CSR GeoSurveys Limited

Ground Penetrating Radar Investigation
Wolfville, Nova Scotia

Submitted To:

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LIST OF ABBREVIATIONS

CSR	CSR GeoSurveys Ltd.
GPR	Ground Penetrating Radar
DGPS	Differential Global Positioning System
RKT	Real-time Kinematic
Hz	Hertz
MHz	Megahertz
m	Metre
Sec	second
uSec	Microsecond
AGC	Automatic Gain Control
m/uSec	Metres per Microsecond
mS/m	Milisiemens per Metre
EM	Electromagnetic
ROI	Region of Interest

REPORT CITATION

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STATEMENT OF QUALITY

CSR GeoSurveys Ltd. warrants that its service with respect to this study was performed with a degree of skill and care equal to or greater than that ordinarily exercised under similar conditions by reputable members of our profession practicing in the same or similar locality. No other warranty, expressed or implied, is made or intended. Geophysical surveying is a remote sensing method that may not detect all surface or subsurface features of interest or concern.

CSR Project Team
Howard Black
Nathan Watkinson
Patrick Campbell, P.Geo.

Client Representative
Richard Johnson

1.0 INTRODUCTION

Acadia University contracted CSR GeoSurveys Ltd. (CSR) to conduct a ground penetrating radar (GPR) investigation at the Acadia Athletics Complex in Wolfville, Nova Scotia (Figure 1.1).

The purpose of the investigation was to utilize Ground Penetrating Radar (GPR) over the facilities pool floor in attempt to identify and map sub-slab voiding, movement of sub-surface materials, identify defects in the concrete and other signatures potentially related to a known leak.

The area of the investigation is approximately 500 square metres and consists of three separate elevations. Data collection was completed with the use of a Pulse Ekko 1000MHz and 500MHz GPR system manufactured by Sensors and Software. This system and relatively low center frequencies was selected due to the anticipated thickness of the concrete slab, density of reinforcement and required resoltuion.

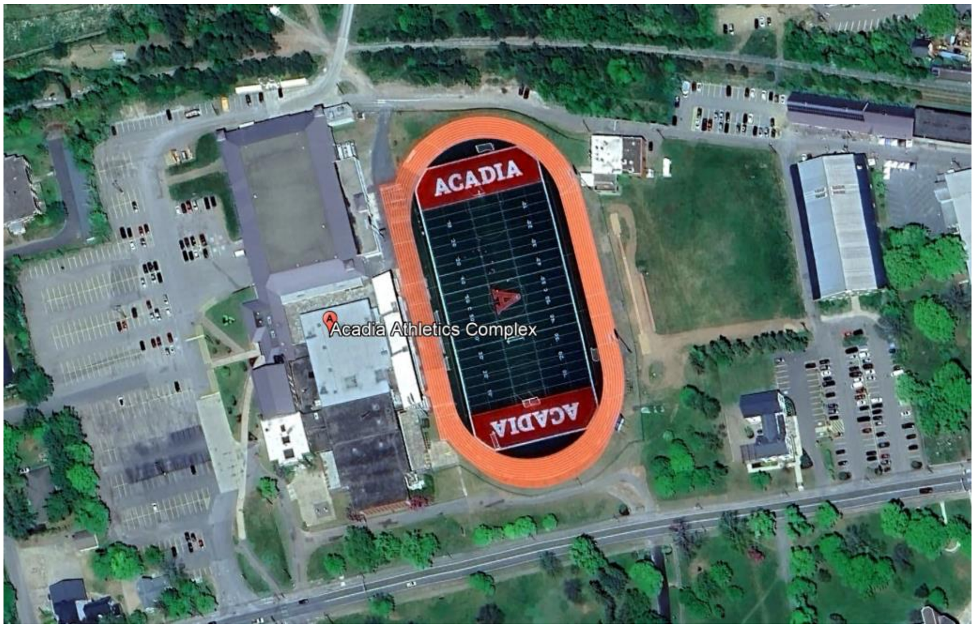


Figure 1.1 – Satellite Imagery showing the location of the Acadia Athletics Complex.

2.0 SURVEY OPERATIONS

Survey operations at the Acadia Athletics Complex facility were conducted on December 18th and 19th, 2023. The survey was conducted during daylight hours. Table 2.1 lists CSR field personnel involved in the project.

Table 2.1 – CSR Survey Personnel

PERSON	***TITLE***	***ROLE***
Howard Black	Project Manager	Party Chief / Data Acquisition
Nathan Watkinson	Geophysical Technician	Data Acquisition

2.1 SURVEY EQUIPMENT

Figure 2.1.1 – Pulse Ekko tow-behind configuration with the 500MHz antenna.

GPR data collection was completed using the Sensors and Software PulseEkko control unit in conjunction with 1000MHz and 500MHz antennas.

The 1000MHz antenna was deployed primarily to provide information pertaining to the construction of the concrete and to provide information from immediately below the slab. The 500MHz antenna was selected to identify deeper features such as draining lines and leakage pathways.

The GPR system was assembled in a tow-behind configuration to improve the ease of data collection over the elevation variations known to exist within the pool. This configuration features an optical encoder to track distance along the collected line.

2.2 EQUIPMENT CALIBRATION

All equipment was calibrated by the manufacturer. Equipment was setup and evaluated at CSR’s office in Porters Lake prior to the survey to ensure all equipment was working properly.

