FEHILY TIMONEY

CONSULTANTS IN ENGINEERING,
ENVIRONMENTAL SCIENCE & PLANNING

APPENDIX 1

Tier 1 Risk Assessment

3. Source – Pathway - Receptor Scores

SPR	Maximum Score	SPR Value	Linkages	Normalised Score
1	10 x (3+5+2) x 3 = 300	7*(2+5+2)*2=126	leachate – s/water	42%
2	10 x (3+5+2) x 3 = 300	7*(9)*0 = 0	leachate - GWDTE	0%
3	10 x (3+5) x 3 = 240	7*(2+5)*1= 49	leachate – private wells	20.4%
4	10 x (3+5) x 3 = 240	7*7*0 = 0	leachate - GWDTE	0%
5	10 x (3+5) x 5 = 400	7*7*5=245	leachate – aquifer	61.25%
6	10 x (3+5) x 7 = 560	7*7*3=147	leachate - PWS	29.4%
7	10 x (3+5) x 3 = 240	7*7*2=98	leachate – s/water	40.1%
8	10 x 2 x 3 = 60	7*2*2=28	leachate – s/water	46.6%
9	10 x 2 x 3 = 60	7*2*0=0	leachate - GWDTE	0%
10	10 x 3 x 5 = 150	7*3*5=105	landfill gas - humans	**70%**
11	10 x 5 x 5 = 250	7*5*5=175	landfill gas - humans	**70%**

High Risk site

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APPENDIX 2

Site Walkover Checklist and Photographic Log

PHOTOGRAPHIC LOG

Client Name: Galway Co. Co.	**Site Location:** Tuam Historic Landfill	**Project Number:** P2282

Photo No.	**Date:**
1	20-05-20

Description:

Evidence of possible leaching or seepage to localized flat area.

Photo No.	**Date:**
2	20-05-20

Description:

Heavy Poaching of Landfill Capping.

PHOTOGRAPHIC LOG

FEHILY TIMONEY
30 YEARS

Client Name: Galway Co. Co.	**Site Location:** Tuam Landfill	**Project Number:** P2282

Photo No.	**Date:**
3	04-03-18

Description:

Leachate monitoring point to top of landfill

Photo No.	**Date:**
4	20-05-20

Description:

View looking North West from top of site, Western side.

PHOTOGRAPHIC LOG

Client Name: Galway Co. Co.	**Site Location:** Tuam Landfill	**Project Number:** P2282

Photo No.	**Date:**
5	26-06-18

Description:

Surface water drain to landfill boundary, site fencing

Photo No.	**Date:**
6	20-05-20

Description:

Evidence of slippage/erosion of landfill capping to side slopes, exposed geocomposite clay liner, evidence of animal damage and poaching

PHOTOGRAPHIC LOG

Client Name:
Galway Co. Co.

Site Location: Tuam Landfill

Project Number: P2282

Photo No. 7

Date: 20-05-20

Description:
Leachate monitoring infrastructure (heavily corroded)

Photo No. 8

Date: 20-05-20

Description:
Further expose G.C.L. to side slopes

PHOTOGRAPHIC LOG

Client Name: Galway Co. Co.	**Site Location:** Tuam Landfill	**Project Number:** P2282

Photo No.	**Date:**
9	20-05-20

Description:

Surface water stream/bog drain, Flow to South West, linked to landfill surface water drains

Photo No.	**Date:**
10	20-05-20

Description:

Groundwater monitoring infrastructure, offsite.

PHOTOGRAPHIC LOG

Client Name: Galway Co. Co.	**Site Location:** Tuam Landfill	**Project Number:** P2282

Photo No.	**Date:**
11	20-05-20

Description:

Groundwater monitoring boreholes at entrance to civic amenity

Photo No.	**Date:**
12	20-05-20

Description:

Groundwater monitoring boreholes

Walkover Survey Checklist

Tuam Historic Landfill Co. Galway

Walkover Survey Checklist		
Information	**Checked**	**Comment (include distances from Site Boundary)**
1. What is the current land use?	✔	Historic landfill site with associated civic amenity site operated by third party
2. What are the neighbouring land uses?	✔	Civic amenity site to east, drained agricultural lands North and south, bog land to west.
3. What is the size of the site?	✔	3.0 ha approx. inc. CA site ex. entrance
4. What is the topography?	✔	Surrounding area is generally flat, the main landfill unnatural elevated above surrounds.
5. Are there potential receptors (if yes, give details)?	✔	
Houses	✔	Approx. 450m North to closest residential dwelling, CA welfare facility onsite
Surface water features (if yes, distance and direction of flow)?	✔	Constructed land drains to base of slopes
Any wetland or protected areas?	✔	
Public water supplies?	✔	Unknown
Private wells?	✔	No evidence
Services?	✔	Overhead electrical services in field to south, site drains
Other buildings?	✔	Civic amenity welfare building and outbuildings
Other?		
6. Are there any potential sources of contamination (if yes, give details)?		
Surface waste (if yes, what type)?	✔	No evidence

Walkover Survey Checklist

Tuam Historic Landfill Co. Galway

Walkover Survey Checklist		
Information	**Checked**	**Comment (include distances from Site Boundary)**
Surface ponding of leachate	✔	Minor evidence of oxidation (no free water/leachate) to poorly drained/flat area on the landfill capping
Leachate seepage	✔	See above
Landfill gas odours	✔	None noted
7. Are there any outfalls to surface water? (If yes, are there discharges and what is the nature of the discharge?)	✔	No direct discharge noted
8. Are there any signs of impact on the environment? (if yes, take photographic evidence)	✔	None noted
Vegetation die off, bare ground	✔	No
Leachate seepages	✔	N Minor evidence of oxidation (no free water/leachate) to poorly drained/flat area on the landfill capping
Odours	✔	No
Litter	✔	No
Gas bubbling through water	✔	No
Signs of settlement	✔	Area of poaching issues shallow GCL on side slopes of landfill
Subsidence, water logged areas	✔	Discrete areas noted on landfill capping
Drainage or hydraulic issues	✔	Generally, poorly drained due to flat nature and surrounding bog land, standing water noted
Downstream water quality appears poorer than upstream water quality	✔	No perceptible visual deterioration
9. Are there any indications of remedial measures? (Provide details)		
Capping	✔	Site capped with soil and GCL, GCL visible in areas due to erosion/poaching by animals. Very shallow soil/topsoil layer to GCL.

Walkover Survey Checklist

Tuam Historic Landfill Co. Galway

Walkover Survey Checklist		
Information	**Checked**	**Comment (include distances from Site Boundary)**
Landfill gas collection	✔	Sampling points noted on drawings, one location found, derelict.
Leachate collection	✔	No
10. Describe fences and security features (if any)	✔	Site fenced along access road, fence in poor repair, agricultural fencing to main site boundary, internal palisade style fencing of civic amenity generally good condition.
Any other relevant information?	✔	Evidence of remediation and other works noted about including groundwater sampling locations.

FEHILY TIMONEY

CONSULTANTS IN ENGINEERING,
ENVIRONMENTAL SCIENCE & PLANNING

APPENDIX 3

Closure and Remediation Plan

COMHAIRLE CHONTAE NA GAILLIMHE
GALWAY COUNTY COUNCIL

Closure & Remediation Plan

for

Tuam Landfill

October 1999

MCOS
M C O SULLIVAN
Consulting · Engineers
COWI

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Introduction

M. C. O'Sullivan & Co. Ltd., Consulting Engineers, were appointed by Galway County Council to prepare a Closure and Remediation Plan for Tuam Landfill in October 1998 in accordance with EPA requirements in order to reduce its impact on the surrounding environment and to re-integrate the landfill as much as possible back into the surrounding landscape.

The landfill served the disposal requirements for municipal and industrial non-hazardous waste arisings in the county until October 1998 when the site was closed. It is currently accepting civic amenity waste only in a separate designated area at the entrance. Prior to closure the landfill was in a poor condition with limited remaining void space and operational difficulties that were extending beyond the site boundary. The site would also have required a Waste Licence from the EPA to continue landfill operations.

This report sets out the proposed measures to restore and remediate the landfill and includes an assessment of the existing condition of the landfill including its current impact on the surrounding surface water and groundwater network. The recommendations of the report are based upon site investigation work and monitoring carried out during the initial assessment of the site as well as historical monitoring data originating from when the site was in operation.

1.2 Objectives of Remediation Plan

Legislation enacted under the Waste Management Act, 1996 and subsequent Waste Management (Licensing) Regulations, 1997 has established a licensing system for the operation of landfills in Ireland. A requirement of the Waste Licence Application to be submitted to the EPA is that proposals for the remediation of existing landfills are set out in the Application. In addition the proposals for final closure and restoration of the landfill are to be included. Tuam landfill was closed in October 1998 prior to the specified date by which a Licence Application was to be forwarded to the EPA and therefore no remediation or closure plan has been prepared for the site to date.

This report constitutes the first phase of such a Remediation Plan and sets out the general objectives and proposals for the remediation and restoration of the landfill. It is proposed that the Plan will be submitted to the EPA for their review prior to the preparation of detailed drawings and specifications.

2. Site Description

2.1 Location

The landfill site is located within the townland of Rinkippeen 2 km south-west of Tuam adjacent to the R347 Regional Road linking Tuam with Athenry **(Figure 2.1)**. The site including the civic amenity area and road entrance covers an area of approximately 3.4 hectares and is located in bogland with a high groundwater table. Surface water is collected by means of a small local stream which discharges to the River Clare. The area immediately around the landfill has a relatively low-density population.

2.2 Site History

Tuam Landfill began operating in the 1950s and accepted municipal and industrial non-hazardous waste collected in Tuam and its environs by Galway County Council and various private contractors

A survey of the amount of waste landfilled at Tuam, which was carried out in 1990 and reviewed and updated by Galway County Council in 1993 indicated that there was some 11,000 tonnes disposed of annually at the site. **Figure 2.2** shows a plan layout of the existing landfill site.

2.3 Topography and Landscape

The area surrounding the landfill is flat and low-lying cut-over bogland. The land rises to the south and east of the landfill along the line of the Athenry Road where the land is better drained. To the north and south of the site land has been reclaimed and is in general pasture. Currently sheep and horses graze the poor quality land adjacent to the landfill to the west.

The landfill itself rises to a height of approximately 6-7 m (46 mOD) above the surrounding land and has relatively steep slopes along the north, west and southern boundaries. The landfill is visible from the road with little screening in place. The lack of cover material at the surface of the waste has given the landfill a poor appearance and litter is present in the surrounding fields and hedgelines.

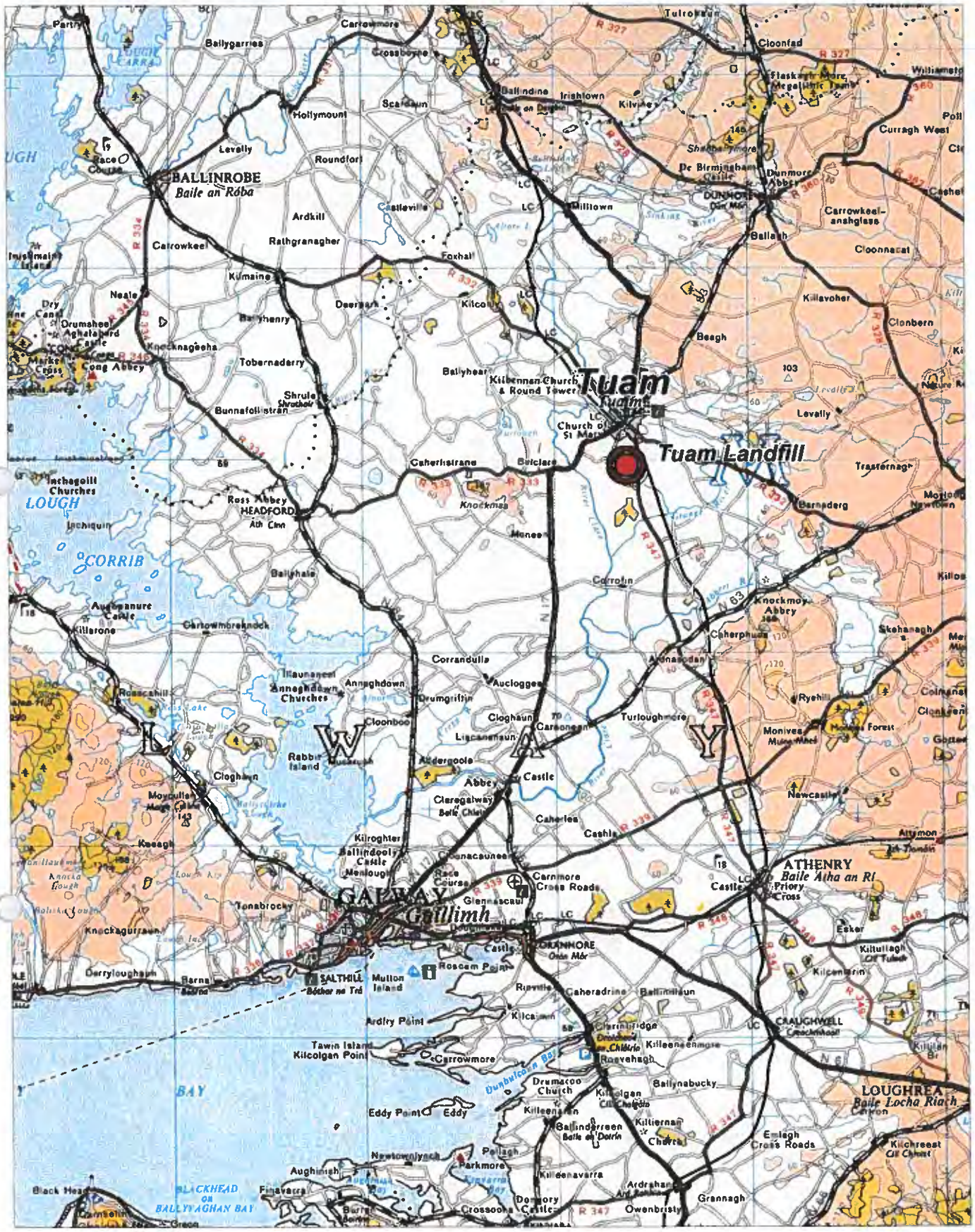
2.4 Geology and Hydrogeology

2.4.1 Regional Geology

The site is mapped as being underlain by Burren limestone, which is a major aquifer in the area. The Burren limestone is karstic and has a high transmissivity.

2.4.2 Overburden Geology

The bedrock is overlain by a layer of glacial deposits consisting of sandy boulder clay, coarse sandy gravel and cobbles and boulder clay with a total thickness of 5 to 6m. The upper part of this layer consists of a gravelly sandy clay of medium permeability. Below the landfill and



Tuam Landfill Closure Plan
Figure 2.1 : Location Map

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to the east, a 1m thick layer of low permeability boulder clay was found at the base of these glacial deposits. At the western side of the landfill, the lower part of these deposits contains a high permeability layer of coarse gravel, varying between 2 to 4m in depth. Vulnerability varies across the site from extreme in the west to high in the east.

A layer of peat up to 2.5m thick in places overlies the clay layer.

The rating of the landfill based on vulnerability and aquifer classification according to the recently published GSI/EPA Groundwater Protection Response Matrix is R4, which is deemed unacceptable for landfill.

2.5 Surface Water

Surface water drainage in the vicinity of the site consists of a number of drains and a small stream that flows at the western side of the landfill. This stream discharges to the north and to the south into small streams which flow in a westerly direction towards the Clare River.

3. Fieldwork

3.1 Previous Site Investigations

As part of the preparation of a report by Tobins & Co. Ltd. on sanitary landfill sites within the county on behalf of Galway Corporation and Galway County Council in January 1993, site investigations were carried out at the landfill site at Tuam. Preliminary investigations consisted of a survey of the overburden soils using a gouge auger by the Civil Engineering Department of University College Galway in mid-1992. Following this a geophysical survey was carried out by B.J. Murphy & Associates during September 1992 to provide information on the nature and distribution of the subsurface strata and to assist in the guidance of the subsequent drilling and borehole installation programme.

Detailed site investigations were conducted in late 1992 to gain definitive information on the geology and overburden type in the area. A total of nine boreholes were installed around the landfill using the auger method of drilling. Fourteen monitoring standpipes of 50mm diameter were installed in the boreholes at varying depths and a number of soil samples were obtained for testing at UCG's Soils Laboratory. A monitoring programme commenced in 1992 and has continued on a regular basis. The location of the boreholes installed during this phase of site investigation work is shown on **Figure 3.1**.

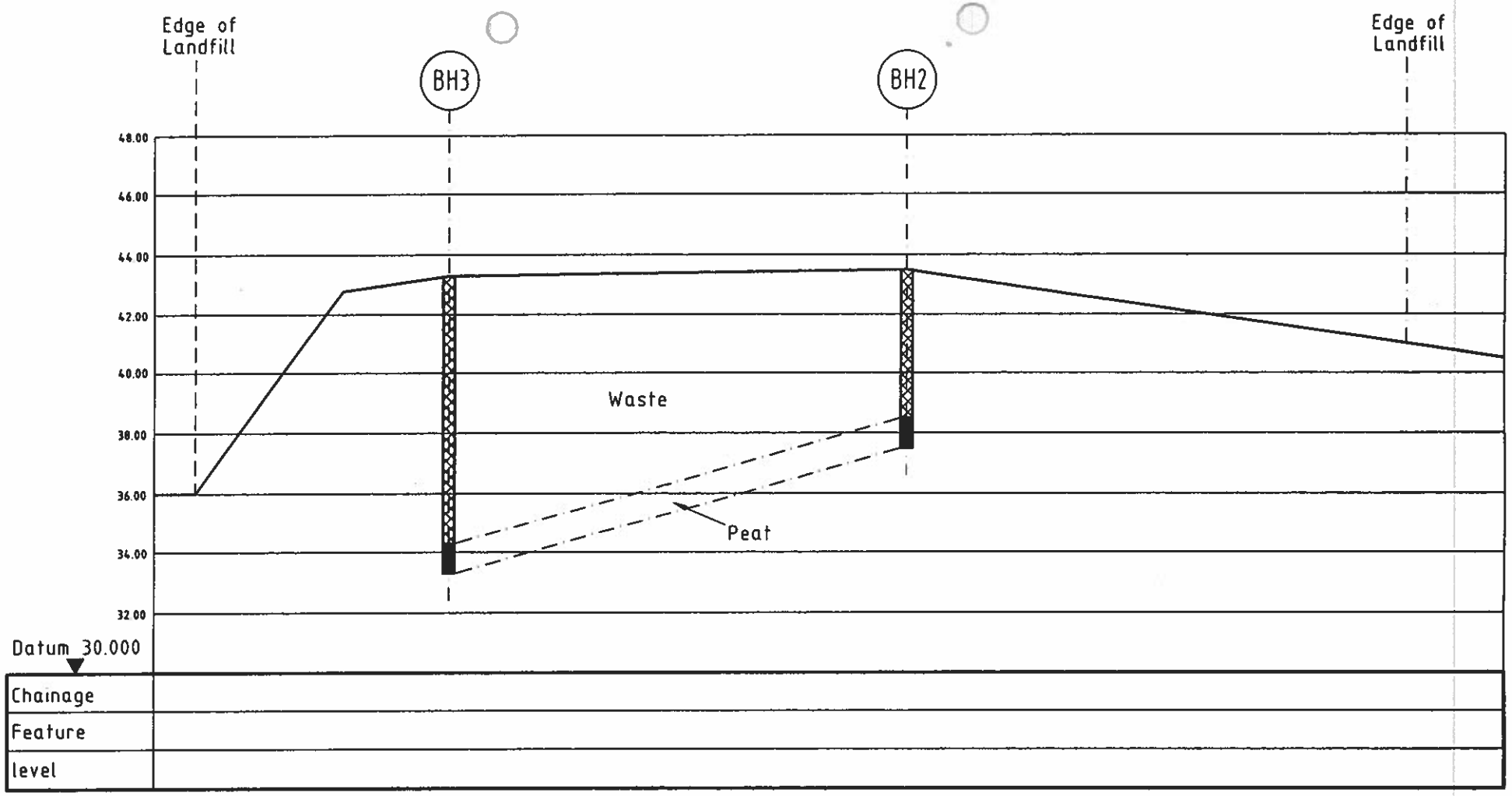
A summary of these boreholes is contained in **Table 3.1** below:

Table 3.1: Summary of Boreholes

Borehole No.	Depth (m)	Stratum
1A	6.8	Rock
1AP	1.5	Peat
1A1	4.6	Gravels/cobbles
2AP	1.15	Peat
3AP	1.2	Peat
4AP	1.3	Peat
5A	4.6	Rock
5AP	1.5	Peat
6AP	1.0	Peat
7AP	1.0	Peat
8A	6.75	Rock
8AP	1.0	Peat
8AF	1.7	Embankment fill

3.2 Recent Site Investigations

Additional site investigations were undertaken in April 1999 for the purpose of providing additional geological information and monitoring boreholes in both the waste and bedrock. Three rotary cored holes, RC1, RC2 and RC3 were drilled into the underlying rock at locations to the north and south outside the site boundary and 50mm slotted standpipes were installed in each borehole. In addition, three shell and auger boreholes, BH1, BH2 and BH3, were installed into the peat underlying the waste to monitor leachate levels within the landfill. The locations of these boreholes are shown on **Figure 3.1** while the factual report containing the site investigation data is contained in **Appendix A.**. A summary of the boreholes is presented in **Table 3.2**. Geological cross-sections generated from the site investigation data are shown on **Figures 3.2, 3.3 and 3.4.**



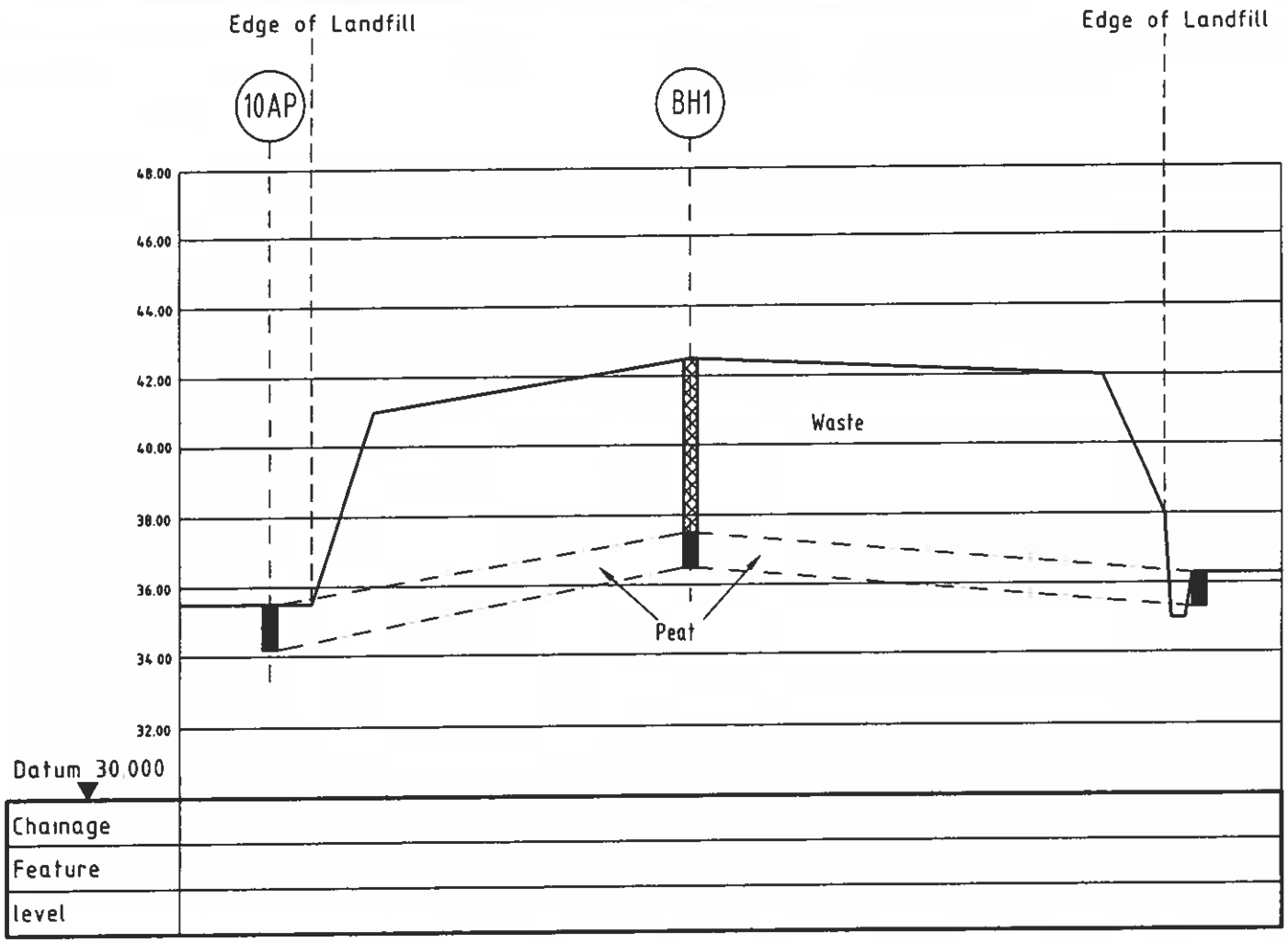
SECTION B-B

SCALE 1:1000 HOR
1:200 VER

NOTES

1. THIS DRAWING TO BE READ IN CONJUNCTION WITH DRG. Nos. Fig 3.2 & Fig 3.4

MCOS M.C.O'SULLIVAN Consulting Engineers COWI	Job: *Remediation of Tuam Landfill*	Drawn: *J.P.M.*	Date: *Oct. '99*
	Title: *Geological Profile Section B-B*	Checked: *W.M.*	Drg. No.: *Fig 3.3*
		Scale: *As Shown*	



SECTION C-C

SCALE 1:1000 HOR
1:200 VER

NOTES

1 THIS DRAWING TO BE READ IN CONJUNCTION WITH DRG. Nos. Fig 3.2 & Fig 3.3.

MCOS / M.C. O'SULLIVAN Consulting Engineers / COWI	Job: *Remediation of Tuam Landfill*	Drawn: *J.P.M.*	Date: *Oct. '99*
	Title: *Geological Profile Section C-C*	Checked: *W.M.*	Drg. No.: *Fig 3.4*
		Scale: *As Shown*	

Table 3.2: Summary of Boreholes

Borehole No.	Depth (m)	Stratum
BH1	6.0	Waste
BH2	6.0	Waste
BH3	10.0	Waste
RC1	9.0	Rock
RC2	10.0	Rock
RC3	23.0	Rock

3.3 MONITORING

A monitoring programme for surface water (SW1-SW4), groundwater (3AP, 4AP 5A, 8A, 8A1, 10AP) and leachate (surface pond) commenced at Tuam Landfill in November 1997 and is on-going. Since its commencement the site has been monitored on the following occasions:

- 24th November 1997
- 12th January 1998
- 18th May 1998
- 17th August 1998
- 30th November 1998
- 8th February 1999

In May 1999 the monitoring programme was extended to include leachate sampling at 3 boreholes (BH1-BH3) and an additional 3 groundwater monitoring boreholes (RC1, RC2 & RC3). The sampling locations are shown on **Figure 3.1**.

The monitoring programme is undertaken on a quarterly basis in accordance with the EPA Landfill Monitoring Manual (1995).

3.4 LABORATORY TESTING

Analysis of the groundwater, surface water and leachate samples is carried out by the EPA Regional Laboratory in Castlebar, Co. Mayo. The results of the analyses are discussed in Chapter 4 and a full set of results can be found in **Appendix B**.

3.5 SOIL SAMPLING

The remediation of the contaminated soil in the fields adjacent to the landfill is one of the objectives of the Closure Plan. Following a visual assessment of the area concerned it appears that the field to the west of the landfill is most in need of attention. Currently this field, which is poor grazing land with an upper layer of peat, appears contaminated on the surface. This is mainly due to the large quantity of water pumped into the landfill over the years in an attempt to extinguish fires within the site which subsequently breached the sides of the landfill and partly flooded the adjacent field.

In order to determine the extent, if any, of field contamination, window sampling of the upper layers of the soil was undertaken by Geotech Ltd. in May and June 1999. A total of 17 sampling points were sampled in a 40 metre by 40 metre grid as shown on **Figure 3.5**. Some difficulties were experienced at the time accessing some of the positions due to the very soft ground underfoot. The sampling depths varied from ground level to 2 metres below ground

LEGEND:

⊗ Sampling Point

MCOS M.C. O'SULLIVAN Consulting • Engineers COWI	Job: *Remediation of Tuam Landfill*	Drawn: *J.P.M.*	Date: *Oct. '99*
	Title: *Plan Showing Contamination Survey Sampling Points*	Checked: *W.M.*	Drg. No. *Fig 3.5*
		Scale: *1:2000*	

TEST REPORT
SOIL SAMPLE ANALYSIS

TESTING
No.1252
No.1411

Geotech Specialists Ltd
Carewswood
Castlemartyr
County Cork
Ireland

TES Report No. 991970

Site: Taum Landfill

Customer reference	B/H S 1 1	B/H S 2 1	B/H S 2 2	B/H S 3 1
Depth (m)	0.00 to 0.25	0.00 to 0.25	0.75 to 1	0.00 to 0.25
Date logged	07/06/99	07/06/99	07/06/99	07/06/99
TES Bretby ID Number	CL/9914233	CL/9914234	CL/9914235	CL/9914236

UKAS accredited	Test No.	CL/9914233	CL/9914234	CL/9914235	CL/9914236
Cadmium	ICPSSS11	<1	<1	<1	<1
Chromium (total)	ICPSSS11	11	<2	<2	14
Mercury	ICPSSS11	<0.5	<0.5	<0.5	<0.5

Results expressed as mg/kg Air Dried unless stated otherwise

Date of Issue: 14/06/99

Tests marked 'not UKAS accredited' in this report are not included in the UKAS Accreditation Schedule for our laboratory.

TES Bretby accepts no responsibility for the sampling related to the above results

TEST REPORT
SOIL SAMPLE ANALYSIS

TESTING
No.1252
No.1411

Geotech Specialists Ltd
Carewswood
Castlemartyr
County Cork
Ireland

TES Report No. 991970

Site: Taum Landfill

Customer reference	B/H S 3 2	B/H S 3 3	B/H S 5 1	B/H S 5 2
Depth (m)	0.75 to 1	1.75 to 2	0.00 ** to 0.25	0.75 to 1
Date logged	07/06/99	07/06/99	07/06/99	07/06/99
TES Bretby ID Number	CL/9914237	CL/9914238	CL/9914239	CL/9914240

UKAS accredited	Test No.	CL/9914237	CL/9914238	CL/9914239	CL/9914240
Cadmium	ICPSSS11	<1	<1	<1	<1
Chromium (total)	ICPSSS11	<2	9	2	<2
Mercury	ICPSSS11	<0.5	<0.5	<0.5	<0.5

Results expressed as mg/kg Air Dried unless stated otherwise
** denotes sample part dry only; analysis not UKAS accredited

Date of Issue: 14/06/99

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TEST REPORT
SOIL SAMPLE ANALYSIS

TESTING
No.1252
No.1411

Geotech Specialists Ltd
Carewswood
Castlemartyr
County Cork
Ireland

TES Report No. 991970

Site: Taum Landfill

Customer reference	B/H S 8 1	B/H S 8 2	B/H S 9 1	B/H S 9 2
Depth (m)	0.00 to 0.25	0.75 to 1	0.00 to 0.25	0.75 to 1
Date logged	07/06/99	07/06/99	07/06/99	07/06/99
TES Bretby ID Number	CL/9914241	CL/9914242	CL/9914243	CL/9914244

UKAS accredited	Test No.	CL/9914241	CL/9914242	CL/9914243	CL/9914244
Cadmium	ICPSSS11	<1	<1	<1	<1
Chromium (total)	ICPSSS11	<2	<2	<2	<2
Mercury	ICPSSS11	<0.5	<0.5	<0.5	<0.5

Results expressed as mg/kg Air Dried unless stated otherwise

Date of Issue: 14/06/99

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TEST REPORT
SOIL SAMPLE ANALYSIS

TESTING
No.1252
No.1411

Geotech Specialists Ltd
Carewswood
Castlemartyr
County Cork
Ireland

TES Report No. 991970

Site: Taum Landfill

Customer reference		B/H S 10 1	B/H S 10 2	B/H S 12 1	B/H S 12 2
Depth (m)		0.00 to 0.25	0.75 to 1	0.00 ** to 0.25	0.75 to 1
Date logged		07/06/99	07/06/99	07/06/99	07/06/99
TES Bretby ID Number		CL/9914245	CL/9914246	CL/9914247	CL/9914248
UKAS accredited	**Test No.**	**CL/9914245**	**CL/9914246**	**CL/9914247**	**CL/9914248**
Cadmium	**ICPSSS11**	<1	<1	<1	<1
Chromium (total)	**ICPSSS11**	<2	<2	7	<2
Mercury	**ICPSSS11**	<0.5	<0.5	<0.5	<0.5

Results expressed as mg/kg Air Dried unless stated otherwise
** denotes sample part dry only; analysis not UKAS accredited

Date of Issue: 14/06/99

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TES Bretby, P.O. Box 100, Burton-on-Trent, DE15 0XD Telephone: 01283 554400 Fax: 01283 554422
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TEST REPORT
SOIL SAMPLE ANALYSIS

TESTING
No.1252
No.1411

Geotech Specialists Ltd
Carewswood
Castlemartyr
County Cork
Ireland

TES Report No. 991970

Site: Taum Landfill

Customer reference	B/H S 13 1	B/H S 13 2	B/H S 14 1	B/H S 14 2
Depth (m)	0.00 to 0.25	0.75 to 1	0.00 to 0.25	0.75 to 1
Date logged	07/06/99	07/06/99	07/06/99	07/06/99
TES Bretby ID Number	CL/9914249	CL/9914250	CL/9914251	CL/9914252

UKAS accredited	Test No.	CL/9914249	CL/9914250	CL/9914251	CL/9914252
Cadmium	ICPSSS11	<1	<1	<1	<1
Chromium (total)	ICPSSS11	<2	<2	<2	<2
Mercury	ICPSSS11	<0.5	<0.5	<0.5	<0.5

Results expressed as mg/kg Air Dried unless stated otherwise

Date of Issue: 14/06/99

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TEST REPORT
SOIL SAMPLE ANALYSIS

TESTING
No.1252
No.1411

Geotech Specialists Ltd
Carewswood
Castlemartyr
County Cork
Ireland

TES Report No. 991970

Site: Taum Landfill

Customer reference	B/H S 19 1	B/H S 19 2	B/H S 20 1	B/H S 20 2
Depth (m)	0.00 to 0.25	0.75 to 1	0.00 to 0.25	0.75 to 1
Date logged	07/06/99	07/06/99	07/06/99	07/06/99
TES Bretby ID Number	CL/9914253	CL/9914254	CL/9914255	CL/9914256

UKAS accredited	Test No.	CL/9914253	CL/9914254	CL/9914255	CL/9914256
Cadmium	ICPSSS11	<1	<1	<1	<1
Chromium (total)	ICPSSS11	15	7	<2	<2
Mercury	ICPSSS11	<0.5	<0.5	<0.5	<0.5

Results expressed as mg/kg Air Dried unless stated otherwise

Date of Issue: 14/06/99

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TEST REPORT
SOIL SAMPLE ANALYSIS

TESTING
No.1252
No.1411

Geotech Specialists Ltd
Carewswood
Castlemartyr
County Cork
Ireland

TES Report No. 991970

Site: Taum Landfill

Customer reference	B/H S 21 1	B/H S 21 2	B/H S 26 1	B/H S 26 2
Depth (m)	0.00 to 0.25	0.75 to 1	0.00 to 0.25	0.75 to 1
Date logged	07/06/99	07/06/99	07/06/99	07/06/99
TES Bretby ID Number	CL/9914257	CL/9914258	CL/9914259	CL/9914260

UKAS accredited	Test No.	CL/9914257	CL/9914258	CL/9914259	CL/9914260
Cadmium	ICPSSS11	<1	<1	<1	<1
Chromium (total)	ICPSSS11	<2	<2	<2	<2
Mercury	ICPSSS11	<0.5	<0.5	<0.5	<0.5

Results expressed as mg/kg Air Dried unless stated otherwise

Date of Issue: 14/06/99

Tests marked 'not UKAS accredited' in this report are not included in the UKAS Accreditation Schedule for our laboratory.

