Surface Regularity Survey

Method comparison

Data captured by

GEO-PRECISE LTD

Calculated and analysed with

Flat 4

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Signed:		**Date:**	*02/08/2021*

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Abstract

The purpose of this document is to compare the conventional floor surveying method using precise level and digital surface profile recording device, with high precision 3D terrestrial laser scanning combined with point cloud processing programs, in relation to their relative and absolute accuracy and overall efficiency from survey engineering point of view.

Introduction

According to Technical Report 34 by Concrete Society, "Surface profiles of floors must be controlled so that departures from a theoretically perfectly flat plane are limited to an extent appropriate to the planned use of the floor."

For many internal ground floors, the most suitable tolerances to be worked to are 'free movement classifications' (FM) as defined in TR34 (4^{th} edition). Areas within 1.5 meters of walls, columns or obstacles are excluded from free movement assessment. The properties measured in FM surveys are '*Property E*' and '*Property F*' (Levelness & Flatness).

Property E:

The elevational difference in millimetres directly between fixed points *3m* apart (not across the diagonals).

Property F:

The change in elevational difference between two consecutive measurements of elevational difference each measured over *300mm*.

Conventional Floor Survey:

A 3m grid was set out, starting 1.5m from each wall at corners of the slab. A precise level was set up multiple times to survey the grid points (always within 30m of all measured points). At the start and end of each setup, a backsight and foresight reading were taken on a known datum point to guarantee the accuracy of the intermediate readings. Then 3 consecutive readings were taken on each intersection point of the 3m grid, the 3 measurements were meaned and results were recorded to the nearest 0.1mm.

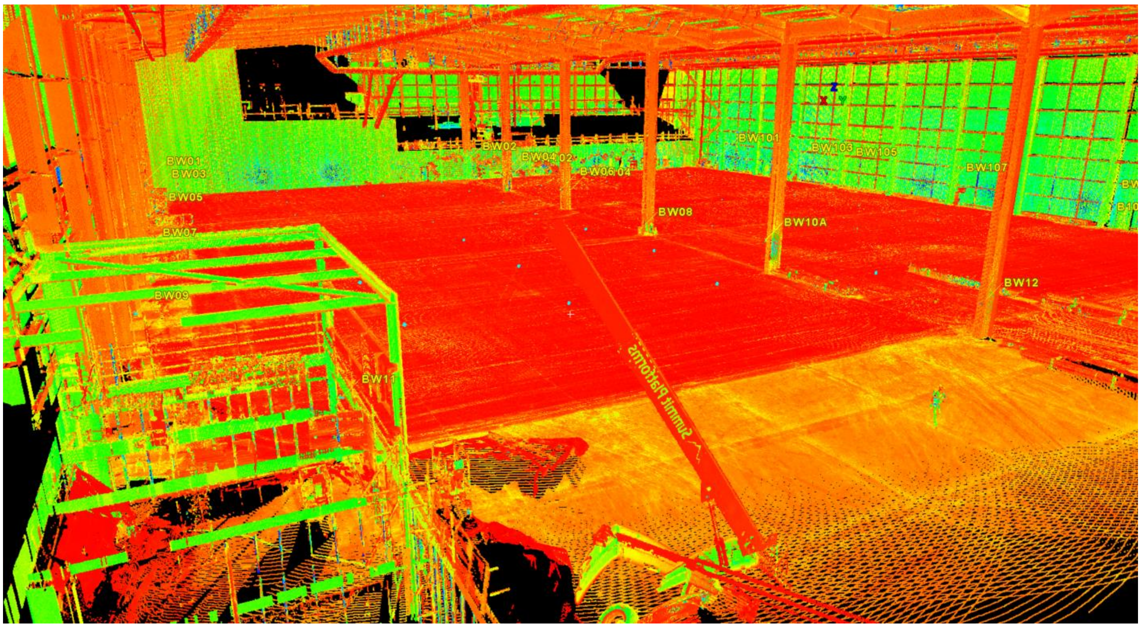
Property E survey data was analysed using Flat4 software, in where the geometric relations of the grid points were calculated and compared against the given specifications (see Property tolerances below).

Property F has been measured using a Digital Property F Recorder.

3D laser scanning

The survey data is collected with high accuracy Laser Scanner from multiple setups, each precisely coordinated with a Total Station. All geodetic information was transformed in the form of point cloud data, which consists of hundreds of millions of 3D coordinates. Later these datasets were registered together with a point cloud processing software called Cyclone by Leica Geo systems.

The registered point cloud was analysed with Flat4, which, in this case, first created the grid surface model from the point millions to the required density, then the geometric relations of these grid points were calculated and compared against the given specification of both Property E and F, by Flat4's algorithms.



Flat4

This software solution for surface geometry analysis is created and owned by GEO-PRECISE LTD. As it was mentioned before, the program uses algorithmic geometry to calculate and compare the relation of the points of a digital surface model. This allows us to run millions of calculations on a digitised surface (e.g. a point cloud extraction of a warehouse floor) in only few seconds, and then convert the results into the required format to create maps and data analytic reports.

