Appendix G

Geology/Hydrogeology
RPS-MCOS Ltd

GEOLOGY & HYDROGEOLOGY OF PROPOSED EXTENSION AREA AT GORTADROMA LANDFILL

METHODOLOGY

This chapter examines the geology and hydrogeology of the proposed landfill extension area at Gortadroma Landfill. The likely significant impacts have been identified and measures have been proposed to mitigate these potential impacts.

The following guidance documents have been consulted in the preparation of this section on geology & hydrogeology:

- Geology In Environmental Impact Statements – A Guide. Institute of Geologists of Ireland (September, 2002).
- Advice Notes On Current Practice In The Preparation Of Environmental Impact Statements. Environmental Protection Agency (1996).
- Guidelines On the Information To Be Contained In Environmental Impact Statements. EPA (March, 2002).
- Groundwater Protection Schemes. Department of Environment and Local Government, Environmental Protection Agency and Geological Survey of Ireland (1999).

This report is based on a desk study. Information on the geology and hydrogeology of the area has been obtained from reports relating to site investigation work for the proposed extension area and for the existing landfill site. The reports which have been used in the desk study are as follows:

- An Foras Forbartha July 1987 Investigation of Proposed Landfill Site at Gortadroma.
- MCOS November 1994 Development Plan for Existing Landfill Site at Gortadroma West Limerick-Report to Limerick County Council (November 1994), MCOS.
- Geological, Geophysical & Hydrogeological Study of Gortadroma Landfill, Co. Limerick. B. J. Murphy & Associates (15th September, 1997).
- Geotech June 1998 Installation of gas monitoring points.
- Strategic Development Plan for Gortadroma Landfill (MCOS May 2001).
- Geotech October 2002 Site Investigation
- Geophysical Survey for Proposed extension to Gortadroma Landfill, Co. Limerick. BMA Geoservices (November 2002).
- Limerick County Council Quarterly Report On Environmental Monitoring at Gortadroma Landfill (Feb 1999 to February 2003).
- County Limerick Groundwater Protection Scheme Report (Geological Survey of Ireland, 1995).

BACKGROUND

Limerick County Council operate a licensed landfill facility at Gortadroma. The site is located approximately 8km south of the Shannon Estuary. The site is located approximately 12km north of Newcastle West, between the villages of Ardagh and Shanagolden. The initial portion of the landfill site was located within a partly worked out sand and gravel pit. Additional development has taken place at the site over the recent years resulting in the construction of additional lined cells. To date a total of 13 cells have been constructed at the landfill site.

An Environmental Impact Statement was submitted in September, 1997 for an earlier extension to the landfill site (Cells 7 – 13).

Limerick County Council propose to extend landfilling operations into the land adjacent to the east of the existing facility boundary. This geological and hydrogeological assessment relates to the proposed future extension area.

DESCRIPTION OF THE EXISTING ENVIRONMENT

TOPOGRAPHY, HYDROLOGY AND LAND USE

An area of approximately 41 hectares is proposed for the extension area of which 19 hectares will be for disposal and 22 hectares for a screening/landscape/buffer area.

The topography in the vicinity of the landfill is undulating with several localised high points. Overall the regional topography rises to the south. Land use in the vicinity of the site is agricultural with linear residential development of houses on the roads to the west and north of the site.

The existing landfill site is located at an elevation of 110m to 132mOD. The proposed extension area is located to the east of the existing site. A topographic survey of the site has been undertaken and indicates that the elevation within the proposed extension area ranges in height from 105m in the south west corner to 158m in the north east. To the west of the site the ground rises to 129m OD high point and falls again to less than 100m adjacent to the White River. To the south of the site, south of the White River the ground rises to approximately 140mOD. Immediately to the north of the site the ground rises to a height of 130m in the Moneymohill area.

The southern portion of the proposed extension area is described as wet and boggy. This area is dissected by a series of land drains and the area contains reeds and rushes. The higher ground while soft is used for pasture. The centre of the site is flat lying and made up of boggy, poorly drained fields. The east and north west parts of the site are located on higher ground with better drained fields.

The existing landfill site and the proposed extension area are located within the catchment of the White River. A number of surface water drainage ditches are located within the proposed extension area. These drains ultimately discharge to the White River which is located to the south of the proposed extension area. The surface water within the proposed extension area drains in a mainly south westerly direction.

REGIONAL GEOLOGY

The bedrock geology map of the area indicates that the proposed site is underlain by the Shannon Group and Clare Shale Formation (Geological Survey of Ireland, Sheet 17 Geology of the Shannon Estuary, 1999). Both these units are Upper Carboniferous in age (Namurian). The Shannon Group (SHG) is described as comprising of mudstone, siltstone and sandstone. The Clare Shale Formation (CS) is described as being composed of dark grey shales with bands of siliceous mudstone common in the lower parts. To the north west of the site Upper Namurian Beds described as alternating sandstones, siltstones and shales are found. The bedrock geology of the area is shown on Figure No. 1 (taken from GSI 1:100,000 bedrock geology map).

LOCAL BEDROCK GEOLOGY

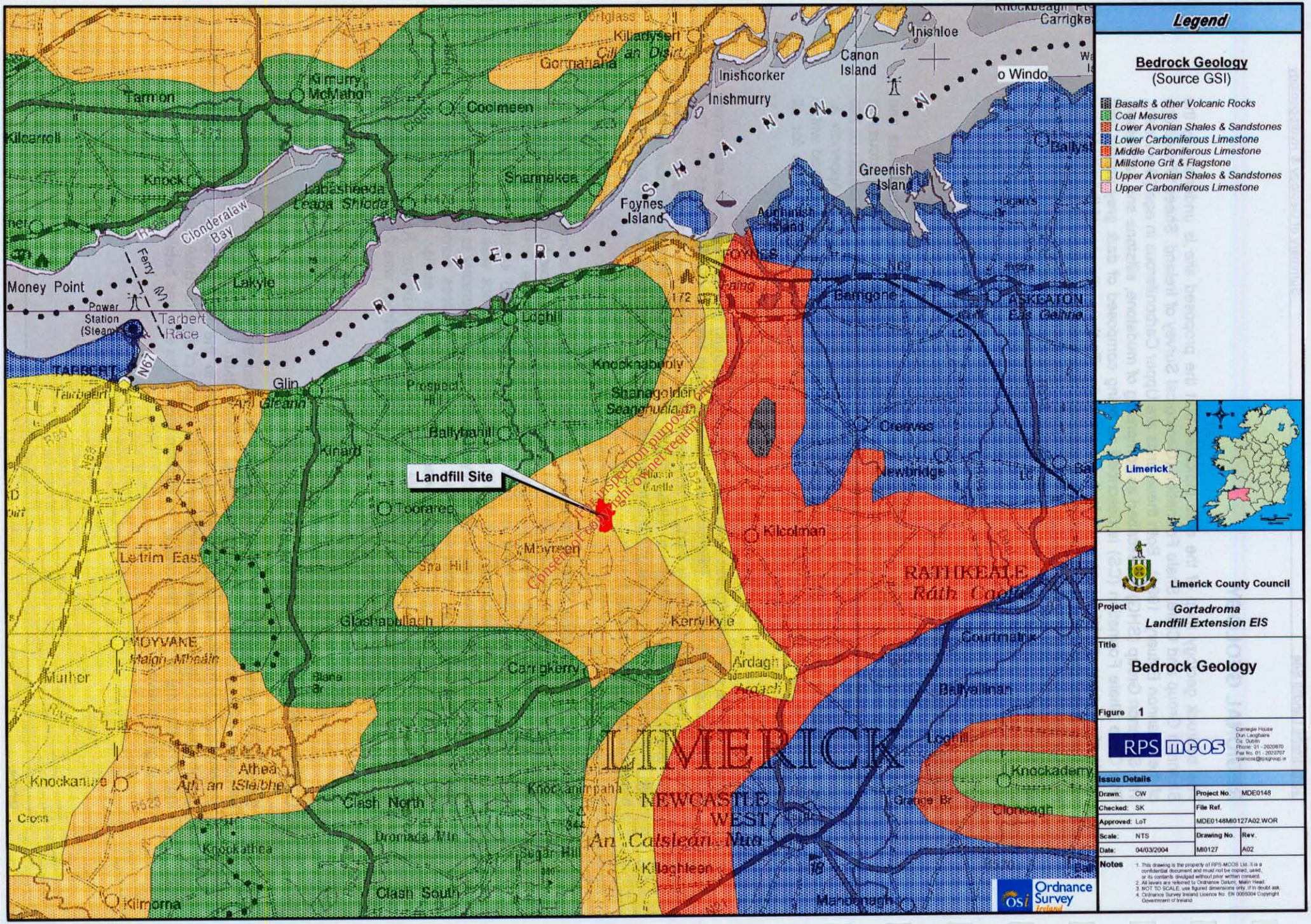
Information on the local bedrock geology is available from the site investigation data and geophysical data. Site investigations in 2002 involved the drilling of 8 cable percussion boreholes (2 were re-drilled) ,3 rotary core holes and geophysical works. The results of this investigation including boreholes logs and geophysical profiles are included as Appendix A. The locations of the boreholes from this investigation are shown on map 3 contained within the report in Appendix A to this report. Figure 2 shows the borehole locations for all investigations.

Only two of the site investigation boreholes within the proposed extension area are confirmed to have intercepted bedrock. Bedrock was encountered in borehole BHRC2 at 15.5m. The bedrock is described as initially being a very strong grey fine sandstone changing to a weak (non intact) dark grey mudstone at 19.6m depth. The sandstone contained discontinuities with slight orange brown discolouration on fracture surfaces. Borehole BHSA6A is reported to have intercepted bedrock at 4.80m.

Previous site investigation studies within the adjacent existing landfill site intercepted bedrock in three of the boreholes, boreholes BHRC-1 (rotary core hole), Borehole No. 5 (shell & auger hole) and Borehole No.6 (shell & auger hole). Rotary corehole BHRC-1 intercepted mudstone and siltstone described as dark grey very fine grained slightly to moderately weathered laminated mudstone (EIS 1997). The depth to bedrock was 36.5m bgl. The discontinuities were described as being tightly to partly open / moderately to extremely closely spaced. Weathering was seen along the discontinuities in places some clay infilling of discontinuities was reported. Bedrock was also intercepted in earlier site investigation boreholes (Borehole No. 5 and Borehole No.6 An Foras Forbartha Report 1987) the intercepted bedrock was described as shale. The depth to bedrock was 24.0m at Borehole No. 5 and 21.6m at Borehole No.6.

GEOPHYSICAL INVESTIGATIONS

Geophysical investigations have been undertaken within the existing landfill site and the proposed extension area. The geophysical survey data has been interpretated by the geophysical contractor in order to assess the depth to the top of bedrock. A surface geophysical survey which was undertaken in 1997 as part of the EIS (BMA, September 1997) indicated that the depth to bedrock in the eastern area of the site was between 20m and 30m below ground level.



Legend

Bedrock Geology
(Source GSI)

- Basalts & other Volcanic Rocks
- Coal Mesures
- Lower Avonian Shales & Sandstones
- Lower Carboniferous Limestone
- Middle Carboniferous Limestone
- Millstone Grit & Flagstone
- Upper Avonian Shales & Sandstones
- Upper Carboniferous Limestone

Limerick County Council

Project: *Gortadroma Landfill Extension EIS*

Title: **Bedrock Geology**

Figure 1

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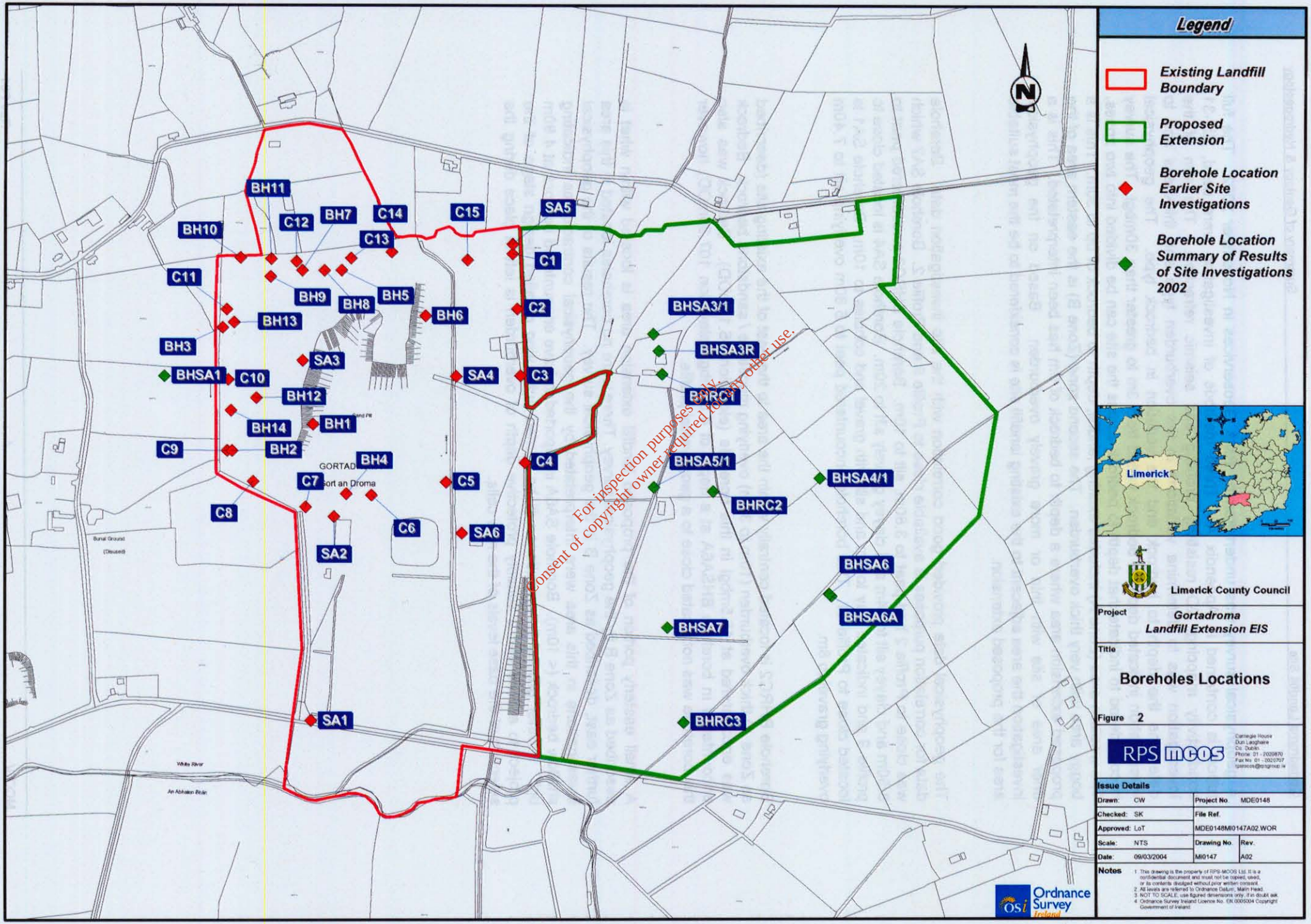


A geophysical survey was undertaken by BMA Geoservices in November 2002. The full report is contained in Appendix A. Three methods of investigation were used, EM-31 conductivity mapping, 2D resistivity profiling and seismic refraction. The aim of the investigation was to determine variations in the overburden type and thickness and to determine the depth to bedrock and the variation in bedrock type. The geophysical investigation indicated depth to bedrock varied from 3m to greater than 30mbgl. The survey is considered to indicate that depth to bedrock across the site can be divided into two zones. The western area (Zone A) includes existing landfill, depth to bedrock of up to 30m. This is a boggy area with very thick overburden. The second zone (Zone B) is the eastern area of the proposed extension area where a depth to bedrock of 5m has been interpretated. This is a drier area of site with thin or more gravely overburden. Based on the geophysical investigation the area adjacent to the existing landfill site is considered to be the most suitable area for the proposed extension.

The geophysical data provided good correlation with the site investigation data. Borehole data for correlation purposes is available close to Profile 9 and Profile 2. Borehole SA7 which was close to Profile 2 had peat to 3.80m, silt to 10m. Borehole BHRC3 encountered peat to 8.50m and clayey silt to 14m and clayey gravely silt to 20m. Borehole SA4 is located close to profile 9 and indicated clay to 3m and silt with gravel and cobbles to 10m. Borehole SA1 is located close to Profile 11. This borehole encountered peat to 5.80m overlying silt to 7.40m overlying gravel to 8m.

Borehole BHRC2 is located centrally within the area to the east of the existing site (described as Zone A) thick overburden (10m to 30m) overlying mudstone / sandstone bedrock. Bedrock was encountered at 15.5mbgl in this borehole (elevation 95.12mOD). Bedrock was also encountered in borehole BHSA6A at a depth of 4.80mbgl (elevation 107.99mOD) however this borehole was not located close to a geophysical profile.

A small easterly portion of the proposed landfill extension area is located within what is described as Zone B by the geophysical survey. There were no boreholes located in this area further east, described as Zone B in the geophysical survey. The results of the geophysical investigations in this area were interpretated by the geophysical contractor as indicating shallow bedrock (< 10m). Borehole SA6A is reported to have encountered bedrock at 4.80m bgl. Further ground investigations will be carried out during detailed design stage of the project to ensure that a suitably protective depth of overburden is left in place during the selection of the base levels of the new cells.

OVERBURDEN GEOLOGY

Information on the general subsoils in the region is available from the Geological Survey of Ireland Groundwater Protection Scheme Report for County Limerick. Map 2 (W) the subsoil map indicates three deposits in the vicinity of the existing landfill and the proposed extension area. In the vicinity of the White River undifferentiated alluvium is present. Gravel deposits are found to the west of the existing site while the remainder of the area is classed as having Namurian head deposits (or slope deposits). These are accumulations or fans of rock debris derived from underlying bedrock. These deposits are found in Limerick on hill and mountain slopes. The deposits are quite variable, dependant on parent rock type and are described as having a stoney matrix.

More detailed site specific information for the proposed extension area is available from the shell and auger boreholes drilled during the site investigation (November, 2002). The data obtained during the most recent site investigation is similar to that obtained during earlier investigations within the existing facility boundary. Within the existing landfill site the overburden prior to the construction of the cells was generally greater than 20m thick. The 2D resistivity profiling which was undertaken as part of the previous EIS (September, 1997) indicated the presence of a higher clay content in the overburden to the east and more gravelly overburden on the western side. This is further backed up by the original site investigation (An Foras Forbartha Report, 1987).

The results of all of the site investigations and the geophysical investigations to date indicate the presence of overburden deposits of between 20m and 30m thick within the existing landfill site. A summary of the site investigation data from within the existing landfill site is contained in Tables 1 to 4. The site investigation data from the earlier investigations within the existing landfill has been included together with the more recent site investigation data.

No borehole data is available to the east of borehole SA6 for the most eastern portion of the proposed extension area but geophysical data for this area suggests it thins to 5m or less. The site investigation data from within the proposed extension area is summarised in Table 5 and 6. The site investigation boreholes are located in the western portion of the proposed extension area, except for BHSA1 which is situated west of the existing site. The logs indicate the presence of peat and silt deposits in the south western portion of the proposed extension area (BHRC3 and SA7). 8.50m of peat was encountered in borehole BHRC3 and 3.40m in borehole SA7.

The remainder of the site is composed of silty and minor granular deposits comprising sand, gravel and boulders in a clayey matrix. This correlates with the drainage conditions with boggy conditions with reeds and rushes in the areas with lower permeability overburden deposits (peat and silt). The proposed extension area was mapped previously (Geomorphology Map Contained in the Strategic Development Plan May, 2001). The Southwest was mapped as having peat deposits, the central portion till deposits with peat further east again.

Based on the available site investigation data the overburden is mainly composed of deposits of peat, silt and clayey sand and clayey gravel. Thin deposits of clean gravels are also found but these appear to be discontinuous and limited in extent.

REGIONAL HYDROGEOLOGY

The Geological Survey of Ireland have completed a Groundwater Protection Scheme Report for County Limerick. The Groundwater Protection Scheme includes maps illustrating the Bedrock Geology, Aquifer Classification, Aquifer Vulnerability and Groundwater Resource Protection.

The Geological Survey of Ireland aquifer classification scheme is based on the value of the groundwater resources and the hydrogeological characteristics of the aquifer. Eight categories have been defined by the GSI as follows:

Regionally Important Aquifers (R) :

- Karstified Aquifers (Rk)
- Fissured bedrock Aquifers (Rf)
- Extensive Sand and Gravel Aquifers (Rg)

Locally Important Aquifers (L)

- Sand / gravel (Lg)
- Bedrock which is Generally Moderately Productive (Lm)
- Bedrock which is Moderately Productive only in Local Zones (Ll)

Poor Aquifers (P)

- Bedrock which is Generally Unproductive except for Local Zones (Pl)
- Bedrock which is Generally Unproductive (Pu)

The existing landfill site and much of the proposed extension area, including the area proposed for the construction of the future lined cells, is located on bedrock of the Shannon Group (SHG). The Geological Survey of Ireland have recently revised the aquifer classification of the Limerick area as part of their work for the Water Framework Directive and to correspond with the most recently published bedrock geology map of the area (GSI Sheet 17, 1999). This has resulted in a change of aquifer classification for the Gortadroma area from that published in the 1995 County Limerick Groundwater Protection Scheme Report. The GSI have assigned a provisional aquifer classification of Ll for the Shannon Group. This relates to bedrock which is moderately productive only in local zones. The Clare Shale Formation (CS) forms the bedrock in the north eastern corner of the proposed extension area. This is provisionally classed by the GSI as Pl. Pl relates to bedrock which is generally unproductive except for local zones

There is no evidence at this time to suggest that the overburden deposits constitute an aquifer in the vicinity of the site. No information is available on the potential groundwater yields from the overburden deposits. It is proposed that additional information will be gathered during the site investigation for the detailed design of the proposed cells. The data from the earlier site investigations for the existing landfill site indicated no significant inflows of water from the isolated pockets of sand and or gravel.

The regional groundwater flow is expected to be northwards towards the Shannon Estuary.

LOCAL HYDROGEOLOGY

Information on the local hydrogeology has been compiled from the site investigation data. There are no hydrogeological features indicated on the Geological Survey of Ireland Hydrogeological Data Map of the region (Map 4(W) of the Groundwater Protection Scheme Report).

Groundwater Flow Direction

It was reported in the previous EIS (September, 1997) that the general groundwater flow direction was from north to south from the higher ground to the north of the site to the White River in the south. Groundwater discharge occurs to the drains to the south of the site and to the White River. It should be noted that there are a number of springs in the area, particularly to the west of the existing landfill.

Groundwater Level Monitoring Proposed Extension Area

Groundwater level monitoring was undertaken on the 04/06/03 and 21/11/03 in the boreholes installed in the proposed extension area. It was not possible to access all of the boreholes. The recent water level monitoring data indicates a north east to south west direction of flow. The available water level information is summarised in Table 7. The groundwater flow direction corresponds to the surface water drainage pattern and the topography of the site i.e in a south westerly direction.

All of the groundwater levels in the overburden deposits remain close to the surface throughout the year and are generally within 1m. Groundwater conditions during drilling in the overburden indicated confined conditions.

Only two of the boreholes in the proposed site extension area encountered bedrock (BHRC2 and BHSA6A). The response zone for the monitoring standpipe in borehole BHRC2 is within the bedrock. The response zone for the monitoring standpipe in borehole BHSA6A is within the overburden deposits. The groundwater level information in the bedrock within the proposed extension area is currently limited to one location borehole BHRC2. The available information indicates that the groundwater in the bedrock at BHRC2 is confined with the groundwater level rising above ground level (artesian conditions).

Additional data will become available for the proposed extension area during the detailed site investigation for the design stage. This will provide more information on the confined nature of the groundwater in the bedrock aquifer.

