	TRENCHLESS TECHNOLOGY RESOURCE CENTRE	
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	SITE SURVEY AND BURIED INFRASTRUCTURE LOCATION	NEW VERSION MAY 2006

INTRODUCTION

The first task for the rehabilitation contractor after site arrival is to locate the sections of pipe he has agreed to rehabilitate .This begins with a set of as built drawings which purport show the location of the pipeline in relation to surface features However, such drawings are frequently inaccurate, and most contracts put the responsibility for verification of this information firmly in the hands of the contractor.

The contractor must also assess the potential impact of the works on adjacent utilities and other buried infrastructure. This is particularly important in the case of technologies such as pipe bursting and high sensitivity utilities such as gas, power and fibre optics. In spite of the growth of central utility record systems of the “one call “type the contractor is ultimately responsible for the prevention of collateral damage to existing infrastructure. The costs, and inconvenience, of such collateral damage have increased dramatically over the past few years, and they are a major cause for concern. This has lead to the development of an alternative approach to the problem which has been given the acronym SUE (Subsurface Utility Engineering) and is discussed below

Chart 1 shows the approximate installed depth range of the main types of buried infrastructure for each utility. The upper depth is the minimum depth of cover while the lower is the maximum depth of cover plus the diameter of the largest pipe used for the particular service. It can be seen that the majority of the distribution systems are
Located in the 0.5m to 1.5m zone and work carried out on any one of them carries a high risk of damaging the others. This is graphically illustrated in Figs 1 which emphasises the complexity of services beneath a city street and Fig 2 which shows the close proximity of a number of utilities. Fig 3 shows the spectacular outcome of a hit on a water main caused by HDD installation of a CATV cable.

Fig 1 complexity of utilities just beneath a city street

fig 2 close proximity of utilities in an access pit

Workers digging hole for fiber optic lines hit the wrong spot

ANDREW CUTRARO / POST-DISPATCH

A stream of water from a broken pipe drenches westbound traffic on Highway 40 (Interstate 64) Thursday afternoon. The pipe was broken by workers for an electrical contractor who were digging to lay fiber optic lines. They cut into a 24-inch reinforced concrete pipe.

Ruptured water pipe disrupts traffic on busy part of Hwy. 40 [redacted]

The renovation of sewers by lining, is the least problematic situation in terms of location, due to the use of existing manholes and remote lateral reinstatement techniques .The use of pipe bursting for sewer replacement does involve the risk of collateral damage, although, the greater depth of the sewers reduces the risk of encountering water and gas mains., Both pipe bursting and conventional sliplining require accurate location of laterals for disconnection and reinstatement via local excavation .and this also creates a damage risk

Pressure pipes, such as water mains, offer a much greater challenge because there are seldom any useful existing surface access points, and the various utilities are frequently installed very close to each other. In these circumstances the use of pipe bursting may involve a high risk of collateral damage, and hence increases the need for accurate location and identification of buried pipes.

The easiest and most direct way to verify the location of the pipe, and adjacent utilities, is by a small excavation, termed a" trial hole." The holes are excavated at key points identified from the as built drawings. If the excavations confirm the information on the as built drawings, the contractor can proceed to the next stage. If there are large discrepancies, either more trial holes must be dug, or alternative location techniques must be used. The excavation and reinstatement of trial holes can be expensive and potentially disruptive, and can also cause collateral damage. The use of vacuum excavation methods, described in Section 9, can help to reduce the costs, risks, and disruption of the trial hole procedure

THE SUE APPROACH

The information on SUE is based on two papers presented at recent N0-Dig Conferences by Arioglou et al (Copenhagen 2002) and Jeong et al; (Montreal 2002)

The SUE concept was developed by the USDOT Federal Highways Administration as a means of reducing the costly effects of collateral damage during projects involving the highways. The process is carried out in the planning and design stage long before the commencement of excavations. There are three main components of the process

A) SUBSURFACE UTILITY DESIGNATING:
Using surface geophysical techniques to determine the existence and approximate horizontal position of underground utilities. The geophysical. techniques include various methods, such as pipe and cable locators, magnetic method, metal detectors, Ground Penetrating Radar (GPR), acoustic emission method, etc.

