APPENDIX 8

Soil, Geology and Hydrogeology of the Development Site

[TES, 2003]

Appendix No. 8
Soil, Geology and Hydrogeology of the Development Site

TOBIN Consulting Engineers

SOIL, GEOLOGY AND HYDROGEOLOGY OF THE DEVELOPMENT SITE

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APPENDIX NO. 8

SOIL, GEOLOGY & HYDROGEOLOGY

1 INTRODUCTION

This report was prepared following a desk study, and site investigations at Derrinumera. Relevant documents that were accessed included:

- Geological maps;
- Publications by the National Soil Survey of Ireland, the Department of the Environment, Heritage and Local Government, Teagasc, the Environmental Protection Agency and the Geological Survey of Ireland; and
- The original Waste Licence Application (No. 21-1) submitted to the EPA by Mayo County Council in 1998.

2 EXISTING ENVIRONMENT

2.1 SOILS

The General Soil Map of Ireland, published by An Foras Taluntais (1969)[1], shows that the principal soil type underlying the region of Derrinumera Landfill is a Low Level Blanket Peat associated with a rolling lowland broad physiographic division. Peat is a partially decomposed mass of vegetation that has grown in a shallow lake or marsh. It is characterised by a high content of organic matter (over 30%) and by being at least 30 cm in depth. Blanket Peats are commonly associated with areas where poor drainage causes a build-up of oxygen starved, partially decomposed biomass. Blanket bogs form where the rainfall exceeds 1,250mm and falls on more than 250 days a year (Cross, 1989)[2].

2.2 QUATERNARY GEOLOGY (SUBSOILS)

General information concerning the Quaternary Geology of the region is contained in the Geological Survey of Ireland (GSI) "Geology of North Mayo" (Long *et al*, 1992)[3]. Ice movement in the North Mayo region was very complex. During the Quaternary period, ice converged on the subject area from a major ice centre in West Galway-South Mayo. Glacial deposits in North Mayo consist of tills, which were deposited at the base of moving glaciers, and to a lesser extent fluvioglacial sand and gravels, which were deposited by glacial meltwaters. Sandy glacial till and fluvioglacial sand, which consists of a range of clast sizes up to and including cobbles and boulders, are the predominant subsoil types underlying the peat in the subject area, as determined during site investigations at the landfill site (refer to

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[1] An Foras Taluntais, (1969), "General Soil Map of Ireland"
[2] Cross, JR, (1989), "Peatlands – wastelands or heritage"
[3] Long, MacDermott, Morris, Sleeman, Tietzsch-Tyler, (1992), "Geology of North Mayo". – Geological Survey of Ireland Publication

Section 3). The peat began to form in poorly drained areas after the ice had melted. As the climate became wetter, blanket bog spread over a large area.

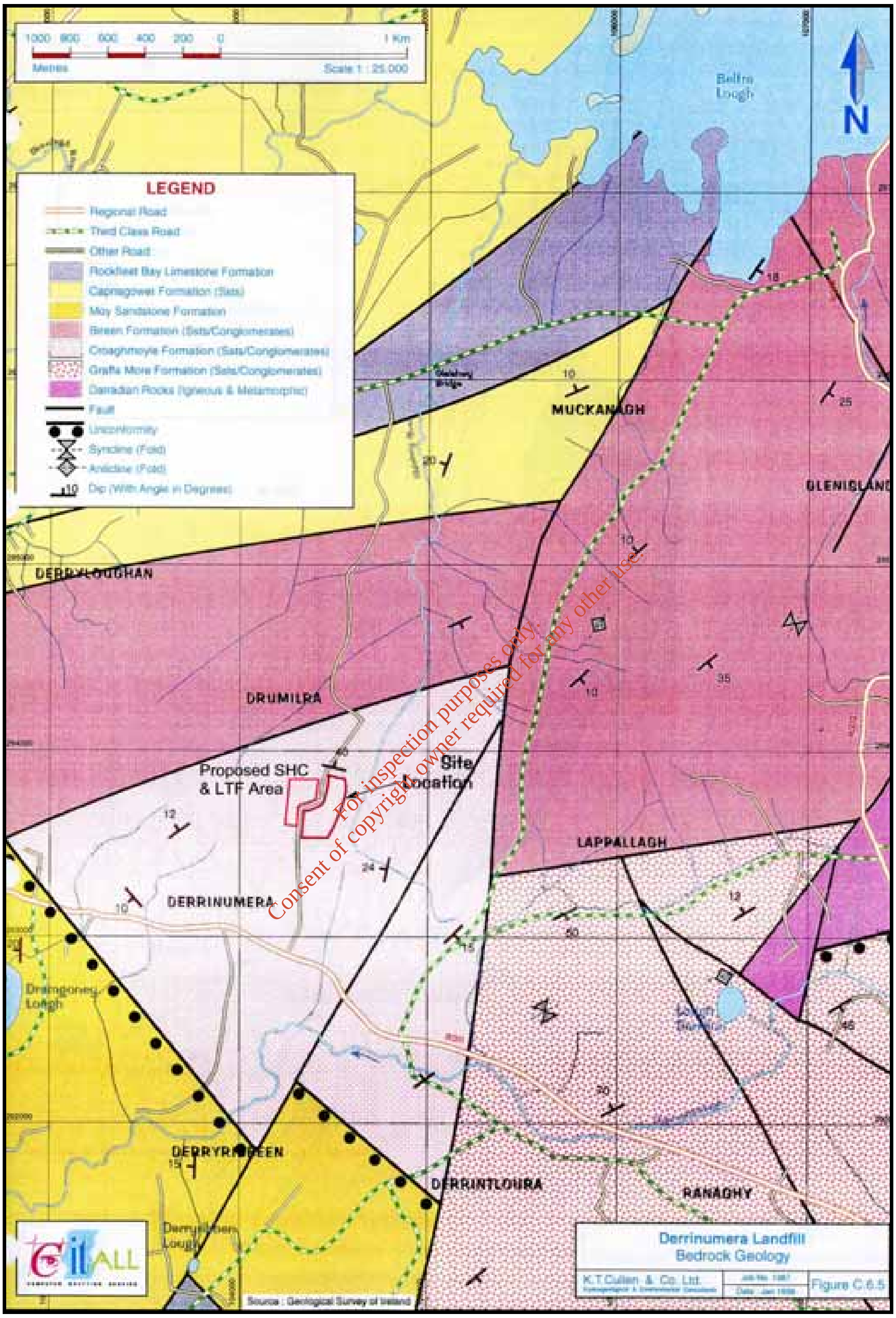
2.3 BEDROCK GEOLOGY

The bedrock geology underlying the subject site is discussed in the Geological Survey of Ireland (GSI) "Geology of North Mayo" (Long *et al*, 1992). The 1:100,000 scale bedrock geology map of the area (Sheet 6), indicates that the subject site is underlain by rocks belonging to the Croaghmoyle Formation (CM), which forms part of the Middle Devonian aged Beltra Group. The Devonian Period lasted from approximately 360 to 410 million years ago. Rocks belonging to the Beltra Group are generally referred to as the Middle Devonian Old Red Sandstone, and were formed in this part of Mayo from alluvial fan deposits, which comprised of eroded material derived from high ground in the Caledonian Mountains. The Croaghmoyle Formation comprises rocks that are described as conglomerates composed mostly of quartzite pebble clasts that were derived from debris flows on an alluvial fan from high ground to the northwest.

The presence of these rapidly deposited Middle Devonian alluvial sandstones and conglomerates of the Beltra Group and the underlying Lower Devonian Islandeady Group suggests a period of active mountain building at that time (Acadian Orogeny), followed by erosion before Upper Devonian times.

The Beltra Group lies unconformably on the underlying rocks of the Islandeady Group, which are more tightly folded. The Islandeady Group was folded prior to deposition of the Beltra Group and then both of these Groups were affected by a second episode of folding, prior to deposition of Carboniferous rocks, which rest unconformably on the Beltra Group rocks. These episodes of folding are associated with periods of mountain building during the Acadian Orogeny.

There are no mapped fault or fold structures at the subject site. However, the landfill site is situated in a region of complex structural geology in which northeast to southwest trending fold and fault structures occur as well as north northeast to south southwest, and east northeast to west southwest trending structures. Northwest to southeast trending structures also occur in the region. The geological setting is shown on Figure 2.3.1. The older trending structures (mostly northeast to southwest) are probably inherited from the Caledonian Orogeny (approximately 410 million years ago), whilst the younger structures (mostly northwest to southeast) may be associated with the Variscan Orogeny (approximately 290 million years ago).



Source: Waste Licence Application EIS for Derrinumera, 1998

Figure 2.3.1 Local Bedrock Geology

3 SITE INVESTIGATIONS

3.1 INTRODUCTION

Site investigations, comprising intrusive drilling, have been undertaken at the landfill site on a number of occasions since 1997. Investigations were completed in 1997, 2000, 2001, and 2003. The various site investigation works are described in the following sections.

