High Accuracy Underground Pipeline Mapping & Hydraulic Characteristics by Michael Blackshaw, AquaCoustic Remote Technologies Inc., Vancouver, British Columbia, CANADA (www.aquacoustic.com) and Dr. Arthur G. Self, Artana Solutions Inc.(www.artanasolutions.com)

AquaCoustic is a leading technology demonstrator for planning and execution of infrastructure rehabilitation for manholes and protection of the community. Over time, the historic information of trunk sewer lines has been lost along with the condition and specific location of underground piping. Other factors such as material wear, terrain movement, pipe repairs, and changes to construction design, will also impact the assumed location of trunk sewers. Access to pipes is typically only through periodic (on the surface) manholes. There is a clear requirement to be able to establish the detailed pipe condition and accurate position of such underground piping – we refer to this as "Underground Pipeline Mapping (UPM)". Mapping underground pipes provides several benefits, contributing to better infrastructure management, safety, and environmental protection. Accurate mapping helps prevent accidental damage to underground pipes during construction or excavation projects, reducing the risk of injuries and fatalities.

The goal for high accuracy UPM is likely to have the ability of determining the locations of underground piping to an accuracy of a few cms (<10cm minimum) per 100m distance travelled. In order to achieve this, we employ a wide range of sensors mounted on a mobile tractor platform. More specifically, a forward-looking multi-beam 3D laser coupled with dual time of flight (TOF) profiling lasers. The TOF lasers will be rotating continuously about a horizontal axis thus providing range information over a wide field of view (FOV). The forward-looking multi-beam 3D laser provides an accurate and long range forward look down the pipe. Simultaneously, the dual fisheye high definition (HD) cameras will image the environment both looking forwards and backwards.

Such a system can provide actionable data, which can be migrated into a CAD system thus enabling the identification of the exact placements of underground pipes. The collected data can be used for computer modeling. These CAD simulations will provide valuable data for planning, decision-making, and resource allocation in the maintenance and development of infrastructure.

In this paper, we describe a project carried out in a city in Alberta, Canada during January 2024. As part of the Rainbow Road Bridge Upgrade project, Volker Stevin Highways (Client) requested a pipe location survey of approximately 467.5 meters of the Rainbow Road Sanitary Trunk Main (1200mm; CONC (HDPE Lined)) located along Range Road 283 in Chestermere, AB. Our long-range system four-wheel drive tractor was deployed. The system utilizes an armored cable that is 1,120 meters (3,674') long with a breaking strength of 5,500 lbs and weighs 110lbs per thousand feet.

Volker Stevin contacted AquaCoustic with a requirement to survey 467 m of 1,200mm diameter pipe. The survey data was to be used for underground pipe mapping. The inspection was conducted using one of our robotic tractor systems equipped with a combination of various sensors including a high precision solid state attitude sensor (Attitude Heading Reference System (AHRS).), Marine HD CCTV, and two Time of Flight laser profilers. All CCTV inspection work was conducted by PACP certified technicians. The pipe conditions encountered were; clean pipe and low flow as required. A suite of computer programs is integrated into the system for data capture and postprocessing.

The purpose of the survey was to locate the existing sanitary sewer tunnel at each bridge abutment to confirm the available clearance between the sanitary sewer tunnel and the proposed abutment and wingwall piles (see Figure 1). The inside diameter of the sanitary sewer tunnel will also be confirmed. The survey was commenced from the downstream access point, the upstream access point was not accessible. The pipe was pre-cleaned. Due to the manhole offset to the pipe, a confined space crew was required to insert the work platform. The client collected RTK GPS positions at each manhole plus an RTK GPS position was collected and used for the initial bearing.

The systems used on the survey utilized a 640-meter electro fiber optic cable on a winch. The survey platforms were set up with an attitude sensor, digital marine CCTV camera, lights, and other sensors. The survey equipment was introduced into the lines through downstream manhole; confines space entry was required to make sure the CCTV/LASER inspection platform negotiated the side of the pipe due to the manhole offset. The umbilical cable fastened to the rear of the vehicle transmits AC power and all telemetry uses a single mode, single strand fiber. The cable was fed through its own pinch rollers to control the cable movement. The operator controlled the vehicle and its speed through the pipes and was set at a rate prescribed in PACP codes or as directed. The orientation of the vehicle is measured while it travels along the pipeline by a pitch and roll sensor with an angular accuracy of 0.1° updated at 200 Hz. A patch test is conducted before the survey. The patch test consists of collecting all sensor data along a track, turning 180° and collecting all sensor data on the return while following the outbound track. The sensor data is then compared, and roll, pitch and timing offsets can be calculated.

Despite the cold, the field collection went well. The bearing, pitch, roll and position of the first data set were very accurate, within 0.25°. The pipe conditions were good; clean and low water. The laser profiling heads collected 360° cross-sectional profiles. The tractor had two laser heads set on the same axis as the pipe. On curves or bends the cross-section will show a profile with an exaggerated width due to the bend radius. An unknown MH was discovered 184.91 meters into the survey (see Figure 2).

Figure 3 shows the pipe meander graph. The total linear length of data collected was 434.57 meters.

