TRAFIKVERKET

REPORT 4D

GPR ON RAILWAY

Railway inspection using 3D Georadar

Part of R&D project “Infrastructure in 3D” in cooperation between Innovation Norge, Trafikverket and TerraTec AS”

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Content

Introduction

By using georadar on railway it is possible to obtain information about the ballast thickness and subgrade without invasive methods whilst collecting data up to 100 km/h.

For this test a portion of railway between *Borlange* and *Sellnäs* was mapped with two different georadar antennas and with different survey settings.

The main purpose of this project is to establish which system gave the best data, and to ascertain what can be found in the data, and how to illustrate it along with surface point cloud data acquired from LiDAR acquisition along the track.

Method

The antennas used was a ground coupled (DXG) and an air launched system (DX). Normally the ground coupled should be in close proximity with the medium of investigation. However, for this test the antenna was suspended approximately 20 cm above the rails. It was made a provisional mount for the antenna that was used by both systems.

The different antennas and the provisional mountings are depicted in figures 1 and 2.

More details regarding georadar method can be obtained in the report" TRV 4A Ground Penetrating Radar"

Figure 1 3DR - DX Georadar attached to Railway cart

Figure 2 3DR - DXG Georadar attached to Railway cart

GPR is susceptible to electromagnetic noise from the surroundings. Along a railway there are several sources of noise. Sources of particular concern are the overhead cables and metal fences along the rail. This noise can be attenuated; however, it will still be present to some degree making higher tier use of the data more difficult.

Results and discussion

DXG (Ground coupled) results

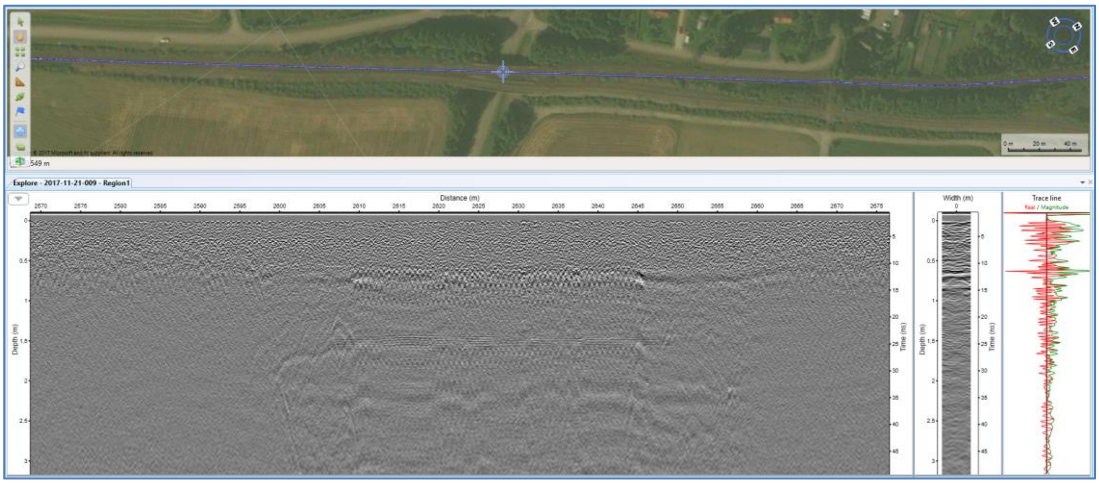

Figure 3 DXG finished result, data example shows a bridge.

