

# SUBSURFACE VIEWS

## GPR INNOVATIONS HARDWARE AND SOFTWARE

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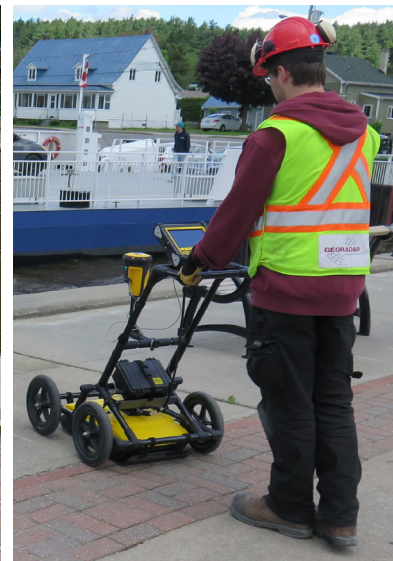
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## GPR for Flood Damage Assessment

In the spring of 2017, southern Quebec, Canada had unprecedented rainfalls and widespread flooding. Rivers in the Montreal area burst their banks and submerged communities. In one community, a local pedestrian pier was completely submerged under 3 feet of water for 2 weeks.

After the flood waters subsided, there was visible damage to the pier. There were several areas on the pier where the interlocking brick walkways had collapsed, indicating the presence of voids. Inspection of the vertical walls of the pier revealed cracks, further increasing concern that additional structural substrate had washed away. Local municipal officials were concerned that the pier may have more voids that could collapse, causing injury to pedestrians.

The municipality contracted a Quebec-based geophysical service-provider to scan the pier and report any problem areas.

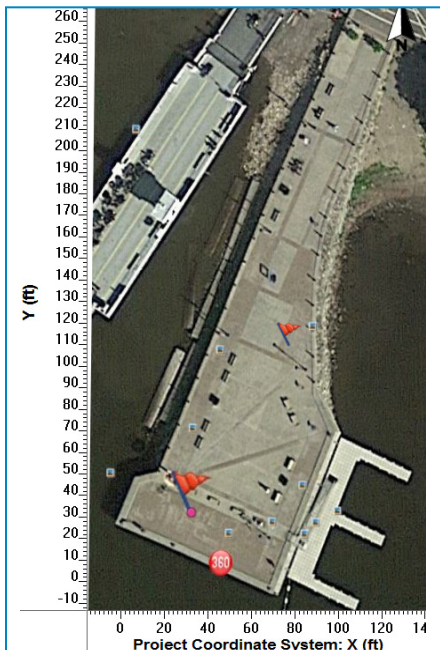


Surface of pier showing concrete and interlocking brick surface materials and a void. The LMX200® was used to collect 12,500 feet of data on a pier that had suffered damage after extensive flooding.

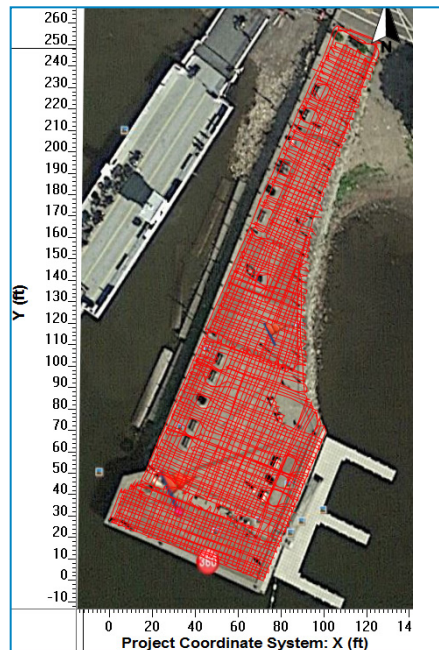


The contractor had initially considered using electromagnetic induction to look for the voids; however, there were many metallic obstacles on the pier, including garbage cans and benches, that would interfere with the results. Instead, they decided to use GPR since the results would not be impacted by these metallic objects.

