Ground-Penetrating Radar
Report# 20808
City of Fort Saskatchewan – Harbour Pool

1 March 2017

To: Kristina Banyard
City of Fort Saskatchewan
Harbour Pool

From: James Harrison
GPR Department Senior Technician
Maverick Inspection Ltd.

Re: **Ground-penetrating Radar Digital Report #20808**

On January 23 and 24, 2017 Maverick Inspection Ltd. was on-site at the Harbour Pool in Fort Saskatchewan, AB in order to perform a series of Ground-penetrating Radar inspections on the concrete pool basin, surrounding pool deck and concrete pool walls.

The purpose of the survey was to detect any previously unknown voids beneath the concrete or within or beyond the concrete walls forming the pool basin. Additionally, the concrete was examined for indications of degradation, honeycomb voiding and other forms of breakdown which might contribute to premature aging of the pool and basin.

Data was gathered over the available floor space within the pool basin, within the deck surrounding the pool basin, and on the walls of the main pool area. The scanned walls include both the deep and shallow end of the lap/lane pool. The exterior walls of the building were not examined.

Prior to our arrival on-site the pool was drained and dried for routine maintenance. Several tile areas were repaired and other work was taking place. This was determined to be a good time to perform the GPR inspection. During the tile repairs, several previously undetected small cracks were noted in the concrete. Based on descriptions supplied to Maverick by our client contact, these cracks were significant enough to allow water to infiltrate the underground tunnel system surrounding the pool.

All of the data was stored electronically and was transferred to a Maverick Inspection Ltd. workstation PC for additional analysis and review. The results can be found attached on the following pages.

Thank you for choosing Maverick Inspection Ltd.

James Harrison
GPR Department Senior Technician
MAVERICK INSPECTION LTD.

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Summary of Findings

There is no obvious evidence of subsurface voiding except for those areas with underground tunnels and rooms.

The pool deck surrounding the "island" contains no top surface steel reinforcement bars. The main pool deck contains a regular recurring pattern consistent with rebar or wire-mesh, however this pattern is absent in the area immediately adjacent to the island structure on the west side of the main pool basin. This is one of the areas in which a previously undetected crack was noted during the pool inspection.

The areas which were unexpectedly cracking yielded no obvious causes which were immediately visible to GPR on a first inspection. There are no obvious major flaws and no obvious significant voids detected in these areas.

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2.0 – Important Notes

The following points contain important Information Regarding Your Maverick Inspection Ltd. Ground-penetrating Radar Report. These notes have been prepared in order to help understand the limits and intentions of the prepared GPR report.

2.1 - Your Report is Based on Site Specific Criteria

Your report has been developed on the basis of your unique project specific requirements as understood by Maverick Inspection Ltd. and applies only to the site investigated.

2.2 - Your Report is Prepared for Specific Purposes and Persons

To avoid misuse of the information contained in your report it is recommended that you confer with Maverick Inspection Ltd. before passing your report on to another party who may not be familiar with the background and purpose of the report. Your report should not be applied to any project other than that originally specified at the time the report was issued.

2.3 - Regarding Provided Locations

Maverick Inspection Ltd. does not employ land surveyors or engage in the practice of land surveying. All drawings, maps, sketches, coordinates, or other positional information provided by Maverick Inspection is limited by the instrumentation and methodologies employed by our technicians. These instruments and methods are chosen according to the job scope and circumstances on a case-by-case basis. None of the locations provided have been surveyed, and no locations are to be taken as certified or absolute relative to property markers or boundaries. On-site surface markings such as flagging, paint, marker, or tape are always the primary reference for the apparent positions of noted features.

2.4 - Regarding Commentary

Maverick Inspection Ltd. does not employ engineers or geologists. We focus instead on hiring and training specialized radar technicians. We are not members of APEGA and are not qualified to make engineering calls or suggestions. Any stated opinions and analysis should be reviewed by a qualified engineer with the appropriate background and experience prior to any action being taken based on the results of GPR. Furthermore, the results obtained using GPR are subject to interference and interpretation of signals obtained by electronic devices. Objects should never be considered positively identified or located based on this information, but should be exposed and physically verified.

