Official – Sensitive

Volume change calculations for Land between Bournewood Sand and Gravel Ltd. and Hockenden Lane, Swanley for December 2018 to January 2022

Author	Dr Kyle Brown
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1 Introduction

Environment Agency Geomatics were approached by Environment Agency Kent, South London and East Sussex team to acquire aerial Light Detection and Ranging (LIDAR) elevation data and aerial photography data over Land between Bournewood Sand and Gravel Ltd. and Hockenden Lane, Swanley. The aerial data were acquired on 6 January 2022. Geomatics were also asked to estimate volume change within the site. This was carried out using archived LIDAR from 22 December 2018 acquired by Environment Agency Geomatics and the January 2022 LIDAR.

The work described in this report uses aerial LIDAR to calculate material volumes. Aerial LIDAR instruments use laser pulses to measure the distance between an aircraft and the ground surface. As the aircraft flies over the survey area a series of laser pulses are fired at the ground. In conjunction with very high accuracy navigation data, the laser pulses are used to build up an accurate elevation dataset of the ground below the aircraft, with spacings between the elevation measurements, or the resolution, of between 0.25 m and 2 m. Though the individual points of the LIDAR survey are slightly less accurate than a ground-based GPS survey, LIDAR instruments provide much more detail, collecting one million elevation measurements every 2 to 30 seconds. The specification for the current Environment Agency LIDAR system is that at least 66% of points are within 0.1 m of the actual value.

This high accuracy and fine detail make LIDAR surveys more accurate than ground-based GPS surveys for measuring volume on sites like the one covered in this report.

2 Method

The datasets used in this report are described in Table 1 and are shown in Figure 1 to Figure 10.

Table 1 Data used for Land between Bournewood Sand and Gravel Ltd. and Hockenden Lane, Swanley in this report. The three APGB aerial photography datasets only cover part of the site.

Data type	Resolution (m)	Date acquired
APGB aerial photography*	0.125	21 October 2018
LIDAR	0.5	22 December 2018
APGB aerial photography**	0.125	29 June 2019
APGB aerial photography*	0.125	31 May 2021
LIDAR	0.5	6 January 2022
Aerial photography	0.1	6 January 2022

APGB= Aerial Photography Great Britain
* data only available for eastern side of site
** data only available for western side of site

Figure 1 APGB aerial photography acquired on 21 October 2018 for Land between Bournewood Sand and Gravel Ltd. and Hockenden Lane, Swanley. Image covers the east side of the site © Bluesky International/Getmapping PLC.