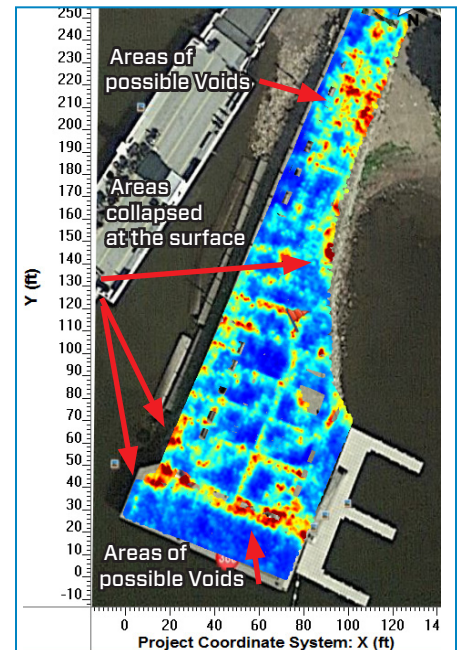
Given the many obstructions and the odd shape of the pier, collecting GPR data in an XY grid pattern would be very difficult (Figure 1). Instead, the contractor decided to collect the data using GPS for positioning the GPR data. This would allow them to cover the full area of the pier much faster than laying out grids. Data was collected in a series of tightly spaced straight lines, using marks on the pavement to ensure consistent spacing, averaging about 18" (0.5 m) between the lines (Figure 2).



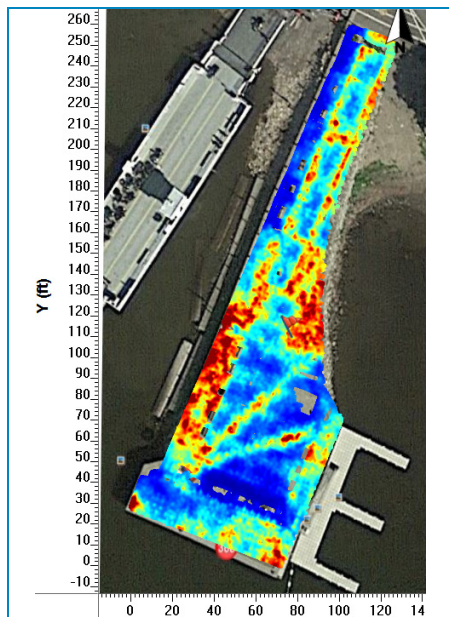
**Figure 1:** Aerial view of the pier showing many obstacles.



**Figure 2:** GPR data collection path. GPS positioning allowed for faster and more complete area coverage than an XY grid.



**Figure 3:** This 1-foot depth slice shows the already collapsed areas and additional areas of possible voids as strong GPR reflectors displayed as red and yellows.



**Figure 4:** The 5.5 foot depth slice shows strong reflections from boulders and cobbles deep below the pier, under the interlocking brick. These areas showed the deepest GPR penetration.

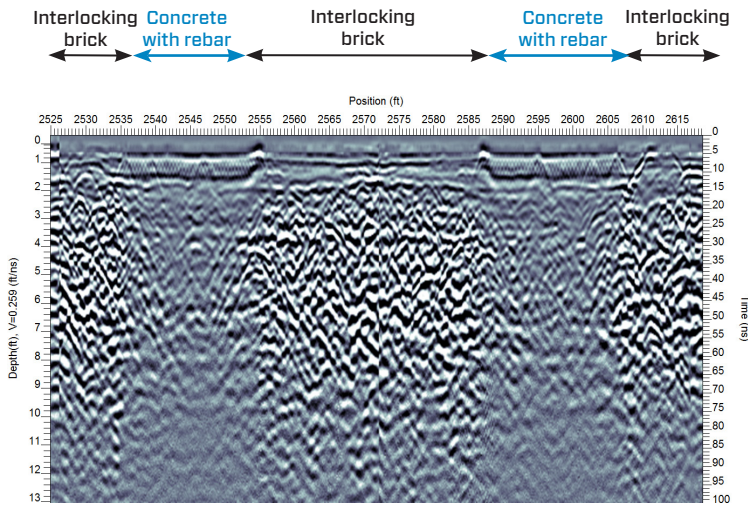
With two technicians onsite, a total of 12,500 feet (2.36 miles or 3.8 km) were collected in just 4 hours.