The optical encoder calibration was confirmed at CSR’s office using a distance of 20 metres. Two separate checks were completed with each configuration providing a variance of less than 5cm.

2.3 SURVEY METHODOLOGY

For the purpose of this report, it was assumed that the building was orientated north/south with the deep end of the pool being located at the southern extent of the survey location. To assist with data collection the interior northeast corner of the pool was selected as the grid origin with lines of data orientated east/west spaced at 1 metre and north/south spaced at 2 metres.

Each antenna was traversed over the collection grid separately by an operator who adjusted collection speed and settings as deemed necessary for real-time interpretations.

Additional lines of data were collected in areas that were not covered by the initial grid spacing to ensure appropriate coverage was achieved.

A total of 741.6 linear metres of data over 41 separate lines was collected in the available survey area with each system. Field notes and sketches were collected to reference the start location, orientation, and direction of each line to the northeastern corner of the pool.

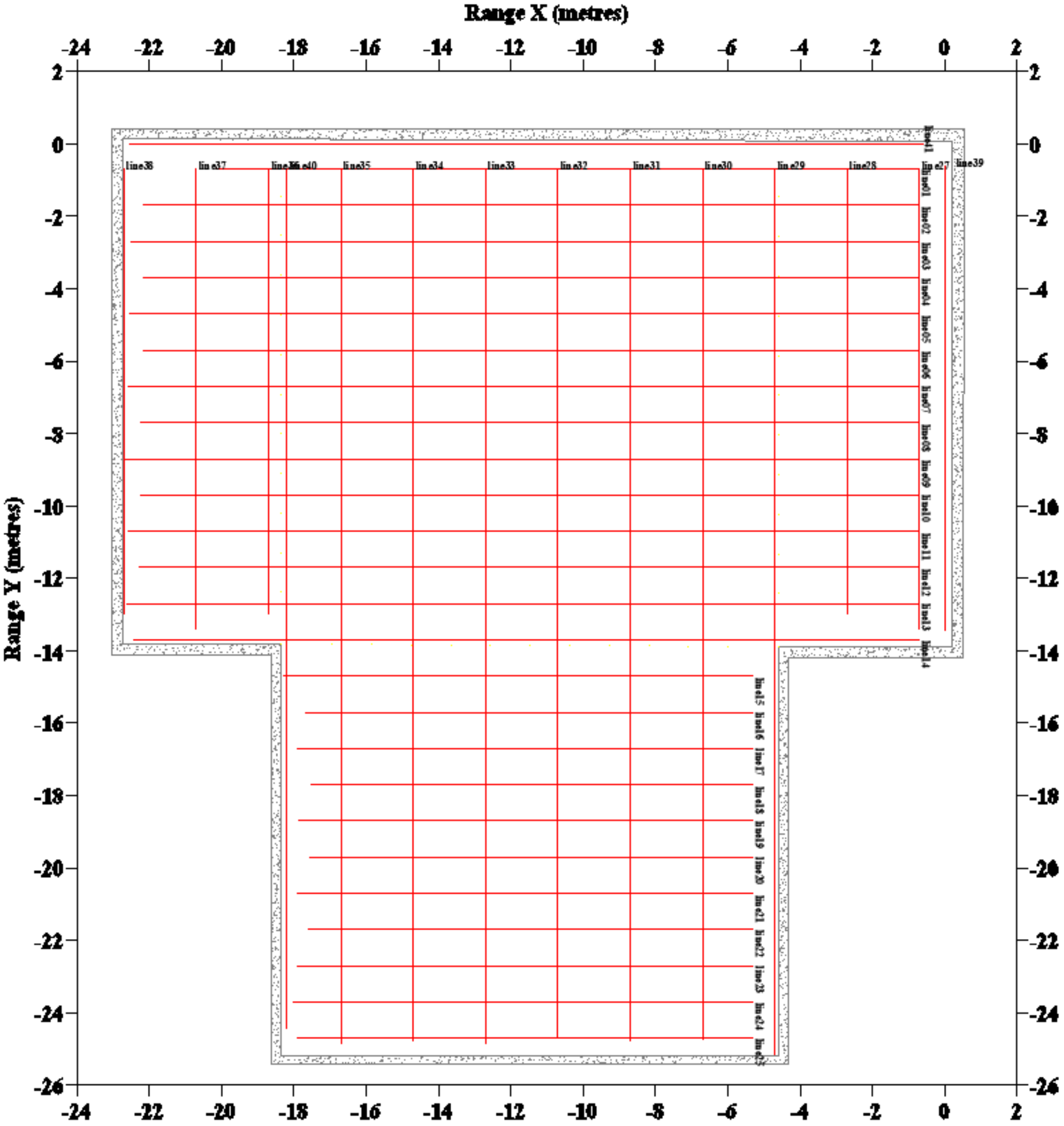


Figure 2.3.1 – Survey line locations collected with the 1000 MHz (red).

3.0 DATA PROCESSING AND ANALYSIS

The GPR data collected on site was processed and analyzed using GPRSlice software from Screening Eagle Technologies. The individual lines were imported and mapped based on information contained within the field notes and sketches.

Once imported basic data and positioning filtering was completed including: DeWow, Bandpass, Background Removal, Time 0 Adjustments, and Automatic Gain Control (AGC).