Survey details

General

Area of floor (m²):	*5002*	Calculation area* (m²):	*4950*
3m grid points in calculation:	*596*	50mm grid points in calculation:	*2093926*
Datum level:	*9.9950m*	Floor Class:	*FM 2*

Instruments used

Property F Recorder:	*DDPFR*	Digital level:	*Leica LS15*
Total Station:	*Leica TS15 (1")*	Laser Scanner:	*Leica P40*

Property Tolerances

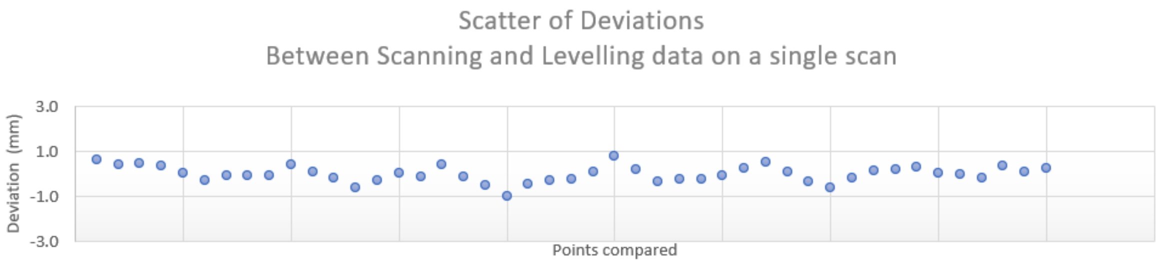
Property E (95%):	*6.5*	*mm over 3m*	Property F (95%):	*2.0*	*mm over 600mm*

Time scales

Levelling + profiling:	*~ 16h on site (2)* *~ 6h processing (1)*	Scanning	*~ 12h on site (2)* *~ 8h processing (1)*

Notes

A comparison of single scans and the data surveyed by the LS15 level, showed that the achievable relative accuracy of the P40 scanner during this survey was abs.0.4mm. This standard deviation was evenly spreading throughout the survey (figure below) in both negative and positive directions, resulting such a small difference in the statistics of Property E (see next page), that it is almost unrecognisable.



* Calculation area = whole floor area – exclusion zones (Areas within 1.5 meters of walls, columns or obstacles)

Results

Statistics

Property E	Total number of measurements	Measurements over tolerance	%
Levelling	*1128*	*26*	*97.7*
Scanning (3m Grid)	*1128*	*29*	*97.4*
Scanning (50mm Grid)	*3 951 968*	*96 871*	*97.5*

Property F Runs	Run Reference	Length of Run (m)	% Of failed measurements Conventional	% Of failed measurements Scanning
1	Y3-D3	62.4	1.31%	2.83%
2	Y7-D7	62.4	2.72%	3.12%
3	A9-Y9	71.4	0.56%	2.66%
4	Y13-N13	32.4	1.79%	1.55%
5	M13-A13	35.4	0.90%	2.00%
6	A19-M19	35.4	4.86%	5.94%
7	N19-Y19	32.4	1.85%	1.70%
8	Y24-N24	32.4	1.60%	2.16%
9	E1-E13	35.4	0.56%	0.99%
10	T1-T25	71.4	1.43%	5.04%
Total		**471**	**1.67%**	**3.00%**

Error maps

Property E Error Map Levelling – Appendix A

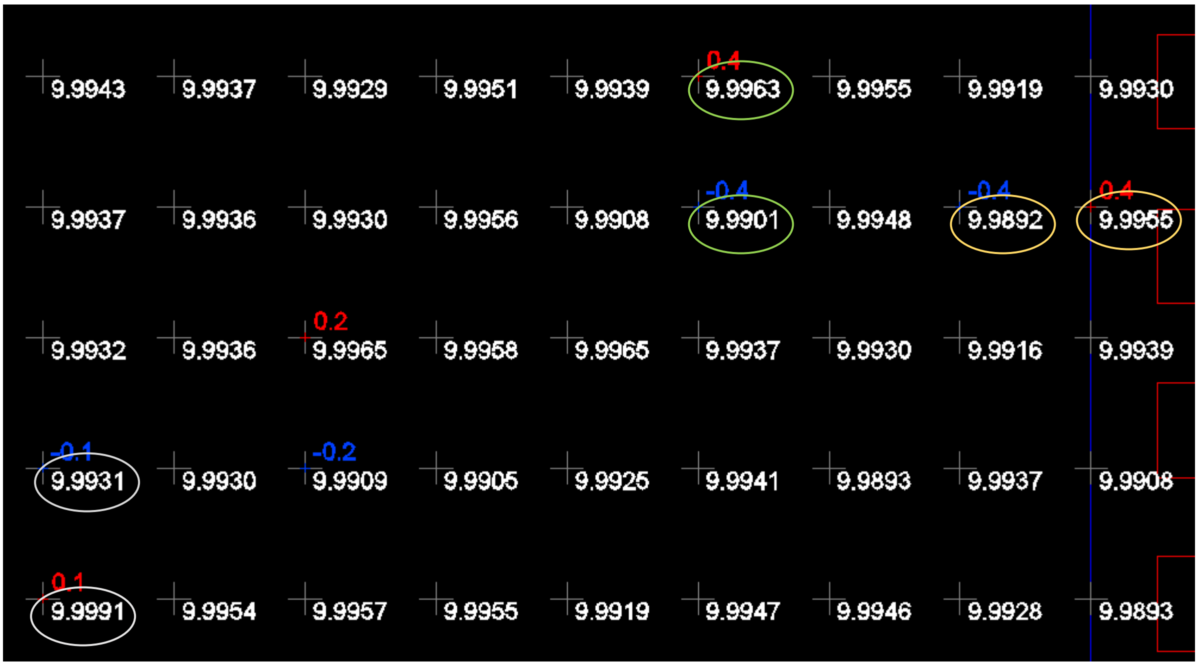
Property E Error Map Scanning – Appendix B