2.5 - Regarding Liability

Although GPR is the most accurate subsurface imaging technology available, as with all forms of remote sensing equipment it has limitations and is not 100% accurate. Maverick Inspection Ltd. provides the highest degree of due diligence in data acquisition and report generation. Although the chance of missing any subsurface feature is low, clients shall not hold Maverick Inspection Ltd. responsible for any missed or misidentified subsurface features, objects, or

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anomalies and will not be held liable for any loss or damages that come from any missed or misidentified subsurface features, objects or anomalies.

The effectiveness of GPR is highly dependent upon ground conditions. GPR can be adversely affected by conductive soils, water saturation, highly variable soil types, surface interference or obstruction and other factors which are outside of our control.

2.6 - Principles of Ground-penetrating Radar

Ground-penetrating radar (GPR) is a non-intrusive method of detecting buried objects or substances in a nonconductive material through the use of UWB radio waves.

GPR systems work by emitting a short electromagnetic pulse in the ground through a wide-band antenna. Reflections from the ground are then measured to form a vector. An image is built by displaying these vectors side by side with the displacement of the antenna. By moving the antenna along a line and taking regularly spaced acquisitions, it is possible to construct an image representing a vertical slice of the ground. The GPR system is connected to a laptop computer that displays these images in real-time. The data is also recorded on the computer for later interpretation and processing.

2.7 - Basic Information Regarding the GPR System Used

The system that Maverick Inspection Ltd. currently utilizes is the CX-11® made by Mala Geoscience Inc. The unit operates at a frequency of 1.6GHz. The transmitter and receiver are both contained in a single unit. The unit incorporates an electronic encoder wheel allowing us to very accurately measure distances and locations. This unit is connected to a "Digital Video Logger" (DVL) which captures and displays the data which can be viewed in real time, and can be transferred to a laptop or PC.

The GPR system used by Maverick to perform the inspection was designed and optimized for concrete inspection, and was chosen for this task because of its size, frequency, reliability, and integrated features/filters, and gain settings.

The system performs a "Power-On Self Test" and will *fail* if not properly calibrated, or if some other problem will not allow the system to function adequately.

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3.0 - Overview/Methodologies

A Grid Origin was selected. The Grid Origin was located approximately 0.3m west of the eastern edge of the pool, and approximately 0.3m south of the northern edge of the pool.

Data from the pool basin was gathered as a series of parallel lines spaced at 0.3m on center. Lines were gathered from north to south, working westward and ending at the shallow/deep transition in the pool basin. Data was gathered in this fashion throughout the entire lap/lane area and into the shallow "Beach" area ending at the steps located on the western edge of the beach.

Additional scanning was conducted in the deep end of the pool with lines gathered from south to north, ending at the shallow/deep transition point. These lines were also gathered at 0.3m line spacing and coverage included the entirety of the floor space at the deep end of the pool.

Scanning of the transition ramp from shallow to deep was completed. The lines from this area were gathered at each edge of the pool and centered on each of the six dark-tiled swimming lanes.

Scanning was conducted along the pool deck surrounding the pool basin. Lines were generally gathered in sets of parallel lines including several lines gathered on the eastern, southern and western edge of the pool. Field-notes were used to track the approximate position of each line of GPR data which was gathered. The field notes included approximate positions, measurements and file-name references allowing Maverick's technicians to resequence the data using a proprietary third-party software suite.

The walls of the pool basin were scanned. The shallow end was scanned by standing in the pool basin. The top of the scanning was limited by the reach of the technicians, but was generally conducted from the pool basin floor to a point within a few cm of the top edge of the pool basin.

The deep end of the pool was scanned in two phases. The lower portion of the wall was scanned by standing on the pool basin floor. The upper portion was scanned using a rolling scaffold system.

