Bolsover Castle, Derbyshire: Ground penetrating radar survey in the Fountain Garden

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1 Introduction

This report details the results of a ground penetrating radar survey in the garden of the Little Castle, at Bolsover Castle (NGR: 447030, 37711; Figure 1). The GPR survey was primarily undertaken to discover the location of two ‘manholes’ relating to services in front of the Little Castle. The survey area was within an enclosed garden with gravel pathways and a lawn. Previous information used in this report on the enclosed fountain garden is derived from two Trent and Peak Archaeological Unit unpublished reports (Sheppard 2000; Sheppard 2002).

2 Geology and site location

Bolsover Castle is sited on a hilltop location, on the western outskirts of the village of Bolsover. The castle has an underlying geology of Magnesium Limestone of the Cadeby Formation, a Permian bedrock. The soil profile is relatively shallow at c. 0.6m BGL and is an argellic brown earth.

3 Survey Aims and objectives

The ground penetrating radar survey had the primary aim of detecting the two ‘manholes’ relating to a failed service at the front of the Little Castle. However, a secondary aim was to map any features considered to be of archaeological origin.

4 Survey methodology

4.1 Justification of methodology: ground penetrating radar survey

Ground penetrating radar surveys use pulses of Electromagnetic (EM) radio waves directed down into the sediment profile from a transmitting antenna, in order to investigate subterranean features. When discontinuities are encountered some of these radio waves are reflected back towards the surface, whilst other waves travel further down into the sediment profile until they meet other discontinuities. At the surface a receiving antenna measures the reflected waves. By measuring the time taken between emission and return of the radar pulse it is possible to measure the depth of a discontinuity in the sediment profile.

The process of estimating the depth of discontinuities within the sediment profile is complicated by different dielectric constants found within different sediment units. The electrical properties of a sediment unit effect the time taken for the radar pulse to travel through it. The dielectric permittivity is a property of an electrical insulating material (dielectric) equal to the ratio of the capacitance of a capacitor filled with the given material to the capacitance of the identical capacitor filled with air. The specific capacitance of a vacuum is Eo = 8.85x 10^{-12} Farads per metre. The relative dielectric constant (Er) for air is 1 and is approximately 81 for fresh water.

The relative dielectric permittivity (RDP) of different sediment units is critical; which is the ability of a sediment to absorb, reflect and be permeated by, the radar pulse. If there is a significant change in RDP between two different units, such as clay and gravel, then strong reflections will result at the interface of the two units. The GPR pulse will be dissipated by materials of high conductivity. Therefore, sediments with high clay and water contents cause rapid attenuation of the GPR signal and are often impenetrable to higher frequency antennas. Key factors that affect the RDP of an unconsolidated material can be listed as:

- Pore size
- Sediment type
- Stratification
- Grain size
- Water content

In order to correctly calibrate the electric depth model created by the GPR it is important that the dielectric properties of the soil profile can be accurately estimated. This in practice is extremely difficult, as within sediment profiles vary in all directions. Therefore, a compromise has to be reached in the dielectric constant that is used. The identification of radar terminations is the basis for constructing a relative chronology for a sequence of sediment units. Interfaces between different sediment units, e.g. a silty clay unit overlying a gravel unit, represent terminal events in either deposition or erosion processes and the start of subsequent processes. Although the ages of these sediment units cannot be ascertained without absolute dating methods, relative sequences can be constructed through studying the form of the interfaces seen.

4.2 Field methodology: ground penetrating radar survey

Data were collected on transects at 1m intervals using a GSSI SIR3000 unit with a 200MHz antennae giving an approximate maximum depth value of c. 4m (depending on ground conditions and attenuation of radar signal). The antennae was programmed for a mid-range viewing window (c. 100ns) collecting data at 512 samples per scan at 64 scans per second, with a vertical high pass filter of 50Mhz and a low pass filter of 600MHz. 5 gain points were used to amplify radar signal and with on-site calibration of the radar signal through identification of high magnitude responses.

4.3 Processing methodology

All data was processed within the Radan 6.0 software. The data were treated using a standard processing procedure of cleaning with a background removal filter, correction of point zero position and a variable velocity migration. The transects were welded into a solid cube and the data was time sliced at 0.3m intervals (each slice being 0.15m thick) down to the contact with the bedrock at c. 1.2m BGL. Each of the time slices were imported into ArcGIS and interpolated into surfaces for interpretation.

4.4 Generic materials and methods

All data from the geoprospection survey was imported into ArcGIS (ver. 8.3). This facilitated data integration with other key data sets for the survey area, such as development plans.

4.5 Interpretation

The most subjective phase of any survey is the interpretation. As Gaffney and Gater (2003, 109) state: “The interpretation of archaeological geophysical data is not an exact science as there is interplay between theory and experience. While a broad knowledge of geophysical techniques and the principles of archaeological geophysics are a necessary requirement, other factors are also important. In particular, an appreciation of the nature of the archaeological features being investigated is fundamental as is an understanding of the local conditions at the site – including the geology, pedology and topography.”

Anomalies were identified in terms of magnitude of attenuation/reflection of the radar pulse. For each anomaly consideration was given to the type of anomaly, factors such as topographic location and magnitude of response, to produce a tiered interpretation process.

4.6 Ground penetrating radar interpretation

- Level 1: identification of response

  For the time sliced data the degree of reflection or attenuation was characterised as high reflectance or high absorption for each digitised anomaly.

- Level 2: interpretation of feature
  Based on the level 1 analysis and morphology of the anomaly an interpretation was made of the nature of each structure, e.g. ‘manhole cover’, ‘service’, ‘wall’, ‘rubble’, etc.

5 Results

The GPR survey produced a good quality data set that revealed a high level of complexity in the fountain garden. In particular, the area adjacent to the Little Castle showed much evidence of disturbed/made ground and several services were mapped traversing the survey area at varying depths. Four potential anomalies were recorded that are interpreted as potential manhole locations. In addition, the western edge of the survey area contained some anomalies that are considered not to be services and are potentially of archaeological significance. The data is presented as a series of times slices with the GPR data, level 1 and level 2 interpretations shown.

5.1 Depth slice 0.3m (Figures 3, 4 and 5)

This depth slice clearly reveals the gravel path around the lawn digitised as a high reflectance anomaly (polygons 0 and 3). Within the boundary of the gravel path are two potential candidates for manhole covers, being high response (reflection) anomalies. Polygon 2 is also of note, as it correlates with the mapped location of a C19th path. Polygon 4 is the high point of the cross path metalling, recorded as feature 0150 in trenches 99/1 and 99/2.

Polygon number	Radar response	Level 2 interpretation
0	High reflectance	Gravel path
1	High reflectance	Gravel path
2	High reflectance	Possible remains of C19th path
3	High reflectance	Gravel path
4	High reflectance	Feature 0150 (Trenches 99/1 and 99/2) TPA
5	High reflectance	Made ground
6	High reflectance	Made ground
7	High reflectance	Made ground
8	High reflectance	Possible manhole cover
9	High reflectance	Possible manhole cover

Table 1: Digitised anomalies from the 0.3m depth slice.

5.2 Depth slice 0.6m (Figures 6, 7 and 8)

The 0.6m depth slice defines a multitude of features within the survey area. Polygon 14 is the remains of a trench excavated by Trent & Peak Archaeology (trenches 99/1, 99/2). Polygons 10 and 27 correlate with the plotted locations of services. Of note is polygon 25 which correlates with the location of an annex for the Little Castle and could represent either rubble, foundations or floors associated with this structure. Polygon 16 is a further potential manhole location, slightly deeper than then first two visible in the 0.3m time slice.

The 0.6m depth slice contains a number of anomalies that are consistent with multiple events of human activity, indicating disturbed or made ground, such as polygons 18, 19, 20, 21, 22 and 24. Polygons 11, 12 and 13 are interpreted as possible archaeology relating to either walls or ditches, although a service is located in this area. The reason for the high reflectance response of polygon 23 is unclear, but it could be an earlier cross path. Polygon 28 is a high reflectance response which correlates with the location of a wall recorded in 1993 (Sheppard 2000; 2002).

Polygon number	Radar response	Level 2 interpretation
10	High reflectance	Service
11	High reflectance	Possible wall
12	High reflectance	Possible wall
13	High absorption	Ditch or foundation
14	High reflectance	Trench 0150 (99/1 and 99/2) NA
15	High reflectance	Possible rubble/disturbed ground
16	High reflectance	Possible manhole cover
17	High reflectance	Gravel path
18	High reflectance	Rubble/disturbed ground/made ground
19	High reflectance	Rubble/disturbed ground/made ground
20	High reflectance	Rubble/disturbed ground/made ground
21	High reflectance	Rubble/disturbed ground/made ground
22	High reflectance	Rubble/disturbed ground/made ground
23	High reflectance	Possible earlier cross path
24	High reflectance	Rubble/disturbed ground/made ground
25	High reflectance	Rubble (probably relating to C19th annex)
26	High reflectance	Rubble/disturbed ground/made ground
27	High reflectance	Service
28	High reflectance	Wall (recorded 1993)

Table 2: Digitised anomalies from the 0.6m depth slice.

5.3 Depth slice 0.9m (Figures 9, 10 and 11)

The 0.9m depth slice shows further high level responses outside the Little Castle, again indicating disturbed/made ground, digitised as polygons 31, 53, 54, 55, 56, 58 and 67. Services are mapped as polygons 29, 30, 32, 43 and 66. Again, further anomalies are seen to the west of the survey area as linear polygons 50, 52 and 57, possibly indicating archaeological remains.