Table 7 Groundwater Levels Proposed Extension Area

BH Code	Elevation Ground Level (mOD)	Water Level (mOD) 04/06/2003	Water Level (mOD) 21/11/2003
BHRC1	117.29	116.74	116.02
BHRC2	110.62	111.07	111.10
BHSA3R	117.82	114.85	114.97
BHSA3/1	116.71	115.06	114.97
BHSA4/1	117.82	117.41	Not available
BHSA5	109.50	Not available	109.50
BHSA6	112.75	112.75	109.41
BHSA7	Access not permitted		

Groundwater Level Monitoring Within Existing Landfill

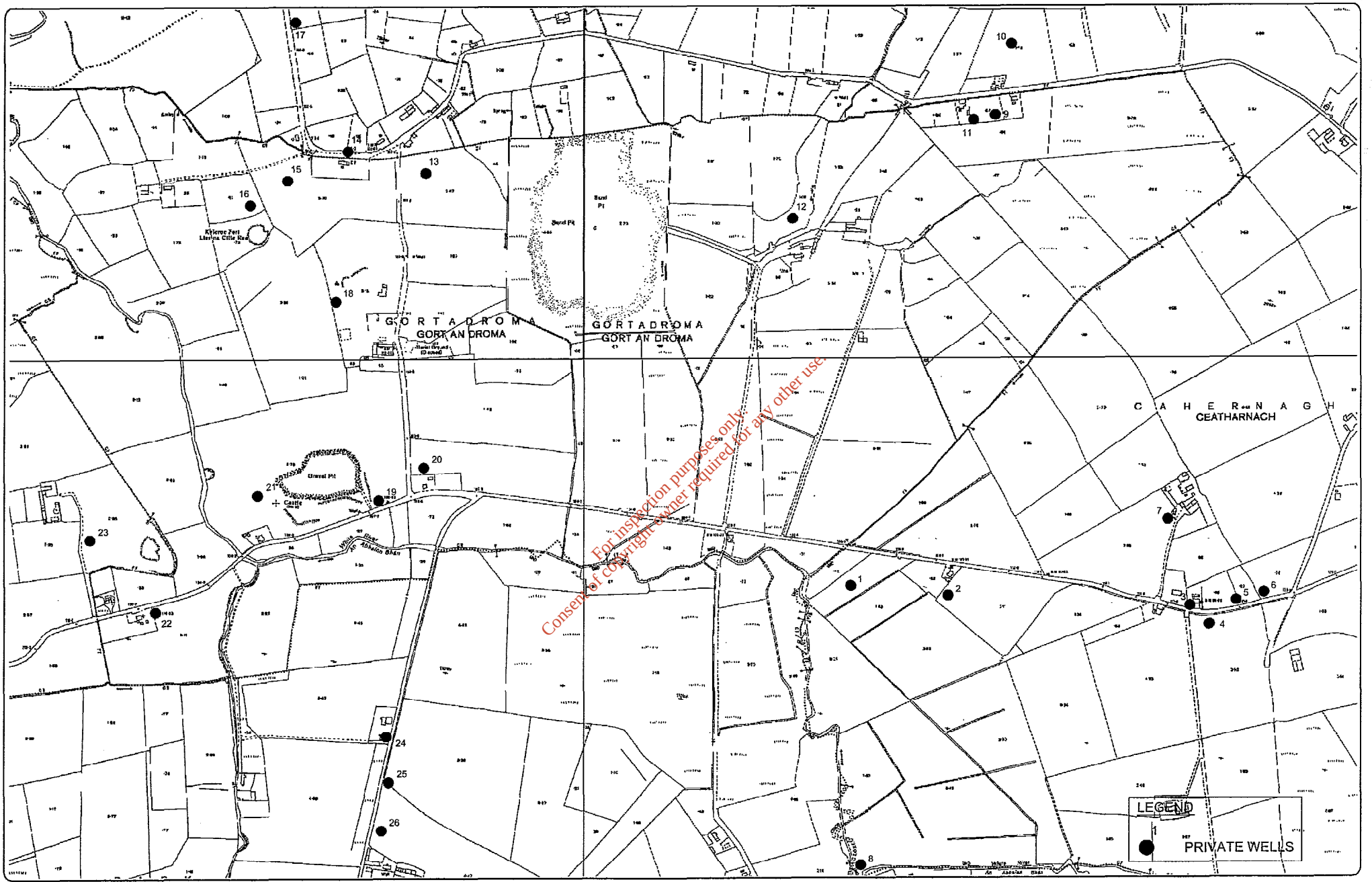
Groundwater level monitoring is undertaken within the existing landfill site on a monthly basis. The monitoring standpipes are located within the overburden deposits. Water level monitoring data is available from November 1998 to end of May 2003. The water level monitoring data indicates a maximum seasonal water level fluctuation of 3.4m during 2002 in BH3. In general the fluctuation at this location is up to 3m. All of the other boreholes show a seasonal fluctuation of less than 1m (except SA1 during 2002).

During the drilling of the shell and auger boreholes within the existing landfill the groundwater conditions were monitored. Confined conditions were encountered in all of the boreholes with the groundwater level rising close to ground level after the initial groundwater strike. Groundwater was generally first encountered at the top of gravel layers but also occurred in silt layers.

During previous investigations carried out at the site Limerick County Council reported on 26 private wells within a 1km radius of the site boundary. It was reported that these domestic boreholes had low yields. The locations of the reported private boreholes are illustrated on Figure No.3. Information on groundwater levels from the boreholes in the vicinity of the landfill indicates artesian conditions in two of the private wells, (Costello's and Keneally's), in the vicinity of the landfill. Costello 's Well is located to the south of the proposed extension area (Private Well No. 1, Figure No. 3). This well is drilled to 16m depth but there is no information available on the depth to bedrock or type of overburden deposits that were encountered during drilling. Keneally's well (Private Well No. 10, Figure No. 3) is located to the north east of the proposed extension area. This well is reported to have been hand dug and is likely to be less than 10m deep.

Permeability Testing

No permeability testing was undertaken during the recent site investigation (November, 2002) within the proposed extension area. Information is available from the site investigation undertaken in the adjacent site. Earlier site investigations indicated permeability values for the overburden deposits ranging from 3.64×10^{-4} m/sec for gravel deposit to 8.7×10^{-10} m/sec for clay. There is considerable variation in the overburden deposits ranging from low permeability clays, silts and peat to thin discontinuous zones of high permeability sands and gravels.



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No.	Date	By	Chd	Amendments
A01	Aug. '03	B.C.		ISSUE FOR APPROVAL

Client
LIMERICK COUNTY COUNCIL

Project
GORTADROMA LANDFILL - EIS EXTENSION AREA

Title of Drawing
LOCATION OF PRIVATE WELLS IN VICINITY OF LANDFILL.

Issued from:	Cork ■	Dublin □ Dun L □ Galway □
Drawn:	B.C.	Job No: MCE0148
Checked:		File No:
Approved:		Drg. No: 3. Rev: A01
Scale:		
Date:	AUG. '03	

Vulnerability Rating

The 1995 Groundwater Protection Scheme Report for County Limerick assigned a high vulnerability classification to the general area. The groundwater vulnerability classification of the Geological Survey of Ireland is based on the vulnerability to pollution of the first groundwater encountered in either sand / gravel aquifers or in bedrock aquifers. The Geological Survey of Ireland Aquifer Classification scheme for the study area does not indicate the presence of any locally important sand and gravel aquifers within the study area.

The vulnerability of the groundwater to pollution in the bedrock aquifer, within the proposed extension area, has been considered. The assessment has been based on the site specific conditions i.e. the thickness and permeability of the sub soils below the level of the potential point of release of contaminants. The formation level of the proposed lined cells has not been finalised at this time. In order to examine the vulnerability of the groundwater in the bedrock aquifer beneath the site to a pollution incident, an approximate level of 8mbgl has been taken as the possible formation level for the cells. This level has been taken as level for the potential release of contaminants.

The Geological Survey of Ireland assessment of vulnerability for a specific activity at a specific site considers the potential depth of release of contaminants, based on the planned site activities. The thickness of the subsoil material below the potential point of release has been assessed as follows (Table 8).

Table 8 Geological Survey of Ireland Vulnerability Mapping Guidelines

Total Sub Soil Thickness Below Level of Potential Point of Release of Contaminants	Hydrogeological Conditions		
	Subsoil Permeability (Type)		
	High permeability (sand/gravel)	Moderate permeability (e.g. sandy subsoil)	Low permeability (e.g. clayey subsoil, clay, peat)
0 – 1m	Extreme	Extreme	Extreme
1 – 3m	High	High	High
3 – 8m	High	High	Moderate
> 8m	High	Moderate	Low

Permeability data for the area is available from the earlier site investigations associated with the existing landfill site. Permeability values for the clay range from 8.7E-10m/s to 3.6E-8 m/s (field tests) and 5.4E-10m/s to 2.9E-9m/s (lab tests) for earlier test results (1997, EIS). The material is regarded as being a low permeability material with clayey subsoil, clay and peat. The low values are considered to be due to high clay /silt content of the overburden. Permeability testing in bedrock at this time indicated values of order of 3.5E-9 m/sec and 7.3E-8 m/sec (reported in BMA report). The ground water flows under the proposed extension area are low and reported to be typical of mudstone or sandstone bedrock. These rocks are likely to have low permeabilities and poor groundwater potential.

The site investigation data for the proposed extension area indicates variable subsoil deposits ranging from low to high permeability (Table 9). Based on the geophysics and borehole logs, the thickness of the overburden is considered to be between 10m and 30m in the western part of the proposed extension area. It is proposed that the future cells are to be located in this area. The geophysical investigations indicate that the depth to bedrock reduces to < 10m in the eastern portion of the proposed extension area, however there is no borehole

information available at this time to confirm this. Additional drilling is proposed prior to the detailed design stage.

The construction of the lined cells is likely to involve the excavation of up to 8m of subsoil deposits. As the proposed formation levels have not been finalised at this time the removal of up to 8m of subsoil has been taken for the assessment of the potential vulnerability of the groundwater to contamination following the construction of the cells. The data from each of the available site investigation boreholes has been assessed (Table 9) to determine the vulnerability of the groundwater in the bedrock aquifer to pollution.

Table 9 Vulnerability Classification

Borehole Code	Permeability	Thickness of Subsoil Below Potential Point of Release of Contaminants	Vulnerability Rating
BHRC1	High	> 12m	High Vulnerability
BHRC2	Moderate	7.50m	High Vulnerability
BHRC3	Low	11.50m	Low Vulnerability
BHSA3/1	Borehole too shallow to classify		
BHSA3R	Moderate	> 2m	High Vulnerability
BHSA4/1	Moderate	> 2m	High Vulnerability
BHSA5/1	Low	> 2m	High Vulnerability
BHSA6A	Rock < 5m		Extreme Vulnerability
BHSA7	Low	> 2m	High Vulnerability

Note: The above vulnerability ratings are based on the available site investigation boreholes within the proposed extension area. Only two of the boreholes encountered bedrock therefore the subsoil thickness may be greater than indicated in Table 9.

Based on the site specific data from the investigations to date i.e. the subsoil type, permeability and thickness, the site would have an extreme to high vulnerability rating based on the depth to bedrock aquifer. The Geological Survey have assigned a provisional aquifer classification of LI for the Shannon Group. This relates to bedrock which is moderately productive only in local zones.

The Department of Environment and Local Government, Environmental Protection Agency and Geological Survey of Ireland (1999) have developed a groundwater protection response matrix in order to assess the location and management of potentially polluting activities in order to protect groundwater resources. These guidance notes provide a response matrix for assessing the suitability of a site for the development of a landfill. As the aquifer beneath the area proposed for the construction of the future cells within the extension area is classed as LI (bedrock which is generally moderately productive only in local zones) the resource protection responses for only this bedrock aquifer category have been examined.

Table 10 Response Matrix For Landfills

Vulnerability Rating	Resource Protection
	Locally Important LI
Extreme	R2[2]
High	R2[1]
Moderate	R2[1]
Low	R1

The vulnerability rating for the proposed extension area ranges from extreme in the vicinity of borehole SA6A to low in the vicinity of BHRC3. Over the area proposed for the location of the future cells the vulnerability rating is classed as high.

The response categories are defined as follows (taken from DoELG, EPA and GSI Groundwater Protection Scheme, 1999):

R1 Acceptable subject to guidance in EPA landfill Site Design Manual (EPA, 1999) or conditions of a waste licence

R2[1] Acceptable subject to guidance in EPA landfill Site Design Manual (EPA, 1999) or conditions of a waste licence

- Special attention should be given to checking for the presence of high permeability zones. If such zones are present then the landfill should only be allowed if it can be proven that the risk of leachate movement to these zones is insignificant. Special attention must be given to existing wells down gradient of the site and to the projected future development of the aquifer.

R2[2] Acceptable subject to guidance in EPA landfill Site Design Manual (EPA, 1999) or conditions of a waste licence

- Special attention should be given to checking for the presence of high permeability zones. If such zones are present then the landfill should only be allowed if it can be proven that the risk of leachate movement to these zones is insignificant. Special attention must be given to existing wells down gradient of the site and to the projected future development of the aquifer.
- Groundwater control measures such as cut off walls or interceptor drains may be necessary to control high water table or the head of leachate may be required to be maintained at a level lower than the water table depending on site conditions.

The response category for the proposed site ranges from R1 to R2[2], in all cases this results in the site being considered suitable for the development of a landfill site subject to guidance in the EPA Landfill Site Design Manual or the conditions of a waste licence.

It should however be noted that the investigation information to date indicates that the groundwater in the bedrock aquifer beneath the landfill site is confined resulting in an upward hydraulic gradient. This provides an additional degree of protection for the groundwater from pollution. Due to the high groundwater levels control measures such as interceptor drains or sub cell drainage will be required for the development of site.

Water Quality

Information on the groundwater quality of the site is available from the groundwater monitoring boreholes within the landfill site. Water quality monitoring has not been undertaken to date in the site investigation boreholes within the proposed extension area.

Groundwater quality in the vicinity of the site is monitored as part of the waste licence requirements for the operation of the existing landfill site. This monitoring programme includes monitoring of boreholes up gradient of the landfilling operations which represent the background water quality in the area. Monitoring borehole SA5 (existing site) is located on north eastern corner of the landfill site. Two additional monitoring boreholes BH2 and BH10 (existing landfill) are located on northern boundary of the site. All of the current up gradient monitoring boreholes are located within the overburden deposits.

The results of monitoring at the upgradient monitoring locations within the existing site have been reviewed to characterise the background groundwater quality. Monitoring borehole

BHSA5 (existing landfill – Geotech 1997) is a shallow borehole located in the overburden (total depth 4.15m) in peat and clay deposits. Borehole BH2 (existing landfill – IGSL Sept 1997) 12m depth, located in overburden deposits. BH10 (existing landfill – IGSL Sept 1994) total depth 10.50m located in overburden, gravel and clay. These monitoring boreholes are considered to represent the background water quality in the vicinity of the site. Monitoring of the chloride, potassium, sodium and total organic carbon is undertaken on a quarterly basis. The chloride concentration is generally between 20 mg/l and 30 mg/l. The potassium concentration is typically between 1mg/l and 5mg/l. The sodium concentration is very variable but is less than 100mg/l on most occasions. The total organic carbon concentration is generally less than 25 mg/l for SA5, 10 mg/l for BH2 and 15 mg/l for BH10. Monthly monitoring of ammonia, electrical conductivity, pH and temperature is carried out. The ph ranges from 6 to 7.5pH units. The electrical conductivity is generally less than 1,000 us/cm.

The monitoring data from the existing landfill indicates that the impact of landfilling is seen along the western boundary of the site, to west of unlined portion of the site. This unlined portion (cells 1 – 4) are now enclosed in a bentonite cut off wall, which prevents uncontrolled leachate discharge from the cells. It is considered that the pumping of leachate from this area (due to commence during 2003) will improve groundwater quality.

Monitoring of Water Quality In Private Boreholes

Monitoring of the water quality in the private boreholes in the vicinity of landfill site is carried out on an annual basis by Limerick County Council. Monitoring has been undertaken during the past three years. The monitoring programme includes all private wells within 500m upgradient of the landfill site and 1,000m downgradient of the site. The monitoring for 2003 indicates that 31 of the 33 private wells in the area have microbial contamination. The principal sources of this microbial contamination would appear to be septic tanks and agriculture. There is no indication that the landfill is impacting on groundwater quality . There is very little information available on the depth and construction details of the private boreholes in the vicinity of the landfill site.

LIKELY SIGNIFICANT IMPACTS

The proposed development will involve the construction of lined cells for the landfilling of waste. This will involve the excavation of the overburden material below existing ground level and the compaction of soils during the construction period. This change in the local geology will not result in a significant or adverse impact as the overburden deposits and bedrock are not of geological significance or intrinsic scientific value.

The groundwater table will be locally lowered during the construction of the new cells. This will involve a programme of pumping during the construction phase. This will be of a temporary nature and the groundwater conditions will equilibrate after cell completion. Due to the naturally high groundwater levels groundwater control measures such as interceptor drains and / or a sub cell drainage system will be required to control the high water table.

The landfilling of waste has the potential to contaminate the groundwater and surface water in the vicinity of the landfill site. Groundwater is used as a water supply source by householders in the vicinity of the landfill site as the area is not served by a public water supply scheme. There are reported to be 26 private boreholes in the vicinity of the landfill site. The operation of the landfill site will not impact on the yield of boreholes in the vicinity of the site however it has the potential to impact on the water quality.

The potential contamination of groundwater also has the knock on effect of potentially impacting on surface water. Groundwater appears to be discharging to the surface water in the vicinity of the site.

In addition to the landfilling of waste other site operations have the potential to contaminate groundwater in the vicinity of the site i.e. leachate storage lagoon, leachate treatment plant, fuel storage areas, areas for refuelling of site machinery. Accidental spillages have the potential to contaminate the groundwater by direct percolation or by interaction with contaminated surface water in areas of high groundwater levels and the various surface water drains.

There is the potential for the erosion of soils during construction. The removal of vegetative cover can lead to the erosion of large quantities of soil particles to watercourses. This can lead to significant pollution of surface water through the generation of suspended solids.

MITIGATION MEASURES

An emergency plan shall be prepared to deal with accidental spillages prior to the commencement of the works and shall be kept on site during the construction period. Additional measures to prevent / avoid contamination include the bunding of refuelling areas and the provision of clean up materials, containment booms for surface water bodies and emergency pumps to deal with any spillages including fuel. A plan shall also be drafted for the operational phase of the landfill. There is already one in place for the existing landfill cells. Petroleum products will be stored as far as possible from drainage ditches, surface water drains and watercourses. Sand shall be available to absorb spillages.

In the event of the private boreholes in the vicinity of the landfill site being contaminated as a result of landfilling activities an alternative water supply will have to be provided to those affected.

The proposed future cells are to be lined and will incorporate a leachate collection system. The leachate from the cells will be pumped to the existing on site leachate treatment plant. The provision of a leachate collection system significantly reduces the head of leachate above the basal liner of the lined cells. This reduces the potential leakage of leachate from the lined cells. The leachate treatment will significantly reduce the strength of the leachate and its potential to contaminate surface water and or groundwater.

It is proposed that the existing environmental monitoring programme will be extended to include the extension area. The existing monitoring system has been successful in monitoring the impact of the existing landfilling operations on the environment. The monitoring programme will include new groundwater monitoring points upgradient and downgradient of the proposed extension area. This will facilitate monitoring of the impact of the landfilling activities on the groundwater and any down gradient private groundwater sources.

The excavation of the cells below existing ground level increases the vulnerability of the groundwater to contamination. In order to mitigate against this impact all of the cells shall be lined in accordance with the requirements of the Environmental Protection Agency in order to safeguard the quality of the groundwater.

There are a number of surface water drains within the proposed extension area. These drains will have to be removed or rerouted during the development of the extension area. Monitoring of any surface water drains flowing from the proposed extension area to the White River shall be undertaken prior to discharging to the White River. A continuous monitoring system has been installed to warn of contamination. In the event of the monitoring system indicating contamination it shall be possible to divert the contaminated water to a retention pond or the leachate lagoon. This measure is proposed to safeguard the quality of the adjacent water course.

Stockpiles and spoil heaps will be located as far as possible from drainage ditches, surface water drains and watercourses. The stockpiles shall be covered where practicable with suitable sheeting or grassed. Disturbed areas will be stabilised as soon as construction is finished. Where possible excavated material will be stored and stockpiled for re use in future landscaping works at the site.

Suitable temporary drainage measures such as settlement ponds, silt traps and interceptor drains are to be provided during the construction operations at the site to intercept and divert run off from undisturbed areas surrounding the construction area and to contain and treat site runoff.

Background monitoring of groundwater quality will be undertaken prior to the construction of the proposed extension to allow for baseline data to be established.

CONCLUSIONS

An assessment of the suitability of the proposed extension area from a hydrogeological point of view, based on the guidelines published by the The Department of Environment and Local Government, Environmental Protection Agency and Geological Survey of Ireland (1999) for Groundwater Protection Schemes, indicates that the site is suitable for the development of a landfill subject to the guidance in the EPA Landfill Site Design Manual or the conditions of a waste licence.

Mitigation measures have been proposed to reduce or remove the potential significant impacts.

SUMMARY OF SITE INVESTIGATION DATA

Table 1 Earlier Site Investigation Data From Within Existing Facility Boundary

BH CODE (Elevation)	STRATA DECSRIPTION	GROUNDWATER	PERMEABILITY
C1	GL – 2.00 Silty CLAY 2.0 – 3.50 SILT 3.50 – 5.00 SILT / GRAVEL	Seepage @ 4m	
C2	GL – 1.00 CLAY 1.00 – 5.00 SILT	Not encountered	
C3	GL – 0.80 Peaty SILT 0.80 – 3.00 sandy SILT 3.00 – 5.20 SILT some gravel	Not encountered	
C4	GL –1.30 Made Ground 1.30 – 2.00 SILT 2.00 – 2.60 PEAT 2.60 – 5.00 sandy SILT	Not encountered	
C5	GL – 1.30 PEAT 1.30 – 3.00 SILT 3.00 – 5.00 Sandy SILT	Seepage @ 3.80m	
C6	GL – 0.15 Topsoil 0.15 – 1.60 PEAT 1.60 – 3.00 SILT 3.00 – 5.00 sandy SILT	Water strike @ 3.5m	
C7	GL – 0.50 Made Ground 0.50 – 1.60 PEAT 1.60 – 4.20 sandy SILT 4.20 – 5.80 SAND 5.80 – 6.50 SILT	Seepage @ 3.80m	
C8	GL – 0.90 Topsoil & cobbles 0.90 – 1.40 SILT with gravel 1.40 – 3.00 Gravelly SILT 3.00 – 6.00 SILT	Not encountered	
C9	GL – 0.40 Topsoil 0.40 – 2.00 sandy CLAY 2.00 – 3.60 gravelly SAND 3.60 – 5.30 GRAVEL	Seepage @ 3.60m	
C10	GL – 1.00 CLAY 1.0 – 1.50 Gravelly CLAY 1.50 – 2.00 sandy CLAY with gravel 2.00 – 2.30 CLAY with peat 2.30 – 4.00 sandy SILT 4.00 – 5.00 GRAVEL	Not encountered	
C11	GL – 0.80 PEAT 0.80 – 2.00 sandy SILT 2.00 – 2.50 silty GRAVEL 2.50 – 4.00 clayey GRAVEL 4.00 – 5.00 gravelly CLAY	Strike @ 2m	
C12	GL – 0.40 Topsoil 0.40 – 2.00 gravelly CLAY 2.00 – 4.00 sandy CLAY, gravel 4.00 –4.50 clayey GRAVEL 4.50 – 6.50 gravelly CLAY	Not encountered	

SUMMARY OF SITE INVESTIGATION DATA

Table 2 Earlier Site Investigation Data From Within Existing Facility Boundary

BH CODE (Elevation)	STRATA DECSRIPTION	GROUNDWATER	PERMEABILITY
C13	GL – 1.00 gravelly CLAY 1.0 – 3.00 gravelly, sandy CLAY 2.0 – 5.0 sandy CLAY 5.0 – 7.30 silty SAND	Not encountered	
C14	GL – 1.50 CLAY 1.50 – 2.50 silty CLAY 2.50 – 4.00 SILT some gravel 4.00 – 5.00 gravelly CLAY	Strike @ 4m	
C15	GL – 1.00 CLAY 1.0 – 2.00 SILT 2.0 – 4.30 CLAY with gravel	Seepage @ 3.50m	
BH1 (108.3)	GL – 2.0 CLAY some pebbles 2.0 – 4.4 SAND 4.4 – 10.0 CLAY silt partings 10.0 – 17.6 CLAY 17.6 – 17.8 GRAVEL		Gravel pocket k= 7.0E-8 m/sec (90.3mOD)
BH2 (111.0)	GL – 1.80 Topsoil 1.8 – 5.5 CLAY with gravel 5.5 – 8.5 SAND 8.5 – 9.1 CLAY some gravel 9.1 – 10 CLAY some sand 10 – 12 CLAY	No info on level encountered	Rising Head Test @ 99mOD k = 1.0 x 10^{-8} m/s clay. Rising Head Test @ 99mOD k = 3.6 x 10^{-8} m/s clay.
BH3 (112.5)	GL – 0.3 PEAT 0.3 – 1.2 MARL 1.2 – 3.0 CLAY some sand 3.0 – 6.5 CLAY 6.5 – 7.3 CLAY some gravel 7.3 – 13 SAND 13 – 20 CLAY some gravel	Seepage @ 7.3m?	Falling Head Test @ 103mOD k= 1.8 x 10^{-7} m/s sand. Rising Head Test @ 92mOD k = 3.6 x 10^{-8} m/s clay with some gravel.
BH4 (112.5)	GL – 5.20 SAND 5.20 – 11.0 CLAY some gravel 11.0 – 16.20 CLAY		Lab test @ 100mOD k = 8.7 x 10^{-10} m/s clay, Rising head test @ 97.5mOD k = 1 x 10^{-8} m/sec clay, Falling Head Test @ 97.5mOD k = 5.2 x 10-9 m/s clay.
BH5 (118.5)	GL – 8.2 SAND, clay partings 8.2 – 9.0 SILT, clay partings 9.0 – 11.7 CLAY some gravel 11.7 – 17.0 CLAY some sand 17.0 – 22.0 SAND & GRAVEL 22.0 – 24.0 CLAY some gravel 24.0 – 26.0 SHALE BEDROCK	Seepage @ 17m?	Rising Head Test @ 96.5mOD k = 1.9 x 10-6 m/sec sand. Rising Head Test @ 92.5mOD k = 3.5 x 10^{-9} m/sec shale.