All wall-scanning was performed systematically using the following methods:

- A local origin was selected. Generally, this local origin is either a specific intersection of two walls, or else the edge of available scanned area. Portions of the shallow/deep transition zone could not be safely reached using a rolling scaffold.
- Lines of data were gathered from top to bottom.
- Lines were spaced approximately 0.15m apart on center.
- Data was gathered where ladders are present in the concrete walls, but the data quality in these areas is considered dubious because of the physical constraints of deploying GPR in these specific areas.

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Once all of the data was gathered, and the positions of lines were recorded using field-notes, the data was imported into a proprietary third-party software suite. The software is able to display the original GPR profiles as they appeared at the time of scanning. In addition, the software is able to apply digital signal-processing including time-varying gain, bandpass filtering, background-noise removal and other useful signal enhancements as necessary. Base on user input, the software organizes the original data files and maps the relative position of the lines of data. Using this process, the software is able to perform advanced interpolations on adjacent and nearby lines of data to generate planview GPR reflectivity maps for various depths below grade. These maps can be used to track trends across lines of data which might not otherwise be obvious. Finally, the software creates a pseudo3D workspace into which these various data presentations can be projected, allowing the operator to cross reference the disparate data sets.

In general, when seeking GPR data consistent with voids, the primary point of interest lies at the concrete/soil interface. GPR works by detecting changes in dielectric properties between dissimilar materials. Concrete and most soils have similar dielectric properties, and therefore in the absence of voids, the GPR signature denoting this transition is relatively low-contrast and difficult to distinguish. In the presence of voids however, the GPR impulses transition from concrete to air, which is a significant dielectric contrast. This produces a bright, high-contrast and easily detected subsurface horizon within the data set. The detection of a concrete/air interface where slab-on-grade is expected yields the strongest evidence of subsurface voids.

Some irregular shaped voids or subsurface cavities will produce hyperbolic targets. Specifically, it will produce hyperbolic targets which are inconsistent with the pattern of rebar or wire-mesh found throughout the scanned area. The hyperbolic reflections produced by voids may be asymmetrical, and may appear to be randomly placed when compared against the background rebar patterns. They will also likely appear at different depths.

In the absence of significant subsurface voids, Maverick was asked to examine the data for indications of honeycomb voiding or similar concrete defects. In this instance, Maverick used two avenues of investigation.

1. Obvious honeycomb void signatures tend to include variations in signal attenuation and/or signal velocity calculations based on hyperbola shape matching.
2. The Harbour Pool uses salt-water. Salt-water is not transparent to GPR while concrete is. It is therefore reasonable to presume that areas which contain salt-water will appear less transparent than areas which do not. Given that the pool was drained and dried prior to our arrival on-site, areas in which the signal is more strongly attenuated can be associated with areas in which the salt-water has impregnated the concrete. The presence of salt-water within the concrete may cause corrosion of steel reinforcement bars and result in premature failure of the concrete structure.