Figure 1. Survey Area

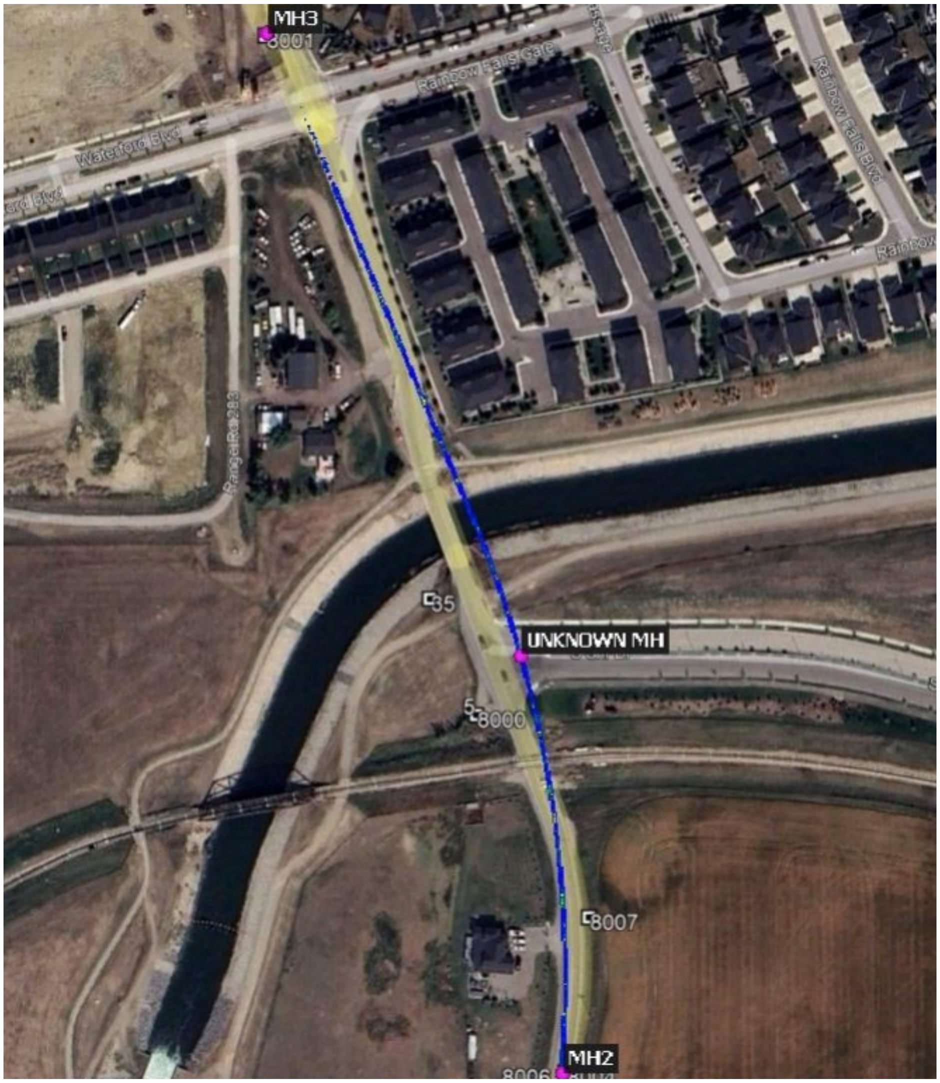

Figure 2. Underground Pipe Mapping Data, overlaid on survey area map

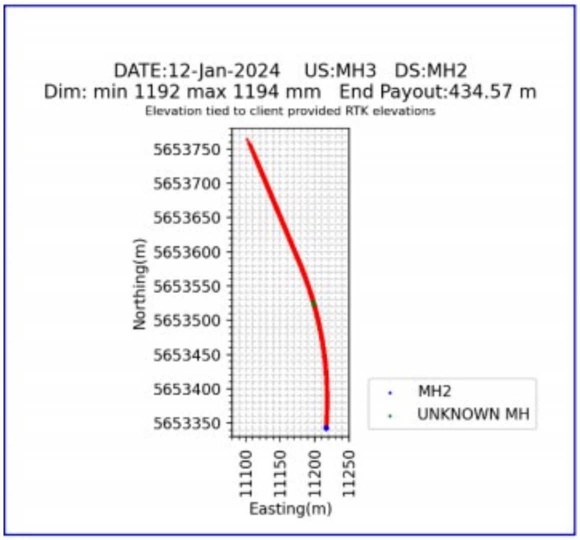

Figure 3. Pipe Meander Graph

Such high accuracy underground pipeline mapping enabled us to locate the existing sanitary sewer tunnel at each bridge abutment to provide actionable information on the available clearance between the sanitary sewer tunnel and the proposed abutment and wingwall piles. Accurate hydraulic data now allows the Client to better schedule maintenance activities, and to identify areas prone to blockage, and predicting where and when problems might occur. Understanding the hydraulic characteristics of sewer pipes helps engineers design more efficient systems, ensuring that pipes are appropriately sized to handle peak flows and reduce the risk of overflow or backups. Finally, identifying potential weak points and vulnerabilities within the sewer system enables proactive measures to mitigate risks associated with pipe failures or capacity issues.
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