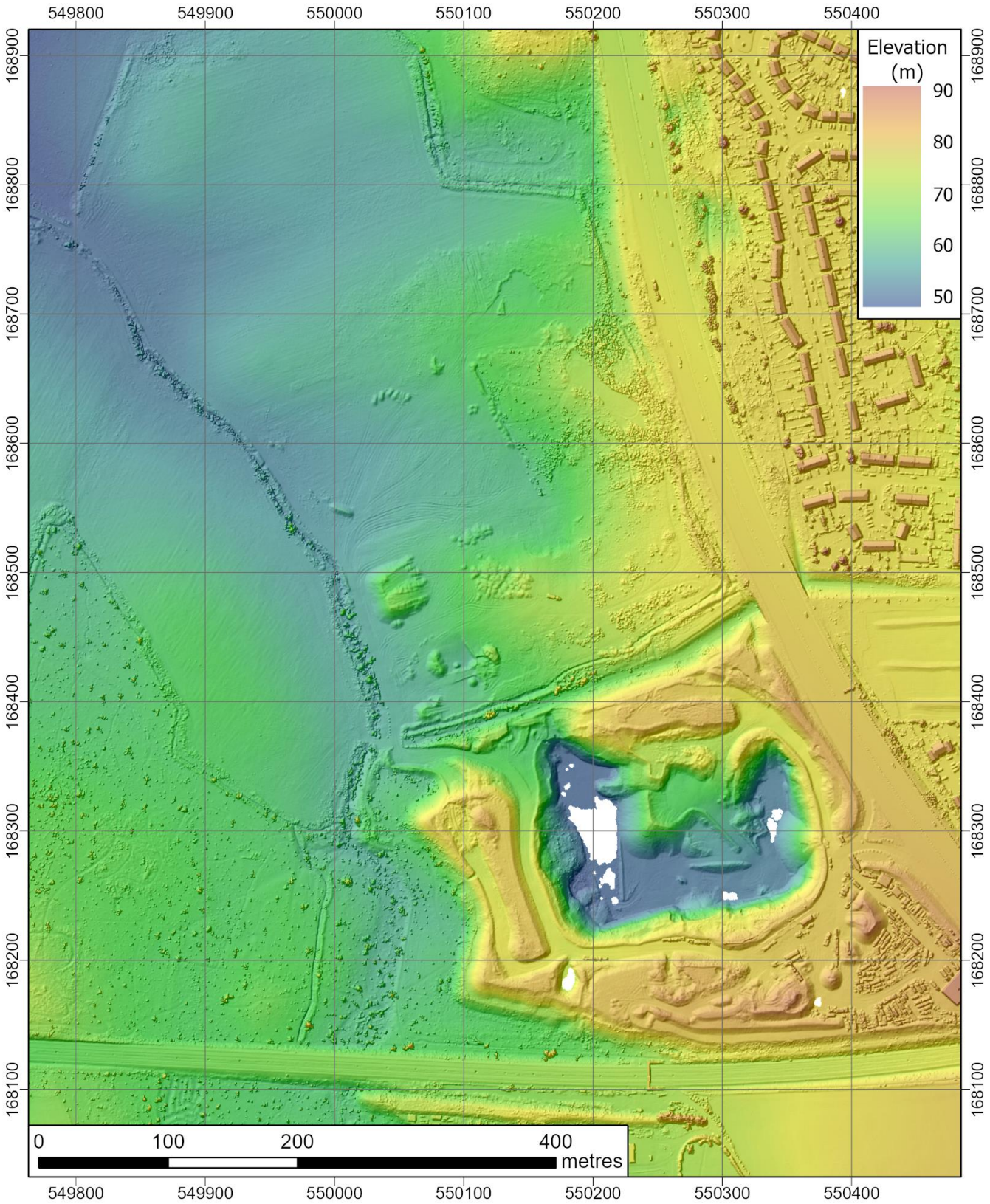

Figure 2 LIDAR elevation data acquired on 22 December 2018 for Land between Bournewood Sand and Gravel Ltd. and Hockenden Lane, Swanley. Image covers the east side of the site

Figure 3 APGB aerial photography acquired on 29 June 2019 for Land between Bournewood Sand and Gravel Ltd. and Hockenden Lane, Swanley. Image covers the east side of the site © Bluesky International/Getmapping PLC.

Figure 4 APGB aerial photography acquired on 31 May 2021 for Land between Bournewood Sand and Gravel Ltd. and Hockenden Lane, Swanley. Image covers the east side of the site © Bluesky International/Getmapping PLC.