SUMMARY OF SITE INVESTIGATION DATA

Table 3 Earlier Site Investigation Data From Within Existing Facility Boundary

BH CODE (Elevation)	STRATA DECSRIPTION	GROUNDWATER	PERMEABILITY
BH6 (114.6)	GL – 9.80 CLAY 9.80 – 21.6 CLAY with sand 21.6 – 25.6 SHALE BEDROCK	No info on level encountered	Rising Head Test @ 89m OD k = 7.3 x 10^{-8} m/sec shale.
BH7 (116.5)	GL – 1.70 Made Ground 1.70 – 4.50 GRAVEL/ COBBLES 4.50 – 5.60 silty gravelly CLAY 5.60 – 7.20 silty SAND 7.20 – 8.40 sandy GRAVEL 8.40 – 9.20 GRAVEL 9.20 – 10.50 silty gravelly CLAY	Strike @ 7.10m and 8.0m rose to 2.10m.	K = 6.01 E-6 m/s 6.50 – 7.00mbgl.
BH8 (116.5)	GL – 5.90 silty SAND, gravel 5.90 – 6.80 SAND 6.80 – 9.50 silty CLAY, gravel	Strike @ 6m rose to 5m after 1 hour.	K = 7.61 E-5 m/s @ 5.50 to 6mbgl.
BH9 (115.92)	GL – 2.10 silty CLAY 2.10 – 3.70 sandy peaty CLAY 3.70 – 5.60 silty fine SAND 5.60 – 7.20 sandy GRAVEL 7.20 – 7.80 silty gravelly CLAY 7.80 – 8.40 sandy GRAVEL 8.40 – 9.50 silty CLAY 9.50 – 10.00 silty CLAY	Strike @ 5.10m rose to 3.80m after 1 hour. Strike @ 7.80m rose to 5.70 after 30 mins.	K = 1.97 E-5 m/s @ 5.50 to 6mbgl.
BH10 (113.84)	GL – 0.30 Made Ground 0.30 –3.70 PEAT 3.70 – 4.60 silty gravelly CLAY 4.60 – 5.90 silty sandy GRAVEL 5.90 – 9.30 GRAVEL 9.30 – 10.50 silty gravelly CLAY	Strike 4.70m rose to 3m after 30 mins.	
BH11 (111.88)	GL – 1.40 silty sandy CLAY 1.40 – 8.50 silty CLAY	Not encountered	
BH12 (109.2)	GL – 2.90 silty SAND, gravel, cobbles 2.90 – 7.00 silty gravelly CLAY	Not encountered	
BH13 (113.28)	GL – 3.40 silty gravelly CLAY 3.40 – 3.90 silty CLAY 3.90 – 5.30 sandy GRAVEL 5.30 – 6.50 SAND 6.50 – 7.10 sandy GRAVEL, cobbles 7.10 – 8.00 silty CLAY	Strike @ 4m, rose to 3.3m after 1 hour. WL at end of boring 6.7m.	K = 7.82 E-5 m/s @ 3.50 to 4mbgl.
BH14 (111.69)	GL – 1.90 silty CLAY 1.90 – 3.80 clayey sandy SILT 3.80 – 5.60 silty sandy gravelly CLAY 5.60 – 7.20 sandy GRAVEL 7.20 – 8.00 silty gravelly CLAY	Strike @ 5.40m, rose to 5.10m after 1 hour. Water level 5.30m at end of boring.	Rising Head Test zone 5.00 – 5.50m bgl no rise in water level.

SUMMARY OF SITE INVESTIGATION DATA

Table 4 Earlier Site Investigation Data From Within Existing Facility Boundary

BH CODE (Elevation)	STRATA DECSRIPTION	GROUNDWATER	PERMEABILITY
SA1	GL – 1.46 PEAT 1.1 – 8.71 SILT 8.71 – 10.65 CLAY		
SA2	GL – 1.8 PEAT 1.8 – 14.77 CLAY		
SA3	GL – 6.3 Made Ground		
SA4	GL – 4.1 CLAY 4.1 – 7.2 SILT 7.2 – 9.1 CLAY		
SA5	GL – 4.14 CLAY		
SA6	GL – 1.5 PEAT 1.5 – 11.16 CLAY		

SUMMARY OF SITE INVESTIGATION DATA

Table 5 SUMMARY OF RESULTS OF THE 2002 SITE INVESTIGATION

BH Ref	Depth to Bedrock	Water Strike	Installation	Groundwater Comment	Description
BHRC1 Elevation 117.29mOD	> 20m	7.50m bgl	Monitoring 12m to 14m bgl in clayey gravel.	Strike at 7.50m rose to GL in 5 mins. Confined conditions.	0 – 3m clayey sandy GRAVEL 3 to 7m clayey SAND 7 to 7.5m boulders 7.5 to 14.5m clayey GRAVEL 14.5 to 15m boulders 15 to 20m clay & boulders
BHRC2 Elevation 110.62mOD	15.50m (elevation 95.12mOD)	5.00m bgl	16.30m to 19.80m bgl in bedrock.	Strike at 5m rose to 4m after 20 min. Confined conditions.	0 – 3m peaty clay 3 to 5m clayey gravely SILT 5 to 8m silty GRAVEL 8 to 15.5m sandy CLAY & BOULDERS 15.5m to 19.60m sandstone 19.60m to 19.80m mudstone
BHRC3 Estimated Elevation 105mOD	> 20m	11.00m bgl	14.00m to 20.00m in clayey gravely SILT	Strike at 11mbgl rose to GL in 5 mins. Fast inflow. Confined conditions.	0 – 8.50m Peat 8.50 to 14m clayey SILT 14m to 20m clayey gravely SILT
BHSA1	> 8m	6.50m bgl	1m to 8m in overburden deposits.	Strike at 6.5m bgl rose to 5.4m after 20 mins. Confined conditions.	0 – 5.80m Peat 5.8 to 7.4m SILT 7.40m – 8m GRAVEL
BHSA3/1 Elevation 117.82mOD	> 8.5m	2.20 m bgl 5.30m bgl	Backfilled. No installation.	Damp at 2.20m. Strike at 5.30m bgl rose to 4m after 20 min. Confined conditions.	0 – 0.30m topsoil. 0.30m to 2.00m sandy, gravely CLAY 2 to 5.30m SILT 5.30m to 6m GRAVEL 6 to 8.50m sandy gravel CLAY

SUMMARY OF SITE INVESTIGATION DATA

Table 6 SUMMARY OF RESULTS OF THE 2002 SITE INVESTIGATION

BH Ref	Depth to Bedrock	Water Strike	Installation	Groundwater Comment	Description
BHSA3R Elevation 117.82mOD	> 10m	2.50m bgl 5.60m bgl	Zone 1m to 2.9m. Zone 3.90m to 6m.	Slow inflow 2.50m rose to 2.20m 20 mins. Strike at 5.60m rose to 3.50m 20 mins. Confined conditions	0 – 0.30m made ground. 0.30m to 1.40m sandy gravely CLAY. 1.40 to 3.90m clayey GRAVEL. 3.90 to 6m SILT. 6 to 7m GRAVEL 7 to 10m SILT
BHSA4/1 Contour 121.00 or 121.50mOD	> 10m	2.30 mbgl	Zone 1.50m to 4.50m.	Strike 2.30m rose to 2m 20 mins. Confined conditions.	0 – 0.30m topsoil 0.30 to 2m CLAY 2m to 10m SILT.
BHSA5/1 Elevation 109.50mOD	> 10m	2.50m bgl 8.20m bgl	Zone 3m to 10m	Slow inflow 2.50m rose to 2.40m 20 mins. Strike 8.20m rose to 6.50m 20 mins.	0 – 0.30m topsoil. 0.30 to 1.40m SILT 1.40 to 2.0m Peat. 2.0 to 9m SILT 9 to 9.7m GRAVEL 9.70 – 10m CLAY
BHSA6 Elevation 112.75	> 5.45m may be top of rock BHSA6A encountered	3.50m bgl	No installation	Strike 3.50m rose to 2.25m 20 mins	0 – 0.30m topsoil 0.3 to 5.20m CLAY 5.20 to 5.45m cobbles.
BHSA6A Elevation 112.79	4.8m (elevation 107.99mOD)	3.50m bgl	Zone 2.60m to 5.00m	Strike at 3.50m rose to 2.85m 20 mins.	0 – 0.30m topsoil 0.30m to 4.80m CLAY 4.80m to 5.05m Limestone.
BHSA7 Estimated approx 106mOD	> 10m	4.40m bgl	Zone 3.50m to 6m	Strike 4.40m rose to 3.70m 20 mins	0 – 0.40m topsoil 0.40 to 3.80m Peat 3.80m to 5.00 SILT organic material 5.00 to 10.00 SILT

APPENDIX A

BMA GeoServices

Geophysical Geotechnical Environmental

Final Report

Geophysical Survey for a proposed extension to Gortadroma Landfill, Co. Limerick.

for

M.C. O'Sullivan & Co. Ltd.

BMA GEOSERVICES LTD
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AUTHOR	CHECKED	JOB NUMBER	DATE
Ruth Staunton	James A. Hodgson	1030	November 2002

FOREWORD

Geophysical surveying is an indirect, non-invasive process and involves interpretation of readings made at the ground surface in terms of likely subsurface conditions. This interpretation is based on the existing knowledge of ground conditions, typical geophysical responses of known materials and the experience of the author. This report has been prepared by BMA GeoServices in line with best current practice and with all reasonable skill, care and diligence within the limitations imposed by the survey technique applied and the resources devoted to it by agreement with the client. The client should take the interpretative basis for any conclusions or opinions contained therein into account in any future use of this report.

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Appendices

Appendix I	Geophysical Methodology.
Appendix II	Seismic Spreads.

1. Summary

- BMA Geoservices, Geophysical Consultants, were requested by M. C. O'Sullivan & Co. Ltd., to carry out a geophysical survey of a proposed landfill extension at Gortadroma, Co. Limerick.

- This report details geophysical interpretation which uses information gleaned from boreholes drilled at selected locations across the site (Map 3). A summary of this borehole data is given in Table 1.

- The EM-31 Survey indicated two conductivity zones (Map 2) interpreted as follows:

Zone	Conductivity (mS/m)	Interpretation
A	< 20	0 – 10m Overburden over Bedrock
B	20 – 45	10 - 30m Overburden over Sand/Gravel/Bedrock

- The interpretation of the results of the 2D-Resistivity profiling (Sections 1-11) and seismic profiling (Appendix II) may be summarised as follows:

Interpretation	Thickness (m)	Velocity (m/s)	Resistivity (ohm-m)	Estimated Stiffness/ Rock Quality*	Excavatability
Peat	> 5	< 500m/s	> 50	Soft	Diggable
Silty Gravelly Clay	0 – 5	250 - 700	15-100	Soft-Firm	Diggable
Sand and Gravel	0 - 5	500 -> 1000	> 450	Soft - Firm	Diggable
Clay with Gravel, Cobbles and Boulders	10 - 15	1000 – 2500	50 – 250	Firm - Very Stiff	Diggable
Sandstone/Mudstone Bedrock	-	2500 – 5000	100 - >400	Moderate - Strong	Break/ Blast

- Based on the results of the geophysical data, depth to bedrock across the site may be divided into two zones (Map 3).

Zone A:

Zone A comprises an area of very thick overburden and encloses the existing landfill area. Depth to bedrock of up to 30m is interpreted. Areas of thick overburden have been verified by borehole data. Incidentally, within Zone A, a small pocket of sand and gravel is interpreted to overlie a sequence of silty gravelly clay and a thick overburden of clay with cobbles and boulders (Profile 10).

Zone B:

Zone B occurs to the east of the site. Depth to bedrock of 5 m is interpreted.

- Depth to bedrock varies between 3 m to greater than 30 m bgl.

- Based on the results and interpretation of the geophysical data, the most favourable part of the site for landfill extension would be the area surrounding the existing landfill (Map 3). The sand and gravel deposits interpreted to overlie a thick clay overburden with cobbles and boulders, to the west of the existing landfill are not extensive and may be excavated.

- The stiffness of the overburden and the presence of a clay matrix indicate that the permeabilities are likely to be generally low.

- Rock velocities are generally low and typical of mudstone or sandstone bedrock. The low resistivity of the mudstone indicates the presence of clay minerals and likely low permeabilities. Intrusive data from borehole locations across the site show the presence of sandstone and mudstone bedrock.

2. Introduction

BMA Geoservices, Geophysical Consultants, were requested by M. C. O'Sullivan & Co. Ltd., to carry out a geophysical survey for a proposed landfill extension at Gortadroma, Co. Limerick.

Objectives

- To outline and investigate by non-destructive geophysical methods the suitability of the site for a proposed extension to the existing landfill in the area.
- To determine variations in overburden type and thickness.
- To determine depth to bedrock and variation in bedrock type.

Methodology

- EM-31 Conductivity mapping to produce a contour map to outline variations in overburden type and thickness across the site and to indicate areas of soft ground and near surface bedrock.
- 2D-resistivity profiles to estimate the overburden thickness and variation in rock type with depth.
- Seismic refraction lines to map the depth to bedrock and determine overburden stiffness and rock quality.
- Integration of borehole data into the geophysical interpretation.

Locations for the geophysical readings are shown on Map 1. Maps were provided by M. C. O'Sullivan & Co. Ltd.

Site Description and Geological Setting

The site under investigation lies to the southwest of Limerick city, approximately 8 km from Ardagh town. The geological bedrock map (Geology of the Shannon Estuary, Sheet 17 1999) indicates that the site is underlain by the Shannon Group. This formation consists of Carboniferous sandstone and mudstone. The site occupies an area of approximately 1.1 hectares and lies at an elevation of 110 mOD. The site comprises an area of low-lying ground to the south. The ground surveyed in this area is wet and boggy containing reeds and rushes together with a series of ditches, which randomly dissect the area. The centre of the site is flat lying and is made up of boggy, poorly drained fields. The east and west parts of the site are more undulating with better drained fields.

Report Outline

The results are discussed in Section 3 and recommendations in Section 4. A detailed account of the geophysical methods and equipment used and data processing is contained in Appendix I.

3. Results

This section integrates the geophysical results with the available geological data together with intrusive data from borehole locations across the site. The interpretation is based on the available factual information, typical geophysical responses of known materials and the experience of the author. The interpreted 2D-Resistivity sections are shown at the end of this report; the seismic sections are displayed in Appendix II.

EM-31 Ground Conductivity

The EM-31 ground conductivity survey has highlighted variations in conductivity across the site with conductivity values ranging from 11 - 43 mS/m. A contour map of the conductivity data is shown on Map 2 and the values are summarized on Map 3. The conductivity contours, in general, follow the elevation and saturation level of the site. Conductivity values of less than 15 mS/m correspond to the drier areas of the site with shallow or more gravelly overburden, whereas the boggy areas with very thick overburden show conductivity values of greater than 30 mS/m. The results of the EM-31 survey can be summarized as follows:

Zone	Conductivity (mS/m)	Interpretation
A	< 20	0 - 10m Overburden over Bedrock
B	20 - 45	10 - 30m Overburden over Sand/Gravel/Bedrock

2D-Resistivity profiles and Seismic spreads were located based on the results of the EM-31 survey.

2D-Resistivity

The 2D-Resistivity profile data shows good correlation with the EM-31 values. The recorded resistivities range from less than 20 Ohm-m to greater than 500 Ohm-m. Two to three layers have been interpreted on each 2D-resistivity profile. The resistivity data may be summarised as follows:

Resistivity (ohm-m)	Interpretation
> 50	Peat
15 - 100	Silty Gravelly Clay
50 - 250	Clay with Gravel, Cobbles and Boulders.
> 450	Sand & Gravel
100 - > 400	Mudstone/Sandstone Bedrock

Seismic Refraction

Just two layers have been interpreted on most of the seismic spreads. The different layers vary in thickness and seismic velocity across the survey area.

The seismic data may be summarized as follows:

Velocity (m/s)	Interpretation	Estimated Stiffness/ Rock Quality*
< 500 m/s	Peat	Diggable
250 - 800	Silty Gravelly Clay	Soft – Firm
800 - 2500	Clay with Gravel, Cobbles and Boulders.	Firm – Very Stiff
2500 - 5000	Mudstone/Sandstone Bedrock	Strong

*Estimates of soil stiffness and rock quality are based on the measured geophysical properties.

Integrated Interpretation

Profiles 1 and 2:

Profiles 1 and 2 run from south to north on low lying boggy ground and have been interpreted as indicating a thin layer (<5 m) of peat overlying a thick sequence of silty gravelly clay of low resistivity (<80 ohm-m) and moderate seismic velocity (1600 m/s). A two layer sequence is interpreted from the seismic spreads. Depth to mudstone bedrock is interpreted to occur at approximately 30 m.

Profile 3:

A three layer seismic velocity sequence is interpreted to occur along Profile 3 comprising a thin top layer with seismic velocities of 500 m/s, interpreted to be silty gravelly clay. Underlying this sequence is a 10 m layer with seismic velocities of 2000 m/s indicative of of a stiff clay sequence with gravel, cobbles and boulders. A layer with a seismic velocity of 3600 m/s signifies the transition into mudstone bedrock. Integrating the seismic data into the interpretation proves to be very useful as the resistivity contrast between the stiff clay sequence (< 250 ohm–m) and mudstone (100-350 ohm–m) is not clear cut. Depth to rock is interpreted to occur at approximately 12.5 m to the west and then shallows to a depth of less than 4 m b.g.l. to the east of the profile.

Profile 4:

Profile 4 has been interpreted as indicating a top layer of low resistivity (60 - 80 ohm) silty gravelly clay directly overlying sandstone/mudstone bedrock of moderate resistivity (100 – 300 ohm–m). A stark contrast in velocities between 420 m/s and 3200 m/s occurring at less than 5 m depth represents the transition to bedrock.

Profile 5:

Profile 5 runs from southwest to northeast and is interpreted to comprise 10 – 15 m of a low resistivity (<100 ohm-m) clay overburden with gravel, cobbles and boulders overlying sandstone/mudstone bedrock of higher resistivity (100-220 ohm-m). A reliable estimate of depth to bedrock cannot be made along this section due to the absence of seismic data.

Profile 6:

A 5 m thick layer of clay with gravel, cobbles and boulders, exhibiting seismic velocities of 1000 m/s and resistivities of 100 ohm-m is interpreted to occur along profile 6. A transition to a seismic velocity layer of 4000 m/s at 5 m signifies depth to bedrock. Higher resistivities (110-320 ohm-m), and seismic velocities are interpreted to be indicative of sandstone/mudstone bedrock.

Profile 7:

A similar sequence to Profile 6 is interpreted along Profile 7. Depth to bedrock is interpreted to occur at 5 m, signified by the transition in seismic velocities from 1000 m/s indicative of the stiff clay sequence to 4000 m/s, characteristic of sandstone/mudstone bedrock.

Profile 8:

Shallow depth to bedrock is once again determined along this profile. Bedrock is interpreted to occur at approximately 5 m depth based on the depth at which a transition in seismic velocities of 700 m/s – 3100 m/s occurs. Material having seismic velocities of 700 m/s and resistivities of < 75 ohm-m is interpreted to represent silty gravelly clay. This material is interpreted to overlie moderately resistive (80 – 220 ohm-m) sandstone/mudstone bedrock having seismic velocities of 3100 m/s.

Profile 9:

A 5 m thick layer of silty gravelly clay, exhibiting seismic velocities of 750 m/s and resistivities of < 100 ohm-m is interpreted to occur along Profile 9. This layer overlies a thick sequence interpreted to be a stiff clay sequence, exhibiting seismic velocities of 2500 m/s and resistivities of 100-220 ohm-m. Intrusive data from a borehole drilled at the south-eastern end of the profile has provided verification as to the nature of the overburden.

Profile 10:

A thin layer (2m) of high resistivity (>450 ohm-m) sand and gravel is interpreted to occur at the surface along Profile 10. Shallow depth to sand and gravel is also indicated by the low conductivity values (<14 mS/m) (Map 3). This sequence overlies a layer of silty gravelly clay, interpreted to occur to approximately 7.5 m depth, where a velocity change from 800 m/s to 2000 m/s signifies the transition to a stiff clay sequence with gravel/cobbles and boulders, of lower resistivity (200 ohm-m).

Profile 11:

Profile 11 runs from south to north and is interpreted to comprise 5 m of peat overlying low resistivity (< 80 ohm-m) silty gravelly clay, which in turn overlies a thick sequence of clay with gravel/cobbles and boulders. Intrusive data from a borehole drilled adjacent to the northern end of the profile has provided verification as to the nature of the overburden. Seismic spread 11 runs perpendicular to this profile at its southern end. A two layer sequence is interpreted. The top layer exhibiting seismic velocities of 500 m/s is interpreted to be sand and gravel deposits, a very small part of which may also be interpreted at the very south of the 2D Resistivity profile, having resistivities of > 300 ohm-

m. A velocity change to 1500 m/s at approximately 1.5 m depth is interpreted to represent the transition to the clay sequence with gravel/cobbles and boulders.

The combined geophysical properties can be summarized as follows:

Interpretation	Thickness (m)	Velocity (m/s)	Resistivity (ohm-m)	Estimated Stiffness/ Rock Quality*	Excavatability
Peat	> 5	< 500	> 50	Soft	Diggable
Silty Gravelly Clay	0 – 5	250 - 700	15-100	Soft-Firm	Diggable
Sand and Gravel	0 - 5	500 -> 1000	> 450	Soft – Firm	Diggable
Clay with Gravel, Cobbles and Boulders	10 - 15	1000 – 2500	50 - 250	Firm - Very Stiff	Diggable
Sandstone/Mudstone Bedrock	-	2500 – 5000	100 - >400	Moderate – Strong	Break/ Blast

- Based on the results and interpretation of the geophysical data, the most favourable part of the site for landfill extension would be the area surrounding the existing landfill (Map 3). The sand and gravel deposits interpreted to overlie a thick clay overburden with cobbles and boulders to the west of the existing landfill are not extensive and may be excavated.
- This area is advantageous in that there is thick overburden, with depth to bedrock in some areas of up to 30 m.
- In addition, the predominantly wet and boggy conditions, together with an amount of standing water indicate an impermeable layer beneath the topsoil. This is important in preventing the downwards migration of leachate and other pollutants.
- The stiffness of the overburden and the presence of a clay matrix indicate that the permeabilities are likely to be generally low.
- Rock velocities are generally low and typical of mudstone or sandstone bedrock. The low resistivity of the mudstone indicates the presence of clay minerals and likely low permeabilities.

Table 1: Summary of Borehole Data (Obtained from engineers logs).