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4.0 - Results/Sample Data

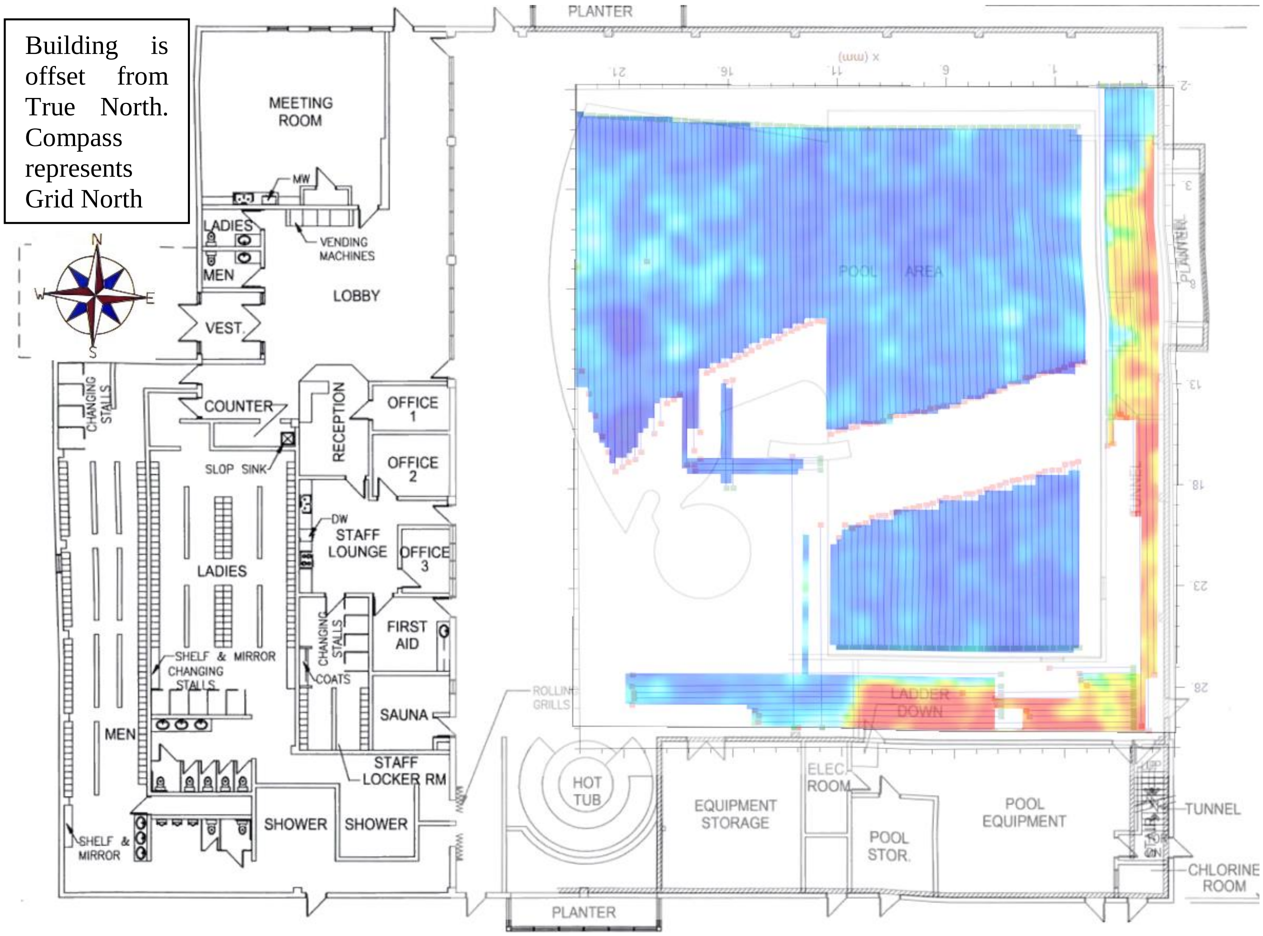

Figure 01: *Overlay of pool area drawing, pool basement drawing, GPR data coverage and reflectivity map from the bottom of the concrete slab.*

The data in the image above shows a large number of highly reflective areas. Typically, such strong reflectivity near the bottom of a concrete slab would coincide with suspected voids. The data lines up consistently with tunnels, rooms and other known voids, shown in the basement map. The areas surrounding tunnels all appear as relatively low reflectivity within a narrow and consistent range. The data which is shown in various shades of blue in the included imagery is considered low probability of voids. The areas within the tunnels and basement rooms all appear red, indicating a high probability of containing voids, which is exactly as expected.

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A few key areas were focussed on once it was determined that there was generally no evidence of critical and previously unknown voids.

These areas of focus correspond to unexplained and newly noted cracks in the concrete surrounding the pool basin.