Once data collection was completed, they used the new SliceView-Lines module in the EKKO\_Project GPR™ processing software to generate depth slices through the pier. The contractors knew that the large boulders below the pier, used as the main structural component of the pier, would not have been washed away by the floodwaters but they were very concerned that the shallower parts of the pier underlain by finer sands and gravels could have been removed by the flooding.

When reviewing the depth slices, high-amplitude GPR reflections can be an indication of voids. This occurs because air or water-filled voids provide a large contrast with the material above, creating a strong GPR reflection. Figure 3 shows the 1-foot depth slice with strong reflectors in reds and yellows and weaker reflectors in blues and greens. The three areas that had already collapsed at the surface are indicated on the figure.

The GPR data shows some interesting phenomenon observed during the survey. For example, the deepest GPR penetration occurred on the parts of the pier covered with interlocking brick while areas with concrete at the surface had much shallower penetration; this is seen in the GPR line in Figure 5. It is also shown by the strong (red) GPR signals on the 5.5-foot depth slice in Figure 4.

These observations are not surprising as concrete has relatively high electrical conductivity and attenuates the GPR signal before it can travel to depth. The sand, gravel, cobbles and boulders under the interlocking brick have much lower electrical conductivity, allowing for the GPR signal to travel much deeper before it is attenuated.



**Figure 5:** Typical GPR line across the pier. GPR signal penetration varies depending on whether the surface was covered with interlocking bricks or reinforced concrete. GPR signals are stronger and penetrate deeper in the areas with interlocking brick at the surface due to the lower electrical conductivity when compared to concrete.

Based on the GPR scan of the complete pier, the GPR service provider quickly identified the shallow areas with strong GPR reflections indicative of possible voiding and provided this in a report to the municipality. From the findings, the municipality targeted repairs to the key areas of concern on the pier. Where possible voids were identified within 2 feet of the surface, they removed the interlocking brick and added fill to fix the shallow voids.

To address any risk of voids deeper in the structure, they injected concrete into the pier wall where the vertical cracks were visible.

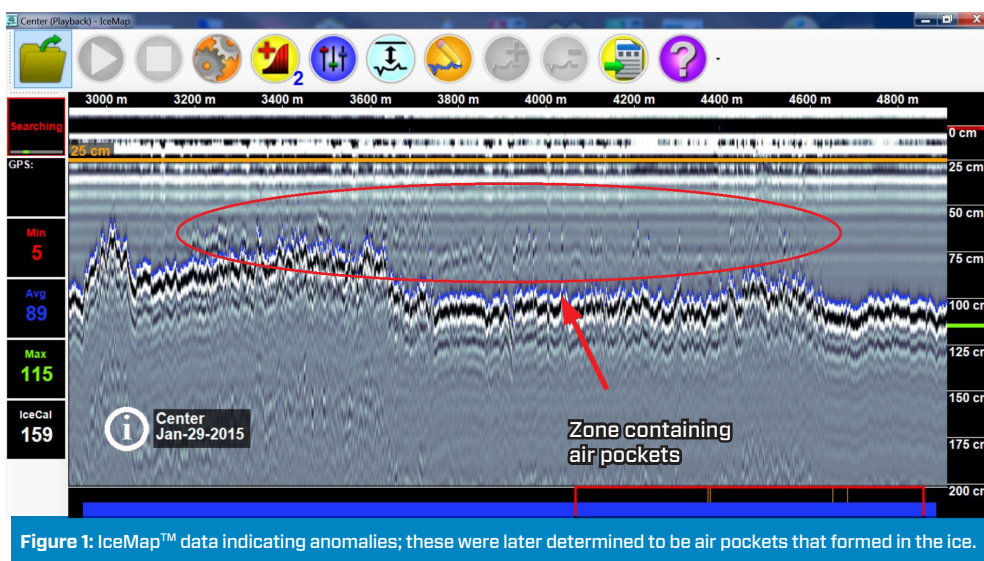
By using GPR, the municipality quickly and cost-effectively assessed the internal damage to the pier due to the severe flooding and could take corrective actions before any injury to the public occurred.