Borehole No.	Co-Ordinates	Depth of Borehole	Nature Overburden	Depth to Bedrock
BHSA1	121782.5, 143730.3	8 m	Peat, stiff silt, sandy gravel.	Bedrock not encountered
BHSA3/1	122480.9, 143790.5	8.5 m	Gravelly clay, sandy silt, clayey gravel with some cobbles, gravelly clay.	Bedrock not encountered
BHSA3/R	122494.6, 143777.8	10 m	Gravelly clay, clayey gravel, silt, sandy gravel with some cobbles, gravelly silt.	Bedrock not encountered
BHSA4/1	122697.1, 143562.4	10 m	Gravelly clay, gravelly silt.	Bedrock not encountered
BHSA5/1	122487.8, 143559.3	10 m	Peat, grey silt with gravel and cobbles.	Bedrock not encountered
BHSA6	122751.1, 143401.0	5.45 m	Gravelly clay, sandy cobbles of weathered sandstone.	Bedrock not encountered
BHSA7	122511.4, 143339.3	10 m	Peat, grey silt.	Bedrock not encountered
BHRC1	122498.6, 143726.9	20 m	Clayey sandy gravel, boulders, gravelly clay with boulders.	Bedrock not encountered
BHRC2	122576.9, 143557.4	19.8 m	Peaty clay, gravelly silt, silty gravel, sandy clay with boulders.	15.5 m – Sandstone 19.6 m - Mudstone
BHRC3	122557.5, 143251.2	20 m	Peat, clayey silt, clayey gravelly silt.	Bedrock not encountered

4. References

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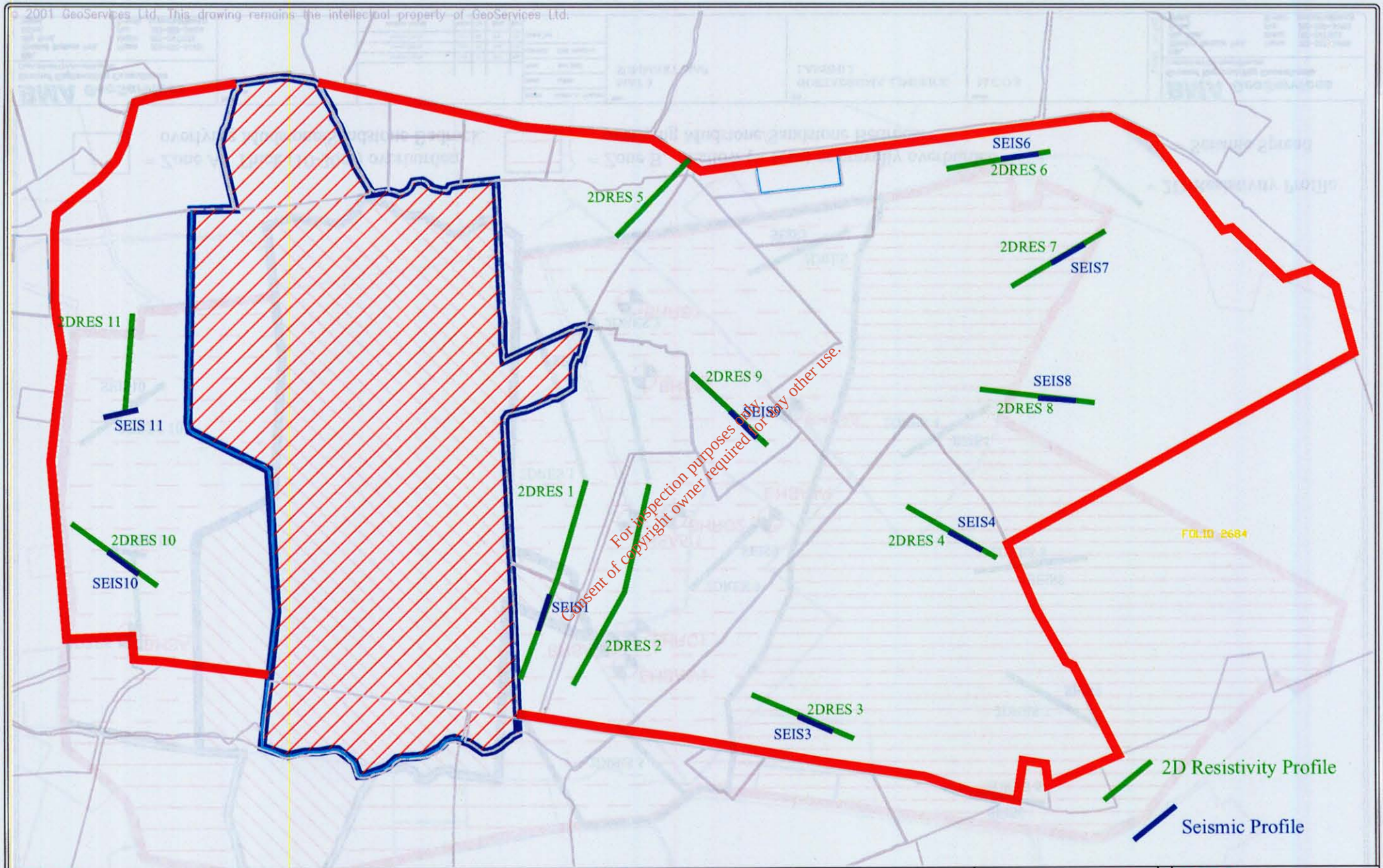
Sleeman, A.G. & Pracht M., 1999: The Geology of the Shannon Estuary.

Soske, J.L. 1959: The blind zone problem in engineering geophysics, *Geophysics, 24*, pp 359-36



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Notes: Rotes

Revision Details	Issue	By	Date	Rev
Revision Details	Issue	By	Date	Rev
Revision Details	Issue	By	Date	Rev
Revision Details	Issue	By	Date	Rev

Drawn: James A. Hodgson
Scale: 1/500
Date: Dec 2001
Checked: Ruth Staunton
Based On:

Title: MAP 1 GEOPHYSICAL LOCATION MAP

Job: GORTADROMA, LIMERICK LANDFILL

Client: M.C.O.S

Drg No: 1030/1

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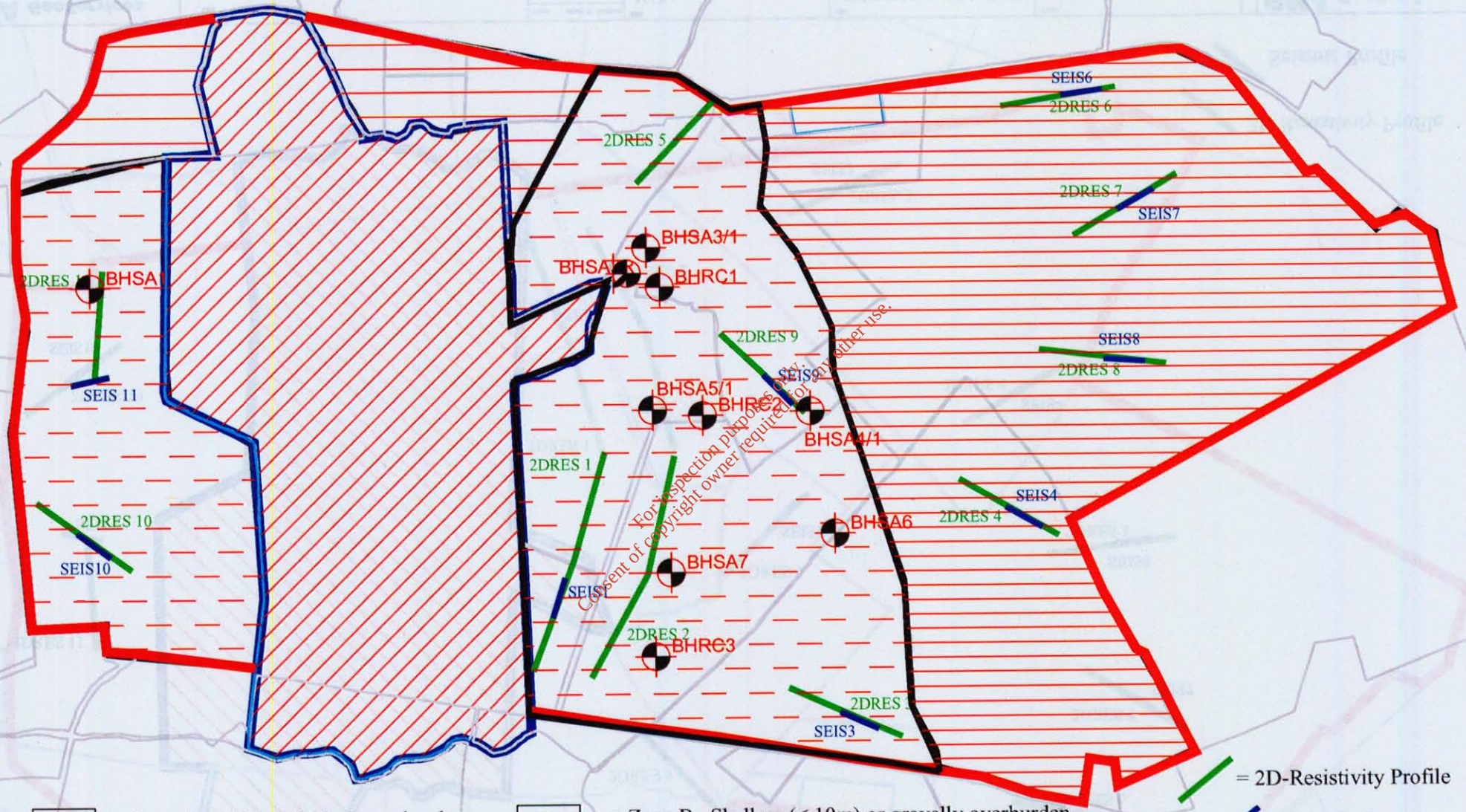

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Drawn: James A. Hodgson
Scale: 1/800
Date: Dec 2001
Checked: Ruth Staunton
Based On:

Title: MAP 3
SUMMARY MAP

Job: GORTADROMA, LIMERICK
LANDFILL

Client: M.C.O.S

Drg No: 1030/2

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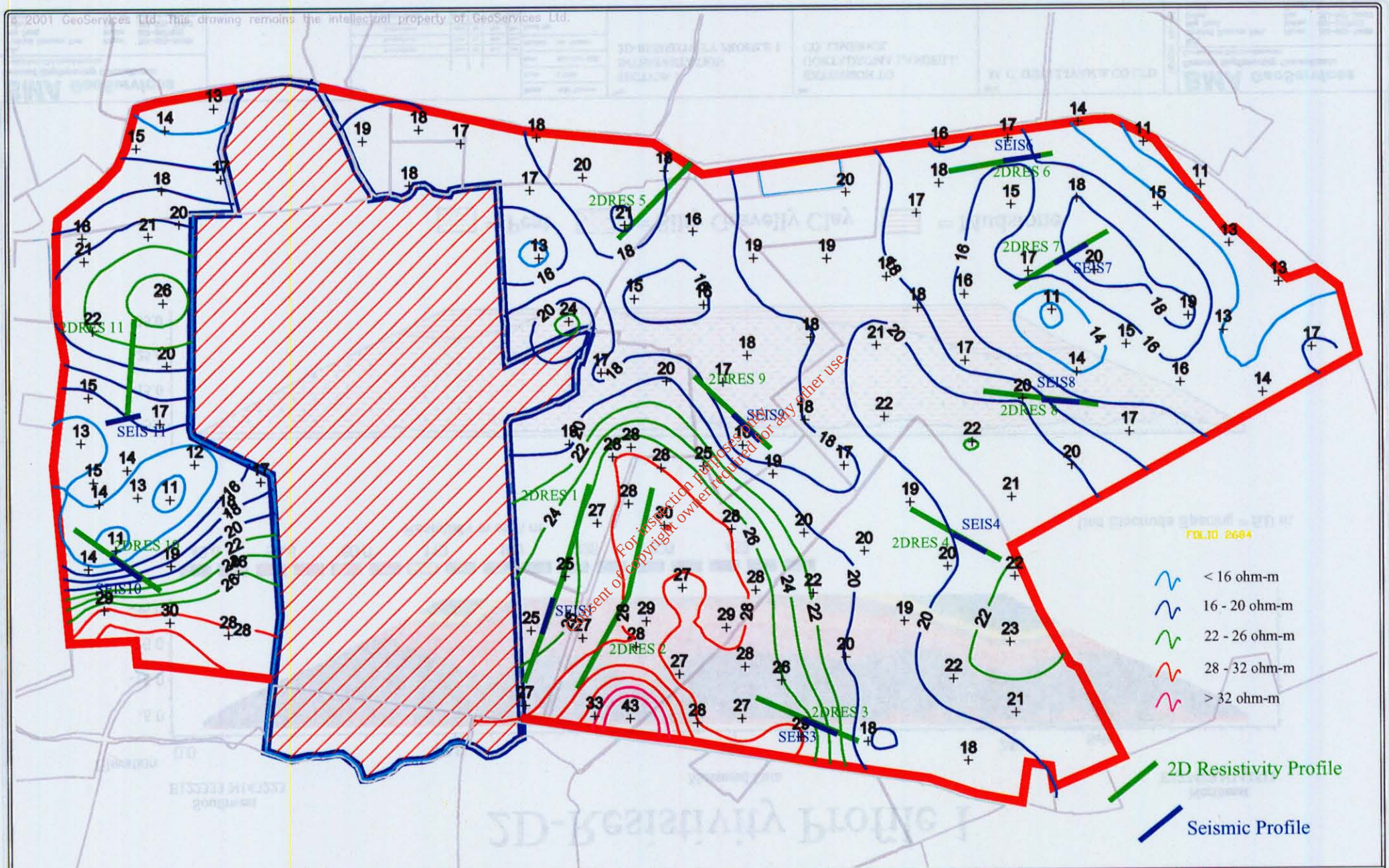

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Notes:

Revision Details	Issue	By	Date	Rev

Drawn: James A. Hodgens
Scale: 1/800
Date: Dec 2001
Checked: Ruth Shanahan
Based On:

Title: MAP 2 APPARENT RESISTIVITY CONTOUR MAP

Job: GORTADROMA, LIMERICK LANDFILL

Client: M.C.O.S

Drg No: 1030/2

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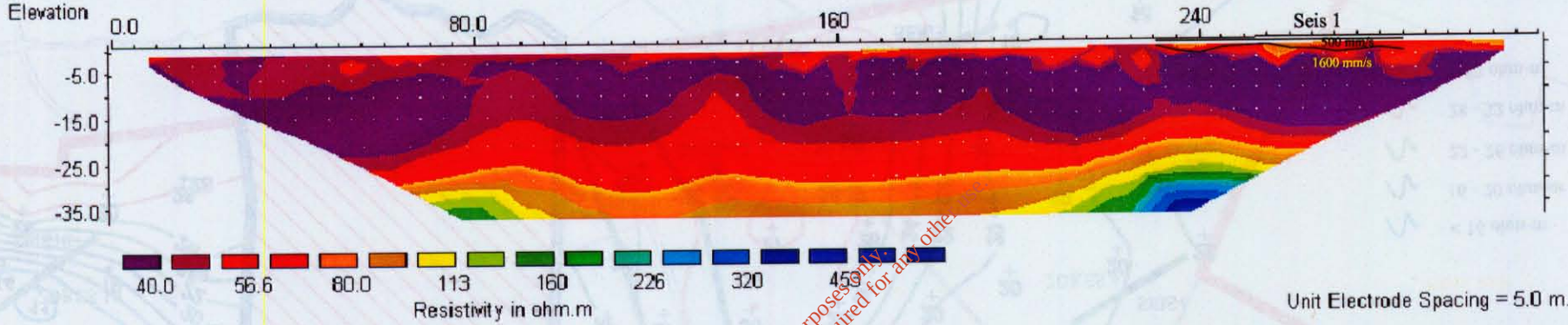
2D-Resistivity Profile 1

Southwest
E122333 N143223

Measured Data

Northeast
E122429 N143511



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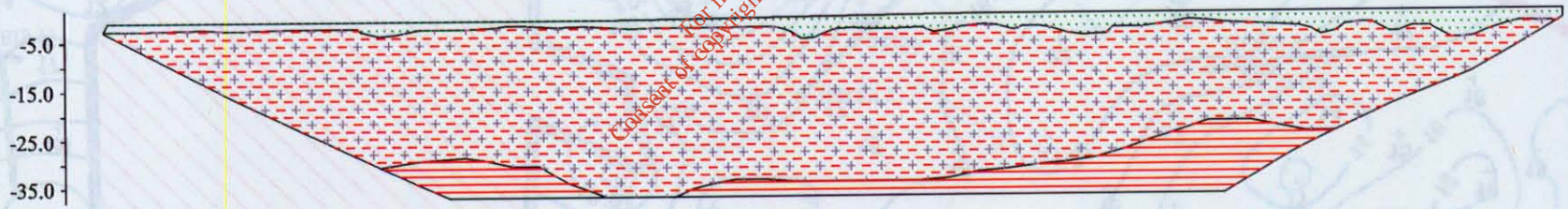

= Peat = Silty Gravelly Clay = Mudstone

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Drawn: Ruth Shanahan
Scale: 1/1000
Date: November 2002
Checked: Jim Hodgens
Based On:

SECTION 1
INTERPRETATION
2D-RESISITIVITY PROFILE 1

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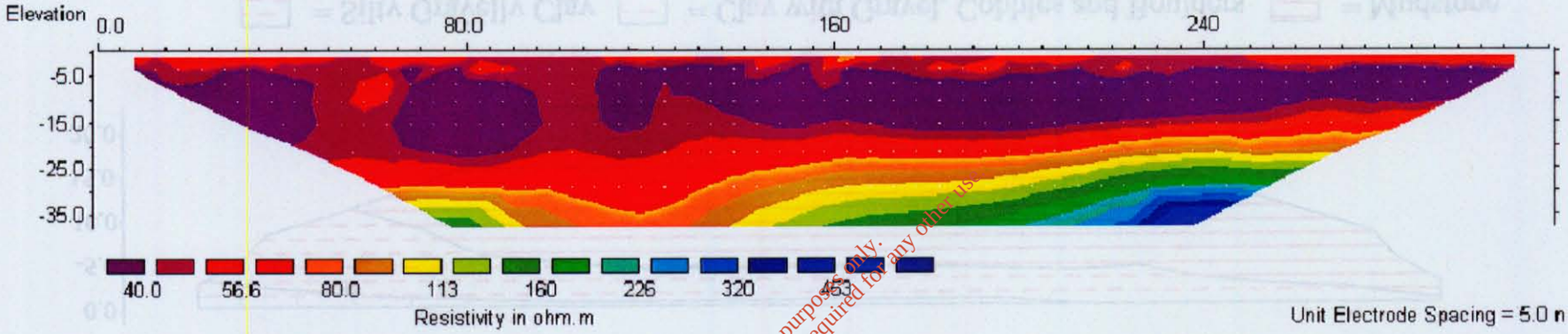
2D-Resistivity Profile 2

Measured Data

Southwest
E122410 N143214

Northeast
E122521 N143505



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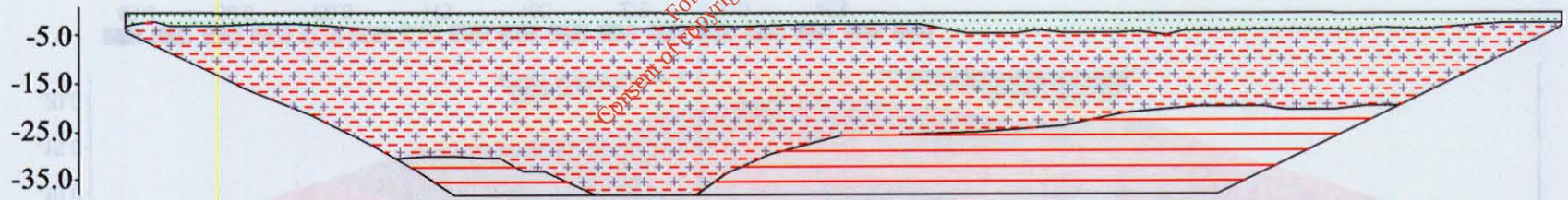

Peat = Silty Gravelly Clay = Mudstone

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Revision Details	Issue	By	Date	Rev

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Scale: 1/1000
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Title:
SECTION 2
INTERPRETATION
2D-RESISITIVITY PROFILE 2

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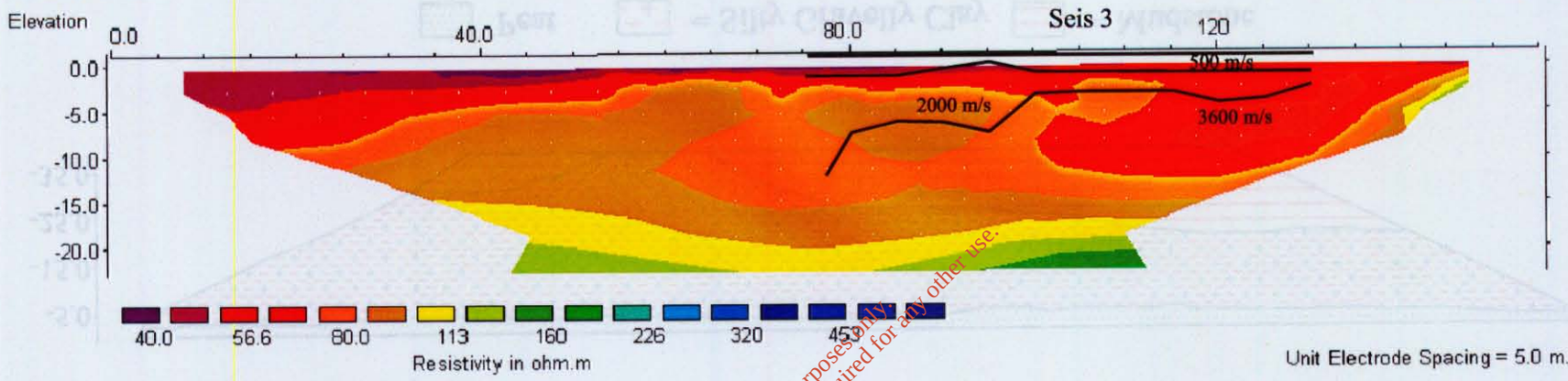
2D-Resistivity Profile 3

Measured Data

West
E122671 N143199

East
E122820 N143135



Unit Electrode Spacing = 5.0 m.