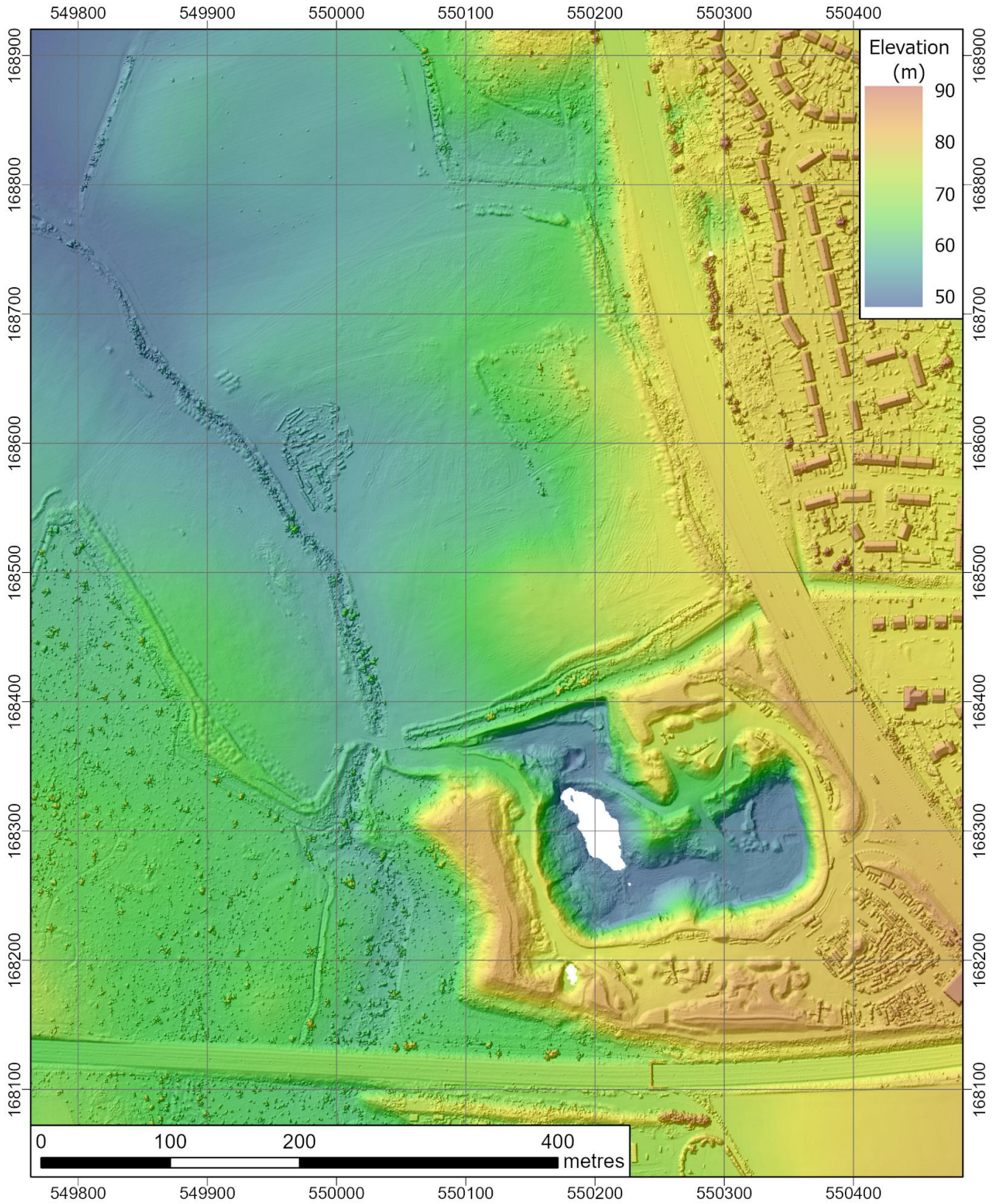

Figure 5 LIDAR elevation data acquired on 6 January 2022 for Land between Bournewood Sand and Gravel Ltd. and Hockenden Lane, Swanley. Image covers the east side of the site.

Figure 6 Aerial photography acquired on 6 January 2022 for Land between Bournewood Sand and Gravel Ltd. and Hockenden Lane, Swanley. Image covers the east side of the site.

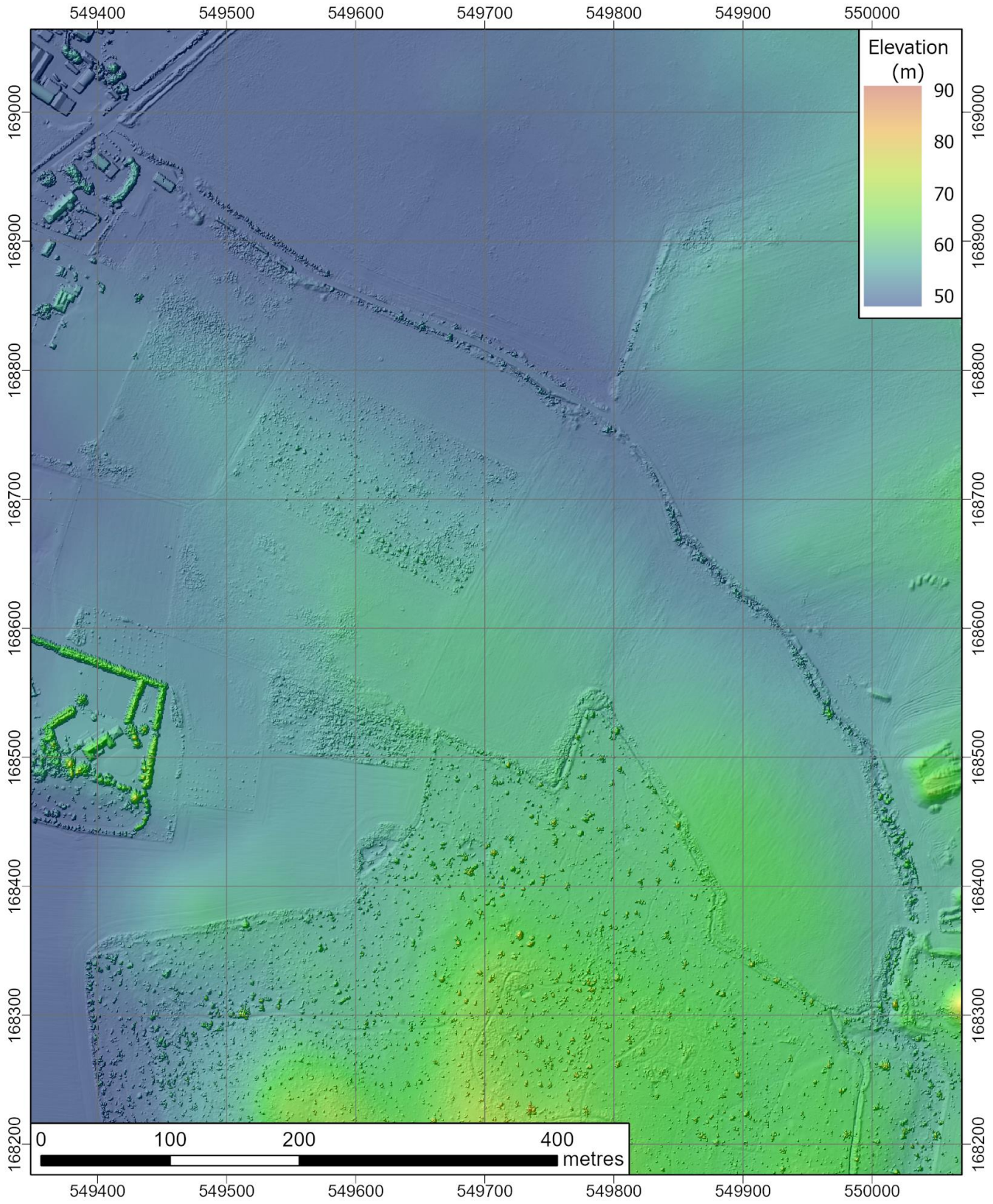

Figure 7 LIDAR elevation data acquired on 22 December 2018 for Land between Bournewood Sand and Gravel Ltd. and Hockenden Lane, Swanley. Image covers the west side of the site.