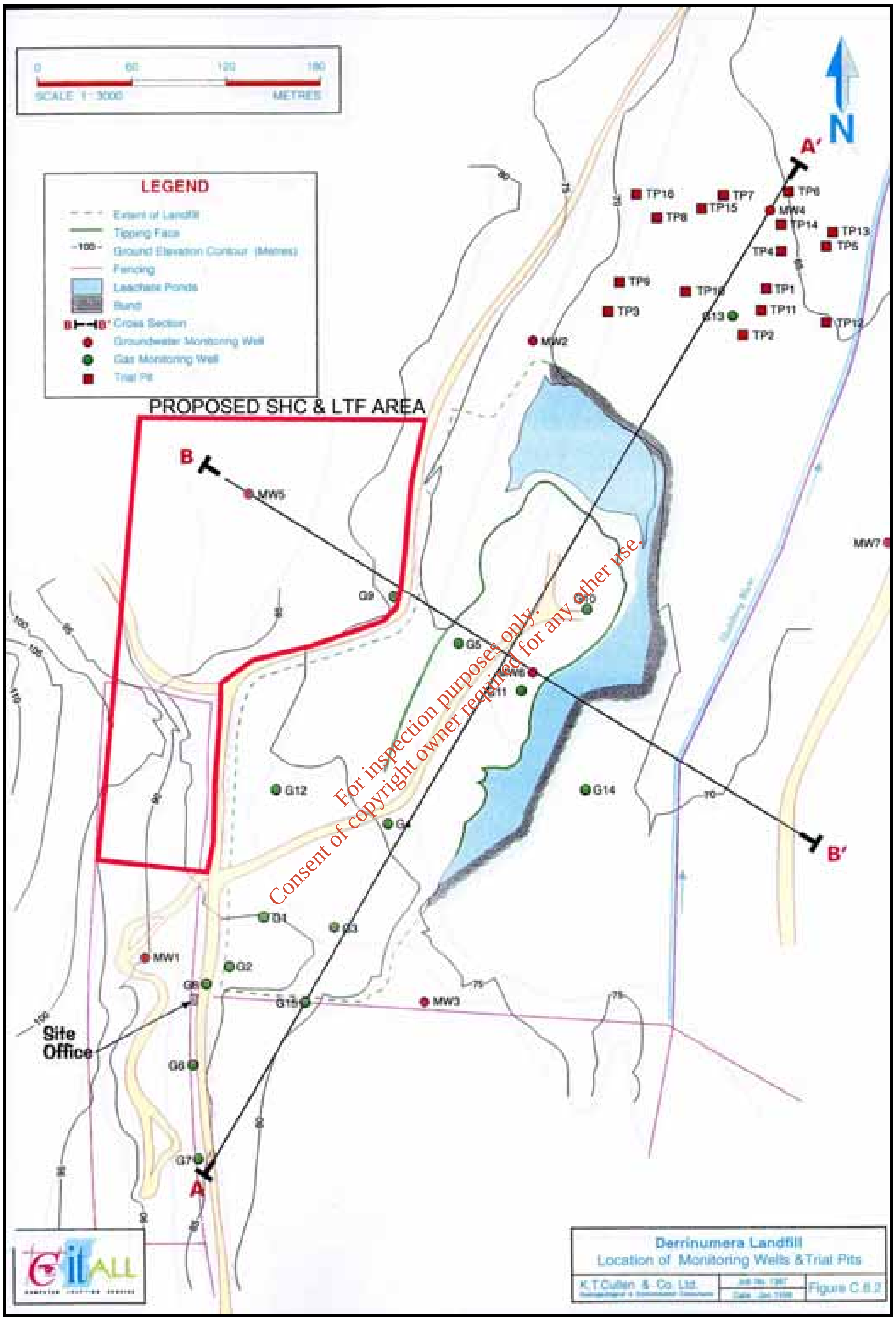
3.2 1997 INVESTIGATIONS

Site investigations were carried out at the landfill site in 1997 by Mayo County Council (MCC) and K.T. Cullen and Co. Ltd. (KTC) as part of a Waste Licence Application to the Environmental Protection Agency (EPA) (Mayo County Council, 1998). A total of 16 No. trial pits were excavated and 9 No. boreholes were installed in order to determine site-specific geological and hydrogeological data, and to establish groundwater-monitoring wells. 15 No. gas monitoring wells were also installed. The locations of these site investigation holes are shown on Figure 3.2.1 and the details of the site investigation holes are presented in Appendix 9, Volume IV.

The trial pits were all situated to the north of the existing landfill and were excavated by a tracked machine to depths varying between 0.9m and 3.35m below ground level. Bedrock was not encountered in any of the trial pits.

The 9 No. boreholes were installed at 7 No. locations as shown on Figure 3.2.1. An air rotary drilling rig was used to drill all of these wells with the exception of MW6 and MW7, which were drilled by a 'Shell & Auger' rig. Groundwater monitoring points were established at all of the drilled boreholes, thus creating both upgradient and downgradient monitoring points. 6 No. of the boreholes were installed into the bedrock and 2 No. shallower boreholes were completed in the overburden (MW2s and MW4s). 1 No. borehole was drilled through the landfill to the base of the fill but did not penetrate into bedrock.

In addition to these groundwater monitoring wells, 15 No. gas monitoring wells were also drilled on and around the landfill. 8 No. of these wells were drilled through waste, whilst the remaining 7 No. were installed through the natural overburden material surrounding the landfill. The gas monitoring wells were drilled to depths varying between 1.5m and 6.0m below ground level by a 'Window Sampler', which is a type of percussion drill. Refusal was met in 6 No. of the boreholes on boulders and bedrock was encountered in 1 No. of the wells at 1.5m below ground level.



Source: Waste Licence Application EIS for Derrinumera, 1998

Figure 3.2.1 S.I Monitoring Locations, 1998

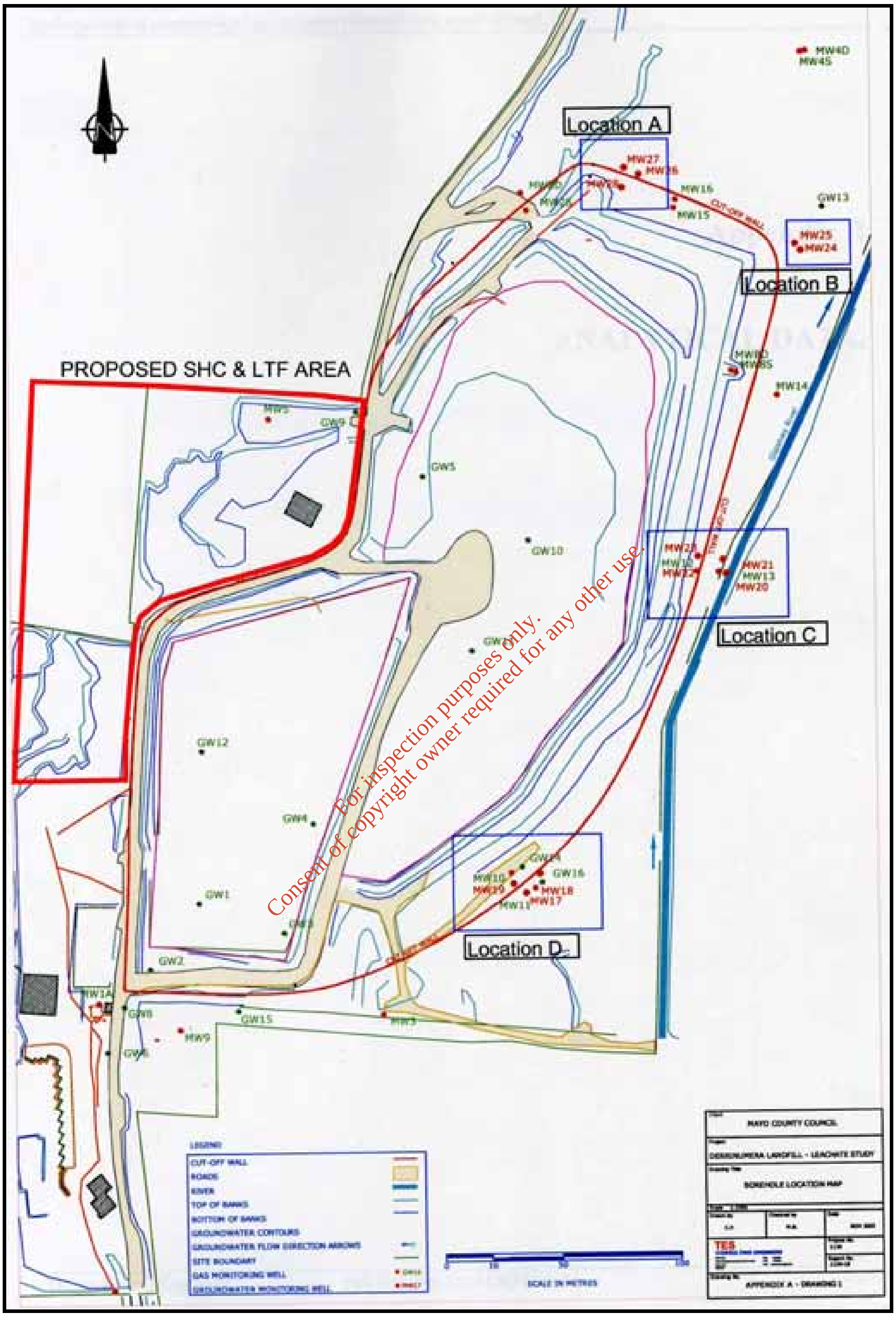
3.3 2000 TO 2001 INVESTIGATIONS

3 No. additional boreholes were installed in April of 2000 at locations shown on Figure 3.4.1. These boreholes are labelled MW8d, MW8s, and MW9. During this drilling programme, MW5 was replaced with a new borehole, also labelled MW5. MW8s and MW8d were replaced in June 2001 with new boreholes, also labelled MW8s and MW8d. The original MW1 borehole installed in 1997 was also replaced, although the date of this re-drilling is unknown. The revised locations for MW1, MW5, MW8s and MW8d are shown on Figure 3.4.1. 7 No. new boreholes labelled MW10 to MW16 were installed in December 2001 at locations shown on Figure 3.4.1. Borehole records are not available for any of these boreholes.

3.4 2003 INVESTIGATIONS

As part of an investigation on contaminated groundwater in the vicinity of the cut-off wall to the east of the waste body, a new set of groundwater monitoring boreholes (12 No.) were installed on either side of the cut-off wall to the north, northeast, east, and southeast of the landfill (TES, 2003). These boreholes were installed on the 30th September and 1st October, 2003 by Glovers Site Investigations Limited using a KLEMM KR708 track mounted air flush rig. The purpose of these new monitoring boreholes, labelled MW17 to MW28, was to facilitate a groundwater-sampling regime to determine whether there had been any migration of leachate across the cut-off wall since its emplacement. The locations of these new monitoring boreholes are shown on Figure 3.4.1. It was considered that the existing monitoring wells situated close to the cut-off wall (MW10 to MW16) were inadequate for the purposes of this investigation and were therefore decommissioned.

Both deep (bedrock) and shallow (overburden) boreholes were installed during this latest drilling programme. The deep bedrock monitoring boreholes were drilled adjacent to shallow monitoring boreholes to permit comparison of overburden and bedrock groundwater quality at specific areas. The deep boreholes were drilled through the overburden and approximately 0.5m into the bedrock using a 200mm diameter hammer and temporary steel casing. The holes were then continued approximately 10m into the bedrock using a 140mm diameter hammer. A 2 inch slotted uPVC screen was inserted from approximately 4m below rockhead to the base of the hole. A 2 inch uPVC casing was installed above the screen to the top of the borehole. Gravel pack was placed in the annulus from the base of the hole to approximately 1m below the rockhead intercept, with a bentonite seal inserted from this depth back up to ground level.



Source: Hydrogeological Assessment of Groundwater Contamination at Derrinumera, 2003

Figure 3.4.1 S.I. Monitoring Locations, 2003

The shallow boreholes were drilled using a 200mm diameter hammer from ground level to approximately 0.5m above bedrock. A 2 inch slotted uPVC screen was inserted from the base of the hole to approximately 2.0m below ground level and a 2 inch uPVC casing was installed from this depth to ground level. Gravel pack was placed in the annulus from the base of the hole to approximately 1.5m below ground level and a bentonite seal was emplaced from 1.5m up to ground level.

Logs showing the borehole construction designs and details of geological formations encountered are presented in Appendix 9, Volume IV. All subsoils and bedrock encountered were described in accordance with the British Standards Institution Code of Practice for Site Investigations (BS5930) (1981).