*Story courtesy of Georadar-Detection Inc.*

## Evaluating ice road quality with IceMap™

Winter roads are operated in many cold weather regions to provide transportation for communities that are otherwise only accessible by air, or to reduce travel time during the winter by providing a shorter, more direct route to the community. Winter roads frequently cross frozen bodies of water, such as lakes or rivers, and require considerable safety precautions prior to use. Manitoba Infrastructure is a unified department proactively leading the delivery of sustainable public infrastructure and services for the province of Manitoba. The department is responsible for maintaining winter roads in Manitoba and will only open a winter road once they have deemed it safe for use.

In northern Manitoba, a winter road is operated between Split Lake and Ilford. Prior to opening the road, extensive ice thickness assessment is required. To measure the ice thickness, Manitoba Infrastructure uses IceMap™, a GPR system that provides continuous measurements of ice thickness as it is towed along the ice surface. The system is deployed every few days as the ice is flooded and the thickness built up.



**Figure 1:** IceMap™ data indicating anomalies; these were later determined to be air pockets that formed in the ice.

During the ice road construction phase a few winters ago, the operators noticed consistent anomalies in the IceMap™ data. These areas were drilled to investigate, and revealed air pockets that formed in the ice (Figure 1).

The mechanism creating the air pockets was believed to be the strong currents present when the ice was forming

Air pockets can weaken the overall load-bearing capacity of the ice and could be dangerous, analogous to a sinkhole forming in the soil subsurface.

*continued on page 4*



As a result of discovering the section of ice road with air pockets, Manitoba Infrastructure used the IceMap™ GPR to map out a new route which didn't have air pockets (Figure 2). Since finding this new road, it has been the route used ever since. The GPS positioning in IceMap™ provides the means to relocate roads repeatedly.

Data collected with IceMap™ can be used in the following ways:

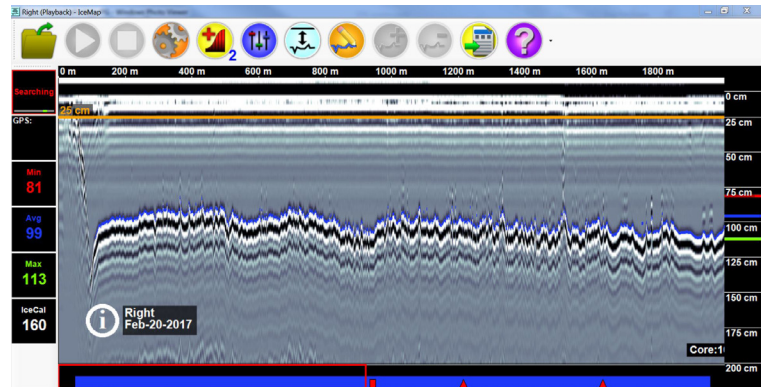
1. For real-time analysis to direct flooding efforts
2. To generate a detailed ice thickness report, showing the location and extent of thin spots
3. Plotted in Google Earth™ to show the path traveled, colour-coded to show the thickness of ice

The Google Earth™ image (Figure 3) shows the old route and the new one. Thick ice is shown in blue, whereas thinner ice is shown in yellow and green. The old route shows the problem area with air pockets, as the road curves.