At this depth there are also a number of high reflectance anomalies that are difficult to interpret due to ambiguous morphology. These have been interpreted as areas of possible rubble/stone (polygons 33, 34, 35, 36, 37, 39, 42, 43, 68). Some of these anomalies display correlation with earth resistance anomalies, most notably of which are polygons 49 and 38. Polygon 63 is a further potential manhole location.

Polygon number	Radar response	Level 2 interpretation
29	High reflectance	Service
30	High reflectance	Service
31	High reflectance	Rubble/disturbed ground/made ground
32	High reflectance	Service
33	High reflectance	Possible rubble
34	High reflectance	Possible rubble
35	High reflectance	Possible rubble
36	High reflectance	Possible rubble
37	High reflectance	Possible rubble
38	High reflectance	Possible rubble (resistance anomaly correlation)
39	High reflectance	Possible rubble
40	High reflectance	Service
41	High reflectance	Trench 09 NA
42	High reflectance	Possible rubble
43	High reflectance	Possible rubble

44	High reflectance	Unknown
45	High reflectance	Unknown
46	High reflectance	Unknown
47	High reflectance	Unknown
48	High reflectance	Unknown
49	High reflectance	Unknown (resistance anomaly correlation)
50	High reflectance	Possible wall
51	High reflectance	Possible rubble
52	High absorption	Ditch
53	High reflectance	Rubble/disturbed ground/made ground
54	High reflectance	Rubble/disturbed ground/made ground
55	High reflectance	Rubble/disturbed ground/made ground
56	High reflectance	Rubble/disturbed ground/made ground
57	High absorption	Ditch
58	High reflectance	Rubble/disturbed ground/made ground
59	High reflectance	Service
60	High reflectance	Possible rubble
61	High reflectance	Unknown
62	High reflectance	Possible rubble
63	High reflectance	Possible manhole cover
64	High reflectance	Gravel path
65	High reflectance	Gravel path
66	High reflectance	Service
67	High reflectance	Rubble/disturbed ground/made ground
68	High reflectance	Trench 0150 (99/1 and 99/2) NA
69	High reflectance	Unknown

Table 3: Digitised anomalies from the 0.9m depth slice.

5.4 Depth slice 1.2m (Figures 12, 13 and 14)

This depth slice clearly defines the location of a large service mapped as polygons 70 and 72. Much of the radar trace is now detecting the top of the geology, digitised as polygons 74, 75, 76, 77 and 78. Also visible at this depth is a linear feature visible as a high reflectance unit and digitised as polygon 73. This anomaly follows the predicted course of the original C17th pipes for the fountain.

Polygon number	Radar response	Level 2 interpretation
70	High reflectance	Service
71	High reflectance	Unknown
72	High reflectance	Service
73	High reflectance	C17th fountain pipe
74	High reflectance	Made ground/geology
75	High reflectance	Made ground/geology
76	High reflectance	Made ground/geology
77	High reflectance	Made ground/geology
78	High reflectance	Made ground/geology
79	High reflectance	Unknown

Table 4: Digitised anomalies from the 1.2m depth slice.

5.5 Depth slice 1.5m (Figures 15, 16 and 17)

This depth slice adds little further data, largely showing the radar pulse traversing through the geology to the north of the survey area.

Polygon number	Radar response	Level 2 interpretation
80	High reflectance	Geology
81	High reflectance	Geology
82	High reflectance	Geology
83	High reflectance	Geology
84	High reflectance	Geology
85	High reflectance	Geology
86	High reflectance	Geology

Table 5: Digitised anomalies from the 1.5m depth slice.

5.6 Synthesised summary of interpretation

A synthesised view of the time slices is given as a single image to provide clarity of the most significant anomalies in the survey area (Figure 18).

6 Discussion

The radar survey has successfully identified a series of anomalies in the survey area which can be related to pre-existing service plans. Significantly, three main anomalies have been identifiied for the location of the manhole covers.

Over salient points of the survey are summarised as:

- The services are visible within the survey area.
- To the west of the survey are a series of linear anomalies that could be possible archaeological remains.
- A large linear anomaly exists to the east of the survey area which is classified as possible earlier cross path, traversing broadly east/west (polygon 23).
- The C17th pipe trench for the fountain was located.
- An area of high reflectance to the south of the little castle might indicate part of the remains of the annex.
- The wall identified in 1993 by Northampton Archaeology (Sheppard 2000) was visible as a discontinuous feature in the radar data.
- The general area to the south of the Little Castle shows a high level of reflectance indicating much disturbed/made ground.

7 Conclusions and recommendations

Based on the results given here there are three probable locations for the' manholes'. Carey Consulting would be happy to give further advice, should this be required, for the next phase of the project, being the excavation and repair of these services.

8 Acknowledgements

Thanks to Richard Sheppard at T&P for this help with the project and all English Heritage staff at Bolsover Castle for accommodating the survey team.

9 Data archive

Processed GPR data archive: BOL2POSOCRBRMIG2.(DZT)

10 Bibliography

Gaffney, C. and Gaiter, J. 2003. *Revealing the buried past*. Chichester.

Sheppard, R., 2000. ‘Bolsover Castle: Archaeological Watching Briefs in the Fountain Garden, Autumn 1999.’Unpublished report for English Heritage by Trent & Peak Archaeological Trust.

Sheppard, R., 2002. ’Bolsover Castle. Archaeological Investigation of the Venus Fountain and its Water Supply.’ Unpublished report for English Heritage by Trent & Peak Archaeological Unit.

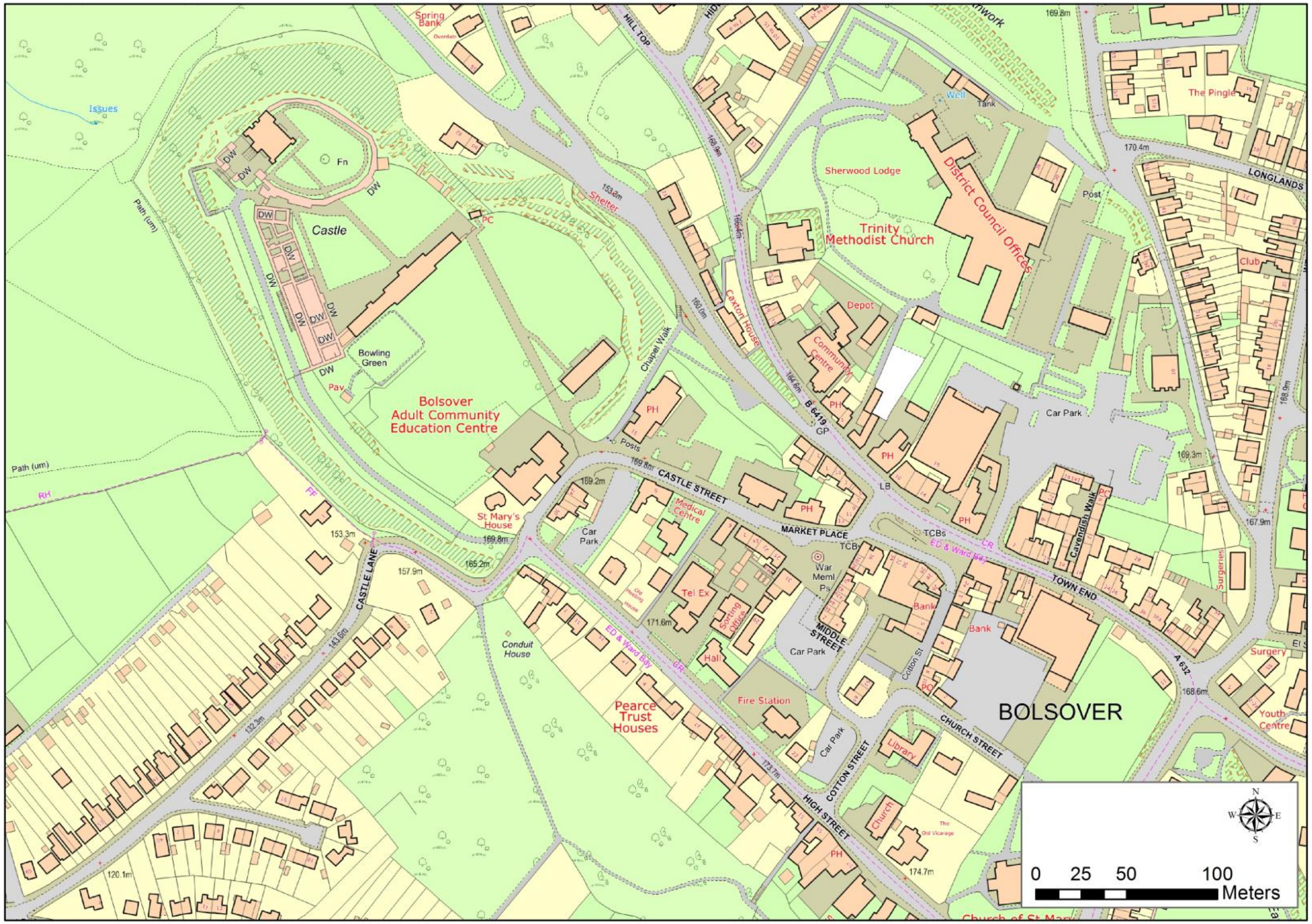

Figure 1: Location of Bolsover Castle (base mapping OS, HMSO Crown Copyright Licence No. **xxxx**).

