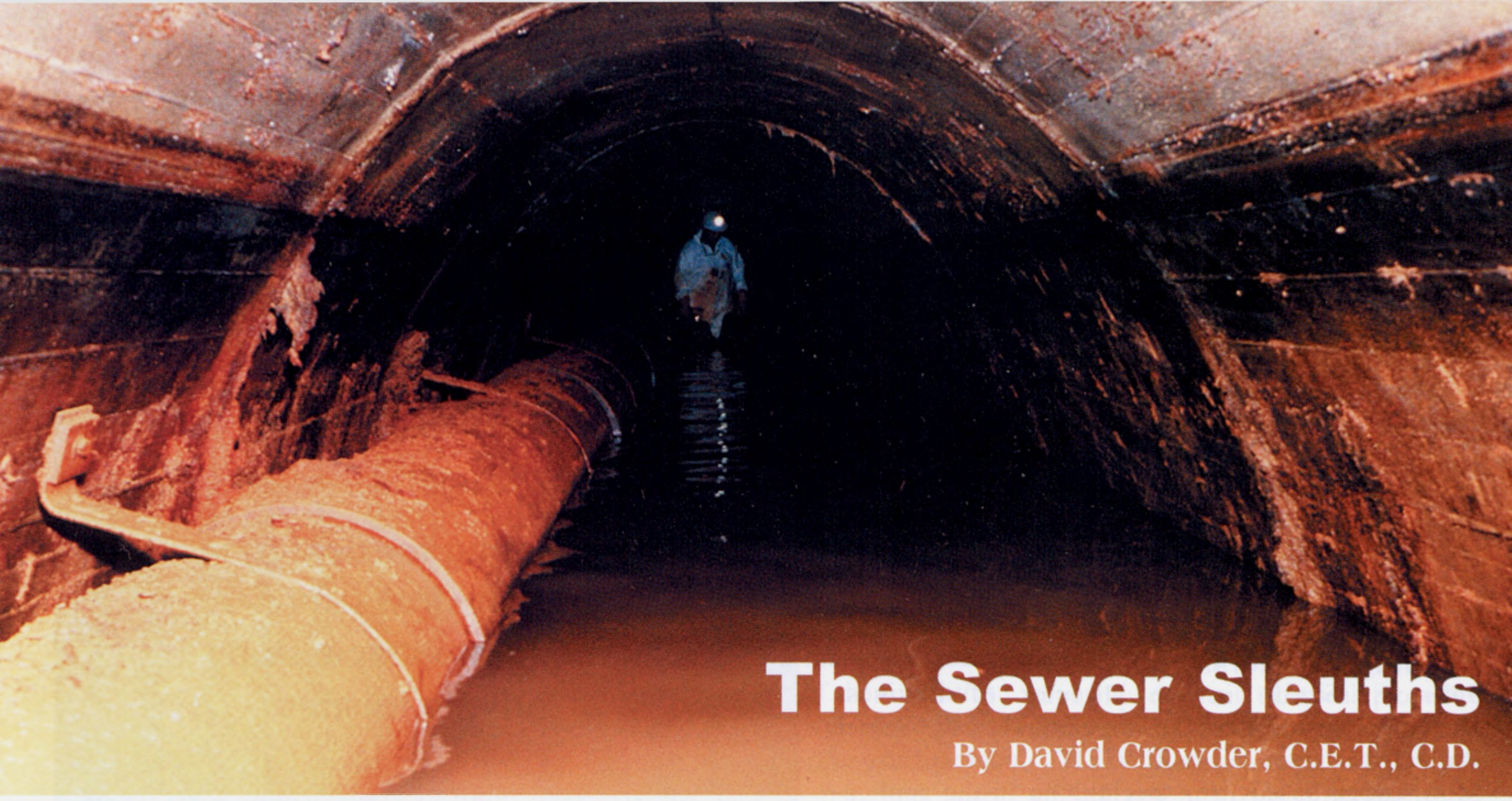

New Technology Detects Toronto's Long-lost Labyrinth

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Few realize it but below the streets and buildings in many cities around the world lie enormous labyrinths of large diameter sewer pipes. As developers renovate, demolish and construct large urban buildings, many of which need deep foundations and multi-level underground parking garages, there is a real danger that these vital underground sewers could be damaged. Although the sewers are large, they can be difficult to locate.

