of Utilities (year)		≤ 10 years		> 10 years, ≤ 25 years	X	> 25 years
7	Estimated Utility Relocation Costs (% of total project cost)		≤ 2 %		> 2, ≤ 5 %	X	> 5 %
8	Estimated Project Traffic Volume (ADT per lane)		≤ 1,500		> 1,500, ≤ 6,000	X	> 6,000
9	Project Time Sensitivity		Low		Medium	X	High
10	Project Area Description		Rural		Suburban	X	Urban
11	Type of Project/Section/Location		Simple		Moderate	X	Complicated
12	Quality of Utility Record		Good	X	Fair		Poor
13	Excavation Depth with Highway Right-of-Way, including Easement (inches)		≤ 18”		> 18”, < 24”	X	≥ 24”
14	Estimated Business Impact		Low		Moderate	X	High
15	Estimated Environmental Impact		Low	X	Moderate		High
16	Estimated Safety Impact		Low	X	Moderate		High
17	Other Impact-Specify:		Low		Moderate		High

Utility Impact Score : 2.81

Recommended Quality Level of SUE : Quality Level A

4. Project 4 – SR 2014-04M

Project Title	:	Cresson Culvert
		County : Cambria **SR :** 2014 **Section :** 04M
Project Cost	:	$2.4 million
		Design Cost : $71,000 **Construction Cost :** $1.7 million
Project Description (General Summary)	:	Lower pavement under RR Culvert to gain OH clearance
Project Scope (Actual Work Scope)	:	Lower road, install drainage

STEP 1

No.	QUESTIONS	Column 1		Column 2	
1	Is there evidence of underground utilities in the project area? (based on information from SUE quality level D&C)		NO	X	YES or Unknown
2	Does the project require any excavation “regardless of depth”? Note: This includes any TCE or other easements.		NO	X	YES or Unknown

STEP 2

No.	QUESTIONS	Column 1		Column 2	
1	What is the depth of project excavation? Note: This includes any TCE or other easements.		≤ 18”	X	> 18”
2	Do you feel that the utility owners in the project area will be able to accommodate the project’s schedule in regard to accurately showing the location of their utility facilities on PennDOT plans?	X	Confident		Doubtful
3	What is the likelihood that project will have impact on the existing utilities?		No Impact	X	Impact
4	How often have the utility owners in the project area provided timely/accurate utility information, if any?		Always	X	Seldom
5	How would you rate the reliability of the designer to provide accurate design-construction related information?	X	Good		Poor

STEP 3

No.	Complexity Factors	Column 1		Column 2		Column 3	
1	Density of Utilities (number)		1		2 or 3	**X**	> 3
2	Type of Utilities		Less Critical		Sub Critical	**X**	Critical
3	Pattern of Utilities (number)		1 parallel or crossing		2 parallel or crossing	**X**	> 2 parallel or crossing
4	Material of Utilities		Rigid		Flexible	**X**	Brittle
5	Access to Utilities		Easy		Medium	**X**	Restricted
6	Age of Utilities (year)		≤ 10 years		> 10 years, ≤ 25 years	**X**	> 25 years
7	Estimated Utility Relocation Costs (% of total project cost)		≤ 2 %	**X**	> 2, ≤ 5 %		> 5 %
8	Estimated Project Traffic Volume (ADT per lane)		≤ 1,500	**X**	> 1,500, ≤ 6,000		> 6,000
9	Project Time Sensitivity		Low	**X**	Medium		High
10	Project Area Description		Rural	**X**	Suburban		Urban
11	Type of Project/Section/Location		Simple	**X**	Moderate		Complicated
12	Quality of Utility Record		Good	**X**	Fair		Poor
13	Excavation Depth with Highway Right-of-Way, including Easement (inches)		≤ 18”		> 18”, < 24”	**X**	≥ 24”
14	Estimated Business Impact		Low	**X**	Moderate		High
15	Estimated Environmental Impact	**X**	Low		Moderate		High
16	Estimated Safety Impact		Low	**X**	Moderate		High
17	Other Impact-Specify:		Low		Moderate		High

Utility Impact Score : **2.37**

Recommended Quality Level of SUE : **Quality Level B or A**

5. **Project 5 – SR 6006-001/002**

Project Title : Towanda River Rd.