Figure 8 APGB aerial photography acquired on 29 June 2019 for Land between Bournewood Sand and Gravel Ltd. and Hockenden Lane, Swanley. Image covers the west side of the site. © Bluesky International/Getmapping PLC.

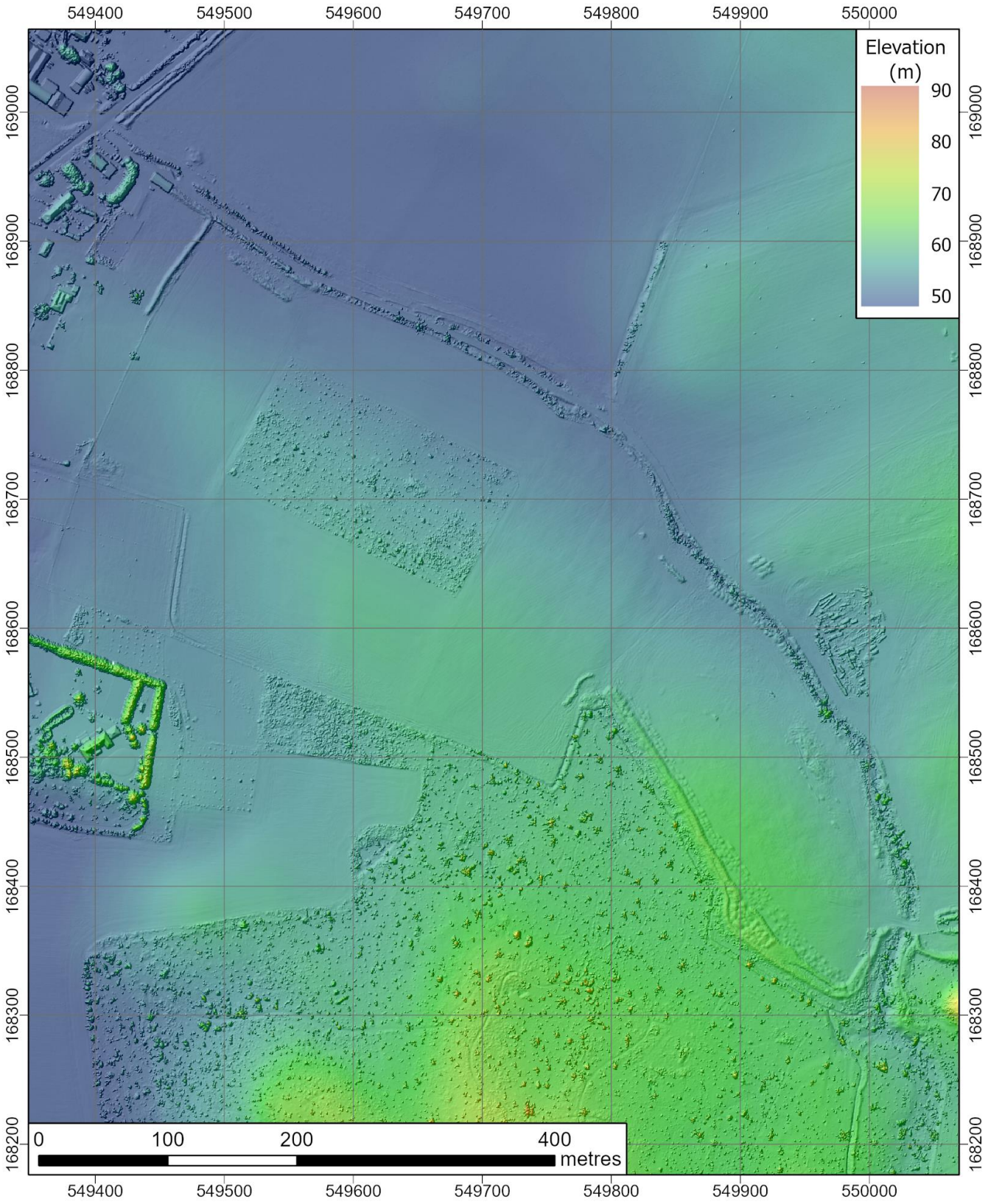

Figure 9 LIDAR elevation data acquired on 6 January 2022 for Land between Bournewood Sand and Gravel Ltd. and Hockenden Lane, Swanley. Image covers the west side of the site.

Figure 10 Aerial photography acquired on 6 January 2022 for Land between Bournewood Sand and Gravel Ltd. and Hockenden Lane, Swanley. Image covers the west side of the site.