One problem is that there is often insufficient recorded data about older infrastructure to accurately determine the location of the sewer. In addition, the old sewer records are often found to be nothing more than schematic representations. This makes locating the sewers virtually impossible without costly excavation. Until recently, confirming the location of these large sewers involved locating manholes and interpolating an alignment between them.

An emerging technology called electromagnetic field detection technology (EM) could help. EM has proven to be one of the best and most economical methods to accurately locate the horizontal and vertical position of large-diameter sewers underneath buildings. The two case studies describe the successful use of this technology to locate large-diameter sewers in Toronto.

Some of the questions a developer must answer if there is a conflict with a large diameter sewer include:

What is the size and location (horizontal or vertical) of the sewer and will it be in the way of the proposed building?

Is there sufficient room to construct a building over top of an existing sewer?

Is it feasible to construct underground parking beside or on top of the existing sewer?

Is it possible to incorporate deep foundations around this sewer?

What limitations will the city place on this proposed project?

How do we accurately locate a large-diameter sewer that is under a building?

Owners usually discover that there is a sewer crossing their property from the sewer easements, identified on the property title. Once the project designer realizes there may be a conflict, a detailed investigation is required to locate all relevant sewer information.

The starting point is commonly the city's engineering department, where sewer maps are filed, and if available, further detailed record drawings. The age of the sewer often determines how much information is available. The sewer maps are usually schematic only, showing general location, size and type of sewer. Older sewer information will show manhole locations and inverts in imperial units only. These drawings may also show the shape of the sewer and the wall thickness.

Several factors affect the choice to use intrusive or non-intrusive methods to locate large-diameter sewers underneath buildings. The major factor is whether a building is situated partially or completely over top of the sewer. It's not feasible to use an intrusive method to locate a sewer if a building still stands over it, or if the sewer is adjacent to an existing building.

After building demolition, experts may use an intrusive method to locate an existing large-diameter sewer under the future build-envelope. They excavate a series of test pits along the expected alignment of the existing sewer to expose the top of the pipe. Then, they complete an accurate survey to determine the sewer location. The company incorporates survey data into the building drawings to determine if there is a conflict with the proposed building.

The test pits can be excavated by hand or by a backhoe to make a hole large enough to make a direct physical inspection and survey an existing sewer, although the process risks damage to the sewer. Some of the oldest sewers in Toronto are made of brick and due to their age (over 100 years) are fragile.

Most of the sites are confined and there is not enough storage for the excavated material. The excavators must truck material away and bring in backfill material, a costly and time-consuming task.

Vacuum excavation

Vacuum excavation uses suction to remove the earth through a hose, exposing a buried utility or a sewer. There are definite restrictions to this method, as the deepest a vacuum can remove material is about seven metres. The other drawback of this method is the uncertainty that the excavation will be over the centre of the sewer. It may be necessary to advance several holes or a short trench to accurately locate the sewer. This could be time consuming especially if the large-diameter sewer has several bends throughout a building site.

There are two advantages to using a non-intrusive method to locate large-diameter sewers underneath buildings or properties. One is the relatively low cost, and the second is that the work can be done without disturbing the building or surface area on the property. There are currently three non-intrusive methods to locate large-diameter sewers.