County : Bradford **SR :** 6006 **Section :** 001/002

Project Cost : $13.0 million

Design Cost : $1.0 million **Construction Cost :** $12.0 million

Project Description (General Summary) : Reconstruction of River Rd.

Project Scope (Actual Work Scope**)** : Reconstruct, widen, curbs, sidewalks, relocate R/R install storm drainage

STEP 1

No.	QUESTIONS	Column 1		Column 2	
1	Is there evidence of underground utilities in the project area? (based on information from SUE quality level D&C)		NO	**X**	YES or Unknown
2	Does the project require any excavation "regardless of depth"? Note: This includes any TCE or other easements.		NO	**X**	YES or Unknown

STEP 2

No.	QUESTIONS	Column 1		Column 2	
1	What is the depth of project excavation? Note: This includes any TCE or other easements.		≤ 18"	**X**	> 18"
2	Do you feel that the utility owners in the project area will be able to accommodate the project's schedule in regard to accurately showing the location of their utility facilities on Penn DOT plans?		Confident	**X**	Doubtful
3	What is the likelihood that project will have impact on the existing utilities?		No Impact	**X**	Impact
4	How often have the utility owners in the project area provided timely/accurate utility information, if any?		Always	**X**	Seldom
5	How would you rate the reliability of the designer to provide accurate design-construction related information?	**X**	Good		Poor

STEP 3

No.	Complexity Factors	Column 1		Column 2		Column 3	
1	Density of Utilities (number)		1		2 or 3	X	> 3
2	Type of Utilities		Less Critical		Sub Critical	X	Critical
3	Pattern of Utilities (number)		1 parallel or crossing		2 parallel or crossing	X	> 2 parallel or crossing
4	Material of Utilities		Rigid		Flexible	X	Brittle
5	Access to Utilities		Easy		Medium	X	Restricted
6	Age of Utilities (year)		≤ 10 years		> 10 years, ≤ 25 years	X	> 25 years
7	Estimated Utility Relocation Costs (% of total project cost)		≤ 2 %		> 2, ≤ 5 %	X	> 5 %
8	Estimated Project Traffic Volume (ADT per lane)		≤ 1,500	X	> 1,500, ≤ 6,000		> 6,000
9	Project Time Sensitivity		Low	X	Medium		High
10	Project Area Description	X	Rural		Suburban		Urban
11	Type of Project/Section/Location		Simple	X	Moderate		Complicated
12	Quality of Utility Record		Good		Fair	X	Poor
13	Excavation Depth with Highway Right-of-Way, including Easement (inches)		≤ 18”		> 18”, < 24”	X	≥ 24”
14	Estimated Business Impact	X	Low		Moderate		High
15	Estimated Environmental Impact		Low	X	Moderate		High
16	Estimated Safety Impact		Low	X	Moderate		High
17	Other Impact-Specify:		Low		Moderate		High

Utility Impact Score : **2.44**

Recommended Quality Level of SUE : **Quality Level B or A**

6. Project 6 – SR 0015-077

Project Title : Market St. River Williamsport

County : Lycoming **SR :** 0015 **Section :** 077

Project Cost : $63.0 million

Design Cost : $10.0 million **Construction Cost :** $53.0 million

Project Description (General Summary) : Replace River Bridge

Project Scope (Actual Work Scope**)** : Construct 4-lane bridge , approaches, drainage, and 3 traffic circles

STEP 1

No.	QUESTIONS	Column 1		Column 2	
1	Is there evidence of underground utilities in the project area? (based on information from SUE quality level D&C)		NO	**X**	YES or Unknown
2	Does the project require any excavation "regardless of depth"? Note: This includes any TCE or other easements.		NO	**X**	YES or Unknown

