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Studies of the geophysical responses of landfills in Northern Ireland using the Tellus Airborne EM data

National Geoscience Framework Programme

Internal Report IR/07/013

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Studies of the geophysical responses of landfills in Northern Ireland using the Tellus Airborne EM data

David Beamish

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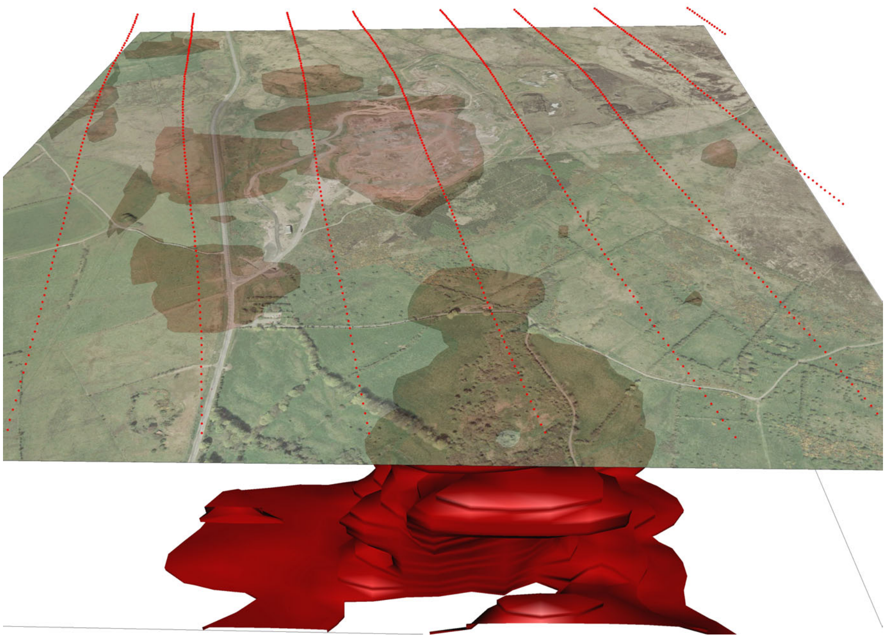

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Foreword

This report describes a rapid assessment of the geophysical responses (data and subsurface models) of selected landfills in Northern Ireland. The studies largely involve at and near-surface conductivities obtained from the Tellus Airborne Geophysical Survey of Northern Ireland carried out in 2005 and 2006.

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Summary

This report provides descriptions of the Tellus airborne geophysical data in the vicinity of landfills in Northern Ireland. The main data considered are the Electromagnetic (EM) data and the conductivity models (half-space and multi-layer) that can be obtained from these data. Some descriptions of the magnetic and radiometric responses are also given. Only the locations of the landfills have been supplied (i.e. no site information is available other than a coordinate). This means that only scant comments regarding an understanding of both observations and models are provided. Ten landfill locations with associated conductivity variations were chosen; the study is therefore not intended to be exhaustive. The first 4 landfills studied use data from the 2005 Phase 1 Tellus survey so that only 2 frequency data are available. The remaining 6 landfills have 4 frequency data available from the 2006 Phase 2 survey.

1 Introduction

The data sets obtained from previous GTK/JAC airborne EM system in the UK have been used in a sequence of investigations at the site investigation scale. The work has been described by Beamish and Kurimo (2000), Beamish et al. (2000), Beamish and Mattsson (2001), Beamish (2002a,b), Peart et al. (2003), Beamish (2003), Beamish (2004), Beamish et al. (2005) and Beamish and Klinck (2006). The GTK/JAC airborne electromagnetic (EM) system is described by Hautaniemi et al. (2005).

The data acquired by the Tellus airborne geophysical survey (Beamish et al., 2006 a.b; Beamish et al., 2007) offer an extensive resource for similar investigations in Northern Ireland. The present study is a rapid assessment of small data tile areas (e.g. typically a few km wide) containing landfill locations obtained from a database. The database was supplied by Tellus/GSNI. A subset of the database, used in this study, is shown in Appendix 1. The subset identifies landfills, or sites with possible landfill associations, only. The Column ID number is the reference number used in this report. Three of the landfills (LF) studied are not in the database; they are referred to as Landfill A, Landfill B and Belfast Hills.

Although a flight line separation of 200 m is defined as high resolution at the national airborne survey scale, at the site investigation scale this sampling can still be considered limiting. Thus, in a number of cases, enhanced conductivities are essentially detected only along a single flight line. Some of the previous studies, as discussed above, have undertaken small-scale infill surveys using a flight line separation of 50 m to attend to this particular sampling issue.

All the studies use Fraser half-space apparent conductivities, at a particular frequency, to provide mapping information. For brevity, we tend to use 3 kHz and 12/14 kHz which are the common frequencies across the complete Tellus EM data set.

The main data considered are the Electromagnetic (EM) data and the conductivity models (half-space and multi-layer) that can be obtained from these data. Some descriptions of the magnetic and radiometric responses are also given. Only the locations of the landfills have been supplied (i.e. no site information is available other than a coordinate). This means that only scant comments regarding an understanding of both observations and models are provided. Ten landfill locations with associated conductivity variations were chosen; the study is therefore not intended to be exhaustive. The first 4 landfills studied use data from the 2005 Phase 1 Tellus survey so that only 2 frequency (2f) data are available. The remaining 6 landfills have 4 frequency (4f) data available from the 2006 Phase 2 survey.

The inversion of the EM data to provide cross-sectional 1D models from the data is described in the next subsection. The ten landfill studies are then presented in the subsequent sections.

1.1 OCCAM INVERSION AND VERTICAL RESOLUTION

When AEM is applied at high resolution in areas containing potentially complex cover/bedrock relationships, the vertical discrimination of the system becomes significant. In a layered earth environment, the two additional frequencies at low and high frequencies should offer increased vertical resolution. This has been studied using a variety of synthetic models. The results of the 1D inversion studies presented here relate to the question: a) given no knowledge of the number of subsurface layers and b) given no knowledge of the true (rather than estimated) noise figures of our data, what is the likely configuration of the subsurface conductivity? This is an initial, pragmatic question that has to be applied to much regional scale data.

To satisfy the first condition, an Occam multi-layer procedure offering regularised, smooth models in the vertical direction is used (e.g. Constable et al., 1989). Such models cannot detect interfaces. To satisfy the second condition, a variety of assumed noise figures must be applied to the synthetic data. The target misfit for the inversion is the chi-square expectation of the data. This is 8 for our 4 frequency data and 4 for the 2 frequency data. The 5-layer model considered here comprises 2 highly conductive layers (100 mS/m) in a resistive (1 mS/m) host. The first conductive layer has a thickness of 5 m and is located between 10 and 15 m. The second conductive layer has a thickness of 20 m located between depths of 60 and 80m. The question posed is to what extent the 2 and 4 frequency data can resolve the 2 conductive features. When applied to a synthetic model data obtained from interfaces, the Occam procedure will not recover 'true' layer conductivity values.

The smooth model Occam results presented in Figure 1 relate to a 31 layer model with layer thicknesses set at 4 m. The synthetic data were obtained assuming a survey elevation of 60 m. The frequencies used in the 4 frequency inversion were 912, 3005, 11962 and 24510 Hz. The frequencies used in the 2 frequency inversion were 3005 and 11962 and are thus similar to those of the previous AEM-95 system. Two sets of results are shown assuming noise in the data exists at the 5% and 1.25% levels. Thus in the 2f (5%) result (obtained from 2 frequency inversion and assuming a 5% noise level), the model conductivity values range from only 14 to 73 mS/m, the model is highly smooth and only detects the lower conductor by virtue of its gradient. The corresponding 4 frequency model displays a larger data value range and the near-surface conductor is detected. The corresponding models assuming 1.25% noise are also shown. These clearly offer improved performance, since the data is assumed to be more accurate. The improved detection performance of the 4 frequency system is demonstrated at both of the 2 noise levels considered. The 4 frequency data clearly offer improved discrimination of conductive features at both shallow and deeper levels.

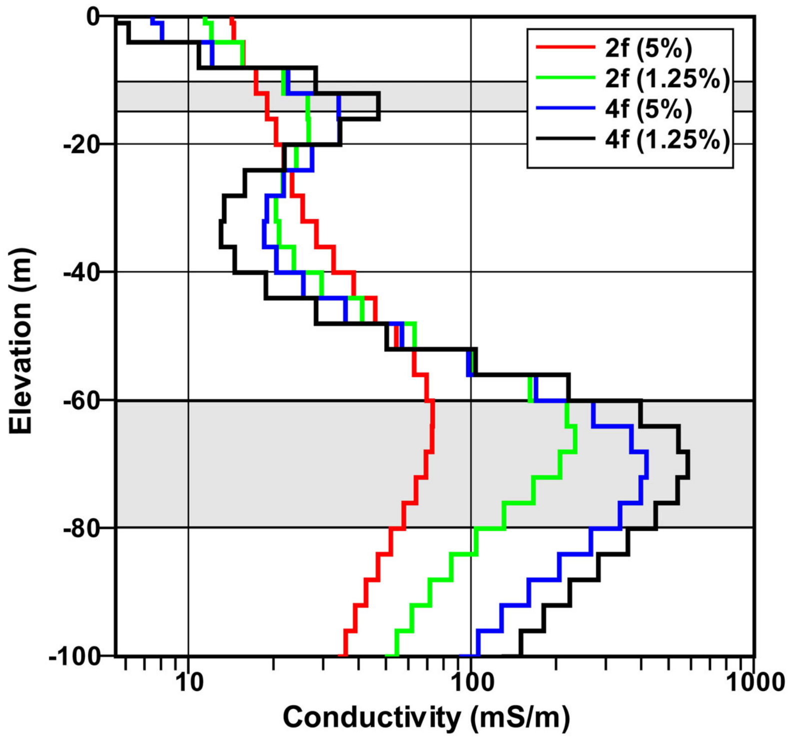


Figure 1. Vertical 1D models obtained by Occam inversion of a synthetic data set using two frequency (2f) and four frequency (4f) data and assuming five percent data noise (5%) and 1.25

percent data noise (1.25%). The vertical axis is elevation in m from 0 to 100 m. The two target conductive zones are shaded.

2 Landfill 06.

This is a refuse tip identified in the LF database. The study area is 2 x 2 km. The grid coordinates are BLHC = 241000, 410000 and TRHC = 243000,412000 m. The study is summarised in the following 6 Figures.

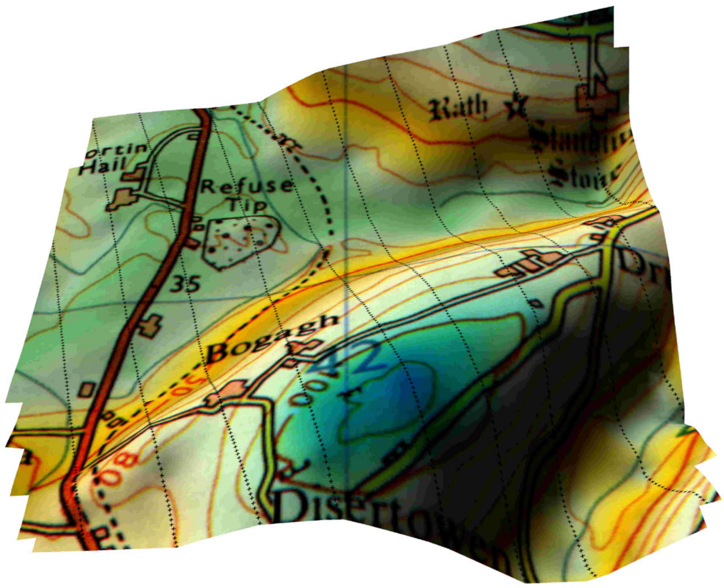


Figure 2. 50k OS on DTM (3D perspective view). Flight lines shown.

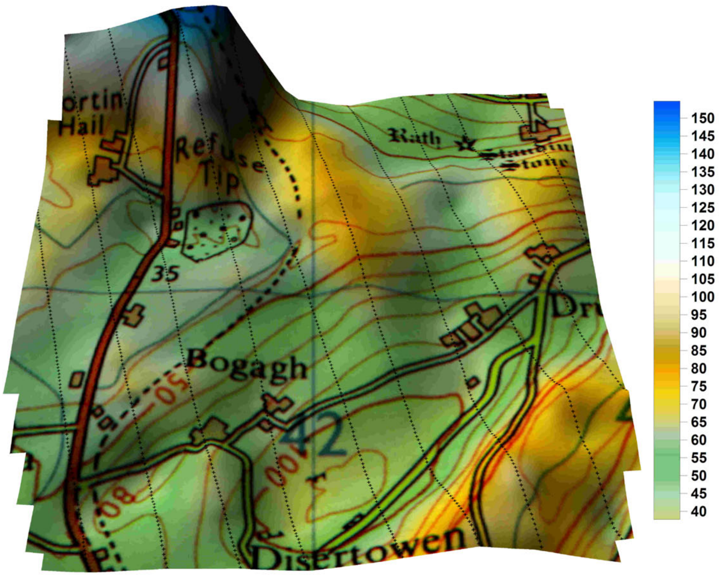


Figure 3. 50k OS on RALT (m) (3D perspective view). Flight lines shown.

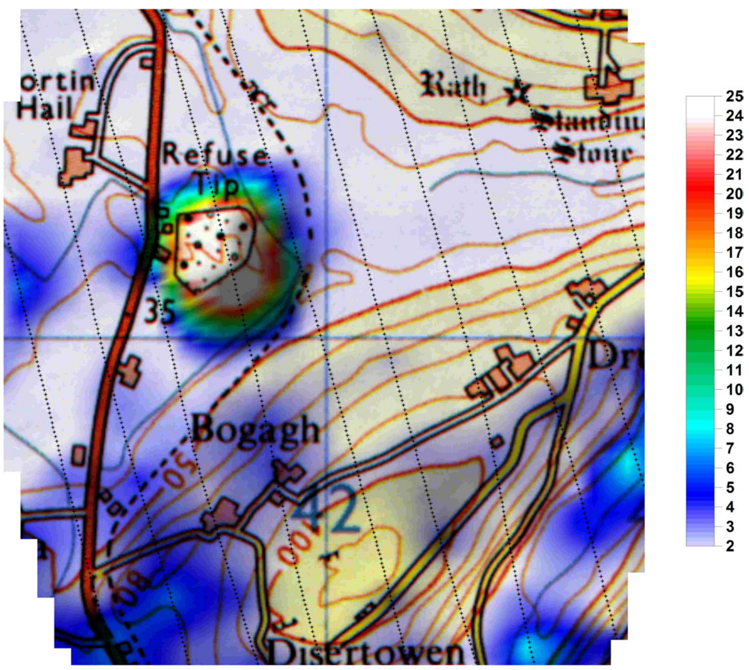


Figure 4. 14k Apparent conductivity (mS/m) on 50k OS map. Flight lines shown.