Property F Error Map – Appendix C

Evaluation

Property E:

Although the difference between the statistical results is only measurable in permilles the error values seem to be alter between the two different methods due to the difference of the achievable accuracy. There is only one area where failed points appear on the laser scan results (blue and red numbers) when the levelling doesn't show errors. If we have a closer look on the levelled elevation values of these points (white numbers), we can see that most of the point pairs are rather close to the 6.5mm threshold.

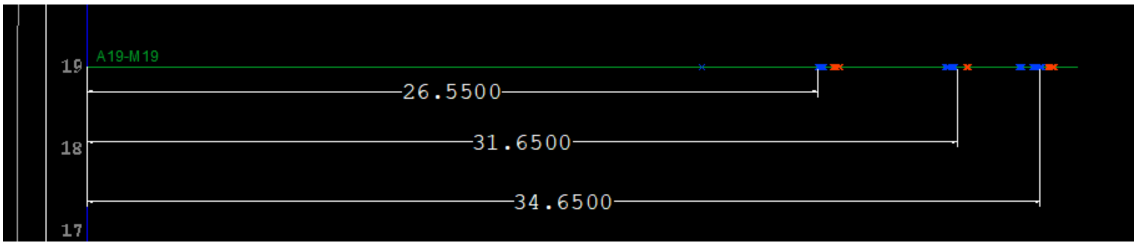


This deviation is also resulting points to fall below the tolerance when they happened to fail according to the levelling, but due to the minor rate and the very even spread of this variation, it will only effect noticeably the precise positioning of the errors in case of remediation and will not disfigure the most important 95% statistical results,

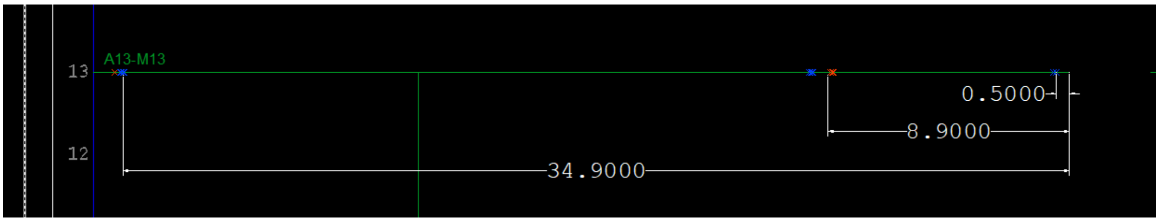
Property F:

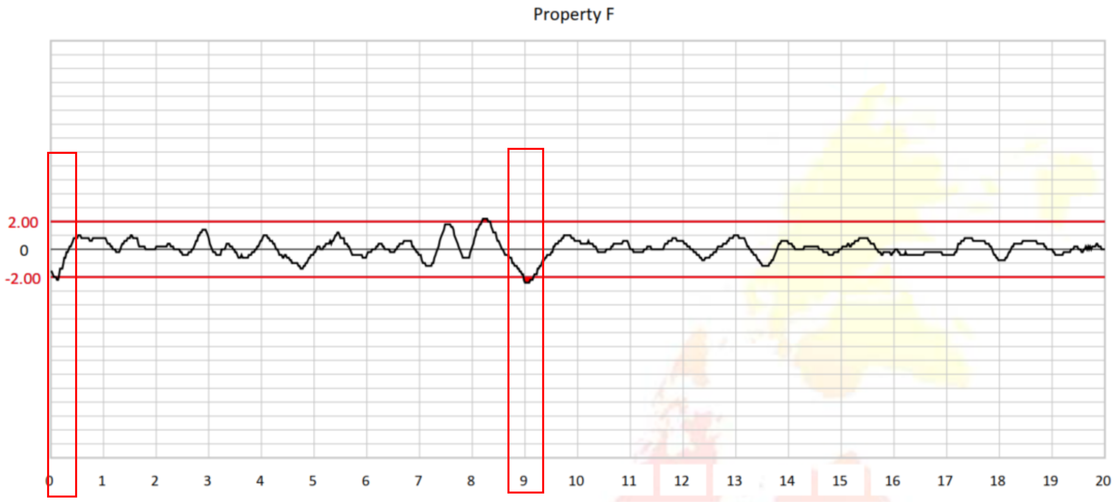
Despite of the threshold number was much lower (2mm) in this case, bringing the above-mentioned scanner accuracy much closer to the target value, the difference of the total error percentage remained close to 1%, This statistical deviation in the most cases are routing in the size and not the presence of the errors, as it is presented below through some example comparisons of DDPFR's graphs and the Property F error maps of the scanning. The statistical differences are displayed next to the title of the diagrams (levelling% / scanning%), the error locations on each run are also highlighted on both diagrams.