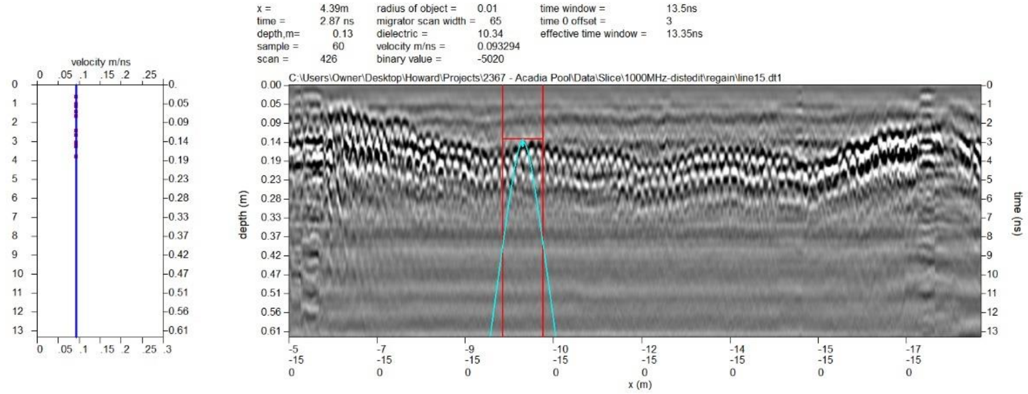
The average velocity of the concrete was determined using the hyperbola matching method (Figure 3.1). This method uses a theoretical hyperbola laid over the data to record the velocity of individual features found within the data. This process was repeated several times on selections of data throughout the investigation area to determine an approximate average velocity for the entirety of the slab.

The data was analyzed in two separate passes:

Pass 1: 2D radargrams and amplitude depth slices were reviewed for indications of potential sub-slab voiding.

Pass 2: 2D radargrams were reviewed for variations in construction, sub-slab features and other potential indications of leakage.

Information obtained during review of the radargrams and depth slices were exported to third party programs to assist with interpretation and generation of visualizations of the results.



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time =      2.87 ns   migrator scan width =    65          time 0 offset =           3
depth,m=    0.13      dielectric =             10.34       effective time window =   13.35ns
sample =    60        velocity m/ns =          0.093294
scan =      426       binary value =           -5020
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Figure 3.1 – Screen capture of velocity estimation process.

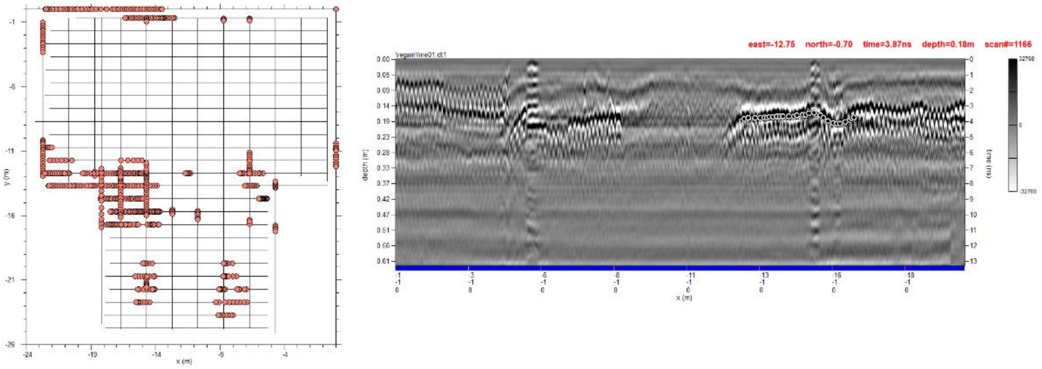

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Figure 3.2 – Screen capture of 2D radargram analysis.

4.0 GEOPHYSICAL SURVEY RESULTS

Our interpretation was based primarily on data acquired with the higher resolution 1000MHz antenna. The 500MHz data was utilized to identify features beneath the slab.

Analysis of the processed GPR data showed a number of features that may be relevant or associated with the known leak of the pool. These features range from potential sub-slab voiding, potential poor compaction of base materials, variation in the pools footprint when compared to provided as-builts, difference between planned and measured concrete thickness, variances in reinforcement pattern, and fluctuations in reinforcement coverage and amplitude return.

Each of the features of note mentioned above are discussed in detail within the following sections.

4.1 CONCRETE SLAB CONSTRUCTION

The GPR data showed several potential variations from the provided as-built drawings. These variations include:

- Difference in the pools footprint
- Difference in concrete thickness
- Difference in reinforcement layout

4.1.1 Pool Footprint

The provided as-built drawings indicate that the widest section of the pool should be approximately 25 metres (82’ 3”) wide running east/west, with the deep section of the pool being centered and also measuring ~25 metres (82’ 3”) from the southern edge to the northern edge of the pool.

As shown in Figure 4.1.1 measurements obtained on-site show that the widest section of the pool footprint measures ~22.5 metrrs (~73’ 10”) wide east/west. The deeper section of the pool running north south is still centered and measures ~25 metres.

The variation of the footprint may indicate a crawl or mechanical space may be present beyond the pool walls, the pool was not constructed to specification, or the pool was modified since the original construction.