STEP 2

No.	QUESTIONS	Column 1		Column 2	
1	What is the depth of project excavation? Note: This includes any TCE or other easements.		≤ 18"	**X**	> 18"
2	Do you feel that the utility owners in the project area will be able to accommodate the project's schedule in regard to accurately showing the location of their utility facilities on Penn DOT plans?		Confident	**X**	Doubtful
3	What is the likelihood that project will have impact on the existing utilities?		No Impact	**X**	Impact
4	How often have the utility owners in the project area provided timely/accurate utility information, if any?		Always	**X**	Seldom
5	How would you rate the reliability of the designer to provide accurate design-construction related information?	**X**	Good		Poor

STEP 3

No.	Complexity Factors	Column 1		Column 2		Column 3	
1	Density of Utilities (number)		1		2 or 3	**X**	> 3
2	Type of Utilities		Less Critical		Sub Critical	**X**	Critical
3	Pattern of Utilities (number)		1 parallel or crossing		2 parallel or crossing	**X**	> 2 parallel or crossing
4	Material of Utilities		Rigid		Flexible	**X**	Brittle
5	Access to Utilities		Easy		Medium	**X**	Restricted
6	Age of Utilities (year)		≤ 10 years		> 10 years, ≤ 25 years	**X**	> 25 years
7	Estimated Utility Relocation Costs (% of total project cost)		≤ 2 %		> 2, ≤ 5 %	**X**	> 5 %
8	Estimated Project Traffic Volume (ADT per lane)		≤ 1,500		> 1,500, ≤ 6,000	**X**	> 6,000
9	Project Time Sensitivity		Low		Medium	**X**	High
10	Project Area Description		Rural		Suburban	**X**	Urban
11	Type of Project/Section/Location		Simple		Moderate	**X**	Complicated
12	Quality of Utility Record		Good		Fair	**X**	Poor
13	Excavation Depth with Highway Right-of-Way, including Easement (inches)		≤ 18”		> 18”, < 24”	**X**	≥ 24”
14	Estimated Business Impact		Low		Moderate	**X**	High
15	Estimated Environmental Impact		Low	**X**	Moderate		High
16	Estimated Safety Impact		Low		Moderate	**X**	High
17	Other Impact-Specify:		Low		Moderate	**X**	High

Utility Impact Score : **2.94**

Recommended Quality Level of SUE : **Quality Level A**

7. Project 7 – SR 0054-014

Project Title : Danville River Bridge

County : Montour **SR :** 0054 **Section :** 014

Project Cost : $9.0 million

Design Cost : $1.0 million **Construction Cost :** $9.0 million

Project Description (General Summary) : Replace river bridge over Susquehanna River

Project Scope (Actual Work Scope**)** : Construct 4-lane bridge, intersection, and R/R improvements

STEP 1

No.	QUESTIONS	Column 1		Column 2	
1	Is there evidence of underground utilities in the project area? (based on information from SUE quality level D&C)		NO	**X**	YES or Unknown
2	Does the project require any excavation "regardless of depth"? Note: This includes any TCE or other easements.		NO	**X**	YES or Unknown

STEP 2

No.	QUESTIONS	Column 1		Column 2	
1	What is the depth of project excavation? Note: This includes any TCE or other easements.		≤ 18"	**X**	> 18"
2	Do you feel that the utility owners in the project area will be able to accommodate the project's schedule in regard to accurately showing the location of their utility facilities on Penn DOT plans?		Confident	**X**	Doubtful
3	What is the likelihood that project will have impact on the existing utilities?		No Impact	**X**	Impact
4	How often have the utility owners in the project area provided timely/accurate utility information, if any?		Always	**X**	Seldom
5	How would you rate the reliability of the designer to provide accurate design-construction related information?	**X**	Good		Poor