A19-M19 – 4,86% / 5,94%

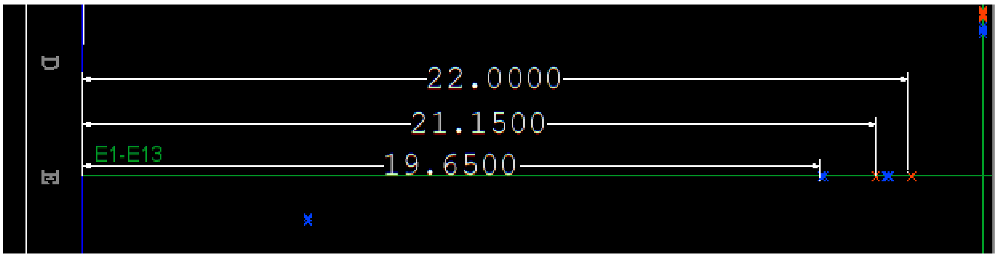


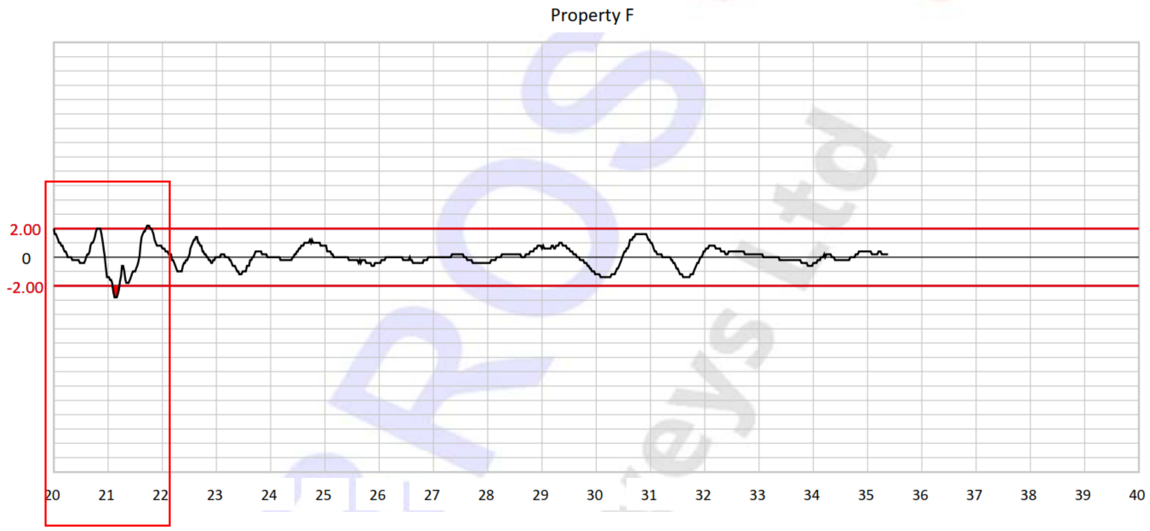
A13-M13 – 0.90% / 2.00%





E1-E13 – 0.56% / 0.99%

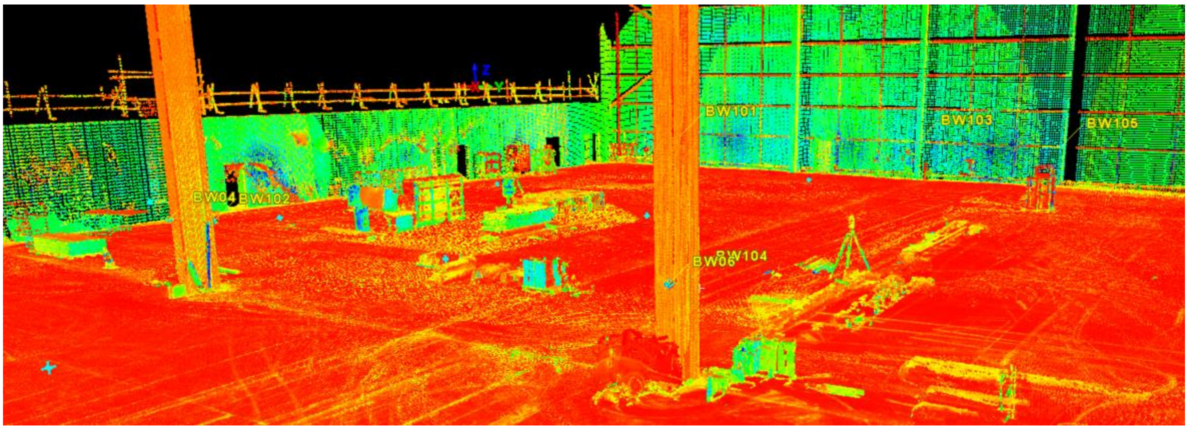




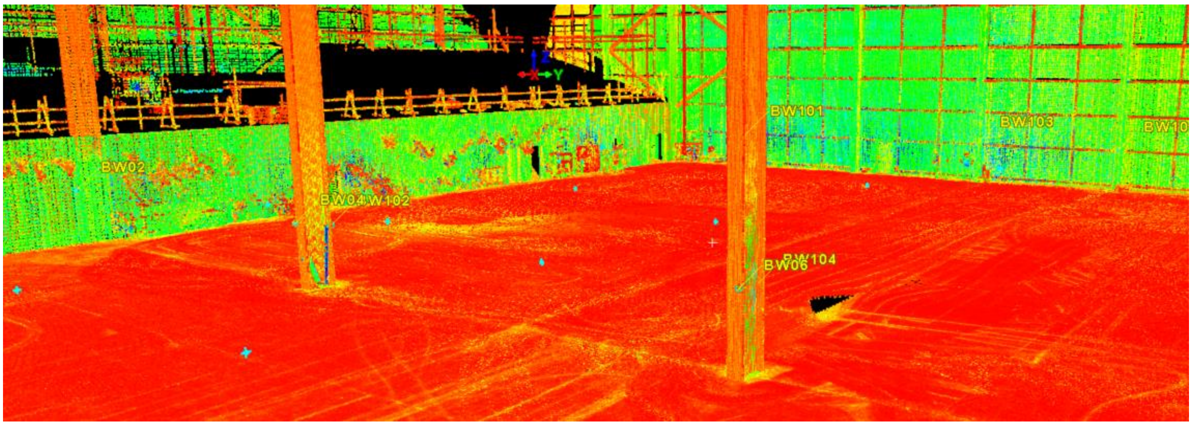
Issues

The biggest issue we were facing during the data collection of both the levelling and the laser scanning, was the busyness of the site. Other construction processes were constantly utilising about 50% of the examined floor area. Due to this, the continuity of both the scanning and levelling