Evaluating the use of Subsurface Utility Engineering in Canada

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Word Count: 4576 + (4 figures , 4 tables) = 6576

Submission Date: July 17, 2006

ABSTRACT

The market for Subsurface Utility Engineering (SUE) in Canada is slowly following its U.S. counterpart. In Ontario, the market for SUE has seen rapid growth especially on large-scale municipal projects. This paper presents the results of a 12-month study that investigated the challenges and opportunities facing SUE in Ontario. The study took an in-depth look at 9 large municipal and highway reconstruction projects that utilized SUE to provide an enhanced depiction of buried utilities. Based on this analysis, a cost model for SUE utilization was proposed that takes into account both tangible and intangible benefits. This model was applied to gauge the expected cost savings due to SUE utilization on these 9 projects. All projects showed a positive return-on-investment (ROI) that ranged from $2.05 to $6.59 for every dollar spent on SUE. Although these ROI figures should not be considered universal, they indicate that with careful scoping of SUE services, project risks can be appropriately reduced at reasonable cost. The paper concludes with a set of lessons learned by various project participants from the SUE experience in Ontario.

INTRODUCTION

The plethora of utilities that wind beneath our transportation corridors are increasingly impacting the design and construction of new infrastructure system. With population growth and expansion of urban cores, our infrastructure assets are expanding, aging and becoming in need of repair. As infrastructure ages, records of buried utilities (or knowledge of them) are becoming increasingly irretrievable or difficult to reference. Reliance solely upon existing utility records creates risks for all project proponents. These risks include – but are not limited to - utility relocation costs, extra work orders, change orders, construction and redesign delays and potential damage to utilities with the resultant consequences of death, injury, property damage, and environmental impacts (1).

The sole reliance on utility records for design purposes can lead to the following problems (1):

- Records were not accurate in the first place. Design drawings are not often "as-built", or installations were "field-run", and no record was ever made of actual locations.
- Even so-called "As-builts" frequently lack the detail and veracity needed for design purposes in a utility-congested environment.
- References are frequently lost. Records show a pipeline offset from buildings that no longer exist or from curbs that have been relocated.
- Problems with abandoned buried facilities. It is very common for a facility to become abandoned, to not be physically removed but to be erased from a company's records. Other problems arise with facilities that are abandoned, physically removed, but not erased from a company's records.

In order to mitigate these risks, Subsurface Utility Engineering has emerged as a valuable process that maps the unseen underground through the use of non-destructive techniques. As with the introduction of new processes in any industry, benefits must outweigh costs in order for it to be systematically adopted. This paper investigates the relatively recent introduction of SUE in Canada (specifically within the province of Ontario) and attempts to assess its effectiveness based on a sample of nine large infrastructure projects in southern Ontario.

PROCESS OF SPATIAL UTILITY INFORMATION EXCHANGE

In order to understand how SUE can be beneficial, a comparison of the status quo is necessary. Based on the observation of the spatial information exchange practices among utility owners and designers, the typical process structure for obtaining such data in Ontario includes:

<u>Hand mark-ups:</u> The designer will send a base-map/drawing of features (streets lanes, curbs, property lines, etc.) to different utilities who will in turn indicate by hand (or mark-up) the location of their buried and exposed plant (2).

<u>Hard copy exchange:</u> The utility company will send the designer a hard copy drawing indicating the location of their buried and exposed plant.

<u>Softcopy mark-ups:</u> The designer sends an electronic base-map/drawing to different utilities who will in turn electronically indicate (or mark-up) the location of their buried and exposed plant.

<u>Softcopy exchange:</u> The utility company will send the designer a soft copy drawing indicating the location of their buried and exposed plant.

Each of these processes suffers from a disadvantage or limitation:

Overlooked abandoned plant: Buried utilities that have been abandoned are sometimes removed from records to reduce clutter and storage space.
Overlooked service lines: Mark-ups may unintentionally neglect some service lines especially if they are short.
Inconsistent base-map features: As base-map features change (widened lanes, displaced curb-lines, displaced property lines, etc…), reference to these features become a source of error in location.
Inconsistent geo-reference: This is caused by utility companies using different coordinate systems or geographic reference for their electronic maps.
Security concerns: As with all information, sharing utility information across different entities will always remain an issue. Security and privacy issues of information will remain to hinder full-scale information exchange.