4 OVERBURDEN AND GEOLOGY ENCOUNTERED

The area surrounding the landfill is covered with blanket peat. In places this peat directly overlies bedrock. Glacial deposits underlie the peat where the bedrock is deeper. In general, these glacial deposits consist of a sandy glacial till overlying fluvioglacial outwash sands. Both of these deposits consist of a range of clast sizes up to and including cobbles and boulders. Unconsolidated deposits that varied from sandy clay-to-clay rich sand were described in the monitoring boreholes installed in 2003 near the cut-off wall to the north, northeast, east, and southeast of the waste body.

As mentioned above, all of the trial pits excavated in 1997 were located to the north of the landfill and were dug to depths varying between 0.9m and 3.35m below ground level. Due to unstable ground conditions and formation collapse, all of the pits were terminated at shallow depths and the complete overburden sequence was not revealed. Thus bedrock was not encountered in any of the pits. The thickness of peat identified in all of these pits ranged from 0.3m to 3.35m. Glacial deposits encountered beneath the peat were described as sandy glacial till and/or fluvioglacial sand as discussed above. In general, the more stable till occurred above the sand deposits, which were generally saturated resulting in formation collapse from this sequence.

The peat layer was found to be very thin or absent in the boreholes installed in 1997 to the south and west of the landfill. However, these boreholes were located on firm ground for reasons of drill rig access and stability. No peat was encountered in MW1, MW2s, MW2d or MW3. A depth of 0.6m of peat was encountered in MW5, which is located to the west of the landfill, and 0.4m of peat was identified in both MW4s and MW4d. The thickest peat was encountered in MW7 (1.55m) located on the opposite side of the Glaishwy River than the landfill. Peat was encountered in all of the monitoring boreholes installed in 2003 (MW17 to MW28) to the north, northeast, east and southeast of the landfill. The thickness of this peat ranged from 2.5m to 4.8m in these boreholes with the exception of MW27 where only a 0.3m thin horizon of peat was encountered.

Approximately 4.5m of sandy glacial till was encountered overlying bedrock in 3 No. gas wells (G6, G7, and G8) installed in 1997 near the site office to the southwest of the landfill and approximately 2.8m of this till was identified overlying presumed bedrock in a gas well drilled to the west of the landfill (G9). Approximately 1.5m of sandy glacial till was encountered overlying presumed bedrock in gas well G15 that was installed to the south of the landfill. Fluvioglacial sands were not identified in any of the boreholes installed to the south or west of the landfill. Sandy glacial till, varying in thickness from 0.45m to 3.0m, was described overlying bedrock in all of the monitoring wells installed in 1997 with the exception of MW1 where no overburden was encountered and MW6, which was drilled in the waste body.

Unconsolidated deposits that varied from sandy clay-to-clay rich sand were described in the monitoring boreholes installed in 2003 near the cut-off wall to the north, northeast, east, and southeast of the waste body. The thickness of the unconsolidated deposits in these boreholes varied from 0.7m to 3.8m. A sand and gravel deposit was identified in 1 No. of these boreholes (MW25), and medium grained sand was described in MW24 and MW27.

The bedrock encountered during drilling of boreholes MW1 to MW7 in 1997 was described as red conglomerate bedrock. Bedrock encountered in the recent drilling of monitoring boreholes MW17 to MW28 was described as a series of interbedded medium to coarse-grained red to purple/brown sandstones and fine to medium grained conglomerates. The conglomerates are composed of rounded to subrounded clasts of quartz, quartzite and sandstone with minor black/green volcanics in a sandstone matrix. There are also thin bands (<10cm thick) of red/brown mudstone.

In general, the depth to bedrock around the landfill is shallow and was in the order of <3.5m in the boreholes installed in 1997. However, the depth to bedrock varied from 4.5m to 7.4m in the monitoring boreholes installed in 2003. Bedrock outcrop occurs as ridges and rocky hills to the west and south of the landfill, respectively. MW1 was drilled in an area where bedrock occurs at ground level to the southwest of the landfill. However, 3 No. gas wells (G6, G7, and G8) were drilled to a depth of c.4.5-4.6m below ground level near the site office without encountering bedrock. These wells were drilled between two areas of bedrock outcrop to the southwest of the landfill. G9 located to the west of the landfill was drilled to a depth of 2.8m, and gas wells G13 and G14 drilled to the north and east of the landfill respectively, were drilled to depths of 3m. The depth to bedrock under the landfill was not determined, as drilling into bedrock under the fill area could have resulted in leachate being introduced to any underlying groundwater resources in the bedrock.

The most relevant boreholes to the proposed SHC and LTF to the west of the landfill site are MW1, MW5 and G9 (refer to Figure 3.4.1). MW1 was drilled in an area where bedrock occurs at ground level and hence no unconsolidated deposits were encountered. G9 was installed to a depth of 2.8m through sandy glacial till without encountering bedrock. The unconsolidated deposits encountered in MW5 comprised 0.6m of peat overlying 2.6m of sandy glacial till. Bedrock was encountered at 3.2m below ground level in this borehole. As mentioned above, the bedrock encountered in both MW1 and MW5 was described as red conglomerate. This is considered to be a solid base for the foundations of the proposed development.

APPENDIX 9

Site Investigation Results – Historical & Recent

SITE INVESTIGATION RESULTS –

HISTORICAL & RECENT

Historical S.I. Results

APPENDIX 5

SUMMARY OF TRIAL PITS

SUMMARY OF GROUNDWATER AND GAS MONITORING

SUMMARY OF PERMEABILITY RESULTS

SUMMARY OF TRAIL PIT RECORDS

SUMMARY OF MONITORING WELL LOGS

Table C.6.1 : Summary of Trial Pits

Trial Pit No.	Depth (m)	Peat (m)	Sandy Till (m)	Sand (m)	Water Entry (m)	Comments
1	2.00	0 - 0.75	0.75 - 1.40	1.40 - 2.00	1.40	-
2	2.90	0 - 2.75	-	2.75 - 2.90	2.75	-
3	3.35	0 - 3.35	-	-	not recorded	-
4	3.35	0 - 3.35	-	-	not recorded	-
5	2.75	0 - 2.40	-	2.40 - 2.75	2.40	-
6	2.10	0 - 0.60		0.60 - 2.10	None	-
7	1.80	0 - 0.60	0.60 - 1.50	1.50 - 1.80	None	-
8	0.90	0 - 0.30	0.30 - 0.90	-	not recorded	-
9	2.20	0 - 0.90	1.00 - 2.20	-	1.70	Stable Pit
10	2.40	0 - 2.30	2.40 - 3.20	-	2.40	Large surface water ingress
11	2.10	0 - 1.00	1.00 - 1.50	1.50 - 2.10	1.50	Collapsing below 1.50
12	2.60	0 - 2.00	-	2.10 - 2.60	2.10	Large surface water ingress
13	2.20	0 - 1.00	-	1.00 - 2.20	1.00	Unstable
14	2.50	0 - 0.40	0.40 - 1.10	1.10 - 2.50	1.20	Unstable
15	2.10	0 - 0.90	0.90 - 1.20	1.20 - 2.10	2.00	Stable
16	1.00	-	-	0.00 - 1.00	0.60	Stable

Table C.6.2 : Summary of Groundwater and Gas Monitoring Wells at Derrinumera Landfill, Co. Mayo.

Well No.	Top of Casing (m.OD)	Casing above Ground (m)	Ground Level (m.OD)	Depth of Hole (m)	Base Elevation (m.OD)	Depth to Bedrock (m)	Bedrock Elevation (m.OD)	Depth to Water (m) (18/12/97)	Water Elevation (m.OD)
G-1	85.69	0.75	84.94	6.00	78.94	> 6.00	< 78.94	4.86	80.83
G-2	86.93	0.75	86.18	6.00	80.18	> 6.00	< 80.18	4.54	82.39
G-3	82.62	0.72	81.90	6.00	75.90	> 6.00	< 75.90	6.05	76.57
G-4	80.64	0.75	79.89	6.00	73.89	> 6.00	< 73.89	4.65	75.99
G-5	79.63	0.75	78.88	6.00	72.88	> 6.00	< 72.88	5.04	74.59
G-6	86.71	0.65	86.06	4.60	81.46	> 4.60	< 81.46	1.66	85.05
G-7	85.96	0.85	85.11	4.50	80.61	> 4.50	< 80.61	1.56	84.40
G-8	87.03	0.75	86.28	4.60	81.68	> 4.60	< 81.68	2.00	85.03
G-9	78.50	0.70	77.80	2.80	75.00	> 2.80	< 75.00	Dry	< 75.16
G-10	78.53	0.80	77.73	6.00	71.73	> 6.00	< 71.73	Dry	< 71.83
G-11	78.80	0.85	77.95	6.00	71.95	> 6.00	< 71.95	4.55	74.25
G-12	83.31	1.20	82.11	6.00	76.11	> 6.00	< 76.11	Dry	< 76.67
G-13	65.82	0.64	65.18	3.00	62.18	> 3.00	< 62.12	-	-
G-14	70.61	0.60	70.01	3.00	67.01	> 3.00	< 67.01	0.62	69.99
G-15	82.35	0.70	81.65	1.50	80.15	1.50	80.15	Dry	< 80.69
MW1	90.61	0.65	89.96	20.10	69.86	0.00	89.96	2.22	88.39
MW2s	71.09	0.42	70.67	3.30	67.37	3.00	67.67	1.15	69.94
MW2d	71.63	0.75	70.88	13.00	57.88	1.30	69.58	1.24	70.39
MW3	79.40	0.55	78.85	14.70	64.15	1.30	77.55	2.94	76.46
MW4s	66.99	0.60	66.39	3.20	63.19	3.20	63.19	2.24	64.75
MW4d	67.10	0.55	66.55	20.50	46.05	2.80	63.75	2.20	64.90
MW5	87.02	0.60	86.42	9.40	77.02	3.20	83.22	5.02	82.00
MW6	78.62	0.44	78.18	10.30	67.88	> 10.30	< 67.88	4.49	74.13
MW7	70.52	0.45	70.07	4.40	65.67	2.00	68.07	1.11	69.41

Table C.6.3 : Summary of Permeability Results

Number	Completed Depth (m)	Bedrock Depth (m below GL)	Filter Zone (m below GL)	Permeability (m/sec)	Test Type
Overburden Wells					
MW2s	3.30	3.00	0.80 - 3.30	9.8 x 10^{-5}	RHT with slug
MW4s	3.20	3.20	1.00 - 3.20	1.3 x 10^{-4}	FHT with slug
Bedrock Wells					
MW2d	13.00	1.30	4.00 - 13.00	4.9 x 10^{-6}	RHT with slug
MW3	14.70	2.00	2.70 - 14.70	5.9 x 10^{-7}	RHT with slug
MW4d	20.50	2.80	8.00 - 20.50	4.0 x 10^{-6}	RHT with slug
MW5	9.40	3.20	1.70 - 9.40	5.5 x 10^{-7}	FHT with slug
MW7	4.40	2.00	2.20 - 4.40	8.9 x 10^{-5}	RHT with slug