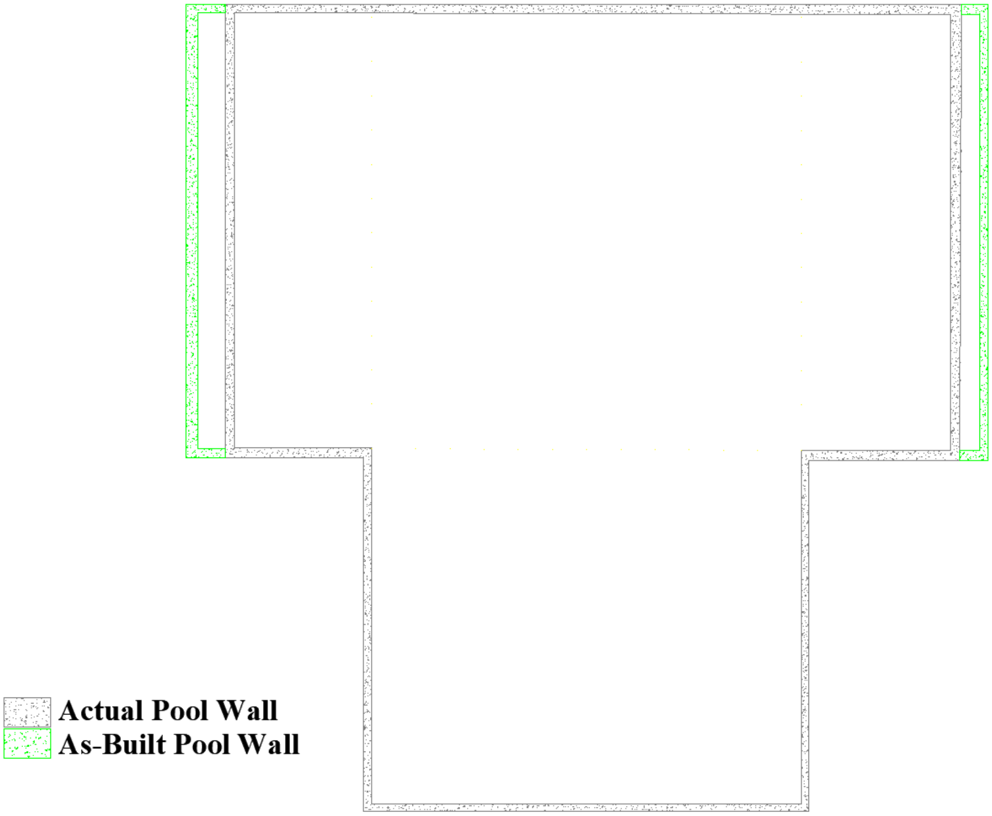

Figure 4.1.1 – Sketch showing the approximate variation between the as-built footprint (green) and measured footprint (grey)

4.1.2 Concrete Thickness

The provided drawings indicated the pool floor was intended to be 150mm (6”) thick and supported by 100mm by 100mm (4” by 4”) welded wire mesh reinforcement.

It is not possible to provide precise measurements of the concrete thickness due to a number of factors including change of materials, density of reinforcement and bond between concrete and base materials. GPR was able to provide estimates for the concrete thickness range from 150mm (6”) to 370mm (14 ½”).

The thicker sections of the concrete slab appear to be located in the deep end of the pool and the northeastern shallow end, potentially associated to recent alterations. The thinner sections of the pool floor are found primarily on the northwestern shallow section and near the drains in the deep section, please see Figures 4.1.2 and 4.1.3.

It is possible the variations in the estimated slab thickness from the as-builts is related to previous repairs, installation of tiles, variations in velocity, leveling pours, and error in the estimates due to the clarity of the identified horizon.

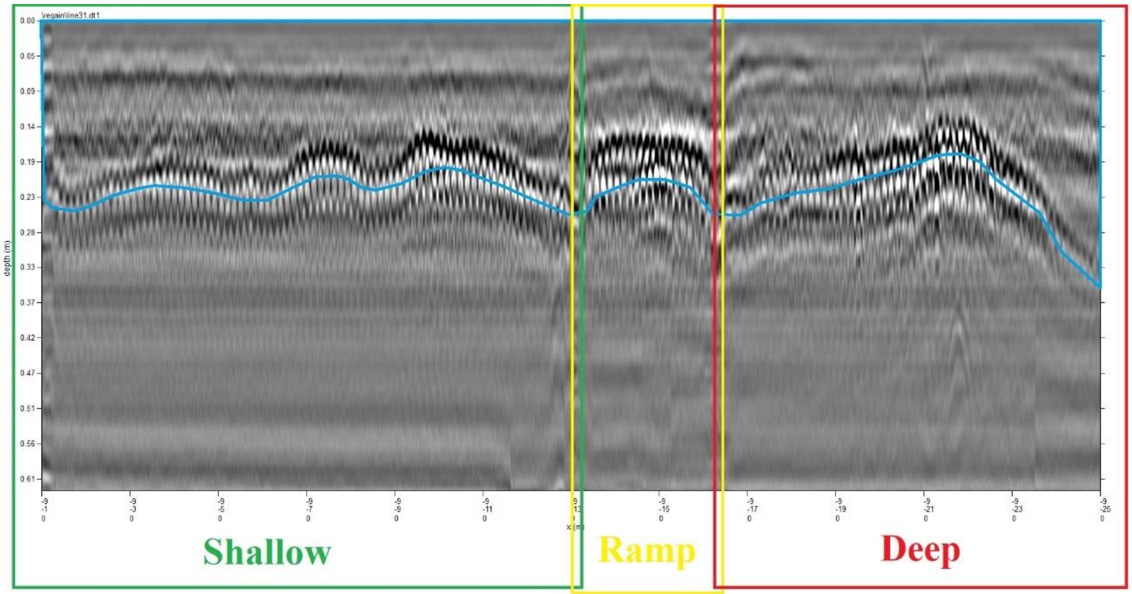

Figure 4.1.2 – Example radargram running north/south through the center east portion of the pool showing the approximate bottom of slab in blue.