TABLE 1 relates the different information exchange processes with their disadvantages / limitations. The processes are organized in order of decreasing risk to project proponents.

If performed correctly, SUE will minimize the risk of the first four occurrences. With regards to security concerns, the fact that SUE does not involve any soft information exchange among utility companies alleviates this concern. The key disadvantage of SUE is the relatively high cost of conducting a full-scale SUE investigation. The following section investigates the fragile balance between utility-related project risks and the cost of mitigating these risks through the use of SUE.

TABLE 1 Comparison between infrastructure spatial information sharing

Problem/ Limitation / Process	Overlooking abandoned plant	Overlooking service lines	Inconsistent base-map features	Inconsistent geo-reference	Security concerns	Cost
Hand mark-ups	High	High	High	N/A	Low	Low
Hard copy exchange	High	Low	Medium	N/A	Medium	Low
Softcopy mark-ups	High	High	N/A	High	High	Low
Softcopy exchange	High	Low	N/A	High	High	Low

THE VALUE OF SUBSURFACE UTILITY INFORMATION

The most significant contribution of SUE to the design and operation of an infrastructure project lies in the increased reliability of buried utility information. With the escalating level of congestion in our urban streets and the lack of consistent and reliable data about existing utilities, the value of accurate information (that could be provided by SUE) is growing. The decision to take on a SUE study hinges mainly on the value of additional information reliability (provided by SUE) in contrast to traditional methods.

FIGURE 1 shows the relationship between information reliability and the risks associated with projects. These risks include (but are not limited to) hitting existing utilities, delays in the project schedule, or safety hazards to working crews. As shown in Figure 1, the increased information reliability comes at a cost. Low information reliability (Region ‘a’ on the figure) will normally be associated with higher risks. As information reliability increases (Portion ‘c’ on the figure), project risks decrease and the cost increases. Portion ‘b’ in the figure is, theoretically, the optimal region where project risks have been sufficiently reduced (and thus money saved) and the cost of obtaining reliable information is still reasonable.

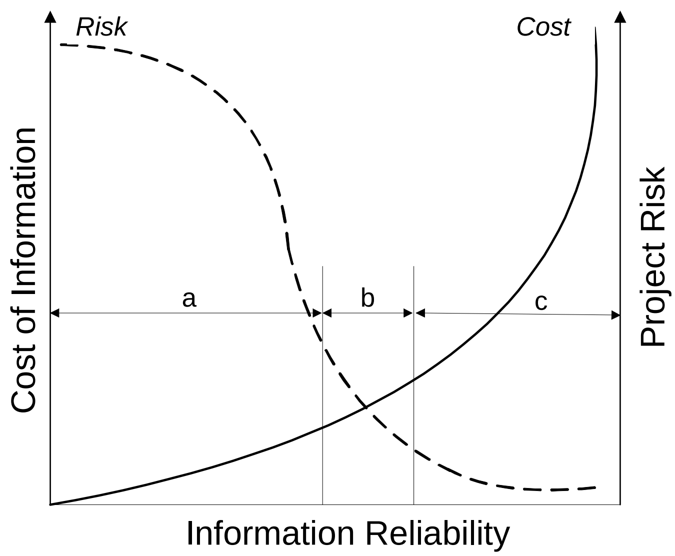

FIGURE 1 The effect of subsurface utility information on project risks

FIGURE 2 schematically illustrates how project risk exposure changes with respect to the reliability of utility information. Let us assume that project ‘A’ takes place in a quiet, new residential suburb with relatively few buried utilities (water, wastewater, and gas), while project ‘B’ takes place in an old downtown business core that has unreliable utility records and a plethora of congested buried utilities. To realize sufficient information reliability, Project ‘A’ requires a small amount of information to be collected, whereas project ‘B’ requires much more detailed information to render the project risks manageable. In order to achieve an acceptable level of risk, Project ‘A’ will only require a typical topographic survey (SUE QL-C), whereas project ‘B’ will require a greater number of subsurface utility investigations of QL-B or QL-A.