TES Bretby accepts no responsibility for the sampling related to the above results

TEST REPORT
SOIL SAMPLE ANALYSIS

TESTING
No.1252
No.1411

Geotech Specialists Ltd
Carewswood
Castlemartyr
County Cork
Ireland

TES Report No. 991970

Site: Taum Landfill

Customer reference	B/H S 27 1	B/H S 27 2	B/H S 28 1	B/H S 28 2
Depth (m)	0.00 to 0.25	0.75 to 1	0.00 to 0.25	0.75 ** to 1
Date logged	07/06/99	07/06/99	07/06/99	07/06/99
TES Bretby ID Number	CL/9914261	CL/9914262	CL/9914263	CL/9914264

UKAS accredited	Test No.	CL/9914261	CL/9914262	CL/9914263	CL/9914264
Cadmium	ICPSSS11	<1	<1	<1	<1
Chromium (total)	ICPSSS11	46	<2	<2	<2
Mercury	ICPSSS11	<0.5	<0.5	<0.5	<0.5

Results expressed as mg/kg Air Dried unless stated otherwise
** denotes sample part dry only; analysis not UKAS accredited

Date of Issue: 14/06/99

Tests marked 'not UKAS accredited' in this report are not included in the UKAS Accreditation Schedule for our laboratory.

TES Bretby accepts no responsibility for the sampling related to the above results

TES Bretby, P.O. Box 100, Burton-on-Trent, DE15 0XD Telephone: 01283 554400 Fax: 01283 554422

ENCLOSURE C

Drawings

	Drawings
Site Location Plan	1
Exploratory Hole Location Plan	2

depending on the location although some samples were lost due to the soft characteristics of the material.

Analysis of the soil samples was undertaken by TES Bretby Ltd., UK for three main parameters - Cadmium, Chromium and Mercury. These three heavy metals, commonly found in landfill leachates, are included in the ICRCL "Guidance on Assessment and Redevelopment of Contaminated Land" (ICRCL 59/83) and give a good indication of the degree and extent of contamination, if any, in the soil.

The results of the chemical analysis, which are included in **Appendix C,** indicate that all of the results of the Cadmium, Chromium and Mercury tests fall below the threshold levels for treatment for a proposed end-use of Domestic Gardens and Allotments which are 3mg/kg, 600mg/kg and 1mg/kg respectively. One sample at location point 27 at 0 to 0.25m depth recorded a chromium level of 46mg/kg which is considerably higher than the rest of the samples but this value is still well below the threshold level.

It can be concluded from the analysis of the samples taken in the peat that the contamination levels are very low. The land immediately west of the site has a poor appearance due to the large quantities of water pumped into the landfill which subsequently spilled over into the adjacent field where it caused ponding on the surface.

By implementing the remediation measures recommended in this report, i.e. regrading the side slopes and improving surface water drainage, the appearance of the land will dramatically improve with time. It may be necessary, however, to remove any loose waste that may have been blown onto the lands over the years. The upper peat layer in the general area acts as a natural filter resulting in any contaminated surface water being considerably attenuated as it passes through the soil. As a result it is not felt necessary to remove any of the soil in the adjacent field since the contamination levels are very low as indicated by the survey results. In addition, the standing surface water in the field will be naturally treated as it passes through the upper layer of peat, leading the overall situation to improve with time.

4. INTERPRETATION OF SURFACE AND GROUNDWATER DATA

4.1 POLLUTION OF SURFACE AND GROUNDWATER

Leachate is produced when rain or groundwater comes in contact with the waste in the landfill. Inorganic and organic soluble material from the waste is dissolved in the water as it percolates through the waste. Thus percolating water gradually deteriorates in quality resulting in a polluted liquid which may contain pollutants from the following four groups of substances:

- Inorganic ions
- Organic matter and nutrients
- Hazardous organic chemicals
- Heavy metals

The leachate will infiltrate into the groundwater and be transported in the direction of the groundwater flow. Leachate may also enter nearby streams, either directly or indirectly via the groundwater.

4.2 SURFACE AND GROUNDWATER FLOW

The landfill is situated in a low-lying cut-over bog with a small stream flowing in the western part of the site. According to the results of site investigations carried out in 1993 most of the leachate infiltrates to the main aquifer which is formed by a coarse gravel layer and an underlying layer of limestone. In these layers the leachate is transported by the ground water in a westerly and south-westerly direction. Some of the rain that infiltrates the landfill waste flows through the shallow peat layers in a west south-westerly direction while some of the generated leachate enters the stream at the western side of the landfill (Patrick J. Tobin & Co and Grontmij Consulting Engineers (1993)).

4.3 MONITORING PROGRAMME

In order to assess the level of pollution caused by the landfill, surface and groundwater around the landfill was monitored six times during the period November 1997-February 1999.

The locations of the groundwater monitoring sites and the surface water sampling sites are shown on **Drg. No. TR-01**. The station numbers shown represent the following types of sampling:

- BH1, BH2 and BH3 are leachate monitoring locations
- RC1, RC2, RC3, 5A, 8A and 8A1 are sites where groundwater samples from the Limestone layer was collected. RC1 is situated downstream of the landfill while the other locations are situated up-stream of the landfill
- 3AP, 4AP, 5AP and 10AP are sites where groundwater samples from the peat layer were collected. 5AP is situated upstream of the landfill while 3AP, 5AP and 10AP are situated downstream.

- SW1, SW2, SW3 and SW4 are sampling sites at a small stream where surface water samples were collected. SW1 represents a site upstream of the landfill not expected to be influenced by the landfill. SW2, SW3 and SW4 are located downstream of the landfill and may be polluted by leachate from the landfill.

Details on the characteristics of the groundwater monitoring boreholes are shown in **Table 4.1.**

Table 4.1: Characteristics of Boreholes

Number	Type	Depth	Response zone	Response material
3AP	Trial pit	1.2	0.7-0.95	Peat
4AP	Trial pit	1.3	0.55-0.8	Saturated peat
5AP	Trial pit	1.5	0.75-1.0	Peat
10AP	Trial pit	1.3	0.75-1.0	Peat
5A	Borehole	4.6	3.25-4.3	Shattered limestone rock
8A	Borehole	6.75	6.35-6.6	Limestone
BH1	Borehole	6.0	4.2-4.5	Waste
BH2	Borehole	6.0	4.2-4.5	Waste
BH3	Borehole	10.0	8.2-8.5	Waste
RC1	Borehole	9.0	4.2-4.5	Limestone
RC2	Borehole	10.0	9.2-9.5	Limestone
RC3	Borehole	23.0	19.5-22.5	Limestone

Table 4.2 gives an overview of the time of sampling for the different samples. The samples were analysed for a wide number of parameters as specified in the EPA Manual on Landfill Monitoring.

Sampling and chemical analysis was carried out by the EPA Regional Laboratory, Castlebar, Co. Mayo. The results are presented in **Appendix B.**

Table 4.2: Chemical Monitoring - Overview of Sampling Programme

	24th November 1997	12th January 1998	18th May 1998	17th August 1998	30th November 1998	8th February 1999	17th May 1999
Leachate							
BH3							x
Groundwater-peat							
3AP	x	x	x	x	x	x	x
4AP	x	x	x	x	x	x	
5AP	x	x	x	x	x	x	
10AP	x	x	x	x	x	x	x
Groundwater-main aquifer							
5A	x	x	x	x	x	x	x
8A	x	x	x	x	x	x	x
8A1	x	x		x			
RC1							x
RC2							x
RC3							x
Leachate contaminated surface pool							
Leachate (L1)	x	x	x	x	x	x	x
Surface water							
SW1	x	x	x	x	x	x	x
SW2	x	x	x	x	x	x	x
SW3	x	x	x	x	x	x	x
SW4	x	x	x	x	x	x	x

4.4 GROUNDWATER

The results of the groundwater analyses are shown in **Tables 4.3, 4.4 and 4.5.** The results are compared to the standards in the *"European Communities (Quality of Water Intended for Human Consumption) Regulations 1988(S.I No 81)"*. Values exceeding these standards are shown in bold.

The groundwater in the peat layer at station 10AP immediately west of the site and 4AP situated 50m west of the site boundary is clearly contaminated by leachate from the landfill. However, a considerable attenuation of pollutants takes place downstream, generally reducing the levels of pollutants from the landfill to well below the EU quality standards for water intended for human consumption at station 3AP 200 m south-west of the landfill boundary (**Table 4.3**).

The electrical conductivity values increase from well below the drinking water standard (MAC) at station 5AP upstream of the landfill to values above MAC at station 4AP and to very high levels at station 10AP. Except for one occasion, the values on station 3AP are at the level encountered upstream of the landfill, indicating that station 3AP is generally not affected by pollution from the landfill (**Figure. 4.1**). The high conductivity values on stations 4AP and 10AP are mainly due to high concentrations of chloride, magnesium, potassium and sodium. The concentrations of these ions violate the standards for drinking water (**Table 4.3**). Downstream at station 3AP the concentrations have decreased to levels comparable to the levels encountered upstream of the landfill at station 5AP and well below the MAC.

Stations 4AP and 10AP are also contaminated by ammonia, TOC, TON and phosphate from the landfill (**Figure. 4.2** and **Table 4.3**). It should be noted that background concentrations of ammonia, violating the standards for drinking water were found in the area. This is probably due to the fact that the area is a bog with anaerobic conditions, where ammonia is the dominant inorganic nitrogen species.

The groundwater immediately west of the site is also polluted with iron and manganese. Background levels in the area violate the standards for drinking water. The high background levels are probably due to the reducing environment in the waterlogged bog that increase the solubility of iron and manganese. The groundwater is not polluted by other heavy metals. (**Table 4.3**)

Elevated levels of alkalinity, cyanide and dry residues violating the drinking water standards were also encountered at the polluted stations west of the site.

Table 4.3: Results of chemical analysis of groundwater samples from the peat layer sampled during the period November 1997-May 1999. The values represent the range measured in seven sampling rounds. The results are compared with EU Standards for quality of water intended for human consumption (SI No 81 of 1988). MAC = Maximum Admissible Concentration

Parameter	5AP upstream	4AP downstream	10AP downstream	3AP downstream	MAC
pH	6.9-7.2	6.4-6.6	7.1-7.6	6.8-7.1	6<pH<9
Conductivity uS/cm	602-712	749-2550	5500-7980	749-2230	1500
Inorganic ions					
Calcium mg/l Ca	72-136	142-179	72-212	96-162	200
Chloride mg/l Cl	15-21	477-734	368-1560	16-23	250
Magnesium mg/l Mg	2.9-13.4	4.6-142	40.8-113	0-9.6	50
Potassium mg/l K	1-2	90-140	400-800	3-5	12
Sodium mg/l Na	10-25	50-275	400-1200	13-15	150
Sulphate mg/l SO_4	0.6-16.3	0.2-34.3	3-75.5	1.2-25.3	250
Organic matter and nutrients					
TOC mg/l C	20-45	20-95	25-416	42-84	-
TON mg/l N	<0.01-0.6	<0.01-1.1	0.04-3.5	<0.01-0.10	-
Ammonia mg/l NH_4	0.06-1.3	16.1-46.6	0.04-543.1	0.1-0.4	0.3
Phosphate mg/l PO_4	0.02-0.07	0.02-1.5	7.3-714	<0.008-0.03	-
Heavy metals					
Arsenic mg/l As	0.005-<0.01	≤0.01	0.006-0.05	<0.005-<0.01	0.05
Barium mg/l Ba	0.07-0.16	0.17-0.27	0.04-0.14	0.07-0.18	0.5
Cadmium mg/lCd	<0.00025	<0.00025-0.0008	<0.00025	<0.00025	0.005
Chromium mg/l Cr	<0.0025-0.003	0.0029-0.008	0.016-0.025	<0.0025-0.0026	0.05
Copper mg/l Cu	<0.001-0.005	0.001-0.006	<0.001-0.005	<0.001-0.004	0.5
Iron mg/l Fe	0.8-3.0	25-330	1.6-5.0	0.1-1.0	0.2
Lead mg/l Pb	<0.005	<0.005-0.011	<0.005	<0.005	0.05
Manganese mg/l Mn	0.6-1.3	1.9-2.9	0.2-0.6	0.7-1.7	0.05
Mercury mg/l Hg	<0.001	<0.001	<0.001	<0.001	0.001
Nickel mg/l Ni	0.012-<0.1	0.028-<0.1	0.03-<0.1	0.019-<0.1	0.05
Silver mg/l Ag	<0.01	<0.01	<0.01	<0.01	0.01
Zinc mg/l Zn	<0.025	<0.025-0.12	<0.025	<0.025	1.0
Other					
Tot Alkal. mg/l HCO_3	303-376	368-580	1652-1904	368-436	30
Boron mg/l Bo	<0.5	<0.5	<0.5	<0.5-0.8	2
Cyanide mg/l Cn	0.007-0.06	0.06-0.5	0.15-0.89	0.005-1.1	0.05
Dry residues mg/l	422-518	1401-1712	2806-4351	526-559	1000
Fluoride mg/l F	0.05-0.1	0.05-<0.1	0.05-0.3	0.05-0.12	1
Phenol mg/l	not detected	not detected	not detected	not detected	0.0005
Selenium mg/l Se	<0.01	<0.01	<0.01	<0.01	0.01

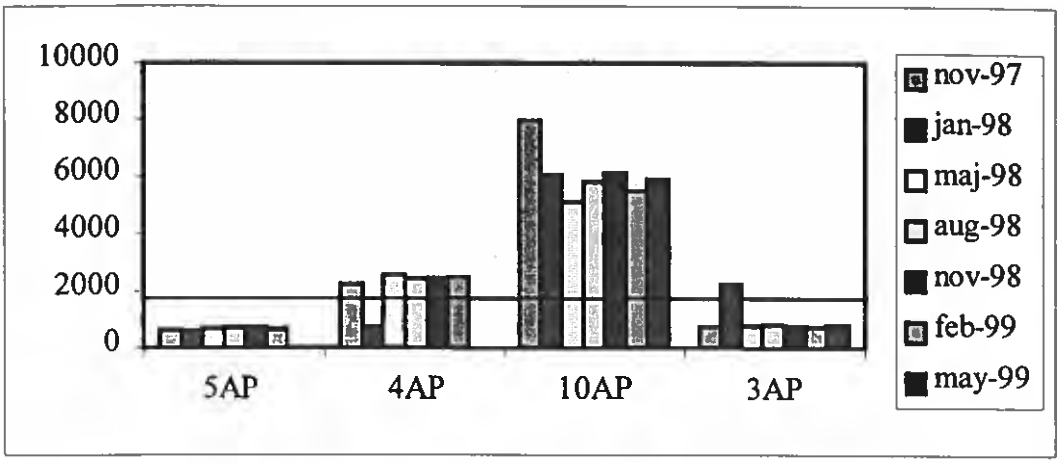

Figure 4.1: Conductivity measured in groundwater samples from the peat layer west and south-west of the landfill. 5AP is situated upstream of the landfill. 4AP, 10AP and 3AP are situated downstream. The horizontal line indicates the Maximum Admissible Concentration for water intended for human consumption.

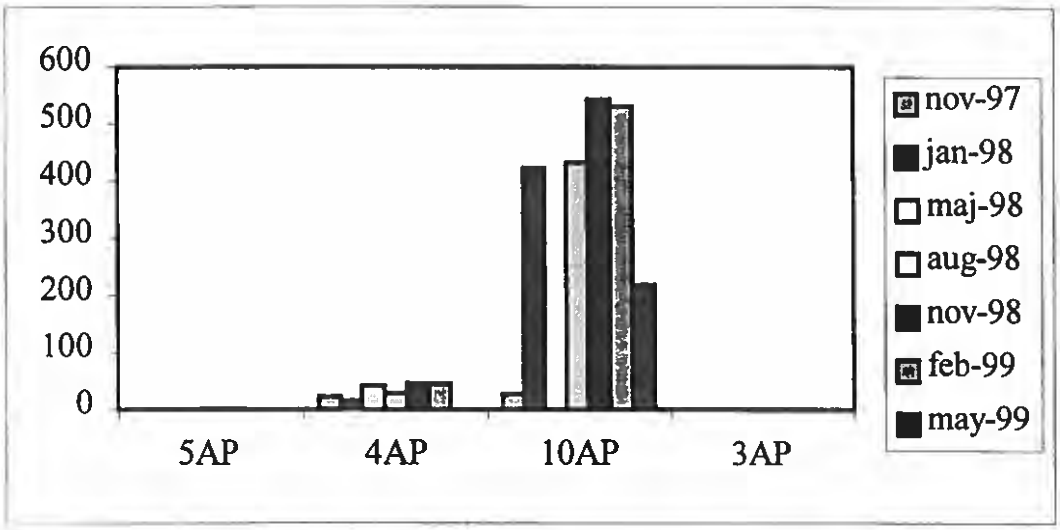

Figure 4.2: Concentrations of ammonium measured in groundwater samples from the peat layer west and southwest of the landfill. 5AP is situated upstream of the landfill. 4AP, 10AP and 3AP are situated downstream of the landfill

4.4.1. Main Aquifer (Limestone Layer)

The groundwater at station RC1, situated 15m south of the landfill boundary is clearly polluted by leachate from the landfill (**Table 4.4**).

Elevated levels of ammonia, iron and manganese violating the drinking water standards were found in the main aquifer on sites not affected by the landfill (i.e. 8A, 8A1, 5A, RC2 and RC3, upstream of the landfill, see **Tables 4.4** and **4.5**). This is a result of the waterlogged, reduced condition of the peat layer in the area (Section 4.4.1).

Table 4.4: Results of chemical analysis of groundwater from the limestone layer on May 17th 1999. The results are compared with EU Standards for quality of water intended for human consumption (SI No 81 of 1988). MAC= Maximum Admissible Concentration

Parameter	RC3 upstream	RC2 upstream	RC1 downstream	MAC
pH	7.3	7.2	6.9	6<pH<9
Conductivity uS/cm	656	713	**3510**	1500
Inorganic ions				
Calcium mg/l Ca	109	125	**376**	200
Chloride mg/l Cl	25	24	**815**	250
Magnesium mg/l Mg	11.5	7.7	50	50
Sulphate mg/l SO_4	6.1	0.3	**339**	250
Organic matter and nutrients				
TON mg/l N	<0.01	<0.01	0.16	-
Ammonia mg/l NH_4	**9.2**	**6.01**	**11.7**	0.3
Phosphate mg/l PO_4	0.05	0.139	0.078	-
Other				
Tot Alkal. mg/l	**324**	**344**	**650**	30
Tot hardness	320	344	1150	
Fluoride mg/l F	0.74	0.7	0.46	1

Table 4.5: **Results of chemical analysis of groundwater from the limestone layer sampled during the period November 1997-May 1999. The values represent the range measured in seven sampling rounds. The results are compared with EU Standards for quality of water intended for human consumption (SI No 81 of 1988). MAC = Maximum Admissible Concentration.**

Parameter	8A up-stream	8A1 up-stream	5A up-stream	MAC
pH	6.9-7.3	7.4-7.6	6.7-7.1	6<pH<9
Conductivity uS/cm	887-917	1090-1247	602-759	1500
Inorganic ions				
Calcium mg/l Ca	117-173	58-176	92-150	200
Chloride mg/l Cl	25-39	29-81	18-30	250
Magnesium mg/l Mg	6-26	4-28	1-42	50
Potassium mg/l K	1-2	3-4	2-4	12
Sodium mg/l Na	10-15	70-100	10-15	150
Sulphate mg/l S O_4	16-34	4-20	0.5-32	250
Organic matter and nutrients				
BOD mg/l O_2	1.1	-	-	-
COD mg/l O_2	-	-	-	-
TOC mg/l C	8-17	16-33	13-30	-
TON mg/l N	<0.01-0.4	0.5-2.9	<0.01-0.1	-
Ammonia mg/l NH_4	**0.9-1.9**	0.07-**0.9**	**1.2-4.3**	0.3
Nitrite mg/l NO_2	-	-	-	0.1
Phosphate mg/l PO_4	0.012-0.047	0.017-0.051	<0.08-0.39	-
Heavy metals				
Arsenic mg/l As	<0.01-0.019	<0.005-<0.01	<0.01-0.009	0.05
Barium mg/l Ba	0.04-0.17	0.14-0.29	0.14-**0.52**	0.5
Cadmium mg/l Cd	<0.00025-0.0045	<0.00025-0.0003	<0.00025-0.005	0.005
Chromium mg/l Cr	<0.0025	0.008-0.017	<0.0025-0.040	0.05
Copper mg/l Cu	≤0.001-0.005	≤0.010-0.018	0.003-0.3	0.5
Iron mg/l Fe	**2-530**	**0.6-3**	**1.5-40**	0.2
Lead mg/l Pb	<0.005	<0.005-0.012	<0.005-**0.09**	0.05
Manganese mg/l Mn	**0.14-0.2**	**0.4-3.3**	**0.9-2.4**	0.05
Mercury mg/l Hg	<0.00025-<0.001	<0.00025	<0.00025-<0.001	0.001
Nickel mg/l Ni	<0.1-0.02	0.045-<0.1	0.026-**0.3**	0.05
Silver mg/l Ag	<0.01-<1	<1	<0.01-<1	0.01
Zinc mg/l Zn	<0.025	<0.025-0.035	0.16-0.65	1.0
Other				
Tot Alkal mg/l HCO_3	**332-504**	**533**	**320-488**	30
Tot hardness	381-532	263-456	360-560	
Boron mg/l Bo	<0.5	<0.5	<0.5	2
Cyanide mg/l Cn	0.009-0.12	0.009	0.009-**0.11**	0.05
Dry residues mg/l	415-615	624-856	963-**12275**	1000
Fluoride mg/l F	0.6-0.9	0.3	0.2-0.6	1
Phenol mg/l	none detected	none detected	none detected	0.0005
Selenium mg/l Se	<0.01	<0.01	<0.01	0.01

Table 4.6: **Results of chemical analysis of leachate (BH3) from May 1999 and from the leachate contaminated pool during the period November 1997-February 1999. The values represent the range measured in six sampling rounds. The results are compared with EU Standards for quality of water intended for human consumption (SI No 81 of 1988). MAC = Maximum Admissible Concentration**

Parameter	BH3	L1	MAC
pH	7.5	7.8-8.3	6<pH<9
Conductivity uS/cm	**15280**	**3400-8180**	1500
Inorganic ions			
Calcium mg/l Ca	**332**	180-**301**	200
Chloride mg/l Cl	**2362**	**357-1336**	250
Magnesium mg/l Mg	**161**	**26-146**	50
Potassium mg/l K	-	**200-700**	12
Sodium mg/l Na	-	**320-700**	150
Sulphate mg/l SO_4	0.7	78-**380**	250
Organic matter and nutrients			
BOD mg/l O_2	73	54.8-1315	-
COD mg/l O_2	**1535**	1302-3600	-
TOC mg/l C	-	37-436	-
TON mg/l N	0.16	<0.01-1.5	-
Ammonia mg/l NH_4	**1019**	**49.7-580**	0.3
Nitrite mg/l NO_2	-	**10**	0.1
Phosphate mg/l PO_4	10.9	1.9-10.8	-
Heavy metals			
Arsenic mg/l As	-	<0.05	0.05
Barium mg/l Ba	-	268	0.5
Cadmium mg/l Cd	-	<0.0002- 0.0012	0.005
Chromium mg/l Cr	-	0.009-0.04	0.05
Copper mg/l Cu	-	0.008-0.04	0.5
Iron mg/l Fe	-	**0.28-14**	0.2
Lead mg/l Pb	-	<0.005-**0.07**	0.05
Manganese mg/l Mn	-	**0.4-1.5**	0.05
Mercury mg/l Hg	-	<0.001	0.001
Nickel mg/l Ni	-	<0.1	0.05
Silver mg/l Ag	-	<1	0.01
Zinc mg/l Zn	-	0.17-1	1.0
Other			
Tot Alkal. mg/l HCO_3	-	**734-860**	30
Tot hardness	1500	788-1214	
Boron mg/l Bo	-	<0.5-**8**	2
Cyanide mg/l Cn	-	-	0.05
Dry residues mg/l	-	-	1000
Fluoride mg/l F	-	-	1
Phenol mg/l	-	none detected	0.0005
Selenium mg/l Se	-	<0.01	0.01

4.5 SURFACE WATER

The results of the analyses of surface water samples are given in **Table 4.7.** The results are compared to Environmental Quality Standards for Surface Waters proposed by EPA (EPA, 1997). Values exceeding the standards are shown in bold. The water in the stream at SW2 is heavily contaminated by the landfill, with elevated levels of conductivity, chloride, sulphate, BOD, ammonia and nitrite violating the quality standards. However, the contamination decreases significantly downstream to levels generally meeting the standards at SW3, some 200m from the landfill boundary (**Table 4.7, Figure 4.3** and **Figure 4.4**).

Table 4.7: Results of chemical analysis of surface water sampled on during the period November 1997-May 1999 upstream (SW1) and downstream (SW2, SW3 and SW4) of the landfill. The values represent the range measured in seven sampling rounds. The results are compared with Environmental Quality Standards (EQS) for Surface Water proposed by the EPA (EPA ,1997).

Parameter	SW1 (upstream)	SW2 (down-stream)	SW3 (down-stream)	SW4 (down-stream)	EQS
pH	7.2-7.7	7.5-7.8	7.2-7.8	7.4-8.1	5.5 < pH < 9.0
Dis Oxygen %sat	25-51	23-51	57-80	73-97	-
Tot Alkalinity mg/l	304-384	79-1010	180-332	196-340	-
Tot Hardness	288-412	780-1510	220-368	268-364	
Conductivity uS/cm	679-860	**4760-13200**	584-**1222**	568-965	1000
Inorganic ions					
Calcium mg/l Ca	74-266	131-440	42-138	44-168	-
Chloride mg/l Cl	21-41	**728-6232**	44-163	35-179	250
Magnesium mg/l Mg	1.9-10.6	78-192	11-12.5	1.9-25	-
Potassium mg/l K	6-20	120-800	5-12	4-10	-
Sodium mg/l Na	10-20	600-1500	25-75	20-75	-
Sulphate mg/l $S O_4$	0.5-31	55-**920**	0.5-58	0.6-51	200
Organic matter and nutrients					
BOD mg/l O_2	1-**13.7**	**8.2-26.9**	3.7-**5.8**	0.9-4.5	≤ 5
COD mg/l O_2	20-86	134-545	30-65	33-99	-
TOC mg/l C	10-49	25-74	2-40	20-46	-
TON mg/l N	1.0--10.8	11.9-23	0.8-3.3	1.1-3.3	-
Ammonia mg/l NH_4	0.04-3.2	**35.5-92.4**	0.8-2.7	0.4-1.8	(b)
Nitrite mg/l NO_2	0.002-0.1	**2-5**	0.002-**0.4**	0.002-**0.5**	0.2 (c)
Phosphate mg/l PO_4	0.1-0.76	0.08-0.9	0.039-0.43	0.03-0.3	-
Heavy metals					
Arsenic mg/l AS	<0.0002-<0.05	<0.0002-<0.05	<0.0002-<0.05	<0.0002-<0.05	0.05
Barium mg/l Ba	0.02-73	0.08-229	0.01-66	70	
Cadmium mg/lCd	<0.0003	0.0003-0.001	<0.0003	<0.0003	0.005
Chromium mg/l Cr	<0.0025	0.003-0.009	<0.0025	<0.0025	0.05
Copper mg/l Cu	0.001-0.004	0.006-0.1	<0.001-0.003	<0.001-0.005	0.1
Iron mg/l Fe	0.006-0.4	0.3-1	0.1-0.4	0.2-0.4	1.0
Lead mg/l Pb	<0.005	<0.005	<0.005	<0.005	0.05
Manganese mg/l Mn	<0.001-0.1	0.2-**0.4**	0.005-0.1	0.01-0.05	0.3
Mercury mg/l Hg	<0.001	<0.001	<0.001	<0.001	0.001
Nickel mg/l Ni	0.008-<0.1	0.014-<0.1	0.006-<0.1	0.007-<0.1	0.1
Selenium mg/l Se	<0.01	<0.01	<0.01	<0.01	
Silver mg/l Ag	<1	<1	<1	<1	
Zinc mg/l Zn	<0.025	0.05-0.5	<0.025	<0.025	-
Other					
Boron mg/l	<0.5	<0.5-2	<0.5	<0.5	

a) For Cyprinid waters. Minimum 6 mg/l for salmonid waters
b) EQS varies with temperature and pH. c) Salmonid waters. EQS for Cyprinid waters is 0.4 mg/l

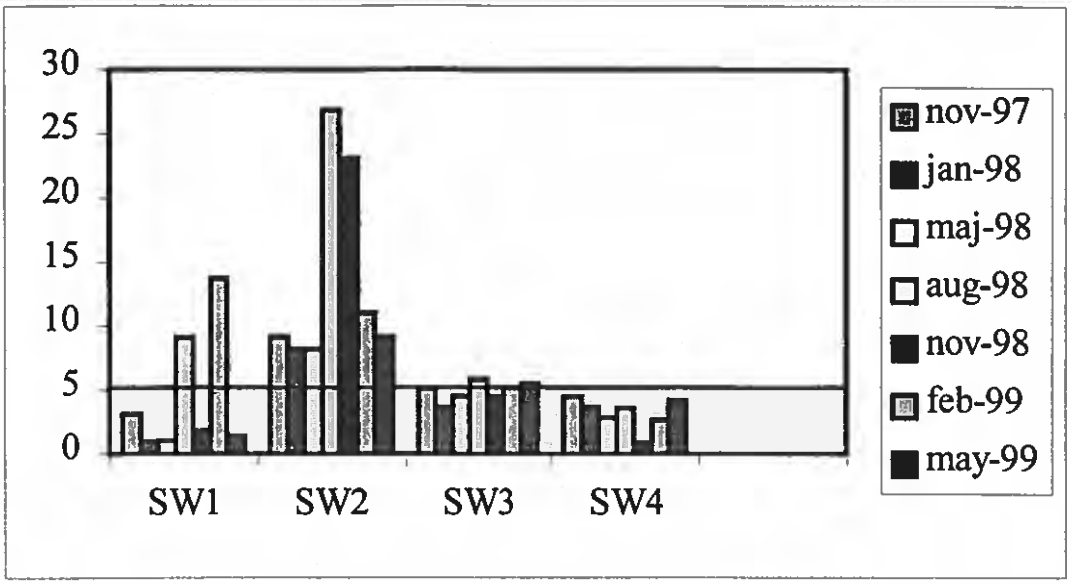

Figure 4.3: BOD measured in surface water samples. SW1 is situated upstream of the landfill. SW2, SW3 and SW3 are situated downstream of the landfill. The horizontal line indicates the EQS value for surface water.