surveys was constantly interrupted, generating a risk of quality and data loss which than resulted in more processing work, and of course extended the timescale of the survey itself. However, the causes of the above issue are definitely reducible with an improved planning of the data collection (e.g. soon after the finishing of the floor, before it is handed over for use of other contractors).

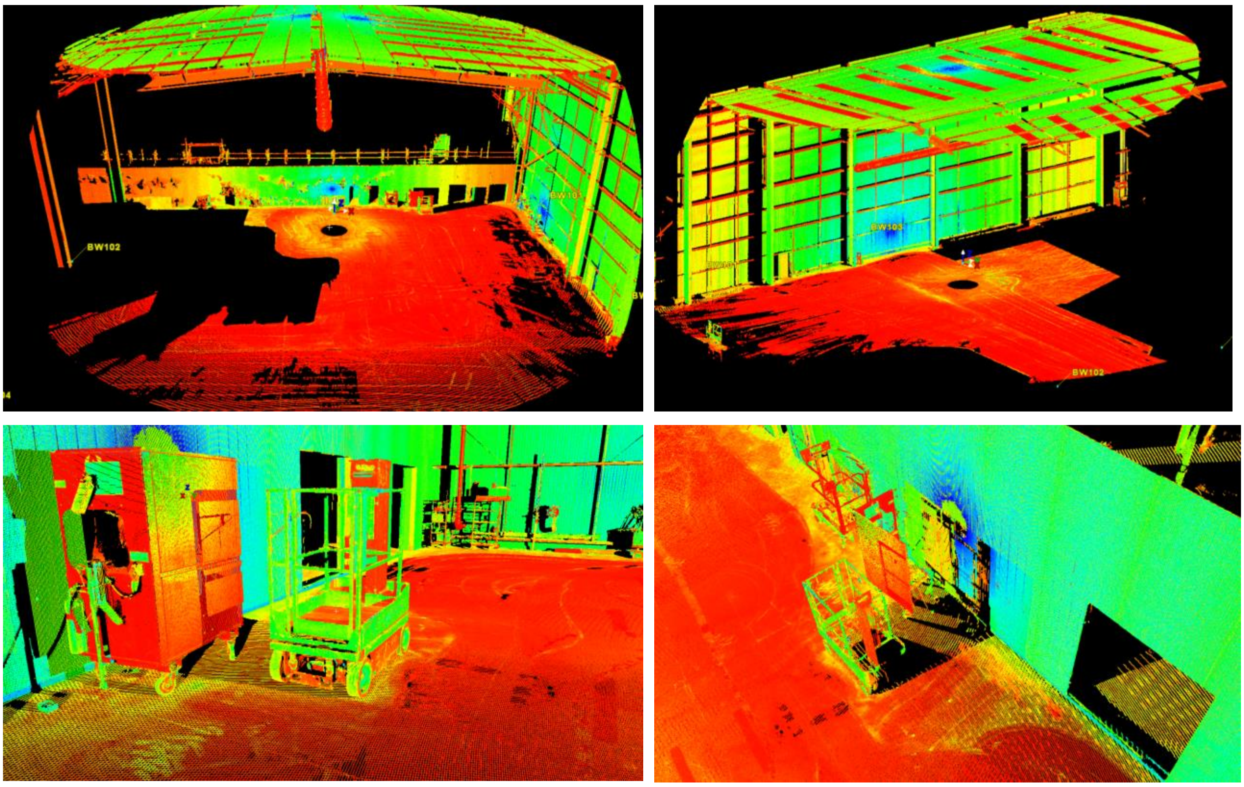
Before data noise reduction:



After noise reduction



Examples of data loss due to utilised floor surface.