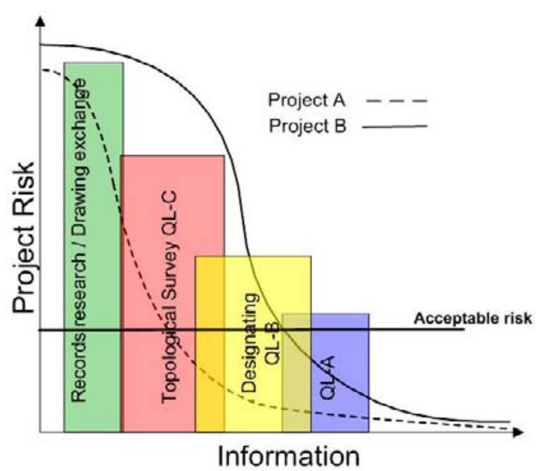

FIGURE 2 The effect of subsurface utility information on project risks for two types of projects

A MODEL FOR THE COST SAVINGS OF SUE

In order to properly account for the benefits of performing SUE on a project, this section presents a generic cost model that incorporates all costs that could be incurred as a direct result of not performing SUE. i.e. the benefits realized through implementing SUE. These costs can be grouped into the following categories:

Cost of Information:

Information Gathering Cost (IGC): The cost & time that the designer or owner would spend to gather information from different utilities and possibly do any field stakeouts using their own crews or by hiring subcontractors.

Information Verification Cost (IVC): The cost that must be paid for field verification of unreliable data (by vacuum excavating, locating, etc.). This is normally done by the contractor and is included in the bid price.

Savings to Project Costs

Design cost (DSC): The existence of reliable information provides for more efficient design. Moreover, the existence of a single CAD file with all utility information means less communication is needed between different personnel in the design team.

Utility relocation cost (URC): SUE can reduce project costs in cases where wrong utility information requires relocating some utilities. i.e. SUE would help avoid such costs in these cases.

Savings to Overall Construction Cost (OCC): Information revealed by SUE will sometimes lead to a more efficient design that will decrease overall construction costs. The accurate identification of subsurface conditions can - in some cases - allow designers to proceed with better designs that would not be considered if there is a high degree of uncertainty

Contractor contingency costs (CCC): Contractors who are faced with unreliable information are expected to increase their contingency allowances during bidding.

Contractor claims & change order costs (CCO): Contractors can request a change order or file a claim in case unexpected utilities are discovered.

Construction Personnel Injury cost (CIC): The cost of injuries to contractor staff due to damaging existing utilities.

Public injury cost (PIC): The cost of injuries to the public due to damaging existing utilities.

Utility damage cost (UDC): The cost of damage to existing utilities during construction. This includes the value of damaged utility and the costs to repair or relocate it.

User Costs

Projects could suffer delays in case an unknown utility is found. This includes the delays due to re-design or to resolve contractors claims. More severe delays exist if there is an injury associated with the unexpected hit of buried utilities.

Travel delay cost (TDC): The cost of travel delays to the motoring public (function of the amount of project delay).

Business impact cost (BIC): The cost of impact on businesses (function of the amount of project delay).

Service Interruption Cost (SIC): The cost of loss of service to utility customers.

Cost of not performing SUE = IGC + IVC + DSC + URC + OCC + CCC + CCO + CIC + PIC + UDC + TDC + BIC + SIC..(Eq-1)

The cost saving items listed in Eq-1 can be divided into two distinct sets:

1- Costs arising due to the identification of one or more buried utilities that were either misidentified (wrongly marked) or unidentified. This identification can occur during one of three phases:
   a. <u>During Design:</u> This has the least impact, and will usually lead to an increase in design cost and time. In some cases, the project may be put on hold indefinitely if the conflict is severe. The costs that are perhaps incurred include **IGC** and **DSC**.
   b. <u>Prior to construction:</u> These discrepancies are discovered during the field verifications performed during pre-construction locates (One-Call services). These discrepancies tend to have a greater impact as the designer has less time to perform redesigns and coordinate utility relocation. Depending on the severity of the conflict, the following costs may be incurred: **IGC, DSC, CCO, URC, TDC, and BIC.**
   c. <u>During construction:</u> This will have the most devastating affect on project cost and schedule. Depending on the severity of the conflict, all of the cost items in Eq-1 may be incurred

2- Costs savings that are achieved as a direct result of utilizing SUE in an efficient way from the early stages of project design. These costs will be realized even if no utility conflicts are discovered. Cost saving items include:
   a. **DSC:** When SUE is utilized in the early stages of a project, designers can proceed with more confidence, and the chance for project redesigns due to utility conflicts is greatly reduced.
   b. **OCC:** Performing SUE as early as possible may give the designer a chance to arrive at more cost effective designs. For example, the information revealed by SUE may lead to the choice of a route that has fewer requirements for trenchless technologies, or is less damaging to existing pavements.
   c. **CCC:** In cases where the SUE information is clearly shown in tender documents, there exists a potential for reduction in contractor bid contingencies due to confidence in subsurface utility information. In some cases, there exists a potential for increased excavation productivity rates, which can result in shortened project durations.