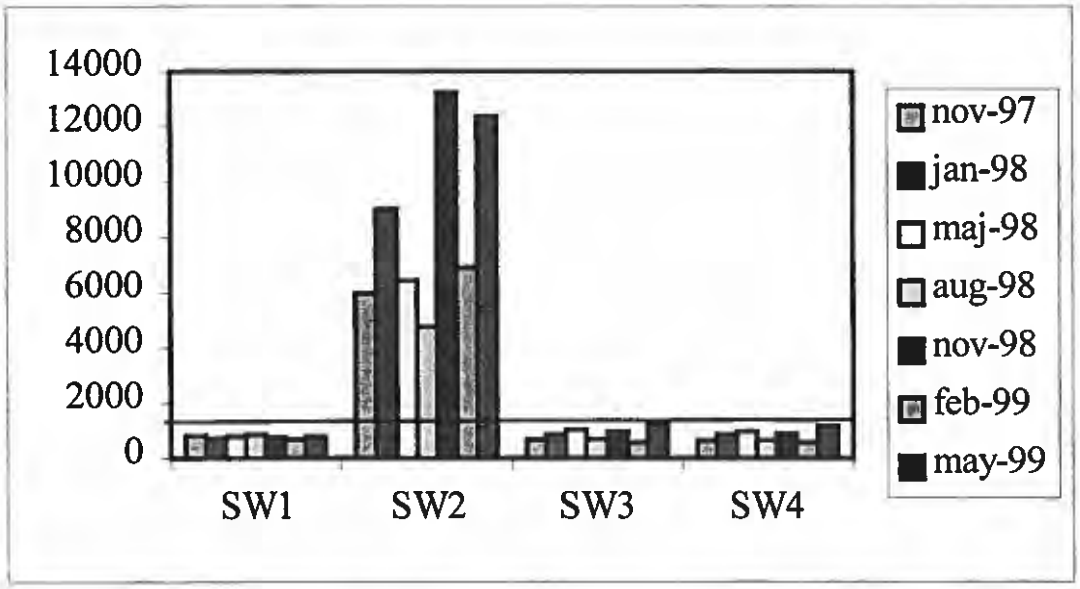

Figure 4.4: Conductivity in surface water samples. SW1 is situated upstream of the landfill. SW2, SW3 and SW3 are situated downstream of the landfill.

4.6 DISCUSSION

The groundwater quality immediately west, south and southwest of the landfill is poor, mainly due to contaminated leachate from the landfill. However, the contaminants are significantly attenuated further downstream of the landfill. A previous study involving sampling in March 1993 (Patrick Tobin & Co Ltd /Grontmij Consulting Engineers 1993) indicated that the leachate contamination was confined within 100-150 m of the landfill site. The results of the present monitoring confirm this assessment of the extent of the pollution. Actually, the results indicate that contamination is limited to within 100 m from the landfill. The stream is also polluted on the stretch in the immediate vicinity of the site.

The attenuation of organic matter, hazardous organic chemicals, heavy metals and cations downgradient of a landfill has previously been described in the literature (Lyngkilde & Christensen 1992, Rügge, Bjerg and Christensen 1995, Christensen et al. 1993a, Christensen et al 1993b, Christensen, Nielsen and Bjerg 1993, Kromann, Ludvigsen and Christensen 1993,).

Attenuation of leachate pollutants may be due to:

- dilution
- precipitation
- sorption
- degradation

Attenuation of all groups of leachate pollutants has recently been demonstrated at Balleally Landfill, Fingal County, where extensive monitoring of groundwater was carried out (MCOS/COWI 1998). The landfill is an unlined facility. The monitoring results showed, that pollutants generated in the landfill and which have infiltrated the groundwater are subjected to a strong attenuation and generally disappear from the groundwater within 50 metres from the landfill. Pollutants which have not disappeared were generally found in environmentally safe concentrations (**Table 4.8**).

Table 4.8: Attenuation of various leachate pollutants in the groundwater downgradient of Balleally Landfill, County Dublin (MCOS/COWI 1998)

Pollutant	Degree of attenuation in groundwater downgradient of landfill
Organic matter	Complete or almost complete attenuation within 50 meters downgradient of the Landfill
Nutrients (NH_3-N, PO_4, NO_3)	Complete or almost complete attenuation within 50 meters downgradient of the Landfill
Hazardous organic chemicals	
Benzene,	Complete attenuation within 50 metres downgradient of the Landfill
Chlorobenzene,	Complete attenuation within 50 metres downgradient of the Landfill
Meta- para ortho xylene,	Complete attenuation within 50 metres downgradient of the Landfill
1,1- dichloroethane	Complete attenuation within 50 metres downgradient of the Landfill
Toluene	Complete attenuation within 50 metres downgradient of the Landfill
Heavy metals	Generally attenuated to environmentally safe concentrations within 50 metres downgradient of the landfill

4.7 CONCLUSION

The monitoring results indicate that leachate contamination from the landfill at Tuam is confined within 100m west, south- west and south of the landfill site.

The background concentrations of ammonia, iron and manganese in the groundwater not affected by the landfill are elevated and do not meet the drinking water standards

This is probably due to the fact that the area is a bog with anaerobic conditions, where ammonia is the dominant inorganic nitrogen species and where the reducing environment increase the solubility of iron and manganese.

References

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Christensen T.H, P.H. Nielsen and P.L. Bjerg (1993). Degradation of organic chemicals in a leachate pollution plume: an in situ experiment. Proceedings Sardinia 1993, Fourth International Landfill Symposium S. Margherita di Pula, Cagliari, Italy 11- 15 October 1993. CISA, Environmental Sanitary Engineering Centre, Cagliary Italy.

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Lyngkilde, J. T.H: Christensen (1992). Fate of organic contaminants in the redox zones of a landfill leachate pollution plumes (Vejen Denmark). Journal of Contaminant Hydrology 10, 291-307.

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Rügge K, P.L. Bjerg and T.H. Christensen (1995). Distribution of organic compounds from municipal solid waste in the groundwater downgradient of a Landfill (Grinsted. Denmark) Environmental Science & Technology 29, 1395-1400.

5. PROPOSED REMEDIATION

5.1 GENERAL OBJECTIVES

The proposed remediation measures will have the following primary aims:

- To reduce leachate generation
- To separate leachate from surface water as much as practicably possible (by preventing leachate from seeping out through the sides of the landfill)
- To control landfill gas migration
- To improve the overall appearance of the landfill
- To provide suitable conditions for plant and other vegetation growth

5.2 BATNEEC

BATNEEC is the abbreviation of "best available technology not entailing excessive costs". Section 40(4) of the Waste Management Act, 1996 notes that BATNEEC *"will be used to prevent or eliminate or, when that is not practicable, to limit, abate or reduce an emission from the activity concerned"*. The Act Section 5(2)(a) also notes that a reference to BATNEEC in the Act shall be construed as a reference to the provision and proper maintenance, use, operation and supervision of facilities which, having regard to all the circumstances, are the most suitable for the purpose. The EPA will be issuing guidelines on the use of BATNEEC although, to date, none have been issued specifically with regard to landfills.

The EPA has however published a document entitled "Waste Management Licensing – Guide to Implementation and Enforcement in Ireland" (1997). In the section in Interpretation of BATNEEC, the document notes that technologies identified as BATNEEC are considered to be state of the art technologies for the purposes of setting emission limit values. It notes that regard shall be had to:

- The current state of technical knowledge
- The requirements of environmental protection
- The application of measures for these purposes, which do not entail excessive costs, having regard to the risk of environmental pollution which, in the opinion of the EPA, exists

For established activities, additional regard shall be had to:

- The nature, extent and effect of the emission concerned
- The nature and age of the existing facilities connected with the activity and the period during which the facilities are likely to be used or to continue in operation, and
- The costs, which would be incurred in improving or replacing these facilities, in relation to the economic situation of activities of the class concerned

The principle of BATNEEC is one therefore that requires that a balance be struck between the cost of an element versus the effectiveness of the element. Different scales of project will warrant different degrees of sophistication in their solutions to minimising emissions, whether

it be leachate or gas. The underlying principle is that the solutions are economically justified not just in terms of their effectiveness, but also in terms of their cost relative to the overall cost of the project. In the situation of a landfill which has been closed and is not subject to the requirements of a Waste Licence Application this is a major consideration in the application of BATNEEC. The measures proposed in this Remediation Plan are considered to fully comply with the principles of BATNEEC.

5.3 PROPOSED MEASURES AND RESTORATION CONSIDERATIONS

5.3.1 Control of Leachate

Leachate Generation

Factors which influence the rate of infiltration of rainfall into the waste and hence the generation of leachate are topography and the configuration of the final top cover, which will affect the site's run-off pattern and the amount of water percolating into the landfill.

Generally steep slopes allow for high water run-off but the existing side slopes at Tuam Landfill are so steep that there is risk of local soil slippage when the final cover is installed. At present a layer of clayey soil of varying thickness and composition covers the east side of the landfill. Waste is exposed on almost all areas of the landfill so the site needs improvements to make the appearance of the site more acceptable.

Leachate Migration

The objective of controlling leachate migration is to stop the leachate from getting into the surface water system. This problem will be significantly reduced by controlling the quantities of leachate which are being produced. Groundwater analysis shows that the level of attenuation of contaminants from leachate is adequate at present. It has therefore been decided that to limit the migration of leachate in a downward direction would provide satisfactory attenuation of leachate contaminants and be in keeping with the principles of BATNEEC.

This will be achieved by the installation of surface water drains along the west and east side of the site. These drains will feed into pre-existing drains along the south and north perimeters. Once this has been achieved the capping of the regraded landfill will be undertaken. The capping will extend down the sides of the landfill and into the sides of the drain until the underlying peat layer is encountered. This will allow the natural attenuation properties of the peat to reduce the polluting potential of the leachate by the time it reaches the surrounding surface/ground water system. The capping layer will divert all surface water away from the waste body and into the surface water drains thereby reducing the volume of leachate produced.

The situation will be monitored over time and it is thought that through the implementation of all of the above procedures both the surface water and groundwater quality around the immediate site should improve. If this does not happen then further action will be required.

A shallow barrier may be constructed as a continuation of the capping, adjacent to the base of the waste. This barrier will toe into the natural ground below the bottom level of the waste and provide complete isolation of the leachate from the surface water system by providing no option for migration into the surface water drain. At present it is considered that this step will not be necessary as the significant reduction in rainwater infiltration due to capping will immediately result in a considerable drop in leachate production.

5.3.2 Control of Surface Water

A surface water drainage system performs the function of collecting and transporting run-off water from the landfill and surrounding area to the drains at the periphery of the landfill. The drainage channel should be located so that surface runoff from the surrounding area is intercepted and diverted before it reaches the waste body.

Surface water arising from rainfall will drain off the surface of the landfill into the surface water drains around the perimeter. It is proposed that surface water run-off will significantly increase once capping is completed and infiltration is drastically reduced. It is necessary therefore to introduce a system which will allow the surface water to flow from the drain without any significant interaction with leachate.

Open channel diversion ditches will be installed in line with the pre-existing drains on the north and south sides of the site. Channels are generally wide and shallow with side slopes of channels not greater than 1:2.5. In order to minimise erosion the channels can be lined with vegetation or rip-rapped.

The gradients of the pre-existing and proposed drains (1:50-1:100) are sufficient for flow. However, it is recommended that the pre-existing drains are improved as they have been blocked by wind-blown litter.

In the re-grading of the landfill it is important to take into account the watersheds which will arise. All watersheds need to be directed towards the surface water drains, which surround the site.

Surface water will continue to be monitored in the future to ensure that the interaction between leachate and surface water is being kept to a minimum.

Figure 5.1 shows the proposed surface water control at the site, including drainage levels.

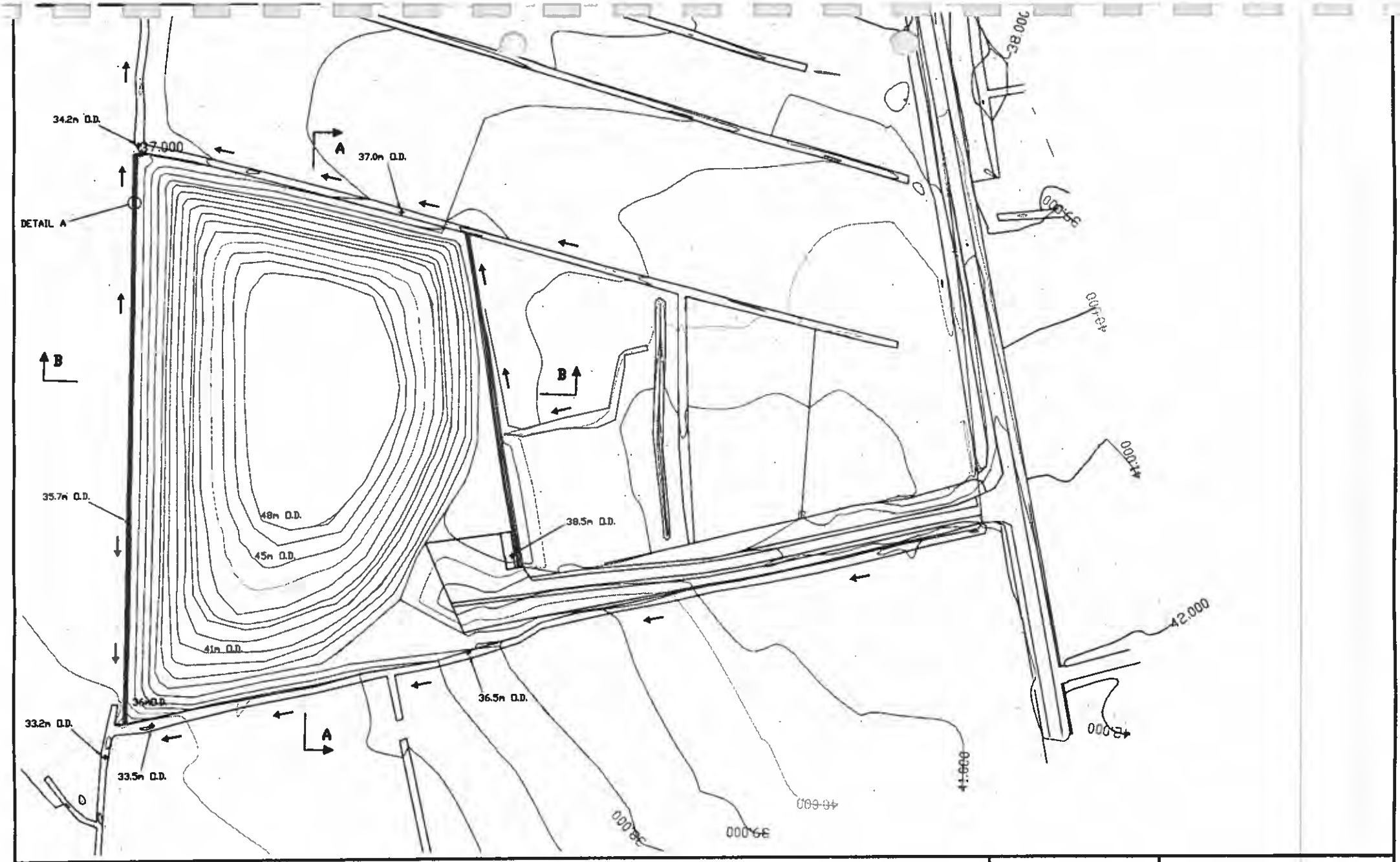
5.3.3 Re-Grading of Landform

The re-grading of the slopes is the most fundamental remediation measure to be carried out on the landfill. It will have a positive effect on the following:

- Stability of the side slopes
- Surface water drainage
- Reduction in the infiltration of rainwater
- General landscaping and scenic amenity

The main aspect of the re-grading is to pull back the side slopes of the landfill to a slope of 1:2.5 or 1:3 where possible. The waste pulled from the sides will be domed on top of the existing landfill. This domed shape will be more in keeping with the surrounding topography. The slopes on the western side of the landfill will be regraded and waste will be pulled back so that the toe of the slopes will be within the site boundary.

The final contour plan for the waste, prior to capping, has been developed using *SCC for Windows 95 and NT*. The earthworks were balanced to within 2% of the total cut value. The volumetric analysis report from *SCC* is shown overleaf in **Figure 5.2**. The volumes were calculated using the prismoidal method. The final landform must also direct surface water towards the surrounding surface water ditches



MCOS M.C. O'SULLIVAN Consulting • Engineers COWI	Job: *Remediation of Tuam Landfill*	Drawn: *J.P.M.*	Date: *Oct. '99*
	Title: *Surface Water Control (including Drainage Levels)*	Checked: *W.M.*	Drg. No. *Fig 5.1*
		Scale: *1:2000*	

Re-grading is also considered advantageous in terms of both stability and aesthetics of the landfill.

The majority of the slopes at the site currently range generally from 1:3 - 1:8. However, in some cases, particularly along the west/southwest sides of the landfill the slopes are steeper than 1:2. Although there is no evidence of instability, regrading of these slopes will improve the factor of safety against instability and will also improve the general landform.

Sections from east-west and north-south **(Figure 5.3)** of the existing landfill show slopes of greater than 1:2.5 on all sides. The proposed landform has been designed to ensure that all slopes are less than 1:2.5 as a maximum.

Figure 5.2 Volumetric Report from SCC showing earthworks balance between cut and fill volumes

Volumetric analysis report (Prismoidal method) Wed Sep 15 16:56:32 1999

Existing model : C:\SCC\Tuam\Model\tuamorig.Model
Proposed model : C:\SCC\Tuam\Model\New2.Model
Isopachyte model : Isopachyte
Output Report file : VOLUMESfinal.REP

Datum ..... : 0.000 meters
Total volume of cut ..... : 39661 cubic meters
Total volume of fill ..... : 35363 cubic meters
Cut to fill ratio ..... : 1 to 0.892
Total surface area for volumes..... : 171246 square meters
Total plan area for volumes..... : 169351 square meters
Total plan area in existing model..... : 169392 square meters
Total plan area in proposed model..... : 169679 square meters
Existing plan area without overlap..... : 41 square meters
Proposed plan area without overlap..... : 329 square meters
Average volume per square meter..... : 0.443 cubic meters
Potential error due to bad overlap..... : 18 cubic meters = 0.02% (Probable)
164 cubic meters = 0.22% (Worst case)

(This is a rough indication of the potential error in the volume measurement attributed to the fact that the existing and proposed models are not exactly co-incident in plan. Errors of this type may be avoided by including the same boundary string in both models. Please consult the SCC user documentation for further information. If you are aware that your models are not of identical plan area, or do not fully overlap, please ignore the above figure)

Potential errors due to level inaccuracy.
Elevations + or - 1mm..... : 169 cubic meters
Elevations + or - 5mm..... : 847 cubic meters
Elevations + or - 10mm..... : 1694 cubic meters
Elevations + or - 33mm ..... : 5086 cubic meters
Elevations + or - 100mm..... : 16935 cubic meters

SCC for Windows v3.1f (C) 1997,1998 Atlas Computers Ltd

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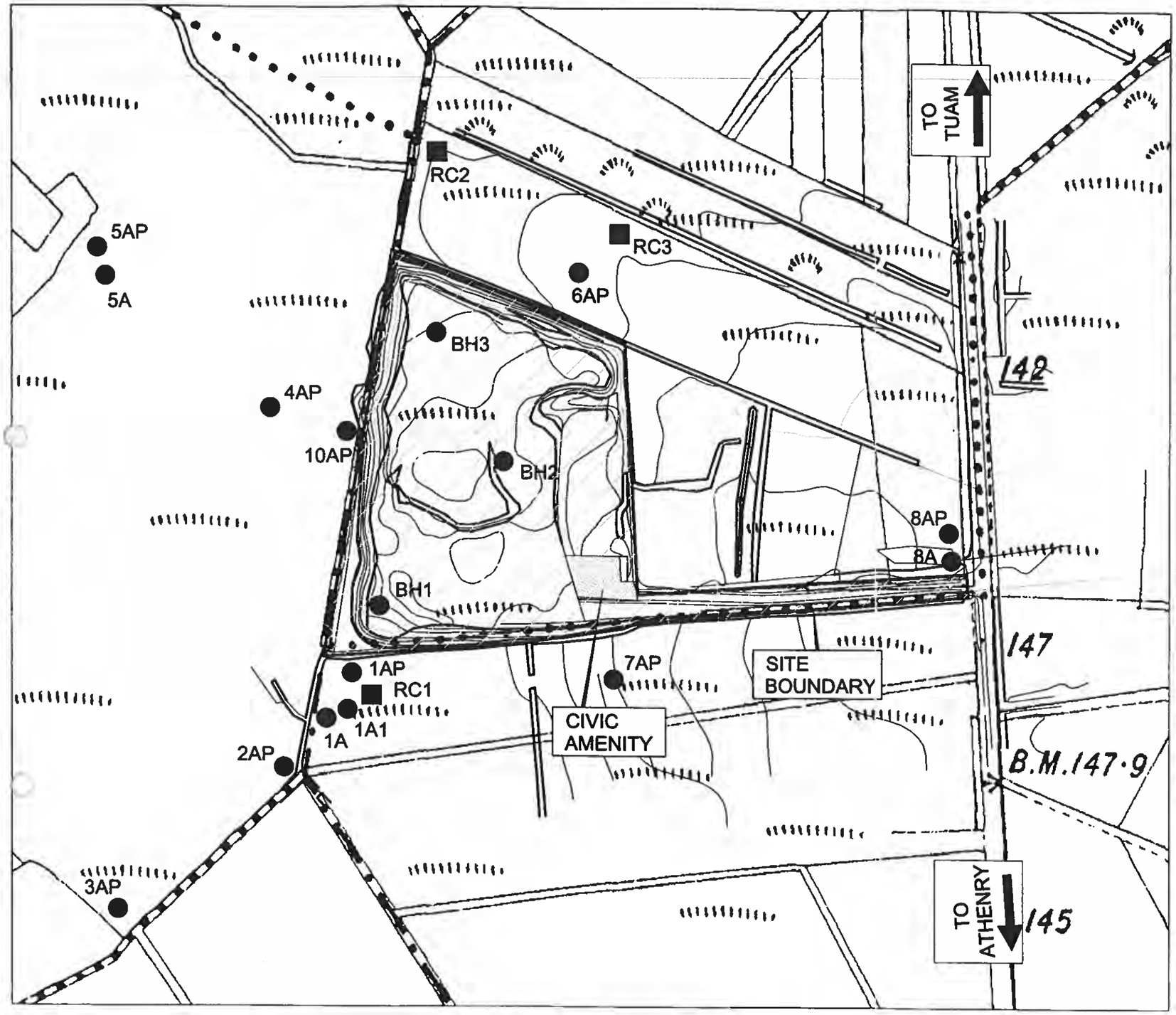
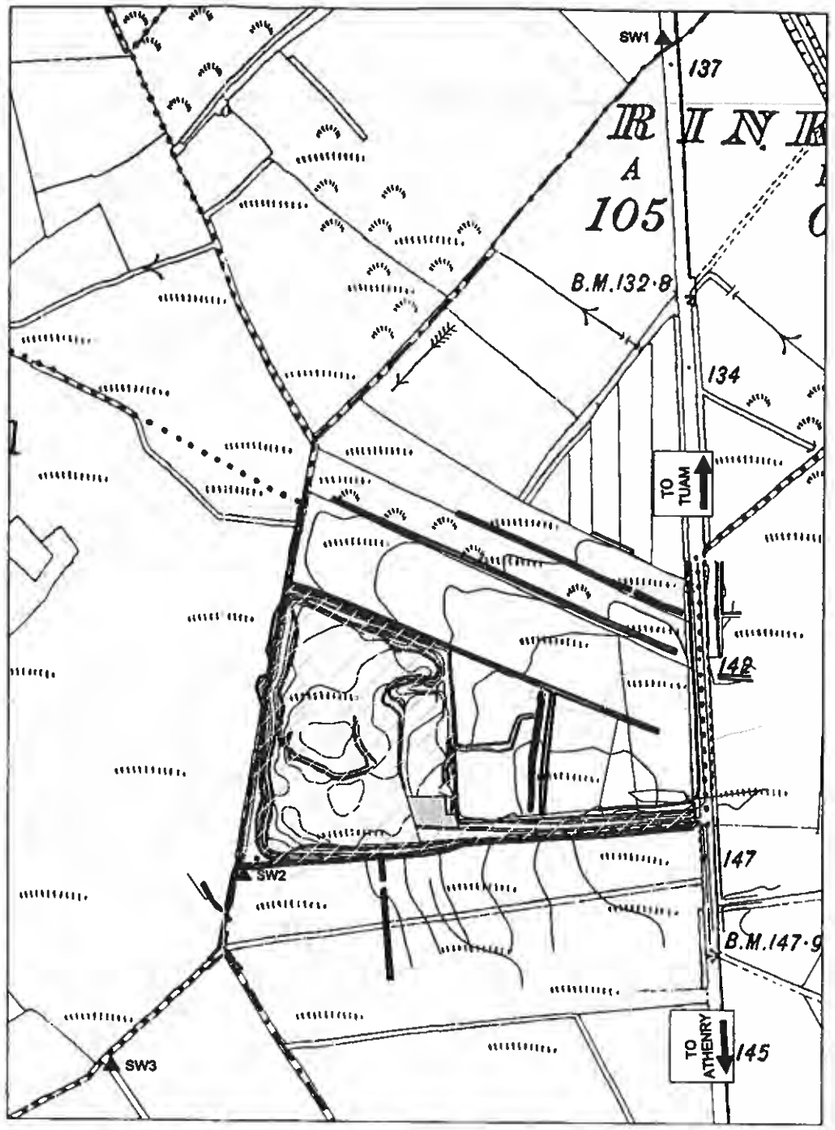
Job	*Remediation of Tuam Landfill*	Drawn *J.P.M.*	Date *Oct. '99*
Title	*Plan Layout of Existing Site*	Checked *W.M.*	Drg. No. *Fig 2.2*
		Scale *1:1000*	



PLAN Scale 1:2500
Showing Location of Boreholes

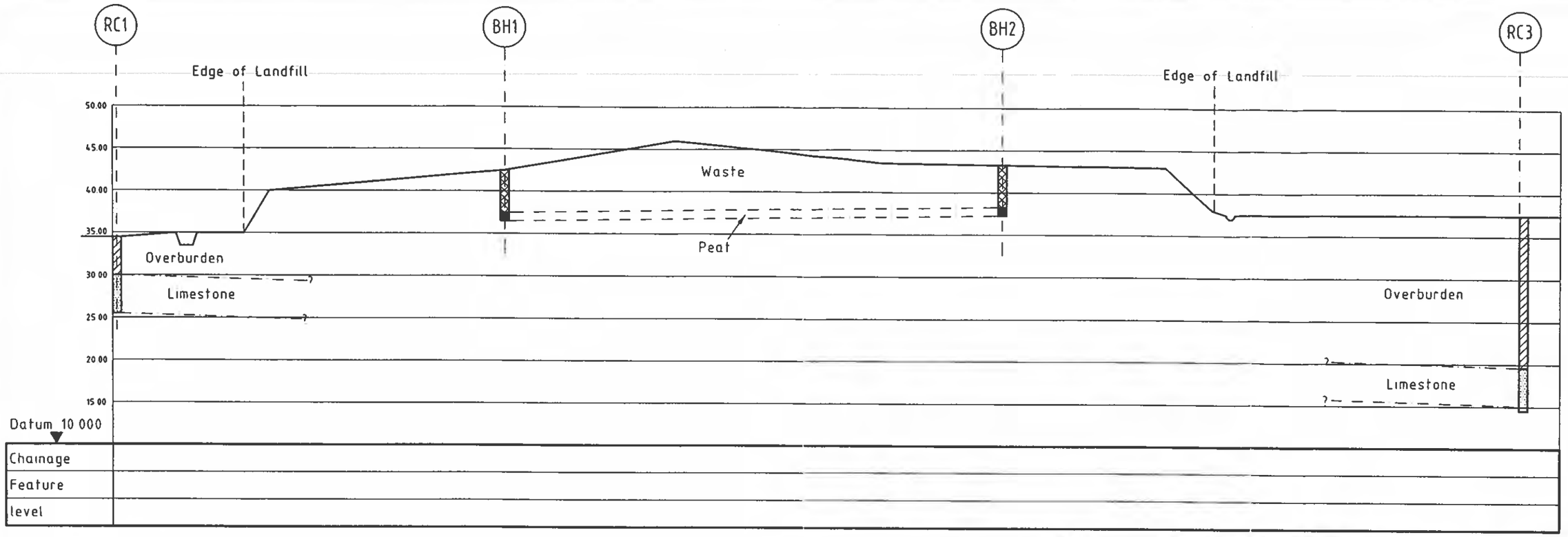


PLAN Scale 15000
Showing Location of Surface Water Monitoring Points

LEGEND:

- ■ RC — Rotary Cored Borehole
- ● — Shell & Auger Borehole
- ▲ SW — Surface Water Monitoring Location

MCOS / COWI	Job: *Remediation of Tuam Landfill*	Drawn: *J.P.M.*	Date: *Oct. '99*
	Title: *Location of Boreholes and Surface Water Monitoring Points*	Checked: *W.M.*	Drg. No. *Fig 3.1*
		Scale: *As Shown*	



SECTION A-A

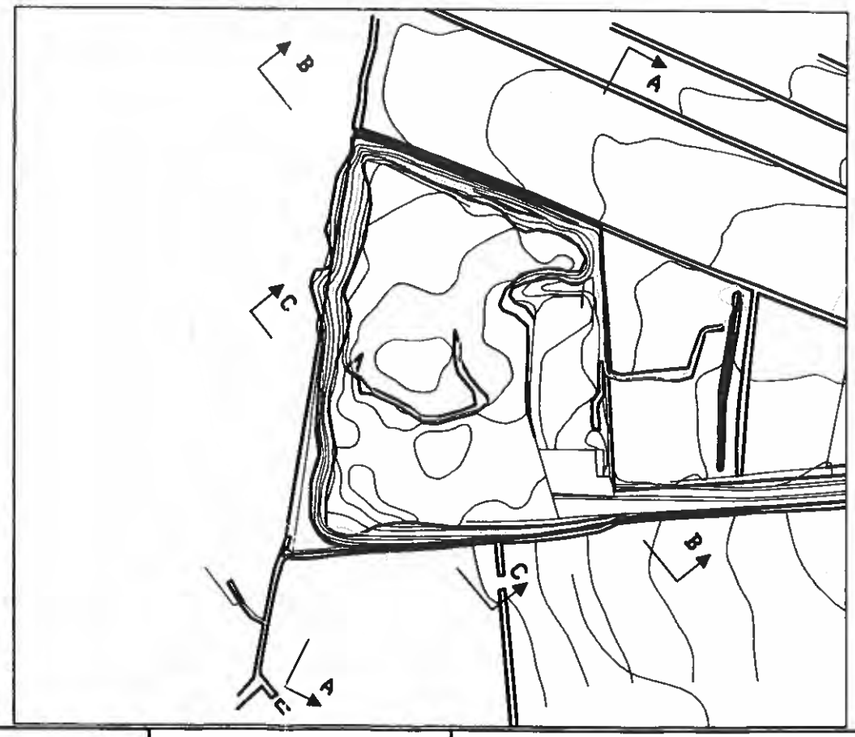
SCALE 1:1000 HOR
1500 VER

NOTES

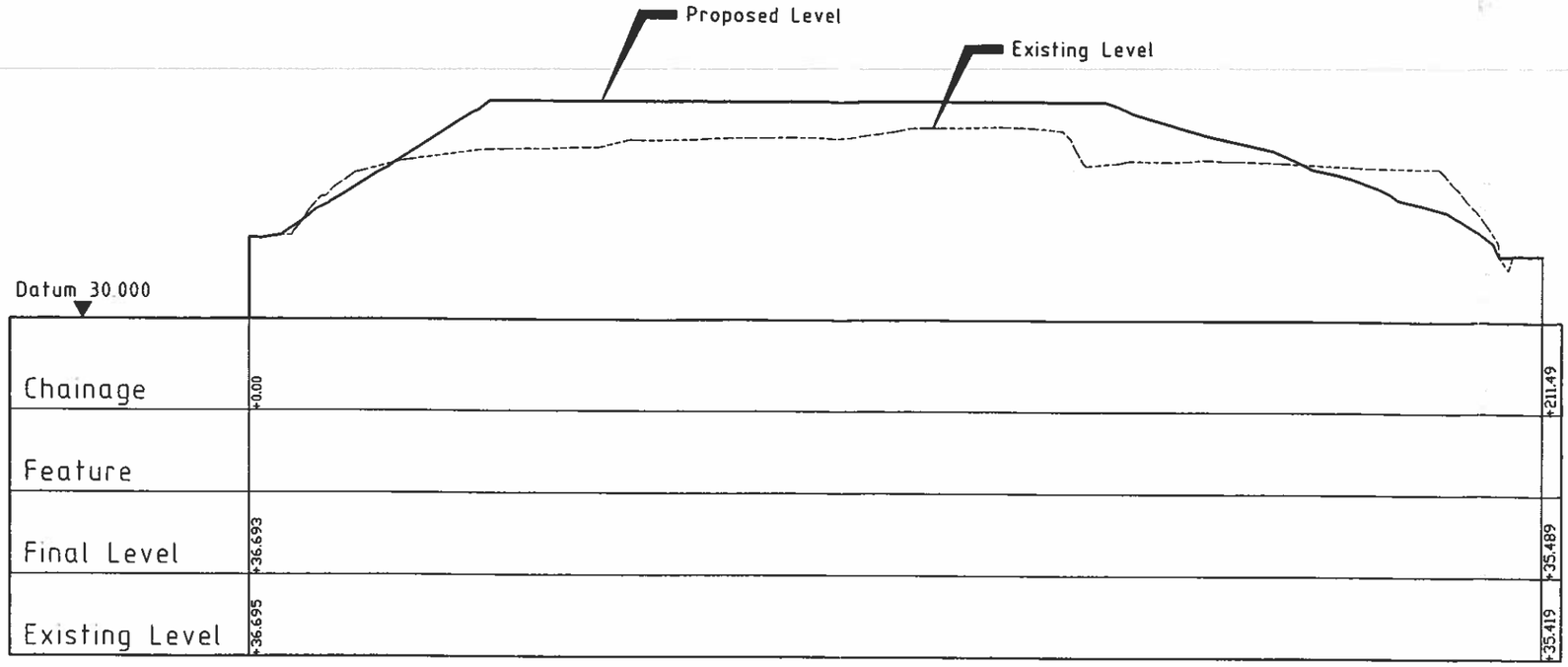
1. THIS DRAWING TO BE READ IN CONJUNCTION WITH DRG Nos Fig 3.3 & Fig 3.4

LOCATION PLAN

NTS

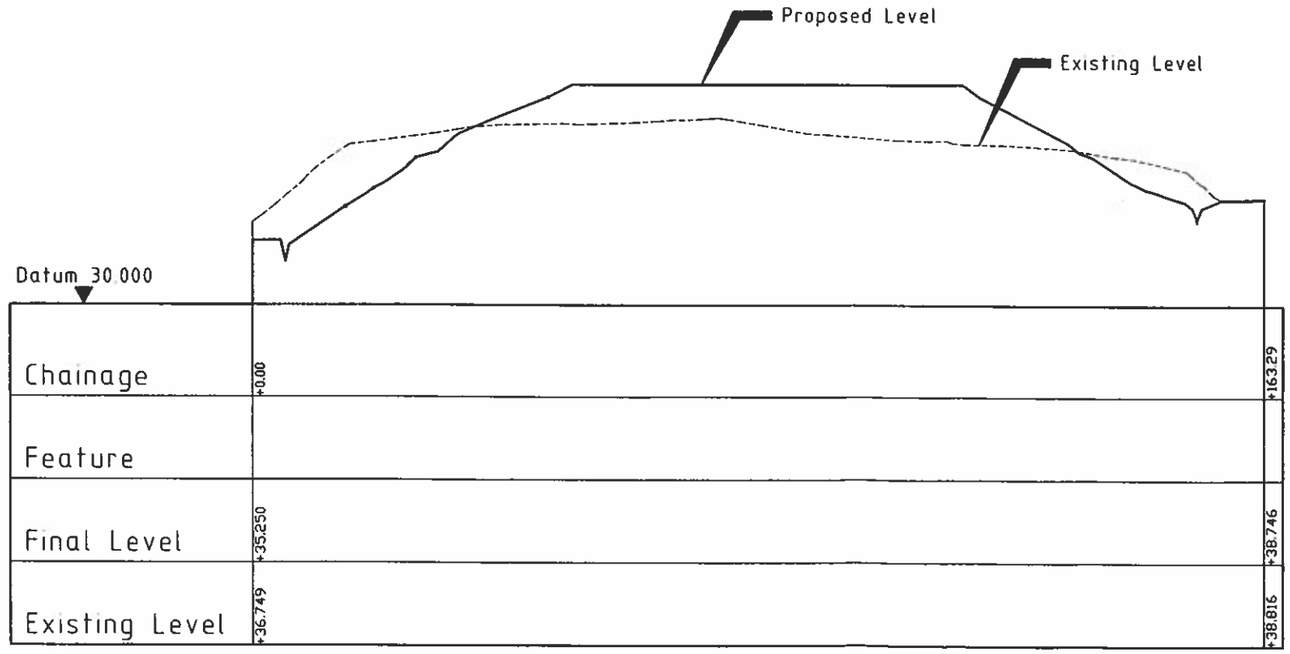


MCOS M.C.O'SULLIVAN Consulting•Engineers COWI	Job: *Remediation of Tuam Landfill*	Drawn: *J.P.M.*	Date: *Oct. '99*
	Title: *Geological Profile Section A-A*	Checked: *W.M.*	Drg. No. *Fig 3.2*
		Scale: *As Shown*	



SECTION A-A

SCALE 1:1000 HOR
1:500 VER



SECTION B-B

SCALE 1:1000 HOR
1:500 VER

NOTES

1. THIS DRAWING TO BE READ IN CONJUNCTION WITH DRG. No. Fig 5.1

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COWI

Job: *Remediation of Tuam Landfill*		Drawn: *J.P.M.*	Date: *Oct. '99*
Title: *Proposed Contours Sections A-A & B-B*		Checked: *W.M.*	Drg. No. *Fig 5.3*
		Scale: *As Shown*	

5.3.4 Final Cover Material

Once the slopes of the landfill are re-graded, capping can begin. The final cover should consist of a low permeable layer to reduce infiltration of rainwater and increase surface water run-off. Installation of a plastic liner in the final cover is not recommended due to the steepness of the existing slopes and the subsequent risk of earth slippage and also due to the fact that the decomposition process in the waste will be reduced or even cease totally if moisture is prevented from entering the waste.

