Heating utility upgrade

3-D laser scanning helps New York City map the network of utility tunnels of the Wards Island Water Pollution Control Plant

Mark S. Coon

Wards Island Water Pollution Control Plant, in need of a new heating source, tapped the technology of three-dimensional (3-D) laser scanning to provide an accurate map of 70-year-old underground utility tunnels. This upfront investment of $79,000 provided the project engineer with a more precise 3-D model, enabling the project to be constructed in "virtual reality." The virtual plant construction will help avoid potential problems that could occur during construction, such as utility route conflicts, saving time and money prior to the actual building of the new heating facility.

A need for heat

New York City's second largest wastewater treatment facility, Wards Island treats approximately 1.04 million m^3/d (275 mgd) using the conventional activated sludge process. The wastewater originates in the western portion of the Bronx and the Upper East Side of Manhattan.

The New York City Department of Environmental Protection (DEP), the authority that owns and operates the plant, will replace its heating power source, which had been provided by a third party, with a DEP-operated heating plant. A consulting firm is developing the design for the plant through New York Power Authority's Energy Services Program.

The upgrade will provide routine heating to the building and heat for stimulating the growth of anaerobic bacteria in the plant's digesters. The resulting methane gas byproduct could be used to produce electricity or to power plant equipment.

◀ Using 3-D laser scanning to map the utility conduits under the Wards Island Water Pollution Control Plant saved time and money. The scanners emit laser pulses in a predefined pattern. When all of the scans are compiled, they form a "point cloud," a 3-D representation of the scanner's surroundings with a quality similar to that of a photograph.
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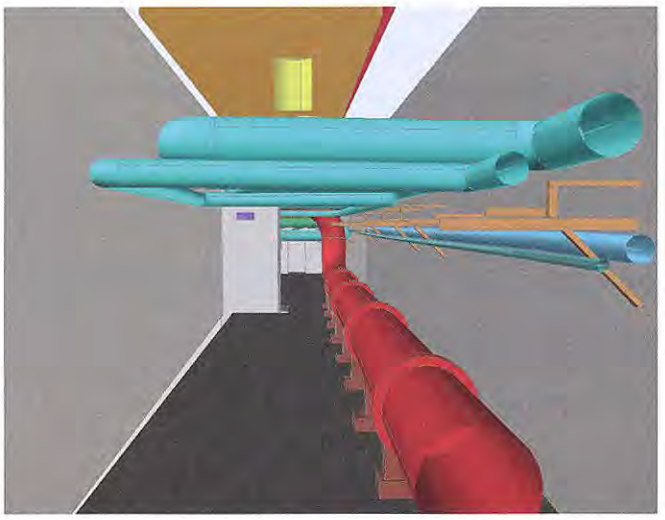
Understanding 3-D laser scanning

Three-dimensional laser scanning brings measurement practices in line with advances in computer-aided design and drafting (CADD) software. Rather than trying to follow all sets of two-dimensional plans, profiles, and cross-sections simultaneously, designers can view the impacts of a layout immediately. The software enables designers to detect and eliminate conflicts between proposed and existing features, which, in turn, reduces onsite construction changes and eliminates unnecessary costs.

Originally constructed more than 75 years ago, the plant and its utility network were modified and improved over time, leaving an inaccurate and incomplete database of record maps. In addition, several of the survey scanning areas are noncontiguous and in multiple alignments. New tunnel data had to relate spatially to a ground-level topographic and utility survey that already had been completed. Accurately tying the model to the project's horizontal and vertical data was essential.

The design engineers enlisted an engineering services firm to devise a spatially accurate and complete method of creating a 3-D model of approximately 1830 linear m (6000 linear ft) of utility tunnels. To capture all the data, the firm recommended combining 3-D laser scanning with conventional total station and global positioning system (GPS) control surveying.