The effect of project characteristics on cost savings

One of the key factors that must be considered in formulating a cost model for SUE is the effect of project-specific characteristics on the value of cost savings. It is acknowledged that higher quality levels of SUE investigation (QL-A & QL-B) will not be required for each and every project. As such, the following section outlines how project characteristics affect the value of cost savings attained by SUE (and hence the ROI for SUE). The following discussion focuses on the first set of costs discussed in the previous section.

The model's main assumption is that cost savings are due to:

1- Finding one or more buried utilities that were either misidentified (wrongly marked) or unidentified (never thought to have existed).
2- Incurring one or more costs due to the above statement (1).

This assumption acknowledges the fact that the mere identification of a utility conflict will not necessarily result in a cost being incurred. A utility conflict encountered during construction on a busy downtown street will be much more critical than one encountered in a quiet residential area in the suburbs. Similarly, damage to a 100 pair fiber optic cable is much more critical (and likely) than damage to a sewer.

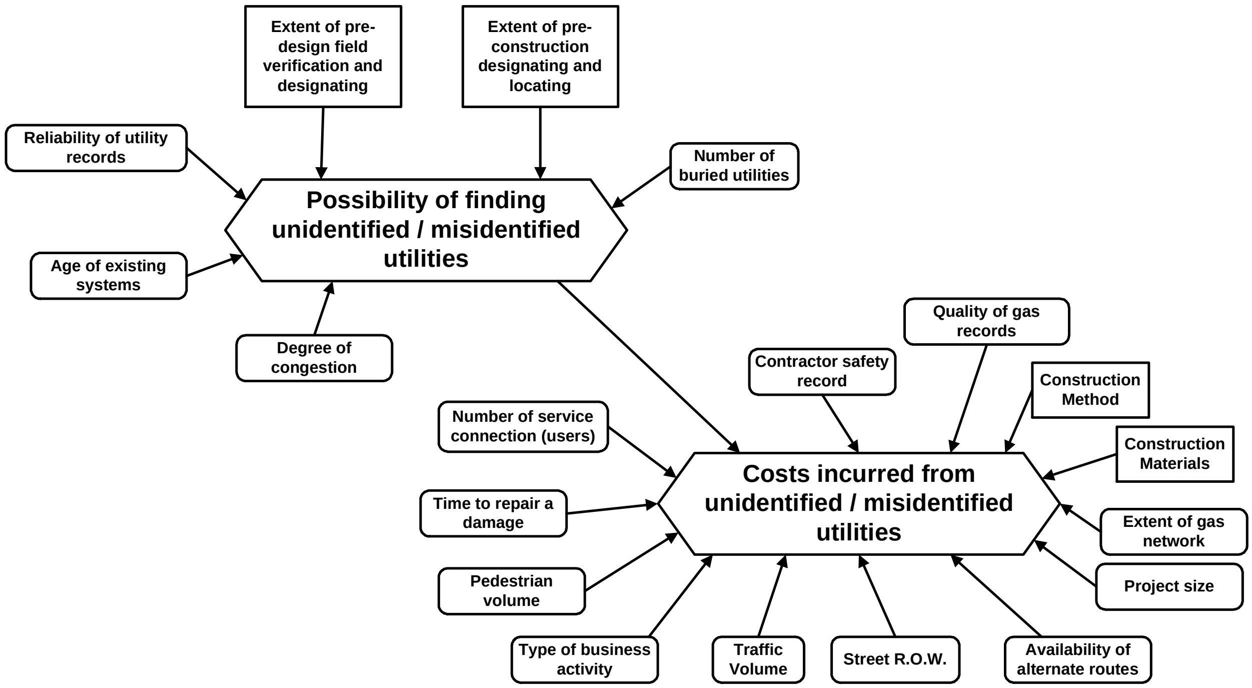

FIGURE 3 Influence diagram showing the relationship between project characteristics and the costs incurred for not performing SUE

The relationships represented by the influence diagram emphasize the notion that simply encountering unidentified/misidentified utilities will not necessarily result in a significant cost being incurred. The actual value of costs incurred will depend largely on a great deal of project-specific characteristics (type of business activity, traffic volume, pedestrian volume, number of buried utilities, etc…).