The top cover as shown on **Figure 5.4** should have a maximum slope of 1:2.5 (1:3 where possible) and consist of:

- 300mm thick low permeable clayey soil layer
- 200mm topsoil layer for grass and other vegetation
- regulation layer varying between 100 – 1000mm in depth

Low Permeability Layer
The main function of this layer is to control leachate generation by minimising the infiltration of water into the underlying waste and to prevent landfill gas from escaping through the surface of the capped landfill. This layer should consist of a compacted low hydraulic conductivity clayey soil material with a hydraulic conductivity of $1x10^{-9}$m/s.

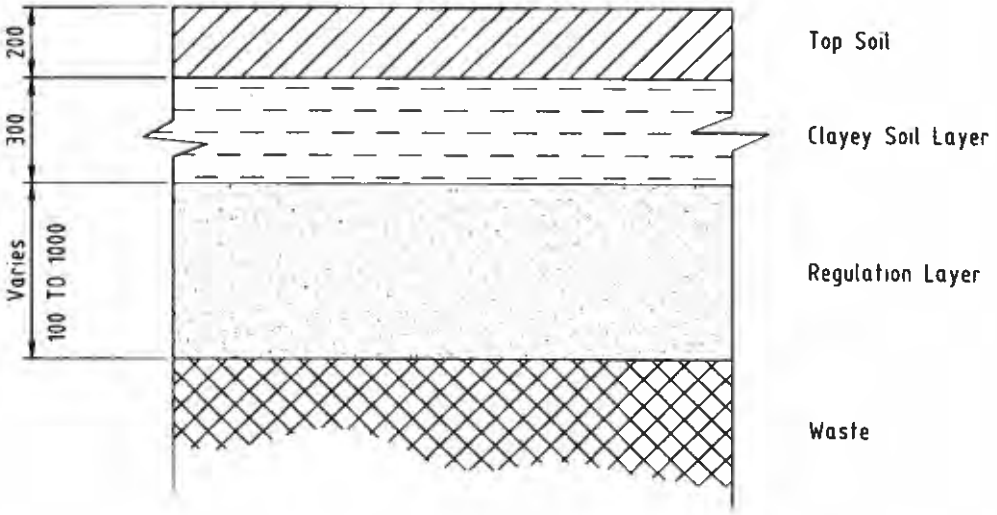
Topsoil Layer
This layer is necessary to provide a foundation into which grass and any other vegetation might be planted. A 200mm covering of this material is necessary to provide adequate depth for root structure to develop. The primary function of the topsoil is to enable the planned afteruse to be achieved. The topsoil should be uniform and have a minimum slope of 1 to 30 to prevent surface water ponding and to promote surface water run-off. The maximum slope will depend on the afteruse but it is recommended that the slope be a maximum of 1:2.5. The topsoil should be thick enough to:

- accommodate root systems
- provide water holding capacity to attenuate moisture from rainfall and to sustain vegetation through dry periods
- allow for long term erosive losses
- prevent desiccation and freezing of the barrier layer

To support vegetative growth the topsoil is usually composed of non-compacted local soils. The topsoil layer and seeding operation should be undertaken as soon as the underlying layers have been placed in order to establish the vegetative cover.

Regulation Layer
A regulation layer (100-1000mm) will need to be applied to the surface of the waste layer in order to create an even surface for the application of the overlying soil material.

It is proposed to extend the capping layer across the surface and down the side slopes of the landfill. The capping layer will be keyed into the existing ground at the toe of the slope as shown as edge detail type A on **Figure 5.5**. This will assist in the attenuation of the leachate and prevent the possibility of leachate seeping out at the base of the slope. These measures will force the limited volumes of leachate further downwards where attenuation of the contaminants will be sufficient to ensure an improvement in groundwater quality below the site.



TOP COVER TO LANDFILL (mm)

MCOS M C O SULLIVAN Consulting • Engineers COWI	Job *Remediation of Tuam Landfill*	Drawn *JPM*	Date *Nov.'99*
	Title *Typical Section Through Capping*	Checked *LOT*	Drg. No. *Fig 5.4*
		Scale *N.T.S.*	

Where the base of the slope coincides with the edge of the existing or proposed surface water drain, the capping should be extended down the inner face of the drain as shown as edge detail type B on **Figure 5.5**.

5.3.5 Specification for Capping Material

It may be possible to source suitable material which meets the requirements of the specification for a 300mm thick clayey soil layer with a hydraulic conductivity not greater than 1×10^{-9} m/s. Parameters that influence hydraulic conductivity are clay content, grain size distribution, particle size content, degree of compaction (density), compaction method and moisture content. The required low hydraulic conductivity is achieved when the soil is compacted wet of optimum moisture content which is achieved at maximum dry density. The minimum hydraulic conductivity value can occur in the range of 1 to 7 % wet of optimum moisture content.

The suitability of the clayey material as capping material should be assessed from soil classification tests, all of which should be carried out in accordance with BS 1377 (1990). Hydraulic conductivity can be examined in the laboratory by performing triaxial compression tests (BS 1377) on undisturbed field samples or laboratory prepared test specimens. In order to achieve this permeability the clayey material should have the following properties:

- Classification Testing: LL – between 25 and 90
  PL – between 10 and 30
  % Clay – not less than 10%
  Casagrande Classification – above 'A' line

- Compaction/Permeability Testing: Permeability not greater than 1×10^{-9} m/s on sample remoulded at natural moisture content and to a minimum 95% Modified Proctor Density

A sample of soil was taken from the construction site of Mr. Tom Lavelle to ascertain if the material would be suitable for use as the low permeability capping recommended in the report. A suite of tests was carried out on this material as follows:

- Particle Size analysis
- Moisture content
- Atterberg Limit
- Five point-compaction test

The results of the analysis are presented in **Appendix D**.

The particle size analysis together with the Atterberg Limit tests show the material to comprise a sandy silty gravel. The organic test shows the soil to have a slight organic content (0.91%). The compaction test gives an optimum moisture content of 22.1% with a natural moisture content ranging from 34.3% to 42.9% which is significantly wetter than the optimum. The test results confirm that the acceptable Plastic Limit (30%) is marginally exceeded by the test material (33%). However more importantly the material has no significant clay content which is necessary to achieve the low permeability required. Therefore the material is considered unsuitable for use in the low permeability capping. The material could possibly be used as the regulation layer beneath the capping, however the sandy silty nature of the material together with the high moisture content (34.3% to 42.9%) relative to the optimum moisture content (22.1%) of the material indicates that traffickability of the material could pose difficulties by large earthmoving plant due to the likelihood of rutting occurring. Some conditioning/drying of the material could be carried out on site if this was found to be a problem.

5.3.6 Landfill Gas Migration

Landfill gas arises during the process of anaerobic degradation of waste within a landfill. The gas consists of methane, carbon dioxide and other trace organic gases. The pattern of landfill gas generation depends on a number of factors such as the type of waste deposited, temperature, pH, waste density and the moisture levels within the waste.

Landfill gas escapes along paths of least resistance. The gas will escape through the top surface or will diffuse out through permeable strata around the site. If the gas migrates to the rooting zone of the vegetation on the landfill, the vegetation will die. Widespread vegetation dieback can be seen on sites with no cap or landfill gas control.

In line with BATNEC principles a gas collection/drainage layer is not necessary in the final capping as the majority of gas generated over the life of the site has already vented passively to the atmosphere as the waste has not been covered with final capping material. The size of the site would not make gas collection or flaring either economical or necessary.

Combined gas/leachate monitoring boreholes (BH1, BH2 & BH3) were installed at the site in 1999 and are shown on **Figure 3.1**. These boreholes are spread evenly across the site and extend the depth of the waste. They are fitted with gas valves for sampling. It is recommended that the concentrations of CH_4, CO_2, O_2 and also atmospheric pressure is measured at each of these boreholes at a minimum on a quarterly basis as part of the on-going monitoring programme. Should abnormal levels of gas be found at any of these locations consideration will then be given to the installation of an active or passive venting system.

5.3.7 Settlement

The final post settlement levels and contours of a landfill must be taken into account. In order to achieve this it is necessary to be able to predict the amount of settlement that will occur and to ensure that this takes place as evenly as possible across the site. The rate and degree of settlement occurring at a landfill will always be site specific and will be influenced by the site conditions, landfill practices, types of waste deposited and the effects of the mechanical and biochemical processes. Settlement values of between 10 and 25 % of the depth of the landfill can be expected for municipal waste landfills. Initial settlement is most prominent with the majority occurring over the first five years. Settlement continues gradually with time until the waste has stabilised. The problems for restoration caused by settlement include:

- Damage to buried services for example gas extraction systems
- Formation of low spots in phased restoration, leading to ponding, infiltration, leachate generation and crop death
- Damage to land drainage including ditches and drains
- Poor landform and reducing after-use options and
- Extending the aftercare period

5.3.8 Final Landscaping

The landfill at Tuam will be planted with grass and trees to aid the integration of the landfill into the landscape. **Figure 5.6** shows an overview of the proposed landform.

Grass is considered the most suitable agricultural crop for the aftercare period as it is tolerant of poor soil conditions, provides all year round soil cover and promotes the development of soil structure. The choice of grass varieties is site specific and dependent on the intended afteruse. Short-term grass leys are suitable on well-drained fertile soils and usually contain perennial grasses with high yielding potential and clover. Long term leys are suitable on

Where the base of the slope coincides with the edge of the existing or proposed surface water drain, the capping should be extended down the inner face of the drain as shown as edge detail type B on **Figure 5.5**.

5.3.5 Specification for Capping Material

It may be possible to source suitable material which meets the requirements of the specification for a 300mm thick clayey soil layer with a hydraulic conductivity not greater than 1×10^{-9} m/s. Parameters that influence hydraulic conductivity are clay content, grain size distribution, particle size content, degree of compaction (density), compaction method and moisture content. The required low hydraulic conductivity is achieved when the soil is compacted wet of optimum moisture content which is achieved at maximum dry density. The minimum hydraulic conductivity value can occur in the range of 1 to 7 % wet of optimum moisture content.

The suitability of the clayey material as capping material should be assessed from soil classification tests, all of which should be carried out in accordance with BS 1377 (1990). Hydraulic conductivity can be examined in the laboratory by performing triaxial compression tests (BS 1377) on undisturbed field samples or laboratory prepared test specimens. In order to achieve this permeability the clayey material should have the following properties:

- Classification Testing: LL – between 25 and 90
  PL – between 10 and 30
  % Clay – not less than 10%
  Casagrande Classification – above 'A' line

- Compaction/Permeability Testing: Permeability not greater than 1×10^{-9} m/s on sample remoulded at natural moisture content and to a minimum 95% Modified Proctor Density

A sample of soil was taken from the construction site of Mr. Tom Lavelle to ascertain if the material would be suitable for use as the low permeability capping recommended in the report. A suite of tests was carried out on this material as follows:

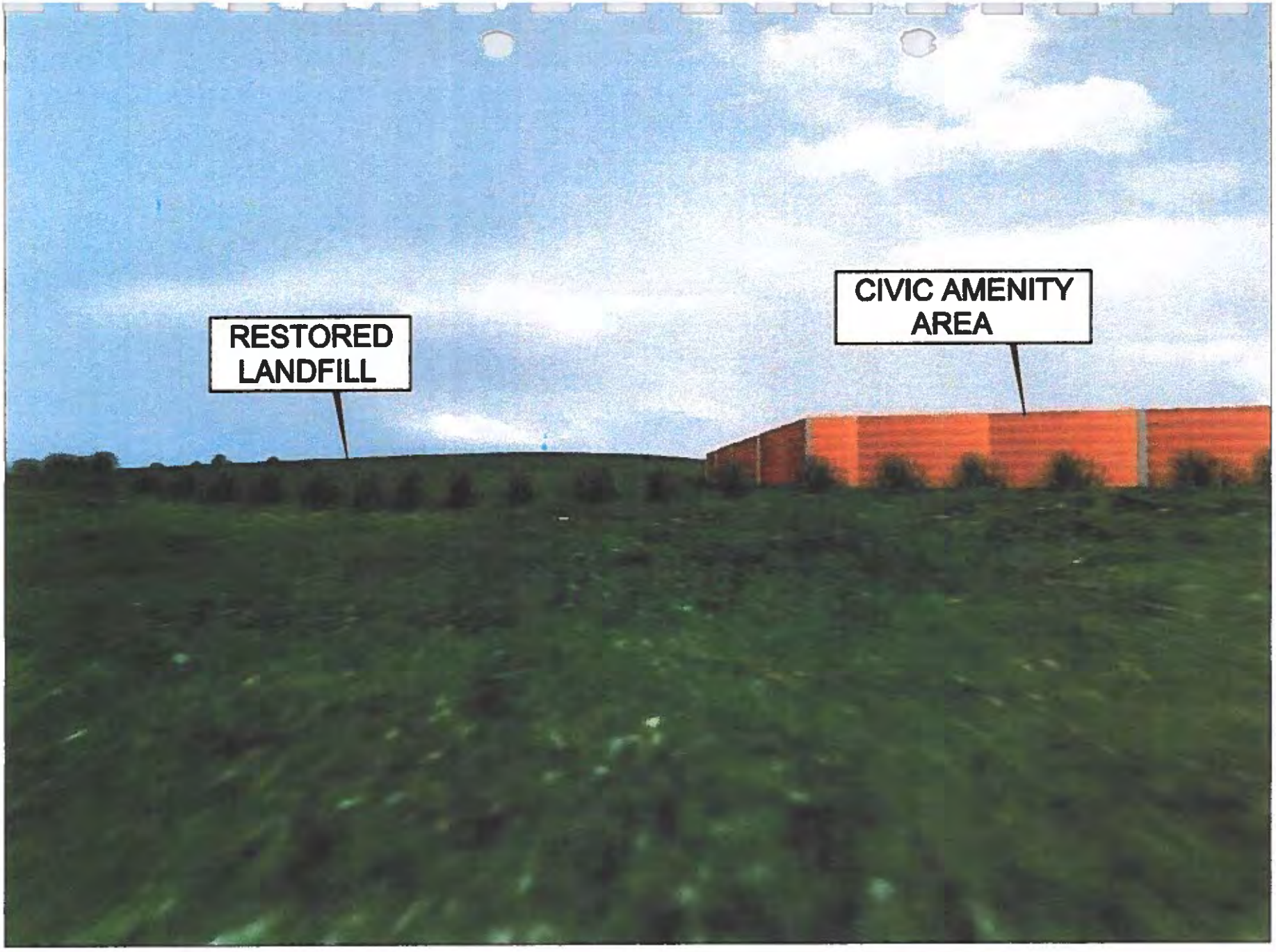
- Particle Size analysis
- Moisture content
- Atterberg Limit
- Five point-compaction test

The results of the analysis are presented in **Appendix D**.

The particle size analysis together with the Atterberg Limit tests show the material to comprise a sandy silty gravel. The organic test shows the soil to have a slight organic content (0.91%). The compaction test gives an optimum moisture content of 22.1% with a natural moisture content ranging from 34.3% to 42.9% which is significantly wetter than the optimum. The test results confirm that the acceptable Plastic Limit (30%) is marginally exceeded by the test material (33%). However more importantly the material has no significant clay content which is necessary to achieve the low permeability required. Therefore the material is considered unsuitable for use in the low permeability capping. The material could possibly be used as the regulation layer beneath the capping, however the sandy silty nature of the material together with the high moisture content (34.3% to 42.9%) relative to the optimum moisture content (22.1%) of the material indicates that traffickability of the material could pose difficulties by large earthmoving plant due to the likelihood of rutting occurring. Some conditioning/drying of the material could be carried out on site if this was found to be a problem.

MCOS / MC O'SULLIVAN Consulting · Engineers / COWI	Job: *Remediation of Tuam Landfill*	Drawn: *JPM*	Date: *Oct. '99*
	Title: *Proposed Landscape Plan*	Checked: *WM*	Drg. No.: *Fig 5.6*
		Scale: *1:2000*	

PROPOSED VIEW FROM ACCESS ROAD



PROPOSED VIEW FROM SOUTH

PROPOSED VIEW FROM EAST

poorer soils, are less intensively managed and generally contain ryegrasses, fescues, timothy and clovers. The latter would be more applicable to the soil conditions at Tuam Landfill. The seeding rates are generally 40-50 kgs/ha depending on the seed mix with sowing generally undertaken in spring, late summer or early autumn. The rate of fertiliser application can be determined through soil analysis.

Fencing and hedges provide field boundaries and stock proof barriers. Hedges also provide landscape features and are important wildlife habitats as well as acting as wildlife corridors. Most of the site perimeter is secured by wire fencing, the remainder of the site should also be fenced or alternatively hedgerow planted. Hedges normally comprise of a line or narrow belt of closely spaced woody trees and shrubs, which are managed so as to form a more or less continuous barrier. Planted hedges should act as a link to existing hedges and enhance the network of wildlife corridors around the site. The type of species is site specific and should reflect the existing hedgerow species. The planting of hedgerows is an alternative option to tree planting around the site. Although tree planting has already taken place along the perimeter of the site a number of the trees are now dying and need to be replaced.

For successful tree establishment to occur on landfill sites, trees must have an adequate soil depth, soils should not be compacted and have effective drainage. Compaction of soils is probably the most critical factor affecting tree growth and it should therefore be avoided wherever possible.

In the past a tree's rooting system was thought to interfere with the low permeability barrier. More recent work however has revealed this to be untrue and tree planting is now recommended as part of the overall restoration of the site. The planting of the final configuration with ecologically appropriate species tolerant of the site conditions is important. Furthermore the preservation and encouragement of the existing plant communities such as the young trees lining the entrance and the perimeter of site will 'visually soften' the existing site, as a temporary visual mitigation measure until the remediation works are completed.

It is recommended that grass be planted on the site prior to tree planting. The advantages associated with grass planting are as follows:

- Reduction in soil erosion by establishing ground cover
- Reduction in water infiltration on capped sites
- Improvement in visual appearance
- Control of weed infestation

It is important to acquire the correct mix of grass seed as both trees and grass must co-habit easily without the grass being too competitive for the trees.

A combination of the above proposals will help in the progressive reintegration of the site into its natural surrounding environment. The final landscape will be a significant improvement on the existing landfill, which is an obtrusive landform in the surrounding flat terrain.

5.3.9 Fencing

Currently there is a concrete post fence along both sides of the access road from the main Tuam-Athenry road to the landfill. There is also a steel gate at the entrance from the main road. It is recommended that a new fence be erected around the perimeter of the landfill to connect with the existing concrete fence along the road. This fence should consist of a suitable material and should clearly mark the boundary of the site. Any broken fencing, loose barbed wire, etc should be removed from the site to improve the overall appearance.

5.3.10 Monitoring

A programme of monitoring of leachate, groundwater and surface water should be set up to monitor the effects and results of the remediation measures at the landfill. It is recommended that samples of each are analysed at least twice annually for the first 3 years post-closure with the frequency of monitoring reviewed at that stage depending on the results at that time. In addition, gas monitoring should be carried out at the boreholes within and around the site to confirm the progress of the waste decomposition processes and to confirm that there is no significant migration of gas off-site.

5.3.11 Health and Safety

The remediation of the landfill will require consideration of a number of health and safety aspects. Particularly the regrading of the side slopes and shaping of the general profile of the landfill will mean excavation of partially decomposed waste with associated odours and fine airborne particles and aerosols.

It is understood that the landfill, prior to closure, accepted municipal and non-hazardous industrial waste. During excavation of material on the site an engineer with appropriate experience should be employed on site by the contractor to assist in identifying potentially hazardous material. Normal safety procedures shall also be adopted by the operations on the site during excavation of the waste including disposable clothing, face shields/cream and eye protection if necessary. Respiratory equipment should be also available on site.

6. RECOMMENDED PHASING PLAN AND PROJECTED COSTS

6.1 PHASING

The following section outlines the phasing plan for the works to be carried out on the landfill at Tuam:

- The existing surface water drains should be cleared of waste and any other blockages using suitable machinery and any excavated material should be placed on the landfill
- Construct new surface water drains along both the west and east sides of the existing landfill to connect into the existing drainage network
- It is recommended that the side slopes are regraded to 1:2.5 or 1:3 if possible and any cut material will be domed on top of the site. Watersheds will be carefully developed to ensure good surface water run-off
- Construct the capping layer consisting of a combination of a low permeability layer and topsoil with a regulation layer as required
- Construct perimeter detail to connect with the capping layer
- Sow grass and other native planting on the surface of the remediated landfill
- Litter picking should be carried out in the surrounding fields and hedgerows in order to improve the general appearance around the landfill
- Construct new fencing around the perimeter of the site

6.2 ESTIMATED COSTS

An estimate of the costs associated with the various elements of work outlined above can be summarised as follows:

- *Upgrade Existing Surface Water Drains:*

The estimated cost of this work based on a unit cost of IR£20/metre is IR£10,000

- *Construct New Surface Water Drains:*

The estimated cost of this work based on a unit cost of IR£50/metre is IR£19,000

- *Regrade Slopes and reshape landform:*

Based on a unit cost of IR£3/m^3 and an estimated 39600m^3 of cut and fill the estimated cost of this work is IR£118,800

- *Capping Layer:*

Based on the above it is estimated that the cost of restoring the landfill will be approximately IR£6/m^2. The cost of remediating the existing landfill with an area of approximately 34,000 m^2 is estimated therefore to be some IR£204,000. This costing assumes that suitable material will be sourced locally (within 10km radius) without a charge. If this does not apply the cost of capping the landfill with suitable material could vary significantly. An additional cost of between IR£100,000-150,000 could be anticipated to cover the cost of sourcing and importing suitable material. It is recommended that Galway County Council set aside this sum in the first instance as it may be difficult to source suitable clayey material locally.

- *Construct Perimeter Detail to Tie Capping Layer:*

It is estimated that this cost based on a unit cost of IR£20/metre is IR£7,600

- *Planting:*

It is recommended that a sum of IR£15,000 is estimated to cover this cost.

- *Litter Control:*

It is assumed that Galway County Council employees will carry out this work.

- *Fencing:*

It is estimated that the cost of new fencing around the perimeter of the site based on a unit cost of IR£50/metre is IR£19,000

In addition, it is recommended that the monitoring programme currently being undertaken by the EPA Regional Laboratory in Castlebar on behalf of Galway County Council be continued in accordance with the EPA Manual on Landfill Monitoring in order to assess the effects of the remediation measures.

6.3 SUMMARY OF COSTS

The total cost for remediating Tuam Landfill in accordance with the proposals of this report is summarised as follows:

Item	***IR£***
Upgrade Surface Water Drains	*10,000*
Construct New Drains	*19,000*
Regrade Slopes	*118,800*
Capping Layer	*354,000*
Construct Perimeter Details	*7,600*
Planting	*15,000*
Fencing	*19,000*
Sub-Total	*543,400*
Add Preliminaries and Contingency (15%)	*81,500*
Total £	***624,900***

The above costs are exclusive of design, consultancy, site supervision or expenses costs.

6.4 TIMESCALE

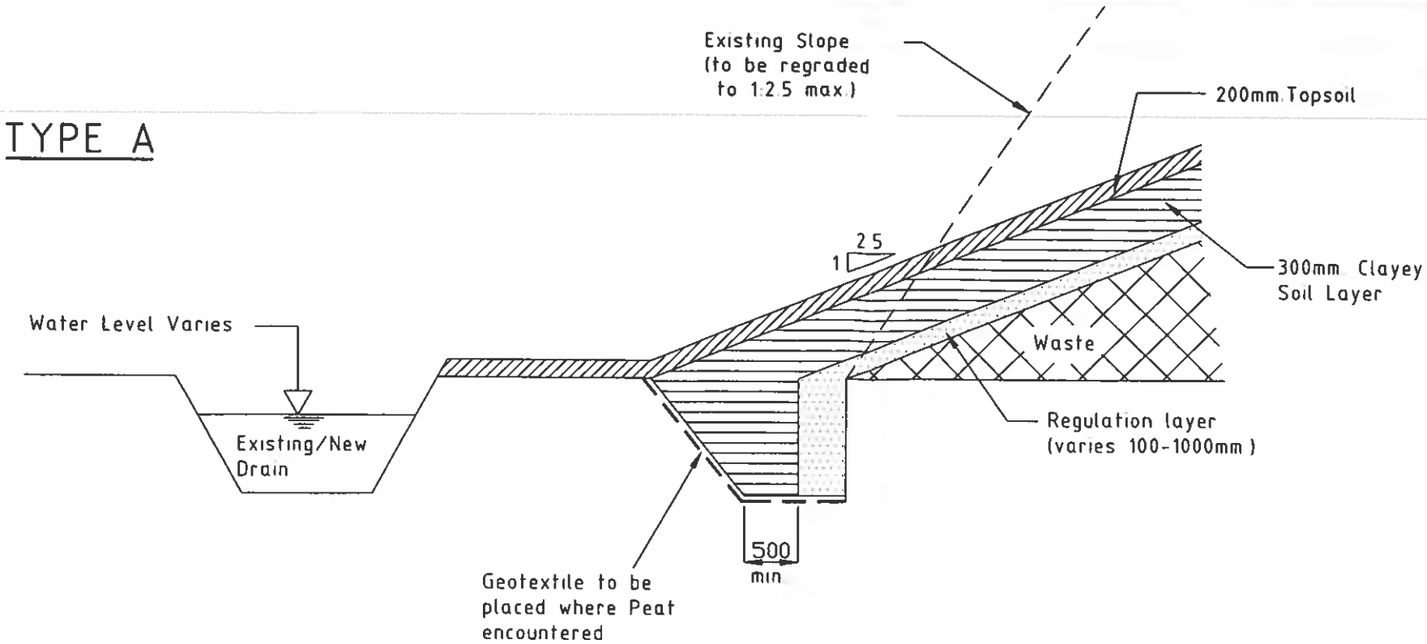
An estimated timescale for the proposed works can be outlined as follows:

• Preparation of Contract Documents	1 month
• Tenders Invited for Project	1 month
• Successful Tenderer Approved	3 weeks
• Contract Awarded	3 weeks
• Commencement of Work	3 weeks
• Contract period	16 weeks

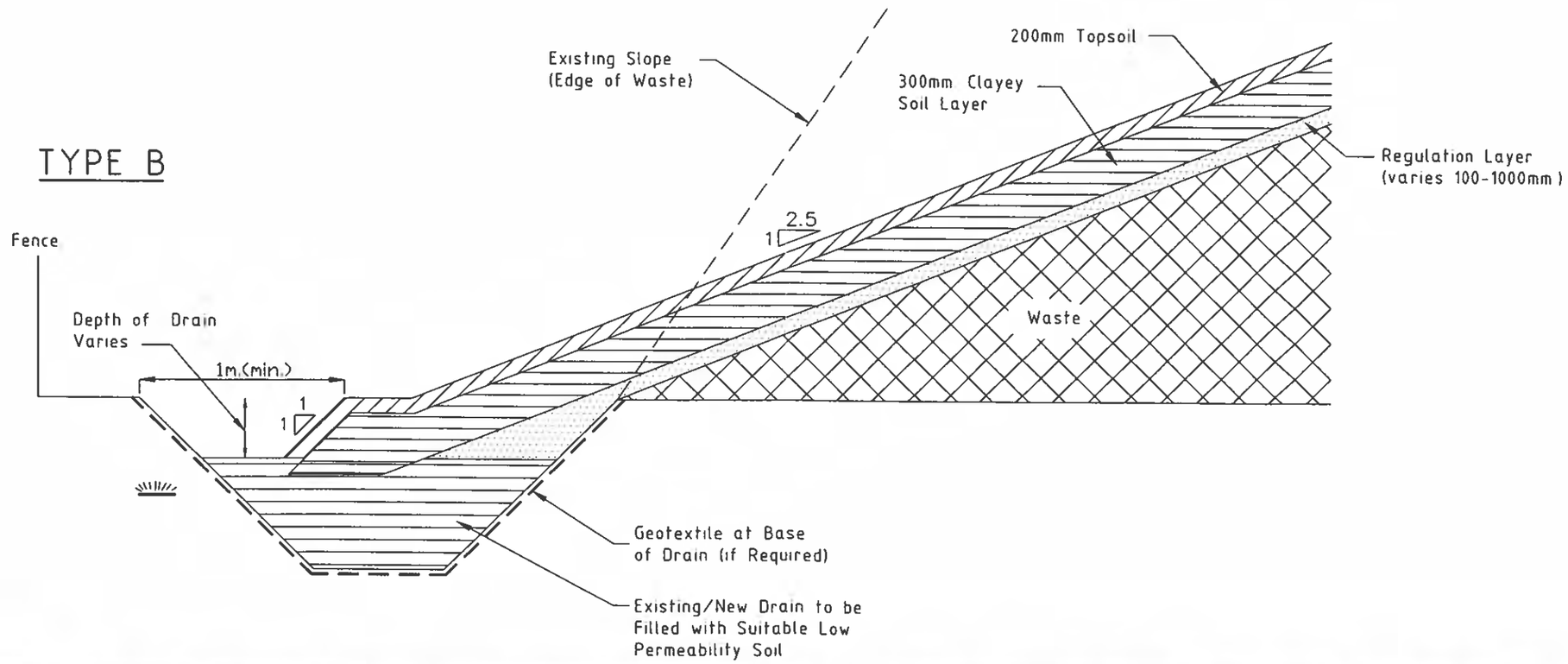
APPENDIX A

SITE INVESTIGATION DATA

TYPE A



TYPE B



MOS M.C.O'SULLIVAN Consulting Engineers COWI	Job: *Remediation of Tuam Landfill*	Drawn: *J.P.M.*	Date: *Oct. '99*
	Title: *Edge Details Types A & B*	Checked: *W.M.*	Drg. No.: *Fig 5.5*
		Scale: *N.T.S.*	

Geotech Specialists Limited

TUAM LANDFILL

Site Investigation Contract
Factual Report No. 179065

Consulting Engineers: M. C. O'Sullivan & Co. Ltd.,

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Castlemartyr
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TUAM LANDFILL

Site Investigation Contract
Factual Report No. 179065

Consulting Engineers: M. C. O'Sullivan & Co. Ltd.,

V.A.T. No. IE 8238170W Company Reg. No. 238170
A subsidiary of Environmental Services Group Limited

CONTENTS

179065

1. INTRODUCTION

As part of a monitoring programme, leachate and gas monitoring wells were required at the Tuam Landfill Site and on the instructions of M.C O'Sullivan & Company, Consulting Engineers, Geotech Specialists Limited carried out this work.

This report contains descriptions of the fieldwork carried out, summaries of the ground and groundwater conditions revealed and results of descriptions made in the field.

The investigation was carried out in general accordance with the relevant Standards[1]. This report must be read in conjunction with the general notes which follow the text.