DX (Air launched) results

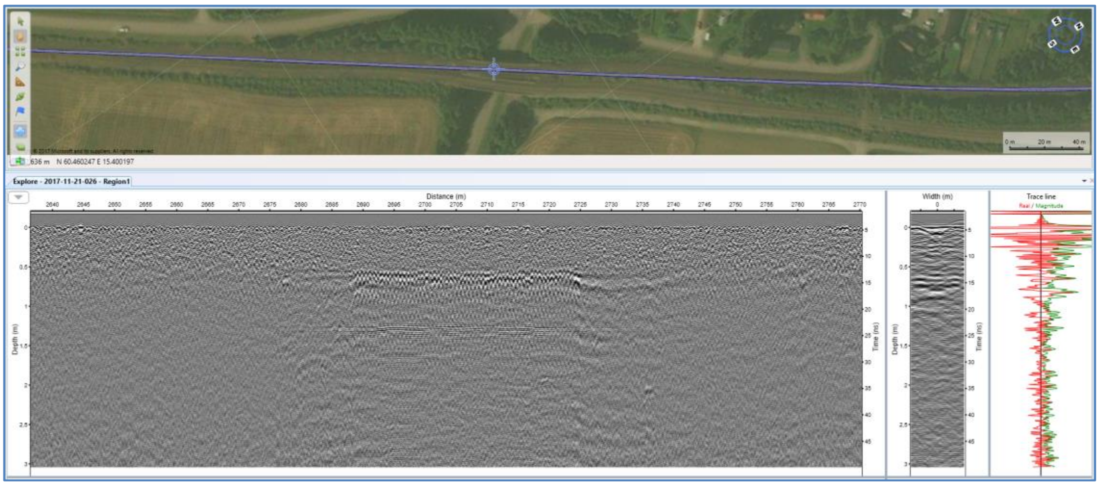

Figure 4 DX finished result, data example shows a bridge.

The two datasets are quite similar, albeit the air launched seems to be more susceptible to external noise as can be seen by the presence of noise from the side fence along the track. Based on this, the preferred system is the ground coupled (DXG system).

Survey parameters and comparison.

3 tests with the DXG was performed with varying survey parameters. The following pictures gives an illustration of the results.

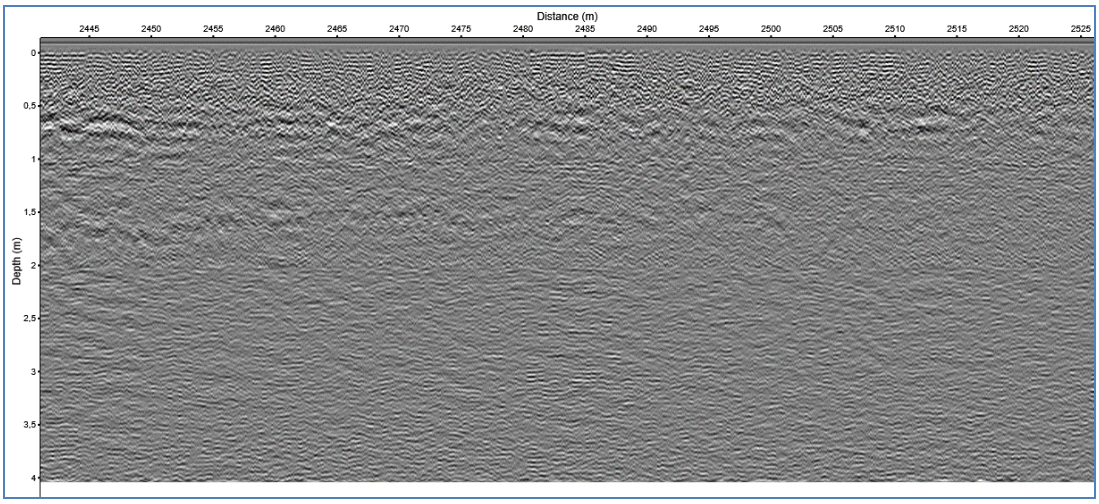

Figure 5 - Test 1 : 12,5 cm sampling interval, 62 ns data window and 10 us dwell time.