Each of the cost items identified in Eq-1 is directly affected by one or more of the project-specific characteristics as shown in FIGURE 3. This relationship is multi-faceted and complex;

TABLE 2 illustrates some of these relationships.

TABLE 2 Relationship between certain potential cost saving items and project-specific characteristics

Cost Saving Item	Project-specific Characteristics
CCO: Contractor Claim Costs	Project size: The size of crews and equipment mobilized will have a direct effect on the value of a claim when a utility conflict is discovered during construction. Construction material: Some materials are more flexible than others when it comes to performing minor on-site re-routing. For example, the use of pre-cast concrete pipes and manholes allows for very little flexibility in rerouting, and the lead time required for placing new orders make any utility conflict very costly.
CIC: Contractor Injury Cost	Extent of gas network: As the main reason for contractor injuries during excavation is due to mistakenly hitting a gas utility, the extent of the gas network in the project area will directly influence the probability of contractor injuries. Quality of gas records: The quality/reliability of gas records will directly influence the probability of mistakenly hitting a buried gas utility. Construction method: The construction method adopted for utility installation will influence the probability of hitting a buried gas utility. Using open equipment excavation will greatly increase the probability of hitting a gas line.
UDC: Utility Damage Cost	Number of service connections: The greater the number of service connections, the greater the opportunity for damage to occur. Number of buried utility systems: Generally speaking, water, wastewater and gas are always buried systems. Electricity and telecommunications are sometimes buried. The greater the number of buried systems, the greater the opportunity for damage to occur. Utility susceptibility: Depending on the route of the proposed work, some utilities will be more susceptible to damage than others. This becomes a great concern when the susceptible utility is very costly to repair if severed. For example, excavation work planned near a large fiber optic cable would be prone to incurring a large utility damage cost compared to work that is planned near a small sewermain.
TDC: Travel Delay Cost	Traffic Volume: The greater the amount of traffic, the greater the number of users who will be affected and hence, the larger the travel delay cost. Alternate routes: Presence of alternative routes and/or detours during the closure will alleviate the travel delay costs incurred by users.

CASE STUDY ANALYSIS

The following set of case studies present nine successful cases of SUE implementation in Ontario from 2002-2004. The study team selected projects that involved the construction of large infrastructure projects (Value greater that $500,000). TABLE 3 shows some characteristics of these projects. Details pertaining to each project can be found in (3).

The case studies were investigated by conducting 1 to 2 hour interviews with project owners, and similar interviews were conducted with contractors who worked on the job whenever possible. Project drawings were carefully studied and discrepancies in utility information before and after SUE were compared. These discrepancies were then analyzed, and what-if-scenarios were created to predict the costs that could have been incurred if the SUE investigation had not been carried out. Cost estimates for these scenarios were obtained from the interviewee whenever possible. On projects that did not go to construction, contractor-related costs were estimated through interviews with experienced contractors in the relevant field. A summary of the cost saving itemized according to our model is presented in TABLE 4.

TABLE 4 illustrates only direct cost saving figures. Project time savings are also realized when SUE is performed. These time savings arise from reduced design times, fewer utility conflicts on site, providing lead time to coordinate utility relocations and the potential for increased contractor productivity. Time savings were not included in the calculation of ROI.