= Silty Gravelly Clay = Clay with Gravel, Cobbles and Boulders = Mudstone

Notes:
Notes

Drawn: Ruth Staunton
Scale: 1 / 750
Date: November 2002
Checked: Jim Hodgson
Based On:

Title:
SECTION 3
INTERPRETATION
2D-RESISTIVITY PROFILE 3

Job:
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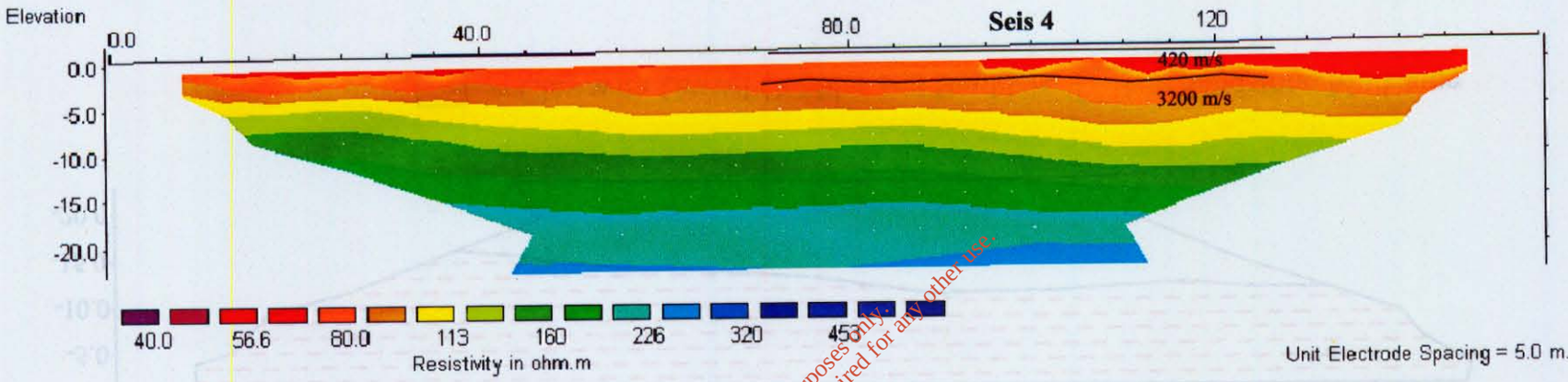
2D-Resistivity Profile 4

Measured Data

Northwest
E122671 N143199

Southeast
E122671 N143199



= Silty Gravelly Clay = Sandstone/Mudstone

Notes: Notes	Drawn: Ruth Staunton Scale: 1 / 750 Date: November 2002 Checked: Jim Hodgson Based On:	Title: SECTION 4 INTERPRETATION 2D-RESISTIVITY PROFILE 4	Job: EXTENSION TO GORTADROMA LANDFILL CO. LIMERICK	Client: M. C. O'SULLIVAN & CO. LTD	Drg No: 1030/R4

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2D-Resistivity Profile 5

Measured Data

Southwest
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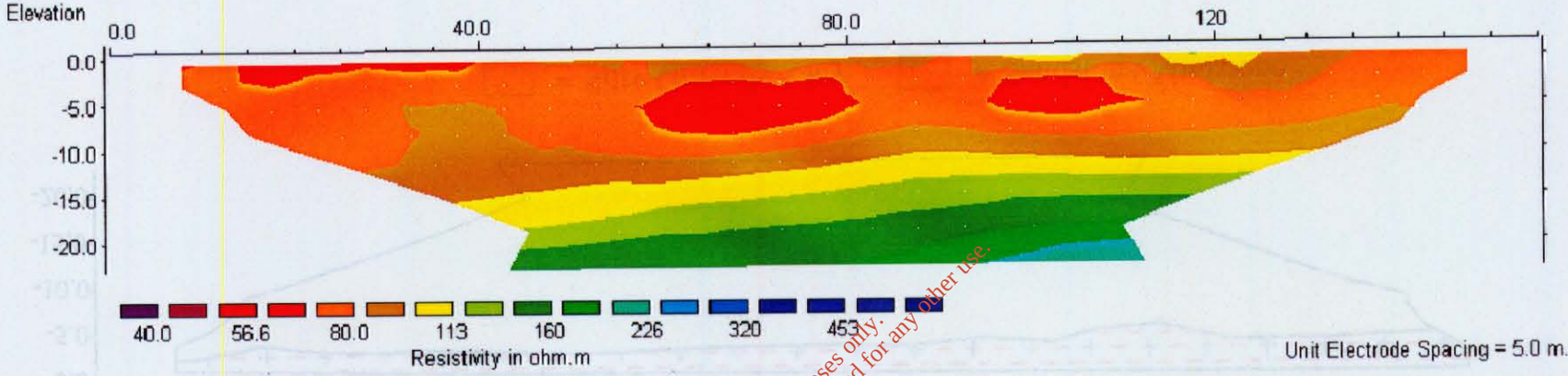
Northeast
E122580 N143976



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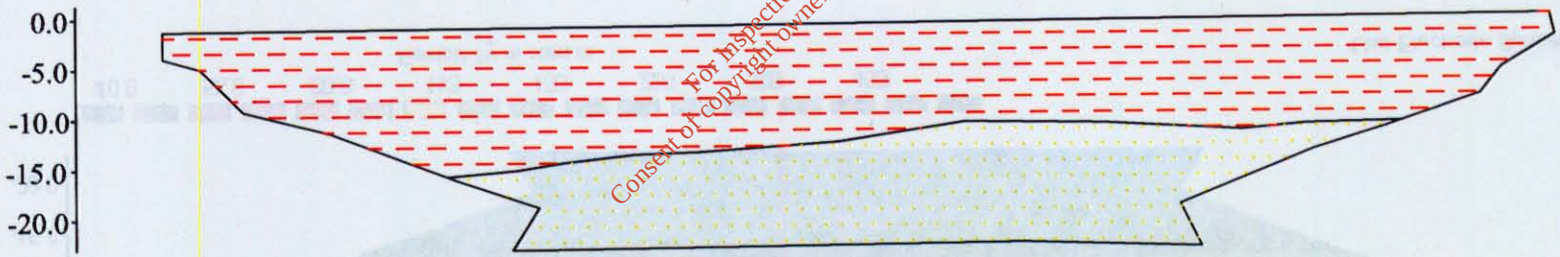

= Clay with Gravel Cobbles and Boulders. = Sandstone/Mudstone

Notes: Notes	Drawn: Ruth Staunton Scale: 1 / 750 Date: November 2002 Checked: Jin Hodgson Based On:	Title: SECTION 5 INTERPRETATION 2D-RESISTIVITY PROFILE 5	Job: EXTENSION TO GORTADROMA LANDFILL CO. LIMERICK	Client: M. C. O'SULLIVAN & CO. LTD	Drg No: 1030/R5

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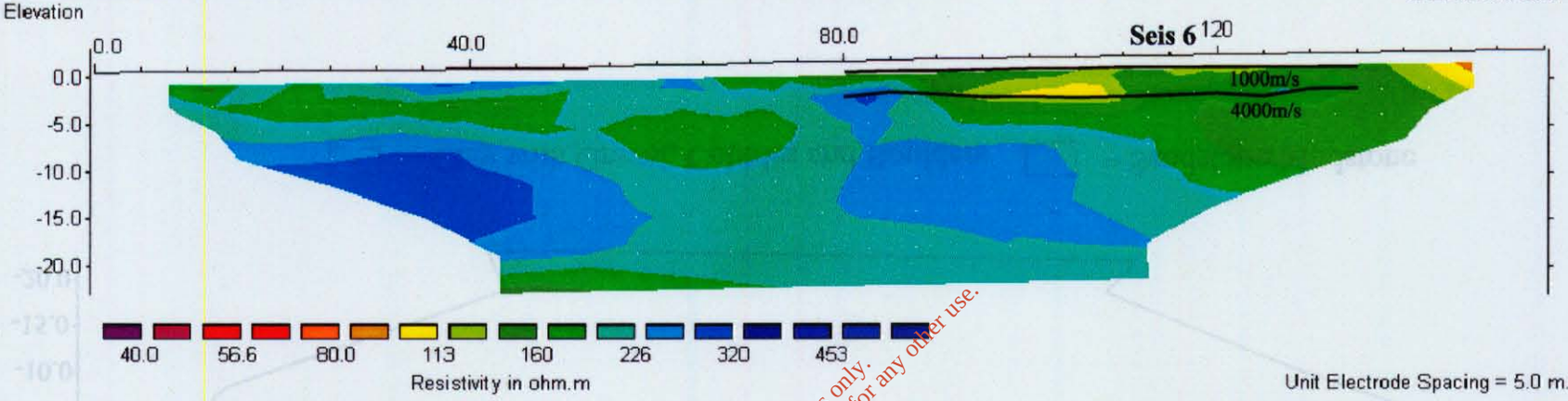
2D-Resistivity Profile 6

Measured Data

West
E122956 N143962
Elevation

East
E123107 N143987



Unit Electrode Spacing = 5.0 m.

= Clay with Gravel, Cobbles and Boulders

= Sandstone/Mudstone

Notes: Notes	Drawn: Ruth Staunton Scale: 1 / 750 Date: November 2002 Checked: James Hodgson Based On:	Title: SECTION 6 INTERPRETATION 2D-RESISTIVITY PROFILE 6	Job: EXTENSION TO GORTADROMA LANDFILL CO. LIMERICK	Client: M.C. O'SULLIVAN & CO. LTD	Drg No: 897/R6	BMA GeoServices Ground Engineering Consultants Comhairleoirí Cré-Innealtóireachta BMA, Strawhall Business Park, Athy Road, Carlow, Ireland. Phone: 353-503-34488 Mobile: 087-2477923 Fax: 353-503-34490 E-mail: bmadublin@bma.ie

2D-Resistivity Profile 7

Measured Data

Southwest
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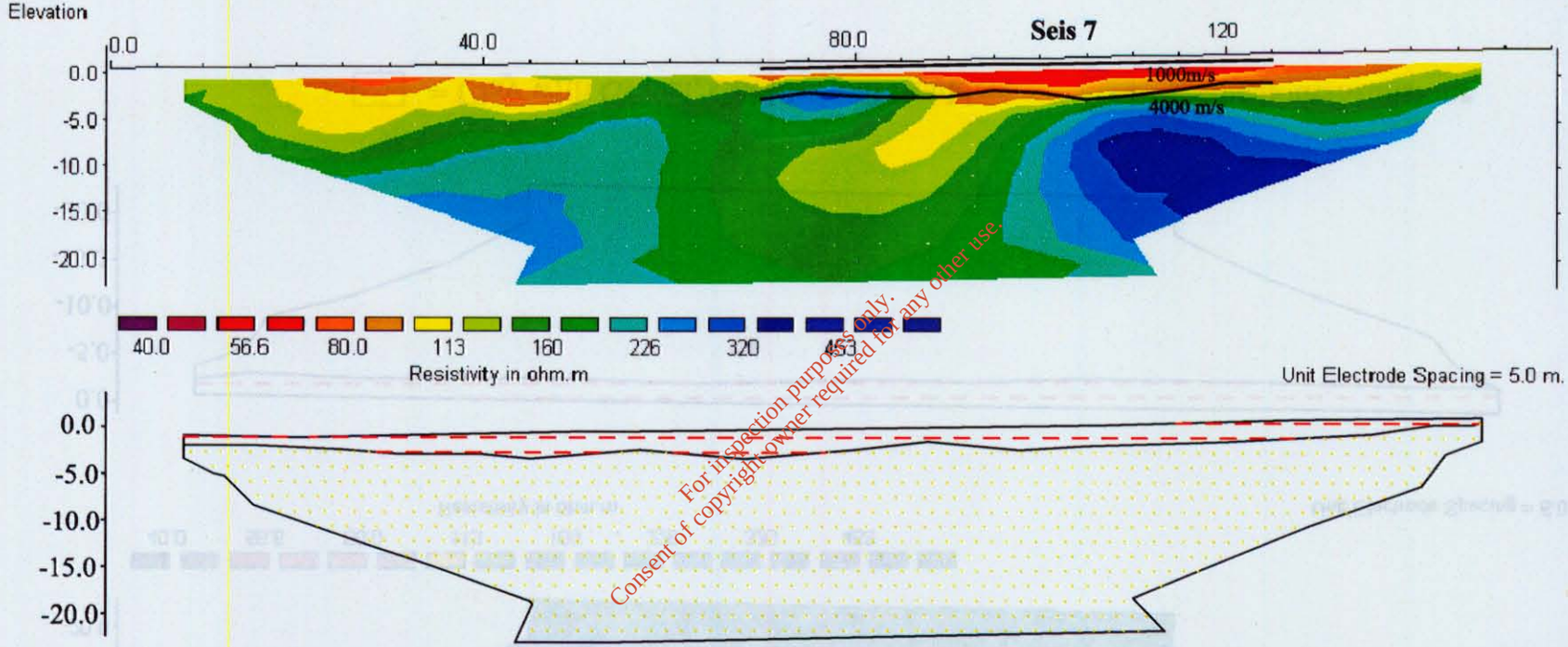
Northeast
E123187 N143872



= Clay with Gravel, Cobbles and Boulders

= Sandstone/Mudstone

Notes: Notes	Drawn: Ruth Staunton Scale: 1 / 750 Date: November 2002 Checked: Jim Hodgson Based On:	Title: SECTION 7 INTERPRETATION 2D-RESISTIVITY PROFILE 7	Job: EXTENSION TO GORTADROMA LANDFILL CO. LIMERICK	Client: M. C. O'SULLIVAN & CO. LTD	Drg No: 1030/R7

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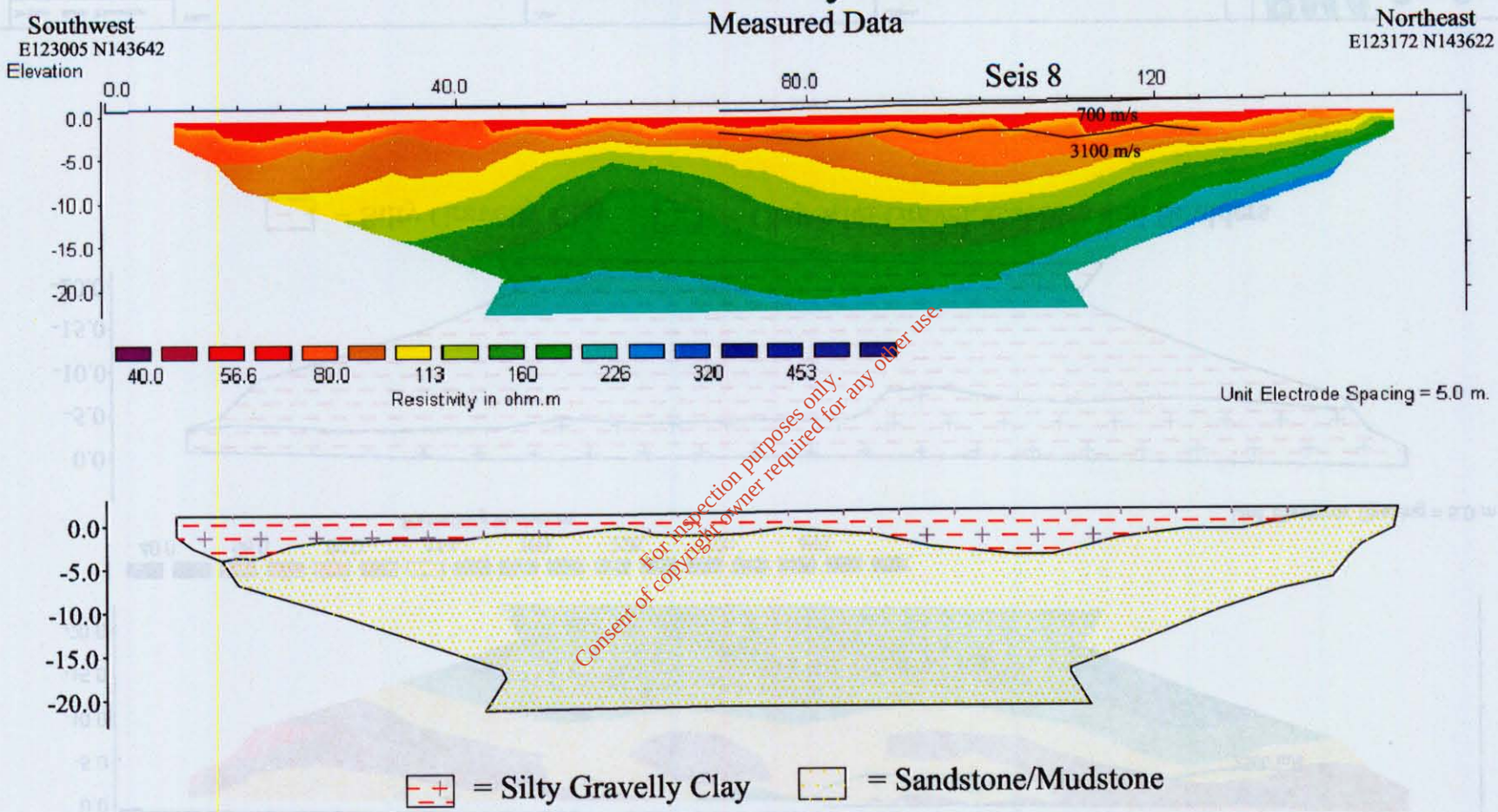
2D-Resistivity Profile 8

Measured Data



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2D-Resistivity Profile 9

Measured Data

Northwest
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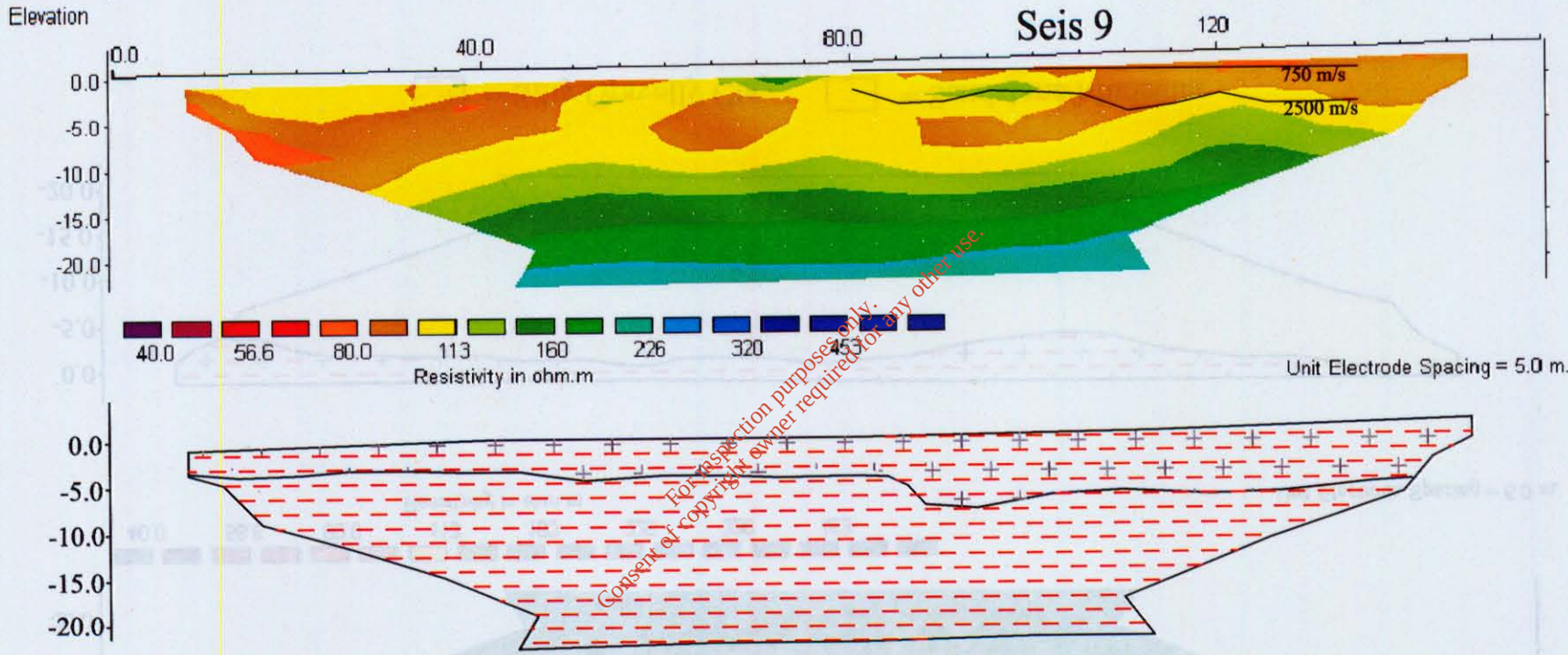
Southeast
E122694 N143561



= Silty Gravelly Clay

= Clay with Gravel, Cobbles and Boulders

Notes:
Notes

Drawn: Ruth Staunton
Scale: 1 / 750
Date: November 2002
Checked: Jim Hodgson
Based On:

Title:
SECTION 9
INTERPRETATION
2D-RESISTIVITY PROFILE 9

Job:
EXTENSION TO
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CO. LIMERICK

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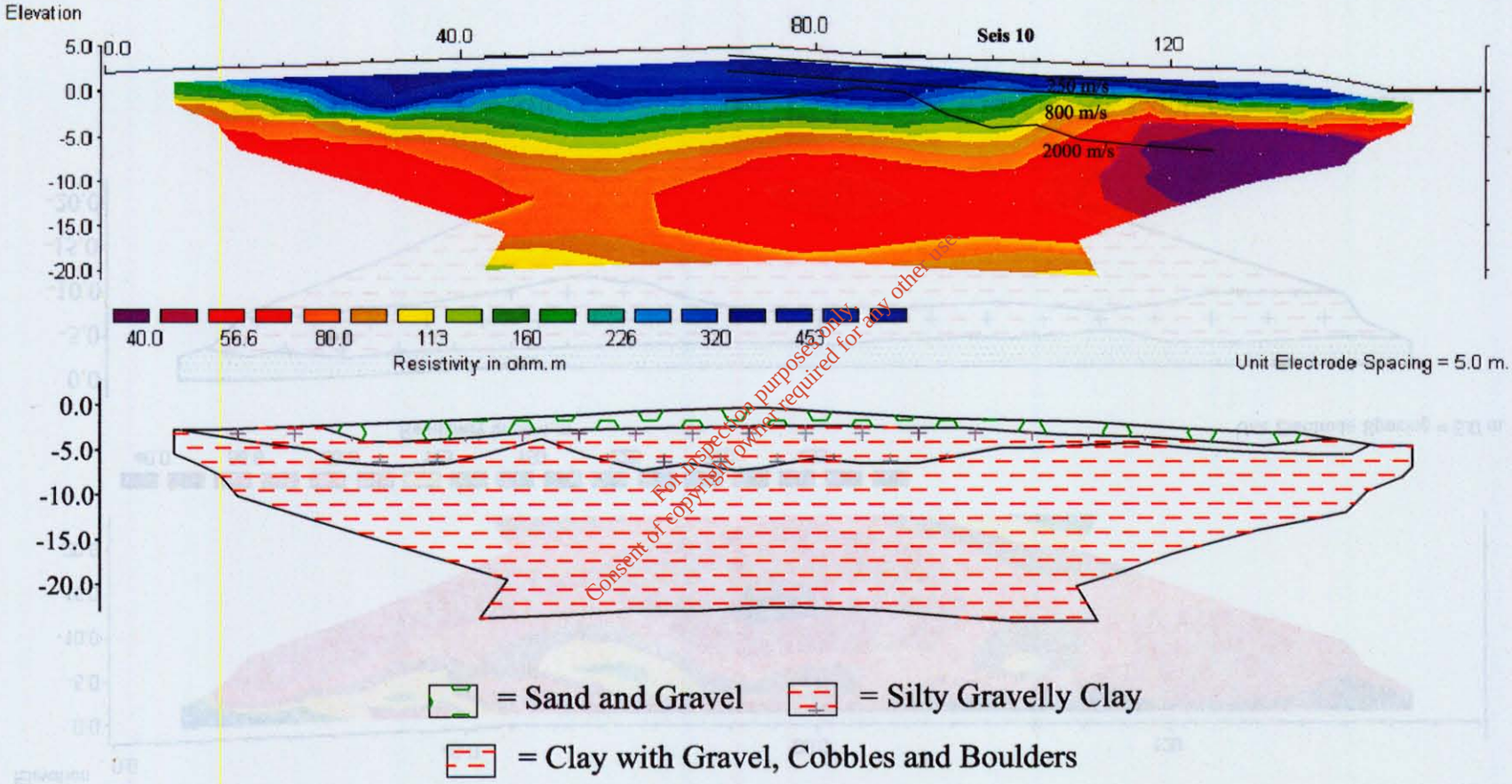
2D-Resistivity Profile 10

Measured Data

Northwest
E121681 N143449

Southeast
E121806 N143359



= Sand and Gravel

= Silty Gravelly Clay

= Clay with Gravel, Cobbles and Boulders

Notes: Notes	Drawn: Ruth Staunton Scale: 1 / 750 Date: November 2002 Checked: Jim Hodgson Based On:	Title: SECTION 10 INTERPRETATION 2D-RESISTIVITY PROFILE 10	Job: EXTENSION TO GORTADROMA LANDFILL CO. LIMERICK	Client: M. C. O'SULLIVAN & CO. LTD	Drg No: 1030/R10

BMA GeoServices
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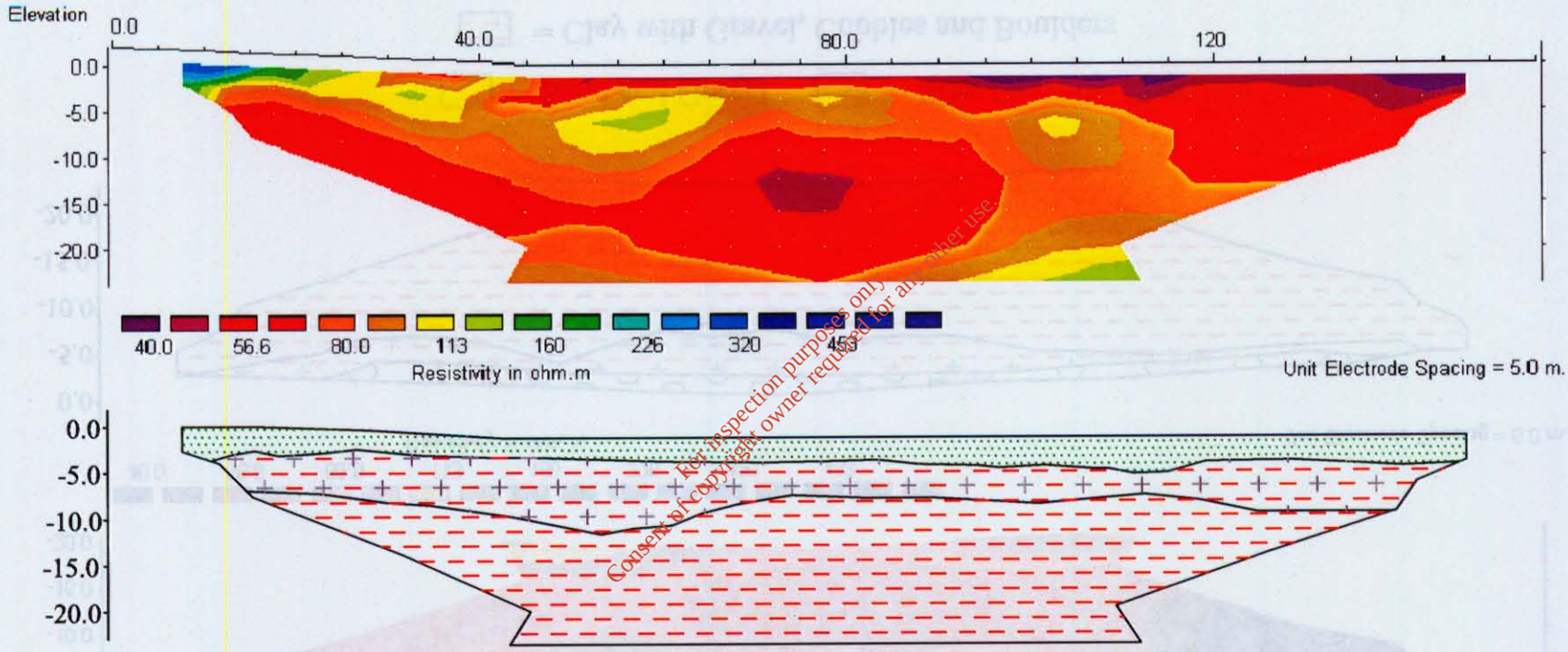
2D-Resistivity Profile 11

Measured Data

South
E121759 N143610

North
E121770 N143754



Notes: Notes	Drawn: Ruth Staunton Scale: 1 / 750 Date: November 2002 Checked: Jm Hodgson Based On:	Title: SECTION 11 INTERPRETATION 2D-RESISTIVITY PROFILE 11	Job: EXTENSION TO GORTADROMA LANDFILL CO. LIMERICK	Client: M. C. O'SULLIVAN & CO. LTD	Drg No: 1030/R11

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Appendix I Geophysical Methodology.