The brief was to install wells for the purpose of monitoring leachate and gas levels.

2. THE SITE

The site is located about 2 miles south of Tuam, off the Athenry Road (R347).

The landfill is surrounded by flat bog lands and streams. At the time of the site investigation the waste material was raised in the region of 12m above natural ground level with part of the site burning.

3. FIELDWORK

The scope of the fieldwork was determined by M.C. O'Sullivan & Company. The exploratory hole positions were set out by taping from existing features according to information given on a drawing provided by M.C. O'Sullivan & Company. The fieldwork was carried out between 29th of March and 5th of May, 1999.

Six boreholes were sunk at the positions shown on the Borehole Location Plan (Drawing 1), three by cable percussive boring techniques and three rotary coring methods.

The depths of the boreholes, descriptions of the strata encountered and comments on the groundwater conditions revealed during the fieldwork operations are given on the borehole records (Enclosure A).

Disturbed samples were taken at the depths shown on the records for identification purposes.

Rock cores of 50mm nominal diameter were obtained in the rotary cored holes from cemented strata. The rotary coring was carried out using NQ corebarrel and diamond bits, with an air/water flush.

Standard Penetration Tests (solid cone) were carried out in cohesive deposits to obtain an indication of their consistency. Values of penetration resistance are presented in Enclosure A, both on the borehole records and on the SPT summary sheets.

Standpipes were installed in all the boreholes to enable subsequent measurements of leachate and gas levels to be made. Details of the installations are given on the relevant borehole records are given in Enclosure A.

The samples and rock cores were despatched to the laboratory at Castlemartyr, Co. Cork for examination. The descriptions of strata, given on the records, were made in general accordance with the recommendations given in BS 5930; 1981[1] but modified in accordance with the procedures outlined in the Enclosures.

4. LABORATORY TESTING

No laboratory testing was required by the M.C. O'Sullivan & Company on samples obtained from the boreholes.

5. GROUND CONDITIONS

5.1 Strata Encountered

Made ground consisting of landfill material was encountered at all the cable percussive boreholes with a thin covering of top soil at the locations of BH1 and BH2.

The made ground extended to depths of 5.00m (BH1 and BH2) and 9.00m (BH3) and rested on soft brown peat to proved depths of 6.00m (BH1 and BH2) and 10.00m (BH3).

Strong grey fossiliferous limestone was encountered beneath the overburden at depths ranging from 4.40m (RC1) and 17.90m (RC3).

5.2 Groundwater

Groundwater was not recorded in any of the cable percussive or rotary boreholes, although this may have been masked by the use of water which was used to aid the drilling or provide flush.

For and on behalf of Geotech Specialists Limited

Ruth O'Regan
Geotechnical Engineer

Chris Lambert
Principal Engineering Geologist

Geotech Specialists Limited
May, 1999

REFERENCES

1. BS 5930 ; 1981. Code of Practice for Site Investigations. British Standards Institution.

2. BS 1377 Parts 1 to 9; 1990. Methods of Test for Soils for Civil Engineering Purposes. British Standards Institution.

General Notes

These notes, which accompany the ground investigation report, are intended to assist the user of the information contained in the report. They point out some inevitable shortcomings of any ground investigation and do not constitute a disclaimer of responsibility for the results obtained by Geotech Specialists Limited.

1. The information in this report is based on the ground conditions encountered during the ground investigation work and the results of any field and laboratory testing. The exploratory records describe the ground conditions at their specific locations and should not be regarded as representative of the ground as a whole.

2. Ground investigations are performed by the company in general accordance with the recommendations in BS 5930 (1981) "Code of Practice for Site Investigations". The testing of soils, rocks and aggregates generally follow the recommendations of BS 1377 (1990) "Methods of test for soils for Civil Engineering Purposes", the International Society of Rock Mechanics (Brown, 1981) "Rock characterisation, testing and monitoring, ISRM suggested methods", and BS 812 (1975) "Methods of sampling and testing of mineral aggregates, sands and filters", respectively.

3. The primary purpose of ground investigation boreholes and trial pits is to probe the stratified sequences of soil and/or rock. From the results of these probings no conclusions should be drawn concerning the presence of size, lithological nature and numbers per unit volume of ground of cobbles and boulders in soil types such as glacial till (boulder clay).

4. When cable percussion boring techniques are used in superficial and drift deposits some mixing of thin-layered soils inevitably occurs. If strong randomly-occurring pieces of rock are encountered in soil material then the rock may be either pushed aside or penetrated and broken up in which case the arisings that are recovered may not be indicative of the nature of the material in situ.

5. Rotary drilling techniques may sometimes be used for drilling through superficial deposits and rocks in order to provide a very general indication of the nature of the ground. Where open-hole methods have been used for the ground investigation the description of the ground is based on the cuttings recovered from the flushing medium and the rate of progress in advancing the hole. Descriptions of strata and the depths of changes in strata may not be accurate under these conditions.

6. Groundwater conditions noted during boring may be subject to change through seasonal and/or other effects such as, for example, boring and constructional excavation. When a groundwater inflow is encountered during boring, work on the hole is suspended, typically for 20 minutes, and any change in level is recorded. The groundwater level recorded on resumption of boring may not be the natural pre-boring standing water level. When piezometers are installed in boreholes the reported groundwater levels may also be subject to variation due to seasonal and/or other effects.

7. The factual information contained within the ground investigation report should not be used for any purpose other than for the development project for which it was prepared unless a check has been carried out on its applicability. Where the ground investigation report contains an interpretation of the factual information that interpretation must be considered in the context of the stated development proposals and should not be used in any other context.

8. This report is for the use of the person or organisation that commissioned the work. Geotech Specialists Limited accepts no responsibility if the information is used by any other party. The information is the property and copyright of the person or organisation that commissioned the investigation. It should not be reproduced or transmitted in any form without the owner's written permission.

March 1995

ENCLOSURE A

Exploratory Hole Records

Summary of Descriptive Methods

1. Terminology used in Soil Descriptions

The procedure and principles given in BS 5930; 1981, Section 8 have generally been adopted in producing soil descriptions but most of the modifications detailed by Norbury et al (1984) have been incorporated. These generally relate to the description of composite soil types referred to in Table 6 and Section 41.3.3.3 of BS 5930. The modifications relating to various mixtures of soil types are summarised below.

i) Predominantly Coarse Soils

BS 5930 Section 8 recommends that the secondary constituents of coarse soils should precede the main soil type. This may become ambiguous if qualifying adjectives also form part of the description. Norbury et al overcame this by suggesting that the secondary constituent may be placed after the main soil type, as outlined in Table B1.

ii) Mixtures of Coarse and Fine Soils

BS 5930 Section 8 Section 41.3.2.1 states that mixtures of coarse and fine soils with more than 35% of fine soil shall be described as clay or silt, otherwise they should be described as sand or gravel. This may lead to misleading descriptions, if strictly adhered to, since a material that in engineering terms behaves as clay may only have a clay content of between 10% and 20%. Thus the above approach is not adopted where it would lead to a description which would not reflect the engineering behaviour of the material. In such cases the percentage unit is relaxed.

iii) Predominantly Fine Soils

Fine soils generally consist of mixtures of silt and clay and are described in BS 5930 as either silt or clay with classification in accordance with plasticity. Borderline cases between silt and clay materials are often difficult to distinguish and where secondary constituent fine soils have an influence on mass behaviour the qualifying terms "very silty" and "very clayey" are used. Coarse secondary constituents may be included either before or after the main soil type, as outlined in Table B2, depending on the grain sizes of the secondary constituents.

Term Before	Principal Term	Term After	Approx % of Secondary Constituent
Slightly (sandy*)	SAND, GRAVEL COBBLES or BOULDERS	with a little (sand*) or occasional (cobbles+)	<5
(Sandy*)		with some (sand*) or some (cobbles+)	5 - 20#
Very (Sandy*)		with much (sand*) or many (cobbles+)	20 - 40#
		and (sand*) or and (cobbles+)	about 50#

* Fine or coarse soil type as appropriate
\+ Very coarse soil type as appropriate
\# Or described as a fine soil depending on mass behaviour

Table B1
Scale of Secondary Constituents with coarse soils

For clays, the extended strength scale is outlined in Table B3. The term hard is not assigned a specific range of shear strengths by BS5930 which indicates that soils possessing shear strengths greater than 150 kPa may be either very stiff or hard. The terms are defined more precisely in Table B3.

References

BS 5930; 1981, Code of Practice for Site Investigations.

Norbury D.R., Child G.H. and Spink T.W.; 1984, A Critical review of Section 8, BS 5930, Soil and Rock Descriptions. Proc. 20th Regional Meeting of the Engineering Group of the Geological Society. Site Investigation Practice, Assessing BS 5930. Univ of Surrey. Pages 353-369 (original proceedings).

Term Before	Principal Term	Term After	Approx % of Secondary Constituent
Slightly (sandy*)		with a little (sand*) or occasional (cobbles+)	<35
(Sandy*)	CLAY or SILT	with some (sand*) or some (cobbles+)	35 - 65
Very (Sandy*)		with much (sand*) or many (cobbles+)	>65#

* Coarse soil type as appropriate
\+ Very coarse soil type as appropriate
\# Or described as a coarse soil depending on mass behaviour.

Table B2
Scale of Secondary Constituents with fine soils

Term	Field Identification	Undrained Shear Strength (kPa)
Very soft	Exudes between fingers when squeezed in hand.	<20
Soft	Moulded by light finger pressure.	20 - 40
Soft to firm	Can be moulded by strong finger pressure.	40 - 50
Firm		50 - 75
Firm to Stiff	Cannot be moulded by finger pressure	75 - 100
Stiff	Can be indented by thumb.	100 - 150
Very Stiff	Can be indented by thumbnail	150 - 300
Hard	No manual indentation possible.	>300

Table B3
Field Assessment of Strength of Clays

2. Engineering Classification of Rock Cores

Rocks are generally described in accordance with the principles of Section 8 of BS 5930; 1981. However the description of the weathered state adheres to the scheme first outlined in the Quarterly Journal of Engineering Geology (QJEG); 1972 as recommended by Norbury et al (1984), and the definition of a discontinuity is made in practical terms.

The classification is therefore based on the terms defined in Tables B4, B5 and B6 and on the fracture state.

Term	Uniaxial Compressive Strength Range (MPa)
Very Weak	< 1.25
Weak	1.25 - 5
Moderately Weak	5 - 12.5
Moderately Strong	12.5 - 50
Strong	50 - 100
Very Strong	100 - 200
Extremely Strong	> 200

Table B4

Scale of Strength of Intact Rock

Term	Description
Fresh	Parent rock showing no discoloration, loss of strength or any other weathering effects.
Slightly Weathered	Rock may be slightly discoloured, particularly adjacent to discontinuities which may be open and will have slightly discoloured surfaces; the intact rock is not noticeably weaker than fresh rock.
Moderately Weathered	Rock is discoloured; discontinuities may be open and will have discoloured surfaces with alteration starting to penetrate inwards; intact rock is noticeably weaker than the fresh rock. (The ratio of the volume of original rock to weathered rock is estimated where possible).
Highly Weathered	Rock is discoloured; discontinuities may be open and will have discoloured surfaces and the original fabric of the rock may be altered. Alteration penetrates deeply inwards, but corestones are still present. (The ratio of the volume of original rock to weathered rock is estimated where possible).
Completely Weathered	Rock is discoloured and has much of the appearance and many of the properties of soil but the original fabric is mainly preserved. There may be occasional small corestones. The soil-like properties of the material are dependent in part on the nature of the parent rock.
Residual Soil	Rock is discoloured and has the appearance and properties of soil; the original rock fabric is completely destroyed.

Table B5

Scale of Weathering Rock Cores

KEY TO SYMBOLS ON EXPLORATORY HOLE RECORDS

All linear dimensions are in metres or millimetres

DESCRIPTIONS

••	:	Drillers Description

SAMPLES

U( )	:	Undisturbed 102mm diameter sample, ( ) denotes number of blows to drive sampler
U ( )F, U ( )P	:	F- not recovered, P - partially recovered
U38	:	Undisturbed 38mm diameter sample
P(F), (P)	:	Piston sample, F - not recovered, P - partially recovered
B	:	Bulk sample - disturbed
D	:	Jar Sample - disturbed
W	:	Water Sample
CBR	:	California Bearing Ratio mould sample
G	:	Gas Sample and depth of hole at time of sampling

CORE RECOVERY AND ROCK QUALITY

TCR	:	Total Core Recovery %
SCR	:	Solid Core Recovery %
RQD	:	Rock Quality Designation %
FI	:	Fracture Index (discontinuities per metre) NI - non intact, NR - no recovery, NA - not applicable

GROUNDWATER

▽	:	Groundwater strike
▼	:	Groundwater level after standing period
Date/Water	:	Date of shift (day/month)/Depth to water at end of previous shift shown above the date and depth to water at beginning of shift given below the date

INSITU TESTING

S	:	Standard Penetration Test - split barrel sampler
C	:	Standard Penetration Test - solid 60° cone
V(H) (R)	:	Vane Test (Hand) (R) demonstrates remoulded strength
K(F),(C),(R),(P)	:	Permeability Test
HP	:	Hand Penetrometer Test

MEASURED PROPERTIES

N	:	Standard Penetration Test - blows required to drive 300mm after seating drive
x/y	:	Denotes x blows for y mm within the Standard Penetration Test
x*/y	:	Denotes x blows for y mm within the seating drive
c_u	:	Undrained Shear Strength (kN/m^2)
CBR	:	California Bearing Ratio

ROTARY DRILLING SIZES

Index Letter	Nominal Diameter (mm)	
	Borehole	Core
N	75	54
H	99	76
P	120	92
S	146	113

Exploratory Hole Symbols	Project Tuam Landfill M.C. O'Sullivan & Co. Ltd.	Contract 179065
GEOTECH		Figure A2

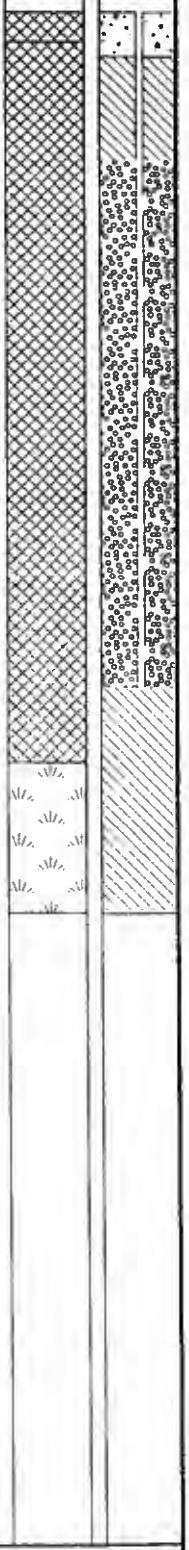
Sampling

Depth	Type	Casing Depth	Date/ Water	SPT N (Cu)
			01/04 1999	
5.00	D			
5.50-5.95 5.50-6.00	C B	5.0		3

Strata

Description	Depth (Thickness)	Level
	G.L.	
MADE GROUND: Topsoil	0.20	
MADE GROUND: Landfill material.	(4.80)	
Soft brown PEAT.	5.00	
	(1.00)	
End of Borehole.	6.00	

Legend



Equipment: Cable Percussion Rig

Borehole Dia (mm): 200 to 6.00m

Casing Dia (mm): 200 to 5.00m

Groundwater

No Struck Behaviour Sealed

No groundwater encountered

Drilled by AM

Logged by

Checked by RoR

Remarks 1. Installed a stand pipe at 4.50m.

See key sheet and appendices for explanations.

Form 1/0

Borehole Record

GEOTECH

Project

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

Contract 179065

Borehole BH1(1 of 1)

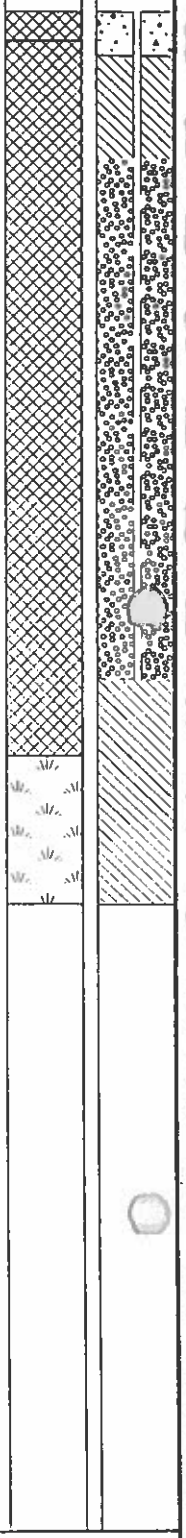
Sampling

Depth	Type	Casing Depth	Date/ Water	SPT N (Cu)
			31/03 1999	
5.00	D			
5.50-5.95	C	5.30		2
5.50-6.00	B			

Strata

Description	Depth (Thickness)	Level
	G.L.	
MADE GROUND: Topsoil.	0.20	
MADE GROUND: Landfill material.	(4.80)	
Soft brown PEAT.	5.00 (1.00)	
End of Borehole.	6.00	

Legend



Equipment: Cable Percussion Rig

Borehole Dia (mm) 200 to 6.00m

Casing Dia (mm) 200 to 5.30m

Groundwater

No Struck Behaviour Sealed

No groundwater encountered

Drilled by AM
Logged by
Checked by RCR

Remarks 1. Installed a stand pipe at 4.50m.

See key sheet and appendices for explanations.

Form 1/0

Borehole Record

GEOTECH

Project

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

Contract 179065

Borehole BH2(1 of 1)

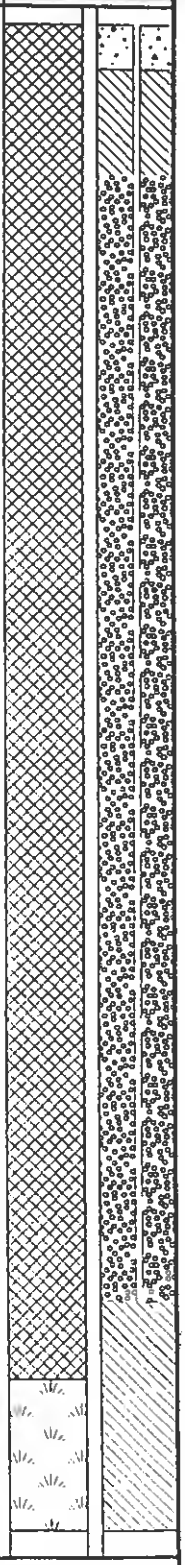
Sampling

Depth	Type	Casing Depth	Date/ Water	SPT N (Cu)
			29/03 1999	
9.00	D			
9.50-9.95	C	9.20		2
9.50	B			

Strata

Description	Depth (Thickness)	Level
MADE GROUND: Landfill material.	G.L.	
	(9.00)	
	9.00	
Soft brown PEAT.	(1.00)	
End of Borehole.	10.00	

Legend



Equipment: Cable Percussion Rig

Borehole Dia (mm) 200 to 10.00m

Casing Dia (mm) 200 to 9.20m

Groundwater

No Struck Behaviour Sealed

No groundwater encountered

Drilled by AM
Logged by
Checked by RCR

Remarks 1. Installed a stand pipe at 8.50m.

See key sheet and appendices for explanations.

Form 1/0

Borehole Record

GEOTECH

Project
Tuam Landfill
M. C. O'Sullivan & Co. Ltd.

Contract 179065

Borehole BH3(1 of 1)

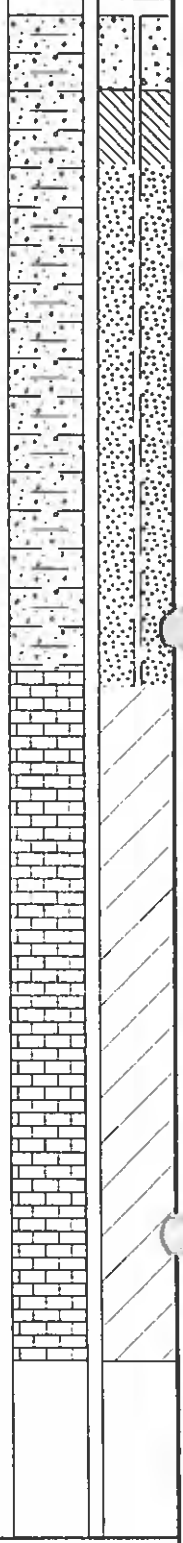
Sampling

Drill Run	TCR (SCR)	Casing (RQD)	Date/ Water	F_s
0.00			29/04 1999	
	4%			
3.50				
	69%			
				25
5.00				4 4 6
	97% (91%)	(78%)		7 17 20
				27 28
6.50				3 15
	93% (93%)	(77%)		69
				2 34
8.00				8 13
	100% (100%)	(100%)		17 30 30
9.00				

Strata

Description	Depth (Thickness)	Level
OVERBURDEN: Recovered as gravel and cobbles.	G.L.	
	(4.40)	
Strong grey fossiliferous LIMESTONE Closely to medium spaced subhorizontal discontinuities, slightly irregular Occasional closed irregular subhorizontal fractures (stylolites). 5.00m - 5.10m: Partings of black calcareous mudstone	4.40	
	(4.60)	
7.38m - 7.68m: Irregular subvertical to 45° calcite veins		
8.70m - 8.80m: Roughly 45° calcite vein		
End of Borehole.	9.00	

Legend



Equipment: Rotary Coring Rig

Borehole Dia (mm) NQ to 9.00m

Casing Dia (mm)

Groundwater

No Struck Behaviour Sealed

Drilled by Hilliards
Logged by ROR
Checked by

Remarks 1. Standpipe installed at 4.50m

See key sheet and appendices for explanations.

Form 1/0

Borehole Record

GEOTECH

Project

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

Contract 179065

Borehole RC1(1 of 1)

Sampling

Drill Run	TCR (SCR)	Casing (RQD)	Date/ Water	F_s
0.00			05/05 1999	
	26%			
2.00				
	37%			
3.50				
	82%			
4.50				
	93%			19 23 35
6.00				7 10 15 35
	100% (100%)	(76%)		15 18 7 4 7 8
7.00				
	100% (100%)	(87%)		12 33
8.50				6 10
				58
	90% (90%)	(85%)		12
				36
10.00				

Strata

Description	Depth (Thickness)	Level	Legend
OVERBURDEN: Recovered as peat, gravel and cobbles	G.L.		
	(4.75)		
Strong grey fossiliferous LIMESTONE Closely to widely spaced subhorizontal discontinuities Occasionally closed irregular sunhorizontal fratures (stylolites) and clacite veins.	4.75		
	(5.25)		
End of Borehole.	10.00		

Equipment: Rotary Coring Rig

Borehole Dia (mm) NQ to 10.00m

Casing Dia (mm)

Groundwater

No. Struck Behaviour Sealed

Drilled by Hilliards
Logged by ROR
Checked by

Remarks 1. Standpipe installed at 9.50m

See key sheet and appendices for explanations.

Form 1/0

Borehole Record

GEOTECH

Project

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

Contract 179065

Borehole RC2(1 of 1)

Sampling

Drill Run	TCR (SCR)	Casing (RQD)	Date/ Water	F_s
0.00			30/04 1999	
	9%			
3.50				
	70%			
4.00				

Strata

Description	Depth (Thickness)	Level	Legend
OVERBURDEN: Recovered as gravel and cobbles	G.L.		
	(17.90)		

Equipment: Rotary Coring Rig

Borehole Dia (mm): NQ to 23.00m

Casing Dia (mm):

Groundwater
No Struck Behaviour Sealed

Drilled by: Hilliards
Logged by: ROR
Checked by:

Remarks 1. Standpipe installed at 22.50m

See key sheet and appendices for explanations.

Form 1/0

Borehole Record

GEOTECH

Project
Tuam Landfill
M. C. O'Sullivan & Co. Ltd.

Contract 179065

Borehole RC3(1 of 3)

Sampling					Strata			
Drill Run	TCR (SCR)	Casing (RQD)	Date/ Water	F_s	Description	Depth (Thickness)	Level	Legend
			30/04		See previous sheet			
	3%							
17.00								
	55%					17.90		
				20 20 25	Strong grey fossiliferous LIMESTONE Predominantly closely to medium spaced subhorizontal discontinuities.			
				3 10 15				
19.00				38				
				13	19.64m - 21.30m: Assumed zone of core loss Recovered as clay filled irregular subvertical fracture.			

Equipment: Rotary Coring Rig

Borehole Dia (mm) NQ to 23.00m

Casing Dia (mm)

Groundwater

No. Struck Behaviour Sealed

Drilled by Hilliards
Logged by ROR
Checked by

Remarks

See key sheet and appendices for explanations.

Form 1/0

Borehole Record

GEOTECH

Project

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

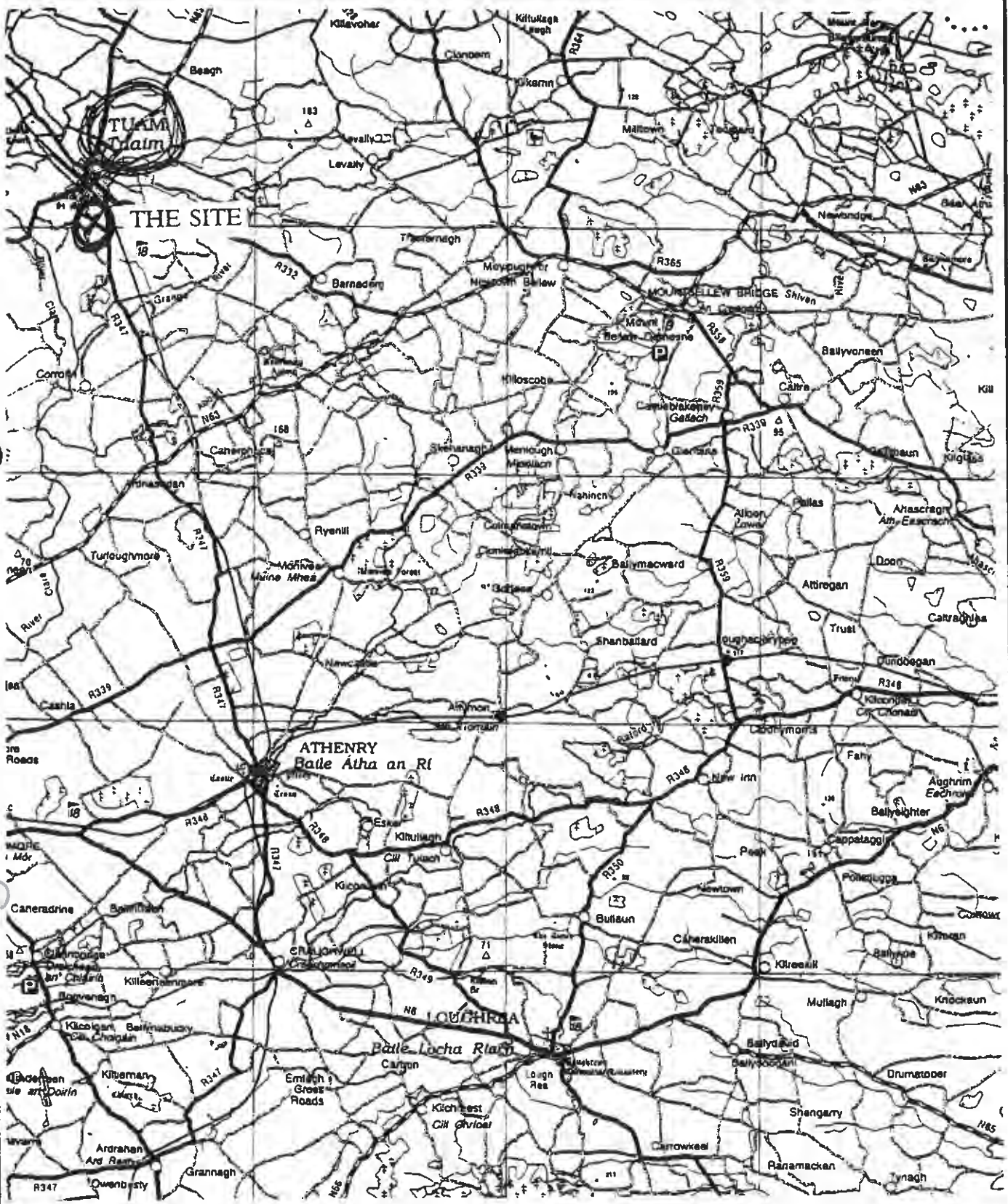
Contract 179065

Borehole RC3(2 of 3)

ENCLOSURE B

Drawings

	Drawings
Site Location Plan	1
Borehole Location Plan	2



Site Location	**Project** Tuam Landfill M.C O'Sullivan & Co. Ltd	Contract 179065
GEOTECH		Figure

RC2

RC3

BH3

Landfill

BH2

Landfill

BH1

Landfill

RC1

APPENDIX B

WINDOW SAMPLING

ENCLOSURE C

Drawings

	Drawings
Site Location Plan	1
Exploratory Hole Location Plan	2

ENCLOSURE C

Drawings

	Drawings
Site Location Plan	1
Exploratory Hole Location Plan	2

GEOTECH

Geotech Specialists Limited

Window Sampling at Tuam Landfill

Site Investigation Contract
Factual Report No. 179112

Consulting Engineers: M.C. O'Sullivan & Company

Carewswood
Castlemartyr
Co. Cork
Ireland

Tel: (021) 667164
Fax: (021) 667630

ENCLOSURE A

Exploratory Hole Records

	Sheet
Window Sampling Boreholes	BH1 to BH5, BH8 to BH10, BH12 to BH14, BH19 to BH21, BH26 to BH28

CONTENTS

179112

1. INTRODUCTION

As part of a monitoring programme, window sampling was required at the Tuam Landfill Site and on the instructions of M.C O'Sullivan & Company, Consulting Engineers, Geotech Specialists Limited carried out this work.

This report contains descriptions of the fieldwork carried out, summaries of the ground conditions revealed and results of descriptions made in the field.

The investigation was carried out in general accordance with the relevant Standards[1]. This report must be read in conjunction with the general notes which follow the text.

The brief was to carry out window sampling for the purpose of obtaining samples for environmental testing.

2. THE SITE

The site is located about 2 miles south of Tuam, off the Athenry Road (R347).

The window sampling was carried out in a rough grid to the west of the existing landfill site in peat material.

3. FIELDWORK

The scope of the fieldwork was determined by M.C. O'Sullivan & Company. The exploratory hole positions were set out by taping from existing features according to information given on a drawing provided by M.C. O'Sullivan & Company. The fieldwork was carried out between 27th of May and 2th of June, 1999.

Window sampling was carried out at 17 positions which are shown on the Exploratory Hole Location Plan (Drawing 1).

The depths of the window sampling and descriptions of the strata encountered revealed during the fieldwork operations are given on the window sampling records (Enclosure A).

Disturbed samples were taken at the depths shown on the records for identification purposes and were then despatched to the laboratory at Castlemartyr, Co. Cork for examination and forwarding to a NAMAS accredited laboratory for testing.

4. LABORATORY TESTING

Environmental laboratory testing was required by the M.C. O'Sullivan & Company on samples obtained from window sampling.

The principal objectives of the testing programme was to determine if the soils were being contaminated from the adjacent landfill site.

The tests carried out were.

- Cadmium
- Chromium
- Mercury

The results of the laboratory tests are given in Enclosure B.

5. GROUND CONDITIONS

5.1 Strata Encountered

Peat was located at all the window sampling positions.

6. ENVIRONMENTAL RESULTS

The results of the chemical analyses indicate that the results of the Cadmium, Chromium (total) and Mercury Tests fall below the threshold levels for Domestic Gardens and Allotments which are 3mg/kg, 600mg/kg and 1mg/kg respectively, as defined by ICRCL "Guidance on Assessment and Redevelopment of Contamination Land" (ICRCL 59/83)[1]. It should be noted that the chromium level recorded at BH27 (window sample 27) at 0.00m to 0.25m was 46mg/kg, which is considerably higher than the rest of the samples.

REFERENCES

1. Inter-departmental Committee on the Redevelopment of Contaminated Land: Guidance on the assessment and redevelopment of contaminated land; ICRCL 59/83, 2nd Ed., 1987.

For and on behalf of Geotech Specialists Limited

Ruth O'Regan
Geotechnical Engineer

Chris Lambert
Principal Engineering Geologist

Geotech Specialists Limited
June, 1999

General Notes

These notes, which accompany the ground investigation report, are intended to assist the user of the information contained in the report. They point out some inevitable shortcomings of any ground investigation and do not constitute a disclaimer of responsibility for the results obtained by Geotech Specialists Limited.

1. The information in this report is based on the ground conditions encountered during the ground investigation work and the results of any field and laboratory testing. The exploratory records describe the ground conditions at their specific locations and should not be regarded as representative of the ground as a whole.

2. Ground investigations are performed by the company in general accordance with the recommendations in BS 5930 (1981) "Code of Practice for Site Investigations". The testing of soils, rocks and aggregates generally follow the recommendations of BS 1377 (1990) "Methods of test for soils for Civil Engineering Purposes", the International Society of Rock Mechanics (Brown, 1981) "Rock characterisation, testing and monitoring, ISRM suggested methods", and BS 812 (1975) "Methods of sampling and testing of mineral aggregates, sands and filters", respectively.

3. The primary purpose of ground investigation boreholes and trial pits is to probe the stratified sequences of soil and/or rock. From the results of these probings no conclusions should be drawn concerning the presence of size, lithological nature and numbers per unit volume of ground of cobbles and boulders in soil types such as glacial till (boulder clay).

4. When cable percussion boring techniques are used in superficial and drift deposits some mixing of thin-layered soils inevitably occurs. If strong randomly-occurring pieces of rock are encountered in soil material then the rock may be either pushed aside or penetrated and broken up in which case the arisings that are recovered may not be indicative of the nature of the material in situ.

5. Rotary drilling techniques may sometimes be used for drilling through superficial deposits and rocks in order to provide a very general indication of the nature of the ground. Where open-hole methods have been used for the ground investigation the description of the ground is based on the cuttings recovered from the flushing medium and the rate of progress in advancing the hole. Descriptions of strata and the depths of changes in strata may not be accurate under these conditions.