In 3-D laser scanning, a scanner emits laser pulses in a predefined array pattern. When a pulse reaches a solid object, it reflects back to the scanner. The distance to the object is determined either by applying the speed of light to the time traveled by the laser pulse (time-of-flight scanner) or by a code shift in the laser (phase-based scanner). These data are used to calculate the direction of the laser pulse and XYZ coordinate values for the point on the object. Coordinate points receive a particular intensity-value based on the return-signal strength. Changes in intensity-value between points differentiate and identify such materials as metal, concrete, and paint colors. When all the points are assembled, they are known as a



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From the point cloud, survey technicians "fit" geometric shapes – such as cylinders for pipes, and planes for walls and floors – and combine the shapes to build the virtual model. This model, which is more detailed than one produced through hand measurements or record plans, is safer and faster, particularly in a confined space, such as an underground, poorly lit utility tunnel.

Mapping Wards Island utility tunnels

The Wards Island mapping project included the utility tunnels and equipment in three buildings. Because the tunnels run in various orientations and some utilities are buried underground between tunnels or buildings, the engineering team modeled separate locations on a common datum to maintain their spatial relationships.

The project team chose the phase-based scanner instead of the time-of-flight scanner to map the narrow, linear layouts of the tunnels characterized by limited visible distances. A time-of-flight scanner would have served well in a situation with greater visible distances.

The team designated scanner setups every 15 to 18 m (50 to 60 ft) along the tunnel. At each setup, the crew chief identified at least four scan control points that would be visible in the adjoining scan. These points were physical objects with well-defined geometric shapes – such as the corner of an angle iron, the head of a bolt, or the corner of a door frame – that could be easily identified in each scan. Because the scans have to be registered together as a complete data set, common scan control points must appear in the subsequent scan. The team marked a rough baseline along the tunnel floor so that the control survey crew could record approximate station and offset values of each scan control point for recovery.

In the meantime, a control survey crew used GPS units to survey control points above the tunnels at ground level. The GPS quickly and economically tied the horizontal data to the New York State Plane Coordinate System, Long Island Zone. The team transferred elevations to the control points from site features on design plans by digital level in order to vertically tie the control to the Manhattan vertical data.

Using a traditional plumb bob and survey rod, the team also transferred points down into the tunnel at every unobstructed vertical opening. From these transferred points, the team ran a conventional traverse through the tunnel to locate the scan control points. Once the team registered the point clouds into one combined data set, the data also translated and rotated onto the common project horizontal and vertical data. The scan crew sketched cross sections of the tunnel contents at each scanner setup, which aided the modeling technicians and served as a quality check during the 3-D model's final review.

Benefits and cost savings

With traditional utility mapping methods, a field technician actually "touches" the object being measured, requiring him or her to climb down a ladder, crawl into a tight space, or reach under or over pipes with a tape measure or folding ruler. This basic two-dimensional method would have been challenging at Wards Island, where one 3.7-m-wide (12-ft-wide) tunnel may contain more than a dozen different pipe, duct, and conduit lines, even if those lines could be accessed. Manual measurements can be complicated, result in confusing field notes, and be translated incorrectly into a CADD model. Technicians often must return to the site for supplemental measurements.

The laser scanning solution offered several tangible benefits for the Wards Island project. Because laser scanning's highly concentrated beam of light reflects back directly from the object being measured, the technology saves the technician from trying to physically access the infrastructure and protects his or her safety. In addition, the crew collects all possible measurements at one time. Shortly after scanning was added to the project scope, the New York City Office of Management and Budget initiated a value engineering review of the Wards Island Heating Plant Upgrade project. The study considered ways that alternative solutions might achieve the same desired results at a lower cost. Laser scanning and 3-D modeling introduced additional savings into that analysis.

A final benefit of this 3-D scanning project is the time and money saved once the construction crew installs the heating piping. For every day between decommissioning the old heating plant and starting up the new heating system, a higher-cost system must be in operation. Each day that can be shaved off that schedule will help. The high accuracy of this 3-D model will minimize errors and downtime.

The American Council of Engineering Companies (Washington, D.C.) New York office recognized this scanning project with a Diamond Engineering Excellence Award, the highest award in the surveying and mapping category. The council also presented a National Recognition award to the project.

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