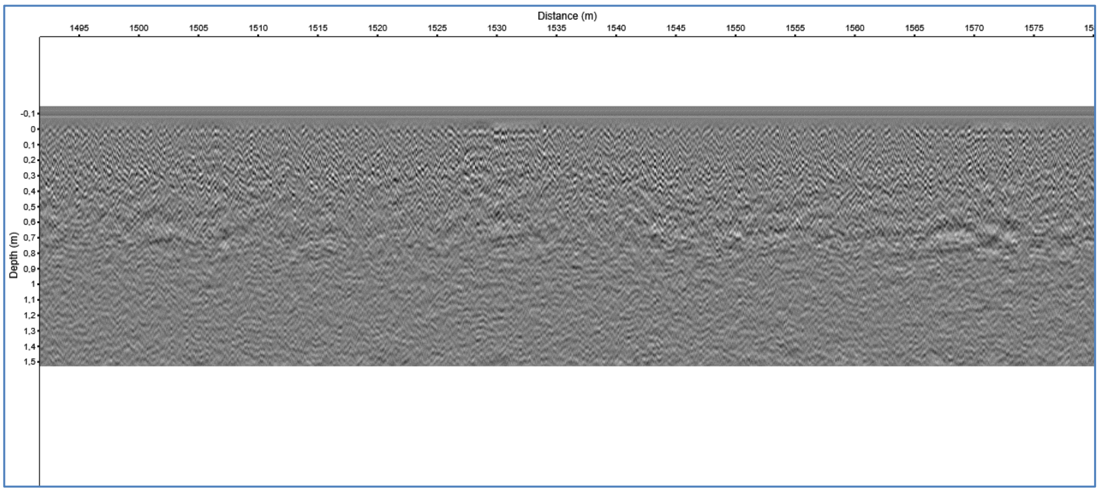

Figure 6 – Test 2: 10 cm sampling interval, 25 ns data window and 3 us dwell time.

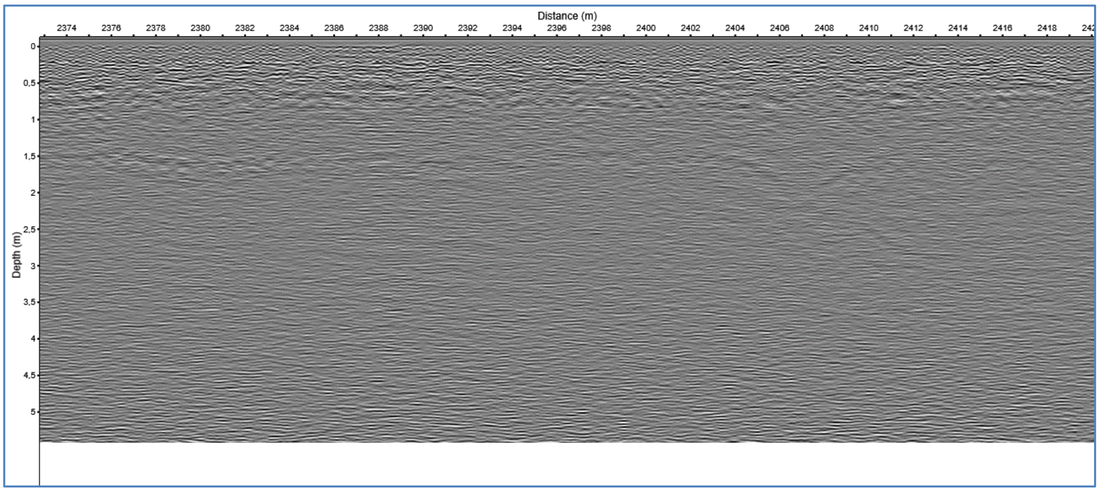

Figure 7 – Test 3: 15 cm sampling interval, 83 ns data window and 3 us dwell time.

Test 1 seems to give a good base for interpretation, albeit it is not easy to interpret this result due to relative weak reflections. This was performed at approximately 50 kmt^{-1}

Test 2 has not enough depth penetration to delineate the sub-grade, and Test 3 looks reasonable with a very long depth range, albeit the reflectors are quite weak, compared to test 1.

Noise attenuation

There are several main sources of noise when doing electromagnetic surveys on railway. It is not possible to foresee all the noise types that are affiliated with railway investigation. However, with more surveys performed it should be possible to build up an empirical base on this.

One major factor is the noise from the overhanging electric cables. This results in a EM field that is recorded by the georadar system and shows up as random noise in the data. However, it can be attenuated quite well by suppress the relevant energy in the frequency domain. This will also remove some of the signal, so it is important to compare the data before and after the procedure. Figure 8 gives an example of before and after this process.