STEP 3

No.	Complexity Factors	Column 1		Column 2		Column 3	
1	Density of Utilities (number)		1	X	2 or 3		> 3
2	Type of Utilities		Less Critical		Sub Critical	X	Critical
3	Pattern of Utilities (number)		1 parallel or crossing	X	2 parallel or crossing		> 2 parallel or crossing
4	Material of Utilities		Rigid		Flexible	X	Brittle
5	Access to Utilities		Easy	X	Medium		Restricted
6	Age of Utilities (year)		≤ 10 years		> 10 years, ≤ 25 years	X	> 25 years
7	Estimated Utility Relocation Costs (% of total project cost)		≤ 2 %	X	> 2, ≤ 5 %		> 5 %
8	Estimated Project Traffic Volume (ADT per lane)		≤ 1,500	X	> 1,500, ≤ 6,000		> 6,000
9	Project Time Sensitivity		Low		Medium	X	High
10	Project Area Description		Rural		Suburban	X	Urban
11	Type of Project/Section/Location		Simple	X	Moderate		Complicated
12	Quality of Utility Record		Good		Fair	X	Poor
13	Excavation Depth with Highway Right-of-Way, including Easement (inches)		≤ 18”		> 18”, < 24”	X	≥ 24”
14	Estimated Business Impact	X	Low		Moderate		High
15	Estimated Environmental Impact	X	Low		Moderate		High
16	Estimated Safety Impact		Low	X	Moderate		High
17	Other Impact-Specify:	X	Low		Moderate		High

Utility Impact Score : 2.24

Recommended Quality Level of SUE : Quality Level B or A

8. Project 8 – SR 0061-079

Project Title	: Cameron Bridge Shamokin
	County : Northumberland **SR :** 0061 **Section :** 079
Project Cost	: $9.0 million
	Design Cost : $1.0 million **Construction Cost :** $8.0 million
Project Description (General Summary)	: Replace Bridge on SR 61
Project Scope (Actual Work Scope)	: Construct 4-lane bridge with approaches and intersection improvements

STEP 1

No.	QUESTIONS	Column 1		Column 2	
1	Is there evidence of underground utilities in the project area? (based on information from SUE quality level D&C)		NO	X	YES or Unknown
2	Does the project require any excavation "regardless of depth"? Note: This includes any TCE or other easements.		NO	X	YES or Unknown

STEP 2

No.	QUESTIONS	Column 1		Column 2	
1	What is the depth of project excavation? Note: This includes any TCE or other easements.		≤ 18"	X	> 18"
2	Do you feel that the utility owners in the project area will be able to accommodate the project's schedule in regard to accurately showing the location of their utility facilities on Penn DOT plans?		Confident	X	Doubtful
3	What is the likelihood that project will have impact on the existing utilities?		No Impact	X	Impact
4	How often have the utility owners in the project area provided timely/accurate utility information, if any?		Always	X	Seldom
5	How would you rate the reliability of the designer to provide accurate design-construction related information?	X	Good		Poor

STEP 3

No.	Complexity Factors	Column 1		Column 2		Column 3	
1	Density of Utilities (number)		1	X	2 or 3		> 3
2	Type of Utilities		Less Critical	X	Sub Critical		Critical
3	Pattern of Utilities (number)		1 parallel or crossing	X	2 parallel or crossing		> 2 parallel or crossing
4	Material of Utilities		Rigid		Flexible	X	Brittle
5	Access to Utilities		Easy	X	Medium		Restricted
6	Age of Utilities (year)		≤ 10 years		> 10 years, ≤ 25 years	X	> 25 years
7	Estimated Utility Relocation Costs (% of total project cost)	X	≤ 2 %		> 2, ≤ 5 %		> 5 %
8	Estimated Project Traffic Volume (ADT per lane)		≤ 1,500	X	> 1,500, ≤ 6,000		> 6,000
9	Project Time Sensitivity		Low		Medium	X	High
10	Project Area Description		Rural	X	Suburban		Urban
11	Type of Project/Section/Location		Simple	X	Moderate		Complicated
12	Quality of Utility Record		Good		Fair	X	Poor
13	Excavation Depth with Highway Right-of-Way, including Easement (inches)		≤ 18”		> 18”, < 24”	X	≥ 24”
14	Estimated Business Impact		Low	X	Moderate		High
15	Estimated Environmental Impact		Low	X	Moderate		High
16	Estimated Safety Impact		Low	X	Moderate		High
17	Other Impact-Specify:		Low	X	Moderate		High