Conventional Survey Method

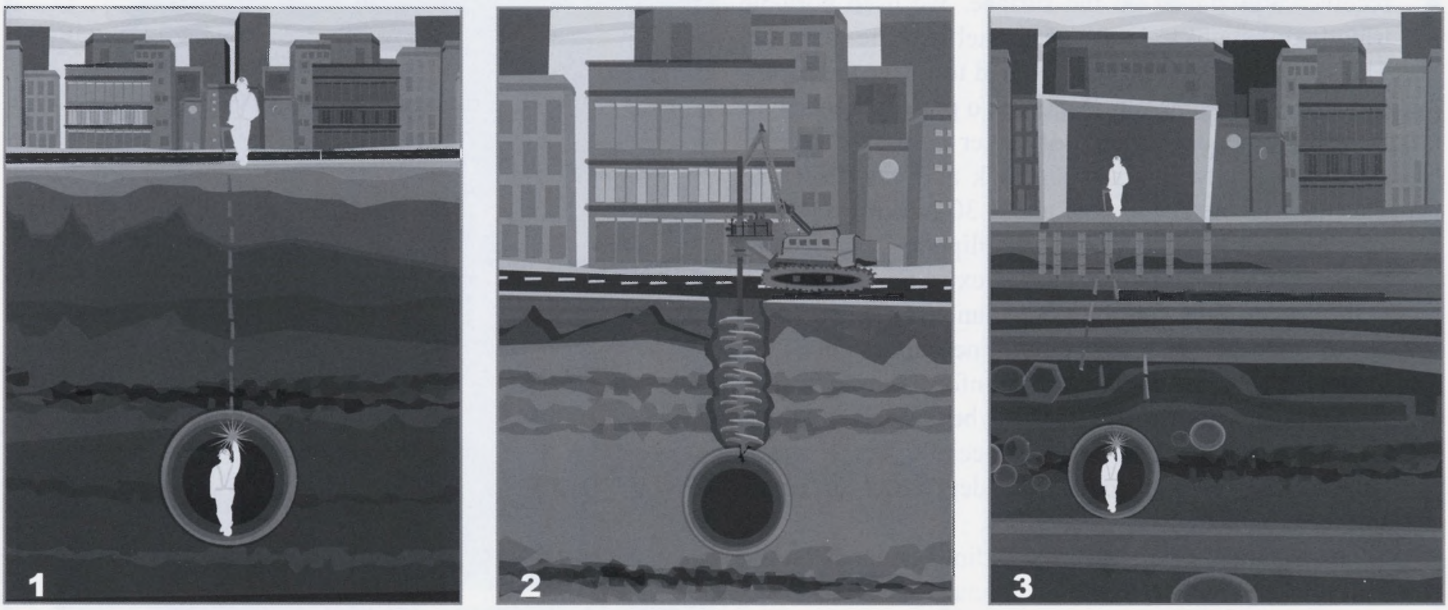
This relatively low-cost method can be used if manholes are relatively accessible. Most large-diameter sewers have few access manholes and therefore the manholes are far apart. If manholes are close and accessible, however, it is possible to complete a traverse survey between the two manholes with a survey crew in the sewer or above ground.

Surveying inside a live sewer poses several hazards, including working in the dark, dealing with existing sewer flows, dealing with slippery conditions, and working in the presence of potential sewer gases. The other problems with using this survey method include the extra labour required to assist the survey crew with manhole entry, lowering the survey equipment down manholes and being prepared to respond in the case of an emergency.

Ground penetrating radar (GPR)

This method uses radar to locate sewers from the ground surface by dragging a toboggan containing a device that emits a radar pulse over the suspected sewer location. The main problem with this method is that soil type can reduce its effectiveness. The best soil type for this technology is sand and gravel, usually found on beaches and in quarries. Toronto's silt and clay soils tend to absorb the radar pulses instead of reflecting the radar signals up to the ground surface.

The other challenge is that the results are often confusing, making it difficult to confirm the precise location of the existing sewers. The equipment is bulky and difficult to use in a



1 A technician takes reading on the surface as another places the sonde in the sewer. 2 If sewer wasn't located, it could be damaged by builders. 3 As reading is taken, there is interference from other sources such as hydro, gas and rebar in the building's floor.

CASE STUDY

Locating a 100-year-old sewer

This case study involves locating a 1.9-metre large-diameter 6.21-metre deep brick sewer in Toronto, beneath an existing building, slated for demolition. We planned to locate and map the precise horizontal and vertical position of this sewer so that the caissons needed to support the new building would not hit the existing sewer. This sewer had to remain in service and before the city would approve this project, the sewer had to be located.

There were no detailed record drawings for this sewer, built more than 100 years ago; sewer maps, however, showed the sewer's general location. A site reconnaissance found the only access manhole in the road fronting the proposed property. This posed even more challenges to locating the sewer because the manhole was nearly 20 feet deep and missing all of the ladder rungs. We determined that a safe sewer entry was possible and contacted the owner for permission.