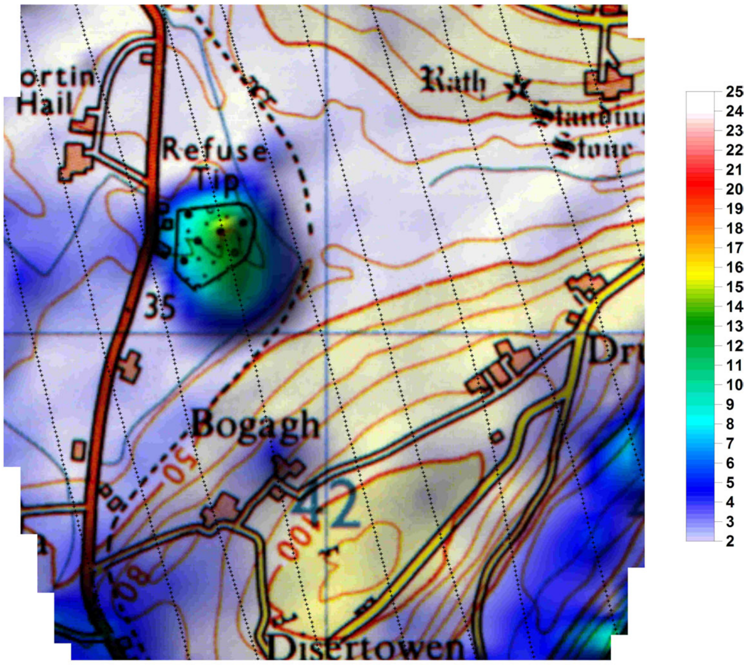


Figure 5. 3k Apparent conductivity (mS/m) on 50k OS map. Flight lines shown.

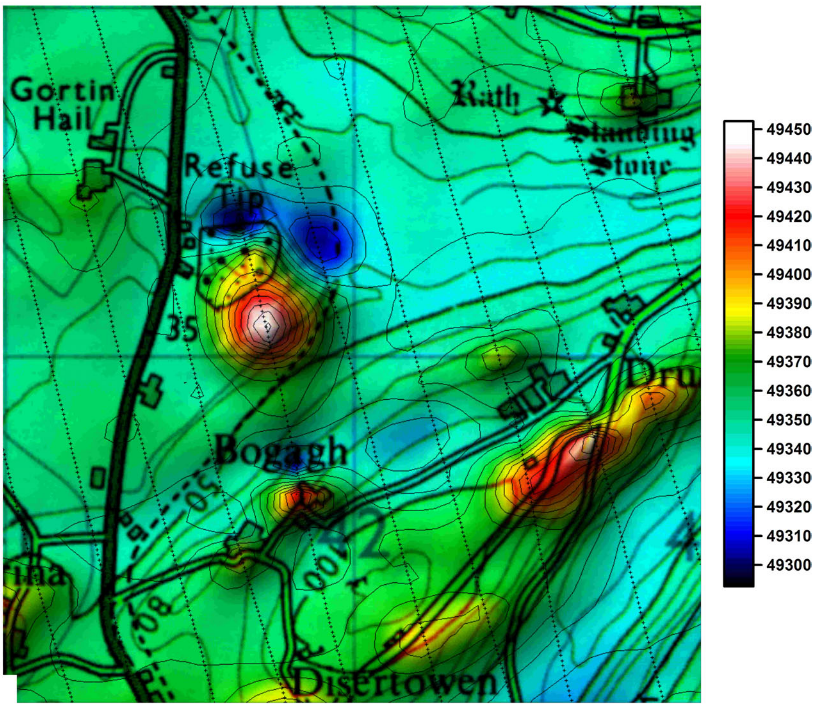


Figure 6. Magnetic Total Intensity on 50k OS map. Flight lines shown.

A conductivity cross-section was constructed from Occam inversions of the 2f data along flight line 330.This line defines the main conductive anomaly. The resulting conductivity model, centred on Landfill 06 is shown below.

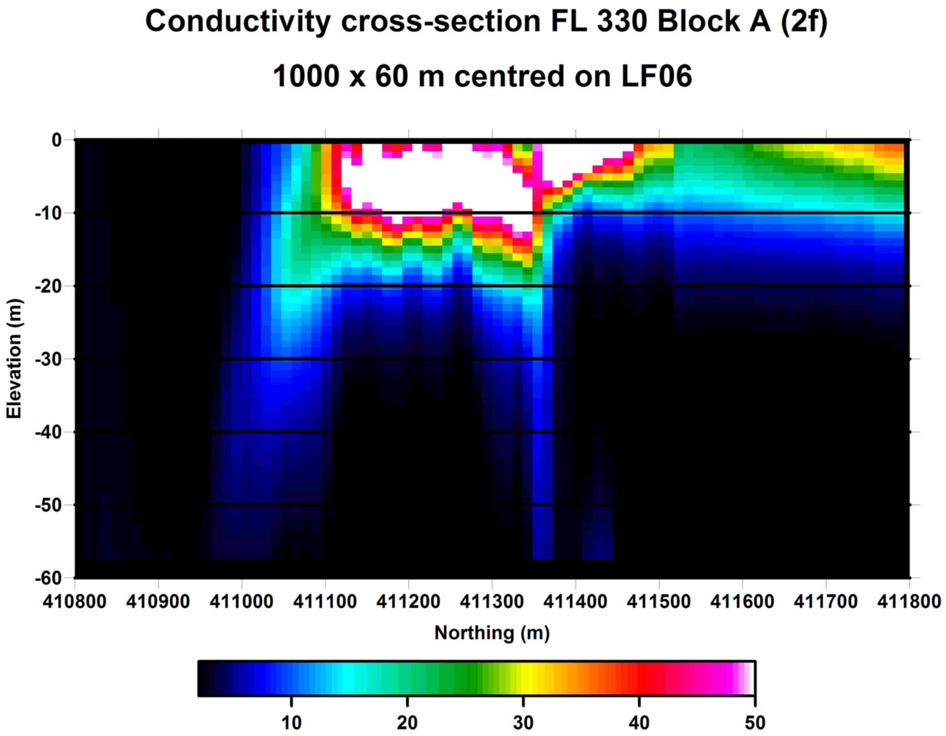


Figure 7. 1D conductivity cross-section centred on LF06.

3 Landfill A.

This is a refuse tip not identified in the LF database. It appears to lie on or close to the border. The study area is 3 x 3 km. It is located just to the west of Strabane. The grid coordinates are BLHC = 231000, 234000 and TRHC = 395000,398000 m. The study is summarised in the following 3 Figures. No subsurface models were investigated.

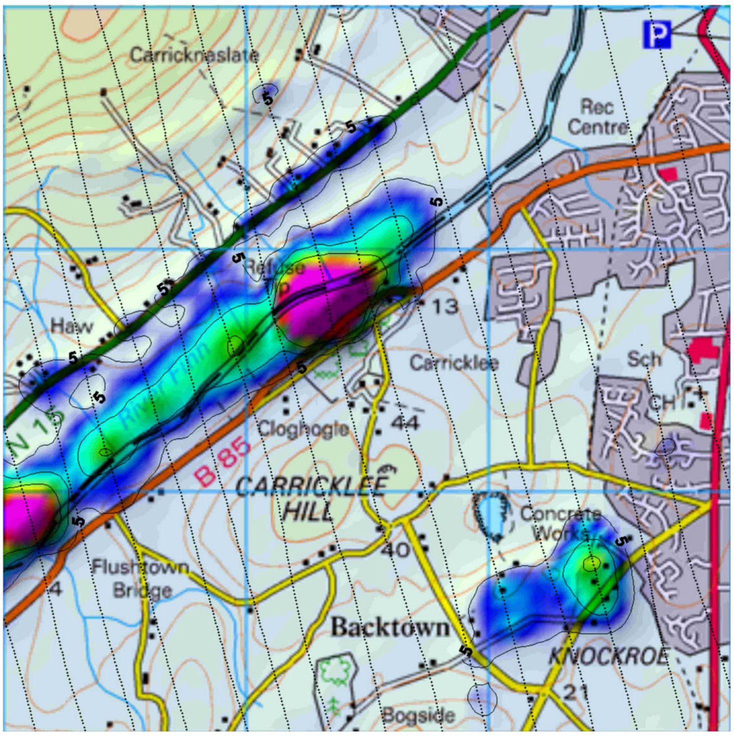


Figure 8. 14 kHz Apparent conductivity (mS/m) on 50k OS map. Flight lines shown. Colour scale is from 5 to 25 mS/m.

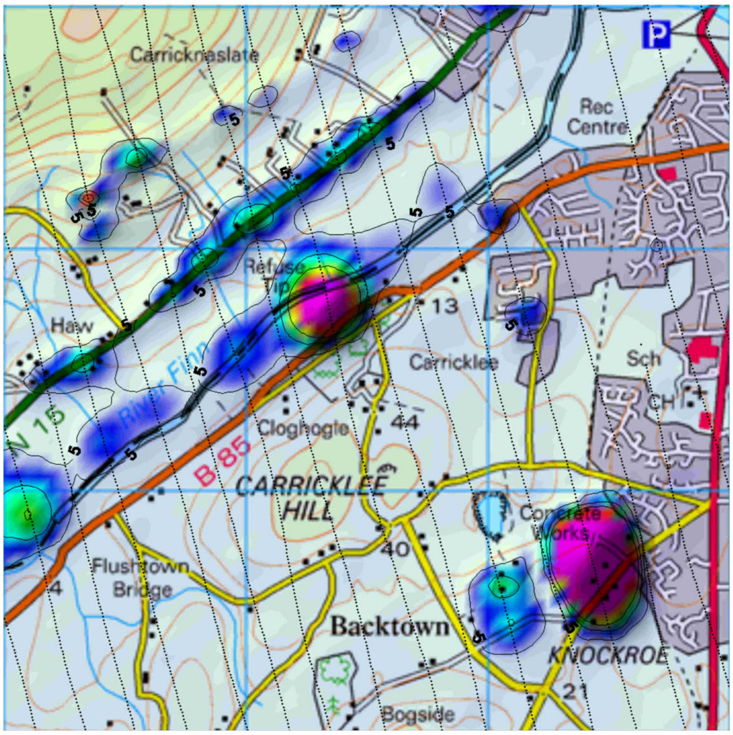


Figure 9. 3 kHz Apparent conductivity (mS/m) on 50k OS map. Flight lines shown. Colour scale is from 5 to 25 mS/m.

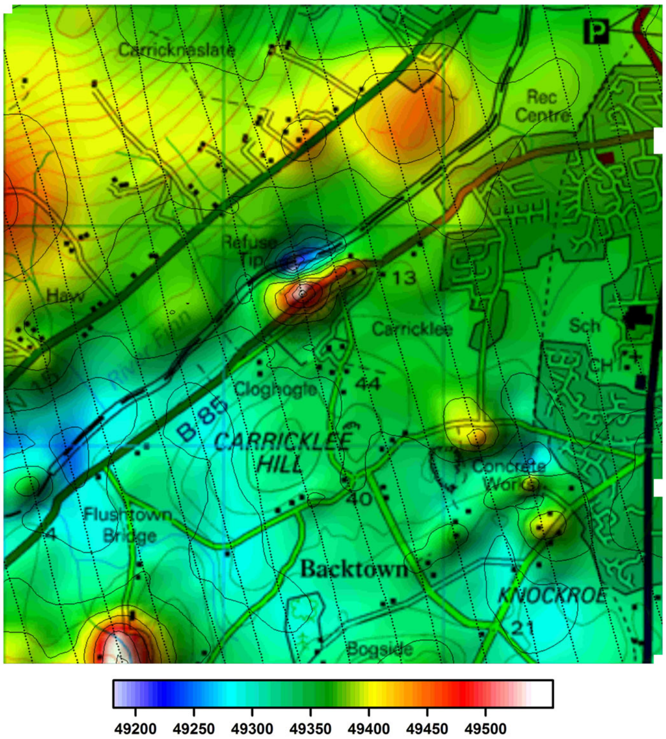


Figure 10. Magnetic Total Intensity on 50k OS map. Flight lines shown.

There are clear indications of enhanced conductivities associated with the river to the SW of the landfill site.

4 Landfill B.

This is a refuse tip, to the SE of Enniskillen, not identified in the LF database. The study area is 3 x 3 km. The grid coordinates are BLHC = 225000, 340000 and TRHC = 228000, 343000 m. The study is summarised in the following 5 Figures.

Figure 11. Location of Enniskillen Refuse Tip

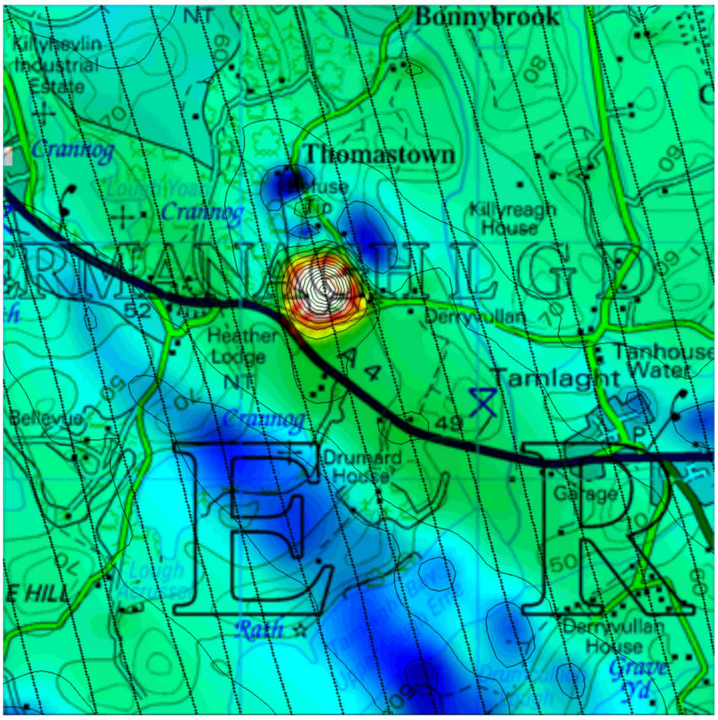


Figure 12. Magnetic Total Intensity on 50k OS map. Flight lines shown.

