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W0047-02

KERDIFFSTOWN LANDFILL

REPORT

ON THE

GEOPHYSICAL SURVEY

FOR

THE EPA

21st September 2010

PRIVATE AND CONFIDENTIAL

THE FINDINGS OF THIS REPORT ARE THE RESULT OF A GEOPHYSICAL SURVEY USING NON-INVASIVE SURVEY TECHNIQUES CARRIED OUT AT THE GROUND SURFACE. INTERPRETATIONS CONTAINED IN THIS REPORT ARE DERIVED FROM A KNOWLEDGE OF THE GROUND CONDITIONS, THE GEOPHYSICAL RESPONSES OF GROUND MATERIALS AND THE EXPERIENCE OF THE AUTHOR. APEX GEOSERVICES LTD. HAS PREPARED THIS REPORT IN LINE WITH BEST CURRENT PRACTICE AND WITH ALL REASONABLE SKILL, CARE AND DILIGENCE IN CONSIDERATION OF THE LIMITS IMPOSED BY THE SURVEY TECHNIQUES USED AND THE RESOURCES DEVOTED TO IT BY AGREEMENT WITH THE CLIENT. THE INTERPRETATIVE BASIS OF THE CONCLUSIONS CONTAINED IN THIS REPORT SHOULD BE TAKEN INTO ACCOUNT IN ANY FUTURE USE OF THIS REPORT.

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1. Executive Summary

- APEX Geoservices Ltd. was requested by the Environmental Protection Agency (EPA) to carry out a geophysical survey at Kerdiffstown Landfill (Licence no. W0047-02) in Co. Kildare to investigate for possible leachate emanating from the site. Kerdiffstown Landfill is located 2 km south-east of Sallins and 1.5 km north-west of Naas. The landfill covers an area of approximately 55 Ha and is the site of a former commercial sand and gravel extraction operation.

- West, northwest and south of the landfill the seismic and resistivity data indicates that the upper 1.6m comprises silt/clay and sandy gravelly silt/clay overlying an average of 18.8m of sand and gravel, and silty clayey sand and gravel, overlying bedrock.

- East and northeast of the landfill the seismic and resistivity data indicates that the upper 1.5m comprises alluvium, silt/clay and sandy gravelly silt/clay overlying an average of 7.4m of silt/clay and sandy gravelly silt/clay, overlying bedrock.

- The seismic and resistivity data indicates that the bedrock comprises mudstone, shale and argillaceous limestone. East and northeast of the landfill the rock levels generally range from 75 to 78mOD. South and west of landfill the rock levels generally range from 71 to 75mOD.

- The geophysical survey outlined five anomalous areas around the perimeter of the site. Of the five areas three were recommended for direct investigation by drilling, and two were drilled by the client.

- The follow-up ground investigation in the first area, within the grounds of Kerdiffstown House, encountered leachate emanating from the landfill as suggested by the elevated conductivity and decreased resistivity values recorded. The rotary core results in this area also provide some evidence for a bedrock channel as suggested by the geophysics.

- The follow-up ground investigation in the second area along Johnstown Road showed that the anomalous feature identified in the resistivity data is not due to the presence of leachate in the subsurface. It can therefore be concluded that the anomaly must be due to a service such as a cast iron main running inside the site boundary and close to the road.

- The geophysical survey has provided screening for leachate emanation around a large part of the site perimeter to a depth of investigation of 25m. It has shown that there is subsurface movement of leachate to the east towards the river, through the grounds of Kerdiffstown House.

2. Introduction

APEX Geoservices Ltd. was requested by the Environmental Protection Agency (EPA) to carry out a geophysical survey at Kerdiffstown Landfill (Licence no. W0047-02) in Co. Kildare.

Kerdiffstown Landfill is located 2 km south-east of Sallins and 1.5 km north-west of Naas. The landfill covers an area of approximately 55 Ha and is the site of a former gravel pit at which commercial sand and gravel extraction took place.