At the northeast corner of the pool basin a crack has formed running roughly east/west, but curving towards the northeast. This crack appears to be located near the northern end of the tunnel system. The concern was described to Maverick as being that a potential void beyond the tunnel, and large amounts of shifting in this case, could allow water intrusion into the tunnel system.

The examination of the GPR data within this area yields little or no evidence of voiding beneath the pool deck slab.

There does appear to be a wider spacing of the steel reinforcement bars in this precise area. In the GPR data, which runs north to south, and displays the east/west rebar, there is a single space between two adjacent rebars which is approximately double the spaces between any of the other rebars. The location of this additional gap appears to coincide with the wall denoting the north end of the tunnel below. This may be as designed/intended.

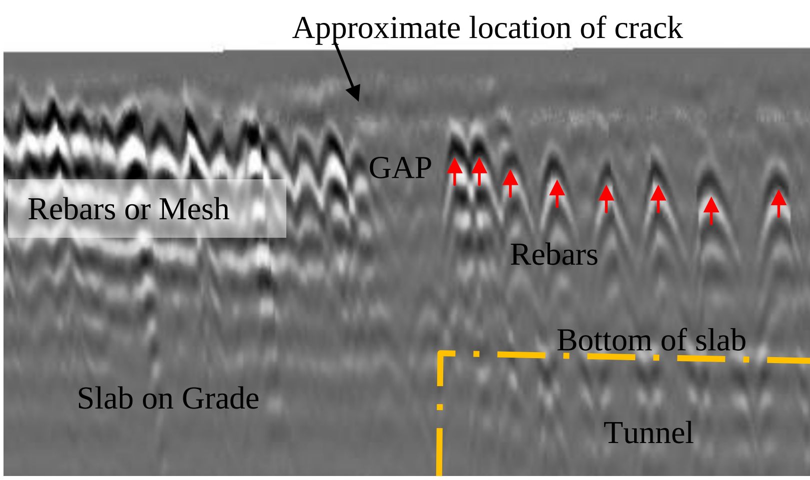

Figure 07: *GPR Profile with some interpreted markings demonstrating a gap in the rebar in the vicinity of a known crack in the concrete. The GAP appears to be located above a concrete wall and may be as designed/intended.*

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At the southwest corner of the pool another crack was noted, running approximately north/south from the edge of the pool. This location also lines up with end of a tunnel in the basement area.

The GPR data from this area indicates a transition from a structural slab containing multiple patterns of steel bar reinforcement to a slab-on-grade containing what appears to be wire-mesh. The crack which formed appears to be in the immediate vicinity of the slab change.