B SUBSURFACE UTILITY LOCATING:
Using minimally intrusive methods of excavation such as vacuum excavation and surveying instruments to allow the precise horizontal and vertical position of the underground utility line to be documented.

C DATA MANAGEMENT:
Surveying utility information to project tolerances and reducing it onto the project design and construction documents. A critical component of this data management involves analyzing all available utility record information with the results of the designating and locating process. Computer Aided Design and Drafting (CADD) and database management technologies are applied to assure the quality, value and utility of the data collected.

The DOTFHA define four quality levels related to the accuracy and completeness of the information derived from the SUE process:

Quality Level D: It is the most basic level of information. It comes solely from existing utility records. It may provide an overall "feel" for the congestion of utilities, but it is often highly limited in terms of comprehensiveness and accuracy. Its usefulness should be confined to project planning and route selection activities

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Quality Level C: It is presently the most commonly used level of information. It involves surveying visible aboveground utility facilities, such as manholes, valve boxes, posts, etc., and correlating this information with existing utility records. When using this information, it is not unusual to find that many underground utilities have been either omitted or erroneously plotted. Its usefulness, therefore, should be confined to rural projects where utilities are not prevalent, or are not too expensive to repair or relocate

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Quality Level B: It is the first level where SUE information is used. It involves "designating" and is usually sufficient to accomplish preliminary engineering goals. Decisions can be made on where to place storm drainage systems, footers, foundations, and other design features in order to avoid conflicts with existing utilities. Slight adjustments in the design can produce substantial cost savings by eliminating utility relocations

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Quality Level A: It is the highest level of accuracy presently available. It involves "locating" and provides precise plan and profile information for use in making final design decisions. By knowing exactly where a utility is positioned in three dimensions, the designer can often make small adjustments in elevations or horizontal locations and hence avoid the need to relocate utilities. Additional information such as utility material, condition, size, soil contamination, and paving thickness, also assists the designer and utility owner in making decisions during the early stages of the project

A wide range of techniques is available to meet the needs of the designating phase and these are listed in Table 1 a and B

TABLE 1 A- AVAILABLE DESIGNATION TECHNIQUES

Methods		Principle of the method	Interpretation of the data	Application information
Electro-magnetic methods (EM)	Pipe and Cable Locator	A transmitter emits an electromagnetic wave (radio frequency, normally ranging from 50 Hz to 480 kHz) to the ground or directly to the pipe and a receiver detects secondary waves generated by the underground utility.	The receiver detects the reflected wave and gives an indication such as a "beep" or a visual sign on the screen for an operator to detect the horizontal position of the underground utility.	Only metallic objects can be detected. - Various application techniques (Conductive, Inductive, Passive, Sonde insertion, Tracing wire/metallic marking tape). - Good for tracing utilities. - Crew size of 1~2 people. -
	Terrain conductivity	A transmitter induces an electromagnetic wave into the ground and a Receiver measures both the primary and resulting secondary magnetic fields.		Typically metallic objects can be detected. Can detect other features associated with ground Conductivity - Effective depth is typically 15 feet or so. - Good for searching utilities - Crew size of 1 person. –
	e-Line Locator	Same as pipe and cable locator but digging a hole and installing an E-Line through a mechanical fitting is required		-Used for plastic gas pipe. - Exact location of pipe is required. - Relatively expensive.
	Metal Detectors	A transmitter emits an AC magnetic field into the ground and a Receiver analyzes the resulting magnetic field.	A receiving unit detects the peak magnetic field and emits a noise, alerting the operator to the presence of the metallic Object.	- Metallic objects can be Detected. - Applicable for shallow manhole lids, valve box Covers and so on. - Crew size of 1 person. - With some types of equipment, the results can be mapped using contouring programs

