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USING SIMULATIONS TO SUPPORT GPR DATA INTERPRETATION

It can be hard to predict the data that will come out of a GPR inspection, especially when looking for defects and variations in the subsurface. Harder still explaining to the client what you will and have seen, before and after the inspection. A good way to improve the data interpretation, discussion with clients, and backing up the results is through a simulation of the inspection. The following is a brief outline of the benefits of data simulation, a real-world example, and how they can support you.

gprMax is a free software that allows for modelling of GPR data, from simple models to complex ones. The software uses Yee's algorithm to solve Maxwell's equations in 3D using the Finite-Difference Time-Domain (FDTD) method. There is a lot of information on the maths behind the software on the website that won't be covered here, along with installation instructions and how to use the software.

Models are created using a text input that can be a bit tricky to get your head around but essentially its providing information on the size of the model, time window, material properties, antenna properties, and the geometry of the simulation. This is created in Notepad and read by the software, an example is presented as Figure 1.

Example - Notepad

File Edit Format View Help

```
#title: QEII
#domain: 40 0.6 0.002
#dx_dy_dz: 0.003 0.003 0.002
#time_window: 7e-9
```

Model extents and time window

```
#material: 5.5 0.01 1 0 Con1
#material: 7.5 0. 1 0 Con2
#material: 16 0.05 1 0 Wet
#material: 12 0.05 1 0 ground
```

Materials used and their properties, including dielectric and conductivity

```
#waveform: ricker 1 2.7e9 my_ricker
#hertzian_dipole: z 0.20 0.51 0.001 my_ricker
#rx: 0.25 0.51 0.001
#src_steps: 0.005 0 0
#rx_steps: 0.005 0 0
```

Antenna type, spacing and A-Scan interval

```
#box: 0 0.5 0 40 0.6 0.002 free_space
#box: 0 0.35 0 40 0.5 0.002 Con2
#box: 0 0.15 0 40 0.35 0.002 Con1
```

Start of modelling dictating the objects size, shape, and location, within the model.

Figure 1: Text input of gprMax

For the example above and used in this article the client had relined a water tunnel using a 150mm thick reinforced concrete liner. There were concerns that there were voids and other defects within the new lining, not visible on the surface, that would need to be rectified. To support the data interpretation and provide assurance to the client of the GPR results, a simulation of the inspection was run. For this data it was not complex, but the client had doubts over the GPR's ability to detect defects.

For these works a model was created from the design information provided by the client of the new tunnel lining. This consisted of a 150mm thick reinforced concrete slab (not curved for simplicity) over a second concrete layer and ground below. To this slab, air voids were created, of varying sizes, at several depths, above and below the bars. Additionally, areas of 'wet' concrete were also created by including areas of concrete with higher conductivity and dielectric. This is not a perfect simulation but served the purpose for this project. The model used a 2.7GHz antenna run at 200 scans per meter, over about 38m. This model was run through gprMax, which simulated every A-Scan and merged them together at the end.

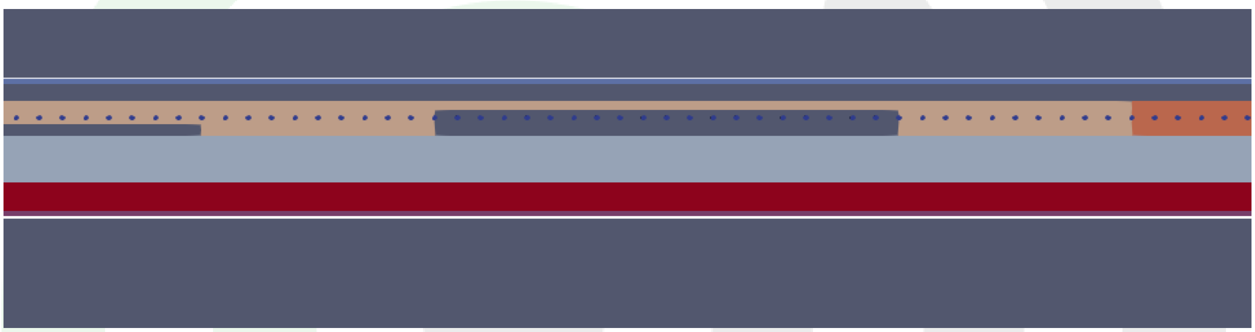

Figure 2: Example model run through gprMax: 150mm of concrete (orange) with bars (blue dots) at 100mm centres. This sits on the original pipe (light blue) and some earth (red). To this we have added voids (the dark blue) and 'wet' patches (orange) (areas of higher conductivity and amplitude).