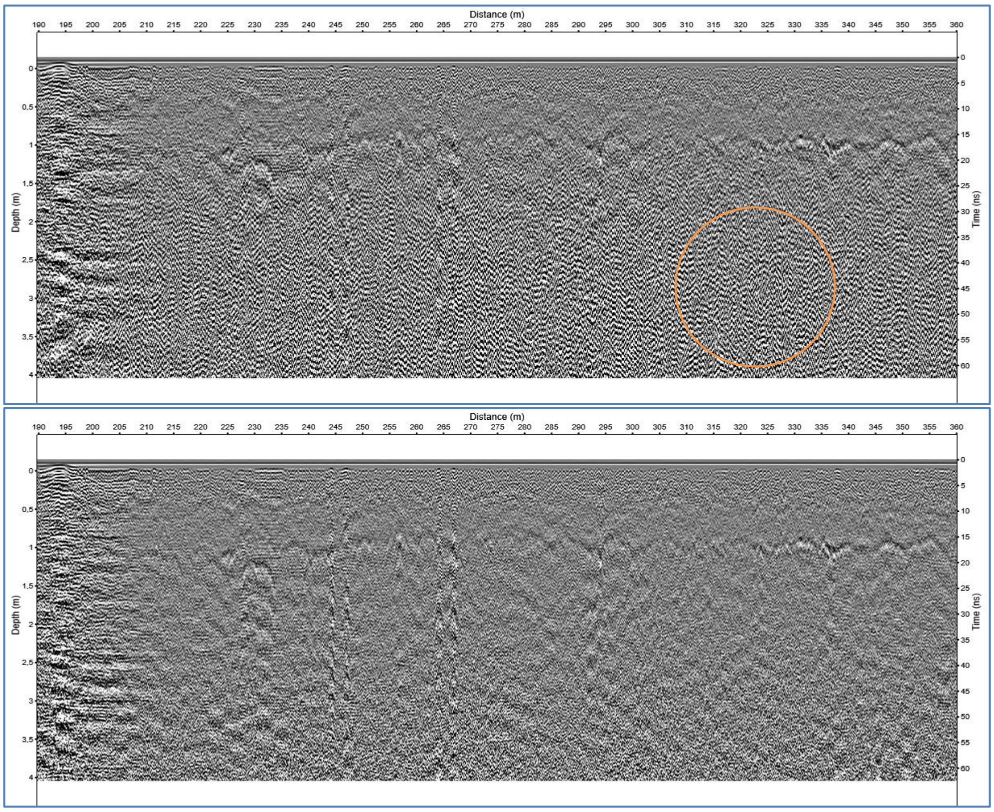

Figure 8 - Before and after frequency filtering of random noise.

Coherent noise in the data is harder to remove, and it should be known beforehand that this type of noise can occur in the data set, so that it is wholly omitted in the interpretation work. One good example of this is the noise generated by the metal fences along the railway track.

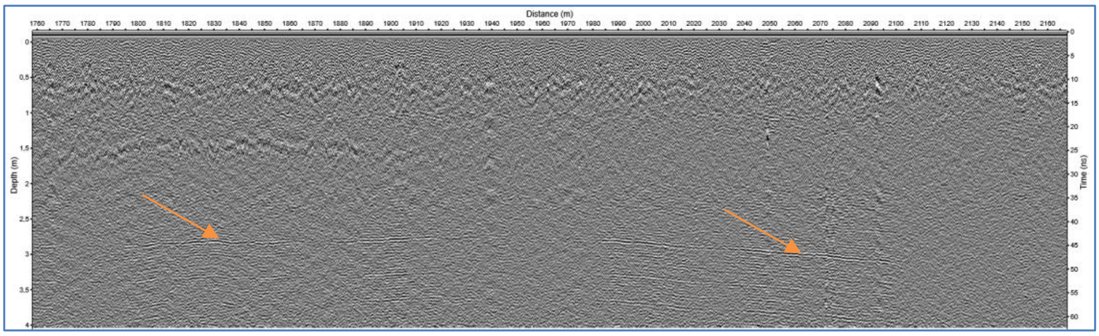

Figure 9 - Coherent noise present in the data. This can be observed at around 3 meters depth.

Interpretation of georadar data

Having taken the remaining noise into consideration when interpretation the data, final results was created.

The events in the data is not very clear, and it requires manual work to obtain decent, albeit somewhat jagged results. Figure 10 gives a good indication on how this work was done. The interpretation work done is the basis of subsequent images with point cloud and TIN data.

A general observation that can be made is that the ballast thickness vary around 0,75 meters and the subgrade varies around 1,5 meters. This is an estimation. For improved accuracy ground truthing should be performed.