The methodology used for estimating volume change was as follows:

- 200 points were identified in the December 2018 and January 2022 elevation data that were on unambiguous hard surfaces. The elevation at each of these points in each of these datasets was extracted. These points were split into two, those used to reduce the systematic error (the offset) between the elevation datasets and those used to test the relative accuracy of the datasets and generate confidence intervals (Figure 11).
- The systematic error was calculated using the average difference between the two elevation datasets. From the systematic error calculations the 2018 data were shifted by -0.001 m.
- The root mean square error (RMSE) from the points used to generate a relative accuracy between the datasets was 0.022 m per pixel. The 99% confidence interval is three times the RMSE, so 0.066 m per pixel.
- The areas to carry out volume analysis were agreed between myself and John Radclyffe of Environment Agency Kent, South London and East Sussex team by Microsoft Teams meeting on 10 February 2022. During the conversation, LIDAR data and aerial photography were shown to John Radclyffe so that he could agree the areas to be analysed. The areas targeted were those where significant change had occurred.
- Objects, such as large vegetation (e.g. trees and bushes), vehicles, heavy plant or containers, were identified in the December 2018 and January 2022 LIDAR data. These objects were removed from the LIDAR data. Where the objects had been identified an interpolation was then carried out on the LIDAR data, using a triangulated irregular network to estimate the elevation. The areas where these objects were identified and removed are shown in Figure 12 and Figure 13.
- In addition to these areas where the LIDAR was interpolated, there were areas where volume increase had probably occurred, but material change could not be certain or it was not possible to interpolate, as the objects where too large or were in areas where the surface elevation was complex. The area to be included in the analysis is shown in Figure 14 and Figure 15. An area of increased volume to the northwest of Area 14 was excluded from the analysis, as the complexity, number and density of objects such containers, skips and vehicles meant that they could not be identified and removed from the analysis for material volume calculations.
- Volume change was estimated using the January 2022 and the December 2018 LIDAR datasets by subtracting the baseline data elevation from the 2022 data. The volume change was then estimated for the areas in Figure 14 and Figure 15.
- The 99% confidence interval for the volume was calculated by multiplying the area of each pixel and 0.066 m (99% confidence interval per pixel).

Figure 11 LIDAR sample points. Systematic error points in red, points used to estimate RMSE and confidence intervals in blue.