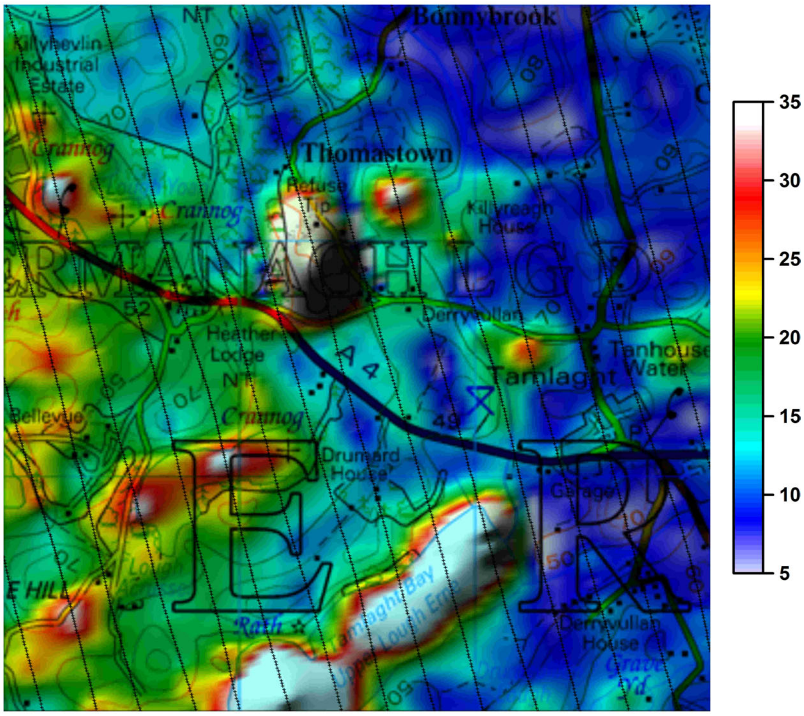


Figure 13. 14 kHz Apparent conductivity (mS/m) on 50k OS map. Flight lines shown.

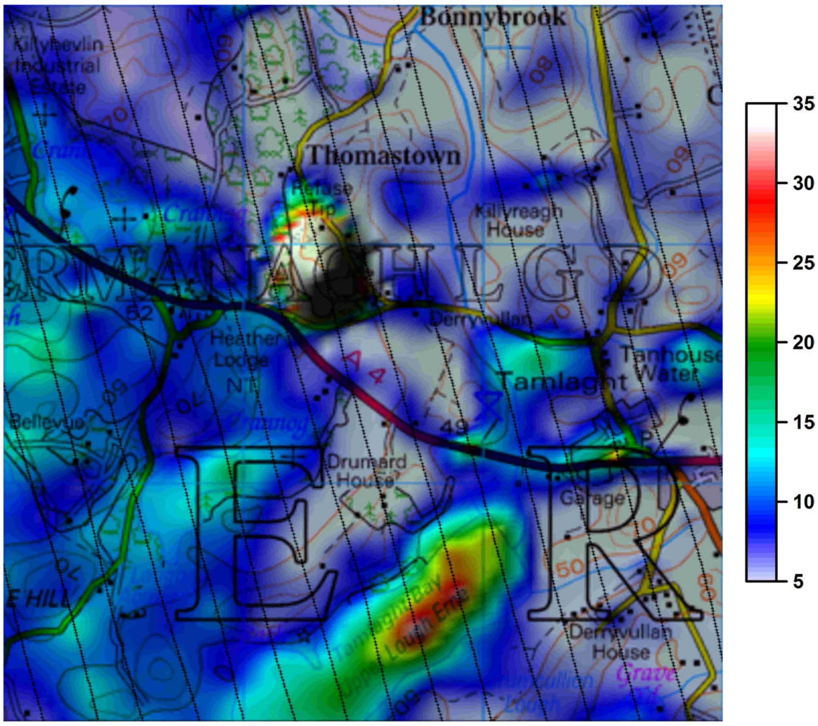


Figure 14. 3 kHz Apparent conductivity (mS/m) on 50k OS map. Flight lines shown.

A conductivity cross-section was constructed from Occam inversions of the 2f data along flight line 666.This line defines the main conductive anomaly. The resulting conductivity model obtained from the whole line (3 km) is shown below. The results also include the conductivity anomaly associated with the bay in Lough Earne, in the south of the area. The landfill appears to provide a particularly deep conductive component that extends to a depth of about 25 m. There are indications of 2 separate cells along the flight line.

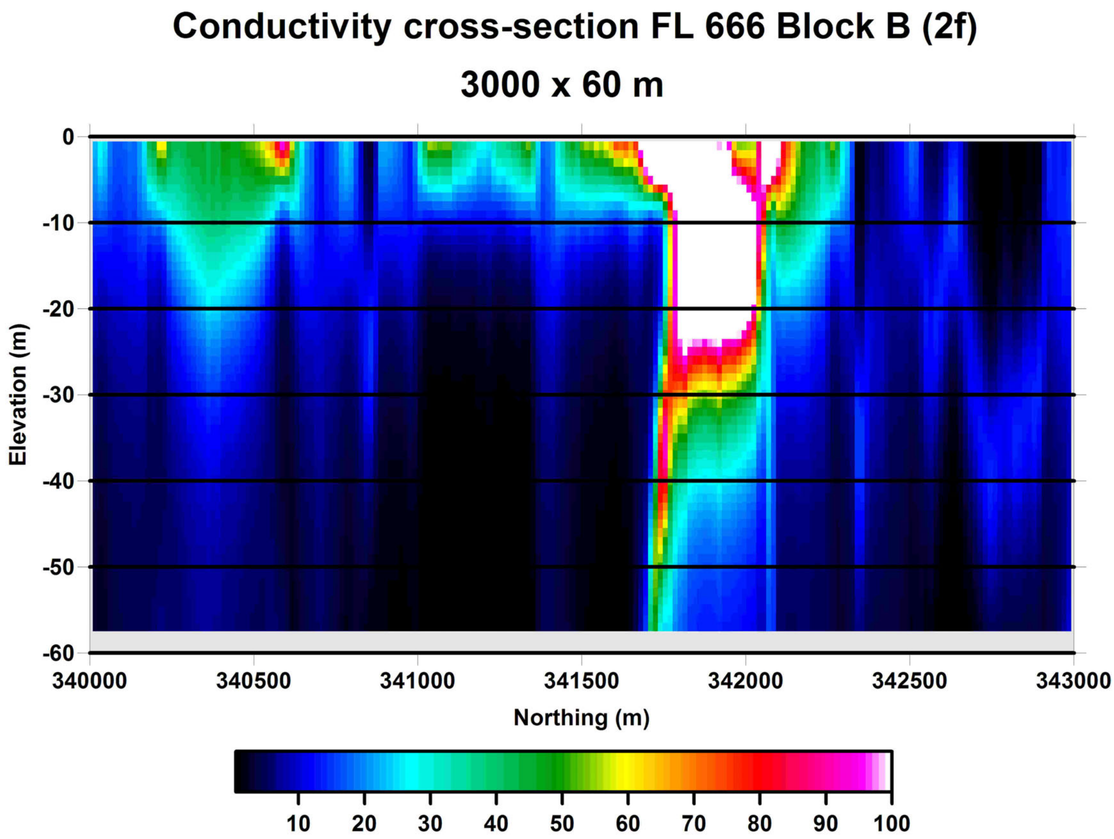


Figure 15. 1D conductivity cross-section crossing Refuse Tip. 3 km x 60 m.

5 Landfill 55.

This is a recycling centre, to the west of Newtonabbey, identified in the LF database. The centre lies within a highly urban setting. The study involves noting the difficulties of obtaining valid geophysical responses in this type of setting. The study area is 3 x 3 km. The grid coordinates are BLHC = 328000, 381000 and TRHC = 331000, 384000 m. The study is summarised in the following 3 Figures.

As can be seen, the centre lies directly under a high voltage power line. The fly-high conditions (above 60 m) are shown in the plot of radar altitude.

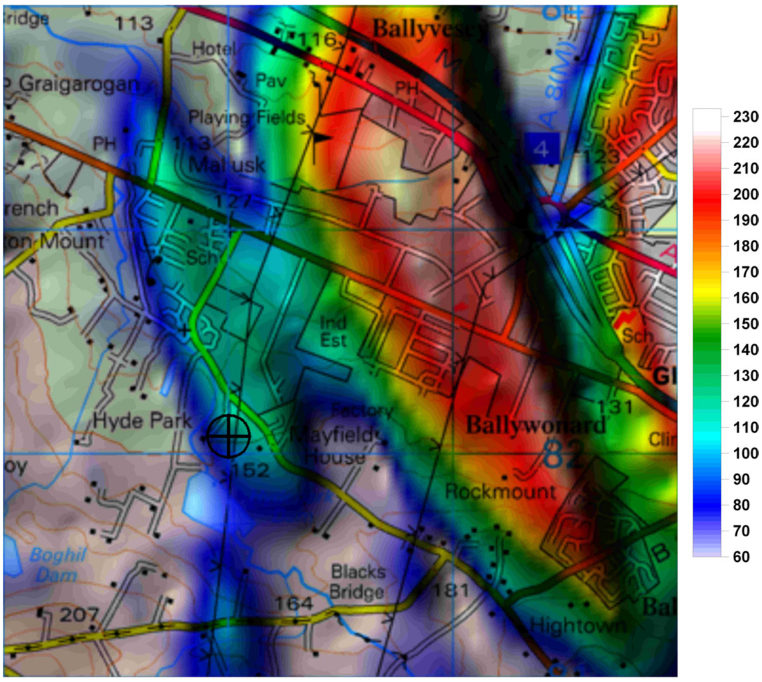


Figure 16. Radar altimeter (RALT, m) above 60m. Site location shown by symbol.

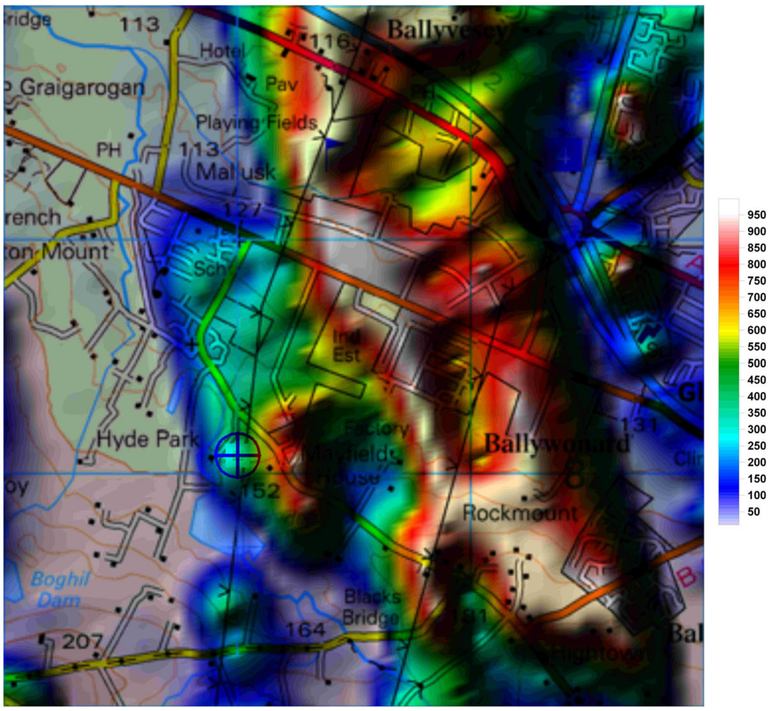


Figure 17. Power line monitor (PLM). Only highest values contoured.

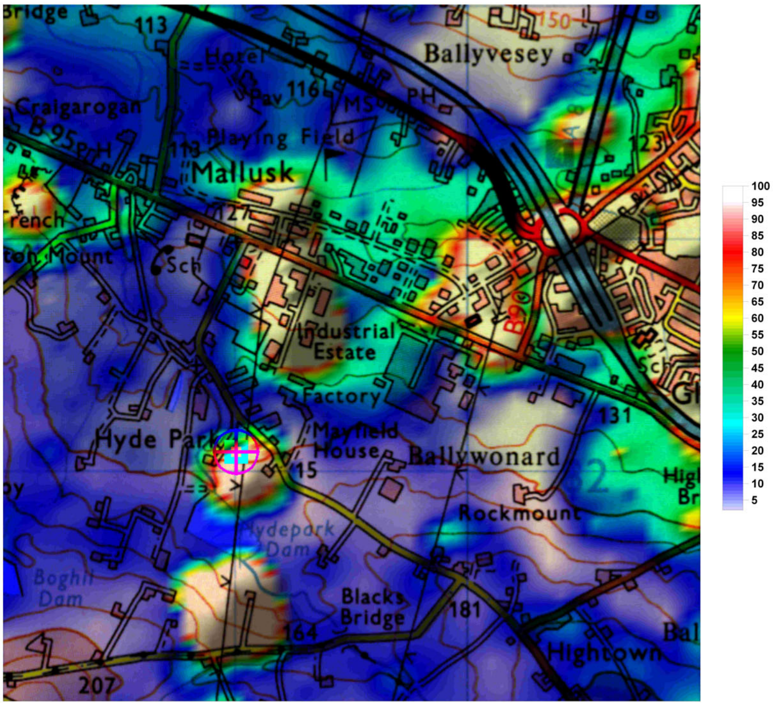


Figure 18. 3 kHz Apparent conductivity (mS/m) on 50k OS map.

Although a conductive anomaly is observed in association with the centre, the setting is too challenging to have achieved reliable data

6 Landfill 40.

This location is identified in the LF database with a comment ‘needs identification’. The study area is 2 x 2 km. The grid coordinates are BLHC = 307000, 354000 and TRHC = 309000, 358000 m. The location (see below) appears to identify a building. The study is summarised in the following 5 Figures.

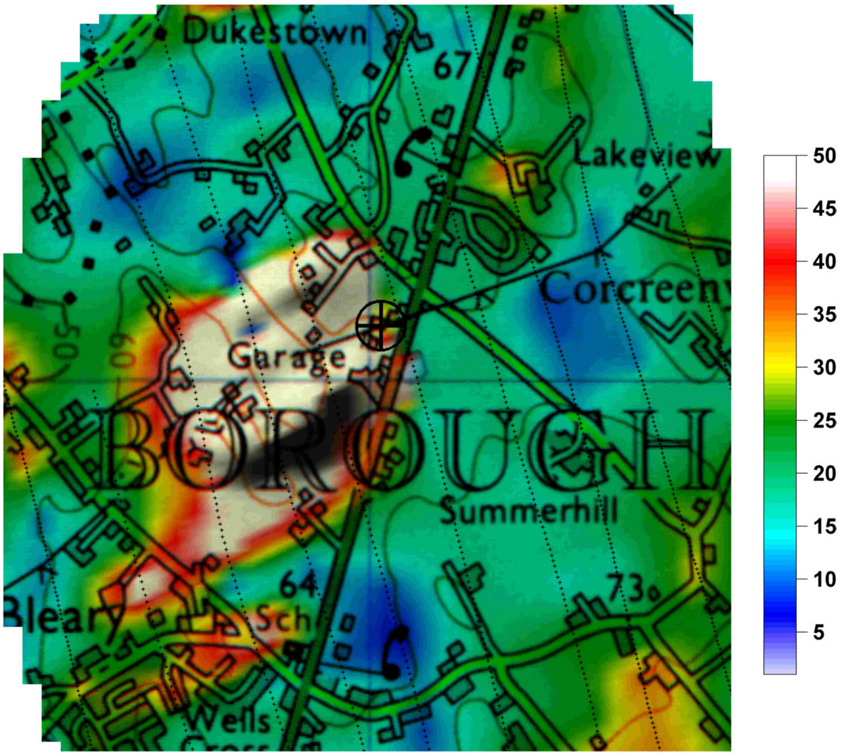


Figure 19. LF 40, location (symbol). 12 kHz Apparent conductivity (mS/m) on 50k map.