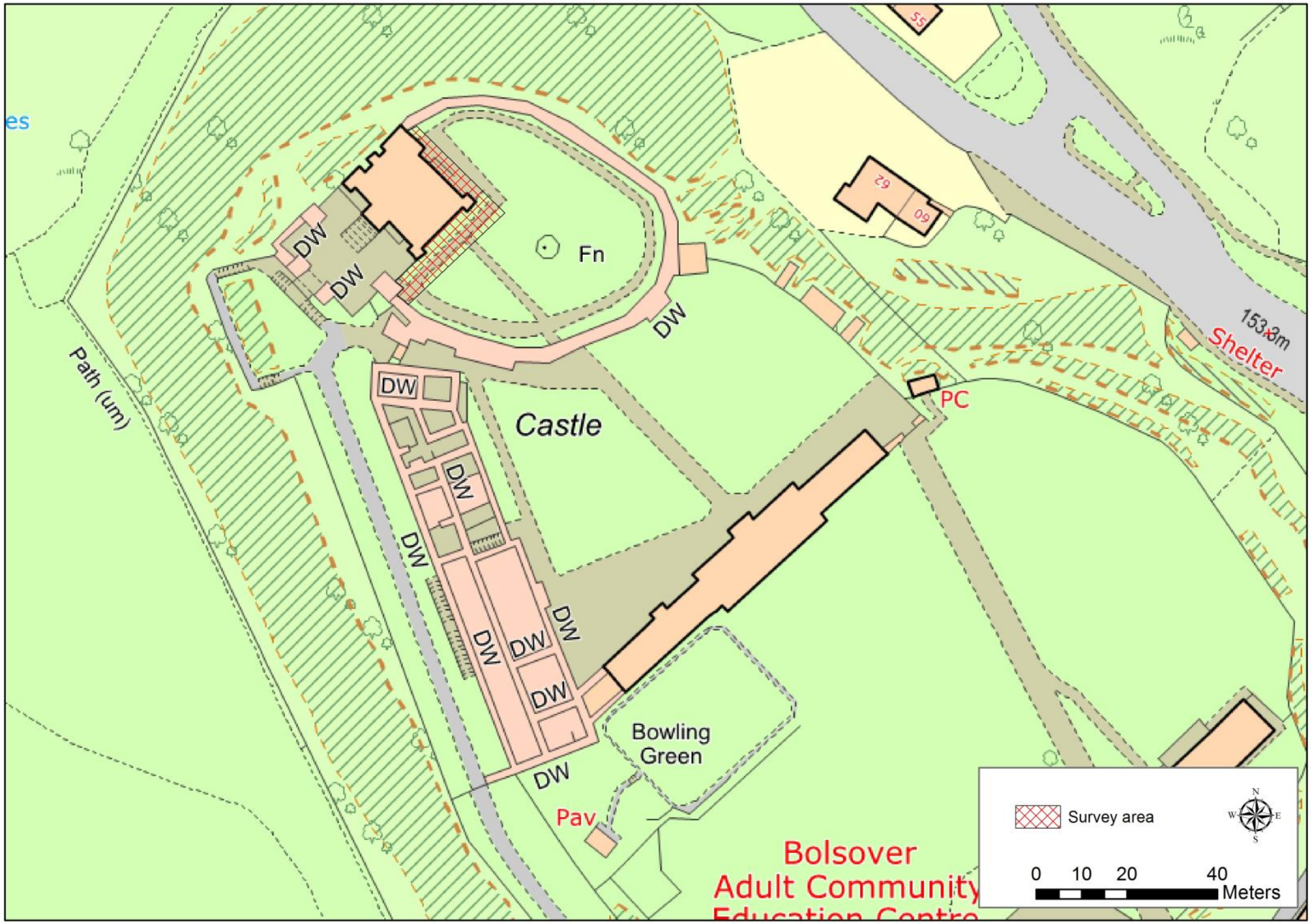

Figure 2: Location of the GPR survey area to find the manhole covers, Bolsover Castle (base mapping OS, HMSO Crown Copyright Licence No. **xxxx**).

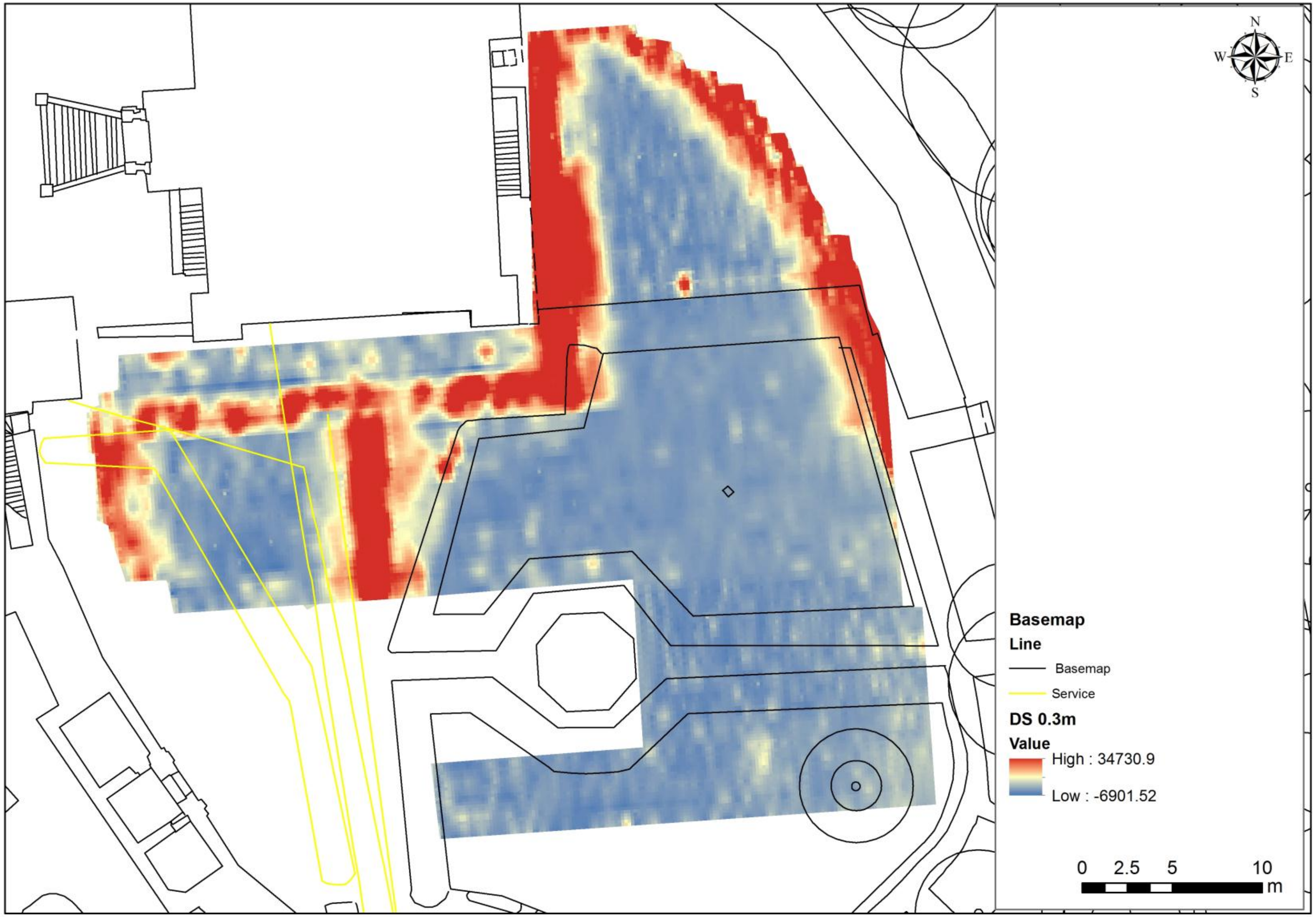

Figure 3: GPR depth slice 0.3m.