It should be noted that the simulation can take time to run, and the more complexity and size of the model will increase this time. It is therefore important to keep the complexity of the model to only what is required for the simulation or have a very high spec computer. The simulation above took approximately 3 days to run on a low spec PC, this was undertaken over a weekend.

The simulated data was outputted from gprMax and opened in Geolitix for viewing. Geolitix allows for clear interpretation of the modelled data and allows for post processing. This means the data can be reviewed the same way as the collected data.

The simulated data allows the team to know what to expect from the data prior to interpretation of the collected data.

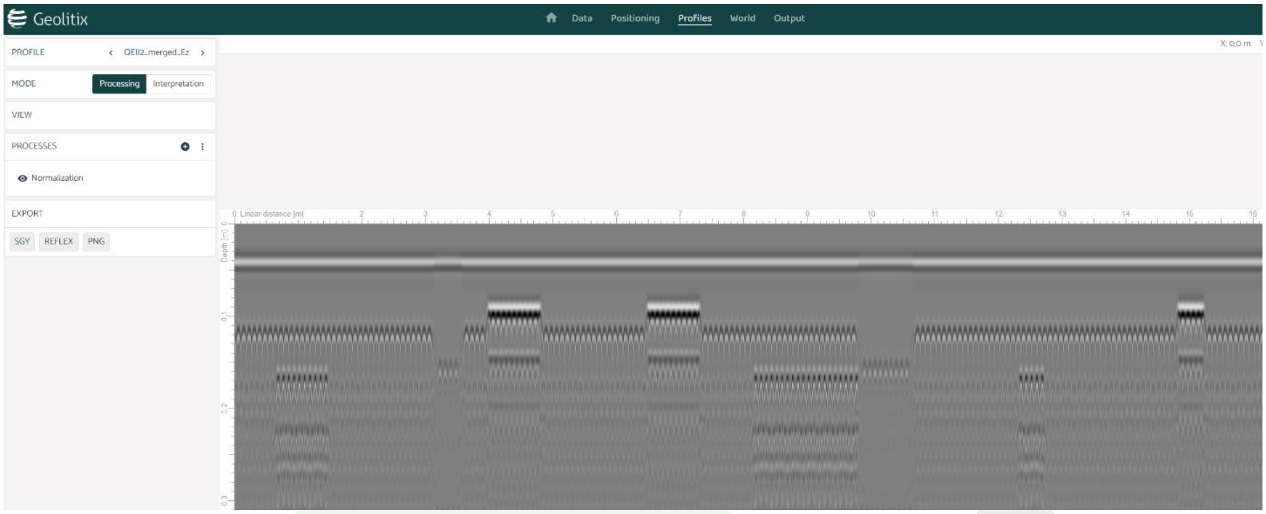

Figure 3: extract from the simulated data showing two voids, above and below the bars, and an area of 'wet' concrete.

For this project it was not possible for our teams to get on site and collect the data, due to timescales and access conditions. Therefore, the client collected the data using an all-in-one GPR system. This is not ideal as it is always better to have trained personnel collect the data, in case of issues on site. The data was collected through several longitudinal lines over 500m of tunnel at 30-degree intervals.

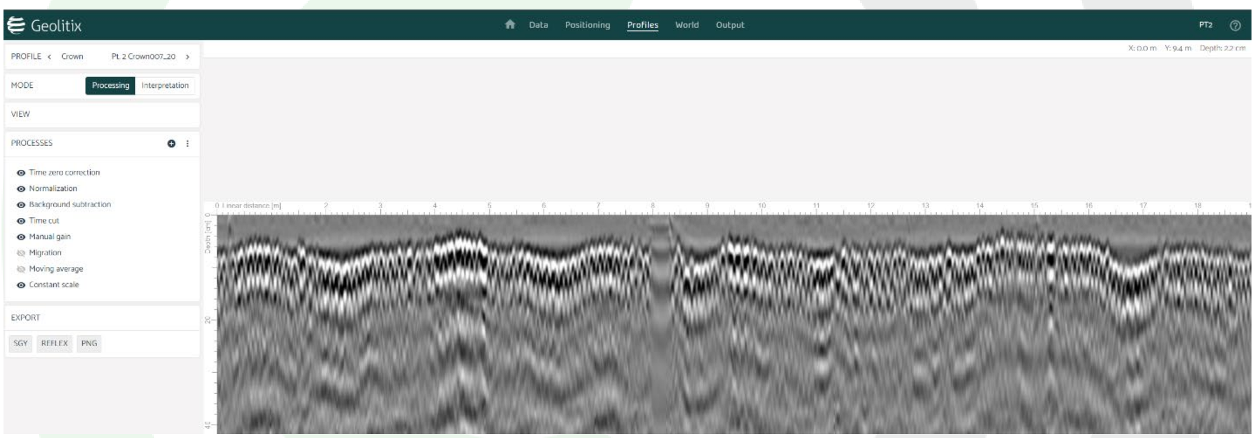

Figure 4: Collected site data with postprocessing showing several variations in the data, including voiding and variations in the dielectric of the concrete.