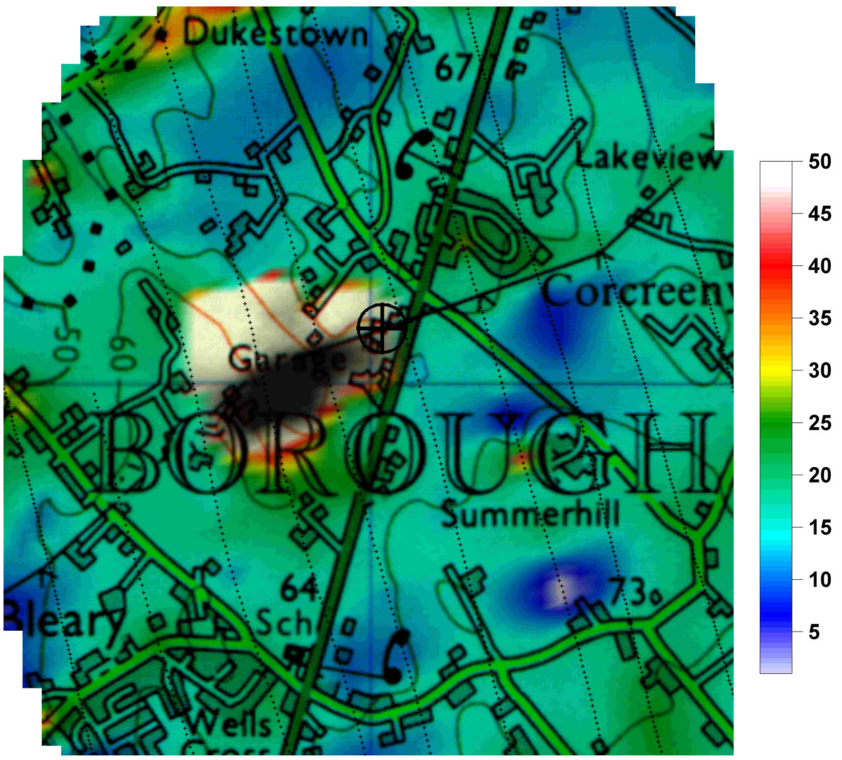


Figure 20. 3 kHz Apparent conductivity (mS/m) on 50k map.

A conductivity cross-section was constructed from Occam inversions of the 4f data along flight line 2222.This line passes through the main conductive anomaly. The resulting conductivity model obtained from the central portion of the line (800 m) is shown below. The at-surface landfill appears as a vertically compact conductive feature. A separate deeper conductive zone is also indicated. Due to setting of the landfill, further studies were undertaken as to possible data distortion (due to power-line effects, etc.). It was concluded that the deeper conductive feature involved a small power line perturbation whose influence increased with decreasing frequency.

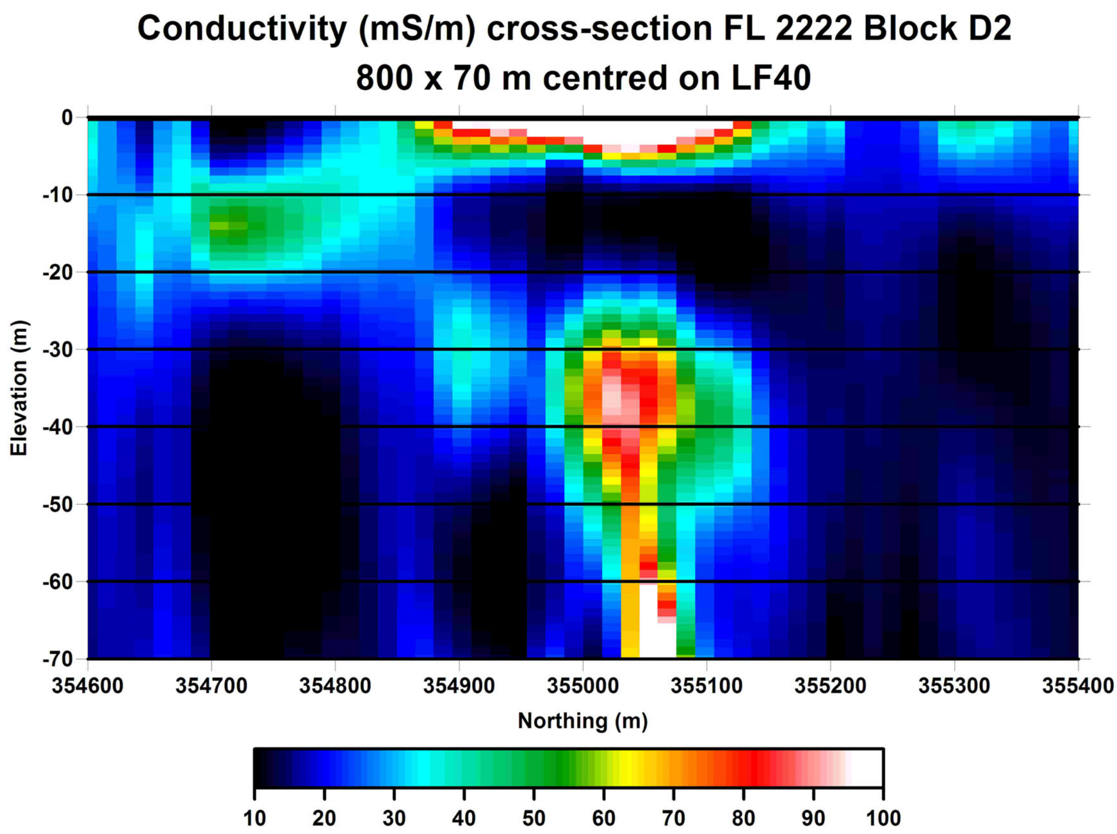


Figure 21. 1D conductivity cross-section across LF40. 800 x 70 m

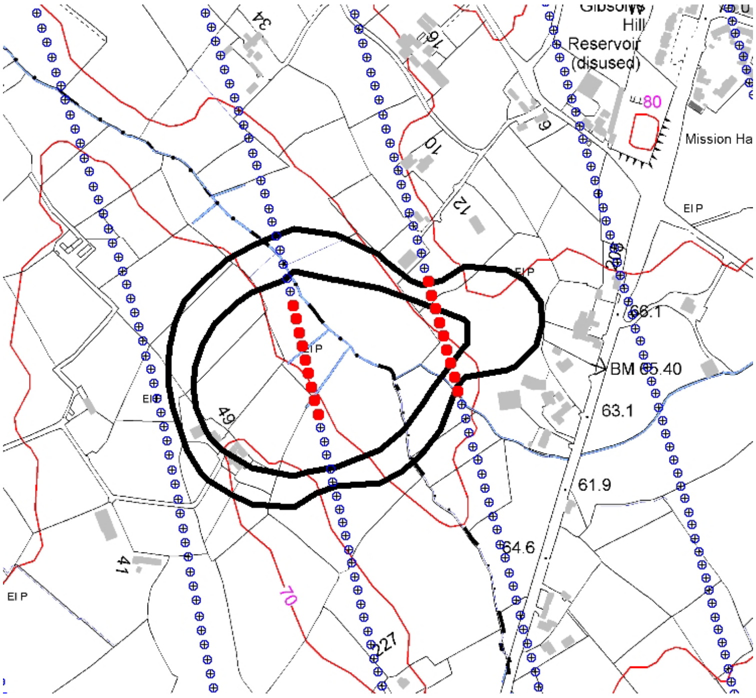


Figure 22. Detail showing 1:10k map, flight lines colour-coded by PLM channel (PLM>128 in red), 400 and 1000 mS/m contours of 3kHz apparent conductivity.

Figure 23. In-flight video frames above anomaly.

7 Landfill 44.

This location is identified in the LF database as site 44. The study area is 4 x 4 km. The grid coordinates are BLHC = 310000, 394000 and TRHC = 314000, 396000 m. The study is summarised in the following 4 Figures.

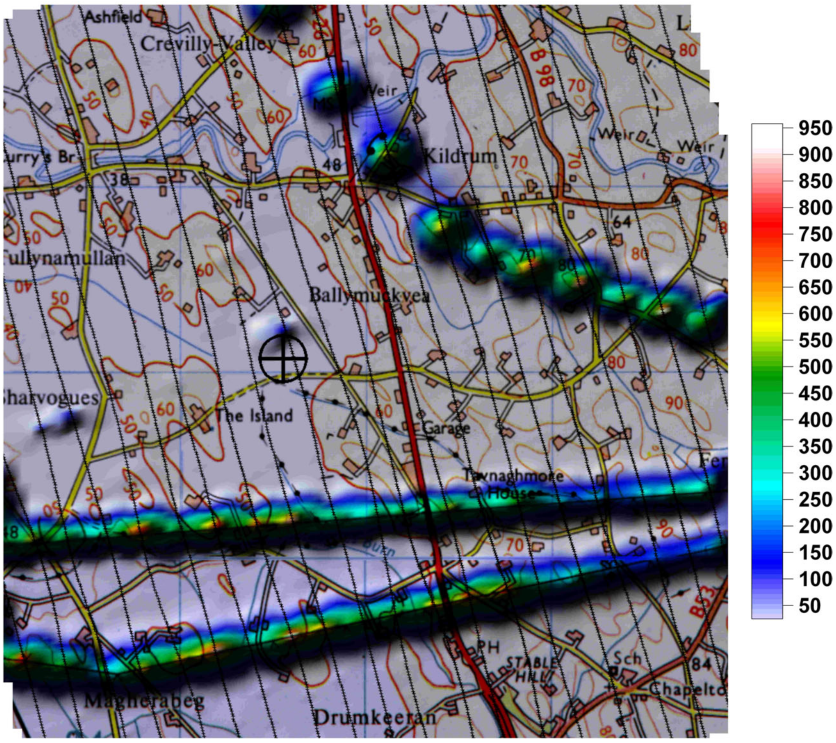


Figure 24. LF 44, location (symbol) and PLM

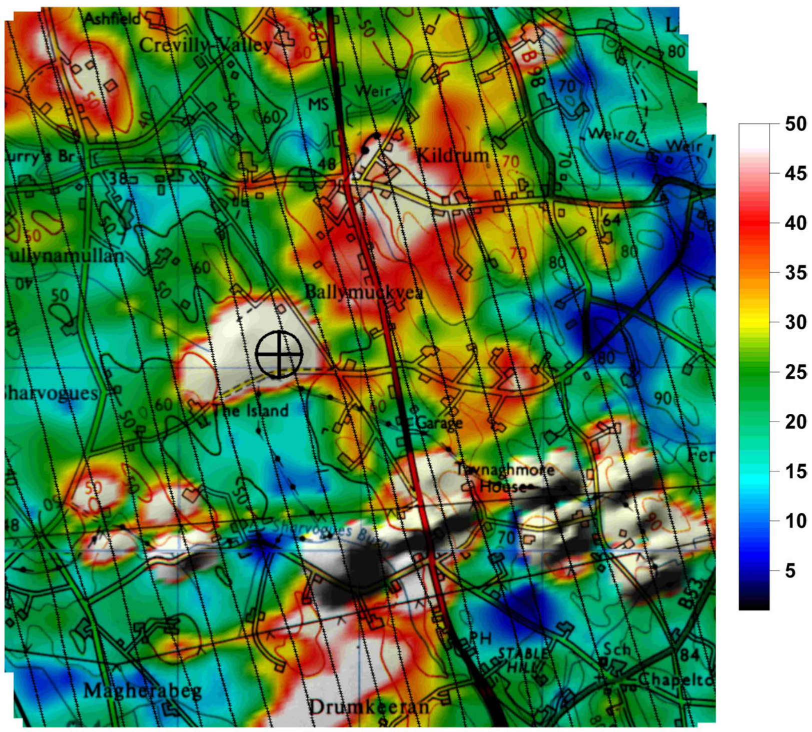


Figure 25. 12 kHz Apparent conductivity (mS/m) on 50k OS map.

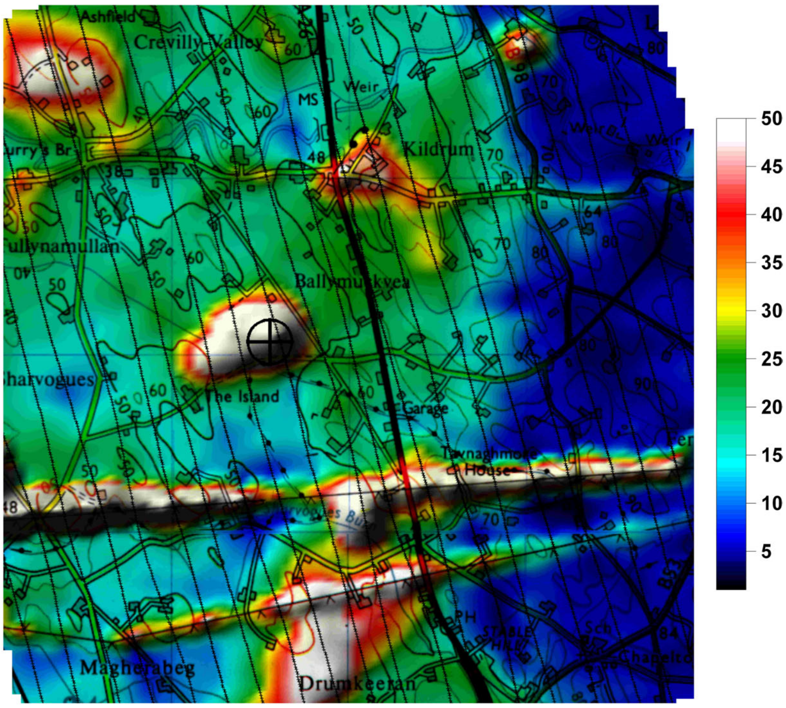


Figure 26. 3kHz Apparent conductivity (mS/m) on 50k OS map.

A conductivity cross-section was constructed from Occam inversions of the 4f data along flight line 2293.This line passes through the main conductive anomaly. The resulting conductivity model obtained from the central portion of the line (1 km) is shown below. The at-surface landfill appears as a vertically compact conductive feature extending to a depth of ~20m.