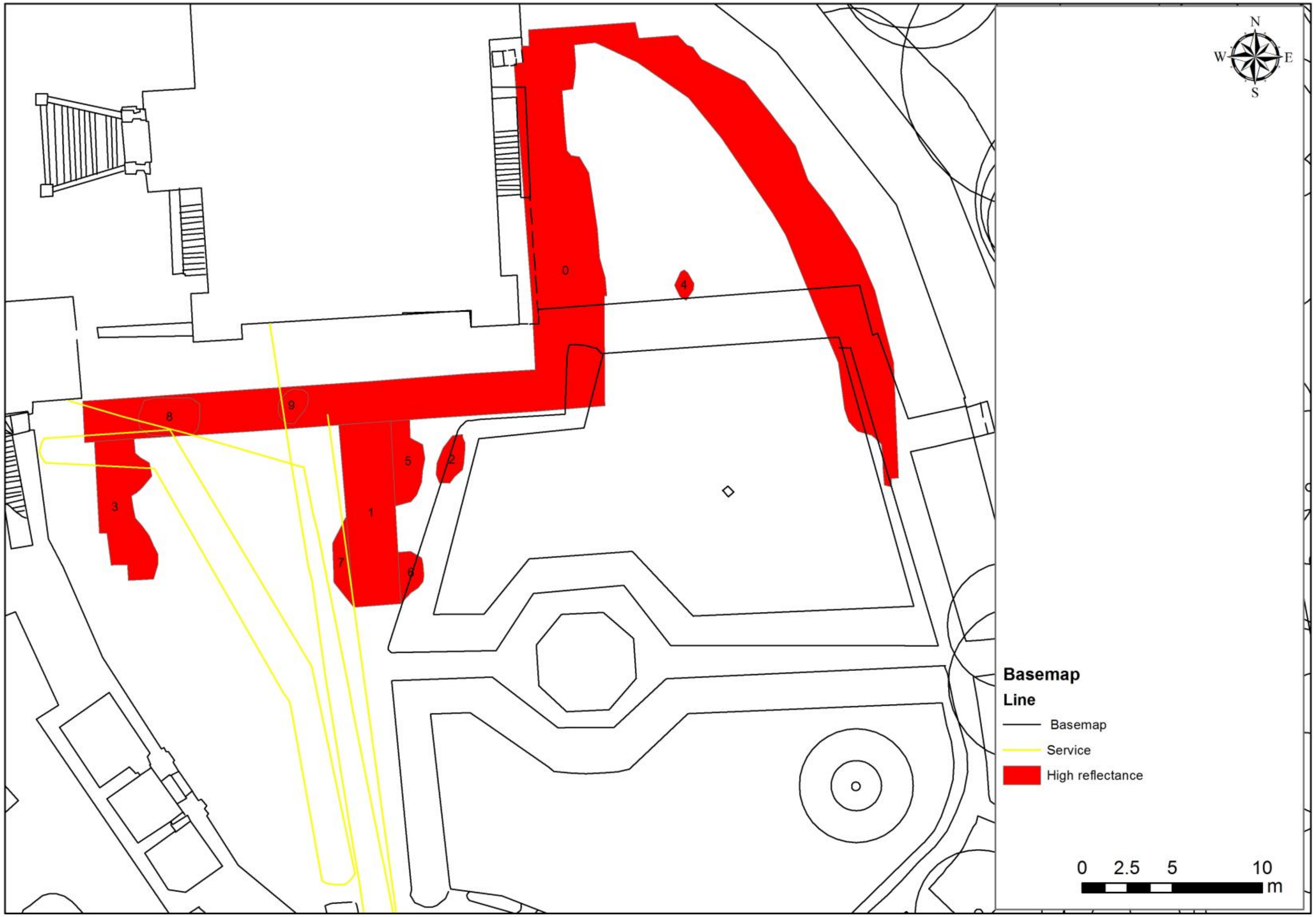

Figure 4: Depth slice 0.3m level 1 interpretation.

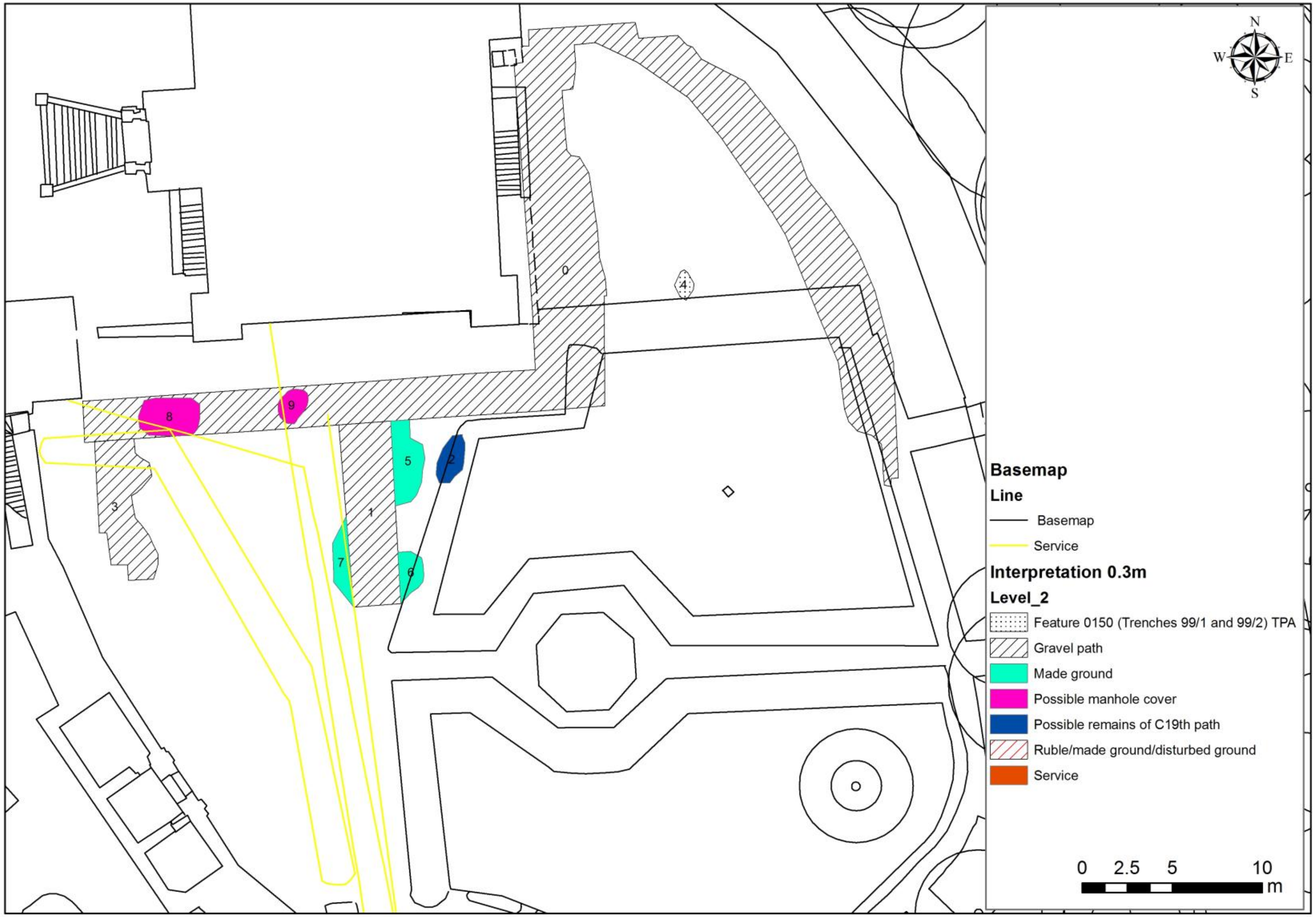

Figure 5: Depth slice 0.3m level 2 interpretation.

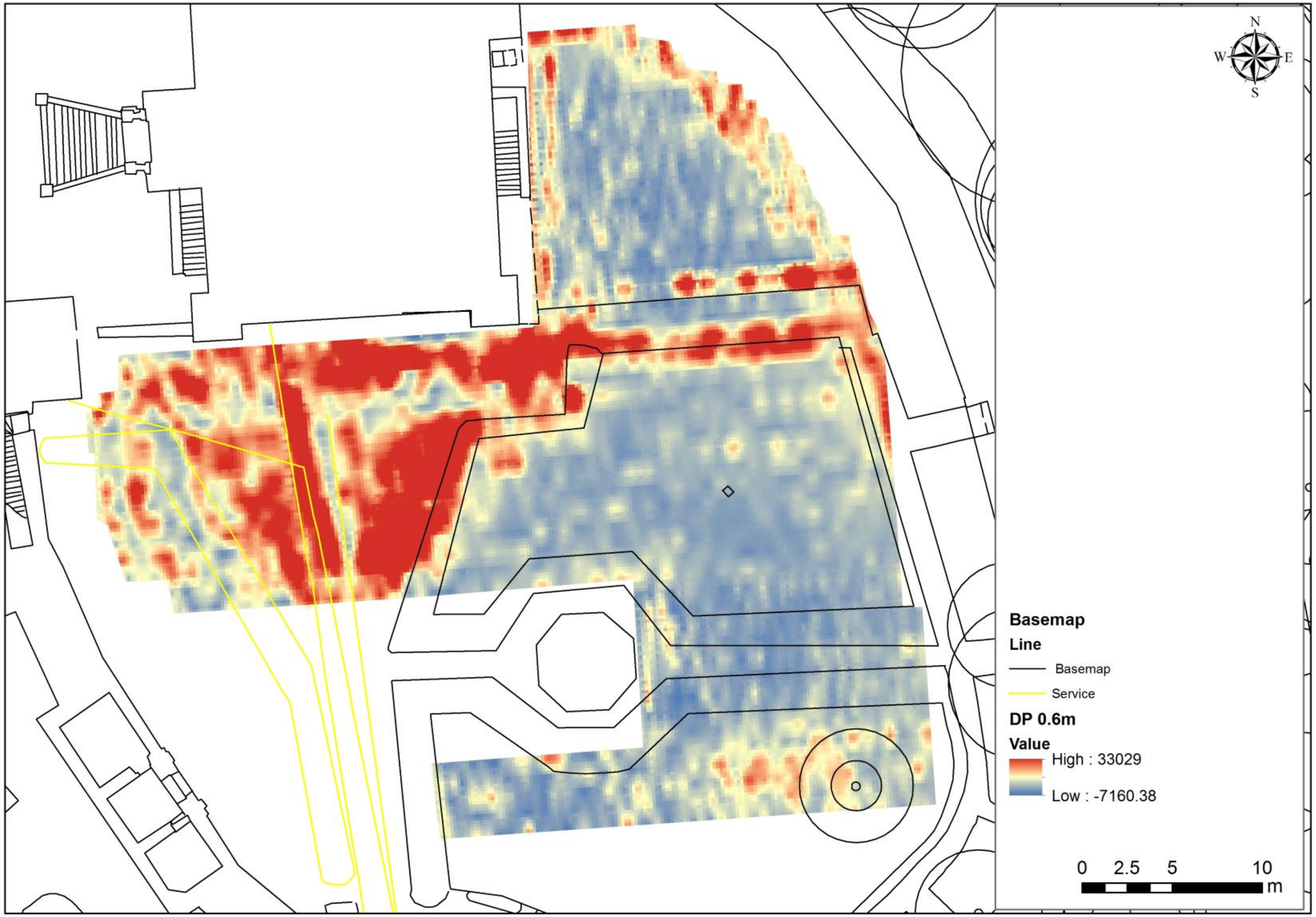

Figure 6: GPR depth slice 0.6m.