By using IceMap™, Manitoba Infrastructure obtains the information they need to safely open their winter roads. Safety is always the driving force and using IceMap™ helps to mitigate any risks and prevent injuries.

In this case, IceMap™ GPR was able to identify the problem area and, rather than allocating resources to fix the problem, IceMap™ operators were able to quickly find a safer, alternate route for the winter road.

*Data courtesy of Manitoba Infrastructure*



**Figure 2:** GPR data collected on the new route, showing no air pockets.



**Figure 3:** Google Earth™ view showing the old winter road where the air pockets were found and the new route where the ice was safe to operate on.

## NEW! Concurrent Receiver Operation with SPIDAR®

Modern GPR systems are very easy to operate and much of the complexity of the underlying electromagnetic (EM) signal character is hidden from the user. In fact, GPR signals are electromagnetic fields which are invisible to the human, vector in nature and spread out over space and time. The ability to capture GPR signals in three dimensions around a GPR transmitting antenna offers huge advantages and creates a path to a wide variety of sensing applications that have not, to-date, been addressed by GPR technology.

The exploration seismic field, which searches for deposits of oil and natural gas, has dealt with the full character of elastic wave fields for several decades. In that time, the industry has developed advanced techniques for imaging underground

structures and extracting important physical properties to better understand the subsurface.

Seismic waves are very analogous to GPR waves so similar processing and imaging techniques can be employed with GPR data. Until now, hardware limitations and cost have prevented GPR practitioners from taking advantage of these innovations.

Sensors & Software introduces the next-generation of SPIDAR® hardware to enable pulseEKKO™ and Noggin® sensors to be integrated into distributed multi-frequency, multi-orientation and multi-field component deployments networked together.



The newest, most flexible and advanced component is the NIC 500X which allows concurrent receiver operation and brings a new dimension to GPR deployment. Historically, GPR was limited to the use of a single transmitter and receiver pair. Multiple channels of data were obtained by multiplexing pairs of transmitters and receivers. More complex surveys required fixing the transmitter and moving the receiver (or vice versa) to measure the wave field over a spatial area; this is both slow and inefficient.

Concurrent receiver operation enables multiple receivers to acquire the signal generated by a single transmitter. This capability makes it possible for rapid acquisition of the fields around the transmitter in space and time; emulating much of the capability that the seismic petroleum field has been able to exploit for many years.

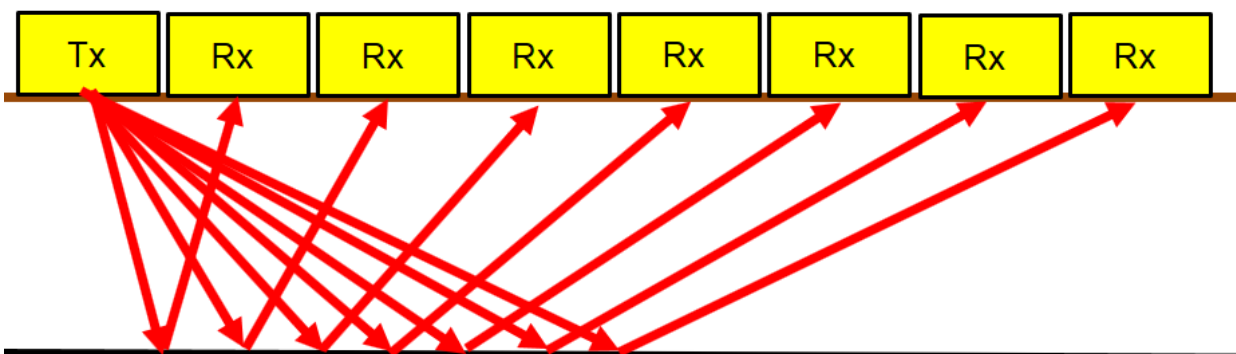


Figure 1: Illustration of a WARR (wide angle reflection and refraction sounding). GPR response is acquired at varying antenna separations