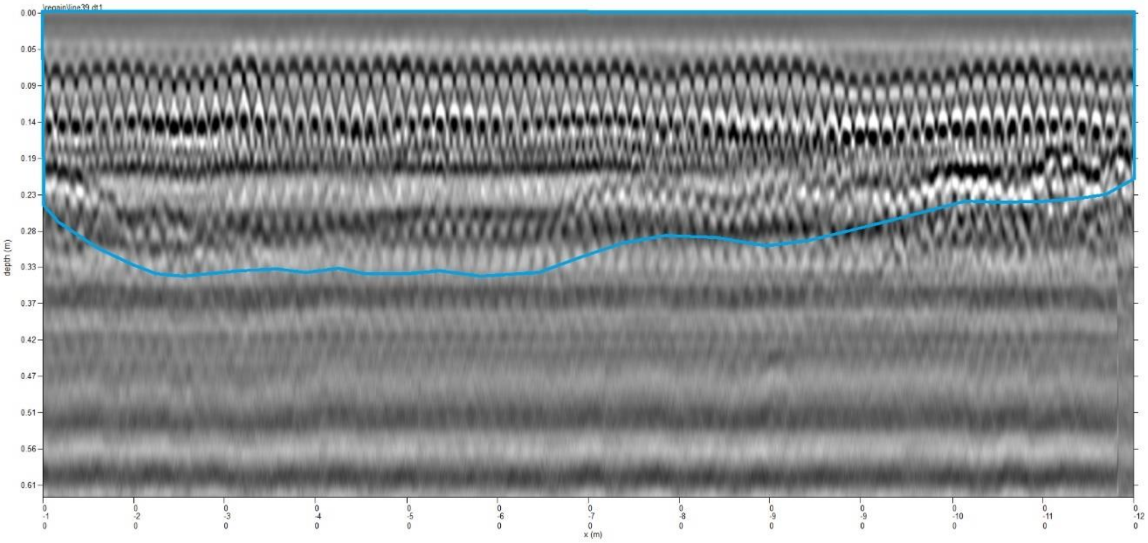

Figure 4.1.3 – Example radargram running north/south over the eastern shallow portion of the pool showing the approximate bottom of slab in blue.

4.1.3 Reinforcement Pattern

The GPR data appears to indicate that a second layer of welded wire mesh is present throughout the eastern shallow section of the pool. Determining the exact location and coverage of the second layer is challenging as the shallower layer reflects the majority of the signal produced by the GPR system.

While technicians from CSR GeoSurveys were on-site a conversation was had with the facility staff indicating the eastern shallow section of the pool had recently been modified to be shallower. It is possible that the recent modifications are the cause of the variation in this area.

If should be noted that due to the double layer of welded wire mesh, identifying sub-slab voiding or total concrete thickness in this area may not be possible.

See Figures 4.1.4 and 4.1.5 for example data.

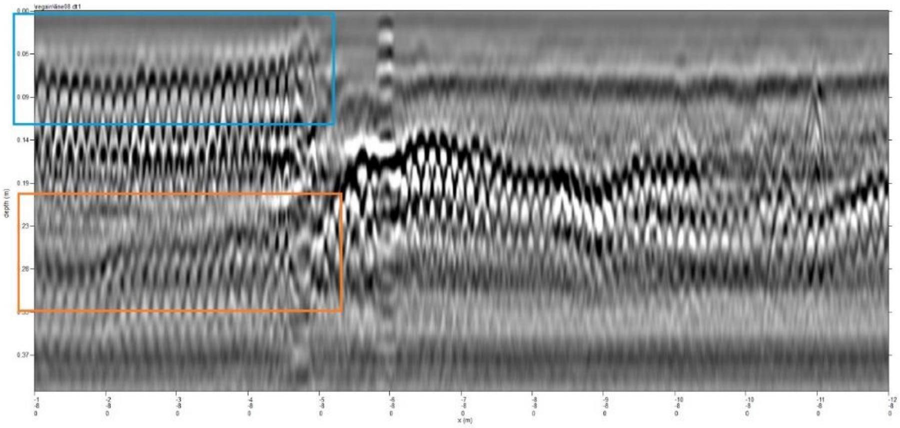

Figure 4.1.4 – Example radargram running east/west through the shallow section of the pool, showing the double layer of welded wire mesh in orange (lower) and blue (upper).