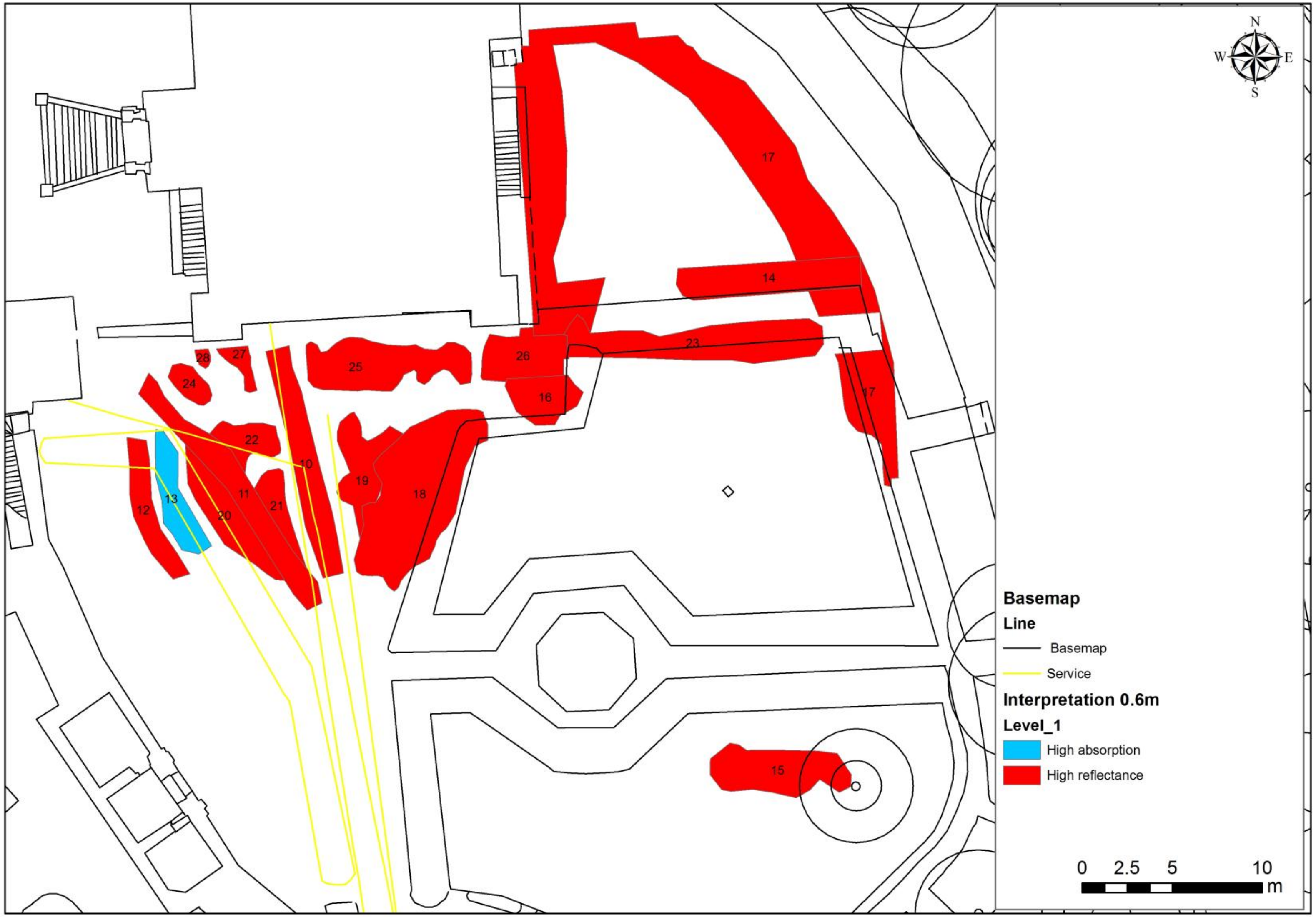

Figure 7: Depth slice 0.6m level 1 interpretation.

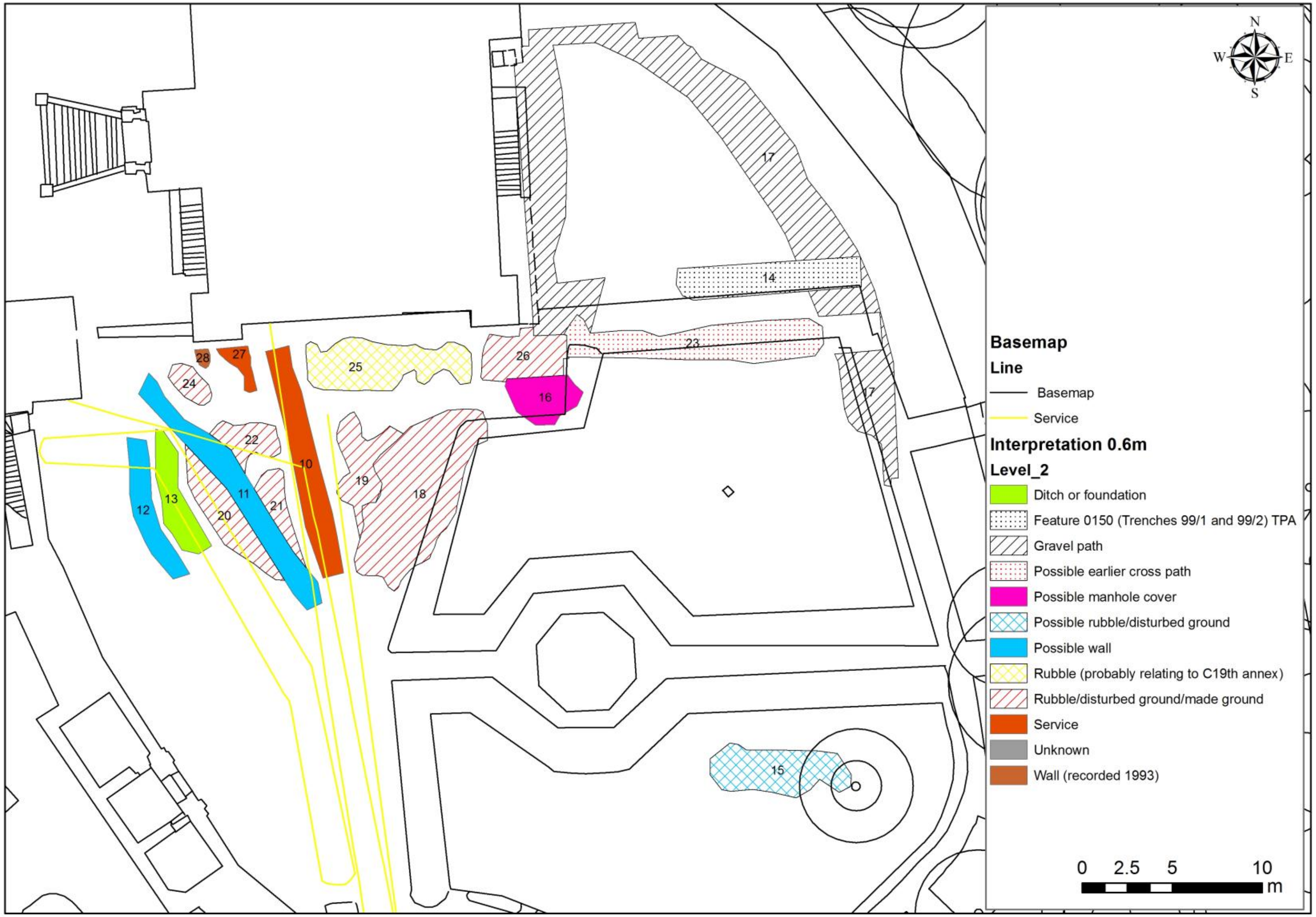

Figure 8: Depth slice 0.6m level 2 interpretation.