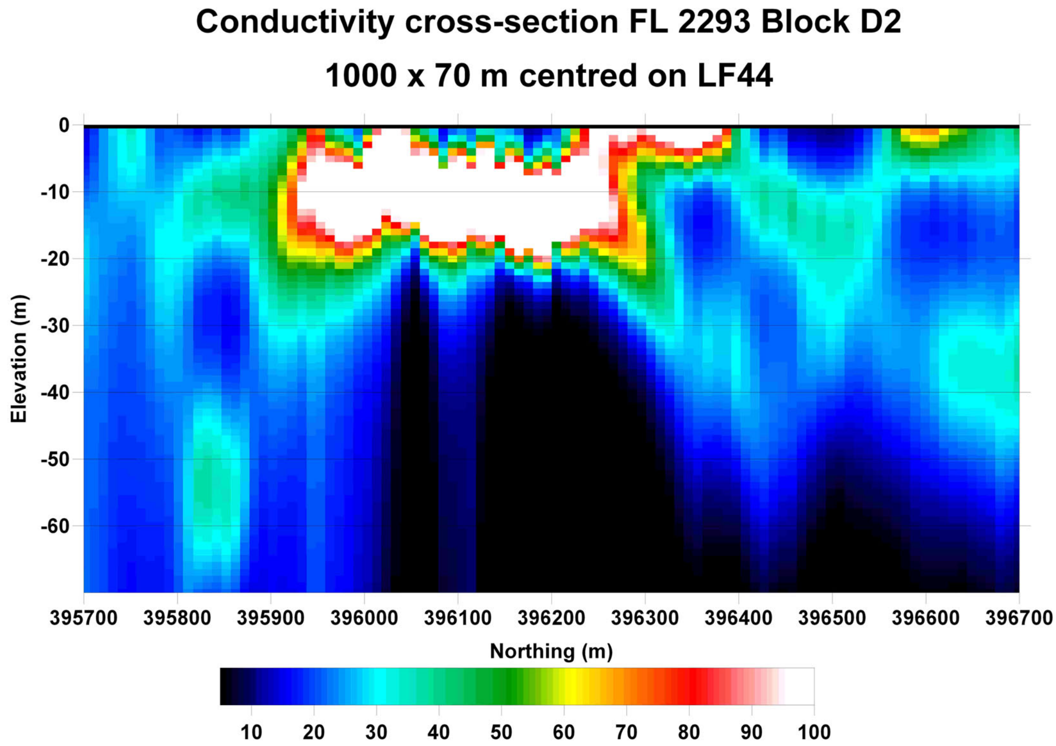


Figure 27. 1D conductivity cross-section across LF44 1000 x 70m.

8 Landfill 48.

This location is identified in the LF database as site 48. The study area is 2 x 2 km. The grid coordinates are BLHC = 317000, 386000 and TRHC = 319000, 388000 m. The study is summarised in the following 2 Figures.

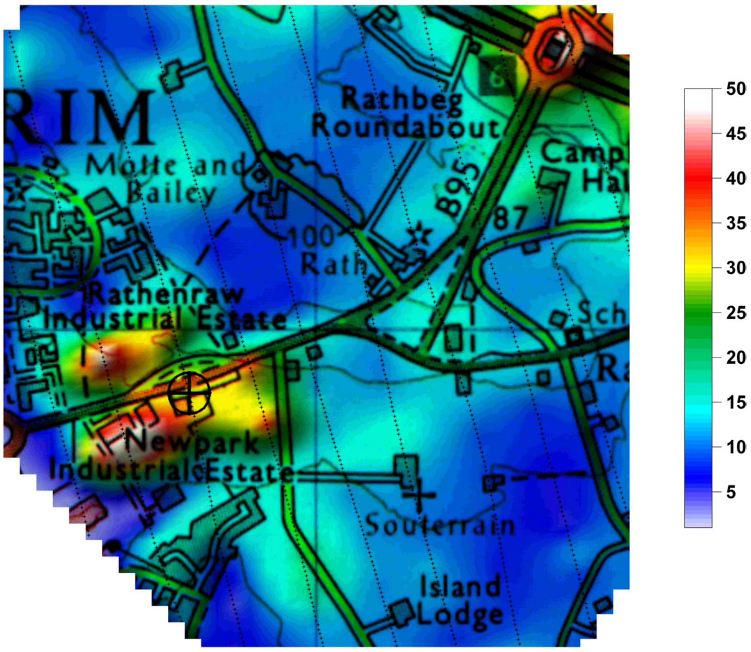


Figure 28. 12 kHz Apparent conductivity (mS/m) on 50k OS map. Symbol denotes site centre. Flight lines shown.

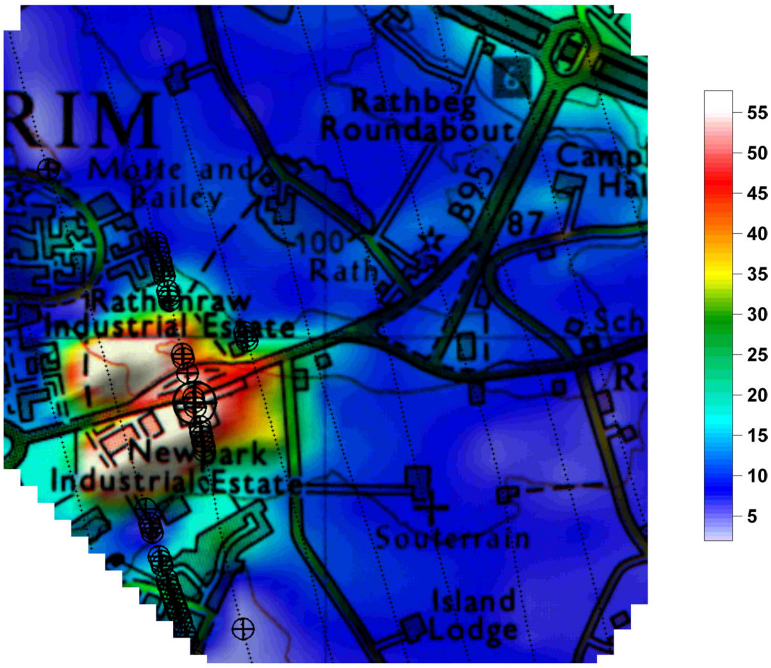


Figure 29. 3 kHz Apparent conductivity (mS/m) on 50k OS map. Symbol denotes site centre. Flight lines shown. Symbols along flight lines denote PLM>40 units.

Due to urban setting and the association of landfill location and strong power line response, this landfill was not studied further.

9 Landfills 25, 26

These locations are identified in the LF database as sites 25 and 26. The initial study area is 3 x 2 km. The grid coordinates are BLHC = 287000, 438000 and TRHC = 290000, 440000 m. Landfill 25 is a modern construction (see below) occupying the former Craighulliar Quarry, near Portrush. The coordinates of Landfill 26 occur close to a second quarry site. No other details of Landfill 26 have been obtained. The initial study is summarised in the following 6 Figures.

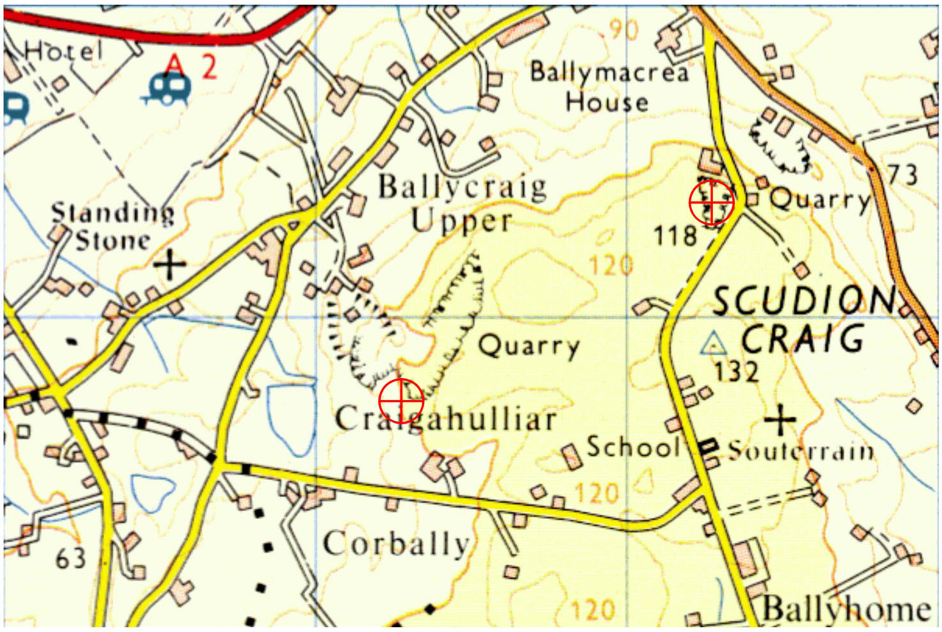


Figure 30. Location of landfills 25, 26 (symbols).

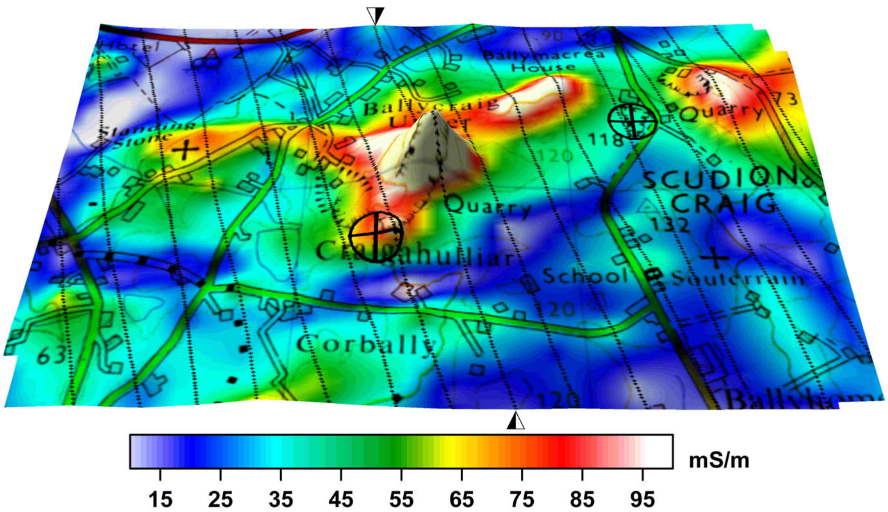


Figure 31. 3 x 2 km area showing 12 kHz apparent conductivity mapped as a 3D perspective view on a background 1:50k topographic map. Two cross symbols denote landfill sites. Flight lines at 345˚. Triangles identify flight line 1228.

Figure 32. 800 x 800 mm area centred on quarry/landfill site. Contours are highest values of 3 kHz apparent conductivity (mS/m) from 85 to 125 mS/m (interval of 10). Background image is an aerial photograph of the site. Flight line 1228 denoted by symbols.

Figure 28 shows the 12 kHz half-space apparent conductivity data observed across the 3 x 2 km area. The data are mapped as a 3D perspective view on a background 1:50k topographic map. The sampling provided by the 200 m flight lines (345˚) is also shown. A database provided the locations of 2 landfills (these often refer to a site office) within the area and these are shown with symbols. The landfill is a modern, engineered structure, with liner, that has been in operation for about 6 years. Further detailed study of the data (Fig. 29) reveals that the largest amplitudes are closely associated with the location of the operational landfill. Figure 30 shows the high value contours (85 to 125 mS/m) of the 3 kHz apparent conductivity data across the central 800 x 800 m area. The background image is an orthorectified aerial photograph. The 2 highest value contour closures occur along 2 adjacent flight lines. The sampling along one of the flight lines (1228) is displayed with symbols.

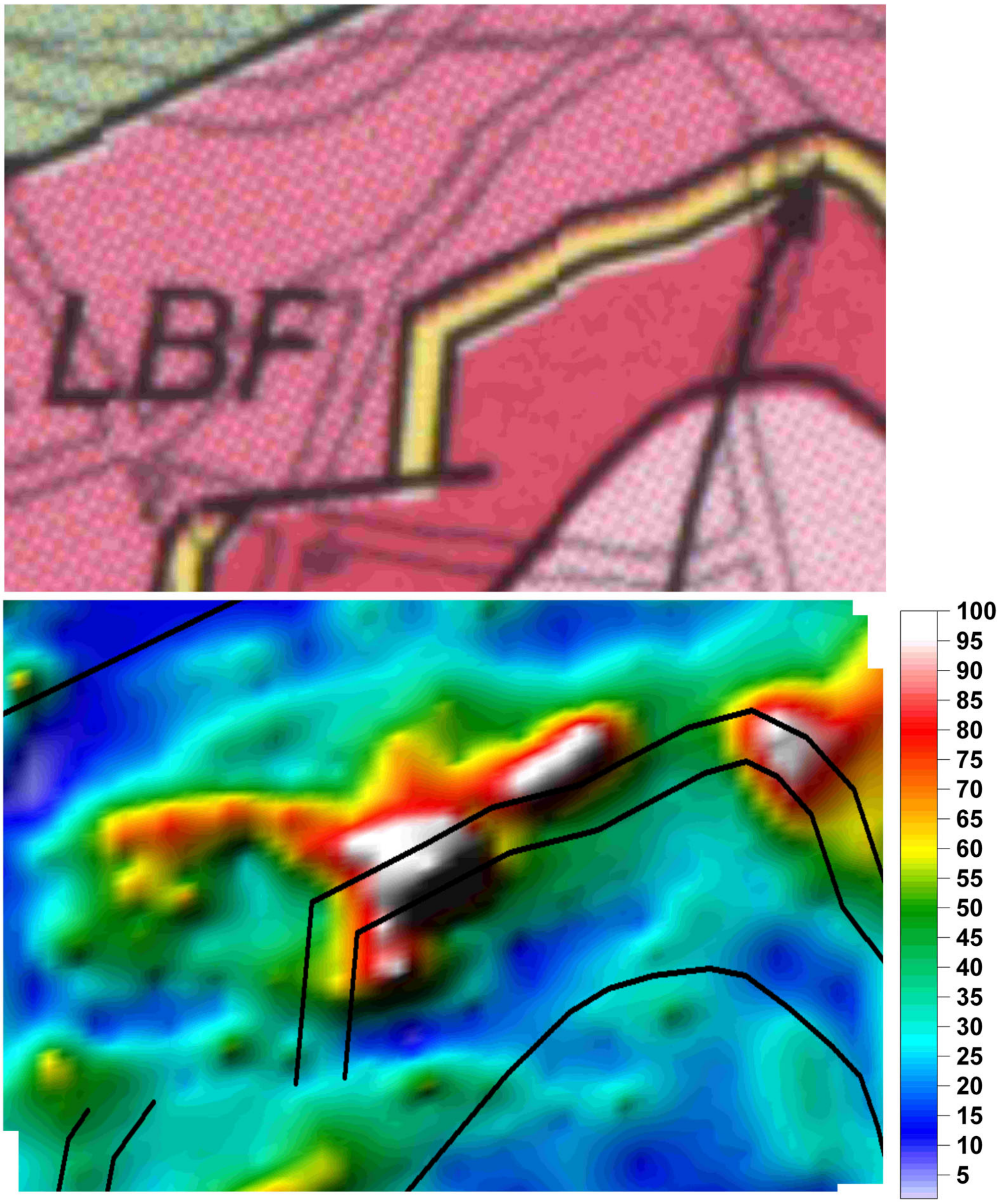


Figure 33. 1:250k geology (upper), 12 kHz apparent conductivity (mS/m) and solid geolines.