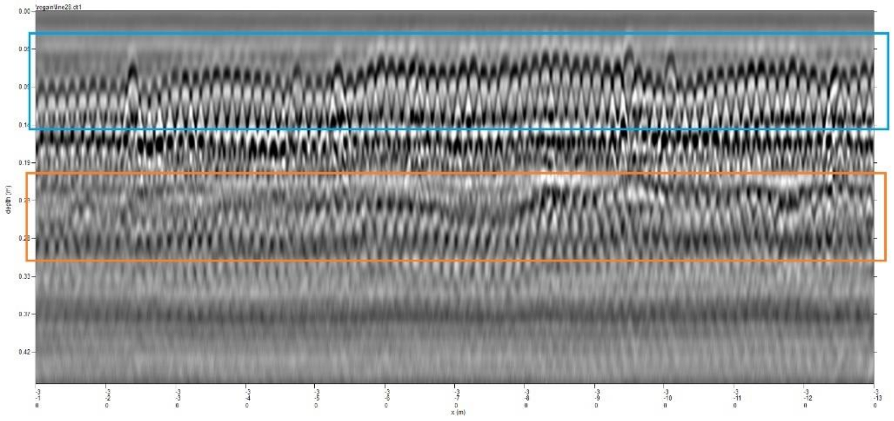

Figure 4.1.5 – Example radargram running north/south through the eastern shallow section of the pool, showing the double layer of welded wire mesh in orange (lower) and blue (upper).

4.2 POTENTIAL SUB-SLAB VOIDING AND COMPACTION OF BASE MATERIALS

Ground penetrating radar can identify areas of potential sub-slab voiding by analyzing the amplitude produced by the interface of the concrete and base materials. As concrete and well compacted gravel share similar electrical properties, mainly the dielectric permittivity, this interface should produce a low amplitude response. The contrast of the electrical properties between concrete and air is large and therefore produces a high amplitude response.

Review of the data collected showed several areas with a high amplitude response at the interface between the concrete and base materials. These areas include the northwestern corner, western corner between the deep and shallow areas of the pool, the eastern corner of the deep and shallow ends of the pool, and in the immediate proximity of both drains located in the deep section of the pool.

In some areas where the high amplitude response was noted it appeared to correspond with the depth of the welded wire mesh while other areas showed no indication of welded wire mesh. This potentially indicates that the wire mesh is either immediately on the bottom of the slab or not within the slab. This could be related to errors at the time of construction or indicate that the bottom of the slab has begun to spall, potentially related to the oxidation of the welded wire mesh.

The variation of amplitude noted in the northwestern corner or the pool and the western corner between the deep and shallow ends are larger than the other areas. These areas are thought to have the highest probability of being associated with sub-slab voiding. The areas noted adjacent to the drains and on the eastern corner between the deep and shallow sections have a lower amplitude response and are potentially associated with poor compaction of base materials or minor voiding.

Sub-slab voiding is often found in relation to leaks and water movement. This is due to the flow of the water removing material from the area or causing slumping in deeper materials.

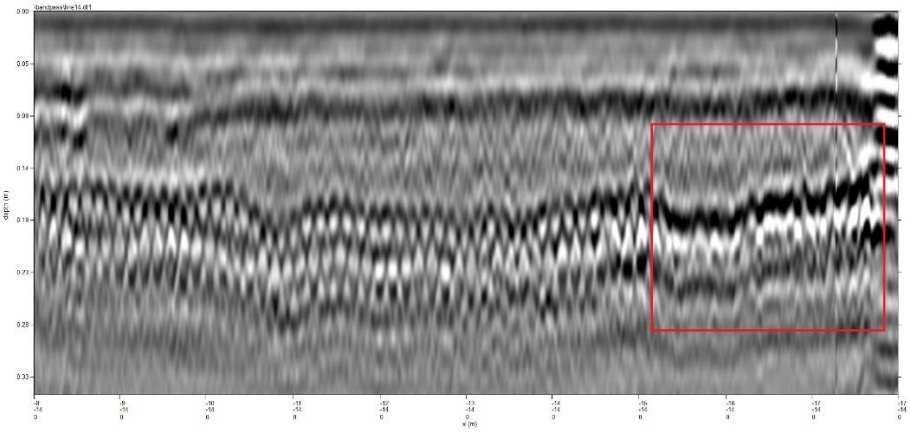

Figure 4.2.1 – Example radargram showing potential sub-slab voiding in red.