6. Groundwater conditions noted during boring may be subject to change through seasonal and/or other effects such as, for example, boring and constructional excavation. When a groundwater inflow is encountered during boring, work on the hole is suspended, typically for 20 minutes, and any change in level is recorded. The groundwater level recorded on resumption of boring may not be the natural pre-boring standing water level. When piezometers are installed in boreholes the reported groundwater levels may also be subject to variation due to seasonal and/or other effects.

7. The factual information contained within the ground investigation report should not be used for any purpose other than for the development project for which it was prepared unless a check has been carried out on its applicability. Where the ground investigation report contains an interpretation of the factual information that interpretation must be considered in the context of the stated development proposals and should not be used in any other context.

8. This report is for the use of the person or organisation that commissioned the work. Geotech Specialists Limited accepts no responsibility if the information is used by any other party. The information is the property and copyright of the person or organisation that commissioned the investigation. It should not be reproduced or transmitted in any form without the owner's written permission.

March 1995

Window Sampling at Tuam Landfill

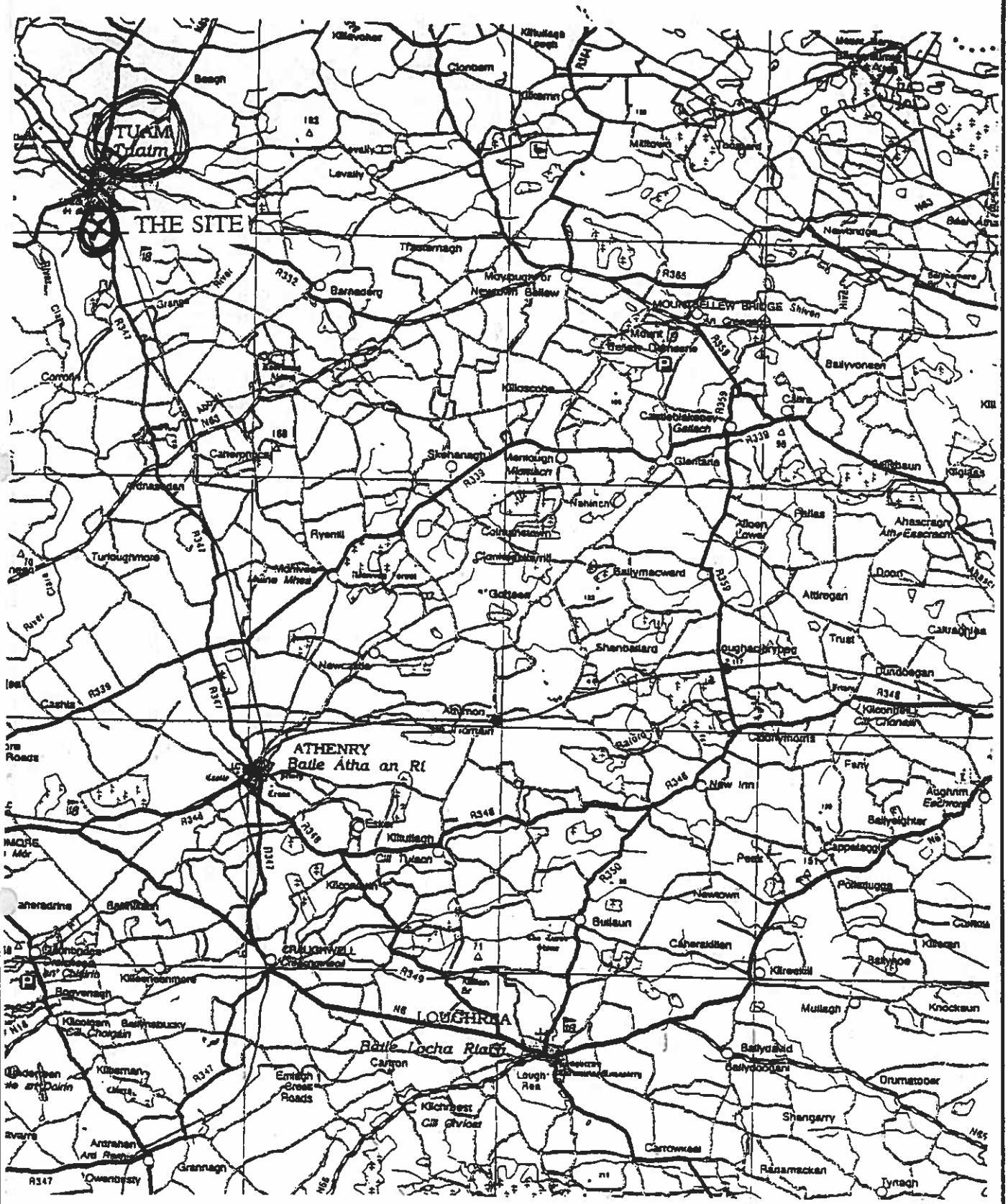
Date	BH No.	Samples	Material	Remarks
02-Jun-99	BH 1	0.00 - 0.25m	Peat	Complete
02-Jun-99	BH 2	0.00 - 0.25m	Peat	Complete
		0.75 - 1.00m	Peat	Complete
		1.75 - 2.00m	Peat	Lost sample due to suction
02-Jun-99	BH 3	0.00 - 0.25m	Peat	Complete
		0.75 - 1.00m	Peat	Complete
		1.75 - 2.00m	Peat	Complete
02-Jun-99	BH 4	0.00 - 0.25m	Peat	Complete
		0.75 - 1.00m	Peat	Complete
		1.75 - 2.00m	Peat	Lost sample due to suction
02-Jun-99	BH 5	0.00 - 0.25m	Peat	Complete
		0.75 - 1.00m	Peat	Complete
		1.75 - 2.00m	Peat	Lost sample due to suction
02-Jun-99	BH 6		Peat	Unable to gain access safely
02-Jun-99	BH 7		Peat	Unable to gain access safely
02-Jun-99	BH 8	0.00 - 0.25m	Peat	Complete
		0.75 - 1.00m	Peat	Complete
02-Jun-99	BH 9	0.00 - 0.25m	Peat	Complete
		0.75 - 1.00m	Peat	Complete
02-Jun-99	BH 10	0.00 - 0.25m	Peat	Complete
		0.75 - 1.00m	Peat	Complete
02-Jun-99	BH 11		Peat	Unable to gain access safely
02-Jun-99	BH 12	0.00 - 0.25m	Peat	Complete
		0.75 - 1.00m	Peat	Complete
27-May-99	BH 13	0.00 - 0.25m	Peat	Complete
		0.75 - 1.00m	Peat	Complete
27-May-99	BH14	0.00 - 0.25m	Peat	Complete
		0.75 - 1.00m	Peat	Complete
27-May-99	BH 15		Peat	Unable to gain access safely
27-May-99	BH 16		Peat	Unable to gain access safely
27-May-99	BH 17		Peat	Unable to gain access safely
27-May-99	BH 18		Peat	Unable to gain access safely
27-May-99	BH 19	0.00 - 0.25m	Peat	Complete
		0.75 - 1.00m	Peat	Complete
27-May-99	BH 20	0.00 - 0.25m	Peat	Complete
		0.75 - 1.00m	Peat	Complete
27-May-99	BH 21	0.00 - 0.25m	Peat	Complete
		0.75 - 1.00m	Peat	Complete
27-May-99	BH 22		Peat	Unable to gain access safely
27-May-99	BH 23		Peat	Unable to gain access safely
27-May-99	BH 24		Peat	Unable to gain access safely
27-May-99	BH 25		Peat	Unable to gain access safely
27-May-99	BH 26	0.00 - 0.25m	Peat	Complete
		0.75 - 1.00m	Peat	Complete
27-May-99	BH 27	0.00 - 0.25m	Peat	Complete
		0.75 - 1.00m	Peat	Complete
27-May-99	BH 28	0.00 - 0.25m	Peat	Complete
		0.75 - 1.00m	Peat	Complete

Borehole Positions	**Project** Window Sampling at Tuam Landfill M.C. O'Sullivan & Company	Contract 179112
GEOTECH		Figure

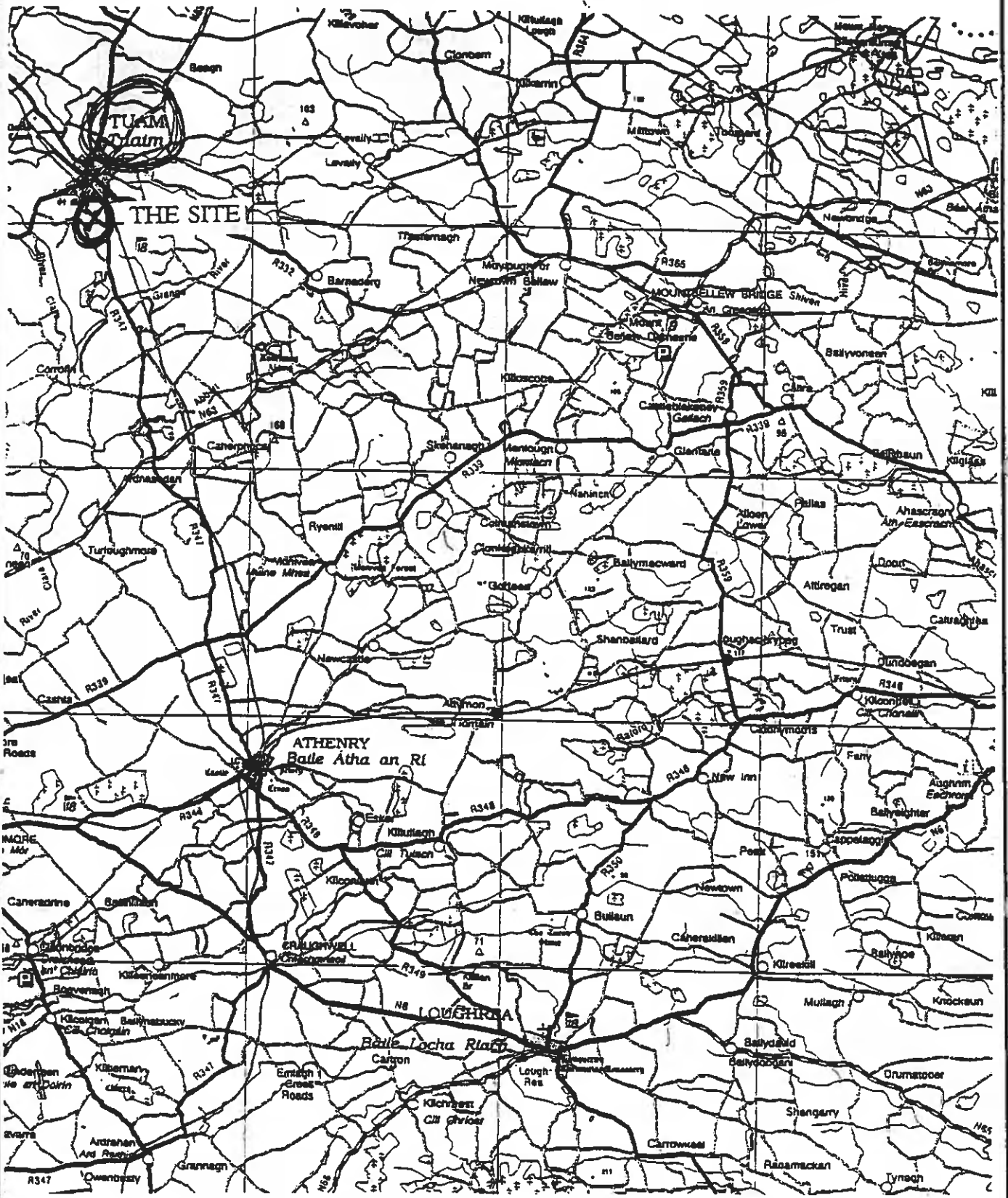
ENCLOSURE B

Environmental Results

Sheets



SITE LOCATION PLAN	**Project** Window Sampling at Tuam Landfill M.C. O'Sullivam & Company	Contract 179112
GEOTECH		Figure **Dwg1**



SITE LOCATION PLAN	**Project** Window Sampling at Tuam Landfill M.C. O'Sullivam & Company	Contract 179112
GEOTECH		Figure **Dwg1**

EXISTING LANDFILL SITE AREA = 3.5ha

BH8
BH1
40m
40m
BH9
BH2
BH10
BH3
BH4
BH26
BH19
BH12
BH5
BH27
BH20
SITE BOUND
BH13
BH28
BH21
BH14
RC2
SURFA
WATEF
DRAIN
SA3
SA2
SA1
RC1
CI
AMI
? → 185

GEOTECH

Project
Tuam Landfill

Borehole Location Plan

Contract	Drawing
179112	2

APPENDIX C

MONITORING DATA

REPORT OF ANALYSIS

Tuam Landfill, Galway

SAMPLED BY: B. O'Shea

Sampling Date	*Lab. Ref.*	Location	Temp. °C	D.O. % Sat	B.O.D. mg/l O2	Cond. uS/cm	pH	O-Phos mg/l	TON mg/l	Ammonia mg/l	Chloride mg/l	C.O.D. mg/l O2	Alkalinity mg/l CaCo3	Total Hardness mg/l CaCo3	Calcium Hardness mg/l CaCo3
12.01.98	*19*	SW1	8.2	51	1	729	7.3	0.181	7.481	0.116	21	20	323	355	335
12.01.98	*20*	SW2	9.2	37	8.2	9000	7.8	0.434	23.036	89.117	2937	298	866	1506	1100
12.01.98	*21*	SW3	7.5	77	3.7	855	7.5	0.045	3.266	1.181	127	65	233	292	246
12.01.98	*22*	SW4	8	84	3.7	856	7.6	0.053	3.344	1.798	118	70	225	286	278
12.01.98	*23*	3AP	8.4	48	N.M.	2230	7	0.014	<0.010	0.213	17	N.M.	368	252	252
12.01.98	*24*	4AP	N.M.	N.M.	N.M.	749	6.6	0.114	<0.010	16.086	652	N.M.	450	493	437
12.01.98	*25*	5A	N.M.	N.M.	N.M.	602	6.9	0.035	<0.010	2.366	18	N.M.	389	383	369
12.01.98	*26*	5AP	N.M.	N.M.	N.M.	602	7.1	0.017	<0.010	0.058	15	N.M.	303	312	300
12.01.98	*27*	8A	8.2	15	N.M.	905	6.9	0.038	<0.010	1.334	25	N.M.	453	381	336
12.01.98	*28*	8A1	9.5	69	N.M.	1090	7.5	0.023	2.853	0.073	29	N.M.	533	349	327
12.01.98	*29*	10AP	N.M.	N.M.	N.M.	6080	7.6	16.359	0.076	422.03	844	N.M.	1904	616	290
12.01.98	*30*	Leachate	N.M.	N.M.	110	3400	7.8	5.183	0.572	117.28	357	1302	734	788	450

Signed:_____

Dr. Michael Flanagan
Regional Manager/Chemist

Date:_____

** N.M. - Not Measured*
N.R. - No Result

REPORT OF ANALYSIS

Tuam Landfill, Galway

SAMPLED BY:

Lab. *Ref.*	Magnesium Hardness mg/l CaCo3	Calcium mg/l	Magnesium mg/l	Copper ug/l	Zinc ug/l	Iron ug/l	Manganese ug/l	Lead ug/l	Chromium ug/l	Nickel ug/l	Sodium ug/l	Potassium ug/l	Boron ug/l	Cadmium ug/l
19	20	134	4.8	3	<25	6	<1	<5	<2.5	<100	15000	9000	<500	<0.25
20	406	440	97.44	100	220	300	380	<5	9	<100	1500000	300000	<500	1.2
21	46	98.4	11.04	3	<25	100	5	<5	<2.5	<100	70000	10000	<500	<0.25
22	8	111.2	1.92	5	25	200	20	<5	<2.5	<100	60000	10000	<500	<0.25
23	0	100.8	0	3	<25	100	710	<5	<2.5	<100	15000	4000	<500	<0.25
24	56	174.8	13.44	50	124	45000	2430	11	8	<100	50000	90000	<500	2
25	14	147.6	3.36	300	430	25000	2390	90	40	200	15000	3000	<500	5
26	12	120	2.88	4	<25	800	560	<5	<2.5	<100	10000	1000	<500	<0.25
27	45	134.4	10.8	5	<25	2000	140	<5	<2.5	<100	10000	2000	<500	<0.25
28	22	130.8	5.28	18	35	2000	1060	12	17	<100	70000	3000	<500	0.3
29	326	116	78.24	5	<25	1600	190	<5	20	<100	800000	300000	<500	<0.25
30	338	180	81.12	8	<25	280	440	<5	9	<100	320000	200000	<500	<0.25

Signed:_____

Dr. Michael Flanagan
Regional Manager/Chemist

Date:_____

** N.M. - Not Measured*
N.R. - No Result

REPORT OF ANALYSIS

Tuam Landfill, Galway

SAMPLED BY:

Lab. Ref.	Arsenic ug/l	Mercury ug/l	Arsenic ug/l	Residue on Evaporation 180°C	Sulphate mg/l	Fluoride mg/l F	Cyanide ug/l	Phenols	TOC mg/l
19	<50	<0.25	<50	N.M.	<10	N.M.	N.M.	N.M.	9.8
20	<50	<0.25	<50	N.M.	920	N.M.	N.M.	N.M.	71.4
21	<50	<0.25	<50	N.M.	6	N.M.	N.M.	N.M.	20.2
22	<50	<0.25	<50	N.M.	7	N.M.	N.M.	N.M.	26.8
23	<50	<0.25	<50	528	10.5	0.0806	0.01	Not Detected	43
24	<50	<0.25	<50	1555	<10	0.0758	0.0678	Not Detected	43.2
25	<50	<0.25	<50	12275	<10	0.59	0.0288	Not Detected	16.3
26	<50	<0.25	<50	422	3	0.0856	0.0083	Not Detected	21.4
27	<50	<0.25	<50	562	34	0.566	0.0123	Not Detected	8.4
28	<50	<0.25	<50	787	4	0.286	0.0089	Not Detected	15.7
29	50	NR	50	3494	3	0.118	0.461	Not Detected	233.4
30	<50	<0.25	<50	N.M.	380	N.M.	N.M.	N.M.	124.1

Signed:_____

Dr. Michael Flanagan
Regional Manager/Chemist

Date:_____

** N.M. - Not Measured*
N.R. - No Result

REPORT OF ANALYSIS

Tuam Landfill, Galway

SAMPLED BY: B. O'Shea

Sampling Date	*Lab. Ref.*	Location	Time	Temp. °C	D.O. % Sat	B.O.D. mg/l O2	Cond. uS/cm	pH	O-Phos mg/l	TON mg/l	Ammonia mg/l	Chloride mg/l	S.S. mg/l	C.O.D. mg/l O2	Nitrites mg/l N	Alkalinity mg/l CaCo3
18.05.98	*2022*	3AP	N.M.	N.M.	N.M.	N.M.	767	6.9	0.011	0.045	0.264	20	N.M.	N.M.	N.M.	392
18.05.98	*2023*	4AP	N.M.	N.M.	N.M.	N.M.	2550	6.5	1.209	0.04	41.224	479	N.M.	N.M.	N.M.	368
18.05.98	*2024*	5A	N.M.	N.M.	N.M.	N.M.	747	6.9	0.108	0.022	1.202	22	N.M.	N.M.	N.M.	320
18.05.98	*2025*	5AP	N.M.	N.M.	N.M.	N.M.	692	7	0.027	<0.010	0.283	16	N.M.	N.M.	N.M.	352
18.05.98	*2026*	8A	N.M.	N.M.	N.M.	N.M.	905	6.9	0.047	0.051	0.906	28	N.M.	N.M.	N.M.	332
18.05.98	*2027*	10AP	N.M.	N.M.	N.M.	N.M.	5140	7.2	7.317	0.039	0.039	368	N.M.	N.M.	N.M.	1652
18.05.98	*2028*	SW1	10.15	10.8	46	1.1	770	7.4	0.119	2.898	0.043	23	<1	27	0.045	372
18.05.98	*2029*	SW2	11.1	18.3	47	8.2	6430	7.8	0.139	12.304	54.919	1205	9	204	2	816
18.05.98	*2030*	SW3	11.15	17	57	4.5	1030	7.6	0.055	2.174	1.428	88	2	30	0.35	332
18.05.98	*2031*	SW4	12.5	19.8	88	2.8	965	8.1	0.036	2.714	0.594	86	7	33	0.45	340
18.05.98	*2032*	L1	N.M.	N.M.	N.M.	160	8140	8.3	1.853	0.203	49.718	490	N.M.	2645	10	N.M.

Not possible to analyse some samples for all parameters due to complex matrix, colour or S.S.

Signed:_____

Dr. Michael Flanagan
Regional Manager/Chemist

Date:_____

N.M. - Not Measured

REPORT OF ANALYSIS

Tuam Landfill, Galway

SAMPLED BY: B. O'Shea

Lab.	Calcium	Magnesium	Copper	Zinc	Iron	Manganese	Lead	Chromium	Nickel	Sodium	Potassium	Boron	Cadmium	Arsenic	Barium
Ref.	mg/l	mg/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	ug/l	mg/l	mg/l
2022	148.8	6.72	4	<20	1000	1500	<5	<2.5	<100	13000	3000	<500	<0.2	<0.01	0.1
2023	150.4	26.88	6	60	70000	1900	<5	8	<100	275000	100000	<500	0.8	<0.01	0.27
2024	124.8	11.52	100	650	40000	2000	55	60	300	13000	4000	<500	4.5	<0.01	0.39
2025	128	13.44	4	<20	3000	800	<5	<2.5	<100	20000	1000	<500	0.2	<0.01	0.1
2026	123.2	25.92	1	<20	5000	200	<5	<2.5	<100	15000	1000	<500	<0.2	<0.01	0.07
2027	97.6	80.64	3	<20	3000	600	<5	16	<100	400000	500000	<500	<0.2	<0.01	0.04
2028	265.6	M.N.	1	20	200	100	<5	<2.5	<100	10000	6000	<500	<0.2	N.M.	N.M.
2029	131.2	126.72	11	60	700	300	<5	<2.5	<100	1000000	800000	<500	0.2	N.M.	N.M.
2030	137.6	20.16	1	<20	400	100	<5	<2.5	<100	75000	12000	<500	<0.2	N.M.	N.M.
2031	168	5.76	1	20	400	50	<5	<2.5	<100	75000	10000	<500	<0.2	N.M.	N.M.
2032	N.M.	N.M.	40	1000	14000	1500	70	40	<100	700000	700000	8000	1.2	N.M.	N.M.

Signed:_____

Dr. Michael Flanagan
Regional Manager/Chemist

Date:_____

N.M. - Not Measured

REPORT OF ANALYSIS

Tuam Landfill, Galway

SAMPLED BY: B. O'Shea

Lab. Ref.	Selenium mg/l	Silver mg/l	Mercury ug/l	Total Residual Chlorine	Sulphate mg/l	Fluoride mg/l F	Cyanide ug/l	Phenols	TOC mg/l	Residue on Evaporation
2022	<0.01	<0.01	<1	N.M.	25.25	0.0608	0.005	N.O.	51.6	543
2023	<0.01	<0.01	<1	N.M.	34.25	0.0557	0.169	N.O.	92.5	1683
2024	<0.01	<0.01	<1	N.M.	32.25	0.236	0.009	N.O.	16.7	5568
2025	<0.01	<0.01	<1	N.M.	16.25	0.0959	0.007	N.O.	19.7	518
2026	<0.01	<0.01	<1	N.M.	15.75	0.809	0.009	N.O.	7.9	546
2027	<0.01	<0.01	<1	N.M.	75.5	0.11	0.89	N.O.	252.2	2806
2028	N.M.	N.M.	<1	0.02	19	N.M.	N.M.	N.M.	10.5	N.M.
2029	N.M.	N.M.	<1	0.03	390	N.M.	N.M.	N.M.	46	N.M.
2030	N.M.	N.M.	<1	0.04	58	N.M.	N.M.	N.M.	2	N.M.
2031	N.M.	N.M.	<1	0.02	51	N.M.	N.M.	N.M.	22.4	N.M.
2032	N.M.	N.M.	<1	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.	N.M.

Signed:_____

Dr. Michael Flanagan
Regional Manager/Chemist

Date:_____

N.M. - Not Measured

REPORT OF ANALYSIS

Tuam Landfill, Galway

SAMPLED BY: B. O'Shea

Sampling Date	Lab. Ref.	Location	Temp. °C	D.O. % Sat	B.O.D. mg/l O2	Cond. uS/cm	pH	O-Phos mg/l	TON mg/l	Ammonia mg/l	Chloride mg/l	C.O.D. mg/l O2	Nitrites mg/l N	Alkalinity mg/l CaCO3	Total Hardness mg/l CaCO3
17.08.98	3426	3AP	16	N.M.	N.M.	810	6.8	0.026	0.047	0.396	18	N.M.	N.M.	N.R.	420
17.08.98	3427	4AP	17	N.M.	N.M.	2430	6.4	0.873	1.083	28.182	477	N.M.	N.M.	N.R.	497
17.08.98	3428	5A	16	N.M.	N.M.	724	6.8	0.394	0.103	1.412	30	N.M.	N.M.	396	368
17.08.98	3429	5AP	15	N.M.	N.M.	712	7.2	0.074	0.57	1.281	18	N.M.	N.M.	392	347
17.08.98	3430	8A	13	N.M.	N.M.	899	6.9	0.032	0.019	0.907	29	N.M.	N.M.	452	444
17.08.98	3431	8A1		N.M.	N.M.	1247	7.6	0.051	0.45	0.313	52	N.M.	N.M.	356	263
17.08.98	3432	10AP	18	N.M.	N.M.	5830	7.1	9.521	0.035	432.474	605	N.M.	N.M.	N.R.	622
17.08.98	3433	SW1	13.9	25	9.1	860	7.4	0.639	0.973	3.167	41	74	0.002	356	372
17.08.98	3434	SW2	16.8	23	26.9	4760	7.6	0.294	11.913	44.264	728	194	2.5	750	780
17.08.98	3435	SW3	16.8	59	5.8	682	7.2	0.061	0.839	0.842	44	54	0.002	288	299
17.08.98	3436	SW4	15.9	79	3.6	657	7.5	0.076	1.101	0.37	35	62	0.002	296	303
17.08.98	3437	L1	18	N.M.	342	6400	7.8	10.77	0.093	173.715	812	2465	N.M.	N.R.	1164

N.R. - Not Recorded
N.O. - No Odour
N.M. - Not Measured

Signed: _____
Dr. Michael Flanagan
Regional Manager/Chemist

Comment: There was some difficulty in the colourimetric determination of hardness and alkalinity due to highly coloured samples.

REPORT OF ANALYSIS

Tuam Landfill, Galway

SAMPLED BY:

Lab. Ref.	Calcium Hardness mg/l CaCO3	Magnesium Hardness mg/l CaCO3	Calcium mg/l	Magnesium mg/l	Copper ug/l	Zinc ug/l	Iron ug/l	Manganese ug/l	Lead ug/l	Chromium ug/l	Nickel ug/l	Sodium ug/l	Potassium ug/l	Boron ug/l
3426	404	16	161.6	3.84	<1	<20	940	1700	<5	2.6	<100	15000	5000	<500
3427	424	73	169.6	17.52	1	<20	330000	2900	<5	2.9	<100	225000	140000	<500
3428	364	4	145.6	0.96	9	160	11000	900	9	17	100	10000	2000	<500
3429	328	19	131.2	4.56	<1	<20	3000	1300	<5	<2.5	<100	25000	2000	<500
3430	364	80	145.6	19.2	<1	<20	530000	200	<5	<2.5	<100	15000	1000	<500
3431	145	118	58	28.32	10	20	3000	400	<5	10	<100	80000	4000	<500
3432	449	173	179.6	41.52	<1	<20	3000	500	<5	16	<100	500000	400000	<500
3433	338	34	135.2	8.16	2	<20	420	100	<5	<2.5	<100	20000	20000	<500
3434	455	325	182	78	7	50	660	200	<5	2.9	<100	600000	120000	<500
3435	271	28	108.4	6.72	<1	<20	230	50	<5	<2.5	<100	25000	11000	<500
3436	279	24	111.6	5.76	<1	<20	260	30	<5	<2.5	<100	20000	9000	<500
3437	556	608	222.4	145.92	25	170	1600	400	12	12	<100	450000	600000	4000

Signed:_____
Dr. Michael Flanagan
Regional Manager/Chemist

Comment: There was some difficulty in the colourimetric determination of hardness and alkalinity due to highly coloured samples.

REPORT OF ANALYSIS

Tuam Landfill, Galway

SAMPLED BY:

Lab. Ref.	Cadmium ug/l	Arsenic mg/l	Barium mg/l	Silver mg/l	Mercury ug/l	Total Residual Chlorine	Sulphate mg/l	Fluoride mg/l F	Phenols	TOC mg/l	Residue on Evaporation	S.S. mg/l	Selenium mg/l	Arsenic mg/l	Cyanide mg/l
3426	<0.2	<5	179	<1	<1	0.03	<10	0.103	N.O.	84	559	N.M.	<0.01	<0.01	1.1
3427	<0.2	10	173	<1	<1	N.M.	14.4	<0.100	N.O.	94.6	1611	N.M.	<0.01	<0.01	0.234
3428	1.1	9	518	<1	<1	N.M.	17.3	0.265	N.O.	29.5	2629	N.M.	<0.01	<0.01	0.116
3429	<0.2	5	160	<1	<1	N.M.	<10	0.101	N.O.	44.8	476	N.M.	<0.01	<0.01	0.0632
3430	<0.2	19	171	<1	<1	N.M.	22.26	0.88	N.O.	16.6	415	N.M.	<0.01	<0.01	0.124
3431	<0.2	<5	292	<1	<1	N.M.	20.47	0.299	N.O.	33	624	N.M.	<0.01	<0.01	
3432	<0.2	6	136	<1	<1	N.M.	<10	0.147	N.O.	416	3283	N.M.	<0.01	<0.01	0.15
3433	<0.2	<5	73	<1	<1	<0.01	30.9	N.M.	N.M.	49.4	N.M.	12	N.M.	N.M.	
3434	<0.2	<5	229	<1	<1	0.01	55	N.M.	N.M.	74.1	N.M.	37	N.M.	N.M.	
3435	<0.2	<5	66	<1	<1	<0.01	30.1	N.M.	N.M.	40.4	N.M.	3	N.M.	N.M.	
3436	<0.2	<5	70	<1	<1	<0.01	10.6	N.M.	N.M.	46	N.M.	2	N.M.	N.M.	
3437	<0.2	<5	268	<1	<1	N.M.	306	N.M.	N.M.	436	N.M.	N.M.	<0.01	N.M.	

Signed:_____

Dr. Michael Flanagan

Regional Manager/Chemist

Comment: There was some difficulty in the colourimetric determination of hardness and alkalinity due to highly coloured samples.

REPORT OF ANALYSIS

Tuam Landfill, Galway

SAMPLED BY: B. O'Shea

Sampling Date	*Lab. Ref.*	Location	Temp. °C	D.O. % Sat	B.O.D. mg/l O2	Cond. uS/cm	pH	O-Phos mg/l	TON mg/l	Ammonia mg/l	Chloride mg/l	C.O.D. mg/l O2	Nitrites mg/l N	Alkalinity mg/l CaCO3	Total Hardness mg/l CaCO3
30.11.98	*4940*	SW1	8.4	36	1.8	739	7.2	0.19	3.428	0.276	22	31	0.1	348	368
30.11.98	*4941*	SW2	9.1	42	23	13200	7.7	0.587	19.605	84.251	6232	263	5	890	1230
30.11.98	*4942*	SW3	7.3	66	4.5	948	7.3	0.114	1.746	1.779	163	63	0.075	248	268
30.11.98	*4943*	SW4	6	73	0.9	890	7.4	0.113	1.772	1.381	157	67	0.1	248	268
30.11.98	*4944*	8A	10.5	26	N.M.	902	6.9	0.024	<0.010	1.307	28	N.M.	N.M.	464	480
30.11.98	*4945*	3AP	9.5	30	N.M.	789	7	0.009	<0.010	0.117	16	N.M.	N.M.	N.M.	408
30.11.98	*4946*	10AP	10.1	20	N.M.	6130	7.1	13.663	0.135	543.138	703	N.M.	N.M.	N.M.	690
30.11.98	*4947*	4AP	9.1	18	N.M.	2450	6.5	1.524	<0.010	46.636	565	N.M.	N.M.	N.M.	510
30.11.98	*4948*	5A	10.9	11	N.M.	740	6.9	0.282	0.089	4.291	24	N.M.	N.M.	N.M.	400
30.11.98	*4949*	5AP	9.5	21	N.M.	710	6.9	0.049	<0.010	1.163	17	N.M.	N.M.	376	380
30.11.98	*4950*	L1	7.9	17	54.8	8180	8.1	4.912	<0.010	580.114	1336	1479	N.M.	N.M.	1040

N.M. - Not Measured.
N.D. - None Detected

Signed:_____
Dr. Michael Flanagan
Regional Manager/Chemist

Comment: There was some difficulty in the colourimetric determination of hardness and alkalinity due to highly coloured samples.

REPORT OF ANALYSIS

Tuam Landfill, Galway

SAMPLED BY:

Lab. Ref.	Calcium Hardness mg/l CaCO3	Magnesium Hardness mg/l CaCO3	Calcium mg/l	Magnesium mg/l	Copper ug/l	Zinc ug/l	Iron ug/l	Manganese ug/l	Lead ug/l	Chromium ug/l	Nickel ug/l	Sodium ug/l	Potassium ug/l	Boron ug/l
4940	360	8	144	1.92										
4941	810	420	324	100.8										
4942	240	28	96	6.72										
4943	244	24	97.6	5.76										
4944	420	60	168	14.4										
4945	388	20	155.2	4.8										
4946	350	340	140	81.6										
4947	420	90	168	21.6										
4948	308	92	123.2	22.08										
4949	340	40	136	9.6										
4950	460	580	184	139.2										

Comment: There was some difficulty in the colourimetric determination of hardness and alkalinity due to highly coloured samples.