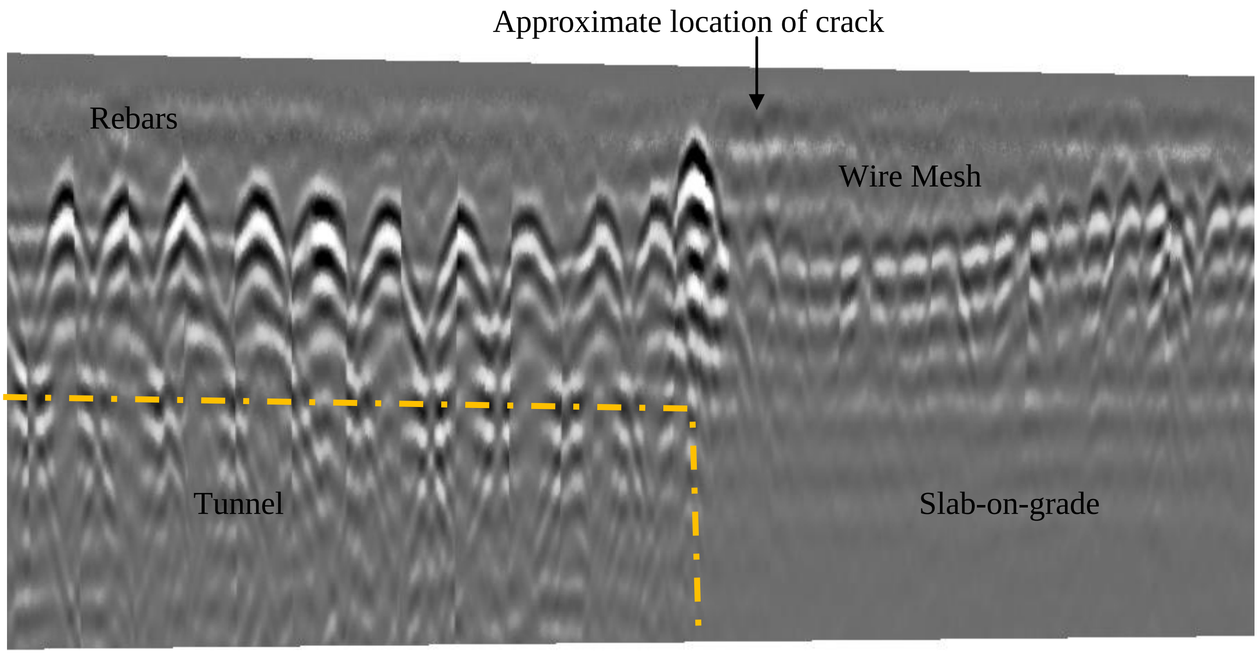

Figure 02: *GPR profile showing the transition from structural slab to wire-mesh slab-on-grade.*

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Figure 03: *A photograph of the "island" structure which includes an unexpected crack in the concrete parallel to its south face.*

The island area was examined using GPR. The lines of data immediately adjacent to the island show a complete lack of top-surface rebar. It may be that the rebar was cut and removed when the island was installed, or it may be that the area was designed to allow for relative movement between the main column and the rest of the pool deck.

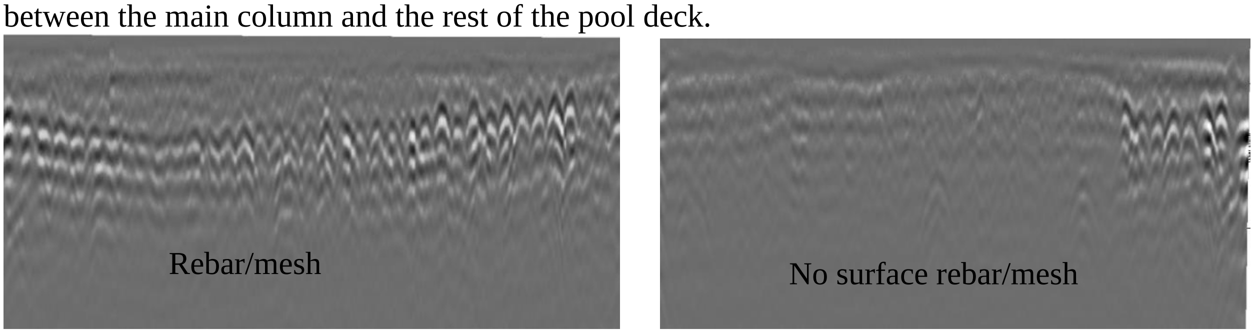

Figure 04: *Two adjacent GPR profiles. The left image was gathered approximately 0.4m from the island, the right image was gathered 0.1m from the island.*

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4.1 - Sample Data and Imagery

Note: The data shown here was not gathered at the Fort Saskatchewan Harbour Pool and has been included to demonstrate cases of known subsurface voiding and honeycomb voiding as seen in other structures.