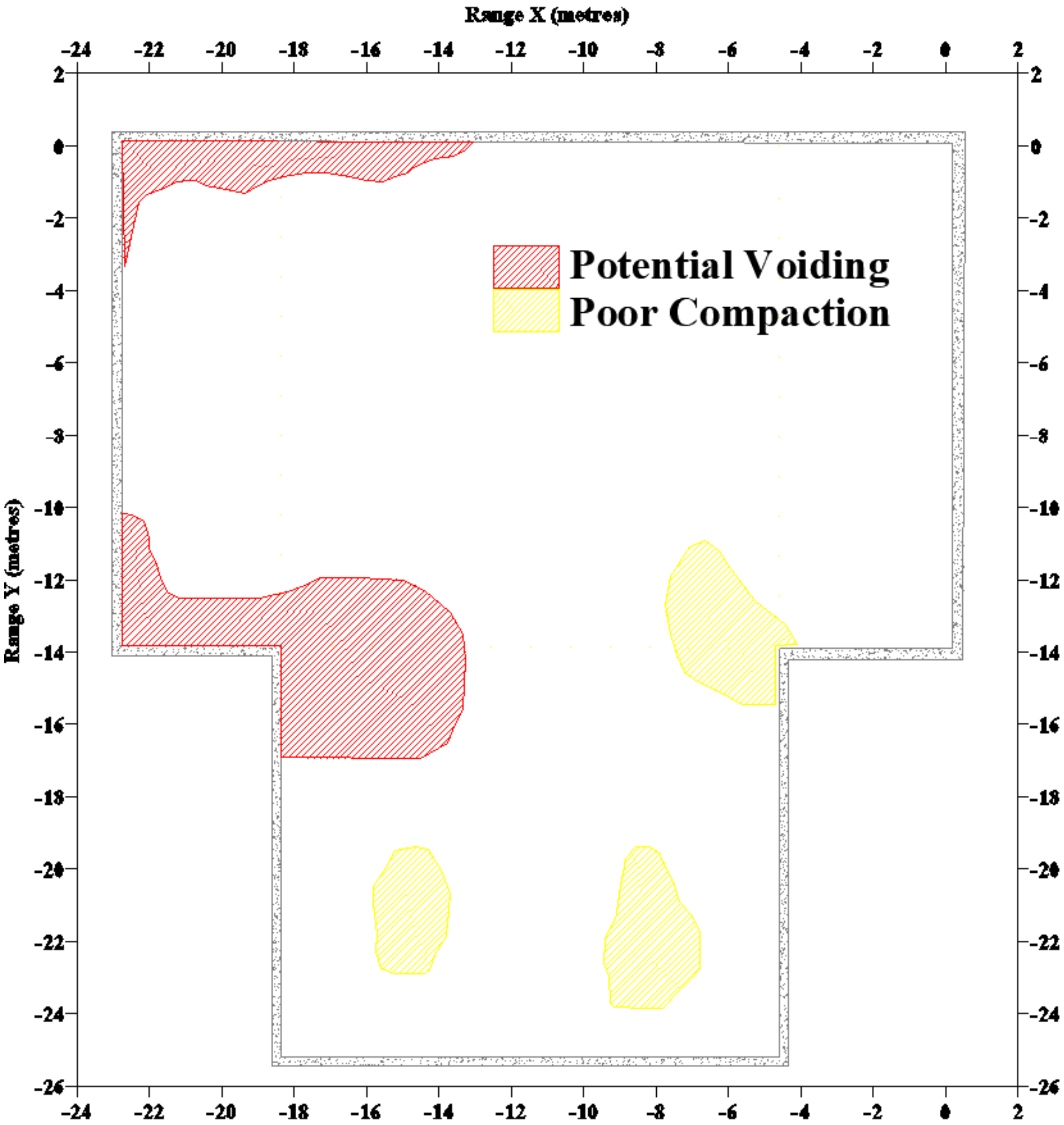

Figure 4.2.2 – Plot showing approximate locations of potential sub-slab voiding and poorly compacted base materials.

4.3 SUB-SLAB FEATURES

The 500MHz antenna was able to identify two features under the slab that may be associated with plumbing or other buried utilities.

Utilities buried under a concrete slab often provide the path of least resistance when water movement is present in the area. This will often result in sub-slab voiding or settlement of materials along the pathway of the utilities. This does not appear to be the case for this investigation as no signatures clearly associated with potential sub-slab voiding are noted in the area of the potential buried utilities.

One of the features appears to run east/west between the two drains in the deep section of the pool. A single hyperbola is noted on 4 parallel lines of data (Figure 4.3.1) which strongly indicates the potential of at least a single utility in the area approximately 3-4 metres long.

The other feature is represented by two adjacent hyperbolas on a single radargram with the adjacent parallel line showing only a single hyperbola (Figure 4.3.2). This feature appears to extend approximately 1-1.5 metres in a north/south orientation beginning on the southern edge of the pool. It is possible the feature continues and GPR was unable to properly image it.

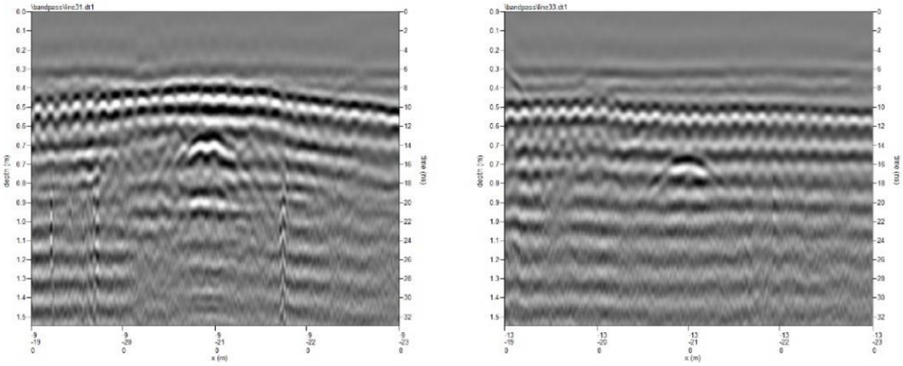

Figure 4.3.1 – Parallel radargrams showing the hyperbola associated with the presumed east/west utility in the area of the pool drains.