Note All Piezometers are 50mm HDPE

RHT = Rising Head Test

FHT = Falling Head Test

Table C.6.4 : Groundwater Quality at Derrinumera Landfill - 5/1/98

Parameters	Units	M.A.C.	Background		Leachate	Downgradient			
			MW - 1	MW - 5	MW - 6	MW - 2d	MW - 3	MW- 4d	MW - 7
Field Measurements									
pH	pH units	6 - 9	9.60	9.70	7.58	7.20	10.07	6.71	6.69
Conductivity	uS/cm @ 25°C	1650	640	960	9320	456	473	313	400
Temperature	°C	25	11.0	11.0	21.0	10.5	11.0	10.0	11.0
Laboratory Measurements									
pH	pH units	6 - 9	10.0	9.5	7.5	7.7	9.8	8.2	7.0
Colour	Hazen Units	-	< 5	< 5	2750	< 5	< 5	< 5	10
Conductivity	uS/cm @ 20°C	1500	820	990	12900	565	535	495	460
Total Hardness	mg/l CaCO3	-	381	513	782	253	183	176	176
Total Alkalinity	mg/l CaCO3	-	539	580	5750	230	275	252	211
Non-Carbonate Hardness	mg/l CaCO3	-	-	-	-	-	-	-	-
Calcium	mg/l Ca	200	4.2	7.5	66	75	7.5	41	41
Magnesium	mg/l Mg	50	90	120	150	16	40	18	18
Sodium	mg/l Na	150	98	53	1250	27	58	49	24
Potassium	mg/l K	12	33	27	670	3.4	16.0	1.4	4.8
Iron	mg/l Fe	0.2	0.01	0.02	5.1	0.13	0.01	0.27	0.76
Manganese	mg/l Mn	0.05	< 0.01	< 0.01	0.33	0.07	< 0.01	0.02	1.0
Copper	mg/l Cu	0.5	< 0.01	< 0.01	0.02	< 0.01	< 0.01	< 0.01	< 0.01
Aluminium	mg/l Al	0.2	< 0.05	0.05	0.68	0.15	< 0.05	0.39	0.25
Nitrate	mg/l NO3	50	11	0.5	< 2	< 0.5	< 0.5	< 0.5	< 0.5
Nitrite	mg/l NO2	0.1	0.51	0.16	< 0.1	0.02	0.08	0.14	< 0.01
Chloride	mg/l Cl	250	56	43	1525	23	45	25	30
Sulphate	mg/l SO4	250	15	13	2.8	4.4	15	5.4	5.6
Total Ammonia	mg/l NH4	0.3	< 0.05	0.07	1322	< 0.05	1.2	< 0.05	2.9
Non Purg. Org. Carbon	mg/l C	-	31	5.6	530	2.2	6.2	2.7	5.9
Sulphur	mg/l S	-	6.2	3.7	27	2.2	5.3	2.6	1.4
Arsenic	mg/l As	0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Tin	mg/l Sn	-	< 0.05	< 0.05	0.07	< 0.05	< 0.05	< 0.05	< 0.05
Mercury	mg/l Hg	0.001	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Chromium	mg/l Cr	0.05	< 0.01	< 0.01	0.25	< 0.01	< 0.01	< 0.01	< 0.01
Phosphorous	mg/l P	1.09	0.06	< 0.05	7.4	< 0.05	< 0.05	< 0.05	< 0.05
Zinc	mg/l Zn	5	< 0.01	< 0.01	0.34	0.38	< 0.01	0.09	0.31
Cadmium	mg/l Cd	0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005	< 0.005
Lead	mg/l Pb	0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Cobalt	mg/l Co	-	< 0.01	< 0.01	0.04	< 0.01	< 0.01	< 0.01	< 0.01
Nickel	mg/l Ni	0.05	< 0.01	< 0.01	0.13	0.03	< 0.01	0.01	0.03
Boron	mg/l B	2	< 0.01	< 0.01	7.7	0.05	0.02	0.11	0.02
Strontium	mg/l Sr	-	0.25	0.20	1.3	1.3	0.20	1.7	0.17
Barium	mg/l Ba	0.5	0.23	0.43	0.44	0.85	0.27	0.67	1.6
Biochemical Oxygen Demand	mg/l	-	-	-	120	-	-	-	-
Chemical Oxygen Demand	mg/l	-	-	-	2860	-	-	-	-

Note

M A C = Maximum Admissible Concentration for Drinking Water (S.I. No 81 of 1988)

< = Less than

All samples were filtered through GF/C grade filters prior to all analyses

Table C.6.5 : Gas Monitoring Results (5/1/98)

LANDFILL GAS MONITORING FORM

(Baseline [ ] Ambient [x])

Site Name : Derrinumera Landfill Site	Site Address : Derrinumera, Newport Co. Mayo
Operator : Mayo Co. Council	National Grid Reference : 104400, 293700
Site Status : Active	Date : 5/1/98 Time: All Day
Instrument Used : GA94 (Infra-Red)	Normal Analytical Range : Date Next Calibration :
Monitoring Personnel : Ronan Doyle (K.T.Cullen & Co. Ltd.)	Weather : Barometric Pressure : See individual readings

Results

Borehole Number	Survey Depth	CH_4 % v/v	CH_4 % L.E.L.	CO_2 % v/v	O_2 % v/v	Atmospheric Pressure (mBar)	Approximate Location
G-1	6.00	68.4	1368	18.8	2.1	992	On Landfill
G-2	6.00	65.0	1300	7.0	4.5	992	On Landfill
G-3	6.00	49.3	986	13.6	3.5	982	On Landfill
G-4	6.00	72.0	1440	31.9	2.6	982	On Landfill
G-5	6.00	62.0	1240	41.7	3.1	984	On Landfill
G-6	4.60	0.0	0	0.0	15.2	992	50m from Landfill
G-7	4.50	0.0	0	0.0	19.6	992	110m from Landfill
G-8	4.60	0.5	10	0.2	11.3	992	5m from Landfill
G-9	2.80	0.0	0	4.6	13.6	992	5m from Landfill
G-10	6.00	59.6	1192	44.9	3.2	964	On Landfill
G-11	6.00	67.7	1354	35.9	3.0	984	On Landfill
G-12	6.00	62.2	1244	26.5	2.9	982	On Landfill
G-13	3.00	0.0	0	0.0	22.6	986	90m from Landfill
G-14	3.00	1.8	36	3.8	14.7	982	25m from Landfill
G-15	1.50	0.2	4.0	0.0	22.8	982	5m from Landfill
MW-1	20.10	0.0	0	0.0	20.8	982	50m from Landfill
MW-2(d)	13.00	0.0	0	4.0	22.6	982	20m from Landfill
MW-3	14.70	0.02	0.40	0.0	19.8	982	30m from Landfill
MW-4(d)	20.50	0.0	0	0.0	22.8	982	150m from Landfill
MW-5	9.40	0.0	0	2.5	22.8	982	120m from Landfill
MW-6	10.30	1.5	30	0.0	21.5	982	On Landfill
MW-7	4.40	0.0	0	0.0	21.8	982	150m from Landfill

TRIAL PIT RECORDS

Project No: 1387 **Location:** Derrinumera, Newport, Co.Mayo **Date:** 12/3/97

Drilling Method: Tracked Excavator **Supervisor:** Steve Verity

Trial Pit No. 1

(m)

Geology: 0 - 0.75 PEAT

0.75 - 1.40 dry yellow sandy Boulder Clay.

1.40 - 2.00 wet running red silty gravelly SAND with cobbles &boulders

Depth to Rock: > 2.00 m

Rock Type: Unknown

Water Entry: 1.40 m

Total Depth: 2.00 m.

Comments:

Trial Pit No. 2

(m)

Geology: 0 - 2.75 PEAT

2.75 - 2.90 wet running red silty gravelly SAND with cobbles &boulders

Depth to Rock: > 2.90 m

Rock Type: Unknown

Water Entry:

Total Depth: 2.90 m.

Comments:

TRIAL PIT RECORDS

'roject No: 1387 Location: Derrinumera, Newport. Co.Mayo Date: 12/3/97

illing Method: Tracked Excavator Supervisor: Steve Verity

Trial Pit No. 3

	(m)	
Geology:	0 - 3.35	PEAT

Depth to Rock: > 3.35 m

Rock Type: Unknown

Water Entry:

Total Depth: 3.35 m.

Comments:

Trial Pit No. 4

	(m)	
Geology:	0 - 3.35	PEAT

Depth to Rock: > 3.35 m

Rock Type: Unknown

Water Entry:

Total Depth: 3.35 m.

Comments:

TRIAL PIT RECORDS

Project No: 1387 **Location:** Derrinumera, Newport, Co.Mayo **Date:** 12/3/97
Drilling Method: Tracked Excavator **Supervisor:** Steve Verity

Trial Pit No. 5

	(m)	
Geology:	0 - 2.40	PEAT
	2.40 - 2.75	wet running red silty gravelly SAND with cobbles & boulders

Depth to Rock: > 2.75 m
Rock Type: Unknown
Water Entry:
Total Depth: 2.75 m.
Comments:

Trial Pit No. 6

	(m)	
Geology:	0 - 0.60	PEAT
	0.60 - 2.10	dry red silty gravelly SAND with cobbles & boulders

Depth to Rock: > 2.10 m
Rock Type: Unknown
Water Entry:
Total Depth: 2.10 m.
Comments:

TRIAL PIT RECORDS

roject No: 1387 Location: Derrinumera, Newport, Co.Mayo Date: 12/3/97

lling Method: Tracked Excavator Supervisor: Steve Verity

Trial Pit No. 7

	(m)	
Geology:	0 - 0.60	PEAT
	0.60 - 1.50	dry yellow sandy Boulder Clay
	1.50 - 1.80	dry red silty gravelly SAND with cobbles & boulders

epth to Rock: > 1.80 m

Rock Type: Unknown

Water Entry:

Total Depth: 1.80 m.

Comments:

Trial Pit No. 8

	(m)	
Geology:	0 - 0.30	PEAT
	0.30 - 0.90	reddish brown hard Boulder Clay with SAND

Depth to Rock: > 0.90 m

Rock Type: Unknown

Water Entry:

Total Depth: 0.90 m.

Comments:

TRIAL PIT RECORDS

Project No: 1387 **Location:** Derrinumera, Newport, Co.Mayo **Date:** 16/10/97

Drilling Method: Tracked Excavator **Supervisor:** Conor Walsh B.Sc.