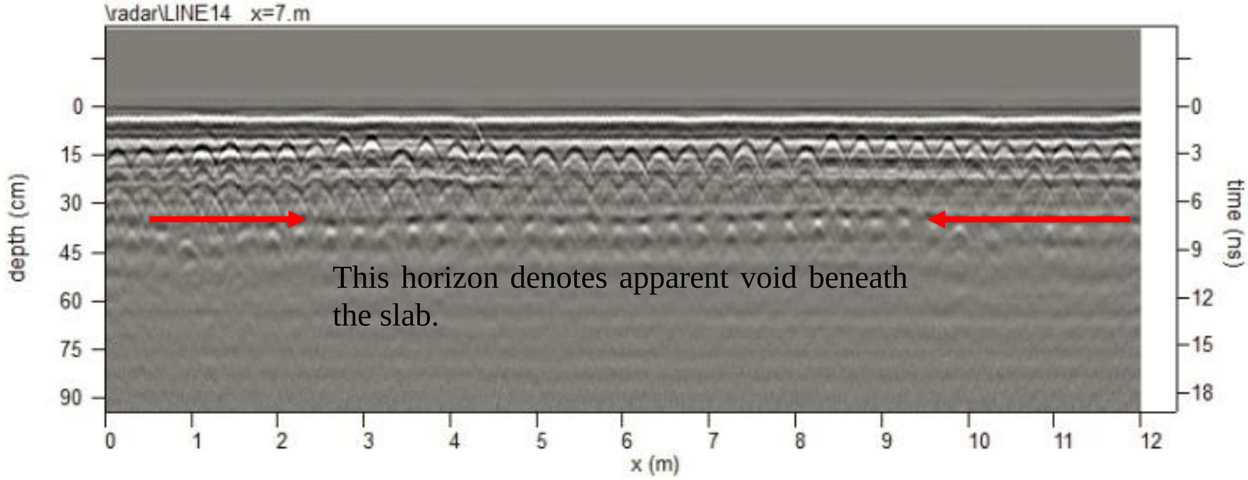

Figure 05: *GPR Profile of data gathered in a pool basin.*

From a depth of 0-~40cm the data appears to attenuate as expected in a relatively thick slab-on-grade. At ~40cm, there is a strong horizon which is visible across the entire GPR profile. This horizon denotes a concrete-air interface and was used to determine that a void-space existed beneath this pool. Consultation with an engineering drawing from this location later corroborated that the pool was built on its own footings as a structural element of the building in which it had been installed. Voiding beneath this particular pool basin was actually part of its design.