Close examination of Table 2 reveals that the bulk of cost savings are concentrated in two main cost items, namely URC and CCC. These results are consistent with similar analysis of SUE cost savings performed in the U.S (4). Analysis of the figures shown in Table 2 and the feedback from owners, designers and contractors revealed:

- The bulk of the cost savings (51%) are attained through the reduction of contractor claim costs. 31% of cost savings are attained through reduction in utility relocation costs, while the remaining 18% is attained through all other cost items.
- Figures for ROI varied considerably across projects. This depended to a great extent on the amount of “information gain” provided by SUE. Some projects that were extremely complex did not have substantial cost savings due to the fact that few discrepancies were identified by SUE. This should not indicate that utilizing SUE was unsuccessful, but rather that the information provided was used to confirm what is already known.
- The 1.1% average figure reported by contractors in the survey for the average value of claims resulting from inaccurate subsurface utility information further reinforces the substantial amounts reported in the CCO cost item. It should be noted that this figure is expected to be much greater on high-risk projects that warrant a SUE investigation (for some many studies that were investigated this figure ranged from 2.5 - 4.5%).
- As most projects were still in the design phase during the collection of information for this study, the value for CCC (Contractor Contingency Cost) was not frequently reported. 50% of respondents from contractors indicate a potential for reducing bid contingencies in cases where SUE was performed (Figure 5(d)). As such, it is expected that more cost savings will be realized once projects are tendered.
- Several cost saving items were realized, but it was not possible to place a dollar value on them through systematic means. Examples include injury costs, impact on businesses, and service interruptions costs. The party investing in SUE does not always directly bear these costs, and hence, it can be argued that a direct return on investment calculation

should not include these figures. Nevertheless, reducing impacts on businesses, injuries and service interruptions should be desirable from both from the public and private-sector perspectives. Whether project owners should invest in SUE to achieve these “user-cost savings” remains questionable.

- Interviews with project designers revealed that in cases when SUE was performed early on in the design process, design times for projects decreased. Rough estimates place these savings at 10-25% of the total design time. These savings are achieved due to the greater level of confidence in information and hence, less amount of ‘guess-work’ and ‘planning-for-the-worst’ are involved. In addition, savings in design are realized due to the reduced amount of redesign that is required once utility conflicts are detected. It should be stressed that these savings will not be fully attained if SUE is performed in the later stages of design.

In an effort to quantify some of the less tangible impacts (reduced traffic disruption, impact on local businesses and the environment), the study team utilized a travel delay model based on estimates for average incomes in Canada (5,6). Based on an average biweekly income of C$2000, the delay value per hour assigned would be $25. To illustrate how the aforementioned model can be utilized, traffic delay costs for the Downtown Hamilton case study will be examined. A traffic diversion plan that will result in the closure of a single lane is assumed, along with an estimated delay of 4 days that could have been encountered if the utility discrepancies were met during construction (assuming that no SUE was performed and a previously unknown utility vault was discovered during construction). Based on AADT values on Hughson St., traffic delay costs associated with the excessive closure of the street are estimated at approximately $50,000.

TABLE 3 Project characteristics of case studies

	Ritson Rd.	Downtown Hamilton	Dunlop Street WM	Weston-Walsh WM	Maj. Mackenzie FM	Homer Watson Interchange	King Street WM	Hall/Reaman st. reconstruction	Weldrick Road Bypass Sewer
Setting	Urban	Urban	Urban	Urban	Urban	Rural	Urban	Urban	Urban
Project	Municipal	Municipal	Municipal	Municipal	Municipal	Highway	Municipal	Municipal	Municipal
Age of Records	Very Old	Very old	Old	Old	Mixed	Old	Very Old	Old	Fairly recent
Land Use	Residential	Commercial	Residential	Mixed	Mixed	Open / Rural	Commercial	Residential	Residential
No. of service connections	Very large	Very large	Large	Large	Medium	Few	Very Large	Large	Medium
Utility congestion	High	Very high	High	High	Medium	Medium	Very High	High	High
Unknown Utilities found	No	Yes	No	Yes	Yes	Yes	No	No	No
Misidentified utilities found	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SUE performed at % design complete	30%	60%	90%	60%	30%	30%	30%	90%	30%
Project Cost ($M)	4.1	N/A	0.5	N/A	8-10	20	1.5	0.9	1.7
SUE % of Total	2.3%	N/A	1.8%	N/A	0.2%-0.25%	0.125%	2.6%	1.2%	3.5

TABLE 4 Summary of Cost Savings and ROI for the nine case studies.