Utility Impact Score : **2.24**

Recommended Quality Level of SUE : **Quality Level B or A**

9. Project 9 – SR 0049-50M

Project Title : Reconstruct Main St. in Elkland

County : Tioga **SR :** 0049 **Section :** 50M

Project Cost : $5.2 million

Design Cost : $700,000.00 **Construction Cost :** $4.5 million

Project Description (General Summary) : Reconstruction of main street

Project Scope (Actual Work Scope**)** : Reconstruct SR 49, replace sanitary and storm sewer, sidewalks, and curbs

STEP 1

No.	QUESTIONS	Column 1		Column 2	
1	Is there evidence of underground utilities in the project area? (based on information from SUE quality level D&C)		NO	**X**	YES or Unknown
2	Does the project require any excavation "regardless of depth"? Note: This includes any TCE or other easements.		NO	**X**	YES or Unknown

STEP 2

No.	QUESTIONS	Column 1		Column 2	
1	What is the depth of project excavation? Note: This includes any TCE or other easements.		≤ 18"	**X**	> 18"
2	Do you feel that the utility owners in the project area will be able to accommodate the project's schedule in regard to accurately showing the location of their utility facilities on Penn DOT plans?		Confident	**X**	Doubtful
3	What is the likelihood that project will have impact on the existing utilities?		No Impact	**X**	Impact
4	How often have the utility owners in the project area provided timely/accurate utility information, if any?		Always	**X**	Seldom
5	How would you rate the reliability of the designer to provide accurate design-construction related information?	**X**	Good		Poor

STEP 3

No.	Complexity Factors	Column 1		Column 2		Column 3	
1	Density of Utilities (number)		1		2 or 3	X	> 3
2	Type of Utilities		Less Critical		Sub Critical	X	Critical
3	Pattern of Utilities (number)		1 parallel or crossing		2 parallel or crossing	X	> 2 parallel or crossing
4	Material of Utilities		Rigid		Flexible	X	Brittle
5	Access to Utilities		Easy		Medium	X	Restricted
6	Age of Utilities (year)		≤ 10 years		> 10 years, ≤ 25 years	X	> 25 years
7	Estimated Utility Relocation Costs (% of total project cost)		≤ 2 %		> 2, ≤ 5 %	X	> 5 %
8	Estimated Project Traffic Volume (ADT per lane)		≤ 1,500		> 1,500, ≤ 6,000	X	> 6,000
9	Project Time Sensitivity		Low	X	Medium		High
10	Project Area Description		Rural		Suburban	X	Urban
11	Type of Project/Section/Location		Simple		Moderate	X	Complicated
12	Quality of Utility Record		Good		Fair	X	Poor
13	Excavation Depth with Highway Right-of-Way, including Easement (inches)		≤ 18”		> 18”, < 24”	X	≥ 24”
14	Estimated Business Impact		Low		Moderate	X	High
15	Estimated Environmental Impact		Low		Moderate	X	High
16	Estimated Safety Impact		Low		Moderate	X	High
17	Other Impact-Specify:		Low		Moderate		High

Utility Impact Score : 2.94

Recommended Quality Level of SUE : Quality Level A

APPENDIX – C

Benefit-Cost Analysis – Case Studies

1. Project 1 – SR 4013-002

Project Title	:	7th St. Bridge, SR 4013-002 (Blair County)
District	:	District 9 – Hollidaysburg
Total Project Cost	:	$11.6 million including design and construction cost
Design Cost	:	$2.0 million
SUE Cost	:	$50,000 (Designating: $23,000; Locating: $27,000)
Project Scope	:	Replace sidewalks, place lighting, and narrow road to provide parking Replace bridge, remove 2 bridges, and realign road
Project Description	:	

The project took place in an urban area and involved replacing an existing bridge, widening traffic lanes, and constructing new bridge approaches. The bridge crossed over Norfolk Southern main railroad tracks and led directly to the area hospital. A large underground phone system had been relocated near the project site two years prior to the project. The project length was approx 1/2 mile. Available information revealed a 16-inch gas line, 12-inch water and sewer line, three underground fiber-optic lines in different conduit runs, buried telephone and vault as well as some unknown lines in the project area. However, the exact location and direction of the existing lines was unknown. For quality level B SUE investigation, electro-magnetic equipment was used together with a field meeting between the SUE firm and the utilities, and coordination with the utilities to carry "beacon" into pipelines. For quality level A, the vacuum excavation method was conducted at 44 different locations. As a result of the SUE investigation, the roadway drainage facilities were successfully designed to save time and relocation expenses; the potential impact of bridge piers construction on the existing lines was avoided; and also the culvert was tied onto the existing pipes.