2.1 Project Objectives

The objective of the survey at the Kerdiffstown Landfill site was to investigate for any possible leachate emanating from the site.

2.2 Site Background

The Geological Survey of Ireland (GSI) geological map for the area indicates that Kerdiffstown Landfill site is predominantly underlain by Ballysteen Formation dark muddy limestone and shale with a small area of Waulsortian Limestone underlying the northwest of the landfill. The GSI aquifer map for the area describes the Ballysteen Formation as a "Locally Important Aquifer - bedrock which is moderately productive only in local zones".

The GSI Teagasc Subsoils Map maps the soil type across the site as Limestone sands and gravels (Carboniferous). The map also indicates alluvial deposits along the northeastern boundary of the landfill and south of the landfill. Made ground has been mapped north of the landfill.

The GSI aquifer map for the area describes the sands and gravels as a "Locally Important Sand & Gravel Aquifer". The GSI vulnerability map for the area classifies the sand and gravel aquifer vulnerability as "High" with some "Low" to "Moderate" vulnerability northeast and south of the landfill.

2.3 Survey Rationale

The following techniques have been employed to achieve the objectives of the survey:

- EM31 ground conductivity mapping has been carried out in the areas adjacent to the landfill in order to investigate the presence of any shallow leachate plume.
- Twelve resistivity profiles have been carried out around the perimeter of the landfill to investigate variations in sub-surface material types including the presence of leachate.
- Eight seismic refraction profiles have been carried out along selected resistivity profiles. The results of the seismic survey have been used to outline the overburden stratigraphy and the depth to bedrock.
- 4 GPR lines were recorded at 1m intervals over a 64m distance along the Kerdiffstown Road to investigate the presence of buried services. A Cable Avoidance Tool (CAT) survey consisting of passive mode sweeps was taken along the GPR profiles.

2.4 Follow-Up Site Investigation

In May 2010 seven shell and auger and one rotary borehole were sunk within the grounds of Kerdiffstown House and two rotary boreholes were cored along the verge of the Johnstown Road in the. The locations are indicated on Drawing 10083_01: Figure 3.

The results of these boreholes and accompanying lab testing have been summarised on the geophysical sections and are discussed in Section 3.4 of this report.

3. Results

The geophysics have been recorded in accessible locations around the perimeter of the landfill. The survey was carried out on the 11th, 12th, 16th and 19th March 2010.

3.1 EM31 Electromagnetic Conductivity Mapping

The EM31 conductivity survey locations are shown on Drawing 10083_ 01: Figure 1. The recorded EM31 conductivity values are contoured on Drawing 10083_01: Figure 2. The conductivity values ranged from 13-34 milliSiemens/metre (mS/m).

The conductivity values have been interpreted as follows:

Conductivity (mS/m)	Interpretation
13 - 20	Gravelly material in upper 6m
20 - 24	Alluvial material in upper 6m
24 - 34	Possible surface water/leachate. Also reworked soils (golf course)

3.2 2D Resistivity Profiling

Twelve resistivity profiles were recorded at accessible locations around the perimeter of the landfill. The locations are indicated on Drawing 10083_01: Figure 1. Interpreted cross sections were compiled for the 2D resistivity profiles and are presented on Drawing 10083_01: Figure 4.

Typical resistivities of Irish overburden deposits as experienced by the author range from 20 ohm-m for in-situ pure clay to around 3000 Ohm-m for clean dry gravel, with the resistivity generally increasing as the sand/gravel content increases. Silty clay typically has values in the range 30-50 Ohm-m and silty gravelly clay typically has resistivity values in the range 50-100 Ohm-m. Excavation and re-working of soils usually lowers their resistivity value.

Deposits of predominantly organic waste such as those occurring in municipal landfills typically have resistivities in the range 5-30 Ohm-m. Leachate saturated soils originating from predominantly organic waste would have a similar resistivity range to organic waste but will be influenced by the resistivities of the host material and the degree of dilution and dispersion of the leachate. Inert C & D waste such as concrete, brick and mixed stone and clay will have resistivities similar to gravelly material (50-500 Ohm-m).