		Ritson Rd.	Downtown Hamilton	Dunlop Street WM	Weston-Walsh WM	Maj. Mackenzie FM	Homer Watson Interchange	King Street WM	Hall/Reaman st. reconstruction	Weldrick Road Bypass Sewer	Total
Cost Saving Item	**URC**	150,000		50,000		10,000				100,000	**310,000**
	DSC	9,000	52,000			NAE	2,000	4,000	2,000	8,000	**77,000**
	CCC	20,000									**20,000**
	OCC				48,800	8,000			1,000		**57,800**
	CCO	10,000	230,000		52,000	60,000	60,000	75,000	30,000		**517,000**
	CIC										
	UDC		NAE‡					NAE		15,000	**15,000**
	PIC										
	TDC		50,000†		NAE		NAE	NAE			
	BIC		NAE		NAE			NAE			
	SIC				NAE			NAE			
Total Savings		**189,000**	**$282,000**	**50,000**	**$100,800**	**$78,000**	**$62,000**	**$79,000**	**$33,000**	**123,000**	**996,800**
SUE Cost		**90,100***	**$42,785**	**9,340**	**$31,000**	**$20,000**	**$25,000**	**$40,000**	**$11,000**	**60,000**	**329,225**
ROI		**2.1**	**6.59**	**5.35**	**3.25**	**3.9**	**2.48**	**1.98**	**3.0**	**2.05**	**3.41**

** It should be noted that the relatively high cost for the SUE investigation at Ritson Road was mainly due for the following reasons: 1) This was the first full-scale SUE investigation in Ontario. At the time, crews, equipment and expertise were being imported from the U.S. at high costs. 2) It is the investigators' opinion that the scope of the SUE investigation was somewhat exaggerated. The 43 test holes that were performed could have been greatly reduced in number without significant sacrifice of information quality.*

† *Not included in ROI calculations*

‡ *NAE: Indicates that this cost saving was realized but no accurate estimate was available.*

Comparison with the Purdue study

One of the most well-cited and comprehensive studies that investigated the benefits of SUE was that commissioned by the FHWA in the late nineties and conducted by Purdue University (7). Comparison of cost savings to the Purdue University study reveals some similarities and certain differences. The highest items in cost savings were similar (Contractor claim costs and utility relocation costs). The Purdue study differed in that the highest item for cost saving was reported as utility relocation cost, while figures in Ontario show that the top cost saving item is contractor claim costs. This discrepancy can be attributed to the fact that the scope of the Purdue study focused on highway-related projects, whereas the case studies in the report are predominantly municipal projects. In highway projects, the decision to relocate a utility has a much more profound financial impact due to the linear extent of most highway projects as compared to the relatively smaller-scale of municipal projects, especially in urban areas.

FIGURE 4 shows a comparison between the cost saving figures. Another interesting difference is that the Purdue study reported accident and injury costs at 11.7% of the total cost savings, whereas this report did not report any qualitative cost savings for injury costs. The Purdue study based their estimates for injury costs as a fixed percentage of the contractor's general liability premium without considering conditions specific to each project. As a more conservative approach, this report does not include any qualitative cost savings for injury costs.

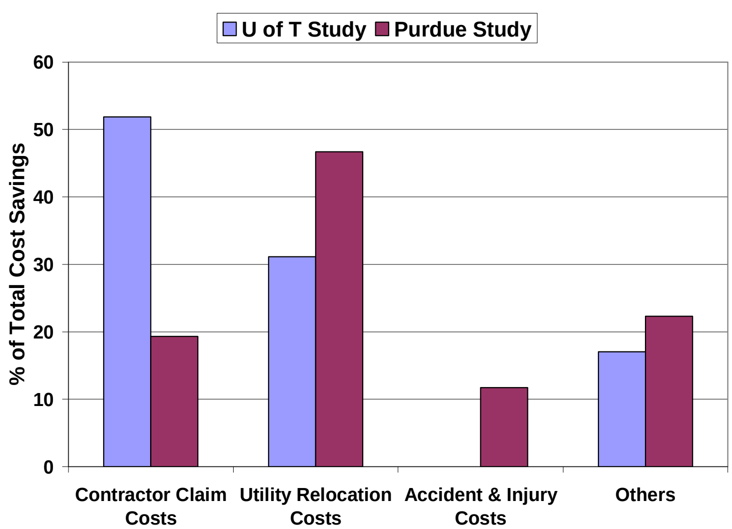

FIGURE 4 Comparison between cost savings items in Ontario and those reported in the Purdue Study

DISCUSSION & LESSONS LEARNED

As part of the investigation, the study team explored the concerns that were expressed by agencies acquiring SUE services. Five main concerns were highlighted:

<u>Need to identify ownership rights:</u> Project owners expressed their concerns over the need to identify proper ownership rights for the information produced by SUE. Owners expressed their concern over the possibility of reselling this detailed information by the SUE provider to other utility owners who might pursue projects in the same area. Although SUE providers are

professionally bound to not disclose this information, some project owners expressed their concerns in this regard.