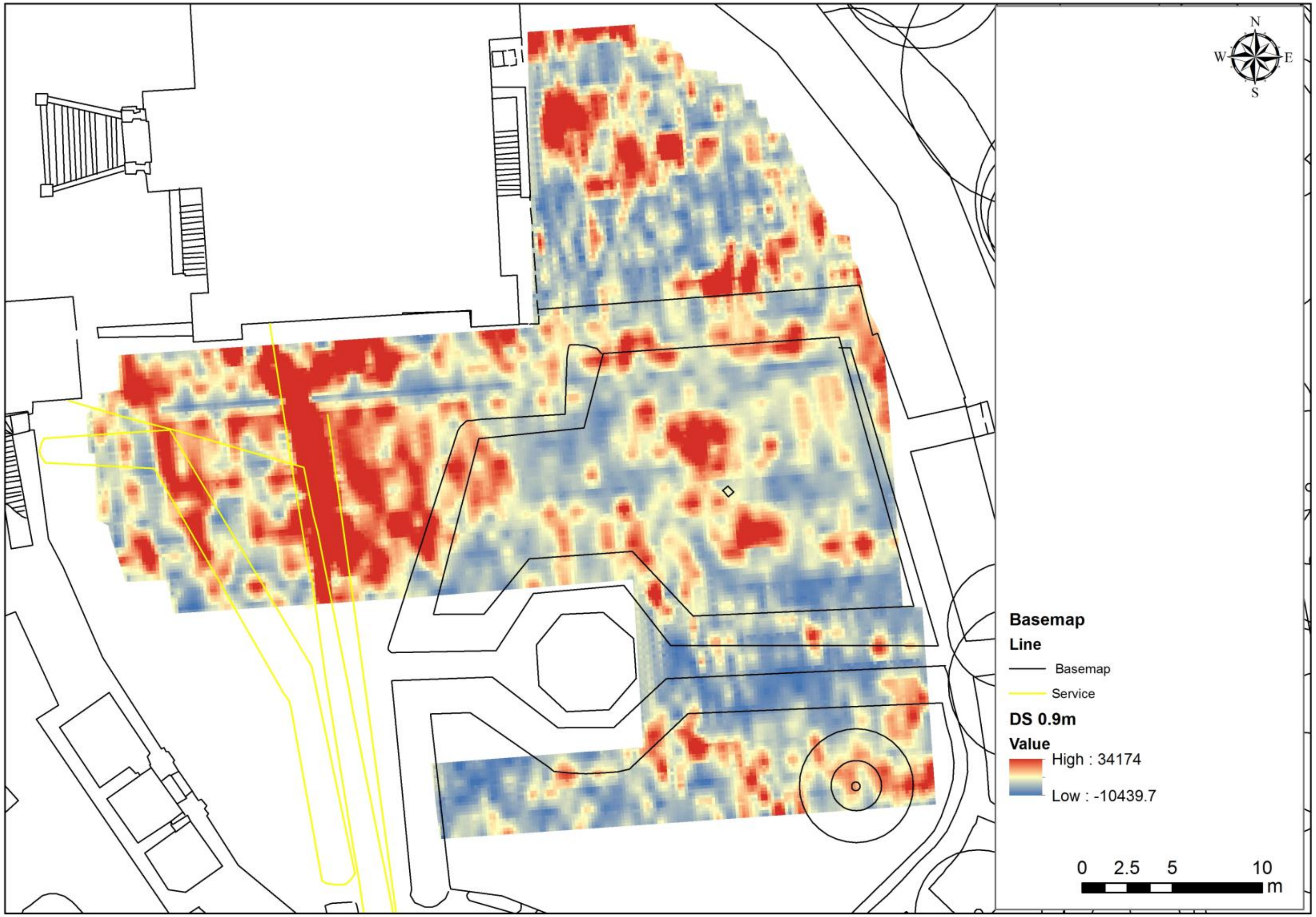

Figure 9: GPR depth slice 0.9m.

Figure 10: Depth slice 0.9m level 1 interpretation.

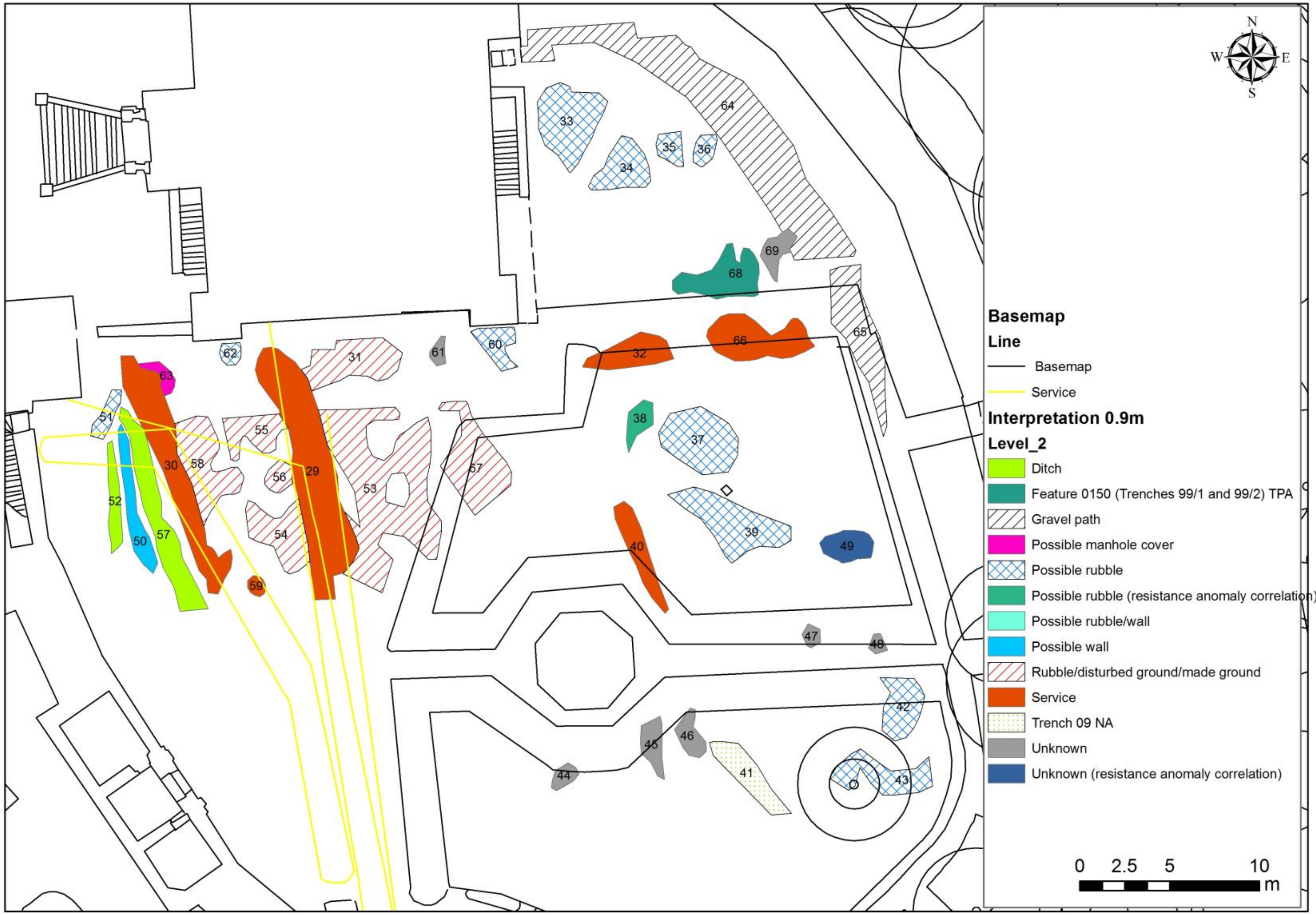

Figure 11: Depth slice 0.9m level 2 interpretation.

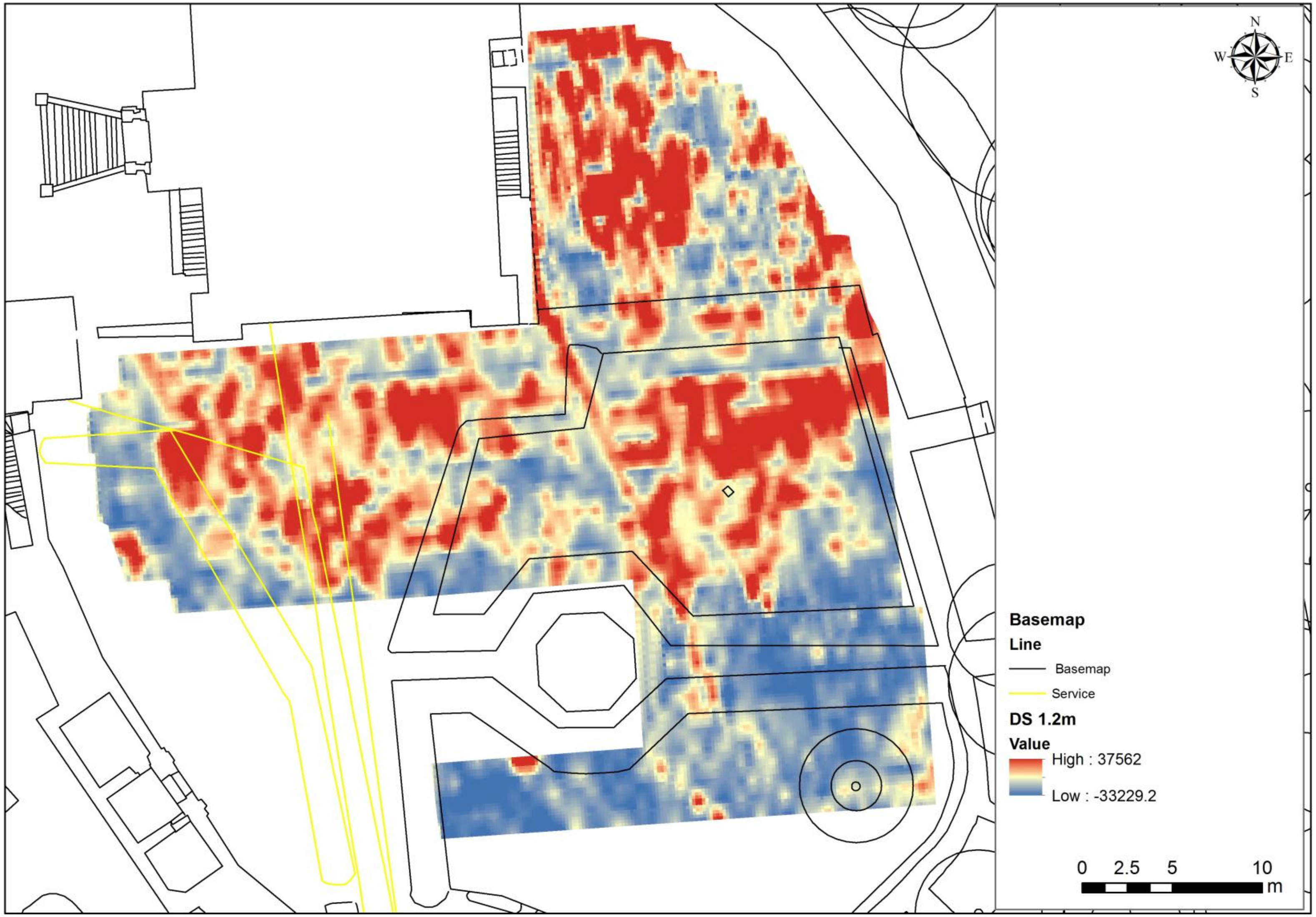

Figure 12: GPR depth slice 1.2m.