Trial Pit No. 9

Geology:

(m)	
0 - 0.90	PEAT with tree trunks
0.90 - 1.00	grey sandy SILT
1.00 - 2.20	pinkish-red clayey silty gravelly SAND with subangular cobbles and boulders (very sandy Boulder Clay)
2.20	BOULDERS

Depth to Rock: > 2.20 m

Rock Type: Unknown

Water Entry: 1.70 m

Total Depth: 2.20 m.

Comments: Stable pit

Trial Pit No. 10

Geology:

(m)	
0 - 2.30	PEAT
2.30 - 2.40	grey sandy SILT
2.40 - 3.20	pinkish-red clayey silty gravelly SAND with subangular cobbles and boulders (very sandy Boulder Clay)

Depth to Rock: > 3.20 m

Rock Type: Unknown

Water Entry: 2.40 m
Large volume of surface water poured into pit.

Total Depth: 3.20 m.

Comments:

TRIAL PIT RECORDS

Project No: 1387 **Location:** Derrinumera, Newport, Co.Mayo **Date:** 16/10/97
Drilling Method: Tracked Excavator **Supervisor:** Conor Walsh B.Sc.

Trial Pit No. 13

Geology:

	(m)	
	0 - 1.00	PEAT
	1.00 - 2.20	pinkish-red silty gravelly SAND with subangular cobbles and boulders
	2.20	BOULDERS

Depth to Rock: > 2.20 m
Rock Type: Unknown
Water Entry: 1.00 m
Total Depth: 2.20 m.
Comments: Unstable pit

Trial Pit No. 14

Geology:

	(m)	
	0 - 0.40	PEAT
	0.40 - 1.10	creamy brown clayey silty gravelly SAND with subangular cobbles & boulders (sandy Boulder Clay)
	1.10 - 1.60	pinkish-red silty gravelly SAND with subangular cobbles &boulders
	1.60 - 2.50	red and grey silty gravelly SAND with subangular cobbles &boulders
	2.50	BOULDERS

Depth to Rock: > 2.50 m
Rock Type: Unknown
Water Entry: 1.20 m
Total Depth: 2.50 m.
Comments: Unstable pit.

TRIAL PIT RECORDS

roject No: 1387 Location: Derrinumera, Newport, Co.Mayo Date: 16/10/97
lling Method: Tracked Excavator Supervisor: Conor Walsh B.Sc.

Trial Pit No. 15

Geology:

(m)	
0 - 0.90	PEAT
0.90 - 1.20	grey clayey silty gravelly SAND with subangular cobbles and boulders (sandy Boulder Clay)
1.20 - 2.10	pinkish-red silty gravelly SAND with subangular cobbles &boulders
2.10	BOULDERS

pth to Rock: > 2.10 m
Rock Type: Unknown
Vater Entry: 2.00 m
Total Depth: 2.10 m.
Comments: Stable pit

Trial Pit No. 16

Geology:

(m)	
0 - 0.60	FILL
0.60 - 1.00	pinkish-red silty gravelly SAND with subangular cobbles &boulders
1.00	BOULDERS

epth to Rock: > 1.00 m
Rock Type: Unknown
Water Entry: 0.60 m
Total Depth: 1.00 m.
Comments: Stable pit.

Monitoring Well Log

Monitoring Well No. 1

Client : P.J. Tobin & Co.
Location : Derrinumera, Castlebar.
Job No : 1387
Date : 4/12/97
Description : Monitoring Well

Drilling Company : Glovers Site Investigations Ltd.
Drilling Method : Air Rotary
Drillers Name : P. Dullea
National Grid Co. Ord. : East North
Ground Surface Elev. : 89.96 m.O.D.
Logged by : John Mitchell B. Eng.

Shell & Auger | Air Rotary | 250 mm Casing | 200 mm Casing | 150 mm Casing | Water Strike | Inflow m3/day | Falling Head (l/min) | Number | SPT

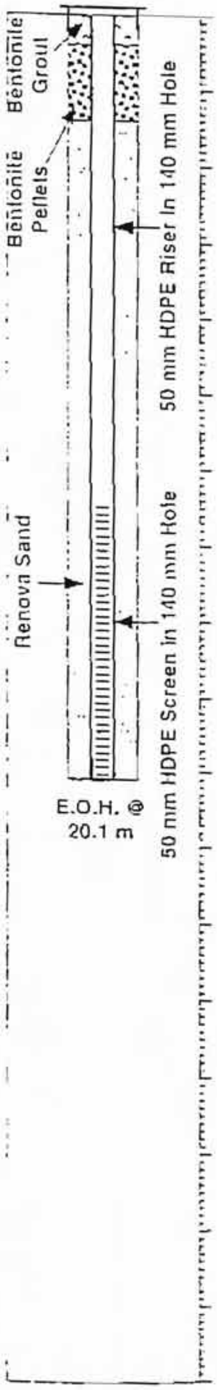
Sample Type	Depth From	Depth To
grab	1.5	
grab	4.5	
grab	7.5	
grab	10.5	
grab	13.5	
grab	16.5	
grab	19.5	

Metres: 0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36

Drilling Notes and Strata Description

0 - 20.1 m Red Conglomerate Bedrock

Construction Details



Sample / Test Legend
U - U100 Tubes
S - Slit Spoon

Monitoring Well Log

Monitoring Well No. 2s

Client : P.J. Tobin & Co.
Location : Derrinumera, Castlebar.
Job No : 1387
Date : 5/12/97
Description : Monitoring Well

Drilling Company : Glovers Site Investigations Ltd.
Drilling Method : Air Rotary
Drillers Name : P. Dullea
National Grid Co. Ord. : East North
Ground Surface Elev. : 70.67 m.O.D.
Logged by : John Mitchell B. Eng.

Shell & Auger	Air Rotary	250 mm Casing	200 mm Casing	150 mm Casing	Water Strike	Inflow m3/day	Falling Head K(m/s)	Samples					Drilling Notes and Strata Description
								Number	SPT	Type	Depth		
											From	To	
										grab	1.5		0 - 3.0 m red/brown clayey silty gravelly coarse SAND with cobbles & boulders
													3.0 - 3.3 m Red Conglomerate Bedrock

Metres

Construction Details

Sample / Test Legend
U - U100 Tubes
SS - Slit Spoon
SPT - Standard [illegible]

Figure No.

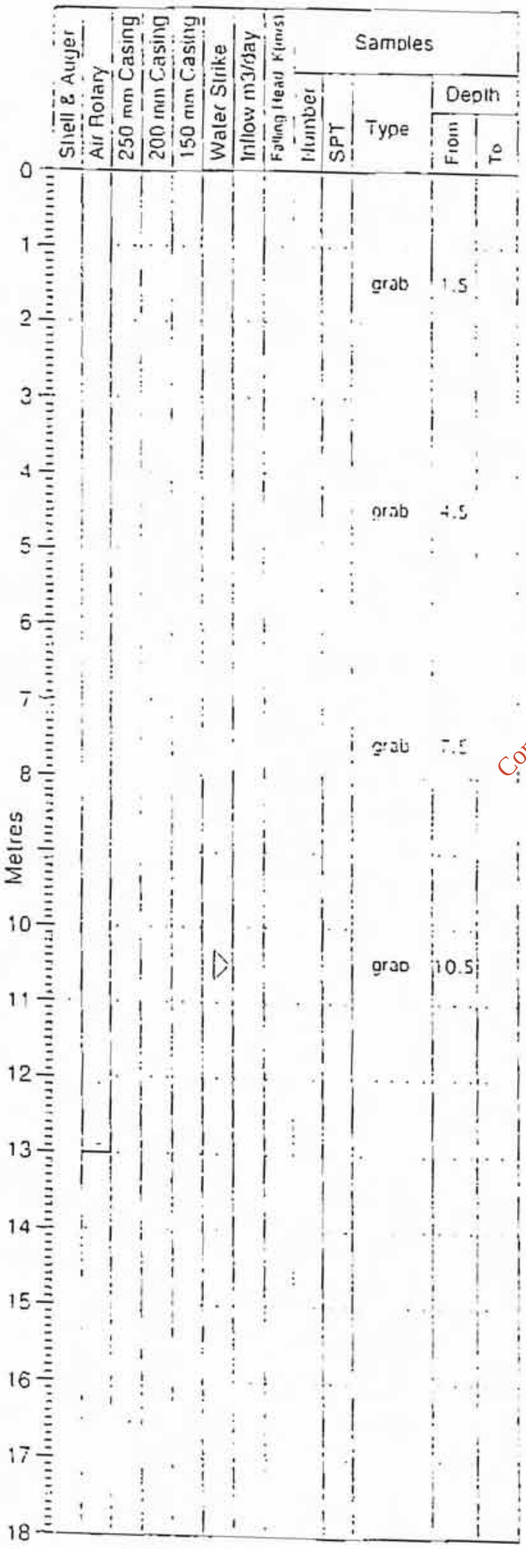
K.T.Cullen & Co. Ltd.
Hydrogeological & Environmental Consultants

Monitoring Well Log

Monitoring Well No. 2d

Client : P.J. Tobin & Co.
Location : Derrinumera, Castlebar.
Job No : 1367
Date : 5/12/97
Description : Monitoring Well

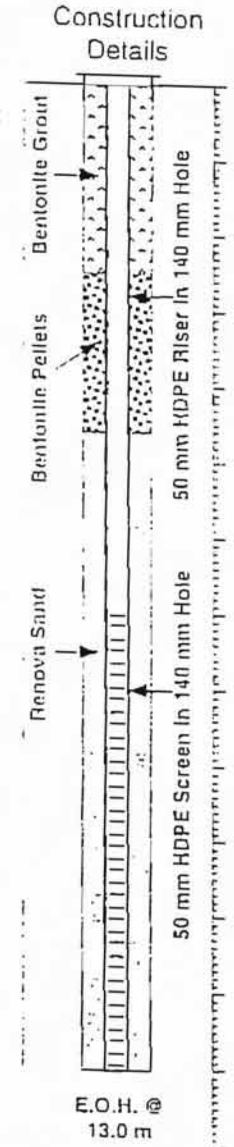
Drilling Company : Glovers Site Investigations Ltd.
Drilling Method : Air Rotary
Drillers Name : P. Dullea
National Grid Co. Ord. : East North
Ground Surface Elev. : 70.88 m.O.D.
Logged by : John Mitchell B. Eng.