The resistivity values recorded at this site have been interpreted as follows:

Resistivity (Ohm-m)	Interpretation
15-30	Possible leachate, Reworked soils, Interference from services
30-50	ALLUVIUM/ SILT/CLAY
50-100	Gravelly SILT/CLAY
100-250	Sandy gravelly SILT/CLAY
250-1000	Silty/clayey SAND/GRAVEL
1000-1500	SAND/GRAVEL
10-320	Mudstone/Shale
320-1500	Argillaceous Limestone

Localised occurrences of lower expected resistivity values may be associated with diluted leachate and these have been highlighted where considered relevant.

3.3 Seismic Refraction Profiling

Eight seismic refraction profiles were recorded along 2D resistivity profiles R1-R6 (S1-S6 respectively) and R9 (S7) and R12 (S8). The locations are indicated on Drawing 10083_01: Figure 1 and the results are included on the interpreted cross sections in Drawing 1083_01: Figure 4.

The seismic velocities have been interpreted as follows:

Layer	Velocity (m/s)	Average Velocity (m/s)	Interpretation
1	189-451	314	Soft-Firm/Loose-Medium Dense Overburden
2	504-1145	745	Firm-Stiff/ Medium Dense-Dense Overburden
3	1163-2113	1598	Stiff-Very Stiff/ Dense-Very Dense Overburden
4	2268-4933	3321	Slightly Weathered to Fresh Rock

3.4 Integrated Geophysical Interpretation

The geophysical data were integrated and the geological interpretation is contained on the summary map in Drawing 10083_01: Figure 3 and the interpreted cross sections in Drawing 1083_01: Figure 4.

West, northwest and south of the landfill the seismic data indicates that the upper 1.6m comprises firm to stiff silt/clay and sandy gravelly silt/clay overlying an average of 18.8m of medium dense to dense to very dense sand and gravel, and silty clayey sand and gravel overlying bedrock.

East and northeast of the landfill the seismic data indicates that the upper 1.5m comprises firm to stiff alluvium, silt/clay and sandy gravelly silt/clay overlying an average of 7.4m of stiff to very stiff silt/clay and sandy gravelly silt/clay overlying bedrock.

The resistivity data indicates that the bedrock comprises both low resistivity mudstone and shale and higher resistivity argillaceous limestone. East and northeast of the landfill the rock levels generally range from 75 to 78mOD. South and west of the landfill the rock levels generally range from 71 to 75mOD.

Five anomalous features were identified in the geophysical data:

1. There is a small area of elevated EM31 conductivities half way along the northern boundary of the landfill at the break in slope where the gravel deposits meet the alluvial deposits. Profile R6 was recorded across these elevated values and there is a slight decrease in resistivity at this point. These elevated conductivities are therefore likely to indicate emerging groundwater (spring) and/or diluted leachate at the surface. Beneath the gravels in this area lower resistivity values were interpreted as mudstone/shale bedrock but may also indicate a channel in the bedrock. A monitoring well was recommended in this area in Draft 01 of this report.

   Follow-up investigation
   Cable percussive boreholes W0047EMW01, W0047EMW02 and W0047EMW04 to W0047EMW08 and rotary percussive W0047EMW03 were sunk within the grounds of Kerdiffstown House. The cable percussive holes were drilled to depths ranging from 5m to 7.3m and generally encountered clayey/gravelly sand with some sandy gravel and sandy gravelly clay. Borehole W0047EMW01 encountered up to 1m of made ground comprising sandy gravelly clay. Seepage was noted at 3m bgl in W0047EMW05. Rotary percussive W0047EMW03 was drilled to 17.5m bgl and encountered sandy predominantly sandy gravelly clay with some clayey/gravelly sand and sandy gravel lenses which supports the possible bedrock channel feature referred to above.