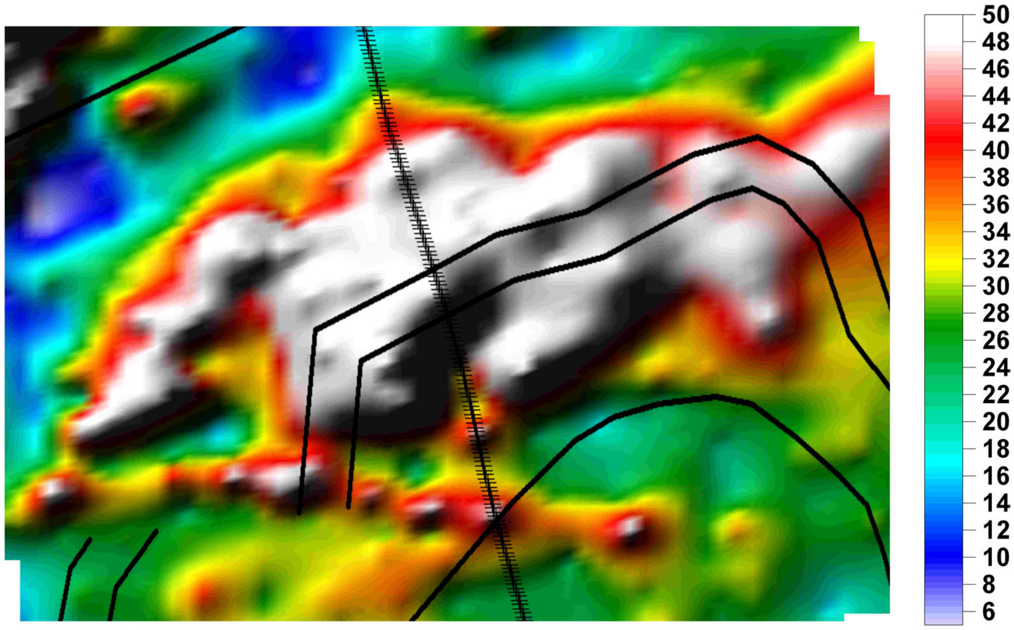


Figure 34. 3 kHz apparent conductivity (mS/m) and solid geolines. Symbols denote line 1228.

The spatial scale and amplitude of the anomaly is far too large to be associated with just anthropogenic activities. The study was extended to include a larger area (see below). A conductivity cross-section along Flight Line 1238 was first obtained.

The profile shown here uses flight line 1228 identified on the previous Figures. Flight elevations range from 40 to 69 m, there are no radiative effects detected by the PLM and data qualities appear good. The Occam inversion assumed a 2.5% noise level in all the channels. The inversion achieved chi-squared misfits close to the expectation level apart from across the central landfill site where lateral gradients appear strongest. The 2 km conductivity cross-section is shown in Figure 33.

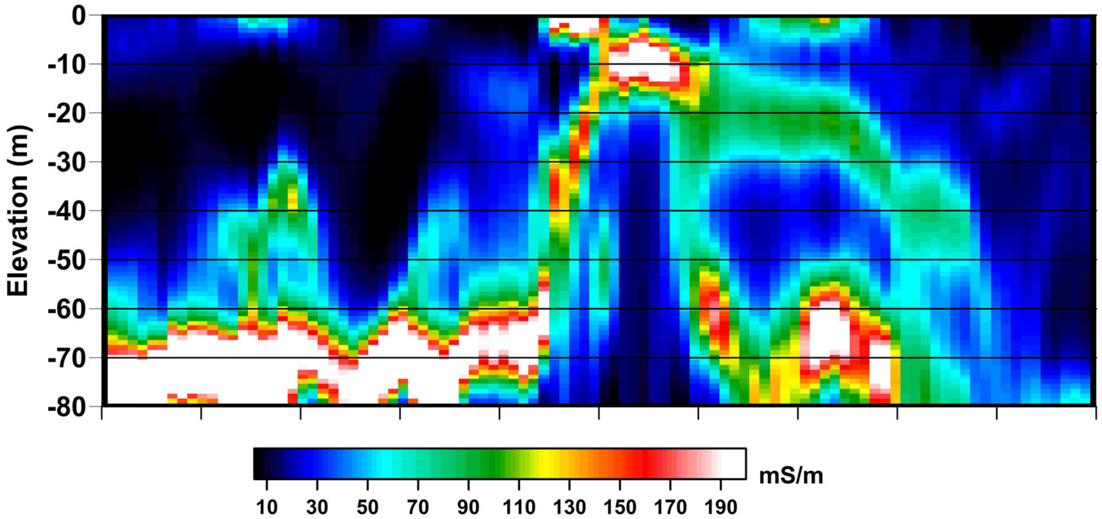


Figure 35. Conductivity cross-section along a 2 km section of flight line 1228, obtained by Occam inversion. Horizontal tick marks every 200 m.

It is perhaps worth pointing out that the large majority of landfills studied provide quite simple behaviours often confined to the near surface. This particular example displays complex, highly conductive pathways suggesting links between the near-surface and much deeper conductive units. The amplitudes (> 500 mS) and implied volumes of the deeper conductor suggest a natural, rather than artificial, source. It should also be noted that the thickness of the deep conductor is largely a modelling artefact; the conductive unit is effectively indistinguishable from a lower conductive half-space.

The site is about 2.25 km from the coast and is situated within the Antrim basalt formations (Lower and Interbasaltic Formations). Part of the sequence comprises massive columnar basalts, as typified by the Giant's Causeway, on the coast nearby. Joints and pipe vesicles are a feature of the geological setting. It is possible that the deeper conductive units represent pockets of deep, inland conductive brines. Their continuity coastwards is not, however, confirmed using the regional scale data (see below)

The detailed 3 x 2 km study was extended to a larger area (7 x 7 km) shown below.

Figure 36. Location map of 7 x 7 km extended area, with landfill symbols. Area is defined by 285,435 292,442.

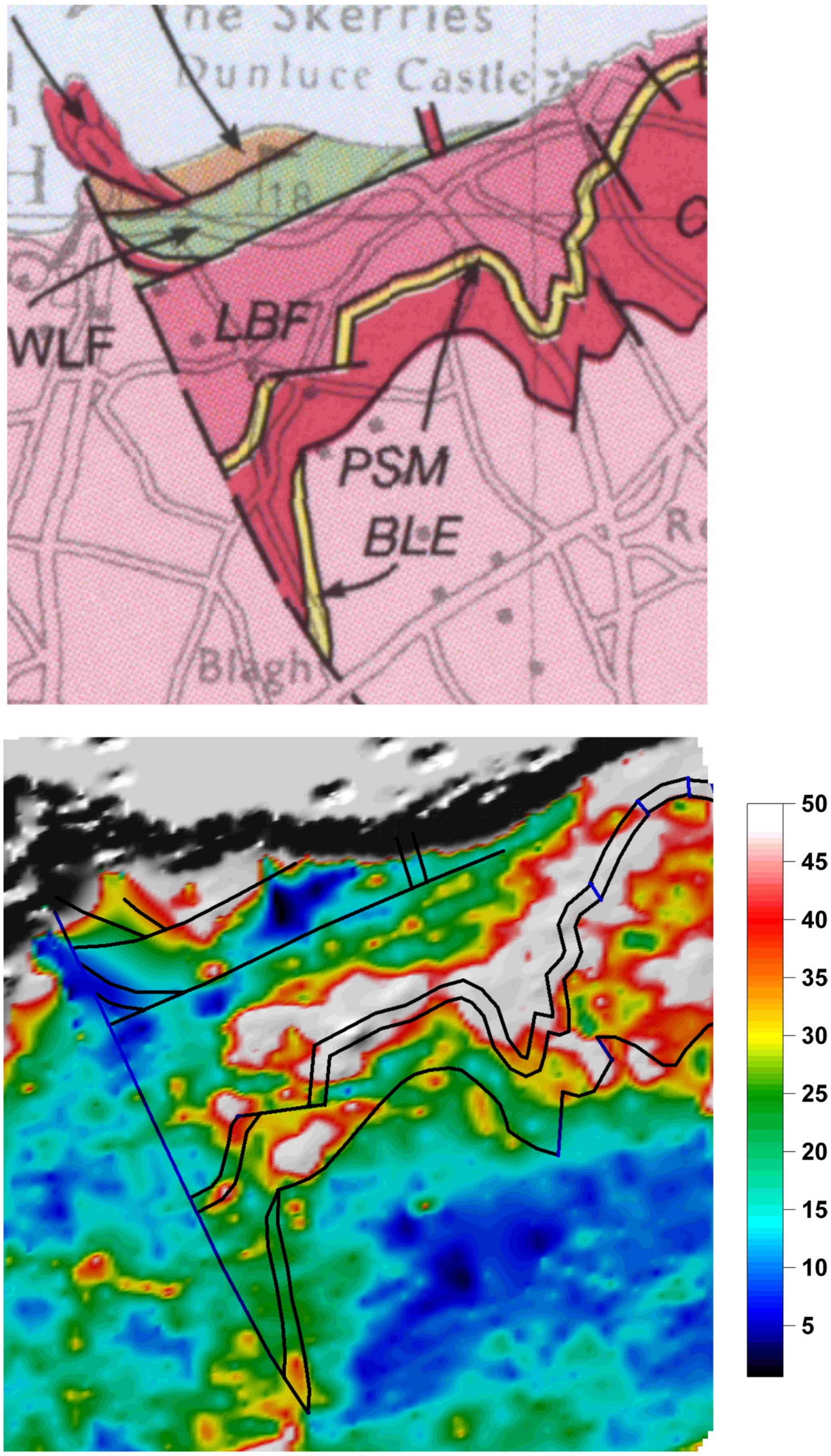


Figure 37. 7x 7 km area. 1:250k solid geology (upper). 12 kHz apparent conductivity (mS/m) with solid and fault contact geolines.

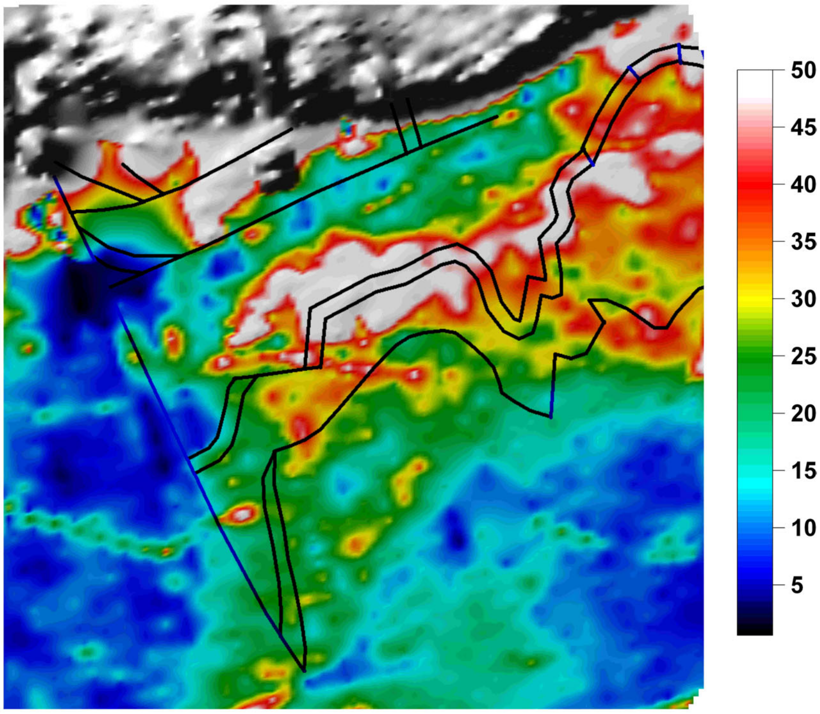


Figure 38. 3 kHz apparent conductivity (mS/m) with solid and fault contact geolines.

Regional scale variations observed across wider 7 x 7 km area, and the coastal location imply inland saline conditions. They appear to be, at least in part, geologically and fault controlled. A local scale landfill/quarry study would be unsafe unless an understanding of regional scale variations can be achieved.

10 Material Reprocessing Centre 92

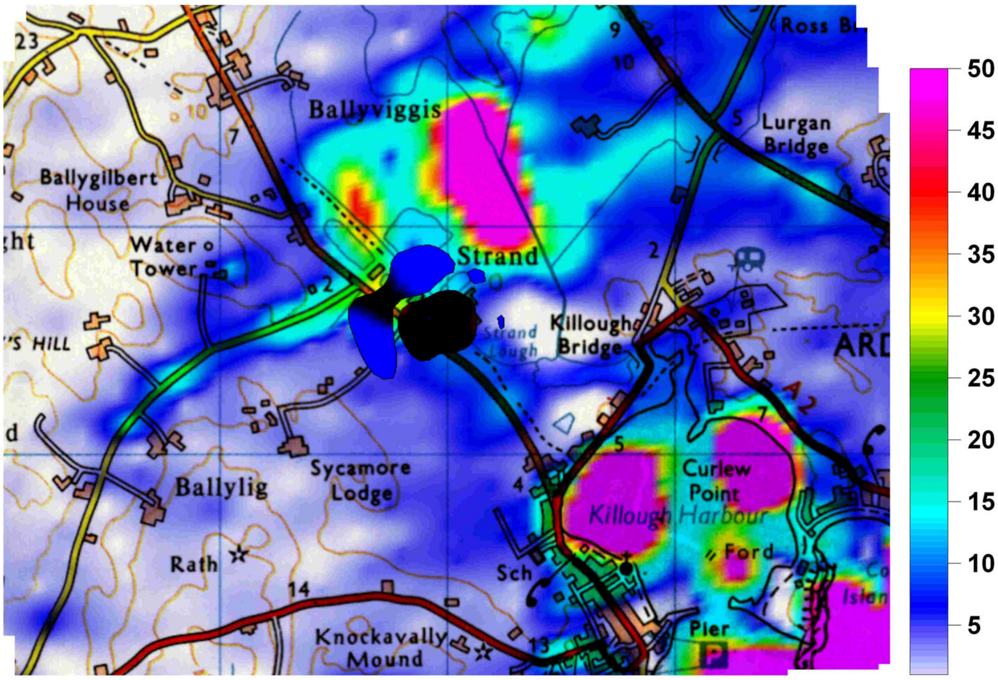
The location is identified in the LF database as site 92 and noted as being a materials processing centre. Since a conductive anomaly was apparent, the site was included in the study. The initial study area is 4 x 3 km. The grid coordinates are BLHC = 351000, 336000 and TRHC = 355000, 339000 m. The initial study is summarised below. The results include the 3 kHz apparent conductivity and main magnetic anomaly, centred on the works. A coastal anomaly associated with the local harbour (seawater/freshwater mixing?) is also apparent.

MATERIAL REPROCESSING (92)

4 x 3 km 3kHz Apparent Conductivity (mS/m)

Large scale conductive anomaly adjacent to site location

Magnetic anomaly (blue/black solid contour) centred on site location



Freshwater/seawater mixing in harbour

Figure 39. 3kHz apparent conductivity on 1:50 k map. Magnetic anomaly centred on site location shown in blue/black infilled contours.

A more detailed study was undertaken across the central 2 x2 km area defined by 35200,337000 and 354000,339000 m.

Figure 40. Location of 2 x 2 km area.