Signed:_____
Dr. Michael Flanagan
Regional Manager/Chemist

REPORT OF ANALYSIS

Tuam Landfill, Galway

SAMPLED BY:

Lab. Ref.	Cadmium ug/l	Arsenic mg/l	Barium mg/l	Silver mg/l	Mercury ug/l	Total Residual Chlorine	Sulphate mg/l	Fluoride mg/l F	Phenols	TOC mg/l	Residue on Evaporation	Selenium mg/l	Arsenic mg/l	Cyanide mg/l
4940						<0.01	16	N.M.	N.M.		N.M.			
4941						<0.01	431	N.M.	N.M.		N.M.			
4942						<0.01	37.9	N.M.	N.M.		N.M.			
4943						<0.01	33.9	N.M.	N.M.		N.M.			
4944						N.M.	24.2	0.563	N.D.		558			
4945						N.M.	1.5	0.0492	N.D.		3317			0.161
4946						N.M.	4.2	0.0504	N.D.		545			0.56
4947						N.M.	0.2	0.0451	N.D.		1606			0.353
4948						N.M.	0.5	0.12	N.D.		3351			0.464
4949						N.M.	0.6	0.0451	N.D.		343			
4950						N.M.	547	N.M.	N.D.		N.M.			

Signed:_____
Dr. Michael Flanagan
Regional Manager/Chemist

Comment: There was some difficulty in the colourimetric determination of hardness and alkalinity due to highly coloured samples.

REPORT OF ANALYSIS

Tuam Landfill, Galway

SAMPLED BY: B O'Shea

Sampling Date	*Lab. Ref.*	Location	Temp. °C	D.O. % Sat	B.O.D. mg/l O2	Cond. uS/cm	pH	O-Phos mg/l	TON mg/l	Ammonia mg/l	Chloride mg/l	C.O.D. mg/l O2	Nitrites mg/l N	Alkalinity g/l CaCO3	Total Hardness mg/l CaCO3
08/02/99	574	SW1	6.2	33	13.7	679	7.3	0.762	1.75	0.171	37	86	0.05	304	352
08/02/99	575	SW2	7.1	19	11	6900	7.5	0.08	21.252	35.487	2570	134	4	79	1250
08/02/99	576	SW3	6	75	5.2	584	7.4	0.43	1.206	1.286	81	53	0.05	180	220
08/02/99	577	SW4	5.6	87	2.7	568	7.5	0.292	1.321	1.025	63	99	0.04	196	288
08/02/99	578	3AP	7.3	37	N.M	756	7	<0.008	<0.010	0.177	20	N.M	N.M	436	440
08/02/99	579	4AP	5.6	41	N.M	2500	6.5	0.345	<0.010	44.702	716	N.M	N.M	580	1180
08/02/99	580	5A	8.1	34	N.M	720	7	<0.008	<0.010	1.772	19	N.M	N.M	488	560
08/02/99	581	5AP	6.3	51	N.M	639	7.1	0.018	<0.010	0.201	21	N.M	N.M	320	328
08/02/99	582	8A	10	14	N.M	917	7.3	0.016	<0.010	1.932	39	N.M	N.M	504	532
08/02/99	583	10AP	6.3	37	N.M	5500	7.5	14.081	0.124	531.966	652	N.M	N.M	N.R	770
08/02/99	584	L1	4	N.M	164.3	6600	8.2	4.884	0.489	419.11	1189	1402	N.M	N.R	1210

REPORT OF ANALYSIS

Tuam Landfill, Galway

SAMPLED BY:

Lab. Ref.	Calcium Hardness g/l CaCO3	Magnesium Hardness g/l CaCO3	Calcium mg/l	Magnesium mg/l	Copper ug/l	Zinc ug/l	Iron ug/l	Manganese ug/l	Lead ug/l	Chromium ug/l	Nickel ug/l	Sodium ug/l	Potassium ug/l	Boron ug/l
574	308	44	73.92	10.56										
575	710	540	170.4	129.6										
576	176	44	42.24	10.56										
577	184	104	44.16	24.96										
578	400	40	96	9.6										
579	590	590	141.6	141.6										
580	384	176	92.16	42.24										
581	300	28	72	6.72										
582	488	44	117.12	10.56										
583	300	470	72	112.8										
584	1100	110	264	26.4										

REPORT OF ANALYSIS

Tuam Landfill, Galway

SAMPLED BY:

Lab. Ref.	Cadmium ug/l	Arsenic mg/l	Barium mg/l	Silver mg/l	Mercury ug/l	Total Residual Chlorine	Sulphate mg/l	S.S mg/l	Fluoride mg/l F	Phenols	TOC mg/l	Total Solids	Selenium mg/l	Cyanide mg/l
574						<0.010	2.1	9.4	N.M		23.02	N.M		
575						<0.010	319.5	17	N.M		24.91	N.M		
576						<0.010	0.9	9	N.M		17.71	N.M		
577						<0.010	1.5	10.2	N.M		20.02	N.M		
578						N.M	1.2	N.M	<0.1		42.48	526		
579						N.M	11.9	N.M	<0.1		20.22	1712		
580						N.M	2	N.M			19.46	963		
581						N.M	2.4	N.M	<0.1		29.82	475		
582						N.M	21.7	N.M	0.76		8.77	615		
583						N.M	3.4	N.M	0.14		24.7	3272		
584						N.M	77.5	N.M	N.M		37.2	N.M		

APPENDIX D

RESULTS OF TESTING OF SOIL FROM CONSTRUCTION SITE OF MR. T. LAVELLE, TUAM

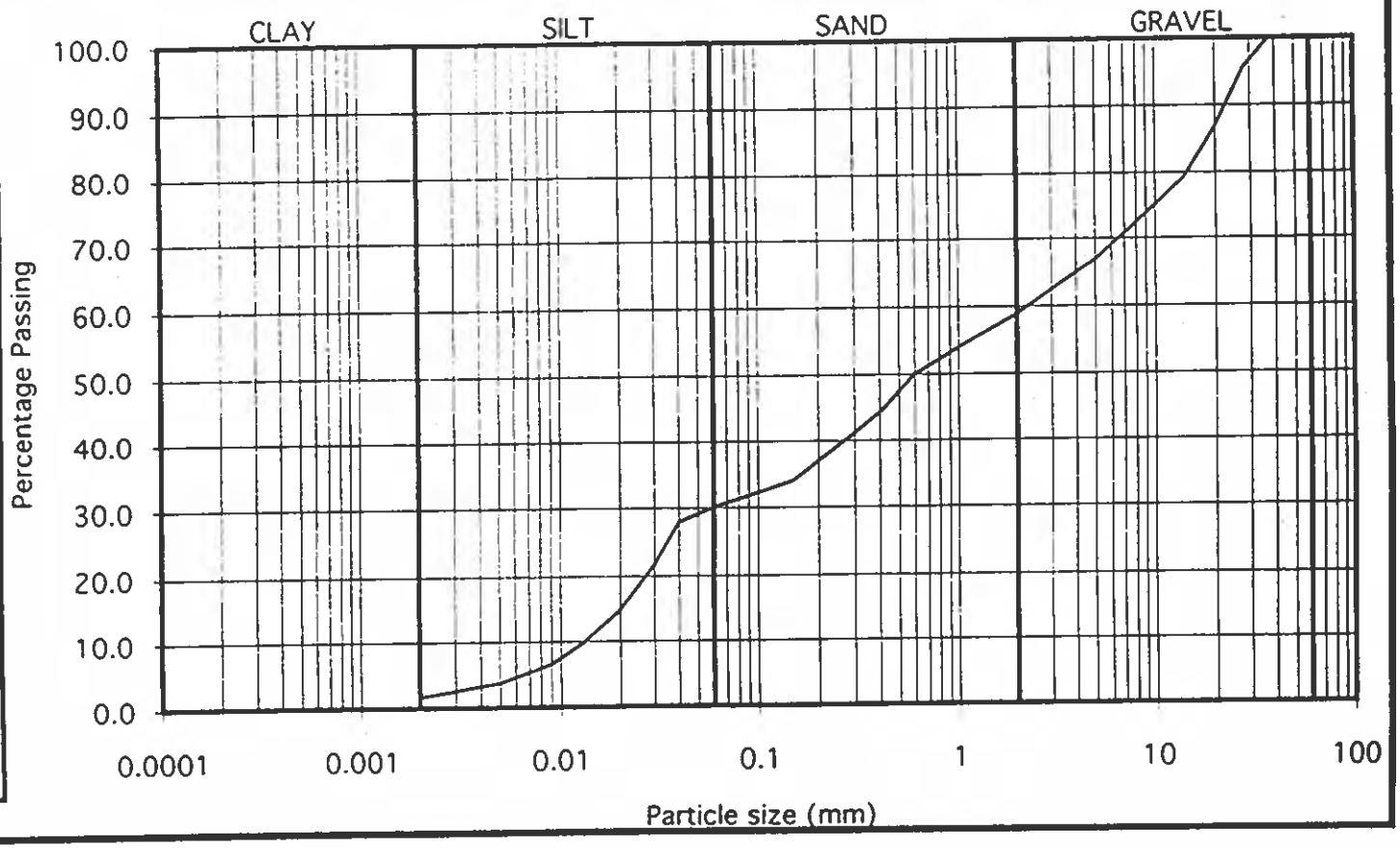
Report No.

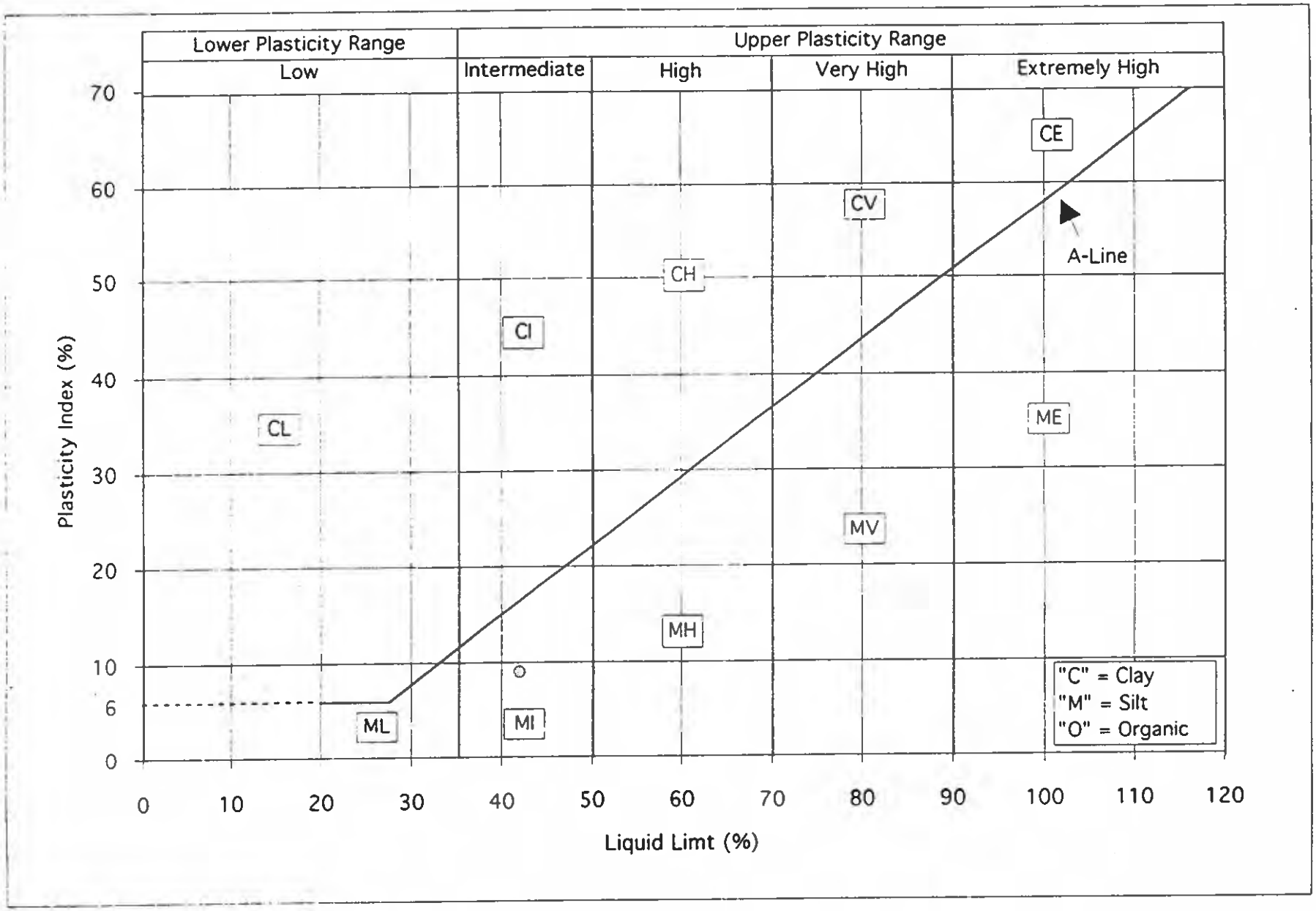
PARTICLE SIZE ANALYSIS

I.G.S.L

CONTRACT: MCOS Order Reference No. 3292
BOREHOLE No. \
SAMPLE No. A
DEPTH: \
TEST: Wet Sieve & Hydrometer

particle size	%passing	
75	100.0	COBBLES
63	100.0	GRAVEL
50	100.0	
37.5	100.0	
28	95.5	
20	86.7	
14	79.2	
10	75.0	
6.3	69.4	
5	66.7	
3.35	63.3	
2	58.9	SAND
1.18	55.2	
0.6	50.0	
0.425	45.0	
0.3	41.1	
0.15	34.0	
0.063	30.3	SILT/CLAY
0.04	27.9	
0.03	21.6	
0.02	14.8	
0.013	9.7	
0.009	6.6	
0.005	3.7	
0.002	1.7	




Lower Plasticity Range
Upper Plasticity Range
Low
Intermediate
High
Very High
Extremely High
Plasticity Index (%)
Liquid Limt (%)
0
6
10
20
30
40
50
60
70
0
10
20
30
40
50
60
70
80
90
100
110
120
CL
ML
CI
MI
CH
MH
CV
MV
CE
ME
A-Line
"C" = Clay
"M" = Silt
"O" = Organic

Report No.	CLASSIFICATION TEST RESULTS							IGSL
Contract:	MCOS Order Reference No. 3292							
Borehole No.	Depth (M)	Reference No.	Liquid Limit (LL)	Plastic Limit (PL)	Plasticity Index (PI)	Water Content %	pH	Sulphate Content %
\	\	A	42	33	9	42.87		

Report:

ORGANIC TEST RESULTS

CONTRACT : MCOS Order Reference No. 3292
CLIENT : M.C.O'Sullivan & Company

BOREHOLE NO.	SAMPLE NO.	DEPTH (M)	SAMPLE TYPE	TEST CODE	PERCENTAGE OF ORGANIC MATTER
\	A	\	D	Org.	0.91

COMPACTION TEST

I.G.S.L.

CONTRACT	LOCATION
CLIENT MCOS	SAMPLE No. A
ENGINEER	DEPTH (m)

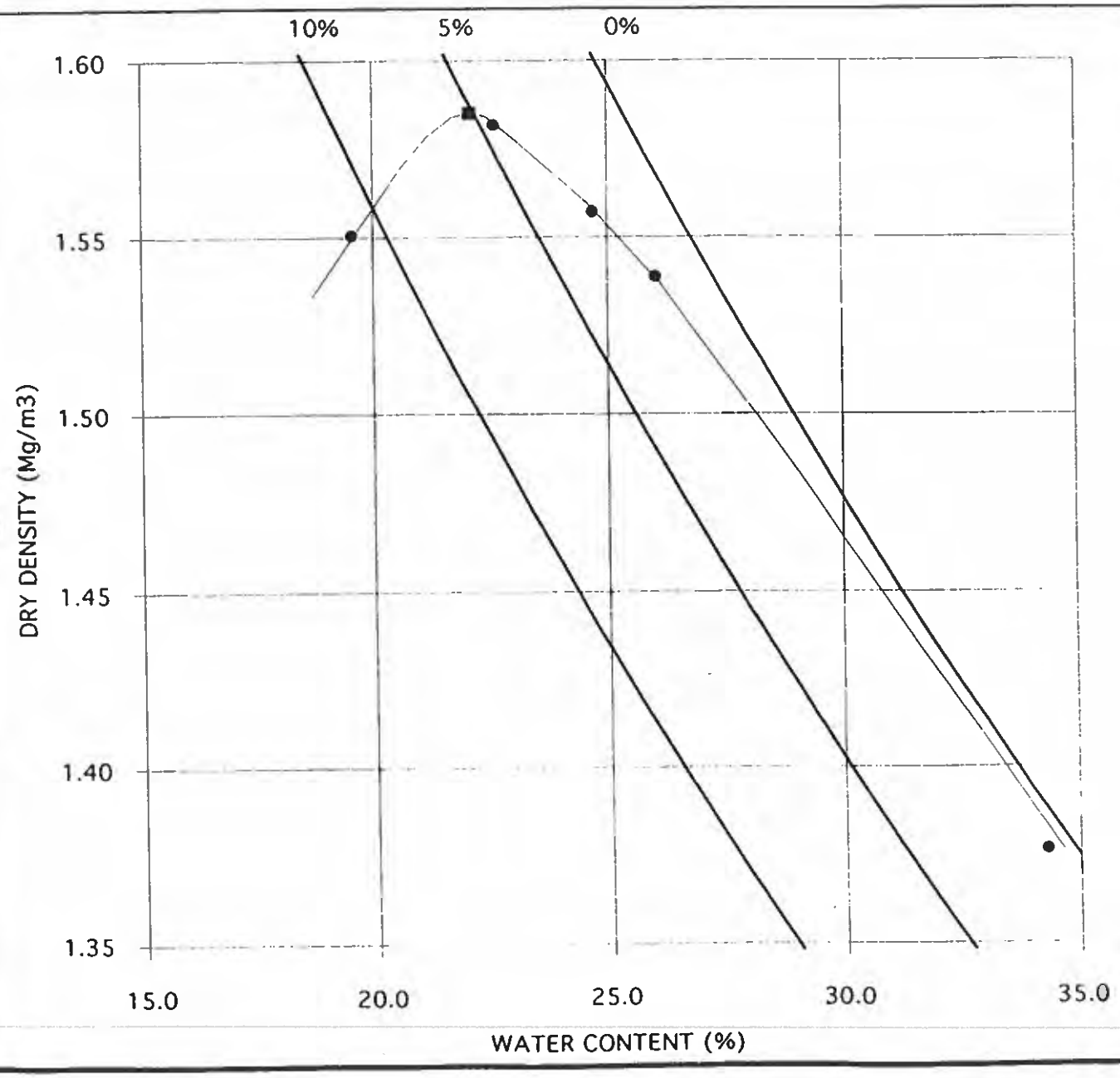
TEST METHOD 2.5 kg
DESCRIPTION
PASSING 20mm SIEVE (%)=

RESULTS:

OPTIMUM DRY DENSITY=	1.59	Mg/m^3
OPTIMUM WATER CONTENT=	22.10	%
NATURAL WATER CONTENT=	34.30	%

WATER CONTENT (%)	19.5	22.6	24.7	26.0	34.3
DRY DENSITY (Mg/m^3)	1.55	1.58	1.56	1.54	1.38

* Gs taken as 2.65



FEHILY TIMONEY

CONSULTANTS IN ENGINEERING,
ENVIRONMENTAL SCIENCE & PLANNING

APPENDIX 4

Topographical Survey

NOTES:
1. All levels are relative to Ordnance Datum Malin Head
2. 50m sq grid relative to Irish Transverse Mercator Co-ordinate reference system
3. Contours are at 0.25m intervals

SYMBOL LEGEND

AV	Air Valve	SV	Sluice Valve
V	Valve	WV	Water Valve
FH	Fire Hydrant	WM	Water Meter
IC	Inspection Chamber	Post	Post
	Telecom Duct		ESB Duct
TC Box	Telcom Box	ESB Box	ESB Box
T	Tree	EP	ESB Pole
	Tree Spread	TP	Telecom Pole
	Bush/Shrub	LS	Lamp Standard
Sign	Sign	T Sign	Traffic Sign
AJ	Armstrong Junction	GY	Gully
ER	Earth Rod	Gas	Gas
TL	Traffic Light	B	Bollard
CATV	Cable TV Duct	Bin	Bin
G	Gate	Stay	Stay
MH / CO	Manhole & Cover Level	Serv	Service
SS	Survey Station	Pipe	Pipe
RH	Ridge Height	Coping	Coping Height
FFL	Finished Floor Level	Gutter	Gutter Height
Eaves	Eaves Height	Roof	Roof Height
6.78	Boundary Height	9.55	Spot Height

LINE TYPE LEGEND

	Wall		Concrete Edge
	Fence		Centerline of Trees
	Footpath		Hedge
	Drain/River		Step
	Flower Bed		Plinth
	ESB Line		Telecom Line
	Mound		Building
	Kerb		Road
11.00	Contour Major	10.75	Contour Minor
	Bottom of Bank		Top of Bank
	Yellow Line		White Line

GRAPHIC SCALE
(IN METERS)
10 0 5 10 20 30 40 50
1 : 500

REVISIONS

No.	Date	Description

Control Surveys
land and building surveyors
Innovation Works, National Technology Park, Plassey, Castletroy, Limerick.
Tel: 061 546982 | Mob: 087 2659112 | Email: cian@controlsurveys.ie
Website: www.controlsurveys.ie
• Topographical Surveys • As Built Surveys •
• Measured Building Surveys • GPS Surveys •
• Legal Mapping • Setting Out •

Client:

Professional:
Fehily Timoney & Co

Project Title:
Topographical Survey of Historical Landfill, Tuam, Co Galway.

Drawn:	SÓ	**Dwg No:**	20-207-01
Scale:	1:500	**Date:**	05-06-20

FEHILY TIMONEY

CONSULTANTS IN ENGINEERING,
ENVIRONMENTAL SCIENCE & PLANNING

APPENDIX 5

Minerex Geoservices
Geophysical Survey Report

Tuam Historic Landfill

Tuam Co. Galway

Geophysical Survey

Report Status: Final

MGX Project Number: 6499

MGX File Ref: 6499f_Tuam-005.doc

4th October 2022

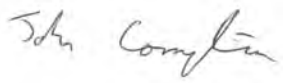
Confidential Report To:

Fehily Timoney & Co.
J5 Plaza
North Park Business Park
North Road
Dublin 11

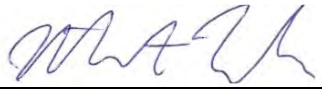
Report submitted by:
Minerex Geophysics Limited

Unit F4, Maynooth Business Campus
Maynooth, Co. Kildare, W23X7Y5
Ireland
Tel.: 01-6510030
Email: info@mgx.ie

Issued by:



Author: John Connaughton (Geophysicist)



Reviewer: Hartmut Krahn (Senior Geophysicist)

Minerex Geophysics Limited

Subsurface Geophysical Investigations

EXECUTIVE SUMMARY

1. Minerex Geophysics Ltd. (MGX) carried out a geophysical survey consisting of EM31 ground conductivity, 2D-Resistivity and seismic refraction (p-wave) surveying for the ground investigation of the Tuam Historic landfill, County Galway.
2. The main objectives of this survey were to identify the extent and depth of the former landfill site, quantify the volume of the waste, provide information on nature of the waste body, waste type and composition, look for evidence of leachate migration from the site and provide information on the underlying subsoil and bedrock.
3. The online geological map of Ireland (GSI, 2019) indicates the bedrock under the site is Visean Limestones, described as undifferentiated limestone. Visean Limestone is karstifiable.
4. The EM31 Ground Conductivity survey shows high conductivities throughout the site which indicates mainly domestic or commercial & industrial (C&I) waste material. The conductivities decrease towards the periphery of the site which indicates a reduction in the thickness of waste material. The extent of the waste material on the site covers an area of 23,300m^2. The extent of the site to the surrounding drain is 27,700 m^2.
5. The depth of the waste layer extends to the level of the surrounding land which is around 35 – 39 mOD. The total average depth of waste material is approx. 8 m.
6. Total volume of waste material is calculated as 186,400 m^3.
7. The layer below the landfill may consist of clay or peat overburden or overburden with leachate.
8. Fresh rock below this layer minimises migration of leachate but there may be possible leachate migration into the rock near the west of the site.

CONTENTS

List of Tables, Maps and Figures:

1. INTRODUCTION

1.1 Background

Minerex Geophysics Ltd. (MGX) carried out a geophysical survey at an historic landfill in Tuam, Co. Galway. The survey consisted of EM31 ground conductivity, 2D-Resistivity and seismic refraction (p-wave) measurements. The survey was commissioned by Fehily Timoney & Co.

The survey employed various geophysical methods that complement each other and improve the interpretation. The role of geophysics as a non-destructive fast method is to allow later targeted direct investigations. Those results can be used to improve the initial results and interpretation.

A geophysical survey is a fast and effective way to investigate the waste size, extent and possible leachate from the landfill in a non-invasive manner. The geological background is also investigated a part of the survey. This survey is part of the Tier 2 site investigation and test report.

1.2 Objectives

The main objectives of the geophysical survey were:

- Identify the extent and depth of the former landfill
- Quantify the volume of the waste
- Provide information on the nature of the waste body, waste type and composition
- Look for evidence of leachate migration from the site
- Provide information on the underlying subsoil and bedrock

1.3 Site Description

The site is located off the R347 south of the town of Tuam. The Barna Waste Recycling Centre is located in the SE corner of the site. The site has a dome shaped topography with the highest elevations in the middle of the site and steep drops in elevations around the edges. The survey area consists of a capped historic landfill, grassed across its extents, surrounded by a wire fence. The site is accessed via the adjoining recycling centre/civic amenity site.

1.4 Geology

The online bedrock geological map of Ireland (GSI, 2019) describes the quaternary sediments as cut over raised peat. The survey area is underlain mostly by Visean Limestone, described as undifferentiated limestone.

Two Rotary Core holes carried out in the adjacent field show peat overlain by silt and clay overburden. GW02 noted limestone at 6.4 m below ground level.

Visean Limestone is karstifiable but the nearest karst features are over 1.7 km NE of the site.

1.5 Report

This report includes the results and interpretation of the geophysical survey. Maps, figures and tables are included to illustrate the results of the survey. More detailed descriptions of geophysical methods and measurements can be found in GSEG (2002), Milsom (1989) and Reynolds (1997).

The client provided maps of the site and the digital version was used as the background map in this report. Elevations were surveyed on site and are used in the vertical sections.

The interpretative nature and the non-invasive survey methods must be taken into account when considering the results of this survey and Minerex Geophysics Limited, while using appropriate practice to execute, interpret and present the data, give no guarantees in relation to the existing subsurface.

2. GEOPHYSICAL SURVEY

2.1 Methodology

The methodology is outlined in the tender documents and consisted of EM31 Ground Conductivity measurements across the site to map and determine targets for additional geophysical methods including 2D-Resistivity and Seismic Refraction Profiling. These profiles were carried out in different directions through the middle of the waste body as identified through the EM31 ground conductivity survey.

The survey locations are indicated on Map 1. The profiles and parameters are tabulated in Table 1 below.

All geophysical surveys are acquired, processed and reported in accordance with British Standards BS 5930:1999 +A2:2010 'Code of Practice for Site Investigations'.

Table 1: Geophysical Survey Locations and Acquisition Parameters

Profile Name	**Electrode/Geophone Spacing/m**	**Number of Electrodes/Geophones**	**Profile Length/m**
R1	3	54	159
R2	3	72	213
SUM			**372**
S1	3	54	159
S2	3	72	213
SUM			**372**

2.2 EM31 Ground Conductivity

The EM31 ground conductivity survey was carried out over the area indicated in Map 1 on lines nominally 10 m apart. Along each line a reading of ground conductivity was taken every second while walking along, thereby resulting in a survey grid of nominally 10 x 2 m. The locations were measured with a sub-meter accuracy SERES DGPS system attached to the EM31 and all data was jointly stored in a data logger. The conductivity meter was a GEONICS EM31 with Allegro data logger and NAV31 data acquisition software. The instrument was checked at a base station, the readings were stable and no drift occurred.

EM31 ground conductivity determines the bulk conductivity of the subsurface over a typical depth between 0 and 6 m below ground level (bgl). and over a radius of approx. 5 m around the instrument.

2.3 2D-Resistivity

2D-Resistivity profiles were surveyed with electrode spacing of 3 m, up to 64 electrodes per set-up and a maximum length of 189 m per profile. The readings were taken with a Tigre Resistivity Meter, Imager Cables, stainless steel electrodes, laptop and ImagerPro acquisition software. Profile R2 was acquired in roll-along mode to achieve continuous depth across the profile.

During 2D-Resistivity surveying data is acquired in the form of linear profiles using a suite of metal electrodes. A current is injected into the ground via a pair of electrodes while a potential difference is measured across a second pair of electrodes. This allows for the recording of the apparent resistivity in a two-dimensional arrangement below the profile. The data is inverted after the survey to obtain a model of subsurface resistivities. The generated model resistivity values and their spatial distribution can then be related to typical values for different geological and manmade materials.

The penetration depth of a resistivity profile increases towards the centre where it reaches an approx. value of 1/6th of the layout length.

2.4 Seismic Refraction

Seismic refraction profiles were surveyed with geophone spacing of 3 m and 24 geophones per set-up resulting in a 69 m length per set-up. The recording equipment consisted of a 24 Channel GEOMETRICS ES-3000 engineering seismograph with 4.5 Hz vertical geophones. The seismic energy source consisted of a hammer and plate. A zero-delay trigger was used to start the recording. Normally 7 shot points per p-wave profile were used.

Set-ups were acquired in longer continuous profiles using common shot points between set-ups and concatenating into longer profiles at the processing stage.

In the seismic refraction survey method, a p-wave is generated by a source at the surface resulting in energy travelling through surface layers directly and along boundaries between layers of differing seismic wave velocities. Processing of the seismic data allows geological layer thicknesses and boundaries to be established.

Seismic Refraction generally determines the depth to horizontal or near horizontal layers where the compaction/strength/rock quality changes with an accuracy of 10 – 20% of depth to that layer. Where low velocity layers or shadow zones are present (e.g. below solid ground surface) or where layers dip with more than 20 degrees angle the accuracy becomes much less.

2.5 Site Work

The data acquisition was carried out on the 21st May and 9th of June 2020. The weather conditions were variable throughout the acquisition period. Health and safety standards were adhered to at all times. The locations and elevations were surveyed with a Carlson NR3 RTK-GPS to accuracy < 0.05 m.

3. RESULTS AND INTERPRETATION

The interpretation of geophysical data was carried out utilising the known response of geophysical measurements, typical physical parameters for subsurface features that may underlay the site, and the experience of the authors.

Direct ground investigations were provided after the survey. Five trial pits were carried out over the identified landfill area. Four of these were terminated at the geo-composite clay liner overlying the landfill at a depth of 0.2 – 0.4 m. TP04 was carried out in a corner of the landfill and identified waste to a depth of 2 m below ground level before being terminated.

3.1 EM31 Ground Conductivity

The EM31 ground conductivity values were merged into one data file for the survey area and contoured and gridded with the SURFER contouring package. The contours are created by gridding and interpolation and care must be taken when using the data. The contour map is overlaid over the location and base map (Map 2) and the values in milliSiemens/metre (mS/m) are indicated on the colour scale bar.

Within the top 6 m bgl, the conductivities are characteristic for certain overburden and rock types. If there is a high content of clay minerals (which are electrically conductive) then the overburden conductivity will be higher than as if there is a high content of clastic grains like sand or gravel. The purer the clay and the lower the sand/gravel content the higher the conductivity. The water content in the overburden also influences the conductivity but generally the clay content has a larger effect.

Non-natural material like waste or leachate will generally have a high conductivity or increase the conductivity of the natural geological material. Many waste materials decompose or dissolve in the ground and enrich the ground and water with ions, which increase the conductivity and decrease the resistivity. Waste material from domestic or commercial and industrial (C&I) sources generally contain more decomposable or dissolvable material than waste from construction or demolition (C&D). Therefore domestic or C&I Waste will have lower resistivities and higher conductivities than C&D waste.

The scale used on this site represents the very high conductivity results surveyed throughout the site. The highest conductivities are found in the centre of the site where conductivities are typically above 60 mS/m. Very high conductivities indicate deep domestic or C&I waste material. Around the edge of the site the conductivities begin to decrease. Conductivities between 20 – 30 mS/m would indicate some waste material, while conductivities of less than 20 mS/m which are only found on the periphery of the site would usually indicate soil and rock fill, natural material or C&D waste.

3.2 2D-Resistivity

The 2D-Resistivity data was positioned and inverted with the RES2DINV inversion package. The programme uses a smoothness constrained least-squares inversion method to produce a 2D model of the subsurface model resistivities from the recorded apparent resistivity values. Three variations of the least squares method are available and for this project the Jacobian Matrix was recalculated for the first three iterations, then a Quasi-Newton approximation was used for subsequent iterations. Each dataset was inverted using seven iterations resulting in a typical RMS error of <3.0%. The resulting models were colour contoured with the same resistivity scale for all profiles and they are displayed as cross sections (Figure 1). A vertical exaggeration of 4 is used for the sections.

The resistivities are the inverse value of the conductivities therefore remarks made above for the conductivity are also valid for the resistivity. It has to be considered that the conductivity is determined as a single bulk value for a depth range from 0 - 6 m bgl while the 2D-Resistivity method determines the values based on depth levels.

Both profiles show a rapid change with depth from low resistivities to high resistivities at approx. 30 mOD. Low resistivities (<62.5 Ohm) indicate mainly domestic or C&I waste material or leachate but may also indicate clay-rich or peat overburden. High resistivities (>500 Ohmm) at depth indicate fresh limestone. Both profiles are laterally consistent which indicates domestic or C&I waste throughout the site.

Profile R1 has low – medium conductivities at depth. This may indicate a karst feature or leachate penetrating into the rock layer. It may also be an artificial effect of the very low resistivities above it and sharp topography along the surface.