We chose electromagnetic field detection technology to locate the sewer instead of GPR because the sewer was below an existing building. Interference from the building and lack of clear space to drag the radar transmitter toboggan would make it difficult to use GPR. The City of Toronto staff agreed with the proposed method and offered to help locate their sewer.

The set-up took an hour and a half including discussing and practising safety. A technician with the receiver unit stayed on the surface. We used portable tripod equipment to lower personnel into the manhole. The space was so tight that we had to lower the equipment slowly in separate sections. To protect themselves from the potential hazards of sewer gases, the technicians wore self-contained air pack and gas detectors. The flow in the sewer was about 30-millimetres deep and the invert of the sewer was slippery. The technicians wore headlamps and carried extra flashlights.

In this case, the surface technician compared a small signal from the sonde to the field measure depth of the sewer crown in the manhole. This information is critical for the technician on the surface because it confirms that the readings are accurate, especially where there's interference that may cause the depth measurements and location signals to wander.

The accuracy of the surface readings depends on the skill and experience of the technician "as electromagnetic locators find alternating magnetic fields, not pipes and cables." The technician started tracking the signal transmitted from the sonde while held at the crown of the pipe. Once the technician confirmed and calibrated the signal just in front of the manhole, we proceeded down the sewer at intervals of about five meters.

Radios do not work well underground so we stationed a person at the bottom of the manhole to serve as a communication link between those on the surface and workers in the sewer. The communication link advised the surface technician when the others reached each bend in the sewer. To ensure that the bends were accurately located, the technician on the surface took several readings.

The paint marks on the surface clearly marked the alignment of the sewer. We surveyed these paint marks and tape markers on the building floor and the designer merged the information into the design drawings.

We discovered a potential conflict with the existing brick sewer and the proposed foundation caissons. The City of Toronto representatives requested an inspection after the builders drilled the caissons and before construction started. This inspection confirmed that no caissons penetrated the brick sewer.

Some of the oldest sewers in Toronto are made of brick and due to their age (over 100 years old in some cases) are fragile.

building or a rough site. Interference from the surrounding buildings may also distort the findings.

Electromagnetic field detection (EM)

This is a "walk-over" method similar to that used in horizontal directional drilling operations to pinpoint the precise horizontal and vertical location of the drill head, as described by S.T. Ariaratnam and E.N. Allouche in their article "Suggested Practices for Installations Using Horizontal Directional Drilling," in Practice Periodical on Structural Design and Construction.

This method can be used to locate large-diameter sewers by simply walking in the sewer and placing a sonde (transmitter) along the top (or obvert) of the sewer. As the sonde transmits an electromagnetic field, a technician walks with a receiving unit over top of the sewer at the ground level or in an existing building. The technician detects the signal from the sonde and tracks the centre line of the existing sewer and depth of the top or obvert of the sewer.

The technician will mark the ground with paint or use tape to mark the floor to show the centre line of the sewer. Surveyors pick up the paint and tape marks from the ground and incorporate the information into the design drawings to show any potential conflict with building a new structure.

The receiver is a portable hand-held unit that measures the strength of the signal sent by the transmitter, say S.T. Ariaratnam and E.N. Allouche in their article.

The transmitter/sonde "comprises nothing more than ferromagnetic rod surrounded by a coil, which is energized with a closely controlled signal frequency by a battery-powered oscillator," says Radiodetection Corporation and Radiodetection Ltd. in its publication The Theory of Buried Pipe and Cable Location.

"Rod, oscillator and battery are usually built as a self-contained water-tight unit, designed to be attached to a drain rod, floats, or other appropriate means of traversing along a length of pipe. The distance over which a sonde can be detected is a function of its transmitting power, which is related to size. A tiny sonde for small-diameter sewers inevitably has a limited detection range compared to a large sonde used in deep sewers."

One of the disadvantages of this technology is that the entry into a large-diameter sewer may be hazardous due to limited and deep manhole access. The technician works in complete darkness and may be exposed to hazardous sewer gases and high sewer flows. In addition, interference from other sources such as utilities near the sewer may cause inaccurate readings.

The advantage in using this technology is the cost. The equipment is relatively inexpensive especially compared to GPR units, or destructive methods such as test pits. The true benefit of this technology is its speed and the accuracy.