Drilling Notes and Strata Description

0 - 1.3 m red/brown clayey silty gravelly coarse SAND with cobbles & boulders

1.3 - 13 m Red Conglomerate Bedrock



Sample / Test Legend
U - U100 Tubes
[illegible]
SPT - Standard [illegible]

Monitoring Well Log

Monitoring Well No. 3

Client : P.J. Tobin & Co.
Location : Derrinumera, Castlebar.
Job No : 1387
Date : 8/12/97
Description : Monitoring Well

Drilling Company : Glovers Site Investigations Ltd.
Drilling Method : Air Rotary
Drillers Name : P. Dullea
National Grid Co. Ord. : East North
Ground Surface Elev. : 78.85 m.O.D.
Logged by : John Mitchell B. Eng.

Shell & Auger	Air Rotary	250 mm Casing	200 mm Casing	150 mm Casing	Water Strike	Inflow m3/day	Falling Head K(m/s)	Samples Number	SPT	Type	Depth From	Depth To
										grab	1.5	
										grab	4.5	
										grab	7.5	
										grab	10.5	
										grab	13.5	

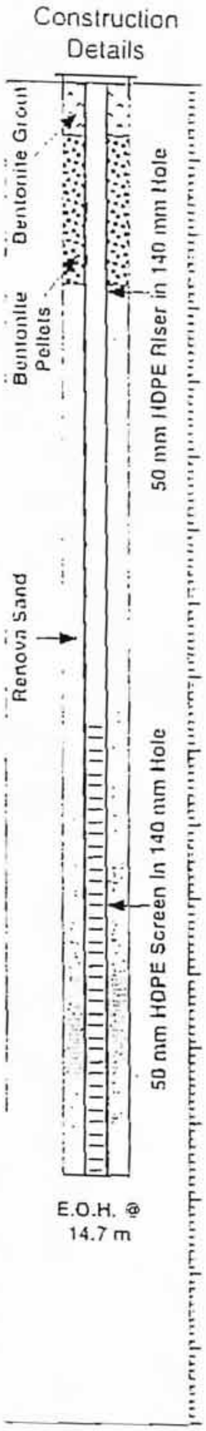
Metres: 0 – 18

Drilling Notes and Strata Description

0 - 2.0 m red/brown clayey silty gravelly coarse SAND with cobbles & boulders

1.3 - 14.7 m Red Conglomerate Bedrock

Construction Details



K.T.Cullen & Co. Ltd.

Sample / Test Legend
U - U100 Tubes
SS - Split Spoon
SPT - Standard Penetration Test

Monitoring Well Log

Monitoring Well No. 4s

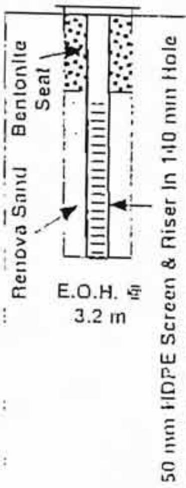
Client : P.J. Tobin & Co.
Location : Derrinumera, Castlebar
Job No : 1387
Date : 9/12/97
Description : Monitoring Well

Drilling Company : Glovers Site Investigations Ltd.
Drilling Method : Air Rotary
Drillers Name : P. Dullea
National Grid Co. Ord. : East North
Ground Surface Elev. : 66.39 m.O.D.
Logged by : John Mitchell B. Eng.

Metres	Shell & Auger	Air Rotary	250 mm Casing	200 mm Casing	150 mm Casing	Water Strike	Inflow m3/day	Falling Head K(m/s)	Samples Number	SPT	Type	Depth From	To	Drilling Notes and Strata Description
0														0 - 0.4 m PEAT
											grab	1.5		0.4 - 3.2 m red/brown clayey silty gravelly coarse SAND with cobbles & boulders
3.2														3.2 m Red Conglomerate Bedrock

Metres: 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

Construction Details



Sample / Test Legend
U - U100 Tubes
[illegible]
SPT - Standard Penetration Test

Figure N

Monitoring Well Log

Monitoring Well No. 4d

Client : P.J. Tobin & Co.
Location : Derrinumera, Castlebar.
Job No : 1387
Date : 9/12/97
Description : Monitoring Well

Drilling Company : Glovers Site Investigations Ltd.
Drilling Method : Air Rotary
Drillers Name : P. Dullea
National Grid Co. Ord. : East North
Ground Surface Elev. : 66.55 m.O.D.
Logged by : John Mitchell B. Eng.

Shell & Auger	Air Rotary	250 mm Casing	200 mm Casing	150 mm Casing	Water Strike	Inflow m3/day	Falling Head K(m/s)	Samples Number	Samples SPT	Samples Type	Samples Depth From	Samples Depth To
										grab	1.5	
										grab	7.5	
										grab	13.5	
										grab	19.5	

Metres: 0 – 36

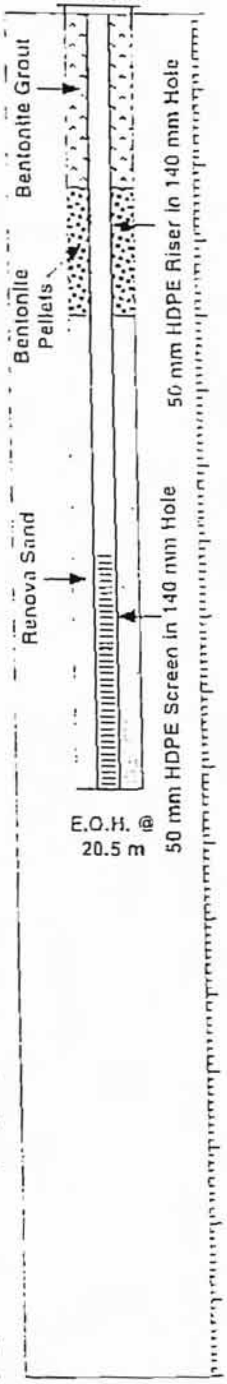
Drilling Notes and Strata Description

0 - 0.4 m PEAT

0.4 - 2.8 m red/brown clayey silty gravelly coarse SAND with cobbles & boulders

2.8 - 20.5 m Red Conglomerate Bedrock

Construction Details



Sample / Test Legend
U - U100 Tubes
S - Split Spoon
- Standard Penetration Test

Monitoring Well Log

Monitoring Well No. 5

Client :	P.J Tobin & Co.	Drilling Company :	Glovers Site Investigations Ltd.
Location :	Derrinumera, Castlebar.	Drilling Method :	Air Rotary
Job No :	1387	Drillers Name :	P. Dullea
Date :	10/12/97	National Grid Co. Ord. :	East North
Description :	Monitoring Well	Ground Surface Elev. :	86.42 m.O.D.
		Logged by :	John Mitchell B. Eng.

Shell & Auger · Air Rotary · 250 mm Casing · 200 mm Casing · 150 mm Casing · Water Strike · Inflow m3/day · Falling Head K(m/s)

Samples

Number	SPT	Type	Depth From	Depth To
		grab	1.5	
		grab	5.0	
		grab	6.5	
		grab	7.5	
		grab	8.0	

Metres 0–18

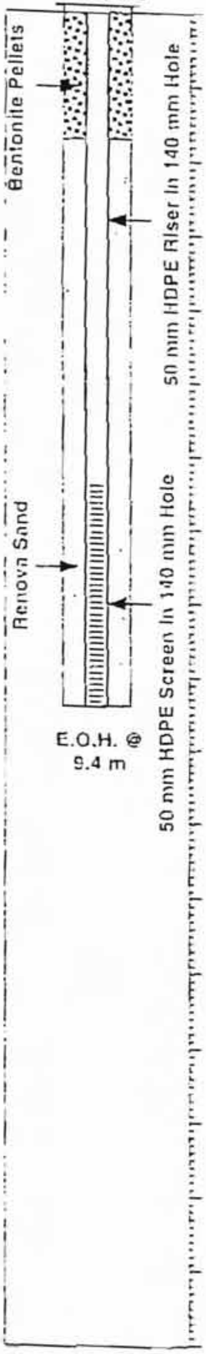
Drilling Notes and Strata Description

0 - 0.6 m PEAT

0.6 - 3.2 m red/brown clayey silty gravelly coarse SAND with cobbles & boulders

3.2 - 9.4 m Red Conglomerate Bedrock

Construction Details



Sample / Test Legend
U - U100 Tubes
SS - Split Spoon
SPT - Standard Penetration Test

K T Cullen & Co. Ltd.
[illegible] Consultants

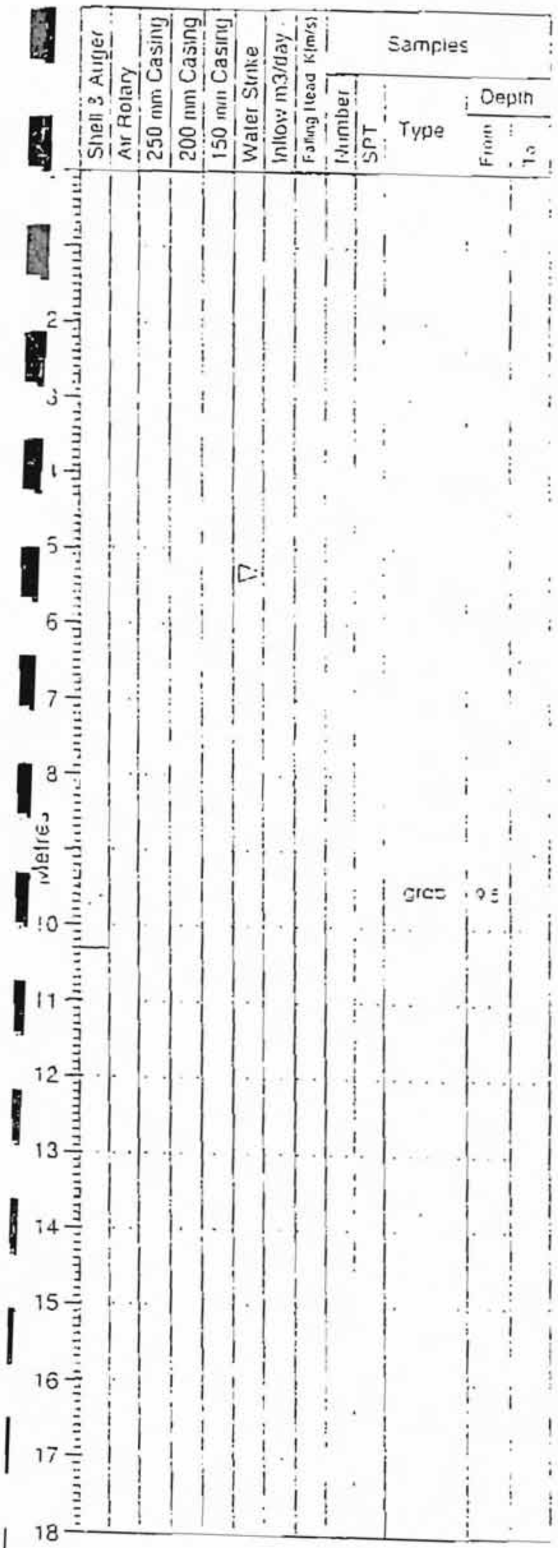
Figure No.