Conclusion

Based on the above presented information we can say that, although the relative accuracy of the currently available laser scanners cannot exceed the precision of the precise level or the digital straight edge just yet, the method itself was able to demonstrate as valuable statistical results as the other two survey methods, in a shorter time scale. Also, it has created the opportunity to take millions of measurements on a realistic surface model of the entire floor instead of evaluating by a handful of samples collected and processed with less effort. If we produce an error plan based on such dense data that will immediately point out the locations of the errors, taking the task to the next step, into the floor remediation.

As a survey engineer who took part in both above-mentioned processes and regularly uses most of the examined survey methods in other fields of the profession too, I think the benefits of the laser scanning, especially in this area are undoubted. Starting from the contactless way of measuring (no need for physical contact with the floor points), through the efficient elimination of the undetectable human errors (moving levelling staff, mistakes in the numbering of the points etc) all the way to its by-product, which is a high-definition point cloud, wildly utilizable for other relevant engineering purposes, like as-built surveys, BIM models or for commercial purposes as a spectacular 3D demonstration for clients or on trainings.

Levelling + profiling

Pros

- Relative accuracy (0.1mm)
- Can be caried out in a busier warehouse with relatively low data distruption

Cons

- Using only small amount of data (~100 points and 100m of Property F runs / 1000m^2)
- Data collection is very phisical and therefore circumstantial.
- Increased risk of human errors that cannot be detected (hand held levelling staff, arbitrory run lines etc.)
- Long re-visit for error remediation.

Laser scanning

Pros

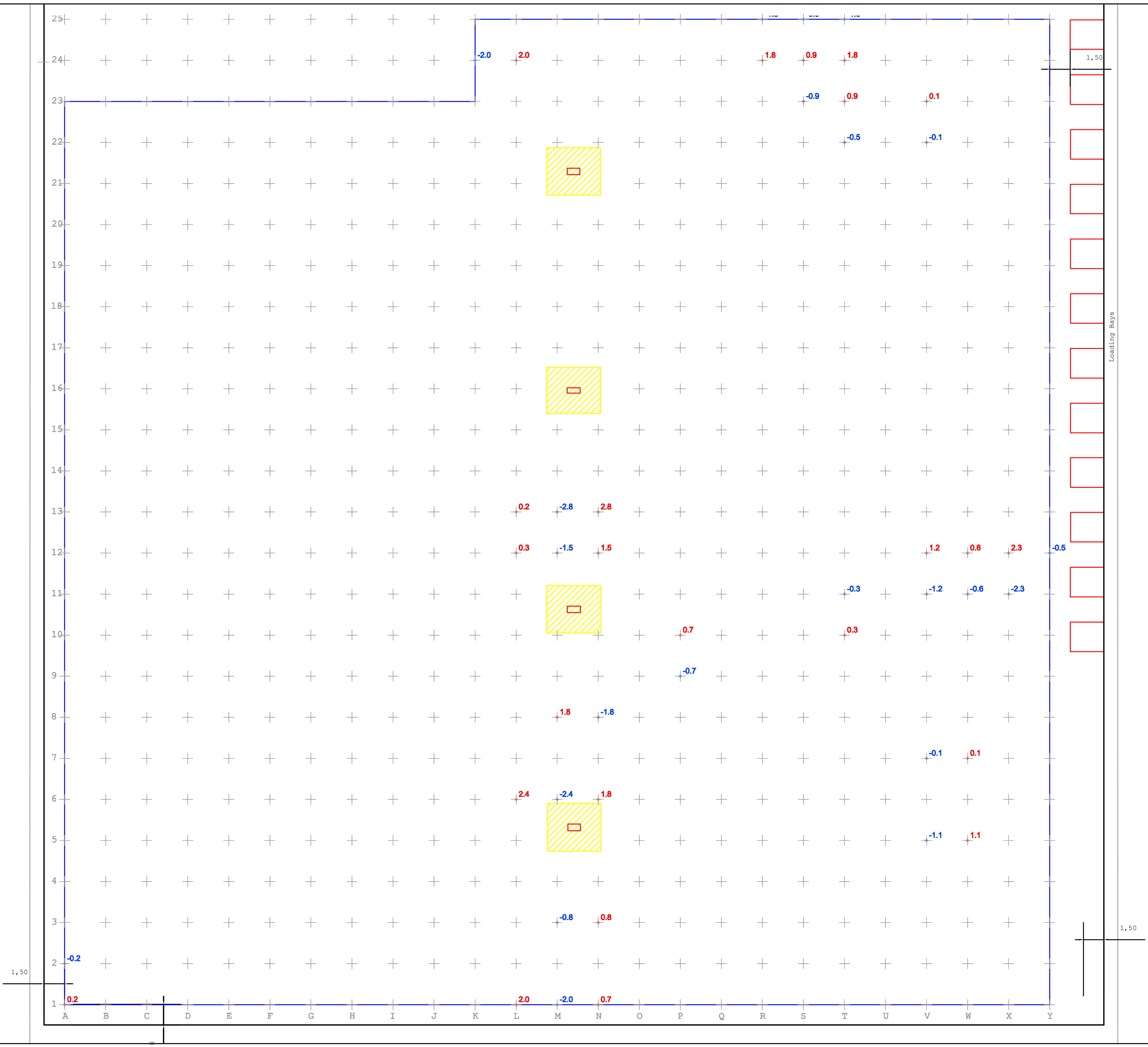
- Using vast amount of floor data in calculation (~500 000 points and 40km of gridlines/ 1000m^2)
- Less time on site
- No re-visit required for remediation plan. (Grinding plan)
- Human errors are eliminated to the minimum (most mistakes can be detected and corrected during data processing).
- Widely usable data (as-built, BIM etc.)