Cost savings by SUE

Utility relocation cost	:	$500,000
Design & construction cost	:	$1.0 million
Information gathering & verification cost	:	$15,000
Total Savings	:	$1,515,000
B/C Ratio	:	$1,515,000 / $50,000 = 30.3

2. Project 2 – SR 0022-024

Project Title	:	3rd Ave. Bridge, SR 0022-024 (Blair County)
District	:	District 9 – Hollidaysburg
Total Project Cost	:	$2.6 million including design and construction cost
Design Cost	:	$600,000
SUE Cost	:	$50,000
Project Scope	:	Bridge replacement
Project Description	:	

The project was a replacement of an entire existing bridge located at an urban area with high traffic volume. There were three water authorities that crossed at this bridge, one around and two under. The two lines were 12 inches in diameter. There was also a telephone conduit system and vault near the bridge with 10 conduits attached to the existing bridge. Homes and businesses were adjacent to the bridge and allowed little or no room to relocate the facilities. The project length was approximately ¼ mile. The bridge had to be fully open to traffic by a certain date, so it was a time-sensitive project. The initial SUE information was incorrect. The SUE firm found that the utility marked plans were wrong. The utility had depicted the facilities assuming the top of the page was north. In fact, on this plan the top of the page was south. The quality level B SUE investigation was conducted using electro-magnetic equipment along with close coordination with the utilities. For quality level A, the vacuum excavation method was performed at nine different locations. As a result of the SUE investigation it was possible to design shoring around existing telephone conduits, design the bridge to accommodate telephone facilities, and positively identify the gas line and determine that it was not impacted.

Cost savings by SUE

Utility relocation cost	:	$150,000
Design & construction cost	:	$100,000
Information gathering & verification cost	:	$15,000
Total Savings	:	$265,000
B/C Ratio	:	$265,000 / $50,000 = 5.3

3. Project 3 – SR 0036-25M

Project Title	:	18^{th} St. Culvert, SR 0036-25M (Blair County)
District	:	District 9 – Hollidaysburg
Total Project Cost	:	$1.6 million including design and construction cost
Design Cost	:	$200,000
SUE Cost	:	$44,804 (Designating: $15,000; Locating: $29,804)
Project Scope	:	Lower road under RR Culvert to gain OH clearance and install drainage
Project Description	:	

The project was to add drainage to an existing road and also to lower the roadway as much as possible to provide additional overhead clearance for trucks to go freely under a railway overpass. The available information revealed that there was a complex existing utility network at the project site. This included a 12-inch-diameter gas line, a 16-inch-diameter water pipeline, a large buried telephone system, an underground electric system, and an abandoned 36-inch sewer culver along with a 72-inch sewer pipe, all within a 22-ft-wide roadway. For SUE quality level B investigation, electro-magnetic equipment was used along with close coordination with the utilities. For quality level A investigation, the vacuum excavation method was conducted at 15 different locations. Results of the SUE investigation indicated that many of those facilities were abandoned and that the proposed gas line relocation would not work. Also, SUE provided proper location for inlet and drainage facility. Time was the most valuable saving for this project. An additional benefit was that based on the SUE results, the water authority was convinced to replace a 24-inch waterline while the road was open and to prevent the road from being torn up by water in the event of a break in the 100-year-old waterline.