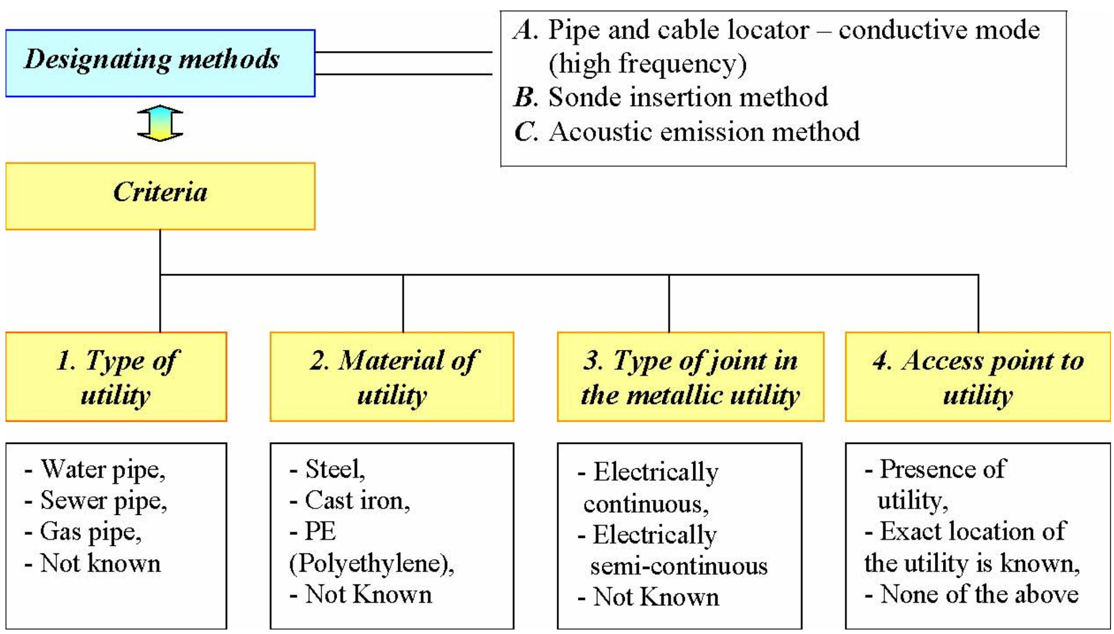
TABLE 1B AVAILABLE DESIGNATION TECHNIQUES0 (Continued)

Methods		Principle of the method	Interpretation of the data	Application information
Electro magnetic methods (EM)	Electronic Marker System (EMS)	A locator transmits electromagnetic signal to the electronic markers and a receiver detects the reflected signal from the electronic markers	The location is indicated with both visual reading and audible tone.	- Usually installed for non-metallic utilities. - Different frequency of electro markers for different type of utility.
	Ground Penetrating Radar (GPR)	The radar sends electromagnetic waves (commonly between 10 - 1,000 MHz) and receives reflected waves from subsurface material. Responds to changes in electrical properties (dielectric and conductivity).	The data to interpret is changes in the materials' electrical properties, through which GPR waves travel. The interpretation is to be made with computer programs by skilled geologists.	- Both metallic and non - metallic utilities may be imaged. - Rule of thumb: from surface up to 6 feet of depth and in very low conductive soils and highly different impedances, a round utility whose diameter in inches does not exceed the depth in feet can be imaged.
Magnetic Methods		It measures the intensity of the earth's magnetic field. Deviation of magnetic intensity caused by ferrous objects is detected by the equipment.	The different intensity of the magnetic field captured by two sensors creates a beep sound or high numeric number on the screen for an operator to detect the existence of metallic object.	- Useful for detecting and tracing ferrous (steel or iron) utilities. - Crew size of 1 person. - Good for searching for vertical and point-source metallic utility structures (e.g. well casings, manhole lids). - Effective depth: 5-10 feet for vertical structures; 2 feet for horizontal structures.
Acoustic Emission Method		An acoustic transducer applies sound waves into utility line. The sound waves travel along the utility lines and special sensors on the ground detect the sound waves that reach the surface.	Special sensors such as geophones or accelerometers are used to detect the sound emitted from the pipe.	- The method is useful for designating plastic pipe (typically water/gas pipe). - The method can service up to 1000 ft (300m) distance for gas pipe and 500 ft for water pipe. - Crew size of 1~2 people.