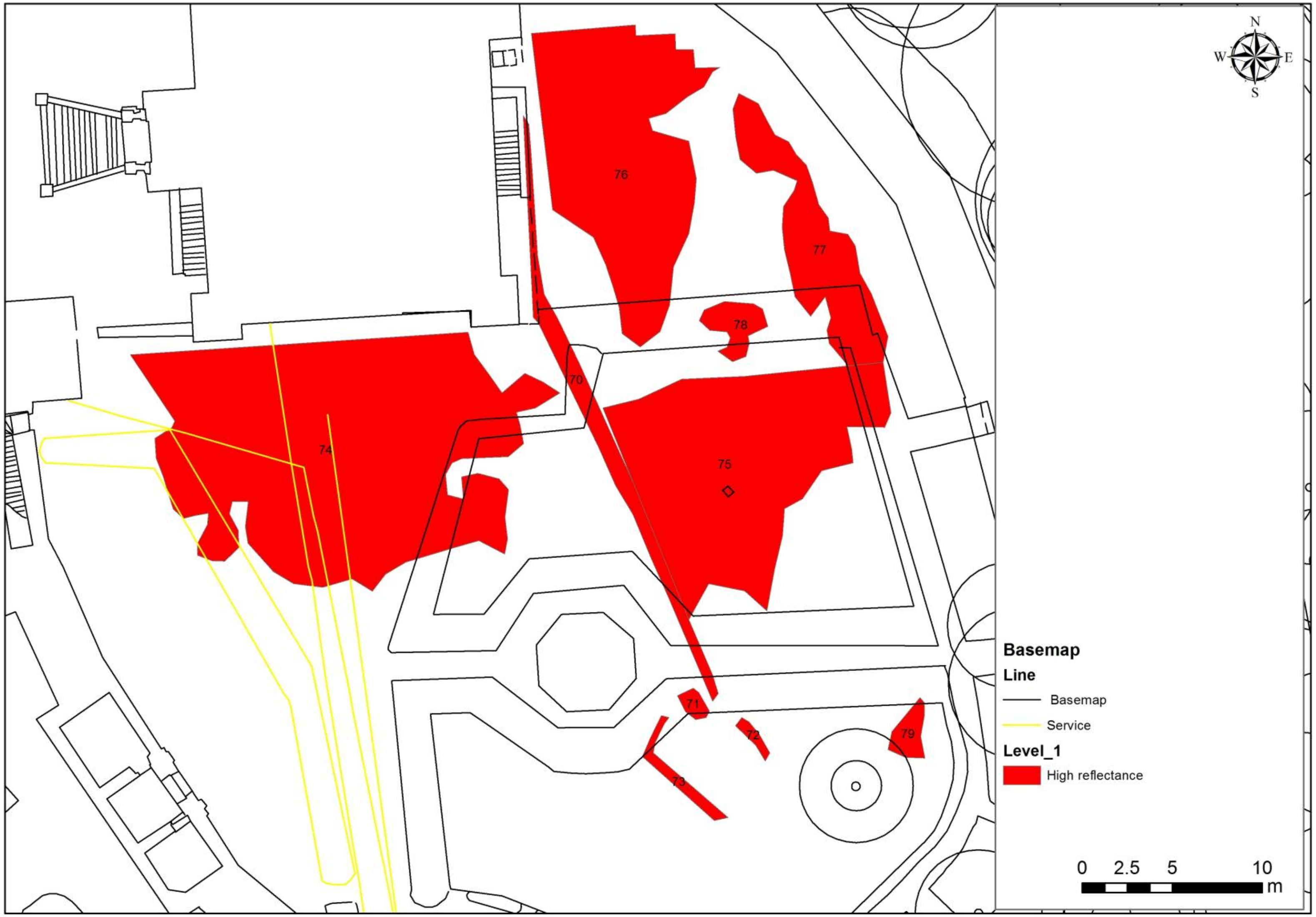

Figure 13: Depth slice 1.2m level 1 interpretation.

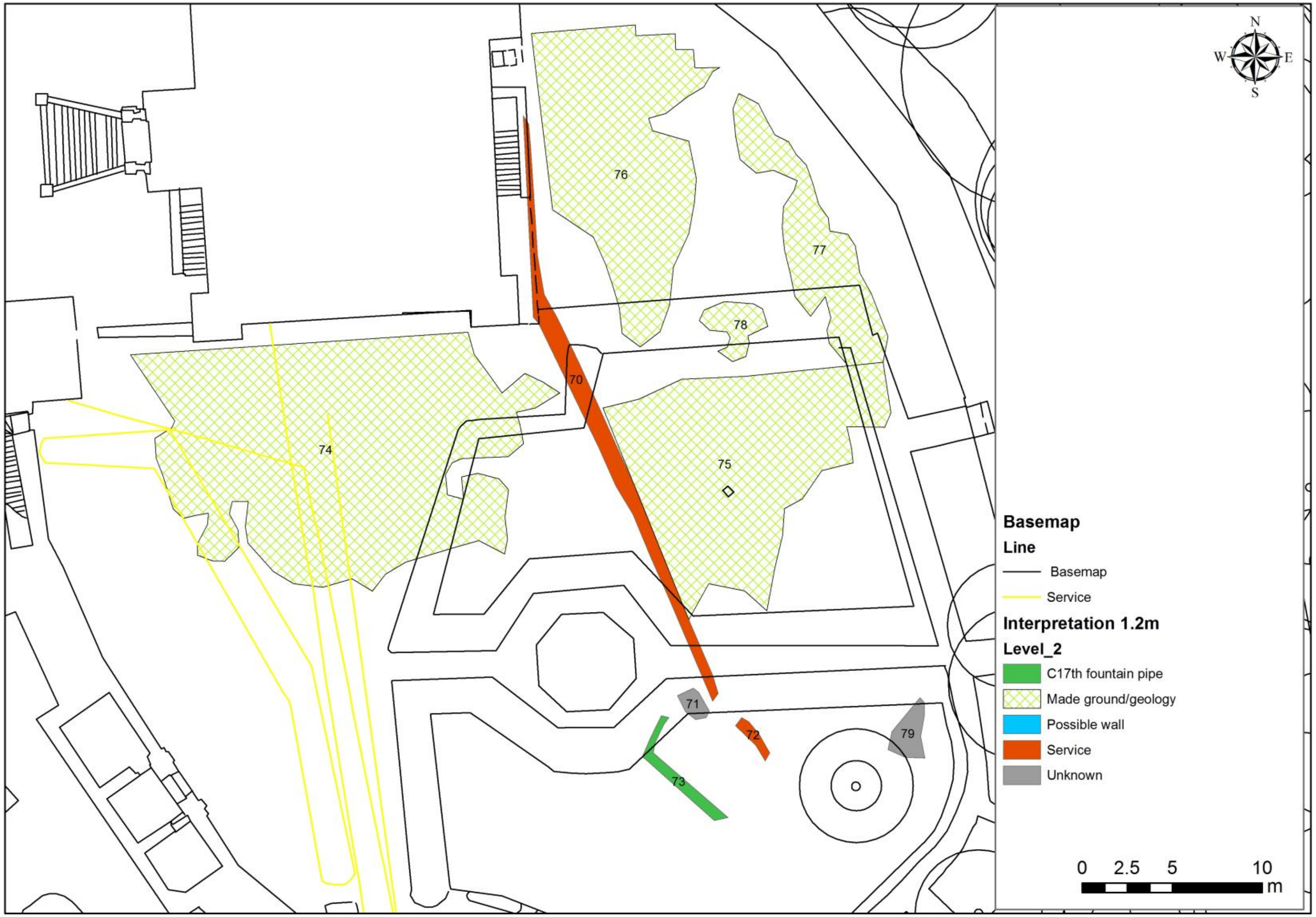

Figure 14: Depth slice 1.2m level 2 interpretation.

Figure 15: GPR depth slice 1.5m.