Cost savings by SUE

Utility relocation cost	:	$275,000
Project delay cost by utility relocation	:	$50,000
Redesign cost	:	$75,000
Design cost	:	$5,000
Construction cost	:	$1,095,000
Information gathering & verification cost	:	$15,000
Total Savings	:	$1,515,000
B/C Ratio	:	$1,515,000 / $44,804 = 33.81

4. Project 4 – SR 2014-04M

Project Title	:	Cresson Culvert, SR 2014-04M (Cambria County)
District	:	District 9 – Hollidaysburg
Total Project Cost	:	$2.4 million including design and construction cost
Design Cost	:	$710,000
SUE Cost	:	$34,243 (Designating: $11,000; Locating: $23,243)
Project Scope	:	Rebuild roadway under RR overpass
Project Description	:	

The project was to rebuild a roadway under a railroad overpass. Work involved complete reconstruction of a portion of roadway and installation of drainage facilities. Preliminary information revealed a gas line parallel to the roadway plus underground telephone line and water pipeline within the project site. However, the exact location and the depth of the pipelines were unknown. SUE investigation was conducted by means of electro-magnetic equipment and close coordination with utilities for quality level B. For quality level A, the vacuum excavation method was performed at 15 different locations. Based on the results of the SUE investigation, the drainage facilities were designed to avoid utilities at various locations. Meanwhile, the results of SUE allowed the gas company to map a better plan for relocation.

Cost savings by SUE

Utility relocation cost	:	$5050
Design & construction cost	:	$150,000
Information gathering & verification cost	:	$10,000
Total Savings	:	$165,050
B/C Ratio	:	$165,050 / $34,243 = 4.82

5. Project 5 – SR 6006-001/002

Project Title	:	Towanda River Road, SR 6006-001/002 (Bradford County)
District	:	District 3 – Montoursville
Total Project Cost	:	$13.0 million including design and construction cost
Design Cost	:	$1.0 million
SUE Cost	:	$141,000 (Designating: $66,000; Locating: $75,000)
Project Scope	:	Reconstruct, widen, curbs, sidewalks, relocate R/R install drainage
Project Description	:	

The project was to construct a roadway bypassing the center of Towanda to relieve traffic congestion. Preliminary information revealed many undocumented underground obstacles at the project site. The underground obstacles included unknown location of sanitary sewer, water, gas, telephone, TV and electric lines. There were also abandoned water and sewer lines throughout the project site, but no one knew their exact locations. In the SUE investigation, pipe and cable locators together with existing maps and guidance by surface features were used to determine quality level B. For quality level A, the vacuum excavation method was performed at approximately 150 locations. Based on the results of the SUE investigation, a decision was made to place the drainage facilities at the site without interference with the existing underground utilities.

Cost savings by SUE

Utility relocation cost	:	$1.5 million
Project delay cost by utility relocation	:	$100,000
Change orders & claims cost	:	$75,000
Restoration cost	:	$35,000
Project delay cost by the emergency	:	$1.5 million
Design cost	:	$1.0 million
Total Savings	:	$4,210,000
B/C Ratio	:	$4,210,000 / $141,000 = 29.86

6. Project 6 – SR 0015-077

Project Title	:	Market St. River, Williamsport, SR 0015-77 (Lycoming County)
District	:	District 3 – Montoursville
Total Project Cost	:	$63.0 million including design and construction cost
Design Cost	:	$10.0 million
SUE Cost	:	$141,000 (Designating: $46,000; Locating: $95,000)
Project Scope	:	Construct 4-lane bridge, approaches, drainages, and 3 traffic circles
Project Description	:	

The project involved replacing a bridge into the city of Williamsport, installing traffic circles, and reconstructing state route SR 15. The main purpose of the project was to relieve traffic congestion and to replace an old bridge that had a weight limit and was also inefficient. The project site had a very complex network of existing underground utilities involving unknown locations of sanitary sewer, water, gas, telephone, TV cable and electric lines. Existing maps, surface features, and pipe and cable locators were used to determine SUE quality level B. Approximately 110 vacuum excavation tests were performed to determine quality level A. The results of SUE investigation provided locations for drainage facilities that had little interference with the existing underground utilities. Also, the utility companies were given an accurate location of their underground facilities in this area.