A1. Methods Used

A1.1 EM31 Ground Conductivity
A1.2 2D-Resistivity Profiling
A1.3 Seismic

A2. Equipment Used

A2.1 EM31 Ground Conductivity
A2.2 2D-Resistivity Profiling
A2.3 Seismic

A3. Field Procedure

A3.3 EM31 Ground Conductivity
A3.2 2D-Resistivity Profiling
A3.3 Seismic

A4. Data Processing

A4.1 EM31 Ground Conductivity
A4.2 2D-Resistivity Profiling
A4.3 Seismic

A1. Methods Used

A1.1 EM31 Ground Conductivity

This method operates on the principle of inducing currents in conductive substrata and measuring the resultant secondary electro-magnetic field. The strength of this secondary EM field is calibrated to give apparent ground conductivity in milliSiemens/m (mS/m). As the effective penetration of this method is around 6m b.g.l., the measured conductivity is a function of the different overburden layers and/or rock from 0 to 6m b.g.l.

A1.2 2D-Resistivity Profiling

A basic measurement technique in resistivity work is the Wenner array, whereby four electrodes are planted along a line in the ground and a current is introduced through the two outer electrodes. The potential difference across the two inner electrodes is then measured and the resistance (physical unit: Ohm) is determined as the quotient of the potential and the current. All measurements are made with a resistivity meter.

To obtain the resistivity (physical unit: Ohm * m), which is a quantity independent of test conditions and characteristic for different soils and liquids, the following formula is applied:

$$\text{Resistivity} = 2 * PI * \text{Spacing} * \text{Resistance}$$

In 2D-Resistivity a large number of resistivity measurements are taken both laterally and vertically in order to map changes in material types in these directions. This is achieved in a very efficient way by connecting a series of electrodes to the resistivity meter and using a computer to control the process of data collection and storage.

A1.3 Seismic Refraction

This method measures the travel-times of the refracted seismic waves through the overburden and rock material and allows an assessment of the thickness and quality of the materials to be made. More compact materials tend to have higher seismic velocities. The depth range of the method varies with geophone spacing but for typical engineering surveys is of the order of 1 to 30 m.

A2. Equipment Used

A2.1 EM31 Ground Conductivity

The equipment used was an EM-31 conductivity meter and data logging system. The instrument does not require ground contact and can be operated by one person.

A2.2 2D-Resistivity Profiling

The Geopulse TIGRE resistivity meter, a multi-core cable with 32 takeouts and 32 stainless steel electrodes were deployed and used to measure the resistivity sections. For two of the profiles, a multi-core cable with 64 takeouts and 64 stainless steel electrodes were used.

The RES2DINV software was used for processing and viewing the data immediately after the survey (Campus Geophysical Instruments, 1997).

A2.3 Seismic Refraction

The seismic data was recorded using a 12-channel Geometrics Smartseis signal enhancement seismograph with a seismic cable and 12 vertical geophones. The seismic source was a hammer and a striking plate.

A3. Field Procedure

The locations of the geophysical measurements were recorded using GPS and are shown on Map 1.

A3.1 EM31 Ground Conductivity

Readings were taken on the site over a grid of 100x100 m.

At each station two readings were taken with the boom orientated in two directions (N-S and W-E). A total of 158 station locations were recorded. Notes were taken of any potential sources of interference and of changes in topography and soil type.

A Garmin 12 XL GPS receiver was used to record the location of each reading. The locations of the conductivity readings are displayed on Map 2.

A3.2 2D-Resistivity Profiling

A total of 11 2D-Resistivity profiles were carried out across the survey area. The profiles were located to <5m accuracy using GPS.

The recording parameters for each profile are listed below.

Table A3.2: 2D-Resistivity Profile locations

	NO. OF ELECTRODES	SPACING (m)	LENGTH (m)	AZIMUTH -	NOMINAL DEPTH (m)
2DRES 1	64	5	315	S-N	35
2DRES 2	64	5	315	S-N	35
2DRES 3	32	5	155	W-E	20
2DRES 4	32	5	155	NW-SE	20
2DRES 5	32	5	155	SW-NE	20
2DRES 6	32	5	155	W-E	20
2DRES 7	32	5	155	W-E	20
2DRES 8	32	5	155	SW-NE	20
2DRES 9	32	5	155	NW-SE	20
2DRES 10	32	5	155	NW-SE	20
2DRES 11	32	5	155	S-N	20

A3.3 Seismic Refraction

Nine seismic refraction spreads were recorded. Each seismic spread consisted of 12 collinear geophones at a spacing of 5 m. Records from five different positions were taken on each spread (2 x off-end, 2 x end, 1 x middle) to ensure optimum coverage of all

refractors. Each seismic profile was located along the corresponding resistivity line except for seismic spread 11, which was located perpendicular to the 2D-Resistivity profile at its southern end.

Table A3.3: Seismic Refraction locations

SPREAD No.	SPACING (m)	LENGTH (m)	AZIMUTH -	NOMINAL DEPTH (m)
1	5	55	S-N	10
3	5	55	W-E	10
4	5	55	NW-SE	10
6	5	55	W-E	10
7	5	55	SW-NE	10
8	5	55	SW-NE	10
9	5	55	NW-SE	10
10	5	55	NW-SE	10
11	5	55	NW-SE	10

A4. Data Processing

A4.1 EM31 Ground Conductivity

The field readings of the conductivities were converted to average conductivities at spacings of 100m.

This method operates on the principle of inducing currents in conductive substrata and measuring the resultant secondary electro-magnetic field. The strength of the out-of-phase component of this secondary EM field is calibrated to give apparent ground conductivity in milliSiemens/m (mS/m). As the effective penetration of this method is around 6m b.g.l., the measured conductivity is a function of the different overburden materials and layers and/or rock from 0 to 6m b.g.l.

The in-phase component of the secondary EM field responds directly to shallow buried metallic objects.

The average conductivity values have been gridded, blanked and contoured for each site with the program WINSURF (Golden Software, 1994).

Note: The gridding method used was the Kriging technique. It should be noted that computer-based gridding and contouring methods interpolate and extrapolate between data points, and reference should be made to the location and value of the original data points when using the contoured data.

A4.2 2D-Resistivity Profiling

The field data were stored in computer files and converted within the TIGRE resistivity meter. The resulting files were loaded into RES2DINV (Campus Geophysical Instruments, 1997), where an inversion with up to 5 iterations of the measured data was carried out for each profile to obtain a 2D-Depth model of the resistivities.

These 2D-Resistivity models and interpreted geology are displayed on Sections 1 - 11. The horizontal axis shows the distance along the profile, while the depth (b.g.l.) is indicated at the sides. Constant contour intervals and colour codes have been used for Sections 1 - 11.

Note: Care should be taken when using these sections. The data displayed is real physical data that can be measured with a high repeatability, but transforming resistivities directly into geological layers requires interpretation of the geophysical results.

A4.3 Seismic Refraction

The data were processed as follows:

(i) 'First breaks' were picked on the field records and traveltime plots constructed for each spread.

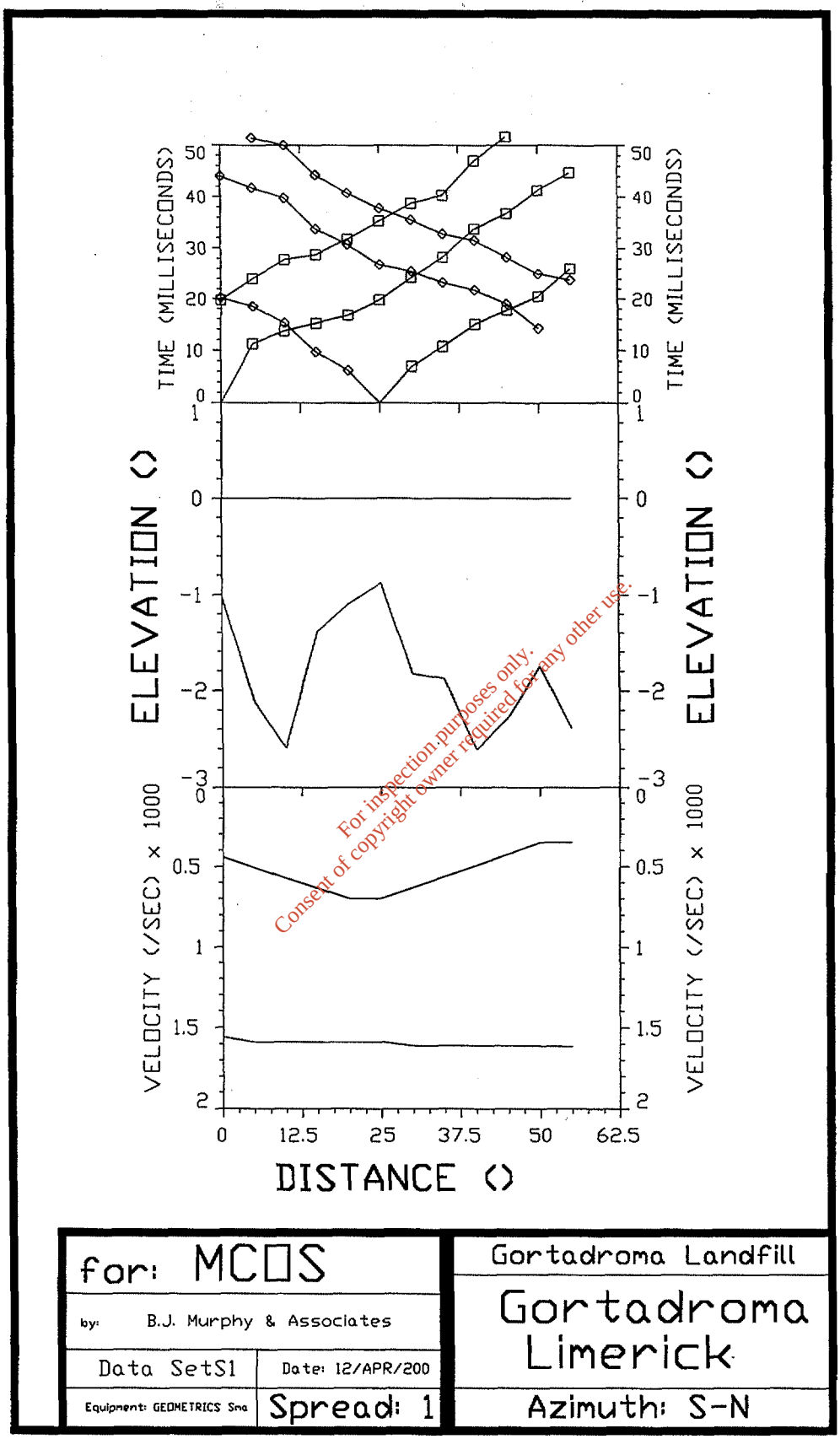
(ii) Seismic velocity phases were picked on each traveltime plot and the thickness of each velocity unit was calculated using the intercept - time method (Redpath, 1973).

The data processing was carried out using the "FIRSTPIX' and "GREMIX" computer programs (Interpex, 1997, 1998). The traveltime graphs, depth sections and velocity graphs for each spread are contained in Appendix II.

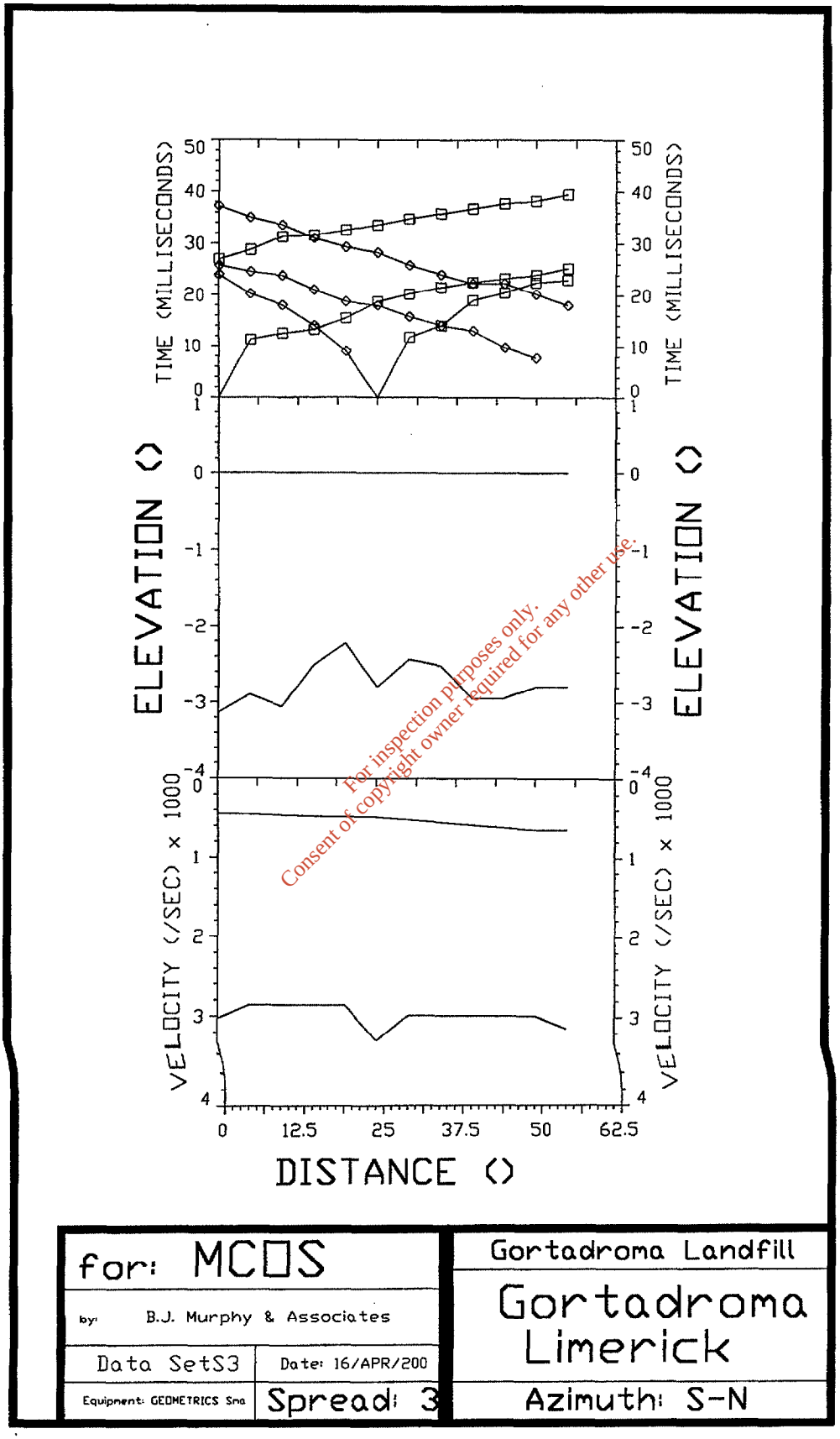
Approximate errors for velocities are estimated to be +/- 10%. Errors for the calculated layer thickness are of the order of +/-20%. Possible errors due to the "hidden layer" and "velocity inversion" effects may also occur (Soske, 1959).

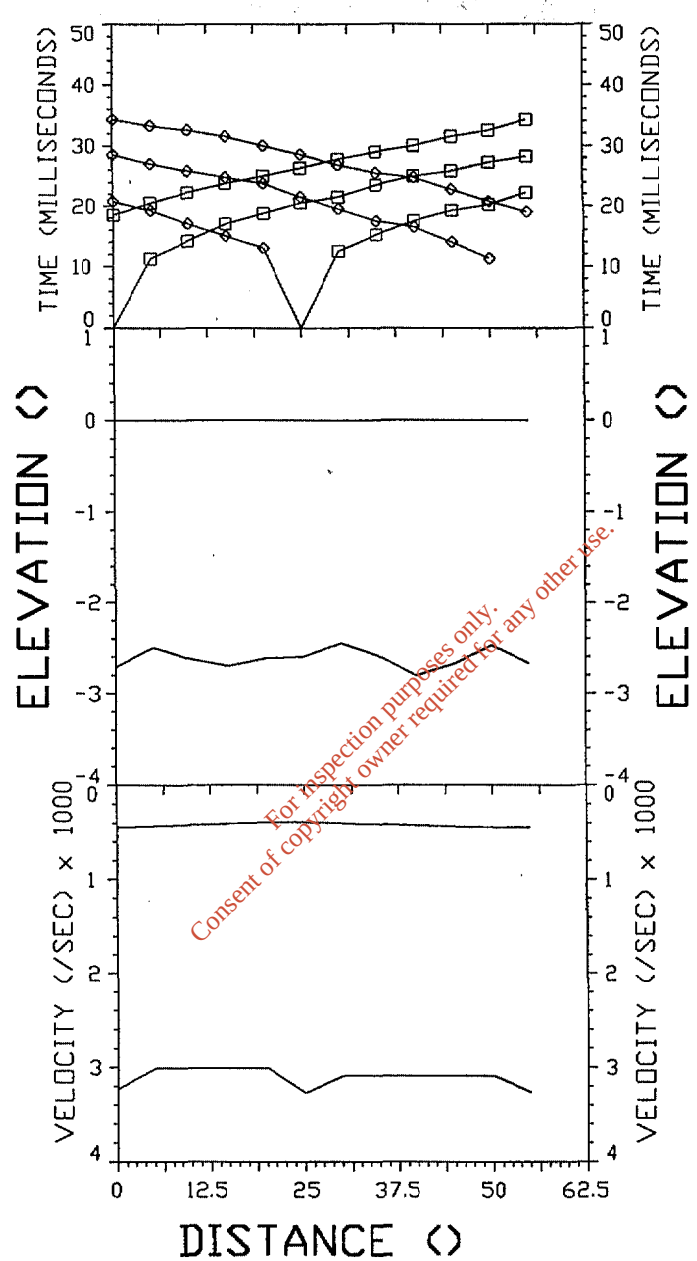
[redacted]

Appendix II Seismic Data.

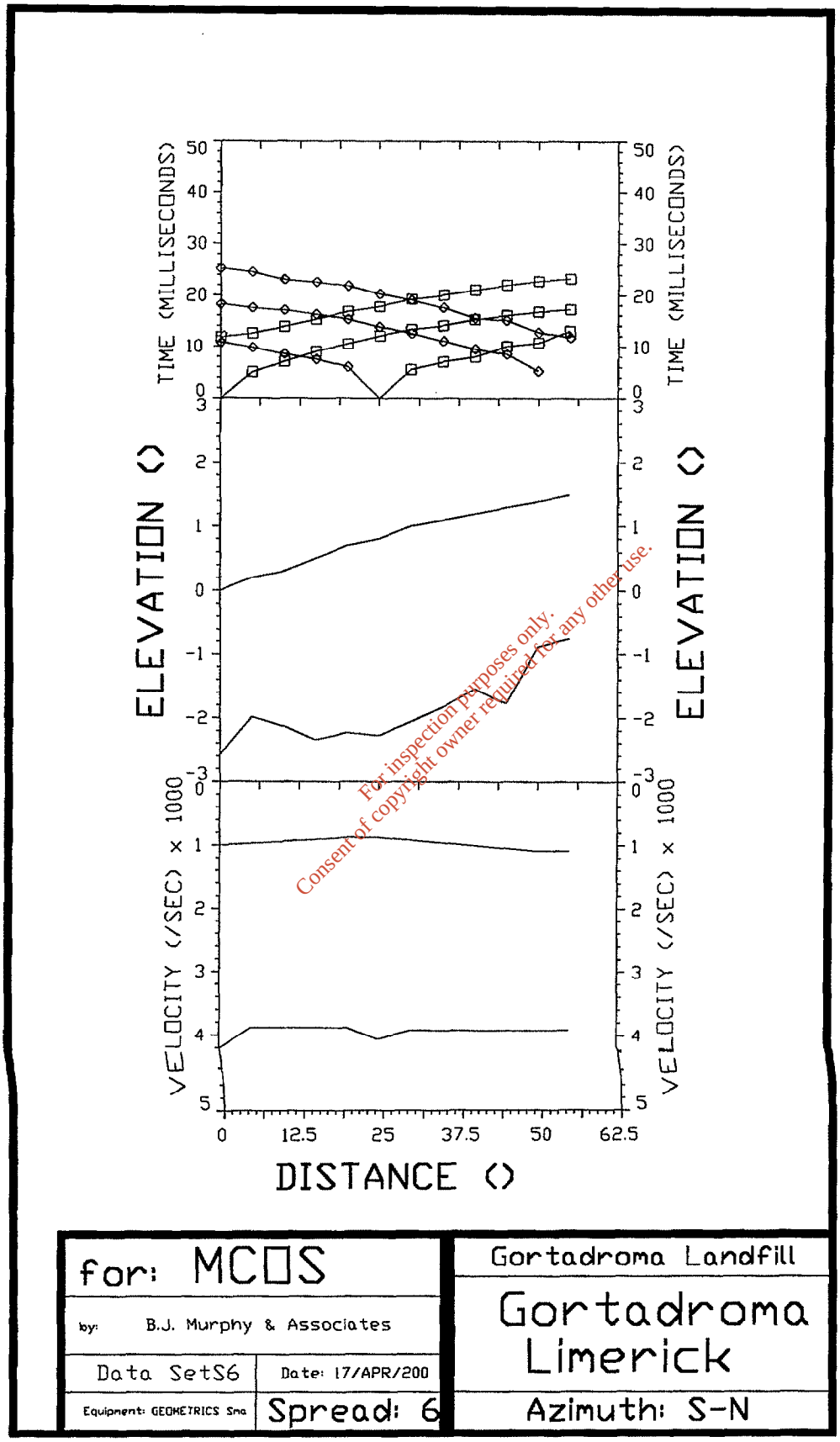


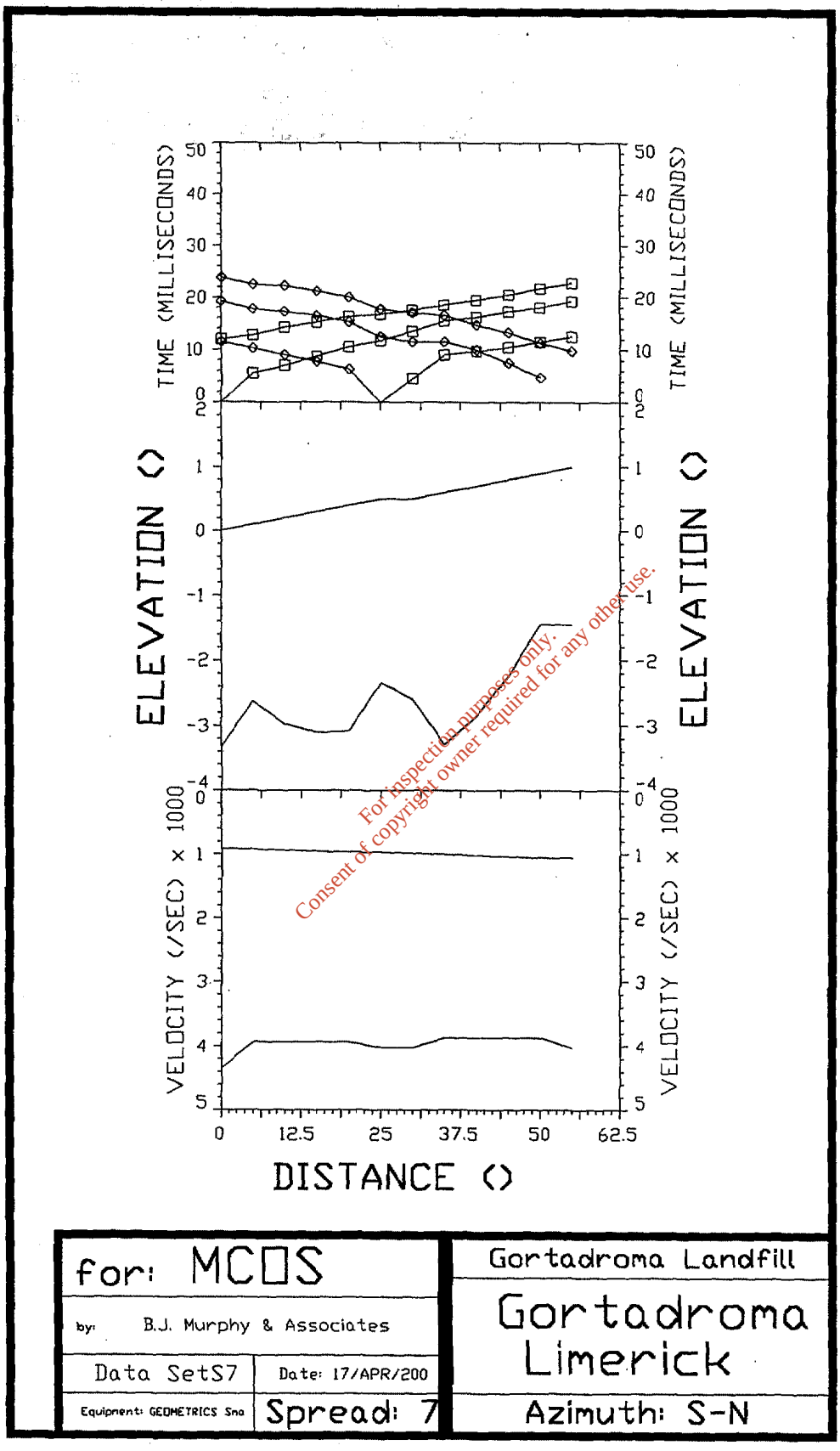
for: MCOS	Gortadroma Landfill
by: B.J. Murphy & Associates	Gortadroma Limerick
Data SetS1 / Date: 12/APR/200	
Equipment: GEOMETRICS Sma / Spread: 1	Azimuth: S-N