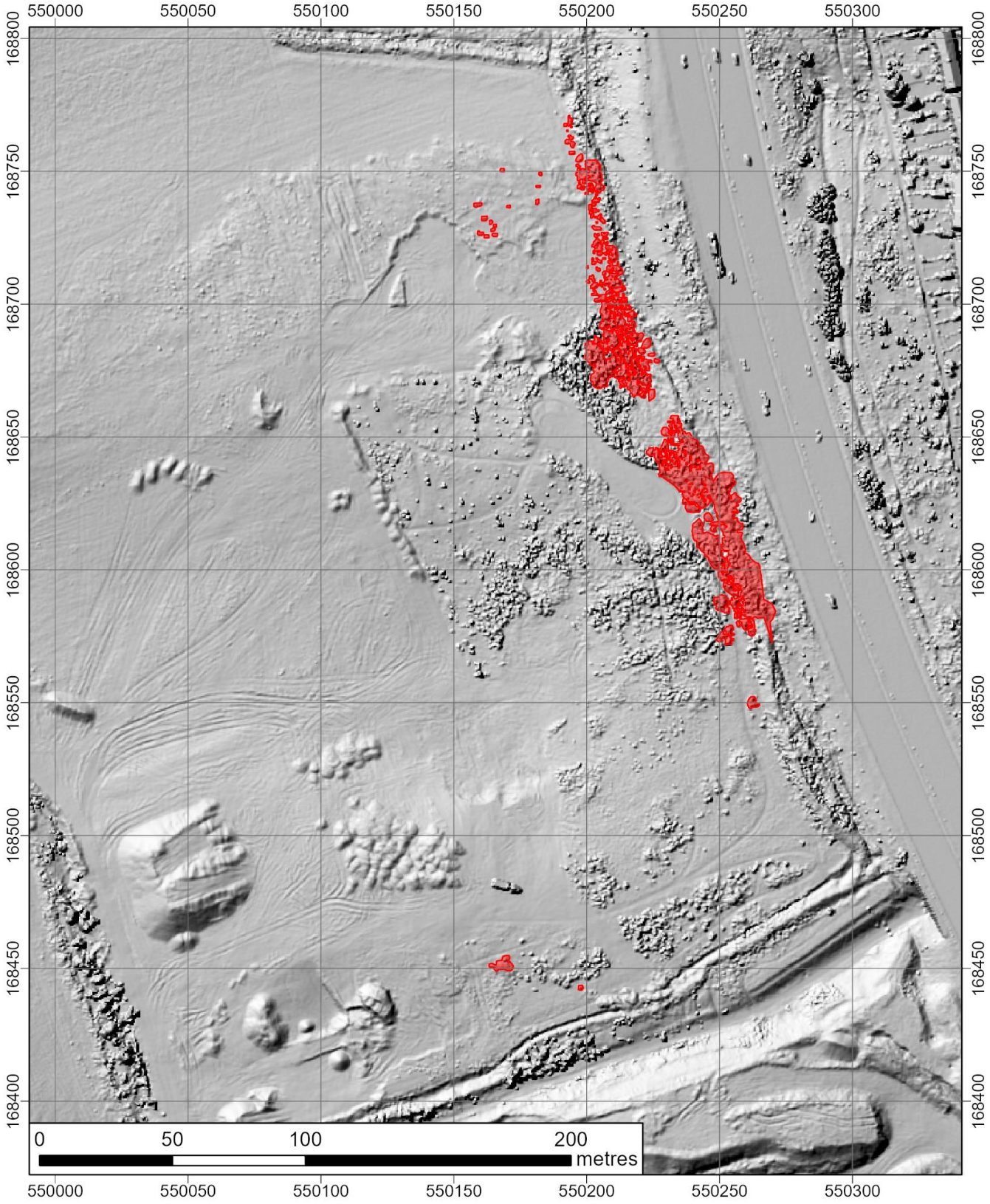

Figure 12 **Areas where the 2018 LIDAR data were interpolated (in red).**

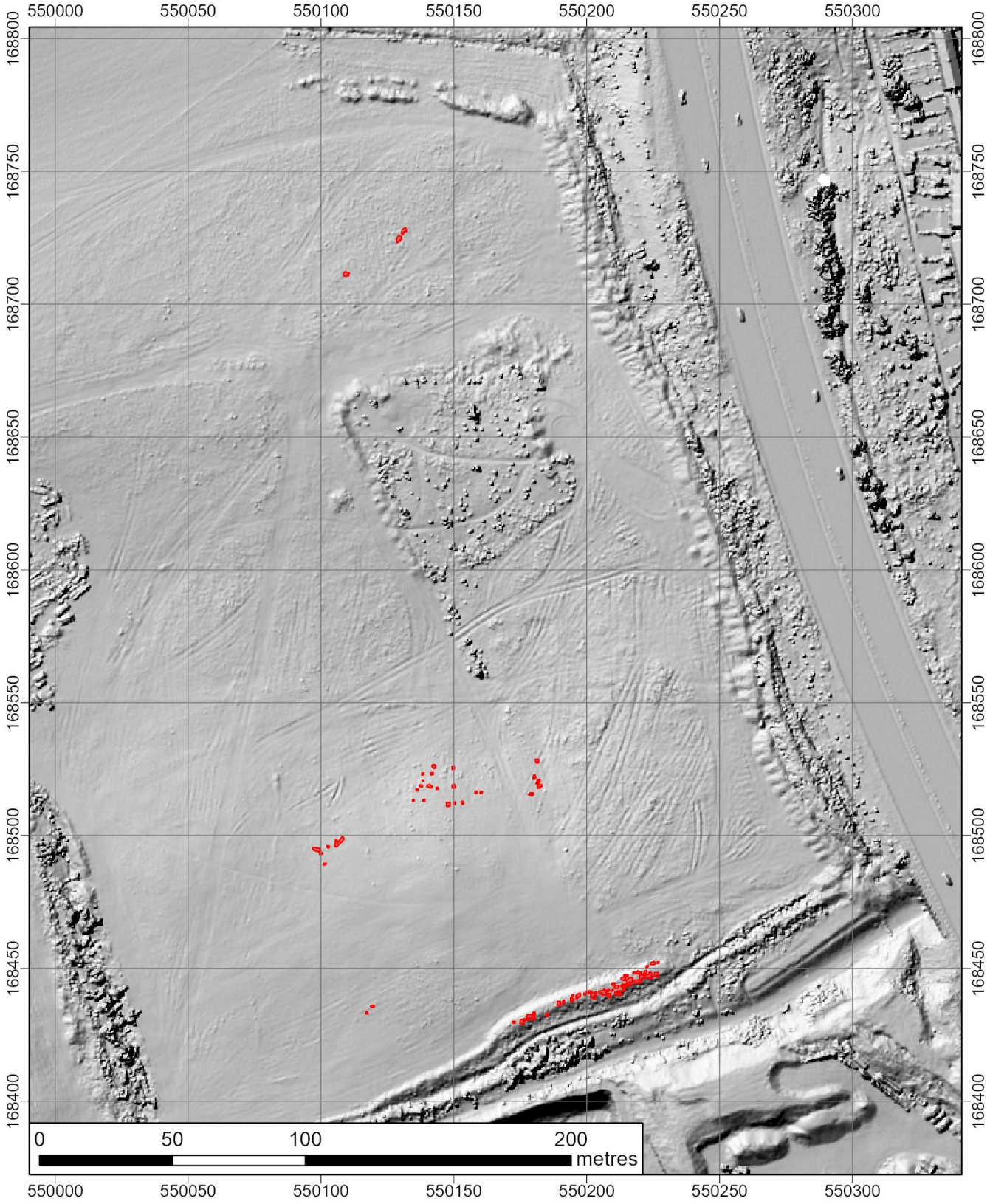

Figure 13 **Areas where the 2022 LIDAR data were interpolated (in red).**

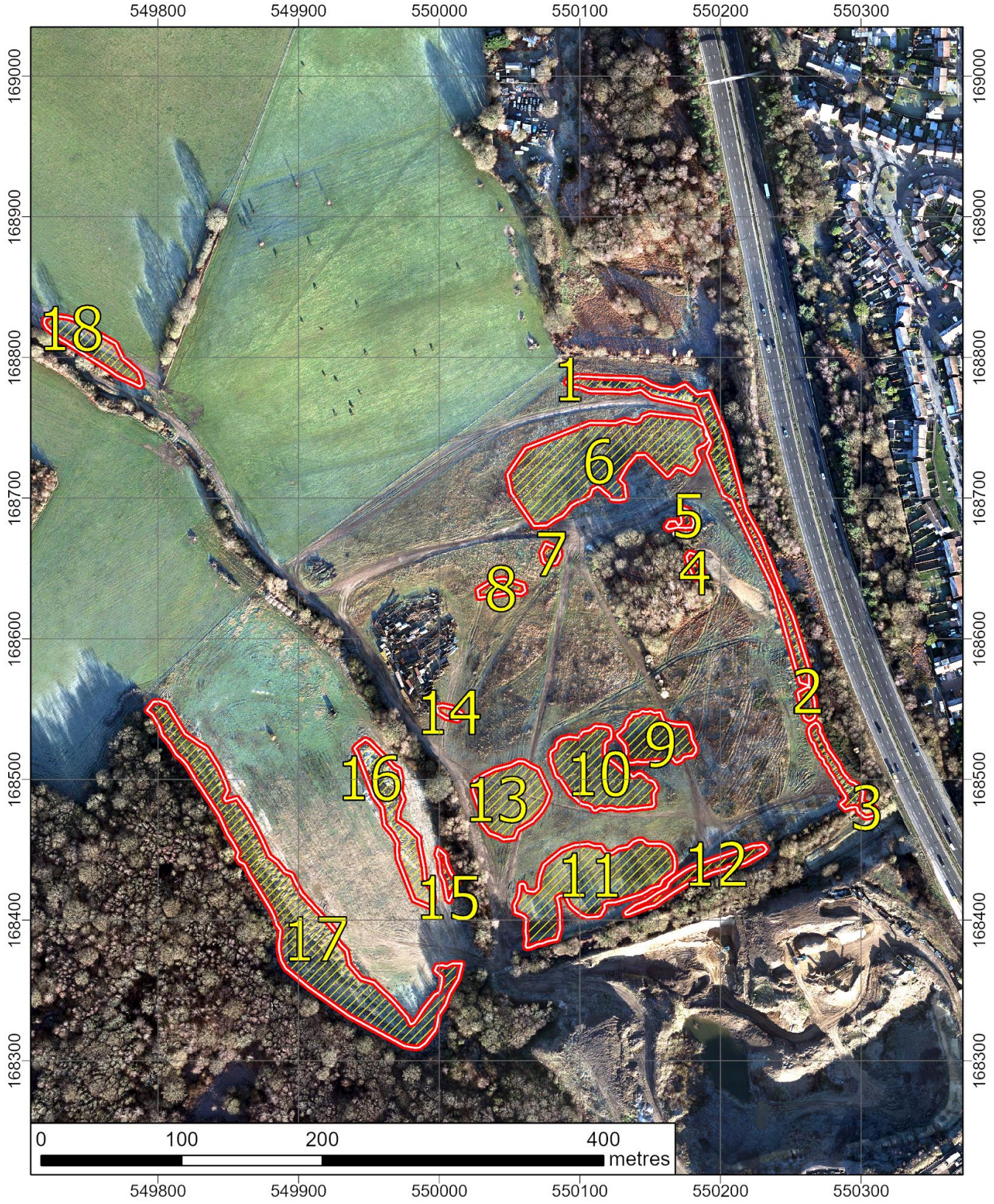

Figure 14 Eastern analysis areas for Land between Bournewood Sand and Gravel Ltd. and Hockenden Lane, Swanley and land to the north (red and white lines).

Figure 15 Western analysis areas for Land between Bournewood Sand and Gravel Ltd. and Hockenden Lane, Swanley and land to the north (red and white lines).

3 Change estimates – volume and elevation

Volume changes for land to north of Land between Bournewood Sand and Gravel Ltd. and Hockenden Lane, Swanley between 22 December 2018 and 6 January 2022 determined using LIDAR are in Table 2. Between 22 December 2018 and 6 January 2022 the volume change, for Areas 1 to 19 in Figure 14 and Figure 15, was 8207 m^3. There is a 99% certainty that the volume change was at least 5951 m^3.

The volume change calculated provides an overall measurement of the net volume change of material at the site. However, it does not provide an indication of how the net volume change occurred, i.e. the total amount of material that was brought into the site and the total amount of material that was removed from the site. If material is burnt on the site, the calculations will only include residue from the burn, not the original material volume. There is also no way of confirming using LIDAR data the nature of the material brought on to site or removed from the site. In this case, the volume calculated approximates the total volume of material brought onto the site minus the total volume of material removed from the site and/or burnt on the site. The site is defined by the analysis areas in Figure 14 and Figure 15.

Table 2 Volume change calculations between 22 December 2018 and 6 January 2022 for land to north of Land between Bournewood Sand and Gravel Ltd. and Hockenden Lane, Swanley. Analysis carried out for areas 1 to 19 in Figure 14 and Figure 15.