The electrical conductivity of the groundwater in the boreholes ranged from 1490-2510 uS/cm for the boreholes located closest to the perimeter of the landfill (EMW3,4,6 and 7) and from 597-1020 uS/cm for the boreholes further away in the direction of the river (EMW2,5 and 8). This confirms that the elevated EM31 conductivities and decreased resistivities observed on the geophysical survey are associated with leachate emanating from the landfill.

2. North of the landfill Profile R4 was affected by interference from a likely buried service in the vicinity of the golf course toilet block. An additional profile (R10) was recorded parallel to R4 but slightly further north, and the interference was shown to be absent. No further investigation was recommended in this area.

3. On the Johnstown road south of the landfill there were anomalously low resistivities where R1 and R2 overlapped. These anomalous values were thought to result from interference by a buried service or to indicate a leachate plume in the clayey sands and gravels.

   No accessible locations were available to record an additional step out resistivity profile to further investigate these anomalies on R1 and R2. A follow-up service inspection was conducted to determine if any services were present. Service maps were obtained from ESB, Bord Gais, Eircom and Kildare County Council. In addition a CAT survey and GPR profiles were conducted.

   The service inspection indicated a 3 inch asbestos cement watermain running parallel to R1 and R2 on the opposite side of the road to the profiles. The GPR survey indicated a possible spur from this asbestos cement watermain crossing the road in the direction of the landfill site. It was not possible to track the spur beyond the boundary of the landfill. Pipes of this type would not normally be expected to affect the electrical resistivity values to the extent shown.

   Also in the vicinity an overhead Eircom line is located along the southern side of Kerdiffstown Road. Again this would not normally be expected to affect the electrical resistivity survey.

   The absence of any conclusive evidence of interference from services therefore left open the possibility that the anomalously low resistivities were due to leachate in the clayey sands and gravels. A monitoring well was therefore recommended in this area in Draft 01 of this report.

   Follow-up investigation
   Rotary percussive boreholes W0047EMW09 and W0047EMW10 were drilled at a 50m separation along the road. They encountered up to 13m of slightly clayey/gravelly sand over sandy gravel. W0047EMW09 encountered bedrock or boulders at 19m bgl. W0047 EMW10 was drilled to 20.5m bgl without encountering bedrock or boulders. Both boreholes were dry and there was no indication of leachate in either borehole.

   The anomalously low resistivities observed on R1 and R2 must therefore be associated with a linear metallic service, such as a cast iron main, running inside the site boundary and close to the road. This should be confirmed if access is obtained to the site in the future.

4. Some lower resistivities were recorded at depths between 5 and 10m below ground level on profiles R3 and R9. These lower resistivites were interpreted as indicating gravelly silt/clay but may indicate a low concentration of leachate. The most significant of these was listed for investigation with a monitoring well in Draft 01 of this report.

   Follow-up investigation
   No boreholes were drilled in this area on this occasion.

5. Elevated conductivities (>25mS/m) were recorded across parts of the golf course on the east of the river. These elevated values are associated with reworked soils caused by the landscaping which has increased the ground level on this side of the river. Transport and reworking of clayey or alluvial soils generally tends to decrease their electrical resistivity due to compaction of the soil structure and retention of water. There is no continuity between these elevated conductivities and those recorded on the south-west bank of the river and they therefore do not result from any possible leachate contamination from the landfill. No further investigation was recommended in this area.

4. Conclusions

The geophysical survey outlined five anomalous areas around the perimeter of the site. Of the five areas, three were recommended for direct investigation by drilling, and two were drilled by the client.

The follow-up ground investigation within the grounds of Kerdiffstown House encountered leachate in this area emanating from the landfill as suggested by the elevated conductivity and decreased resistivity values recorded.

The follow-up ground investigation along Johnstown Road shows no evidence that the anomalous feature identified in the resistivity data is associated with the presence of leachate in the subsurface. It is therefore very probable that the anomaly is due to a service such as a cast iron main running inside the site boundary and close to the road.

The survey has provided screening for leachate emanation around a large part of the site perimeter to a depth of investigation of 25m. It has shown that there is subsurface movement of leachate to the east towards the river, through the grounds of Kerdiffstown House.

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