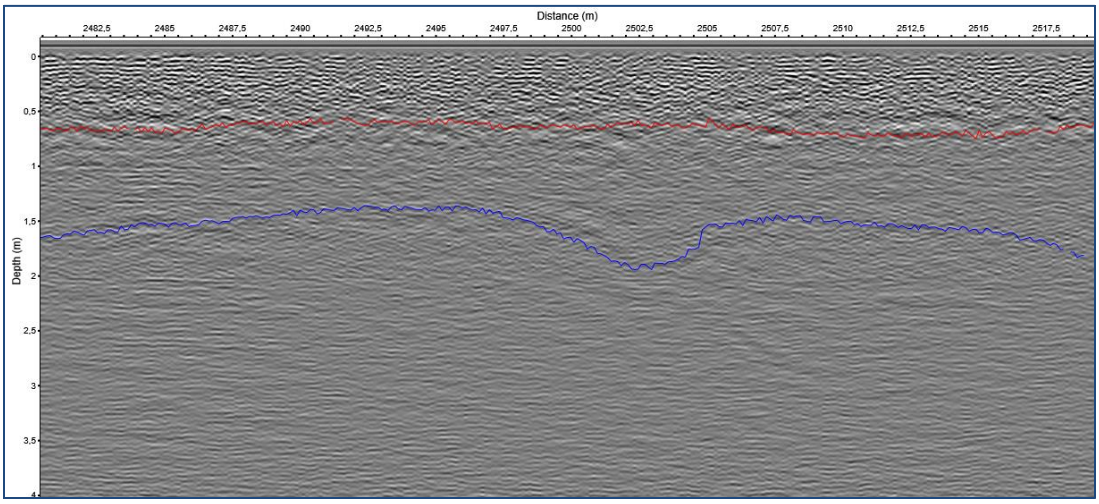

Figure 10 - Interpretation of ballast and sub-grade thickness.

Visualization with LiDAR point cloud

The point cloud export from the georadar survey can be turned in to a TIN model and subsequently visualized alongside a LiDAR point cloud. This can be an effective way of visualization of the different strata in the ballast.

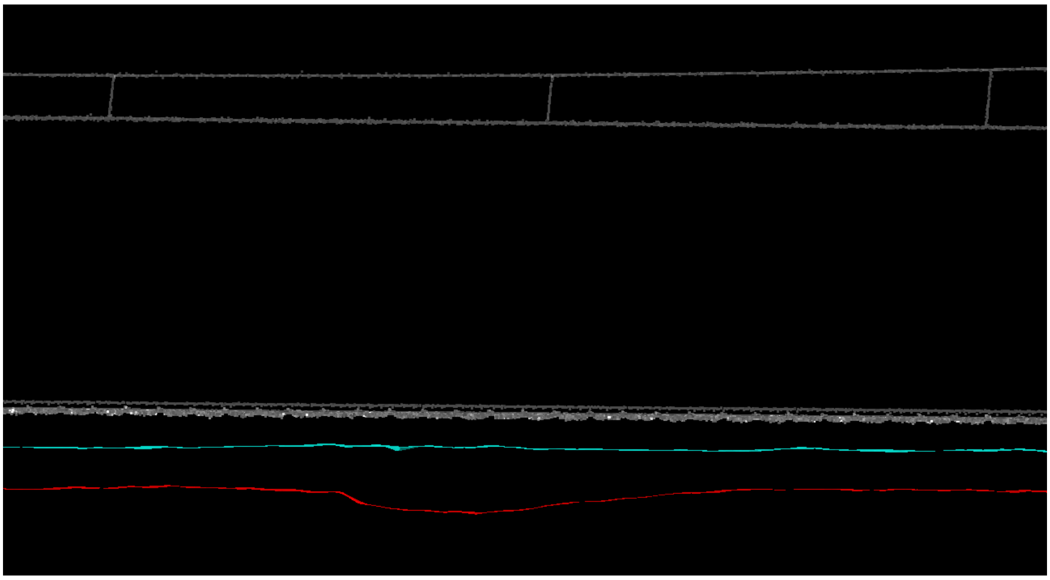

Figure 11 – Visualization of the different strata in the ballast in 2D, along with overhead cables.