The applicability of each method depends upon a wide range of criteria which are listed in Table 2 and illustrated in Fig 4

TABLE 2 – CRITERIA AFFECTING SELECTTION OF DESIGNATING METHOD

Criteria	Entries of criteria	
1) Type of utility	Water, sewer, steam, gas, oil and chemical, electric, telecommunication.	
2) Material of utility	Ferrous metallic	Steel, cast iron, ductile iron
	Metallic	Copper and metallic conduit
	Nonmetallic	Fiberglass reinforced plastic (FRP), Vitrified clay, concrete, asbestos-cement, brick, cement, plastics, Fiber optic cable, etc
3) Joint type of metallic pipe	Electrically continuous, semi-continuous, discontinuous	
4) Special materials for detection	Tracing wire or metallic marking tape installed, electronic markers installed.	
5) Access point to utility	Presence of utility, exactly known location of utility, probable location of utility, none of the above.	
6) Ground surface condition	Paved, reinforced concrete paved, natural surface.	
7) Inner state of pipe/conduit	Full with flowing material, partially full with flowing material, conduits full of cables, full and empty conduit, empty pipe or conduit	
8) Soil type	Highly conductive soil, clay dominated soil, silt dominated soil, sand dominated soil, granular and compacted soil.	
9) Depth of utility		
10) Diameter (inch)/ Depth (feet) ratio of utility	>1, <1.	



The paper by Jeong describes in considerable detail a structured approach to technique selection. Some recent costs for use of selected techniques in the USA are listed below

	Source	**Pipe and Cable Locator Method ($ / Meter)**	**GPR Method ($ / Day)**	**Vacuum Excavation Method ($ / Test hole)**
Case 1	An Indiana Utility Company	4.90	-	645.00
Case 2	INDOT	4.25	3,268.00	654.00
Case 3	ILDOT	7.09	-	-
Case 4	A Private Consulting Company	9.35	-	734.00
Average		6.40	3,268.00	678.00
Standard Deviation		2.31	-	49.00

3.1 Commonly Used SUE Application Methods

The most commonly used underground utility designating methods are Pipe and Cable Locators (Electromagnetic Method), Elastic Wave methods, and Ground Penetration Radar (GPR). Vacuum Excavation is the most commonly used underground utility locating method in USA.

When Pipe and Cable Locators are used, a transmitter emits an electromagnetic wave (radio frequency) and a tuned receiver detects any changes in the wave. If the wave comes in contact with a metallic object, an electromagnetic current is subsequently produced on that object by the emitting wave. This current creates a magnetic field around the conductor. The receiver will detect and process the magnetic field, giving the operator a relative signal strength indication. Thus, given this signal strength indication, a trained and skilled operator is able to detect the subsurface target. Where non-metallic pipes need to be traced and mapped, a transmitter sonde can be pushed on a rod through the pipe from a known starting point, provided access can be obtained without interrupting the service. The signal from this can then be traced using the tracing antenna as above.

GPR is a reflection technique that uses high frequency electromagnetic waves to acquire subsurface information. The radar unit emits and receives reflected signals millions of times per second. As a result, not only do the relative depths and "strengths" of the targets appear, but also the image or shape of the target can be inferred on the monitor. Ground penetrating radar responds to changes in electrical properties (dielectric and conductivity), which are a function of soil and rock material and moisture content Early systems required a lot of expertise, and relied heavily on individual interpretation of results. Over the past few years however, advances in software have meant that much of the interpretation is now completed by the machine and its on-board computer. GPR systems come in a variety of forms, from small single channel units, to multi-channel ones, that claim to be able to give a much higher degree of resolution to the survey. Depending on the circumstances in which they are to be used, each has its advantages and disadvantages. One of the main advantages of any GPR system, is the ability to locate and map non-metallic, non-conducting materials such as plastic pipes, and concrete or clay ware sewers.

A pipe under mechanical stress may deform and generate noise. This noise (an acoustic emission or Elastic Wave) can be monitored by various transducers (basically a linear accelerometer that translates motion into electrical signals). The premise is that the noise will be loudest directly over the pipe because the elastic wave travel distance is the shortest at this point. However, type of surface (e.g. soil vs. concrete), fill (e.g. rock vs. clay), compaction, ground moisture, etc., may distort the noise distribution. There are three main methods to utilize acoustic emission techniques. All these methods are susceptible to interference from existing noise, such as aircraft, automobiles, trains, electrical transformers, and so forth.

Vacuum Excavation creates 0.3 - 0.5 m diameter holes to physically confirm the position and depth of an underground utility. Vacuum excavation is an underground utility locating method, using non-destructive digging techniques to determine the precise horizontal and vertical position of the underground utility line. Vacuum excavation provides the window through which Quality Level A information is obtained.

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