3.3 Seismic Refraction

The p-wave seismic velocity is closely linked to the density of subsurface materials and to parameters like compaction, stiffness, strength and rock quality. The higher the density of the subsurface materials the higher the seismic velocity. Similarly, for the other parameters it is generally valid that a more compacted, stiffer and stronger material will have a higher seismic velocity. For rock, the seismic velocity is higher when the rock is stronger, less weathered and has a higher quality. If the rock is more weathered, broken, fractured, fissured or karstified then the seismic velocity will be reduced compared to that of intact fresh rock.

The seismic refraction data was positioned and processed with the SEISIMAGER software package. The data shows very low seismic velocities near the surface but did not identify any higher velocity layers within the parameters of the survey. This occurs typically when the waste material is generally greater than 5 m thick. Velocities were determined for the ground below the surface and these are annotated on the sections on Figure 1.

3.4 Interpretation of Resistivity and Seismic Refraction

The seismic refraction and 2D-Resistivity provide information on two physical parameters of the waste material, however as discussed above the waste material may share some of these physical parameters with other material. Therefore, by using both methods together a clearer picture of the waste body is obtained.

Waste material generally consists of low velocity, low resistivity material. The 2D-Resistivity data and the seismic refraction data shows low velocities and resistivities near the surface across the survey area. Historic maps do not show any development on the site previous to it being a landfill and it is assumed the waste was dumped on the surface rather than in an excavation. The surrounding elevations are around 35 – 39 mOD which is the assumed depth of the landfill. This gives a waste layer which is up to 10 m thick near the middle of the site but becomes very thin near the edges where the topography drops off.

Where low resistivities continue below this, it is an indication of leachate in the natural ground below the landfill. The low resistivities below the landfill may also be due to clay-rich or peat overburden.

High resistivities beginning at between 25 and 30 mOD along both profiles give an indication of rock depth as the seismic refraction model do not penetrate to this depth. The high resistivities are interpreted as good limestone with no leachate.

Along Profile R1, low – medium resistivities at depth may indicate leachate in the rock layer, karstified rock or it may be an artificial effect from the strong topographical gradient on the surface and the fact that the profile does not reach the natural ground around the landfill.

Table 2 summarises the interpretation. Interpreted cross sections are shown in Figure 2. The interpretation has been made from all available information. The resistivity models have been used to delineate between waste and natural material and the depth to rock. Resistivity data is better suited to show rock types and features within the rock while seismic refraction velocities are indicating the change of compaction, stiffness or rock quality with depth.

Table 2: Summary of Interpretation

Layer	**General Seismic Velocity Range (m/sec)**	**General Resistivity Range (Ohmm)**	**Interpretation**
1	200	<62.5	Waste (Mainly Domestic or C&I Waste)
2	700	>62.5	Overburden with Leachate
3a	N/A	>500 (At Depth)	Fresh Limestone
3b	N/A	<500 (At Depth)	Karstified Limestone, Leachate within Limestone or Artificial Effect

4. CONCLUSIONS AND RECOMMENDATIONS

Geological Background

The geophysical survey indicates the landfill is underlain by overburden over fresh limestone. The overburden material below the waste material is approx. 9 m thick and could contain any material like peat, clay or sand and gravel. The fresh limestone should restrict the movement of leachate below the waste and overburden however low resistivities along profile R1 may indicate leachate penetration towards the west of the site.

Lateral extent of waste and landfill boundary

The area outlined in orange on Map 3 shows the interpreted extent of the landfill using all the information available. The interpreted landfill extent covers an area of approx. 23,300 m^2. The extent of the site to the surrounding drain covers an area of 27,700m^2.

Vertical extent (depth) of waste

The thickness/depth has been estimated from the seismic refraction and 2D-Resistivity data. Considering the thickness of the interpreted Layer 1, an average thickness of 8 m has been calculated for the waste material. This estimate includes any capping or natural fill material on top of the main waste body.

Including the layer of overburden below the landfill containing leachate (Layer 2), the total depth of waste and leachate reaches an average of 17 m bgl.

Volume of waste

Considering the areas and average thickness above, the volume of the waste body is estimated at 186, 400 m^3.

Nature of waste

Low resistivities and seismic velocities measured are consistent with domestic or commercial & industrial (C&I) waste throughout of the landfill.

Capping layer

The geophysical survey does not show any significant natural material over the landfill. Trial pits have determined there is a geo-composite clay liner overlying the landfill at a depth of 0.2 – 0.4 m.

Leachate

Low resistivities below the waste body is interpreted as likely leachate. The fresh limestone below this layer should generally restrict the leachate movement but there may be leachate penetration into the rock along profile R1.

5. REFERENCES

1. **GSEG 2002.** Geophysics in Engineering Investigations. Geological Society Engineering Geology Special Publication 19, London, 2002.

2. **GSI, 2019.** Online Bedrock Geological Map of Ireland. Geological Survey of Ireland 2019.

3. **Milsom, 1989.** Field Geophysics. John Wiley and Sons.

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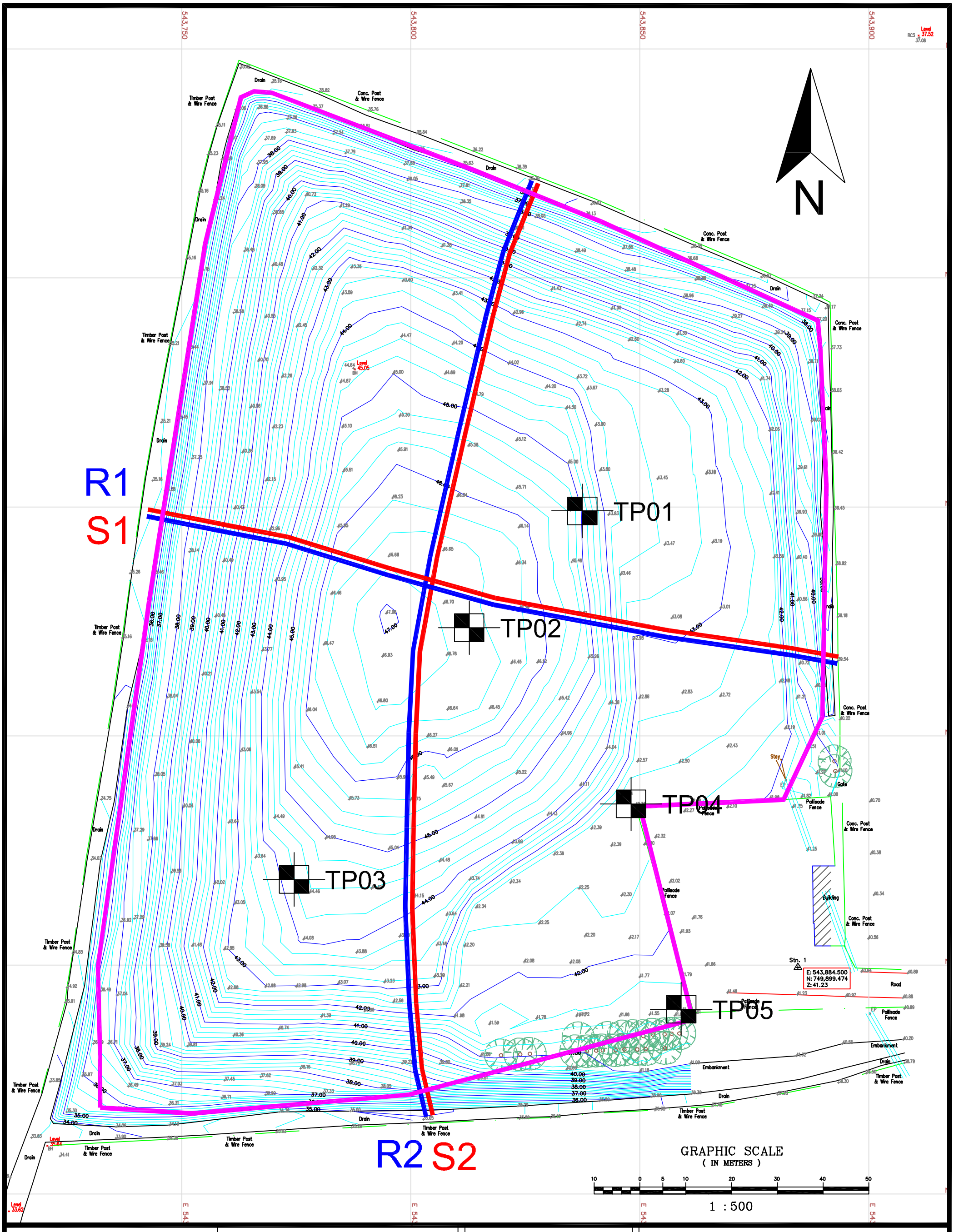

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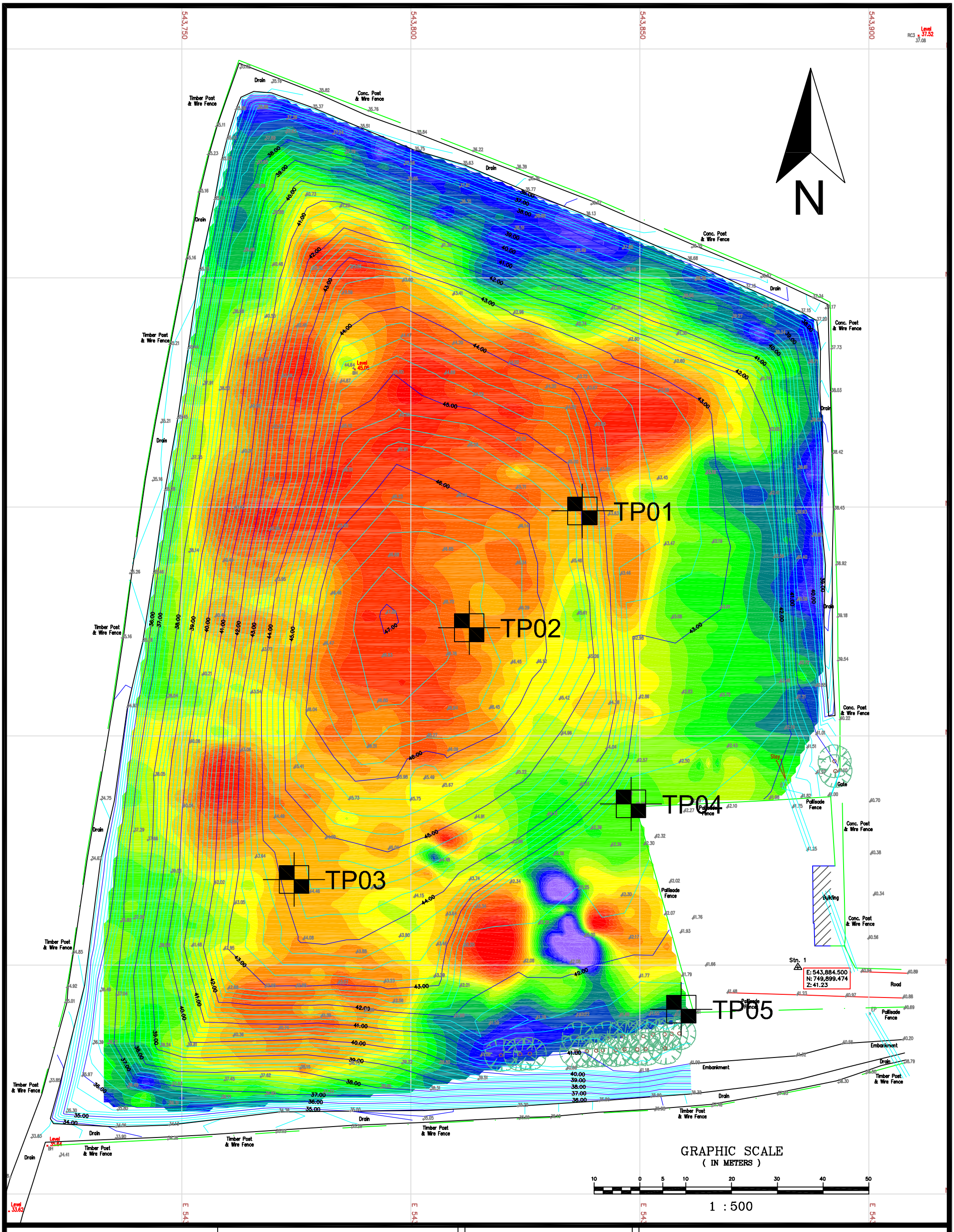
CLIENT	FTCO
PROJECT	Tuam Historic Landfill Geophysical Survey
TITLE	Map 1: Geophysical Survey Location Map

SCALE:	1:750 @ A3
PROJECT:	6499
DRAWN:	JC
DATE:	22/05/2020
MGX FILE:	6499f_Tuam_MapsFigs.dwg
STATUS:	Final

LEGEND: Geophysical Survey Locations:

- R2 — 2D-Resistivity Profile
- S1 — Seismic Refraction Profile
- EM31 Survey Area



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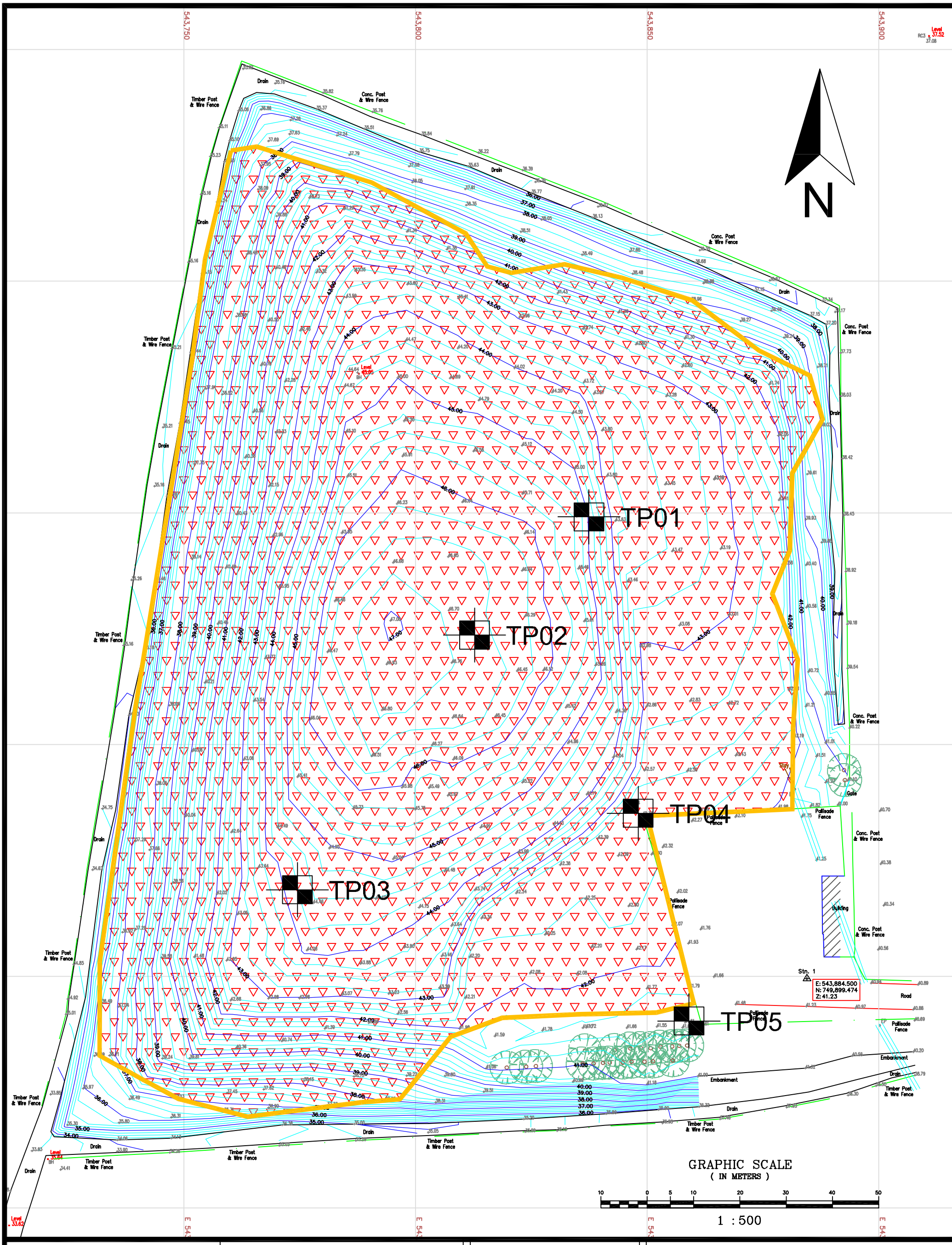
CLIENT	FTCO
PROJECT	Tuam Historic Landfill Geophysical Survey
TITLE	Map 2: EM31 Ground Conductivity Contour Map

SCALE:	1:750 @ A3
PROJECT:	6499
DRAWN:	JC
DATE:	22/05/2020
MGX FILE:	6499f_Tuam_MapsFigs.dwg
STATUS:	Final

LEGEND: EM31 Ground Conductivity Values:

0 10 20 30 40 50 60 70 80 90 100

The map shows the EM31 ground conductivity contours mS/m. The low (blue) conductivities indicate the no waste material. The middle range (green) values indicates some waste material. The high (red) values indicates the deepest waste area.



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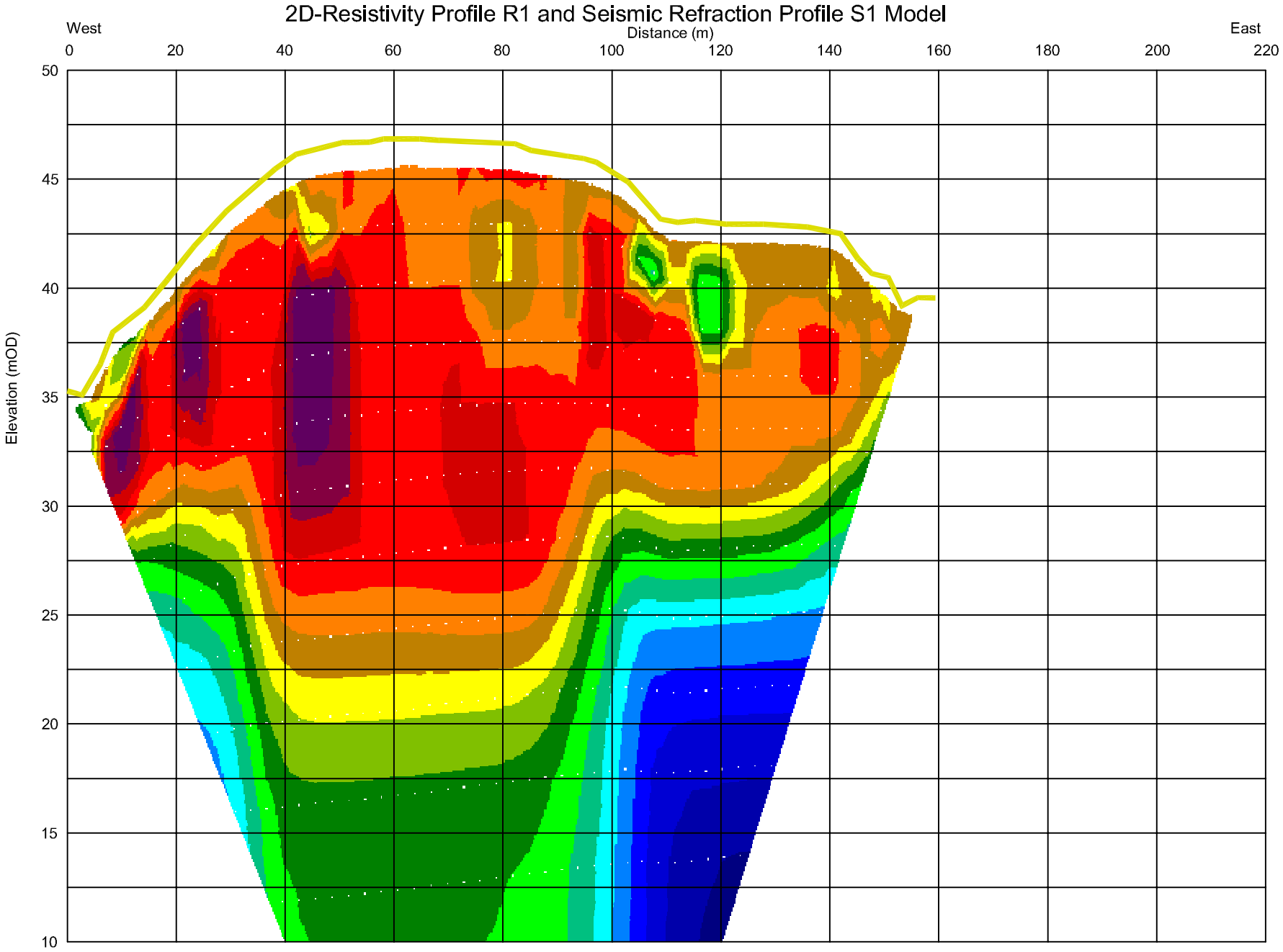
CLIENT	FTCO
PROJECT	Tuam Historic Landfill Geophysical Survey
TITLE	Map 3: Geophysical Survey Interpretation Map

SCALE:	1:750 @ A3
PROJECT:	6499
DRAWN:	JC
DATE:	22/05/2020
MGX FILE:	6499f_Tuam_MapsFigs.dwg
STATUS:	Final

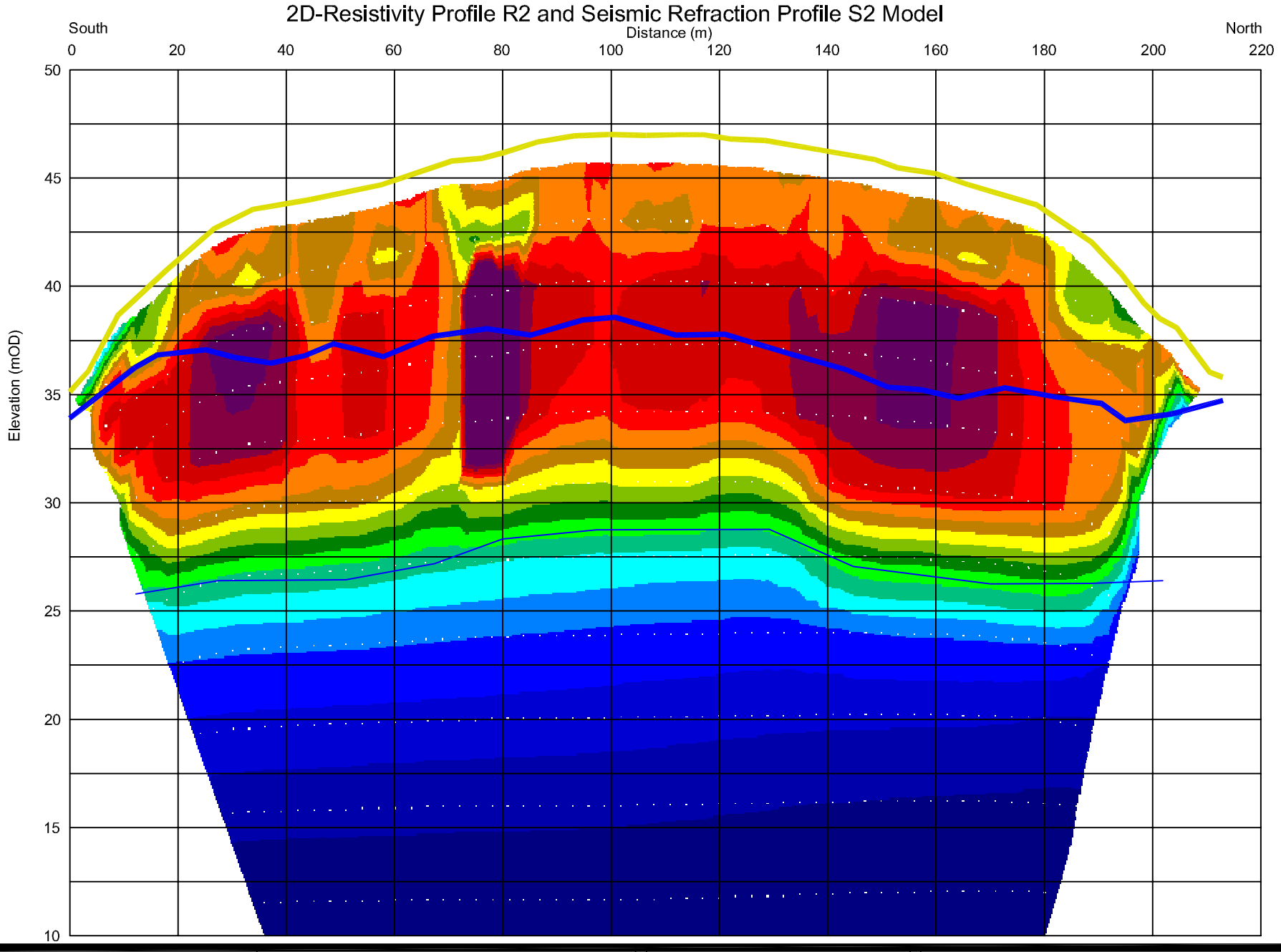
LEGEND: Geophysical Interpretation:

Extent of domestic or C&I Waste

2D-Resistivity Profile R1 and Seismic Refraction Profile S1 Model



2D-Resistivity Profile R2 and Seismic Refraction Profile S2 Model



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CLIENT	FTCO
PROJECT	Tuam Historic Landfill Geophysical Survey
TITLE	Figure 1: Models of Geophysical Survey

SCALE:	1:1000 @ A3
PROJECT:	6499
DRAWN:	JC
DATE:	22/06/2020
MGX FILE:	6499f_Tuam_MapsFigs.dwg
STATUS:	Final

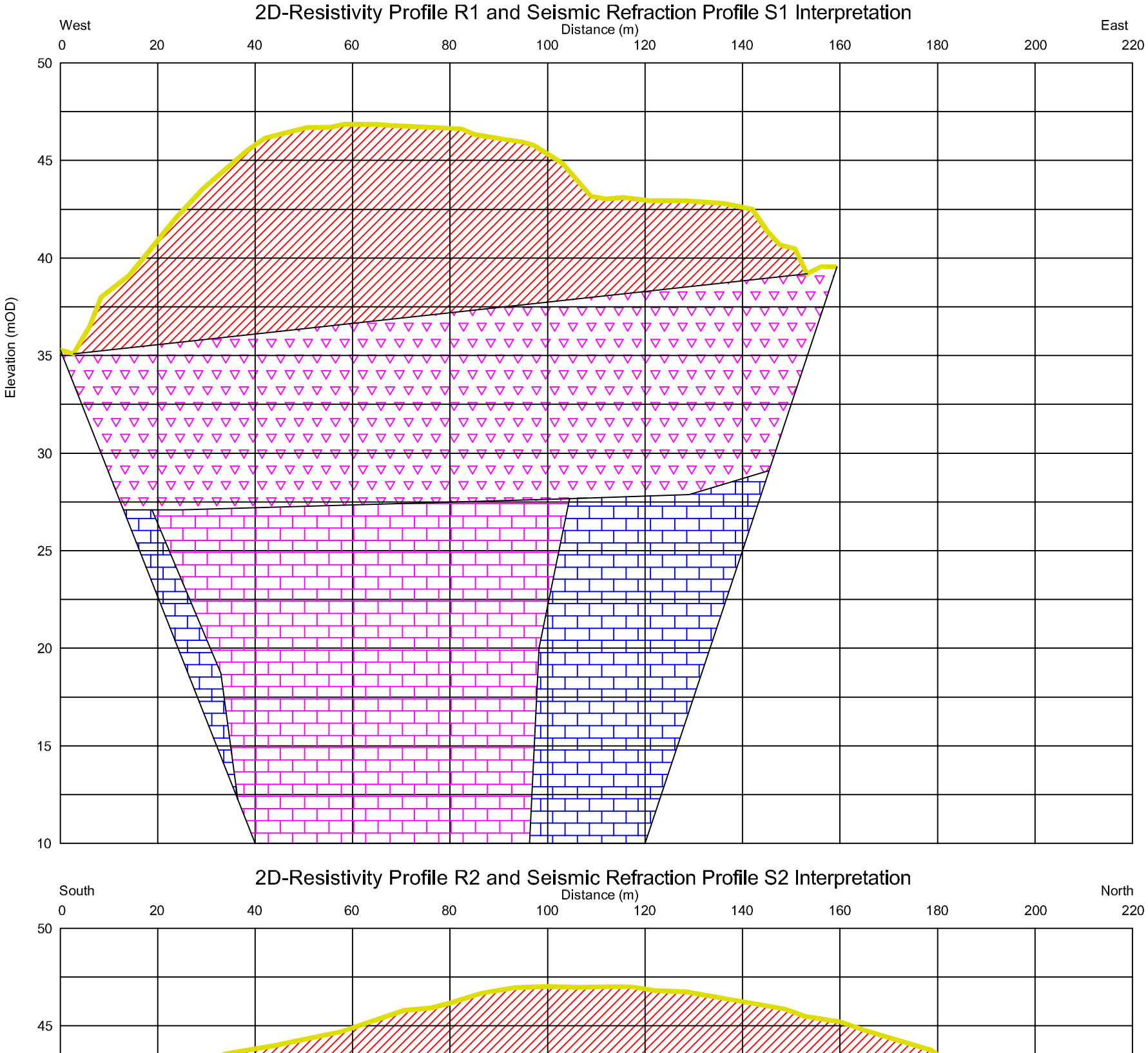
LEGEND: Layers from Seismic Refraction Model:

- Ground Surface/Top of Layer 1 (200 m/s)
- Top of Layer 2 (700 m/s)

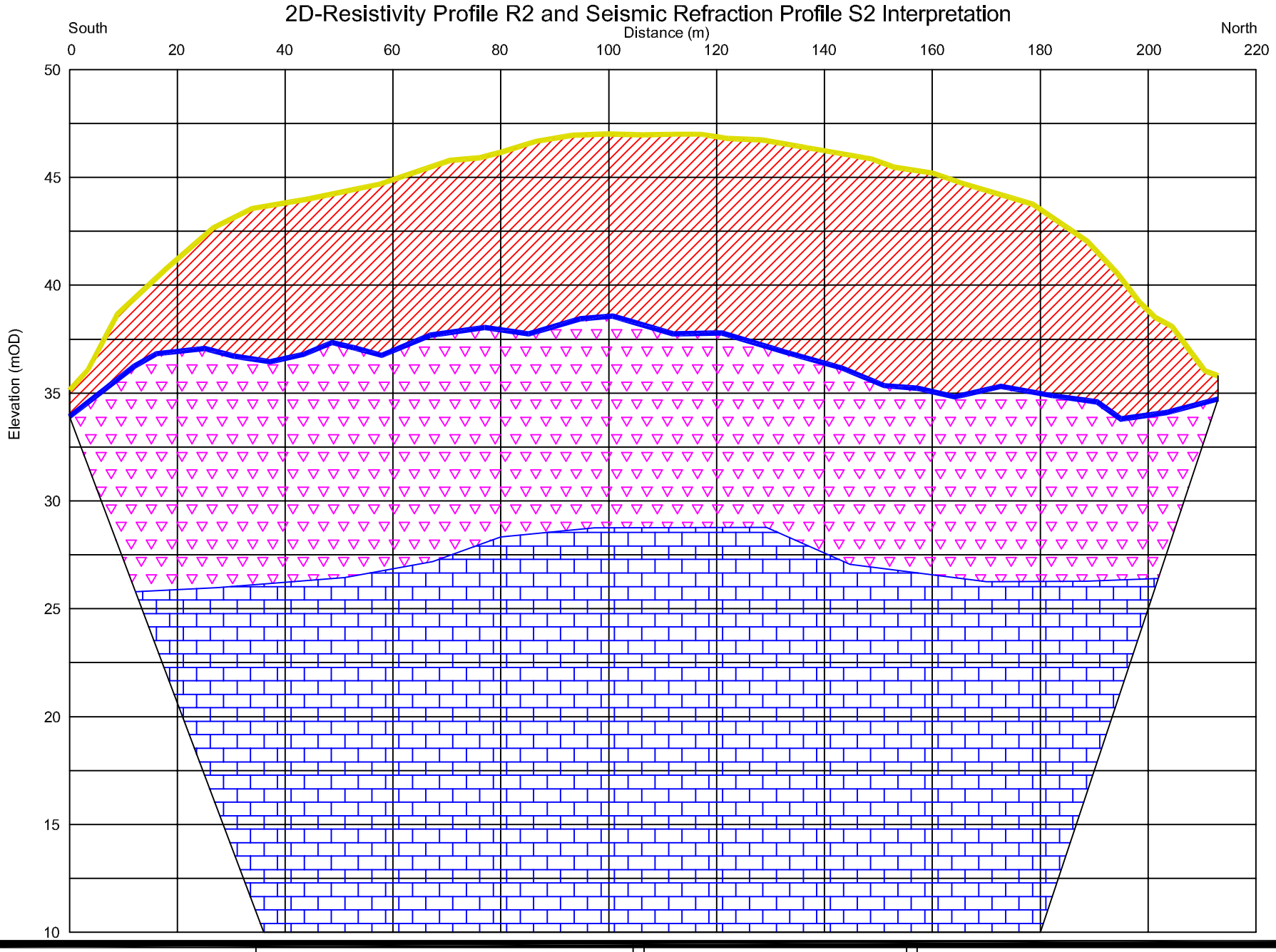
2D-Resistivity Model Values:

7.82 | 15.6 | 31.3 | 62.5 | 125 | 250 | 500 | 1000

2D-Resistivity Profile R1 and Seismic Refraction Profile S1 Interpretation



2D-Resistivity Profile R2 and Seismic Refraction Profile S2 Interpretation



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CLIENT	FTCO
PROJECT	Tuam Historic Landfill Geophysical Survey
TITLE	Figure 2: Interpretation of Geophysical Survey

SCALE:	1:1000 @ A3
PROJECT:	6499
DRAWN:	JC
DATE:	22/06/2020
MGX FILE:	6499f_Tuam_MapsFigs.dwg
STATUS:	Final

LEGEND:

Interpretation:

- 1 Waste (Mainly domestic or C&I Waste)
- 2 Overburden with Leachate
- 3a Fresh Limestone
- 3b Karstified Limestone, Leachate within Limestone or Artificial Effect