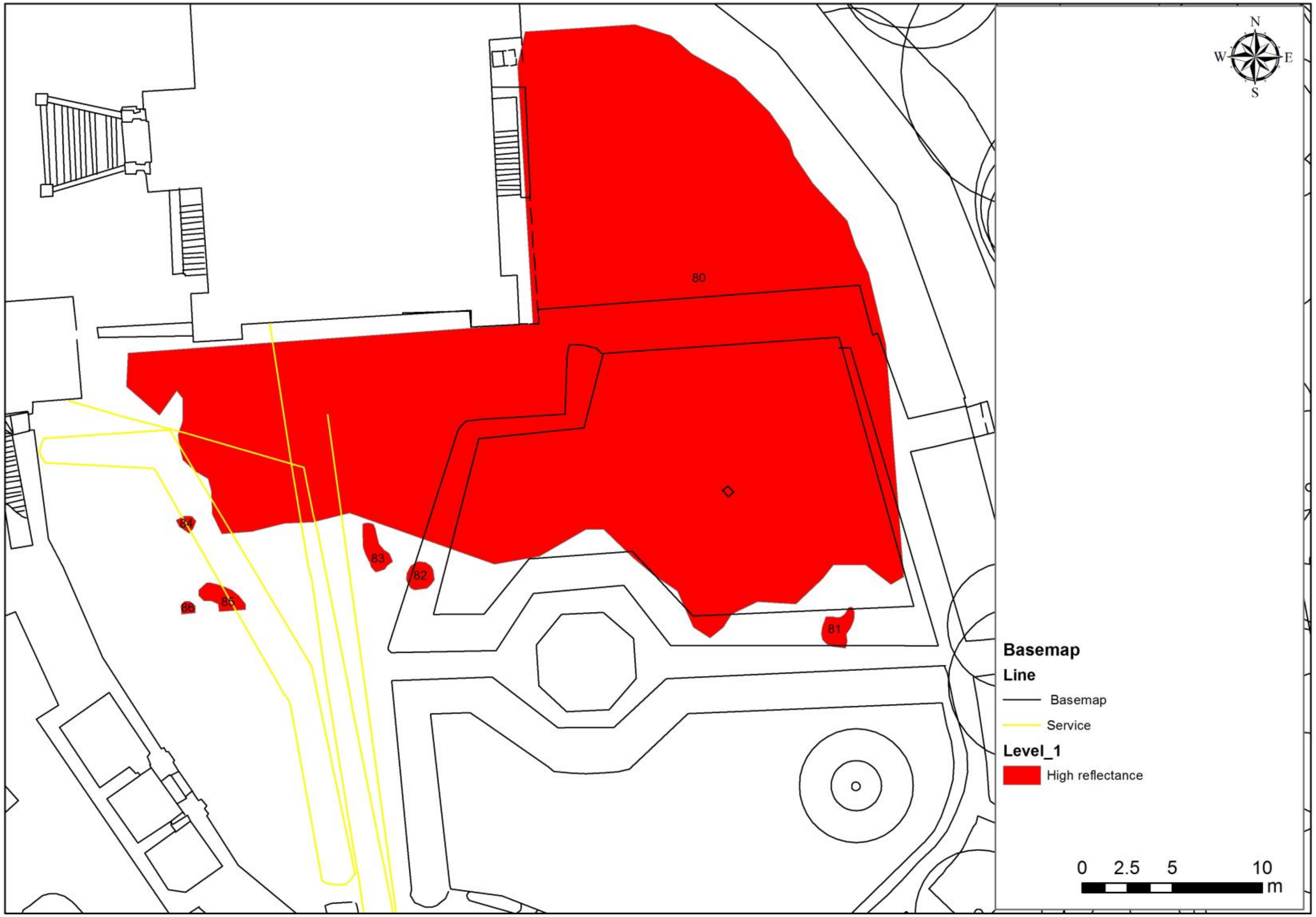

Figure 16: Depth slice 1.5m level 1 interpretation.

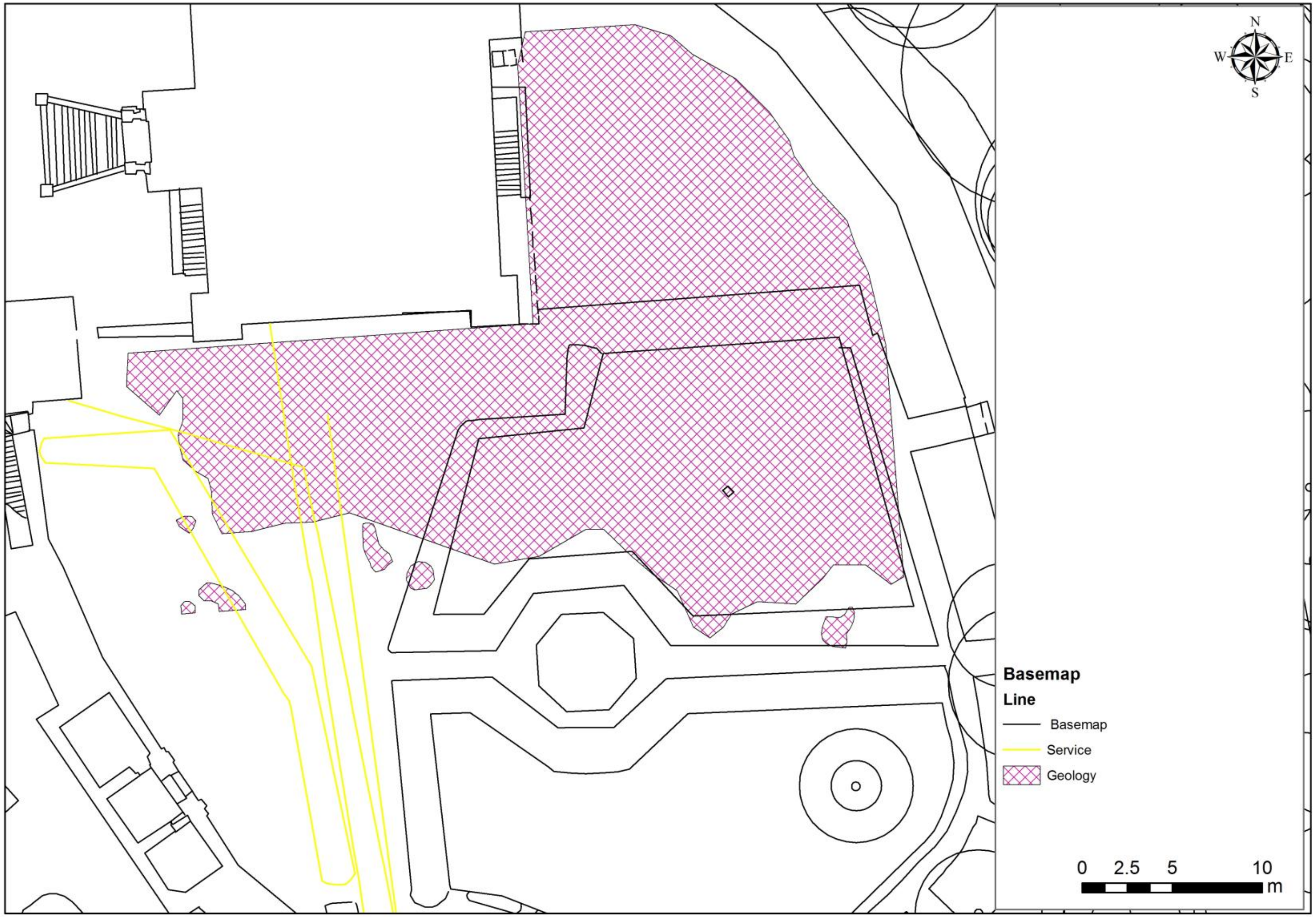

Figure 17: Depth slice 1.5m level 2 interpretation.

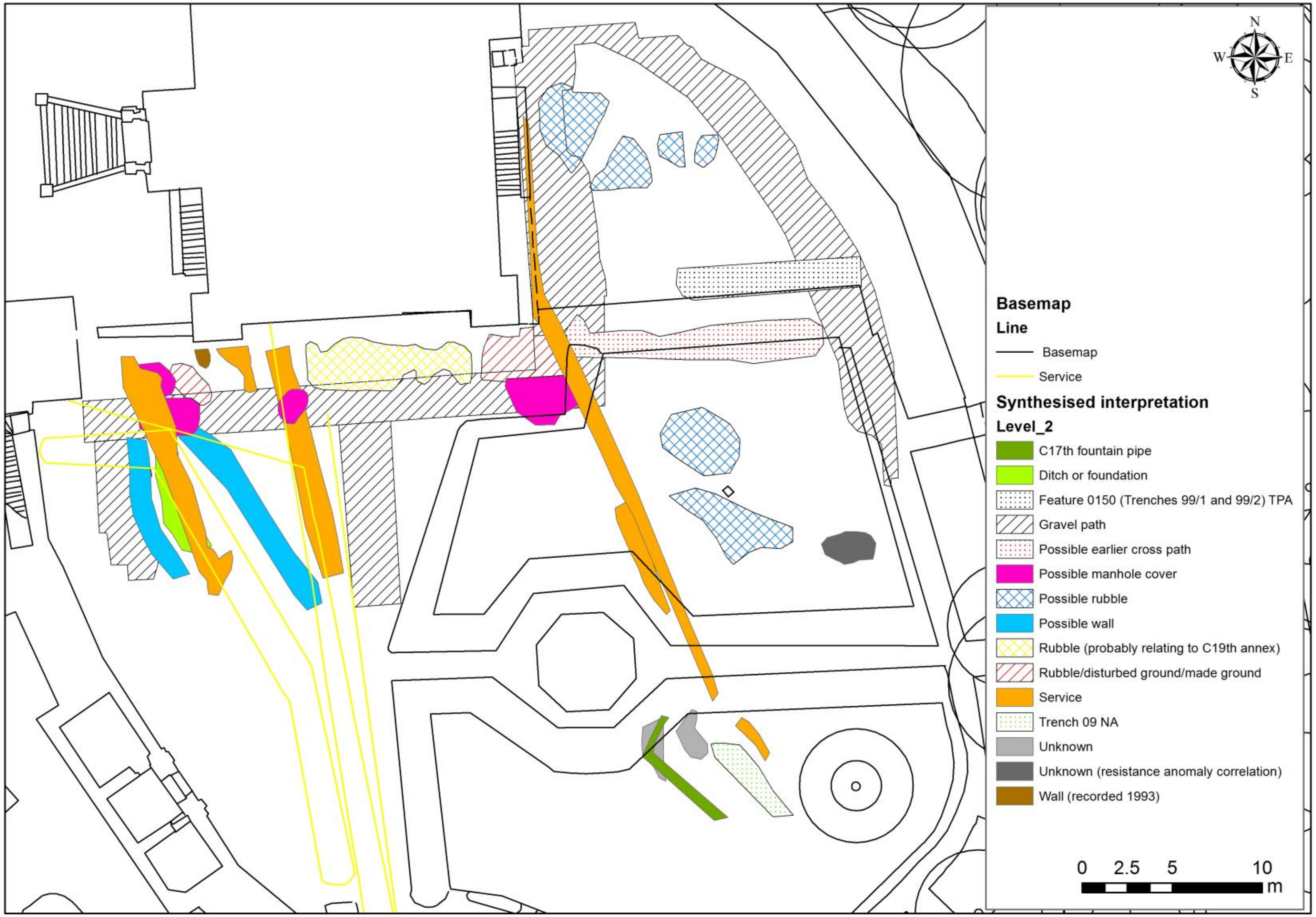

Figure 18: Synthesised view of all anomalies in the survey area.