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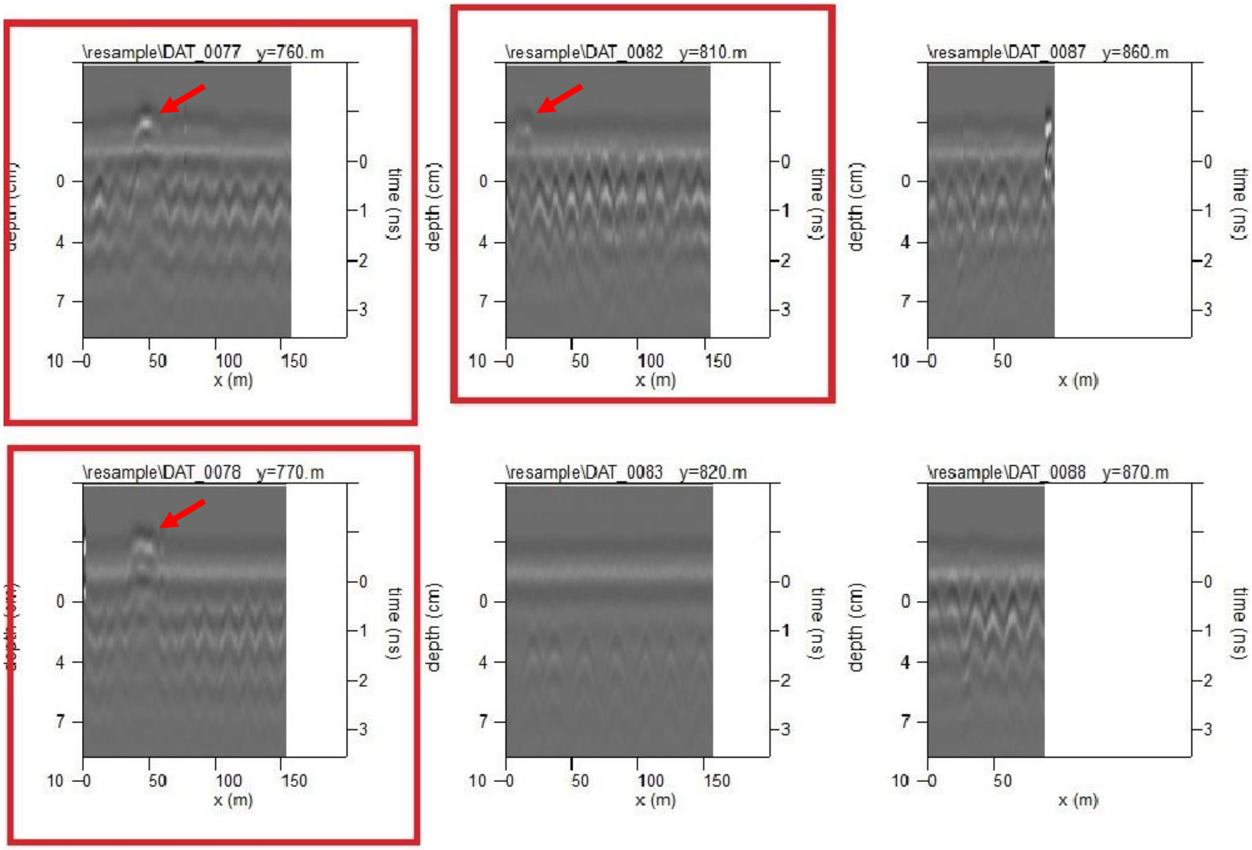

Figure 06:*GPR profile showing confirmed honeycomb voiding in a concrete structure.*

Honeycomb voiding is a relatively common failure in concrete and is the result of construction methods which fail to cause the cement and aggregate mixture in the concrete to settle appropriately. This causes air pockets to be trapped in the concrete. In the case of a salt-water pool basin, honeycomb voiding may provide a path for the salt-water to contact the steel reinforcement bars causing premature corrosion and rebar failure.

In the figure shown above, three of the profiles contain significant indications of honeycomb voiding near the concrete surface, while the other three do not. This was data gathered on an unrelated project. No such data was gathered at the Harbour Pool.

5.0 - Conclusion

Maverick Inspection Ltd. was able to perform Ground-penetrating Radar in the requested areas. This inspection appears to have yielded usable results, which fulfilled the scope of work as requested.

No significant voiding was detected beneath the concrete pool basin, pool deck or behind the pool-basin walls, except for those areas known to contain tunnels and mechanical areas.

Portions of the data include known underground tunnels, rooms and other structures built into the Harbour Pool surrounding the pool basin. These areas did appear void-like, as expected. This also provides evidence that the GPR unit deployed to site would be expected to detect voids beneath the concrete slabs examined and provide imagery adequate to perform the scope of work.

Three additional areas of focus were examined. These three areas coincide with unexpected cracking on the concrete surface requiring repairs. These cracks in the concrete could indicate additional movement or unexpected settling of the building. In each of the three areas, the cracking appeared to coincide with variations in the steel reinforcement bars. Variations in rebar include gaps in otherwise regular rebar patterns, transitions from structural slab to wire-mesh slab-on-grade or the complete absence of bars near the concrete surface surrounding the island. In each of these cases there is little or no GPR evidence of subsurface voiding to correspond with the cracking, and while future monitoring may be recommended in these areas due to salt-water intrusion through the cracks, the source of the crack does not immediately appear to be related to a potential imminent failure, significant subsurface voids/washouts or similar source.

If you require assistance with this report, please contact James Harrison or Steven Toner at our office: 780-467-1606.

Thank you for choosing Maverick Inspection Ltd.

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