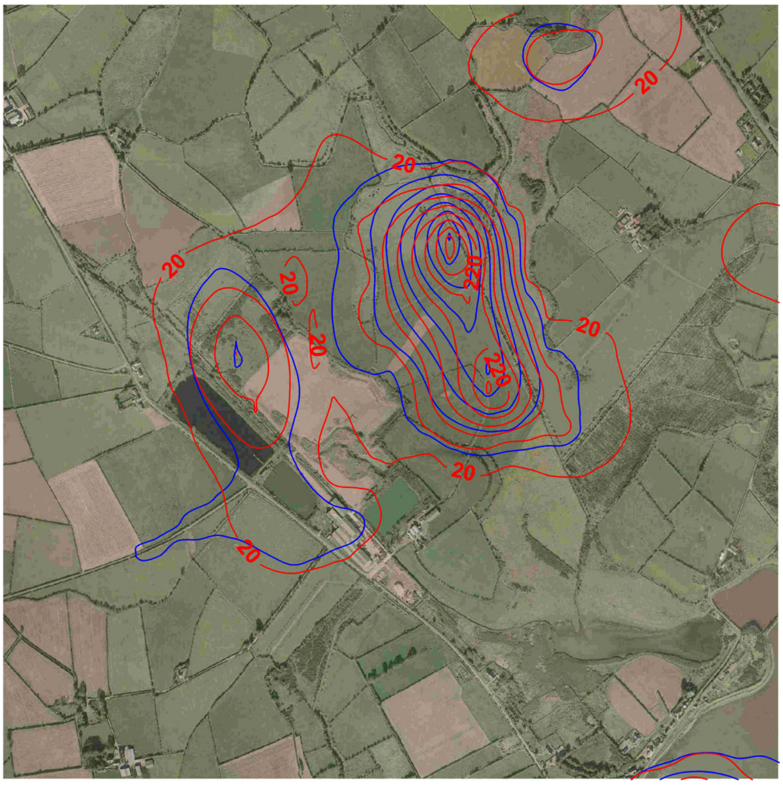


Figure 41. 3kHz apparent conductivity (mS/m) in blue contours. (> 20 mS/m). 12kHz apparent conductivity (mS/m) in red contours. (> 20 mS/m). Both on aerial image.

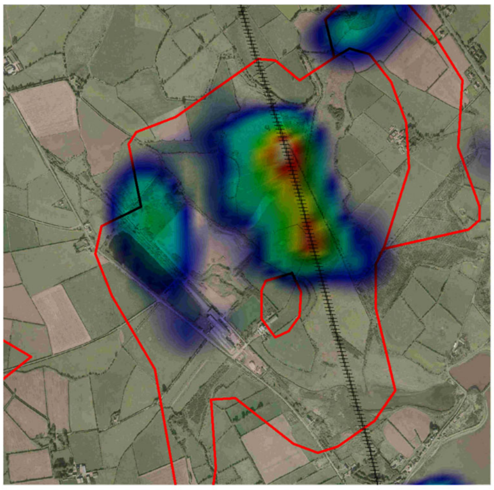


Figure 42. 12 kHz apparent conductivity and superficial geolines (red) on aerial image. Location of flight line 3420 shown with symbols.

A conductivity cross-section was obtained across the 2 km length of flight line 3420 shown above.

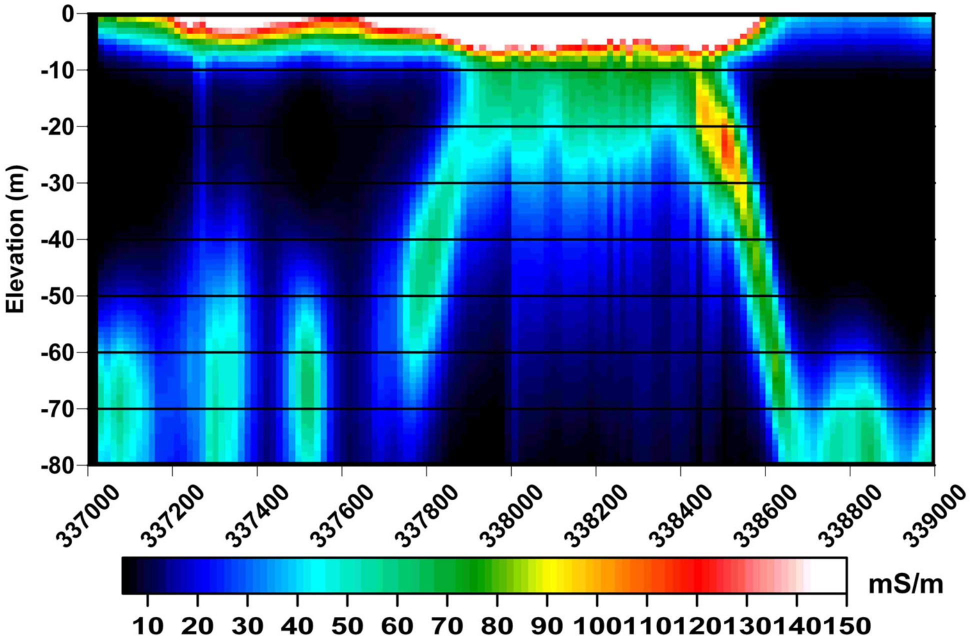


Figure 43. Conductivity cross-section along a 2 km section of flight line 4320, obtained by Occam inversion. Horizontal tick marks every 200 m.

The termination of the semi-continuous, at-surface conductive feature in the north displays a close association with the closure of mapped superficial deposits. The materials are remarkably conductive and probably screen/mask any deeper variations. A shallow-to-deep conductive feature appears in the north. The geometry appears artificial.

The 1D models across the 2 x 2 km area were stitched together and visualised. The conductivity distribution, at the surface (and below) is no longer subject to the assumption of a half-space. The figure below shows the at-surface (0 to 4 m) distribution of conductivity using this approach.

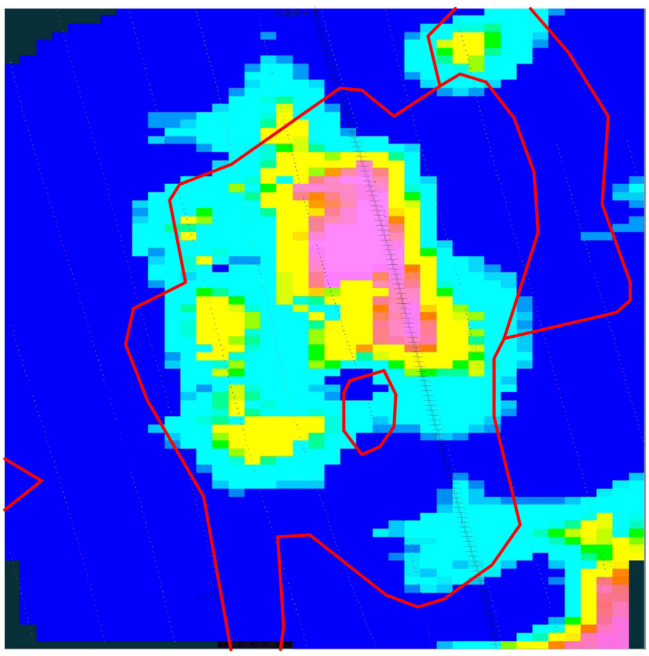


Figure 44. Near-surface (0 to 4 m) conductivity model and superficial geolines (red). Pink values exceed 500 mS/m. Location of flight line 3420 shown with symbols.

The model conductivity volume can also be inspected in 3D. The perspective images below show the same a conductivity isovolume of 60 mS/m across the area below a depth of 4 m. The model is shown to a depth of 76 m. A coastal zone effect is observed in the SE corner. The descending conductivity zone in the north, as noted above, is observed. Two other conductive zones show a spatial coincidence with a road and the works area and thus may represent artificial distortions.

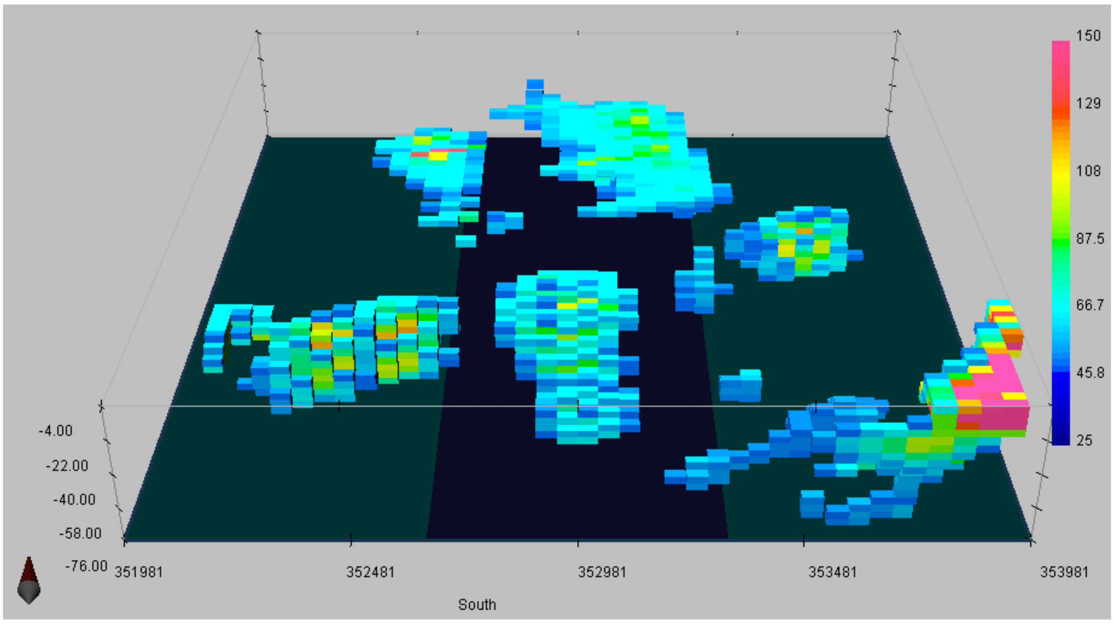


Figure 45. 2x 2 km conductivity isovolume (> 60 mS/m), depths from 4 to 76 m. 3D perspective view. View from above, south to north.

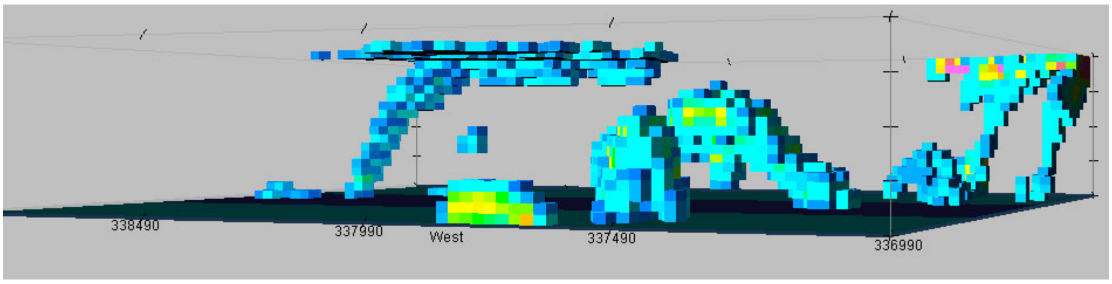


Figure 46. 2x 2 km conductivity isovolume (> 60 mS/m), depths from 4 to 76 m. 3D perspective view. Oblique view.

11 Belfast Hills

The location is not identified in the LF database. The initial study area is 4 x 4 km. The grid coordinates are BLHC = 329000, 378000 and TRHC = 333000, 382000 m. No details of the site were provided. Due to high conditions in the environs of Belfast, the main EM study area was restricted using the altitude condition: RALT< 120 m.

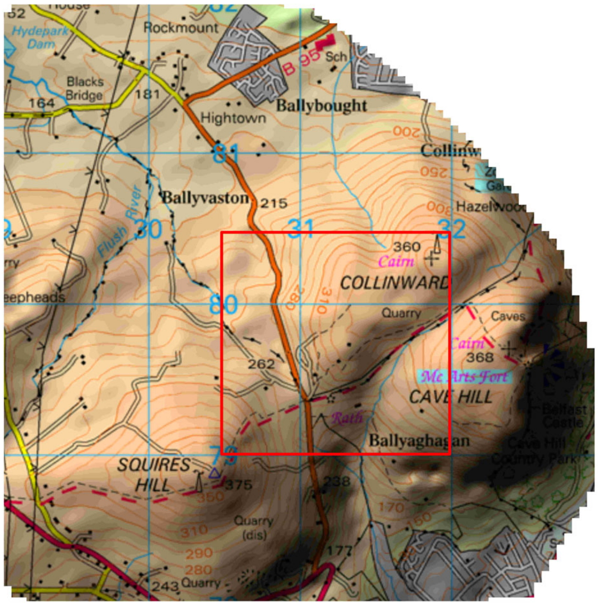


Figure 47. Belfast Hills, 4 x 4 km location map. Area clipped to zone with RALT < 120 m. 1.5 x 1.5 km area of conductivity model in red.

Figure 48. Belfast Hills, 4 x 4 km location map. Area clipped to zone with RALT < 120 m. 1:50k topographic map on DTM. Landfill location shown with symbol. Flight line shown.

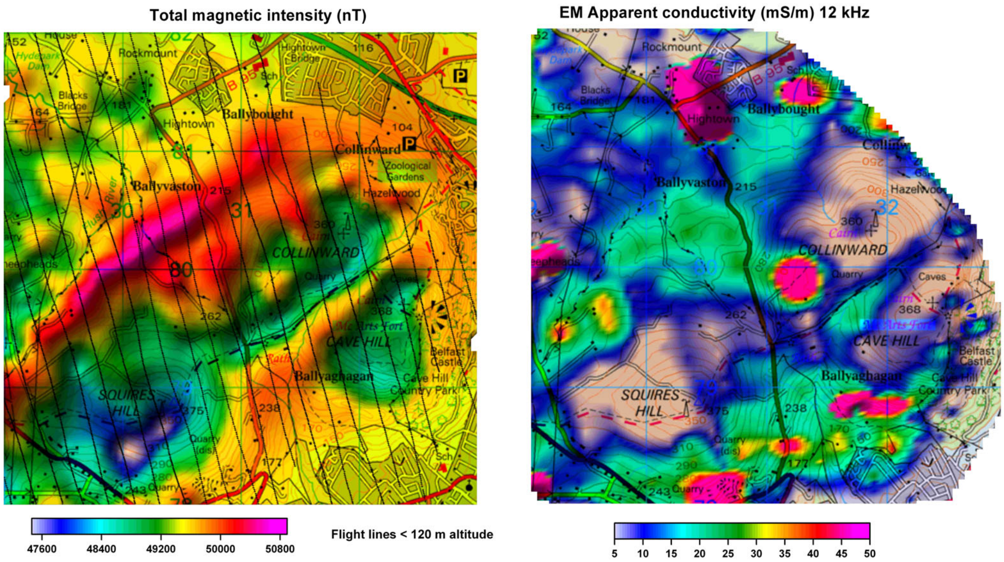


Figure 49. LEFT: Magnetic Total Intensity on 50k OS map. Flight lines shown. RIGHT: 12kHz apparent conductivity (mS/m).