The details can be complex so we will limit discussion here to a single example of the “WARR machine”, as presented at the IWAGPR 2017 conference (paper available upon request). A WARR (wide angle reflection and refraction) sounding measures the GPR fields at differing transmitter and receiver separations as depicted in Figure 1. Such surveys allow analysis of ground velocity variations and variations of reflectivity with angle of incidence that provide valuable diagnostic information. While WARR surveys have been used for decades in the GPR field, data acquisition is slow because the receiving antenna had to be moved (usually manually) between each measurement point.

Figure 2 shows a 500 MHz WARR machine deployment which controls a single 500 MHz pulseEKKOTM transmitter and seven 500 MHz receivers mounted in-line at fixed offsets. Deploying the system on a cart (Figure 2) or a sled with odometer triggering allows full WARR data sets to be acquired at the same rate as traditional, single channel (one transmitter-receiver pair) GPR surveys.



Figure 2: Two 500 MHz WARR machine configurations using the NIC 500X and a pulseEKKO™ transmitter and 7 receivers.

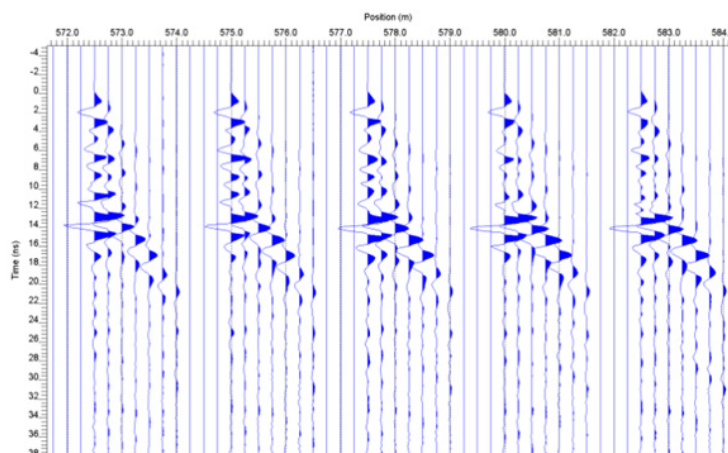


Figure 3: Example of multiple WARR soundings as the WARR machine is moved continuously along a transect.

Data processing and analysis are more complex with these types of concurrent receiver deployments and this will be addressed in future publications.

To put this benefit in context, 25 years ago, a skilled crew could acquire WARR soundings at a rate of 10 to 20 per hour. Even a few years ago, rates of acquisition had only doubled to 30/hour. The WARR machine can acquire 10,000 WARR soundings per hour (Figure 3). This massive increase in speed of acquisition opens the door to many interesting and advanced applications of GPR including routine generation of velocity and water content sections.

GPR will never be the same.

## Upcoming Courses

[Subsurface Imaging with GPR course](#) - November 6, 2017. Mississauga, ON, Canada

[Concrete Scanning with GPR course](#) - November 7, 2017. Mississauga, ON, Canada

[Generating Reports with EKKO\\_Project™ V5 webinar](#) - November 15, 2017. Register at [sensoft.ca/training-events/](http://sensoft.ca/training-events/)

## Upcoming Events

[Geological Society of America Annual Meeting](#)

October 22-25, 2017, Washington State Convention Center, Seattle, Washington, USA

[American Geophysical Union Fall Meeting](#)

December 11-15, 2017, New Orleans Ernest N. Morial Convention Center, New Orleans, Louisiana, USA

[Transportation Research Board Annual Meeting](#)

January 7-11, 2018, Walter E. Washington Convention Center, Washington, DC, USA

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