Monitoring Well Log

Monitoring Well No. 6

Client : P.J. Tobin & Co.
Location : Derrinumera, Castlebar.
Job No : 1387
Date : 16/12/97
Description : Monitoring Well

Drilling Company : Glovers Site Investigations Ltd.
Drilling Method : Shell & Auger
Drillers Name : John Campbell
National Grid Co. Ord. : East North
Ground Surface Elev. : 78.18 m.O.D.
Logged by : C. Walsh B.Sc.



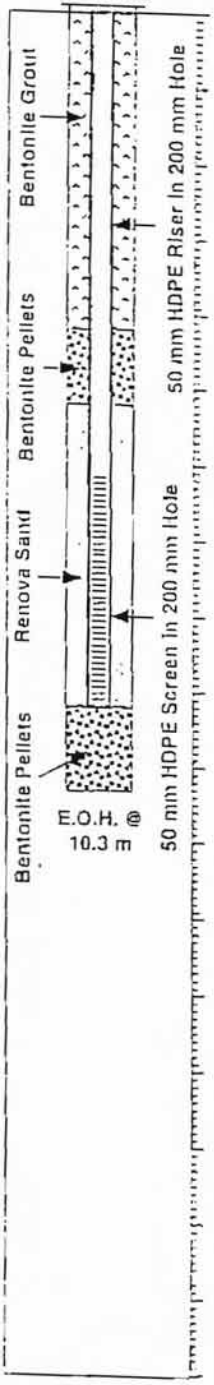
Drilling Notes and Strata Description

0 - 0.6 m Clay Fill with boulders

0.6 - 9.2 m Waste

9.2 -10.3 m compressed PEAT

Construction Details



K.T.Cullen & Co. Ltd.

Sample / Test Legend
U - U100 Tubes
SS - Slit Spoon
[illegible]

Monitoring Well Log

Monitoring Well No. 7

Client : P.J. Tobin & Co.
Location : Derrinumera, Castlebar.
Job No : 1387
Date : 17/12/97
Description : Monitoring Well

Drilling Company : Glovers Site Investigations Ltd.
Drilling Method : Shell & Auger
Drillers Name : John Campbell
National Grid Co. Ord. : East North
Ground Surface Elev. : 70.07 m.O.D.
Logged by : C. Walsh B.Sc.

Metres	Shell & Auger	Air Rotary	250 mm Casing	200 mm Casing	150 mm Casing	Water Strike	Inflow m3/day	Falling Head K(m/s)	Samples				
									Number	SPT	Type	Depth From	Depth To
1											grab	1.0	
1.6						∇					grab	1.6	
3											grab	3.0	
4											grab	4.0	

Drilling Notes and Strata Description

0 - 1.55 m PEAT

1.55 - 2.00 m red clayey silty gravelly SAND with subangular cobbles & boulders

2.00 - 4.40 m weathered red Conglomerate Bedrock

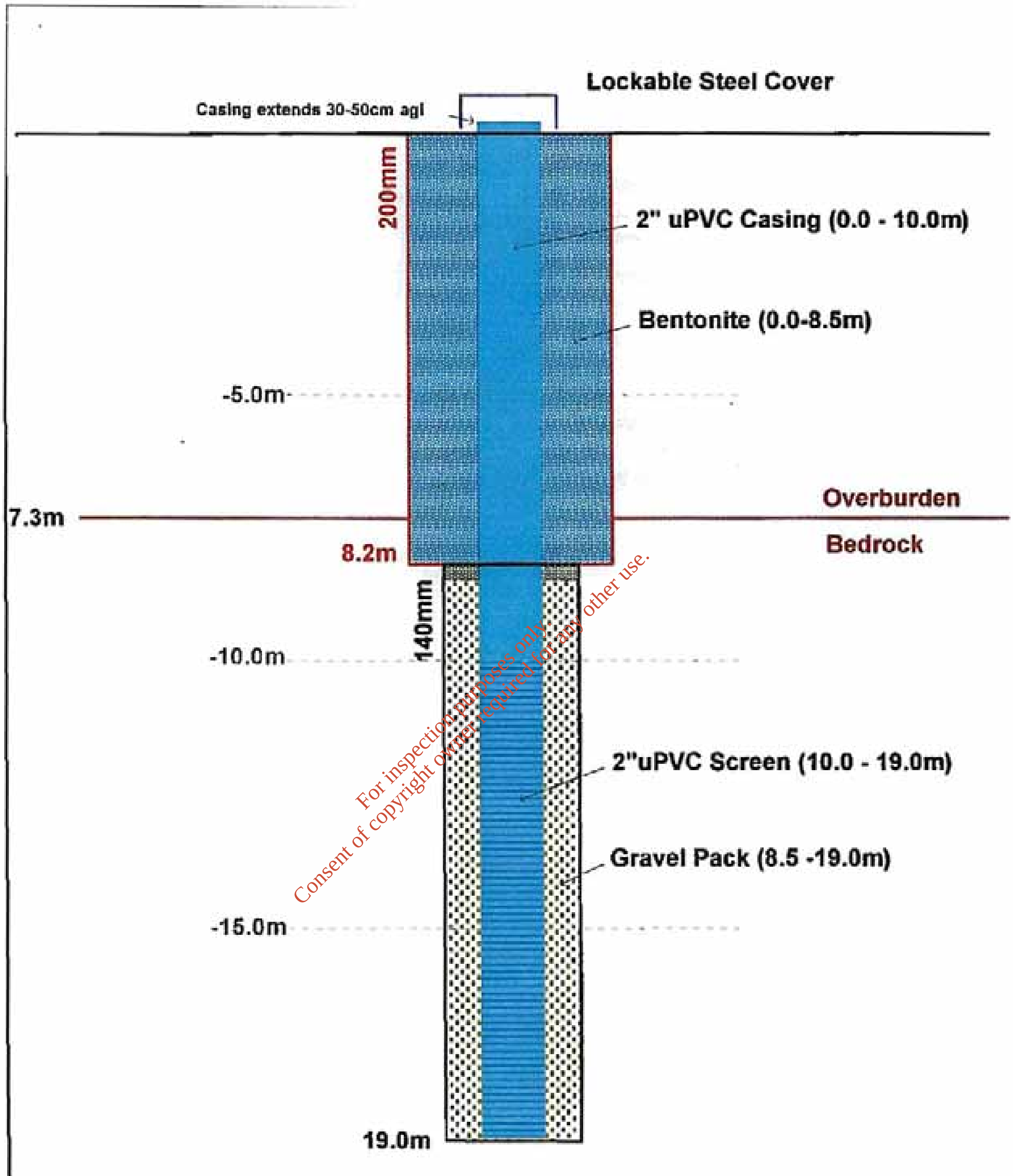
Construction Details

K.T.Cullen & Co. Ltd.
Hydrogeological & Environmental Consultants

Sample / Test Legend
U - U100 Tubes
SS - Slit Spoon
SPT - Standard Penetration Test

Figure No.