The data collected shows several variations visible within the collected site data. Some of this is due to simple variations in the depth of reinforcement, created during installation. There are also various defects within the concrete including voiding and increases of the material dielectric. The site data was collected with a GPR system with a lower horizontal resolution than that modeled leading to complex data interpretation for this project.

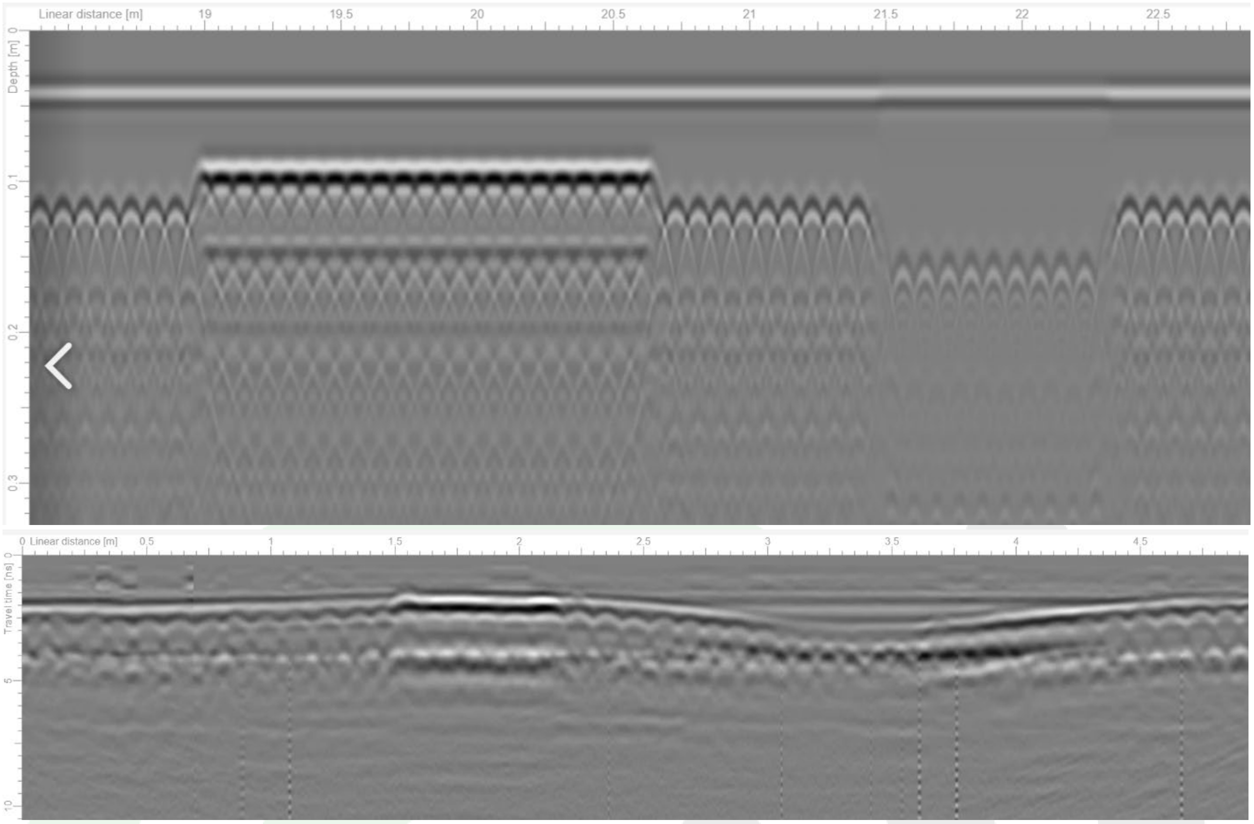

Figure 5: Simulated data above and real data below showing an air void above the bars with an area of 'wet' concrete.

The data from the simulation was directly comparable to the data collected on site. Although, the simulation was perfect, with straight edges and distinct features, while the collected data showed less distinction between features.

The collected data was not always clear, due the variations in the bar centres and depth, but the simulation allows for a better understanding and interpretation of the data.