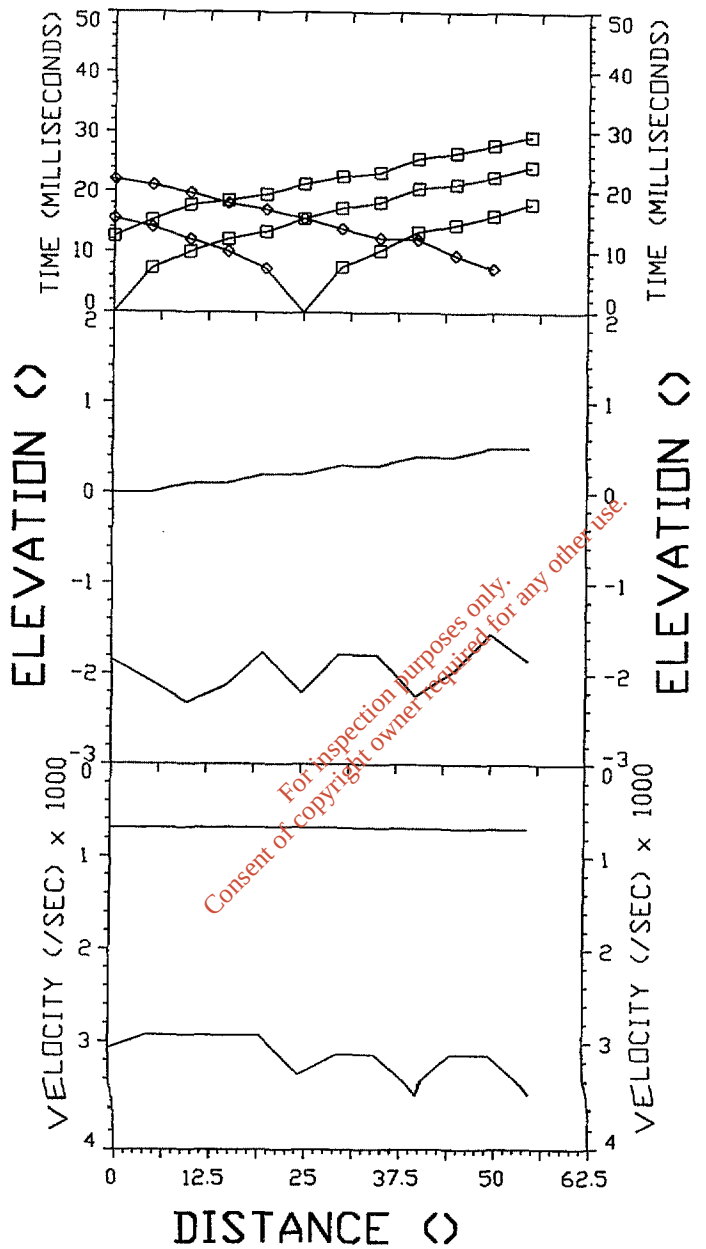


for: MCOS	Gortadroma Landfill
by: B.J. Murphy & Associates	Gortadroma Limerick
Data SetS4 / Date: 16/APR/200	
Equipment: GEOMETRICS Sma / Spread: 4	Azimuth: S-N

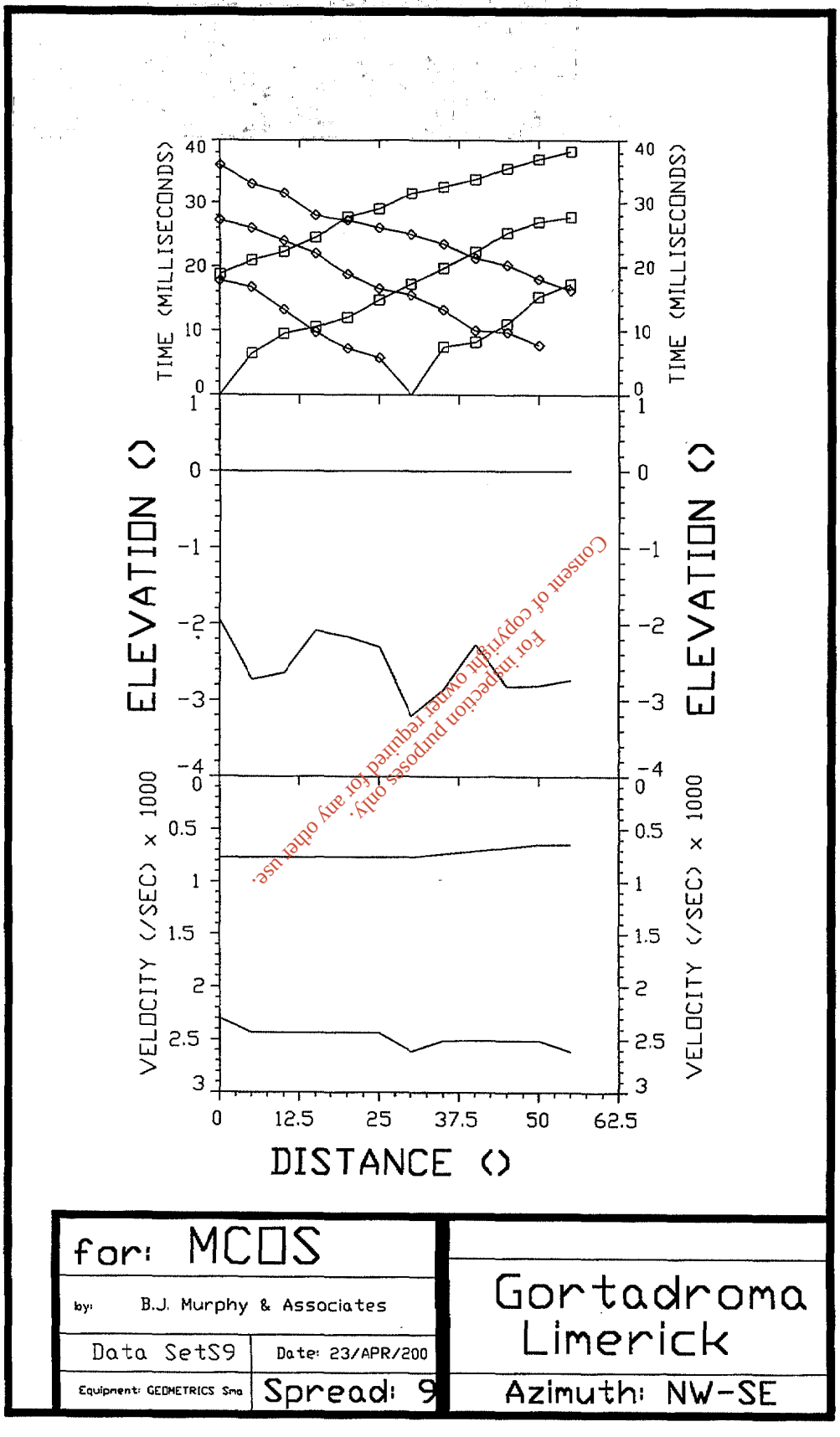


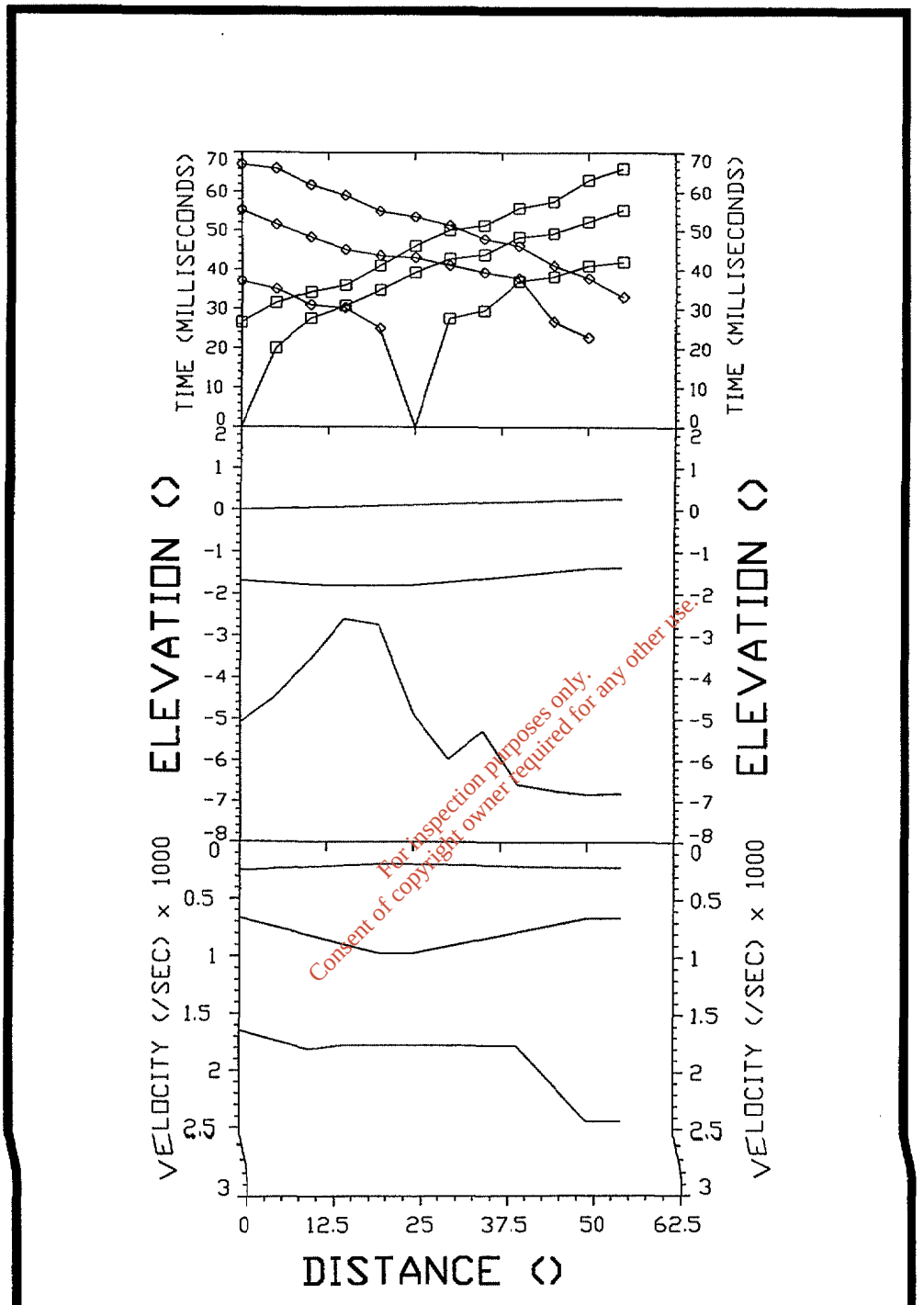


for: MCOS	Gortadroma Landfill
by: B.J. Murphy & Associates	Gortadroma Limerick
Data SetS7 / Date: 17/APR/200	
Equipment: GEOMETRICS Sna / Spread: 7	Azimuth: S-N



for: MCOS	Gortadroma Landfill
by: B.J. Murphy & Associates	Gortadroma Limerick
Data SetS8 / Date: 17/APR/200	
Equipment: GEOMETRICS Sma / Spread: 8	Azimuth: S-N

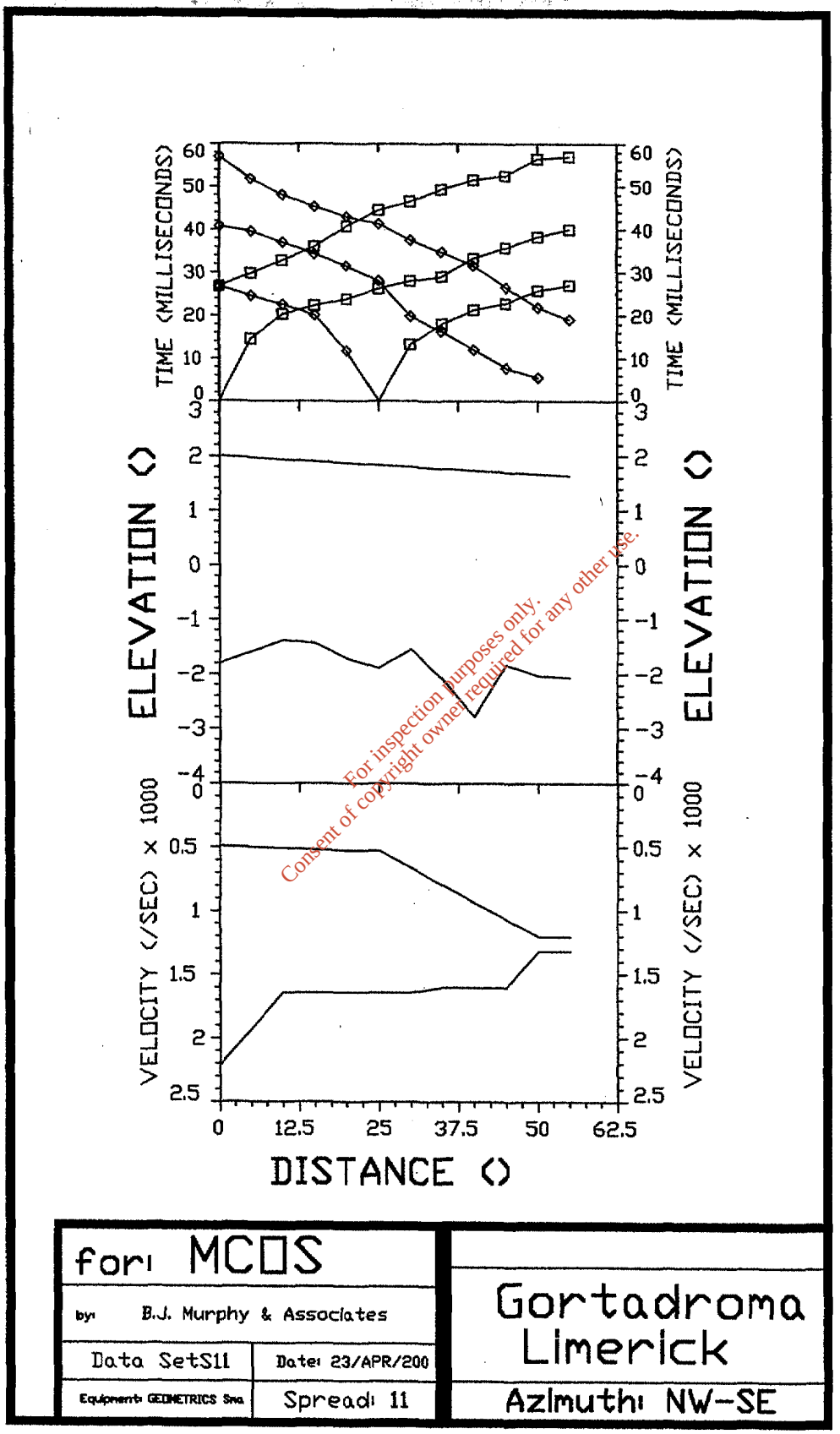




for: MCOS	
by: B.J. Murphy & Associates	
Data SetS10	Date: 23/APR/200
Equipment: GEOMETRICS Sma	Spread: 10

Gortadroma
Limerick

Azimuth: NW-SE



Borehole Log

GEOTECH

Drilled by JC Logged by Checked by	Equipment and Methods Rotary Open Hole 100 mm diameter from 0.00m to 14.50m. Rotary Cored 75 mm diameter from 14.50m to 15.00m. Rotary Open Hole 100 mm diameter from 15.00m to 20.00m.	Ground Level National Grid Coordinates

Samples and Tests

Depth	TCR SCR RQD	If	Records	Date Casing	Time Water
0.00 - 14.50m			Open Hole	03/10/2002	

Strata

Description	Depth,Level (Thickness)
Clayey sandy GRAVEL**	(3.00)
	3.00
Clayey SAND**	(4.00)
	7.00
BOULDER**	(0.50)
	7.50
Clayey GRAVEL**	(7.00)

Legend: g, 1

Groundwater

No.	Struck	Behaviour
1	7.50m	Rising to 0.00m after 5 mins.

Remarks

Hole backfill : 0.00m to 12.00m Grout (g), 14.00m to 14.50m Bentonite (b), 14.50m to 20.00m Bentonite (b).
Surface protection : Stop Cock Cover
Standpipe installed, 50mm diameter, response zone from 12.00m to 14.00m.

Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.
Scale 1 : 50

Project GORTADROMA LANDFILL
Project no. 172138
Carried out for M.C. O'Sullivan & Co. Ltd.

Borehole
BHRC1
Sheet 1 of 2

18/12/2002 14:35:19 ESGLog v2.11

Borehole Log

GEOTECH

Drilled by JC	Equipment and Methods	Ground Level
Logged by	See sheet 1	National Grid Coordinates
Checked by		

Samples and Tests

Strata

Depth	TCR SCR RQD	If	Records	Date Casing	Time Water	Description	Depth,Level (Thickness)	Legend
0.00 - 14.50m			Open Hole			As sheet 1	(7.00)	
14.50 - 15.00m				03/10/2002 12.00	0.00	BOULDER**	14.50 (0.50)	
				04/10/2002 12.00	0.00		15.00	
15.00 - 20.00m			Open Hole			Black slightly gravelly CLAY and BOULDERS**	(5.00pen)	
				04/10/2002 18.00				
						EXPLORATORY HOLE ENDS AT 20.00 m.	20.00	

Groundwater
No. Struck Behaviour

Remarks

Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.
Scale 1 : 50

Project GORTADROMA LANDFILL
Project no. 172138
Carried out for M.C. O'Sullivan & Co. Ltd.

Borehole **BHRC1**
Sheet 2 of 2

18/12/2002 14:35:26 ESGLog v2.11

Borehole Log

GEOTECH

Drilled by JC Logged by NS Checked by	Equipment and Methods Rotary Open Hole 100 mm diameter from 0.00m to 15.50m. Rotary Cored 75 mm diameter from 15.50m to 19.80m.		Ground Level National Grid Coordinates

Samples and Tests

Depth	TCR SCR RQD	If	Records	Date Casing	Time Water
				02/10/2002	
0.00 - 15.50m			Open Hole		

Strata

Description	Depth,Level (Thickness)	Legend
Peaty CLAY**	(3.00)	
	3.00	
Grey clayey gravelly SILT**	(2.00)	
	5.00	
Silty GRAVEL**	(3.00)	
	8.00	
Sandy CLAY and BOULDERS**	(7.50)	

Groundwater

No.	Struck	Behaviour
1	5.00m	Rising to 4.00m after 20 mins.

Remarks

Hole backfill : 0.00m to 16.30m Bentonite (b).
Standpipe installed, 50mm diameter, response zone from 16.30m to 19.80m.

Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.
Scale 1 : 50

Project GORTADROMA LANDFILL
Project no. 172138
Carried out for M.C. O'Sullivan & Co. Ltd.

Borehole **BHRC2**
Sheet 1 of 2

18/12/2002 14:35:36 ESGLog v2.11

Borehole Log

GEOTECH

Drilled by JC Logged by NS Checked by	Equipment and Methods See sheet 1	Ground Level National Grid Coordinates

Samples and Tests

Strata

Depth	TCR SCR RQD	If	Records	Date Casing	Time Water	Description	Depth,Level (Thickness)	Legend
0.00 - 15.50m			Open Hole			As sheet 1	(7.50)	
				02/10/2002 15.40				
				03/10/2002 15.40			15.50	
15.50 - 16.70m	42 42 14					15.50m - 16.20m: Assumed zone of core loss. Very strong grey fine SANDSTONE. Fractures: 1) Subhorizontal - 20° planar stepped rough smooth clean with occasional slight orange brown weathering.		
16.70 - 18.20m	87 80 46	17 230 583				16.70m - 16.90m: Assumed zone of core loss. 2) 16.50m - 16.70m: Subvertical undulating smooth slight orange brown weathered.	(3.70)	
18.20 - 19.20m	94 91 87					Strong dark grey very fine SANDSTONE. Fractures: 10-20° planar smooth clean. 19.62m - 19.67m: Non intact.	19.20 (0.40)	
19.20 - 19.80m	78 57 20	8 60 138		03/10/2002		Weak dark grey MUDSTONE. All non intact. 19.67m - 19.80m: Assumed zone of core loss. EXPLORATORY HOLE ENDS AT 19.80 m.	19.60 19.80	

Groundwater
No. Struck Behaviour

Remarks

Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.
Scale 1 : 50

Project GORTADROMA LANDFILL
Project no. 172138
Carried out for M.C. O'Sullivan & Co. Ltd.

Borehole
BHRC2
Sheet 2 of 2

18/12/2002 14:35:45 ESGLog V2.11

Borehole Log

GEOTECH

Drilled by	JC	Equipment and Methods	Ground Level
Logged by		Rotary Open Hole 100 mm diameter from 0.00m to 20.00m.	National Grid Coordinates
Checked by			

Samples and Tests

Depth	TCR SCR RQD	If	Records	Date Casing	Time Water
0.00 - 20.00m			Open Hole	01/10/2002	

Strata

Description	Depth,Level (Thickness)	Legend
PEAT**	(8.50)	g
Clayey SILT**	8.50 (5.50)	

Groundwater
No. Struck Behaviour

Remarks
Hole backfill : 0.00m to 14.00m Grout (g).
Standpipe installed, 50mm diameter, response zone from 14.00m to 20.00m.

Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.
Scale 1 : 50

Project GORTADROMA LANDFILL
Project no. 172138
Carried out for M.C. O'Sullivan & Co. Ltd.

Borehole **BHRC3**
Sheet 1 of 2

18/12/2002 14:35:54 ESGLog v2.11

Borehole Log

GEOTECH

Drilled by JC	Equipment and Methods	Ground Level
Logged by	See sheet 1	National Grid Coordinates
Checked by		

Samples and Tests

Strata

Depth	TCR SCR RQD	If	Records	Date Casing	Time Water	Description	Depth,Level (Thickness)	Legend
0.00 - 20.00m			Open Hole			As sheet 1	(5.50)	
							14.00	
						Clayey gravelly SILT**	(6.00pen)	
				01/10/2002 14.50				
						EXPLORATORY HOLE ENDS AT 20.00 m.	20.00	

Groundwater

No.	Struck	Behaviour
1	11.00m	Rising to 0.00m after 5 mins. Fast inflow

Remarks

Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.
Scale 1 : 50

Project	GORTADROMA LANDFILL
Project no.	172138
Carried out for	M.C. O'Sullivan & Co. Ltd.

Borehole
BHRC3
Sheet 2 of 2

18/12/2002 14:36:00 ESGLog v2.11

Borehole Log

GEOTECH

Drilled by	GB	Equipment and Methods	Ground Level
Logged by	NS	Cable Percussion 200 mm diameter from 0.00m to 8.00m.	National Grid Coordinates
Checked by			

Samples and Tests

Depth	Type & No.	Records	Date / Casing	Time / Water
			03/09/2002	
0.40 - 0.80	B1			
1.00 - 1.45		S,N=4 1,1/1,1,1,1	1.00	
1.40 - 1.80	B2			
2.00 - 2.45		S,N=5 1,1/1,2,1,1	2.00	
2.40 - 2.80	B3			
3.00 - 3.45		S,N=5 1,2/2,1,1,1	3.00	
3.40 - 3.80	B4			
4.00 - 4.45		S,N=5 1,1/1,2,1,1	4.00	
4.60 - 5.00	B5		03/09/2002 5.00	
			04/09/2002 5.00	
5.40 - 5.80	B6			
6.50 - 6.95		S,N=15 2,2/3,3,4,5	6.50	5.50
7.00 - 7.40	B7			
7.50 - 7.90	B8			
			04/09/2002 8.00	

Strata

Description	Depth,Level (Thickness)
Grass over brown PEAT**	0.10
Very soft to soft dark brown plastic amorphous PEAT with some plant material. (with small amounts of firm fibrous peat).	(2.80)
	2.90
Soft dark brown mottled grey silty PEAT. Peat is plastic and amorphous.	(2.90)
	5.80
Firm to stiff grey SILT	(1.60)
	7.40
Grey slightly sandy GRAVEL. Gravel is angular to subrounded fine to medium.	(0.60pen)
EXPLORATORY HOLE ENDS AT 8.00 m.	8.00

Legend: c, b, 1, 1

Groundwater

No.	Struck	Behaviour
1	6.50m	Rising to 5.40m after 20 mins.

Remarks

Chiselling : 7.90m to 8.00m 60minutes
Hole backfill : 0.00m to 0.30m Concrete (c), 0.30m to 1.00m Bentonite (b).
Standpipe installed, 50mm diameter, response zone from 1.00m to 8.00m.

Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.
Scale 1 : 50

Project	GORTADROMA LANDFILL
Project no.	172138
Carried out for	M.C. O'Sullivan & Co. Ltd.

Borehole BHSA1
Sheet 1 of 1

18/12/2002 14:36:12 ESGLog v2.11

Borehole Log

GEOTECH

Drilled by	GC	Equipment and Methods	Ground Level
Logged by	JF	Cable Percussion 200 mm diameter from 0.00m to 8.40m.	National Grid Coordinates
Checked by			

Samples and Tests

Depth	Type & No.	Records	Date / Casing	Time / Water
			10/10/2002	
1.00 - 1.45	U1	1 blows		
1.00 - 1.50	B2			
1.45 - 1.60	D3			
2.50 - 2.95	D4	S,N=3 -,-/1,1,-,-1		
2.50 - 2.95	D5			
4.00 - 4.45	D7	S,N=3 -,-/1,-,1,1		
4.00 - 4.40	B6			
5.40 - 5.80	B8			
6.00 - 6.45	D10	S,N=19 1,2/3,5,4,7		
6.00 - 6.40	B9			
			10/10/2002 7.00	dry
			14/10/2002 7.00	6.90
7.00 - 7.25	U11	11 blows		
7.00 - 7.50	B12			
7.45 - 7.60	D13			
7.50 - 7.90	B14			
8.00 - 8.45	D16	S,N=31 5,6/8,7,8,8		
8.00 - 8.40	B15			
			14/10/2002 8.50	

Strata

Description	Depth,Level (Thickness)
TOPSOIL**	(0.30)
	0.30
Orange brown mottled grey sandy slightly gravelly CLAY (occasionally thinly laminated). Gravel is angular to subrounded fine. Below 1.60m: Becoming slightly gravelly to gravelly	(1.70)
	2.00
Very soft grey slightly sandy (occasionally thinly laminated) SILT	(3.30)
Grey black slightly clayey GRAVEL with occasional cobbles. Gravel is angular to subangular fine to coarse. Cobbles are subangular.	5.30 (0.70) 6.00
Stiff to very stiff dark grey black slightly sandy to sandy gravelly CLAY. Gravel is angular to subangular fine to coarse.	(2.50pen)
EXPLORATORY HOLE ENDS AT 8.50 m.	8.50

Legend: b, a, 1, 2, 2

Groundwater

No.	Struck	Behaviour
1	2.20m	Damp
2	5.30m	Rising to 4.00m after 20 mins. Sealed 6.50.

Remarks

Hole backfill : 0.00m to 1.00m Bentonite (b), 1.00m to 8.50m Arisings (a).

Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.
Scale 1 : 50

Project	GORTADROMA LANDFILL
Project no.	172138
Carried out for	M.C. O'Sullivan & Co. Ltd.

Borehole BHSA3/1
Sheet 1 of 1

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Borehole Log

GEOTECH

Drilled by GC Logged by JF/NS Checked by	Equipment and Methods Cable Percussion 200 mm diameter from 0.00m to 10.00m.	Ground Level National Grid Coordinates

Samples and Tests

Depth	Type & No.	Records	Date / Time Casing / Water
			21/10/2002
0.30 - 0.70	B1		
1.00 - 1.40	B2		
1.50 - 1.95	D4	S,N=3 1,1/-,1,1,1	
1.50 - 1.90	B3		
2.00 - 2.40	B5		
2.50 - 2.90	B6		
			21/10/2002 3.00
			22/10/2002 3.00
3.00 - 3.45		S,N=2 -,1/1,-,1,-	
3.00 - 3.40	B7		
3.50 - 3.90	B8		
4.00 - 4.40	B9		
4.50 - 4.95	D11	S,N=7 1,2/1,2,2,2	
4.50 - 4.90	B10		
5.00 - 5.45	U12	20 blows No recovery	
5.00 - 5.45	B13		
5.50 - 5.90	B14		
6.00 - 6.45	D16	S,N=8 2,1/1,2,2,3	
6.00 - 6.45	D17		
6.00 - 6.40	B15		
6.50 - 6.90	B18		
7.00 - 7.40	B19		
7.50 - 7.95	D21	S,N=40 5,15/9,8,11,12	
7.50 - 7.90	B20		
8.00 - 8.40	B22		
8.50 - 8.90	B23		
9.00 - 9.45	D25	S,N=53 6,11/12,11,11,19	
9.00 - 9.40	B24		
9.50 - 9.90	B26		
			22/10/2002 10.00

Strata

Description	Depth,Level (Thickness)
MADE GROUND: Hardcore with CLAY and COBBLES**	(0.30) 0.30
Brown sandy gravelly CLAY. Gravel is subangular to subrounded fine to coarse.	(1.10)
	1.40
Very loose brown clayey GRAVEL. Gravel is angular fine to coarse.	(2.50)
	3.90
Soft grey thinly laminated SILT.	(2.10)
	6.00
Loose grey silty sandy GRAVEL with frequent cobbles. Gravel is subangular to subrounded fine to coarse. Cobbles are subangular.	(1.00)
	7.00
Stiff to very stiff dark grey sandy gravelly SILT (almost silt / clay in places) with rare cobbles. Gravel is subangular to subrounded fine to coarse. Cobbles are subrounded. Below 8.0m: Frequent cobbles. 8.50-9.00m: Very gravelly.	(3.00pen)
EXPLORATORY HOLE ENDS AT 10.00 m.	10.00

Legend: b, 1, 1, b, 2, 2, a

Groundwater

No.	Struck	Behaviour
1	2.50m	Rising to 2.20m after 20 mins. Slow inflow
2	5.60m	Rising to 3.50m after 20 mins.

Remarks

Chiselling : 0.00m to 0.25m 30minutes
Hole backfill : 0.00m to 1.00m Bentonite (b), 2.90m to 3.90m Bentonite (b), 6.00m to 10.00m Arisings (a).
Standpipe Piezometer installed, 19mm diameter, response zone from 1.00m to 2.90m.
Standpipe installed, 50mm diameter, response zone from 3.90m to 6.00m.

Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.
Scale 1 : 50

Project GORTADROMA LANDFILL
Project no. 172138
Carried out for M.C. O'Sullivan & Co. Ltd.

Borehole **BHSA3R**
Sheet 1 of 1

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Borehole Log

GEOTECH

Drilled by	GC	Equipment and Methods	Ground Level
Logged by	JF	Cable Percussion 200 mm diameter from 0.00m to 10.00m.	National Grid Coordinates
Checked by			

Samples and Tests

Depth	Type & No.	Records	Date / Time Casing / Water
			14/10/2002
0.40 - 0.80	B1		
1.00 - 1.40	B2		
1.50 - 1.95	D4	S,N=11 2,3/3,2,3,3	
1.50 - 1.90	B3		14/10/2002 2.00
			15/10/2002 2.00
2.00 - 2.45	U5	80 blows 280mm recovered	
2.00 - 2.50	B6		
2.45 - 2.60	D7		
2.50 - 2.90	B8		
3.00 - 3.35	D9	S,50 12,9/13,16,21 for 45mm	
3.00 - 3.40	B10		
3.50 - 3.90	B11		
4.00 - 4.40	B12		
4.50 - 4.95	D14	S,N=44 7,7/13,10,10,11	
4.50 - 4.90	B13		
5.00 - 5.40	B15		
5.50 - 5.90	B16		
6.00 - 6.42	D18	S,50 11,9/12,11,18,9 for 40mm	
6.00 - 6.40	B17		
6.50 - 6.90	B19		
7.00 - 7.40	B20		
			15/10/2002 7.50
			16/10/2002 7.50 2.00
7.50 - 7.95	D22	S,N=41 3,7/7,9,11,14	
7.50 - 7.90	B21		
8.00 - 8.40	B23		
8.50 - 8.90	B24		
9.00 - 9.37		S,50 7,10/12,17,21 for 70mm	
9.00 - 9.45	D26		
9.00 - 9.40	B25		
9.50 - 9.90	B27		
			16/10/2002

Strata

Description	Depth,Level (Thickness)
TOPSOIL**	(0.30)
	0.30
Firm grey brown mottled orange slightly sandy slightly gravelly CLAY with rootlets. Gravel is subangular to subrounded fine to medium. (Becoming gravely below 1.0m)	(1.70)
	2.00
4.0-4.4m: Beoming gravelly to very gravelly	
Stiff to very stiff grey slightly sandy slightly gravelly SILT (almost clay / silt)with occasional subangular cobbles. Gravel is subangular to subrounded fine to coarse. 5.0-7.40m: Absence of cobbles	(8.00pen)
EXPLORATORY HOLE ENDS AT 10.00 m.	10.00

Legend: b, 1, 1, a

Groundwater

No.	Struck	Behaviour
1	2.30m	Rising to 2.00m after 20 mins.

Remarks

Chiselling : 2.60m to 2.90m 45minutes, 4.00m to 4.20m 30minutes, 6.90m to 7.10m 30minutes
Hole backfill : 0.00m to 1.50m Bentonite (b), 4.50m to 10.00m Arisings (a). Surface protection : Gas Barrel Standpipe installed, 50mm diameter, response zone from 1.50m to 4.50m.

Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.
Scale 1 : 50

Project	GORTADROMA LANDFILL
Project no.	172138
Carried out for	M.C. O'Sullivan & Co. Ltd.

Borehole BHSA4/1
Sheet 1 of 1

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Borehole Log

GEOTECH

Drilled by GC Logged by JF Checked by	Equipment and Methods Cable Percussion 200 mm diameter from 0.00m to 10.00m.	Ground Level National Grid Coordinates

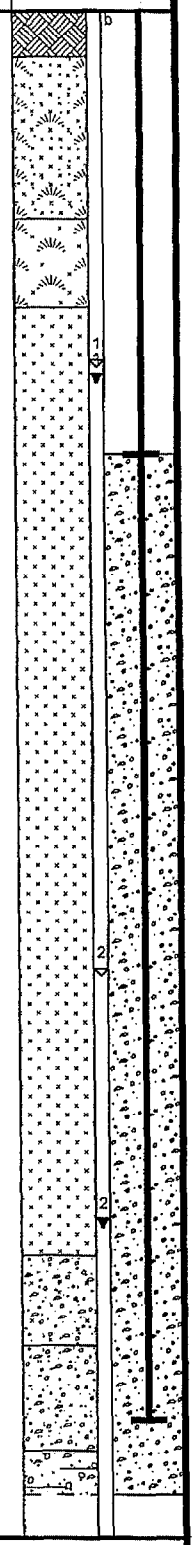
Samples and Tests

Depth	Type & No.	Records	Date / Casing	Time / Water
			16/10/2002	
0.30 - 0.70	B1			
1.00 - 1.40	B2			
1.50 - 1.95		S,N=1 -,1/-,-,1,-		
1.50 - 1.90	B3			
2.00 - 2.45	U4	18 blows		
2.00 - 2.50	B5			
2.45 - 2.60	D6			
2.50 - 2.90	B7			
			16/10/2002 3.00	
			18/10/2002 3.00	
3.00 - 3.45	D9	S,N=12 1,2/3,3,3,3		
3.00 - 3.40	B8			
3.50 - 3.95	U10	45 blows		
3.50 - 4.00	B11			
3.95 - 4.10	D12			
4.00 - 4.40	B13			
4.50 - 4.95	D15	S,N=7 1,2/1,2,2,2		
4.50 - 4.90	B14			
5.00 - 5.45	U16	25 blows		
5.00 - 5.50	B17			
5.45 - 5.60	D18			
5.50 - 5.90	B19			
6.00 - 6.45	D21	S,N=8 1,2/2,2,2,2		
6.00 - 6.40	B20			
6.50 - 6.95	U22	20 blows		
6.50 - 7.00	B23			
6.95 - 7.10	D24			
7.00 - 7.40	B25			
7.50 - 7.95		S,N=10 1,2/2,3,2,3		
7.50 - 7.90	B26			
8.00 - 8.45	U28	No recovery		
8.00 - 8.40	B27			
8.50 - 8.90	B29			
			18/10/2002 9.00	
			21/10/2002 9.00	0.60
9.00 - 9.45	D31	S,N=15 1,2/3,4,4,4		
9.00 - 9.40	B30			
9.70 - 10.00	B32			
			21/10/2002	

Strata

Description	Depth,Level (Thickness)
TOPSOIL**	(0.30)
	0.30
Dark brown sandy SILT with occasional rootlets and becoming slightly organic below 1.0m..	(1.10)
	1.40
Very soft brown amorphous PEAT with pockets of grey silt.	(0.60)
	2.00
Soft to firm grey (occasionally thinly laminated) SILT	(6.40)
6.0-6.4m: Becoming slightly sandy	
7.0-7.4m: Becoming slightly sandy	
Black slightly sandy slightly gravelly SILT. Gravel is angular fine.	
Medium dense black sandy GRAVEL. Gravel is angular to subangular fine to coarse	8.40 (0.60)
	9.00
Black sandy gravelly CLAY with occasional subangular cobbles. Gravel is angular to subrounded fine to medium.	(0.70)
	9.70
	(0.30pen)
EXPLORATORY HOLE ENDS AT 10.00 m.	10.00

Legend



Groundwater

No.	Struck	Behaviour
1	2.50m	Rising to 2.40m after 20 mins. Slow inflow
2	8.20m	Rising to 6.50m after 20 mins. Medium inflow

Remarks

Hole backfill : 0.00m to 3.00m Bentonite (b). Surface protection : Gas Barrel Standpipe installed, 50mm diameter, response zone from 3.00m to 10.00m.

Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.
Scale 1 : 50

Project	GORTADROMA LANDFILL
Project no.	172138
Carried out for	M.C. O'Sullivan & Co. Ltd.

Borehole
BHSA5/1
Sheet 1 of 1

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Borehole Log

GEOTECH

Drilled by GC/MY Logged by NS Checked by	Equipment and Methods Cable Percussion 200 mm diameter from 0.00m to 5.45m.	Ground Level National Grid Coordinates

Samples and Tests

Depth	Type & No.	Records	Date / Casing	Time / Water
0.30 - 0.70	B1		07/10/2002	
1.00 - 1.45		S,N=5 1,1/1,2,1,1		
1.00 - 1.40	B2			
2.50	U3	85 blows No recovery		
2.50 - 2.90	B4		07/10/2002 3.00	dry
			08/10/2002 3.00	2.90
4.00 - 4.45		S,N=30 2,5/6,9,7,8	08/10/2002 4.40	
			09/10/2002	0.60
4.00 - 4.45	D6			
4.00 - 4.40	B5			
5.20 - 5.40	B7		09/10/2002 5.45	
5.45 - 5.61		S,50 19,6 for 10mm/47,3 for 0mm		

Strata

Description	Depth,Level (Thickness)
TOPSOIL**	(0.30)
	0.30
Soft grey mottled orange brown slightly gravelly CLAY. Gravel is angular to subangular fine to medium.	(1.10)
	1.40
Stiff dark grey slightly sandy slightly gravelly CLAY with occasional cobbles. Gravel is angular to subangular fine to coarse.	(3.80)
Very dense brown slightly sandy to sandy COBBLES of weathered sandstone. Cobbles are angular.	5.20
EXPLORATORY HOLE ENDS AT 5.45 m.	5.45

Legend: a; 1; 1

Groundwater

No.	Struck	Behaviour
1	3.50m	Rising to 2.25m after 20 mins.

Remarks

Chiselling : 4.40m to 4.55m 45minutes, 5.25m to 5.45m 90minutes
Hole backfill : 0.00m to 5.45m Arisings (a).

Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.
Scale 1 : 50

Project: GORTADROMA LANDFILL
Project no.: 172138
Carried out for: M.C. O'Sullivan & Co. Ltd.

Borehole: **BHSA6**
Sheet 1 of 1

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Borehole Log

GEOTECH

Drilled by GC Logged by Checked by	Equipment and Methods Cable Percussion 200 mm diameter from 0.00m to 5.05m.	Ground Level National Grid Coordinates

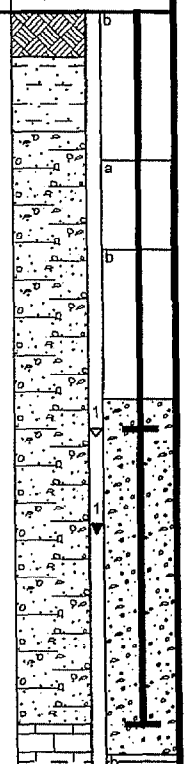
Samples and Tests

Depth	Type & No.	Records	Date / Casing	Time / Water
			09/10/2002	
			09/10/2002	5.00

Strata

Description	Depth,Level (Thickness)
TOPSOIL**	(0.30)
Grey brown sandy CLAY**	0.30 (0.50)
Dark grey sandy gravelly CLAY with occasional cobbles**	0.80 (4.00)
Dark angular LIMESTONE**	4.80
EXPLORATORY HOLE ENDS AT 5.05 m.	5.05

Legend



Groundwater

No.	Struck	Behaviour
1	3.50m	Rising to 2.85m after 20 mins.

Remarks

Chiselling : 4.85m to 5.05m 60minutes
Hole backfill : 0.00m to 1.00m Bentonite (b), 1.00m to 1.60m Arisings (a), 1.60m to 2.60m Bentonite (b), 5.00m to 5.05m Bentonite (b).
Standpipe installed, 50mm diameter, response zone from 2.60m to 5.00m.

Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.
Scale 1 : 50

Project: GORTADROMA LANDFILL
Project no.: 172138
Carried out for: M.C. O'Sullivan & Co. Ltd.

Borehole BHSA6A
Sheet 1 of 1

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Borehole Log

GEOTECH

Drilled by GB/GC Logged by JF Checked by	**Equipment and Methods** Cable Percussion 200 mm diameter from 0.00m to 10.00m.	**Ground Level** **National Grid Coordinates**

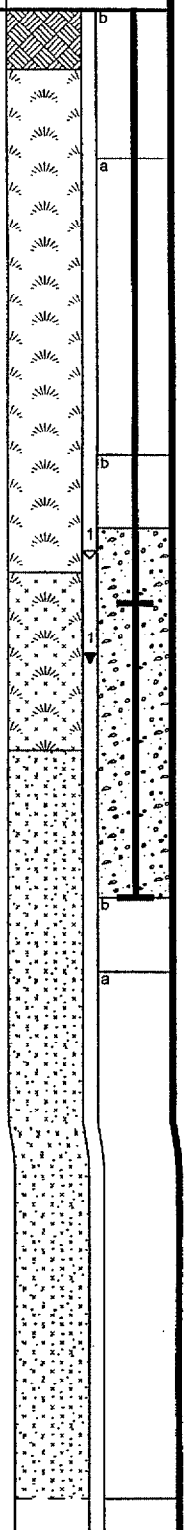
Samples and Tests

Depth	Type & No.	Records	Date / Casing	Time / Water
			05/09/2002	
0.50 - 0.90	B1			
1.00 - 1.45		C,N=2 1,-/-,-,1,1	1.00	
1.40 - 1.80	B2			
2.00 - 2.45		C,N=4 1,1/1,1,1,1	2.00	
2.40 - 2.80	B3			
3.00 - 3.45		C,N=4 1,1/1,1,1,1	3.00	
3.40 - 3.80	B4			
4.00 - 4.45		C,N=5 1,2/2,1,1,1	4.00	
4.40 - 4.80	B5			
5.00 - 5.45		C,N=5 2,2/1,2,1,1	5.00	
5.40 - 5.80	B6			
6.50 - 6.95		C,N=7 2,2/2,1,2,2	6.50	6.00
8.00 - 8.45		C,N=7 2,2/1,1,2,3	8.00	7.30
8.50 - 9.00	B7			
			05/09/2002	

Strata

Description	Depth,Level (Thickness)
TOPSOIL**	(0.40)
	0.40
Very soft light to dark brown mottled grey fibrous PEAT with large amounts of wood and plant material	(3.40)
	3.80
Soft grey slightly sandy slightly gravelly SILT with small amounts of organic material. Gravel is subangular to subrounded fine to medium.	(1.20)
	5.00
Soft to firm grey slightly sandy thinly laminated SILT	(5.00pen)
EXPLORATORY HOLE ENDS AT 10.00 m.	10.00

Legend



Groundwater

No.	Struck	Behaviour
1	4.40m	Rising to 3.70m after 20 mins.

Remarks

Hole backfill : 0.00m to 1.00m Bentonite (b), 1.00m to 3.00m Arisings (a), 3.00m to 3.50m Bentonite (b), 6.00m to 6.50m Bentonite (b), 6.50m to 10.00m Arisings (a).
Standpipe installed, 50mm diameter, response zone from 3.50m to 6.00m.

Notes : For explanation of symbols and abbreviations see key sheet. All depths and reduced levels in metres. Stratum thickness given in brackets in depth column.
Scale 1 : 50

Project GORTADROMA LANDFILL
Project no. 172138
Carried out for M.C. O'Sullivan & Co. Ltd.

Borehole BHSA7
Sheet 1 of 1

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