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Illustrations by Kati Miller.

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The CEC is offering money for research papers

The Continuing Education Committee (CEC) is looking for research papers on topics that would be of interest to AOLS members. It is willing to assist with the costs required for research and publication. Contact Murray LeGris, OLS, OLIP, Executive Director of the AOLS for further details by phone: 416-491-9020, ext. 27 or email: murray@aols.org

Calendar of Events

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August 7th to 10th, 2004
Survey and GIS Summit 2004
Bridging the Gap
San Diego, California
www.esri.com/events/survey

September 12th to 16th, 2004
ASPRS - Images to Decisions: Remote Sensing Foundations for GIS
Kansas City, Missouri
www.asprs.org/fall2004/index.htm

September 22nd to 24th, 2004
AOLS Professional Lecture Course
Toronto, Ontario

October 6th to 8th, 2004
GIS in the Rockies
Denver, Colorado
www.gisintherockies.org

October 15th to 16th, 2004
Survey Law II commences
(3 part course)
Toronto, Ontario

October 27th to 28th, 2004
CIG/ACSG Montreal Branch
Geomatics 2004 -
A Strategic Choice
Montreal, Québec
www.geomatics2004.com

November 7th to 10th, 2004
URISA Annual Conference
Reno, Nevada
www.urisa.org/annual.htm

November 25th to 26th, 2004
AOLS Examinations
Toronto, Ontario

CASE STUDY

Horseshoe sewer

This case study involves a 2.1-by-1.8-metre concrete horseshoe-shaped sewer tunnel, which lies about 17 metres under a parking lot beside a commercial grocery store. The intent of this project was to demolish the existing store and construct a new super store on the entire property over this deep sewer. The existing store was sitting on various layers of mixed fill that were not sufficient for the new store. The builder had to drill caissons to a depth of 25 metres to provide stable foundations for the new super store.

Like the first case, we had little information about this sewer. In fact, some city staff assumed that it was abandoned more than 30 years ago when a much larger trunk storm tunnel was constructed 30 metres to the east of the horseshoe tunnel. Further investigation confirmed that when the city built a larger trunk sewer, it relocated a 750-millimetre sanitary sewer into the existing horseshoe storm tunnel.

There was only one access manhole in the area, however, it happened to be located in the parking lot of the existing grocery store. The access manhole was a large concrete shaft with three separate levels. The concrete was generally in good condition but, as in most old manholes, most of the ladder rungs were either missing or partially corroded. The City crew installed additional ladder rungs.

We used the same EM method to locate this sewer as in the previous case study. Due to the sewer's depth, it took longer to calibrate in the sonde with the receiver at the ground above. We monitored gas readings constantly because there was the potential hazard of gases being introduced into the sewer from a sanitary sewer inspection tee, located on the west wall of this storm sewer tunnel, that was missing its top cap.

The sewer was relatively straight but had a slight change in direction from the manhole. This was obvious from the paint marks on the surface. The surveyors picked up the paint marks and the designer merged the information into the drawings. There would have been a conflict if this sewer had not been located. Shortly after the store was completed, an inspection confirmed that no caissons had penetrated the sewer.

It's easier to accurately locate existing sewers under buildings with the electromagnetic field detection technology and this method can be adapted to most situations with little disruption to surface activities. Other methods are available, but each has its limitations. The relative speed and cost savings to the owner is apparent when using this method.

As an interesting side note, we discovered that records of old sewers are often non-existent or very poor with respect to accurate locations. Often the information is misleading to the point where record keepers don't know the sewer's location, its use or even its existence. Therefore, any record should be suspect until the actual date is confirmed. As confirmed on many occasions, the best source for information is the inspection and maintenance crews, the people who work in the field.

Sites to See

— www.geographynetwork.ca —

The Geography Network Canada is an online resource for finding and sharing Canadian geographic content, including maps and data from many of our country's leading providers. The geographic content ranges from "live" map services that can be viewed online to static geographic data sets that can be downloaded for use with mapping software.

— www.fig.net/figtree/pub/monthly_articles —

FIG - International Federation of Surveyors has been publishing an Article of the Month on its website since July 2003. Each monthly paper focuses on a topic of interest to all surveyors.