Area	Volume change (m^3)	Lower 99% confidence interval (m^3)
1	3276	3085
2	261	247
3	937	890
4	114	105
5	-120	-129
6	-3791	-4192
7	-82	-92
8	-114	-133
9	1375	1278
10	-2537	-2711
11	1123	832
12	1050	995
13	-5016	-5154
14	-168	-176
15	190	175
16	1376	1247
17	8963	8447
18	818	741
19	552	496
Total	**8207**	**5951**

Maps of the elevation change are given in Figure 16 and Figure 17

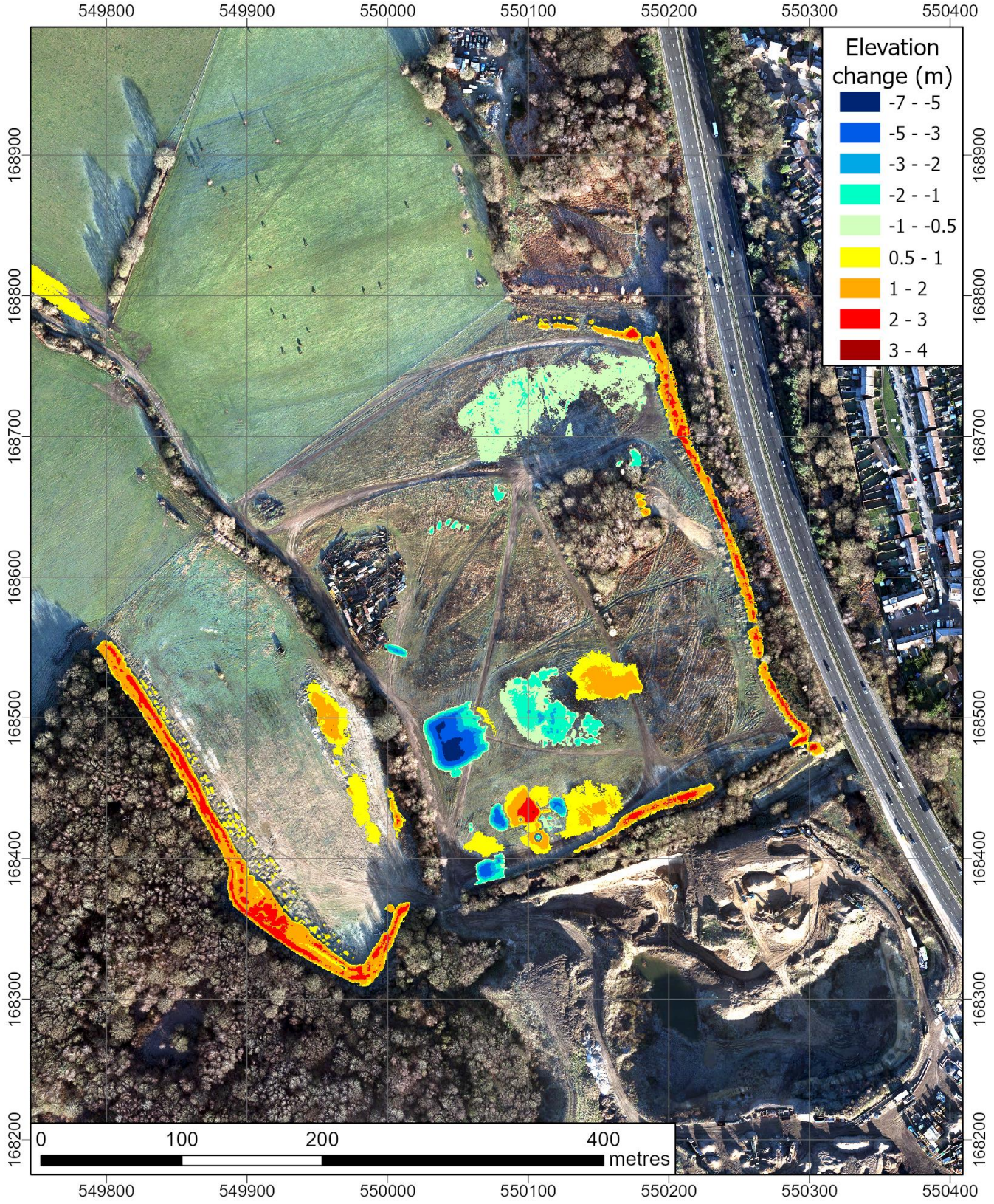

Figure 16 2022 aerial photography of the eastern area of Land between Bournewood Sand and Gravel Ltd. and Hockenden Lane, Swanley with elevation difference between 22 December 2018 and 6 January 2022 overlaid. Analysis carried out for areas in Figure 14 and Figure 15.

Figure 17 2022 aerial photography of the western area of Land between Bournewood Sand and Gravel Ltd. and Hockenden Lane, Swanley with elevation difference between 22 December 2018 and 6 January 2022 overlaid. Analysis carried out for areas in Figure 14 and Figure 15.