Cons

- Relative accuracy (0.4mm)
- The survey requires clean floor surface with minimum obstruction.

All data used during this comparison is available on request.

Appendix A



ERROR MAP

Legend

(blue box)	Survey Area
(yellow hatched box)	Exclusion zone
(red box)	Obstruction
(black box)	Slab boundary
(grey box)	External wall
9.999	Measured point height (m)
-1.2 / 1.2	Tolerance exceeded by (mm)

NOTES

1. Exclusion zone: 1.5m from walls and obstructions
2. Coordinate list of grid points available in attached .csv file named: *GP_SR_0003_G-PARK_grid_coords_200721.csv*

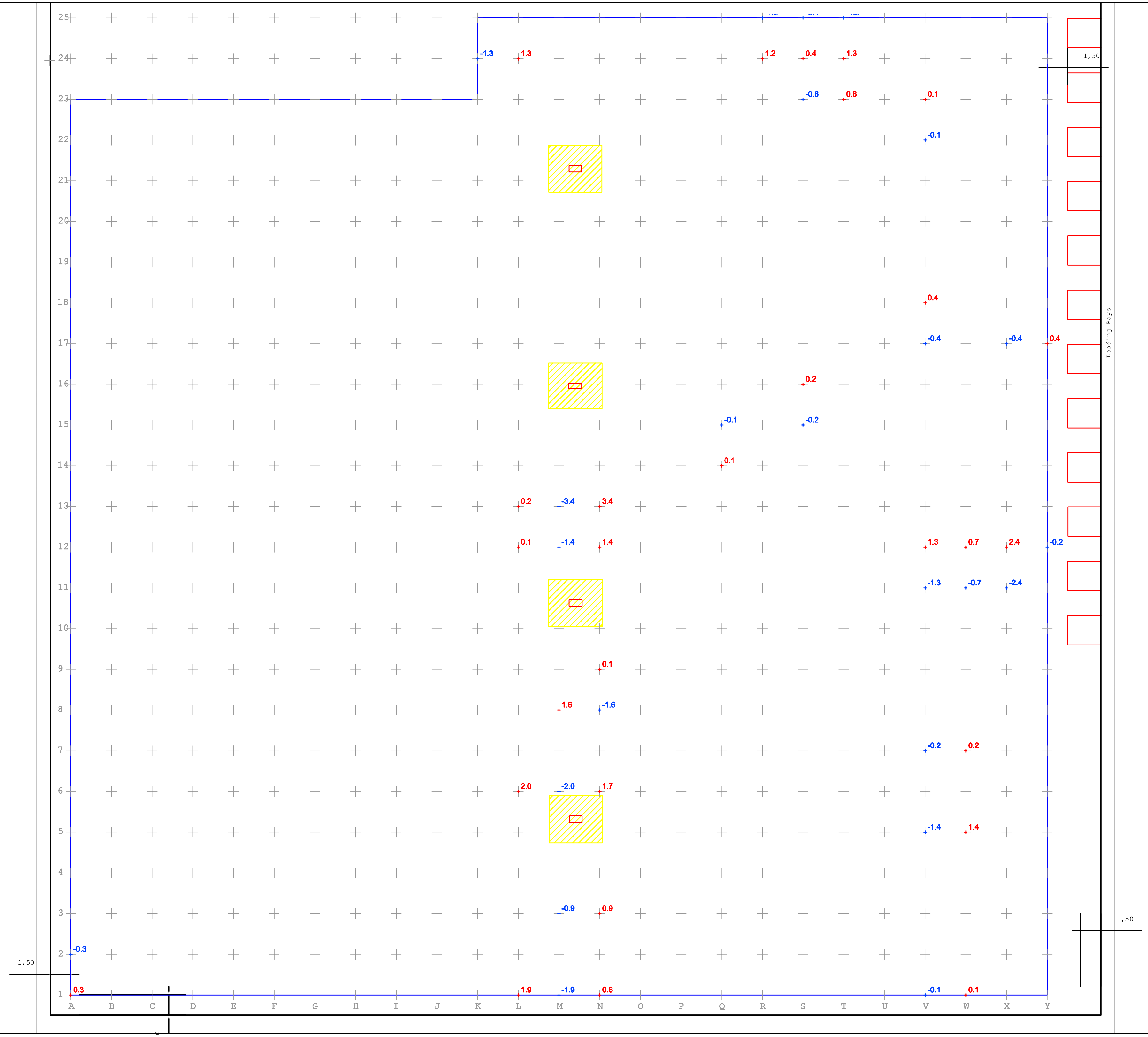
This drawing is not to be used in whole or part other than for the intended purpose and project as defined on this drawing. Refer to the contract for full terms and conditions.