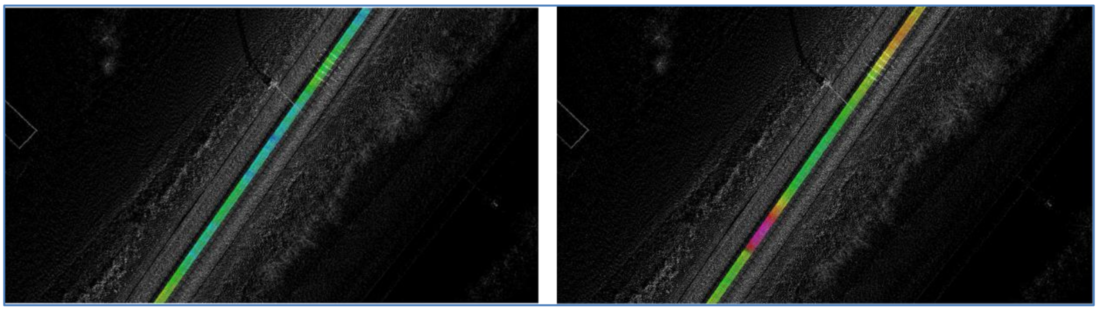

Figure 12 - Illustration of ballast(left)- and subgrade (right) thickness.

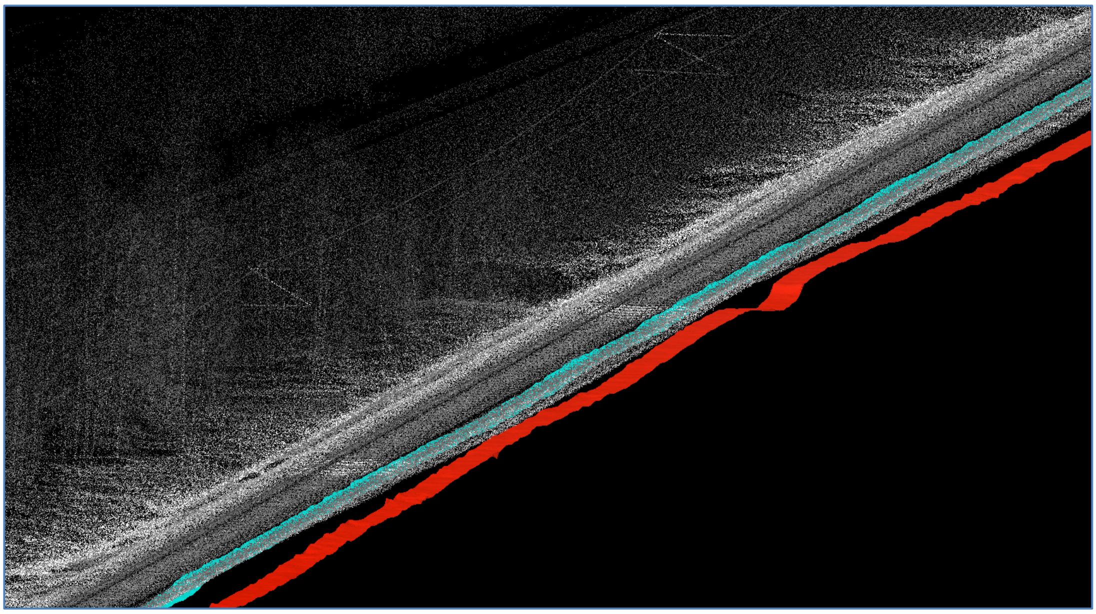

Figure 13 - Illustration of railway construction with ballast- and subgrade thickness, in 3D.

Conclusion

The findings of this report suggest that georadar can effectively be applied on railway to obtain more information about the ballast and subgrade, especially to investigate the thickness of the layers.

For ballast and subgrade investigations ground truthing should be available along the area of interest to improve the knowledge of the EM waves behavior in the medium. This will greatly improve the accuracy of the measurements.

Based on the findings in this report a typical georadar survey on railway with the ground coupled 3D-Georadar system should then typically have the following settings:

- Relatively dense spatial sampling, e.g. 10-15 cm intervals.

- Medium to deep time window (e.g. be able to penetrate up to 4 meters), with as high dwell time as possible (this parameter can be used to vary the acquisition speed).

This enables the acquisition speed to be around 60-80 km/h.

The interpreter needs a clear understanding of the noise types, and avoid including them in the final interpretation.

Future work should focus on understanding ballast fouling (accumulation of fine particles) and the effect that is has on the georadar signal. This can then be used to visualize areas with higher degree of ballast fouling.

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