Overconfidence: Project owners that have acquired SUE services complain of the overconfidence that their design team has felt during the design stage. Although basing designs on confident information allows the design process to proceed smoothly (and hence, saves design time and money), an overconfident design team that believes that all information is precise is more prone to design errors. This issue should be resolved by better education of designers on the meaning of different quality levels, their level of accuracy, and the techniques employed in collecting subsurface utility data.

Desiring too much information: One of the project owners indicated that when a SUE investigation is performed, it is likely that the project proponents (especially those with ventured interest in eliminating their risks) might get a *'Craving for Information'*. This desire for too much information could cause the scope of the SUE investigation to increase and hence, the cost of SUE to soar. It is imperative that the scope of SUE be fine-tuned to truly reflect the designer's needs as well as the project conditions.

Possibility for work duplication: In a scenario where the design is not performed in-house, some owners expressed concern about the possibility of some work duplication between the SUE provider and the designer. If the interface is not properly managed, and the scopes are not well defined beforehand, the possibility of some work duplication exists amongst the two. This duplication will usually exist in the processes of records research (QL-D) and in some cases may extend to field surveys (QL-C).

Selecting the proper level of SUE: The accuracy of information revealed by SUE is directly related to the scope of SUE service. In many cases where only a QL-C is performed, the owner runs the risk of missing some service connections or an abandoned plant. In many cases, QL-A could be seen as "over reaching". There is a need for developing some guidelines for selecting the proper SUE level.

Some of the major recommendations supported by the case studies and input from industry include:

- Increasing awareness of SUE: Although most municipalities and utility companies are quite aware of the SUE process and its various quality levels, this is not the case among contractors. Responses to contractor's survey revealed a reluctance to adjust bid contingencies in cases where SUE investigations were performed. It is believed that this was mainly due to the fact that contractors are not entirely aware of the SUE process, how it differs from traditional methods of information collection, and the meaning of the 4 quality levels. This increase in awareness can be achieved through various contractor associations and industry groups.
- Explicit transfer of risk pertaining to utility information: In order to leverage the full benefits of SUE, it is believed that project owners should amend contract conditions such that the risk pertaining to inaccurate subsurface utility information is bared by those parties that are best capable of managing it. Traditional contract clauses that transfer all such risks to contractors will eventually prevent contractors from adjusting their bid contingencies in cases where substantial SUE investigations are performed. When a full-scale SUE investigation is performed the owner and SUE provider are best fit to assume these risks. Transferring this risk to contractors is unnecessary and will only lead to higher bid contingencies.

- Systematic incorporation of SUE: Conducting a SUE investigation should not be considered an ad-hoc exercise by project owners. In this regard, SUE should be considered as an integral part of the greater process of project risk management (where the risk to be managed is the inaccurate location of subsurface utilities). As such, all project owners should systematically consider the use of SUE on all projects that pose a substantial amount of risk.
- Formalizing guidelines for level of SUE utilization: Faced with constrained budgets, project owners will be unable to perform higher quality levels of SUE (QL-A & QL-B) on all high-risk projects. Guidelines are required to assist project owners in allocating limited budgets to projects that will benefit the most from these levels of SUE. This study presented some project-related characteristics that could warrant a SUE investigation worthwhile, but much more analysis is needed to create formal guidelines to assist project owners in their decision-making process.
- Utilizing SUE early along the design process: Based on feedback from organizations that acquired SUE, there was a consensus that if a SUE investigation is performed, it should be brought in is as early as possible in the design stage. This will ensure that the information that SUE provides will not lead to substantial amounts of costly re-design. Ideally, SUE should be utilized throughout the planning and design stages. It should be noted that in some cases the SUE process was extended over a length of time and not performed all at once. This flexibility can provide project owners with the appropriate amount (and quality) of information that is required at each stage of design.

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