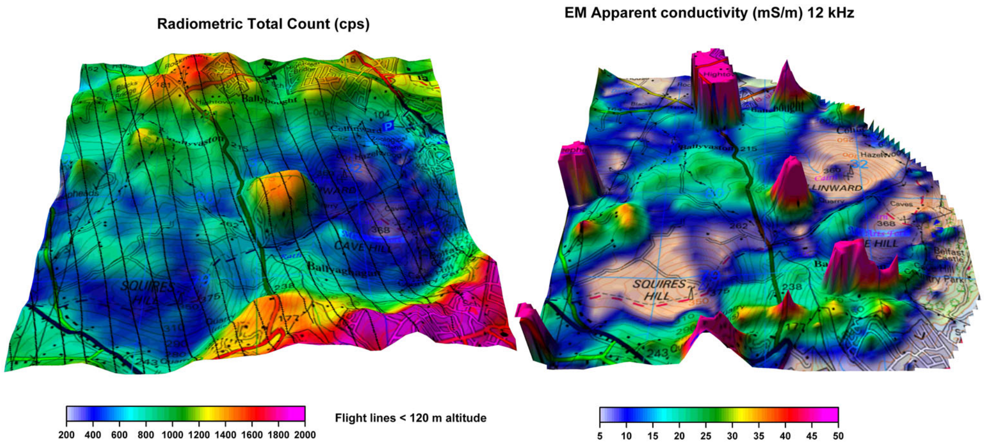


Figure 50. 3D perspective views of data. LEFT: Radiometric Total Intensity (cps) on 50k OS map. Flight lines shown. RIGHT: 12kHz apparent conductivity (mS/m). Values clipped to 100 mS/m due to cultural interference.

A more detailed investigation across the central 1.5 x 1.5 km area, centred on the location of the landfill was undertaken.

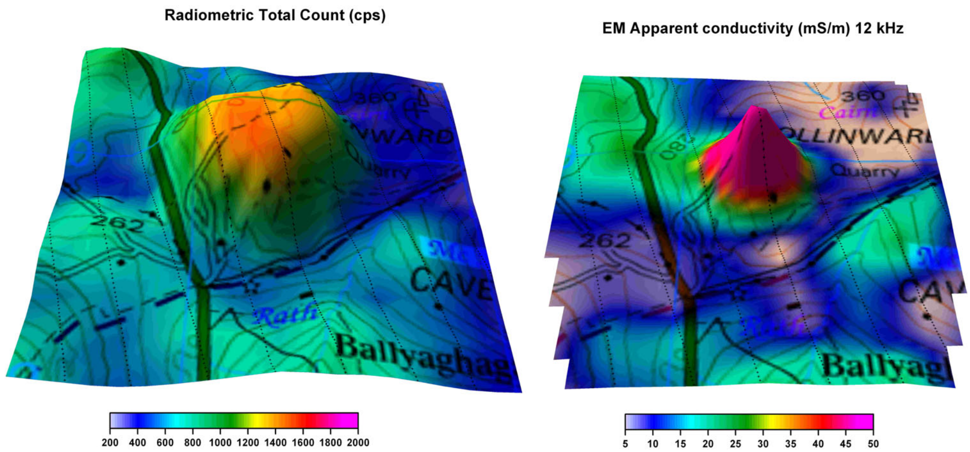


Figure 51. 3D perspective views of data across central 1.5 x 1.5 km area. LEFT: Radiometric Total Intensity (cps) on 50k OS map. Flight lines shown. RIGHT: 12kHz apparent conductivity (mS/m).

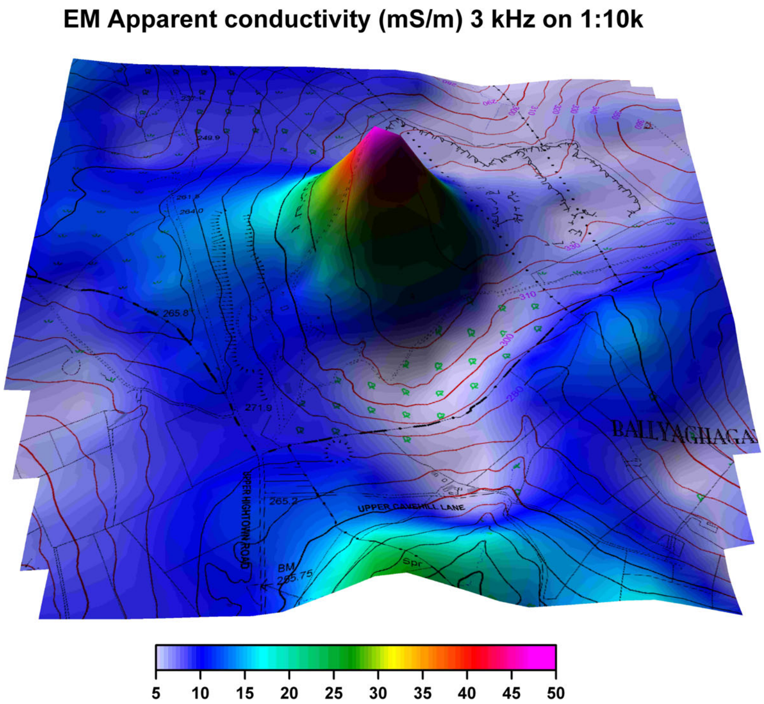


Figure 52. 3D perspective view of 3kHz apparent conductivity (mS/m) on background 1:10k topographic map.

1D conductivity models, obtained by Occam inversion, across the 1.5 x 1.5 km area were stitched together and visualised. Figure 50 shows a 3D perspective plan view of the conductivity distribution across a volume of 1.5 x 1.5 km x 75 m. The red volume defines an isosurface of 60 mS. This identifies the most conductive elements of the subsurface. Flight lines are shown with coloured symbols representing model misfit (blue=low, red=high).

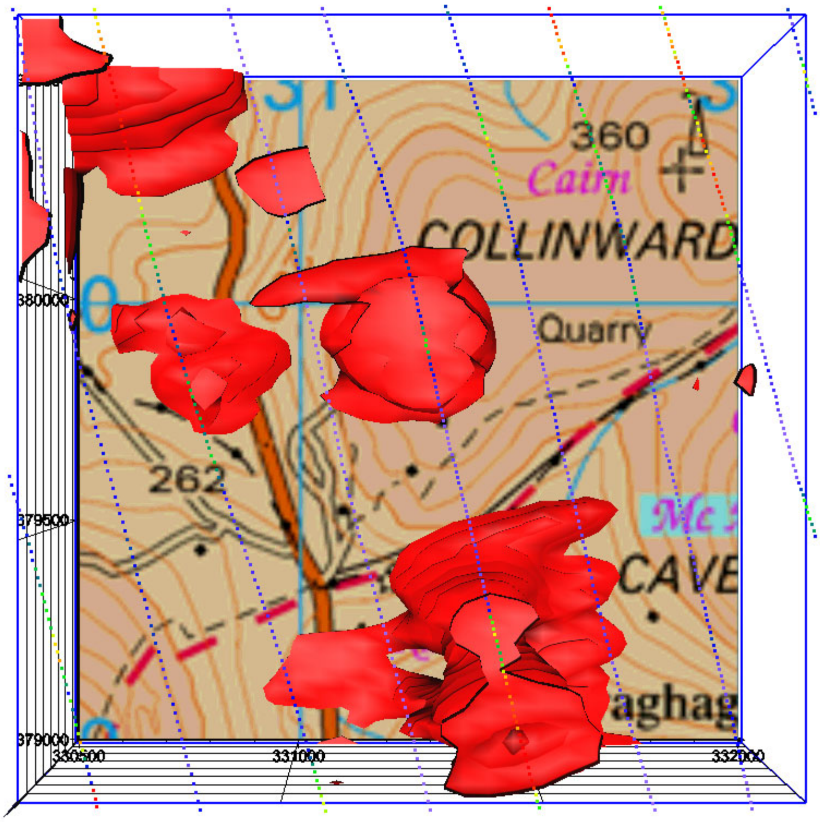


Figure 53. 3D perspective plan view of the conductivity distribution across a volume of 1.5 x 1.5 km x 75 m. The red volume defines an isosurface of 60 mS. This identifies the most conductive elements of the subsurface. Flight lines are shown with coloured symbols representing model misfit (blue=low, red=high).

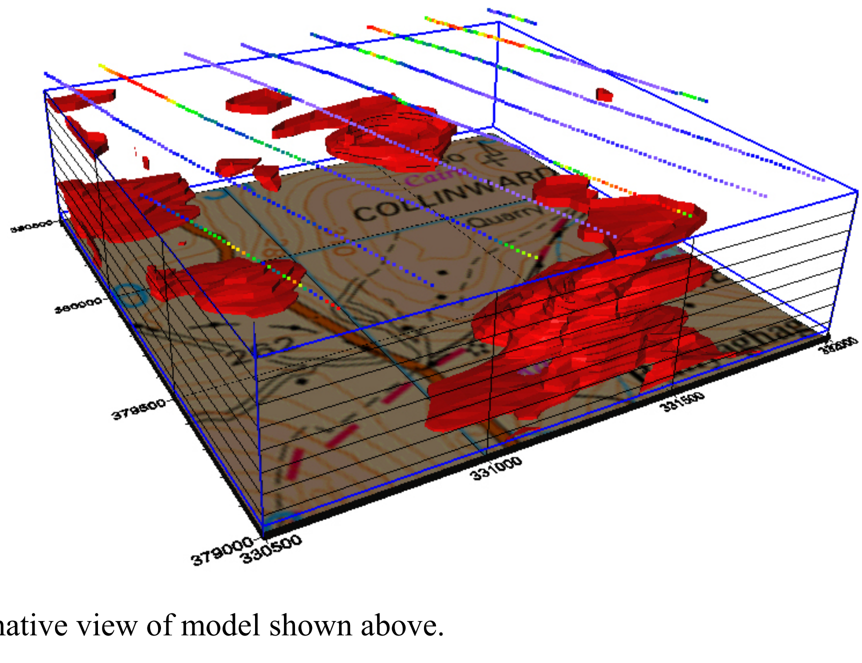


Figure 54. Alternative view of model shown above.

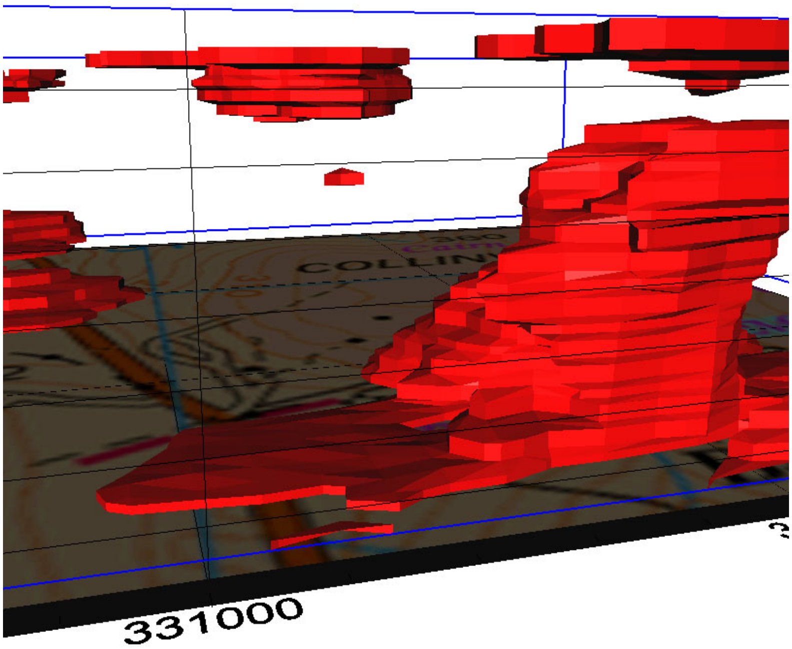


Figure 55. Alternative view of model shown above.

The model defines the central landfill as a vertically compact conductive feature. The causes of the other conductive features, particular the extensive subsurface anomaly in the south of the area have not been investigated.

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Appendix 1

Subset of the landfill coordinate database used in the study. It is assumed that the coordinates are Irish National Grid.

X	Y	COMMENTS	ID
223645.2	344606.1	Needs identified	1
241672.7	411308.8	Landfill Site	6
242949.7	417885.3	Needs identified	7
247923	423936.8	Landfill Site	11
248017.1	419379	Landfill Site	12
248096.6	412923.7	Landfill Site	13
249508.4	414546.4	Landfill Site	14
266354.8	425030.9	Landfill Site	16
283885.5	342184.5	Needs identified	18
284623.5	438173.9	Landfill Site	19
286112.7	350043.5		21
288275.9	438726.7	Landfill Site	25
289271.4	439364.5	Landfill Site For Inert Waste	26
291456.7	380485.8	Needs identified	27
294572	345498.6	Landfill Site	28
298375.8	351036.4	Needs identified	31
302338.5	356175.5	Needs identified	34
303551.8	344718.1	Landfill Site	37
306943.2	350899.8	Landfill Site	39
308035.8	355137.7	Needs identified	40
308473.7	357875.6	Needs identified	41
311556.5	396070.4	Landfill Site	44
315700.2	378028.3	Needs identified	46
316324.9	388485.7	Needs identified	47
317613.2	386797.2	Special Waste Transfer Station	48
318966.4	356233.6	Waste oil Recycling Facility	49
324340	368273.1	Landfill Site	50
325323.6	370430.1	Landfill Site	51
326204	370154	Needs identified	52
326737.5	372599.5	Landfill Site	53
328070	372437.7	Transfer Station	64
331773.1	373553.5	Recycling & Processing	56

332236.4	372646.7	Landfill Site	58
333600.3	376529.6		60
334747	376821.5	Landfill Site	65
334925.2	378581.5	Needs identified	66
335546.7	364122.8	Landfill Site	67
335745.5	398277.4	Landfill Site	68
336310.9	375580.6	Special Waste Transfer Station	71
338107.2	370934.2	Landfill Site	72
338355.6	370832.8	Needs identified	73
339621.7	388478.5	Landfill Site	74
339772.6	371873.4	Landfill Site	75
340079.1	388037.9	Landfill Site	76
343147.9	389307.8	Landfill Site	79
343192	393994.8	Landfill site	80
343440.4	398611.1	Landfill Site	81
343847.8	388704.5	Landfill Site	83
344996.8	389836.9	Landfill Site	84
345260.5	390310.8	Landfill Site	85
346606.9	391990.5	Landfill Site	86
347270.5	399422		87
349237.9	375144.4	Landfill Site	89
349345.8	340957	Landfill Site	90
351767.5	374871.6	Needs Identified	91
352878.7	337613.1	Materials Recovery Facility & Transfer Station	92
354360.6	375584.9	Landfill Site	93