GEO-PRECISE LTD

DRIVEN BY PRECISION

PROJECT:	G-PARK, Stoke on Trent
FLOOR CLASS:	FM2
Type of Irregularity:	Property E - Levelled
Date: 05/08/2021	Prepared by: A Bodoczi
Tolerance:	6.5mm over 3m
SR Report No:	GP_SR_Survey_Method_comparison
	Calculated with Flat4

Appendix B



ERROR MAP

Legend

(blue box)	Survey Area
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(red box)	Obstruction
(black box)	Slab boundary
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-1.2 / 1.2	Tolerance exceeded by (mm)

NOTES

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GEO-PRECISE LTD

DRIVEN BY PRECISION

PROJECT: G-PARK, Stoke on Trent

FLOOR CLASS: FM2

Type of irregularity: Property E - Scanned

Date: 05/08/2021

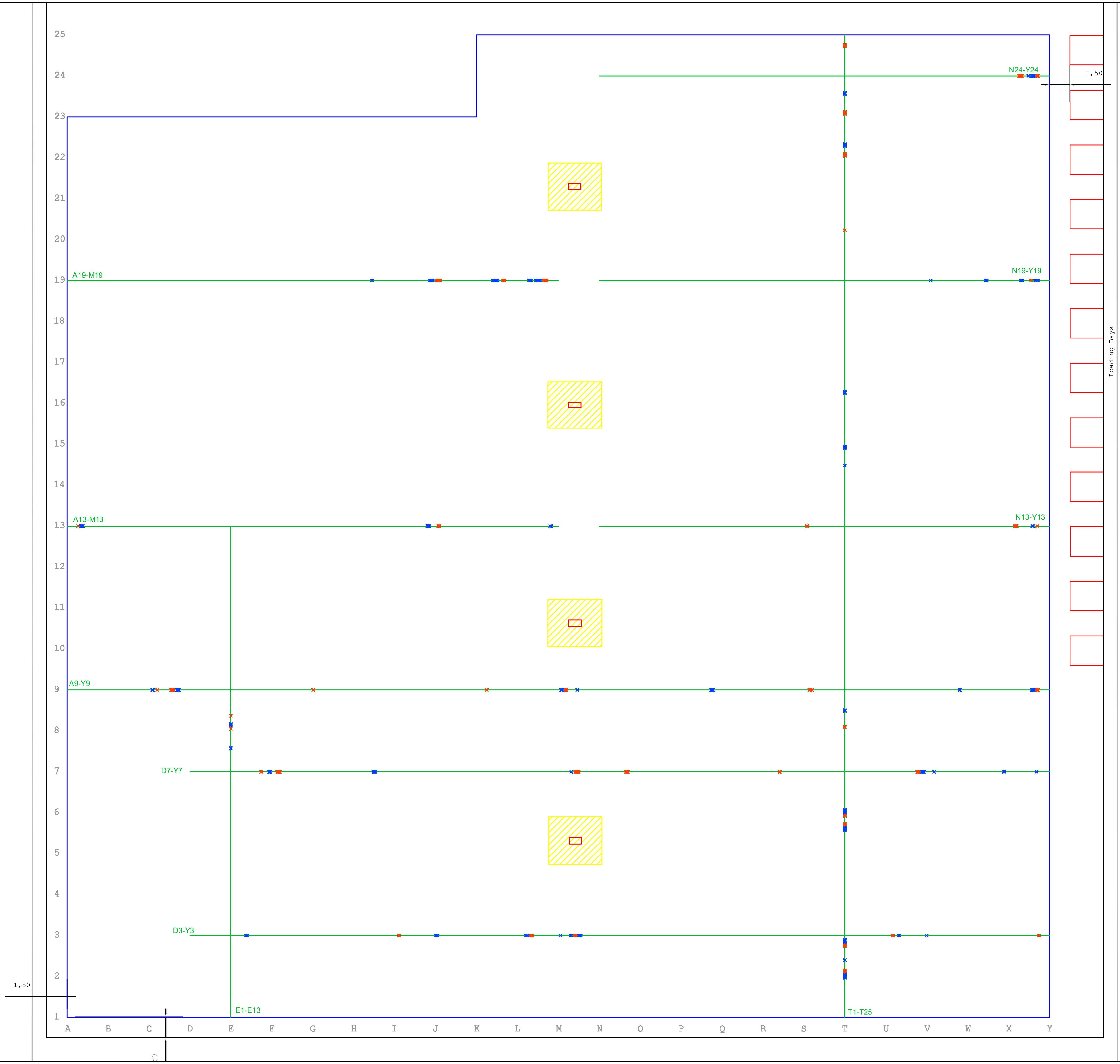
Prepared by: A Bodoczi

Tolerance: 6.5mm over 3m

SR Report No: GP_SR_Survey_Method_comparison

Calculated with Flat4

Appendix C



ERROR MAP

Legend

(blue box)	Survey Area
(yellow hatched box)	Exclusion zone
(red box)	Obstruction
(black box)	Slab boundary
(grey box)	External wall
(green line)	Property F Run
X (blue)	Property F Error Negative
X (red)	Property F Error Positive

NOTES

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2. Coordinate list of grid points available in attached .csv file named: *GP_SR_0003_G-PARK_grid_coords_200721.c*

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GEO-PRECISE LTD
DRIVEN BY PRECISION

PROJECT:	G-PARK, Stoke on Trent
FLOOR CLASS:	FM2
Type of irregurality:	Property F - Scanned
Date: 05/08/2021	Prepared by: A Bodoczi
Tolerance :	2mm over 600mm
SR Report No:	GP_SR_Survey_Method_comparison

Calculated with Flat4