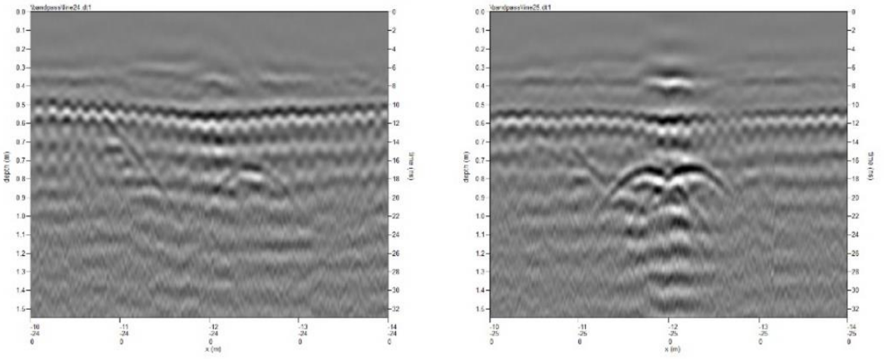

Figure 4.3.2 – Parallel radargrams showing the hyperbola associated with the presumed north/south utilities running from the southern edge of the pool.

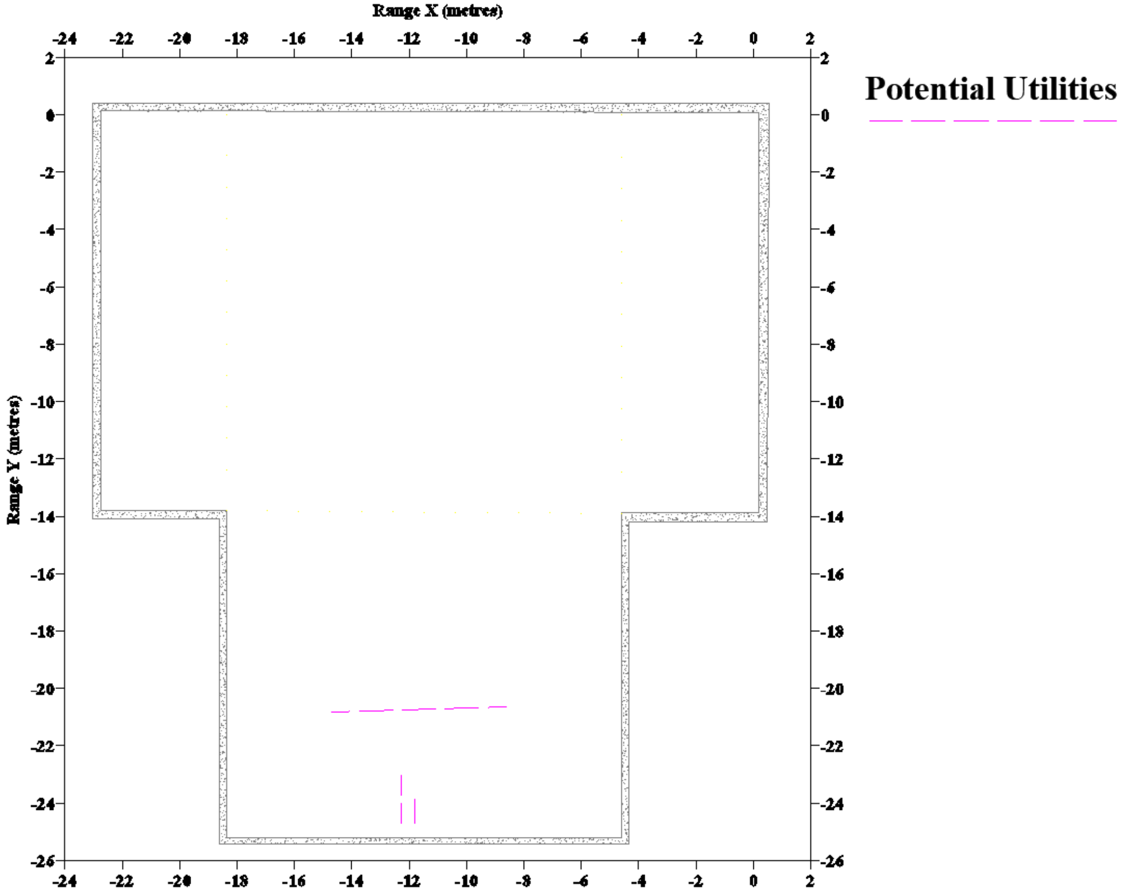

Figure 4.3.3 – Sketch showing the approximate locations of the potential buried utilities.

5.0 SUMMARY

CSR GeoSurveys Ltd. was contracted by Acadia University to conduct a ground penetrating radar investigation at the Acadia Athletics Complex in Wolfville, Nova Scotia. The purpose of the investigation was to utilize GPR over the facilities pool floor in attempt to identify and map sub-slab voiding, movement of sub-surface materials, identify defects in the concrete, and other signatures potentially related to a known leak.

Data was collected throughout the available area utilizing antennas with center frequencies of 1000MHz and 500MHz. The 1000MHz antenna was used primarily to identify in-slab features and sub-slab voiding while the 500MHz identified features beneath the slab

The GPR system was able to identify several variations in construction of the concrete slab from the provided as built drawings. Although variations in the concrete slabs' construction from the provided as built drawings were identified there is no clear relation in the GPR data to these variations and the known pool leak.

Sub-slab voiding and poor compaction of base materials are often found in association with water movement under a concrete slab. Several areas with potential sub-slab voiding and poor compaction of base materials were identified that may be associated with the leak. The areas of higher concern were the northwest corner of the shallow section and western corner between the shallow and deep sections of the pool. The areas of less concern include those around the drains in the deep section of the pool and the eastern corner between the shallow and deep sections of the pool.