For this project the data was interpreted, and the locations of detected defects were presented in tabular format within a written report. Using experience and simulated data it was possible to provide context and definition to the features and anomalies extracted from the data. This allowed the client to drill on indicated locations and repair voids found.

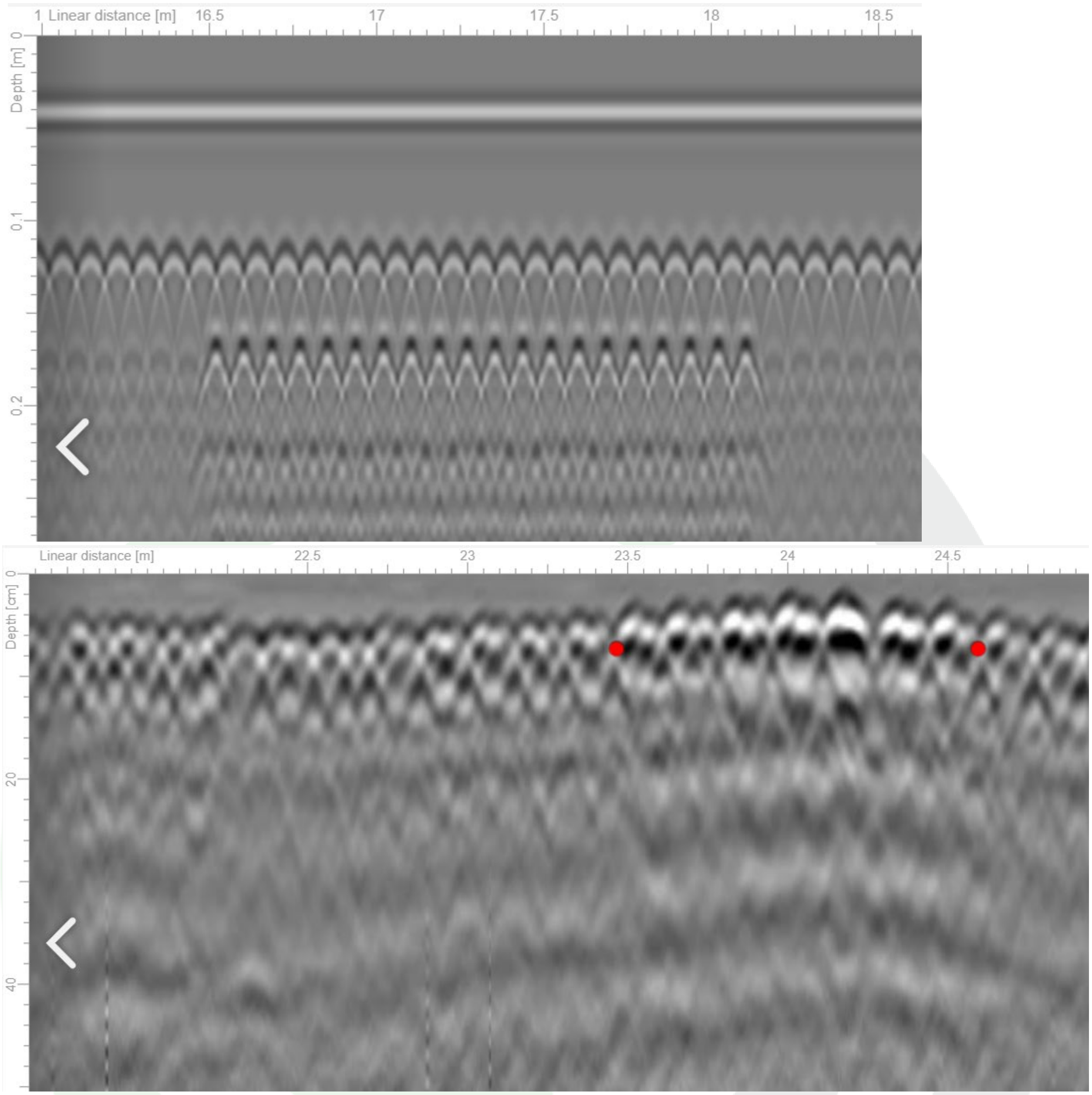

Figure 6: simulated data above and collected below, showing voids below the bars

Using the simulated data, it was possible to better understand the results of the GPR data collected on site. This improved the data interpretation and provided reassurance to the client that what was described as a void was such. However, this is only a tool and real data is never perfect like the simulation.

While it can be time consuming, simulations can provide a lot of information for both the GPR professional and client.