Cost savings by SUE

Utility relocation cost	:	$3.0 million
Redesign cost	:	$500,000
Design cost	:	$1.0 million
Total Savings	:	$4.5 million
B/C Ratio	:	$4.5 million / $141,000 = 31.91

7. Project 7 – SR 0054-014

Project Title	:	Danville River Bridge, SR 0054-014 (Montour County)
District	:	District 3 – Montoursville
Total Project Cost	:	$9.0 million including design and construction cost
Design Cost	:	$1.0 million
SUE Cost	:	$101,000 (Designating: $21,000; Locating: $80,000)
Project Scope	:	Construct 4-lane bridge, intersection, and R/R improvements
Project Description	:	

The project was to replace an inefficient bridge and to improve traffic conditions as well as a railroad crossing in the Borough of Danville. At the project site, there were unknown locations of sanitary sewer, water, gas, telephone, TV cable, and electric lines. Very few maps of the existing pipelines were available. Pipe and cable locators guided with surface features were used to determine SUE quality level B. Approximately 25 vacuum excavation tests were performed to determine quality lever A. Based on the results of the SUE investigation, a decision was made to place the drainage facilities at locations that were least affected by existing underground utilities. Also, the utility companies now have an accurate location of their underground facilities in this area.

Cost savings by SUE

Utility relocation cost	:	$1.0 million
Design cost	:	$1.5 million
Construction cost	:	$150,000
Total Savings	:	$2,515,000
B/C Ratio	:	$2,650,000 / $101,000 = 26.23

8. Project 8 – SR 0061-079

Project Title	:	Cameron Bridge, Shamokin, SR 0061-079 (Northumberland County)
District	:	District 3 – Montoursville
Total Project Cost	:	$9.0 million including design and construction cost
Design Cost	:	$1.0 million
SUE Cost	:	$66,000 (Designating: $20,000; Locating: $46,000)
Project Scope	:	Construct 4-lane bridge with approaches and intersection improvements
Project Description	:	

The project was to replace an inefficient bridge and to relieve traffic congestion in the city of Shamokin. At the project site, there existed a very complex, undocumented underground network of pipelines including sanitary sewer, water, gas, telephone, TV cable, and electric lines. Also there were over five existing water lines that needed to be temporarily and then permanently relocated. To determine SUE quality level B, pipe and cable locators guided with surface features were used. For quality level A, approximately 30 vacuum excavation tests were conducted. The results of the SUE investigation provided locations for drainage facilities that were least affected by the existing underground utilities. Meanwhile, the accurate locations of underground utilities at the project site are now documented.

Cost savings by SUE

Utility relocation cost	:	$250,000
Redesign cost	:	$1.0 million
Restoration cost	:	$50,000
Construction cost	:	$200,000
Total Savings	:	$1,500,000
B/C Ratio	:	$1,500,000 / $60,000 = 22.72

9. Project 9 – SR 0049-50M

Project Title	:	Reconstruct Main St. in Elkland, SR 0049-50M (Tioga County)
District	:	District 3 – Montoursville
Total Project Cost	:	$5.2 million including design and construction cost
Design Cost	:	$700,000
SUE Cost	:	$56,000 (Designating: $26,000; Locating: $30,000)
Project Scope	:	Reconstruct SR 49 and replace sanitary and storm sewer, sidewalks, and curbs
Project Description	:	

To improve drainage and to alleviate traffic congestion, this project involved reconstruction of SR 49 as well as replacement of sanitary and storm sewers, sidewalks, and curbs. Preliminary information revealed sanitary sewer, water, and gas lines at the project site without knowledge of their locations. Because very few maps of existing underground pipelines were available, pipe and cable locators guided with surface features were used to determine SUE quality level B. Quality level A was determined by conducting vacuum excavation tests at approximately 75 different locations throughout the project site. From the results of the SUE investigation, the roadway drainage facilities were located at places with least interference with the existing underground utilities. The results of the SUE investigation also provided the utility companies with an accurate location of their underground pipelines.

Cost savings by SUE

Utility relocation cost	:	$1.8 million
Construction cost	:	$100,000
Total Savings	:	$1.9 million
B/C Ratio	:	$1.9 million / $56,000 = 33.92