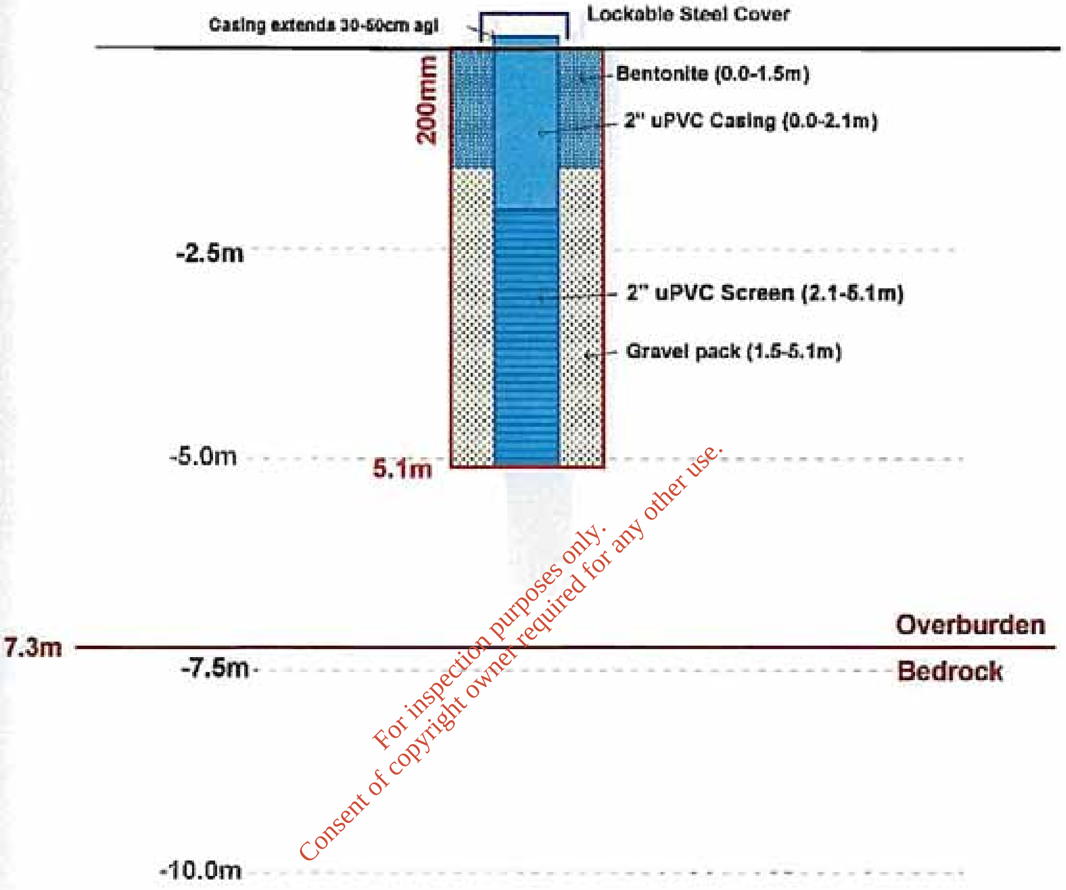
Recent S.I. Results



MW-17 Instalation Log

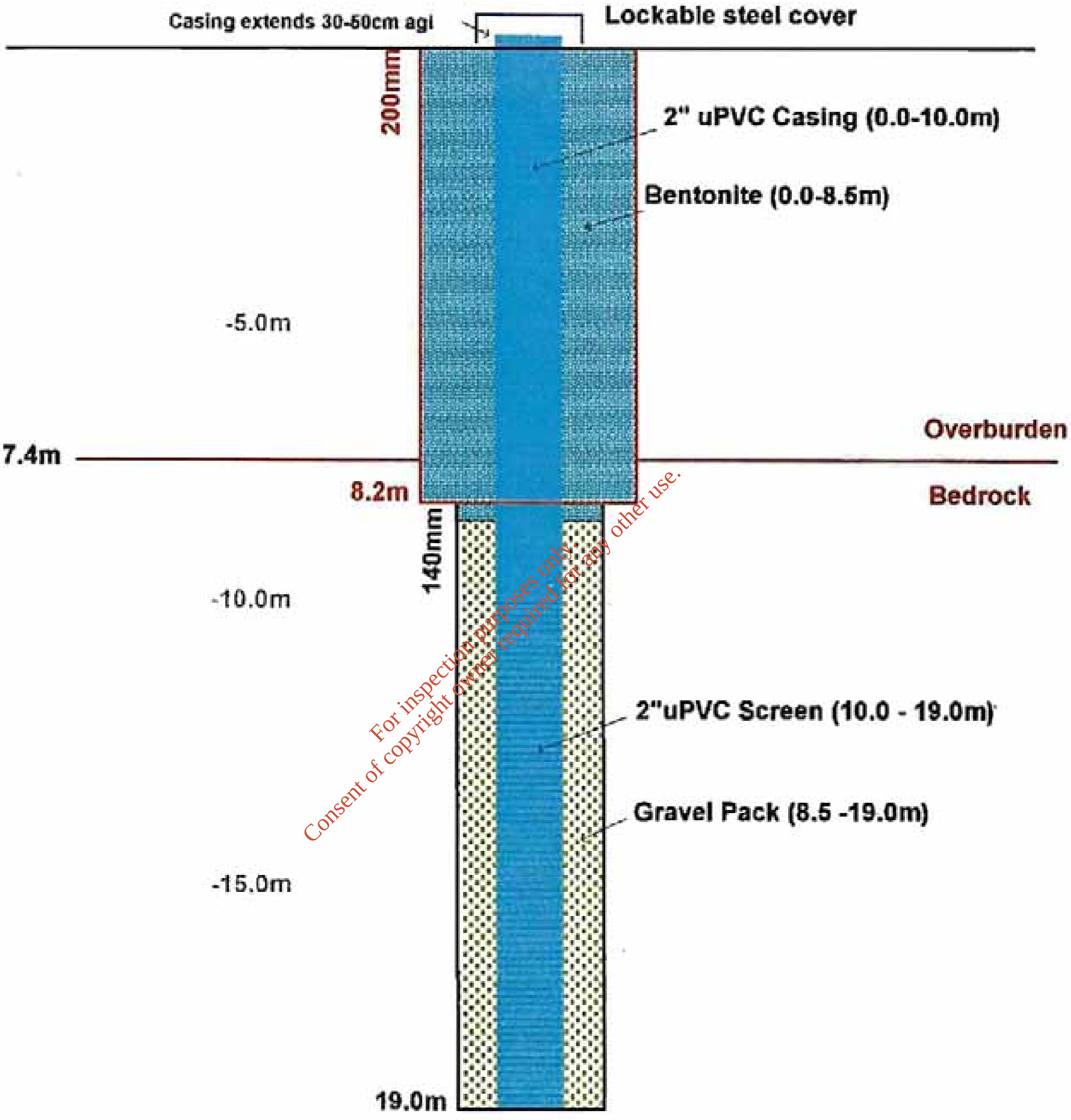
[illegible]	Drawn By: D [illegible]
Project No : 10/03	Date: 4 October 2003
Map [illegible]	WorkSpace: BRD/TES/Contract 5/MW[illegible]
Map Scale : 1:100	Projection: Non Earth Metres

brg



MW-18 Instalation Log

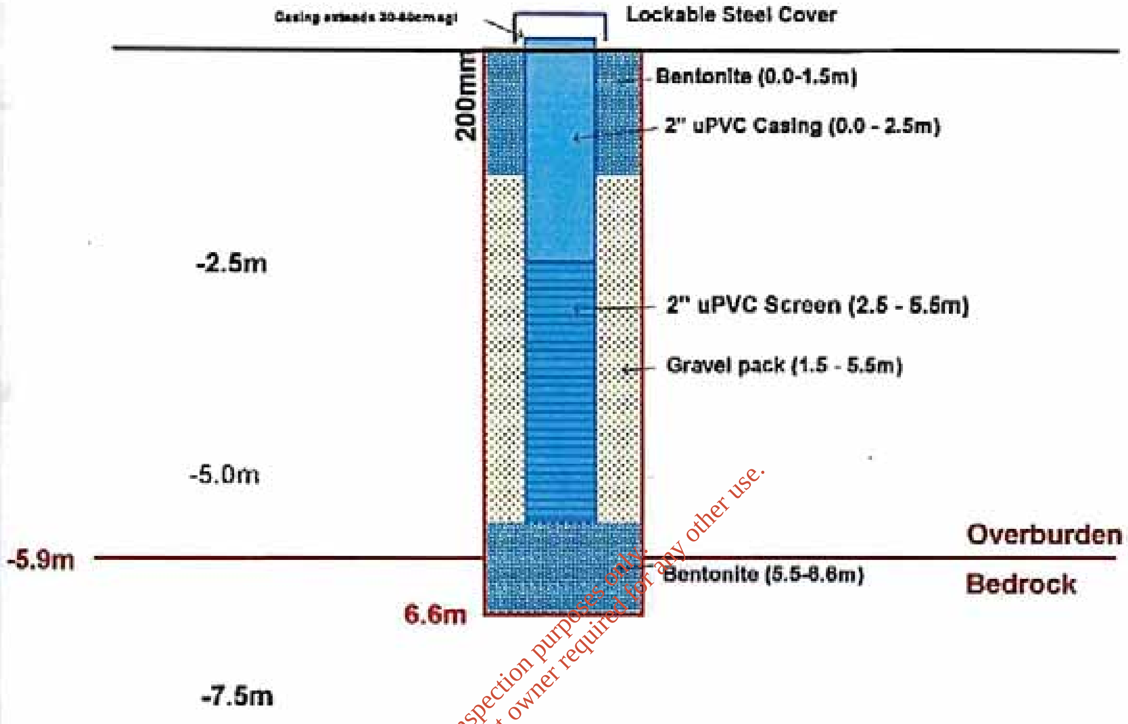
Project: TES 05/03	Drawn By: D Blaney
Project No.: 10/03	Date: 6 October 2003
Map:instlog	WorkSpace:BRG/TES/Contract 5/MW1
Map Scale :1:75	Projection: Non-Earth Metres



MW-20 Instalation Log

Project: TES 01/03	Drawn By: D Blaney
Project No : 10/03	Date: 6 October 2003
Map: Insting	WorkSpace: DRO/TES/Contract 5/MW20
Map Scale : 1:100	Projection: Non-Earth Metres

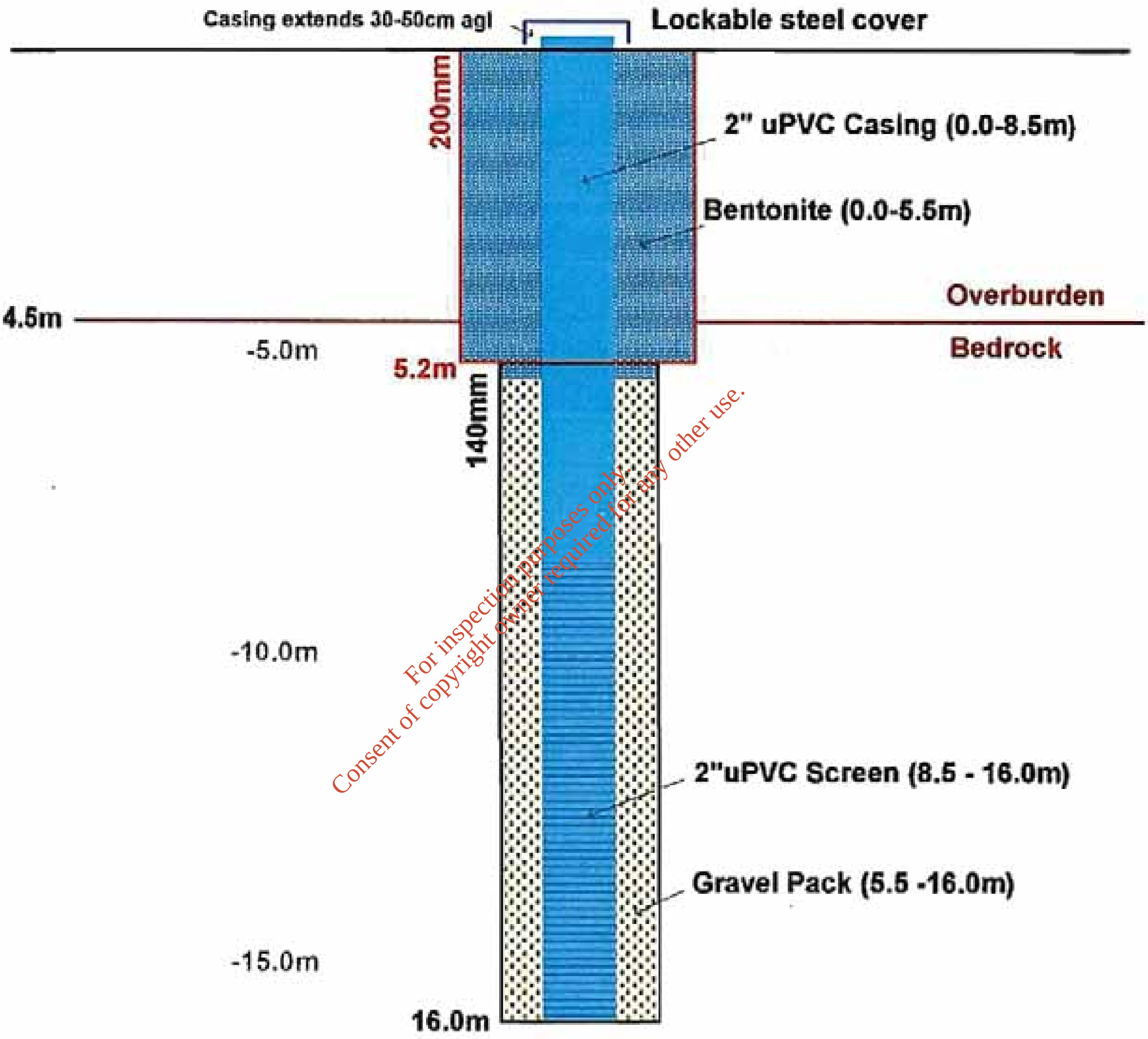
brg



MW-21 Instalation Log

Project: TES 05/03	Drawn By: D Blaney
Project No: 10/03	Date: 5 October 2003
Map: Instlog	WorkSpace:BRG/TES/Contract 5/MW21
Map Scale :1:75	Projection: Non-Earth Metres

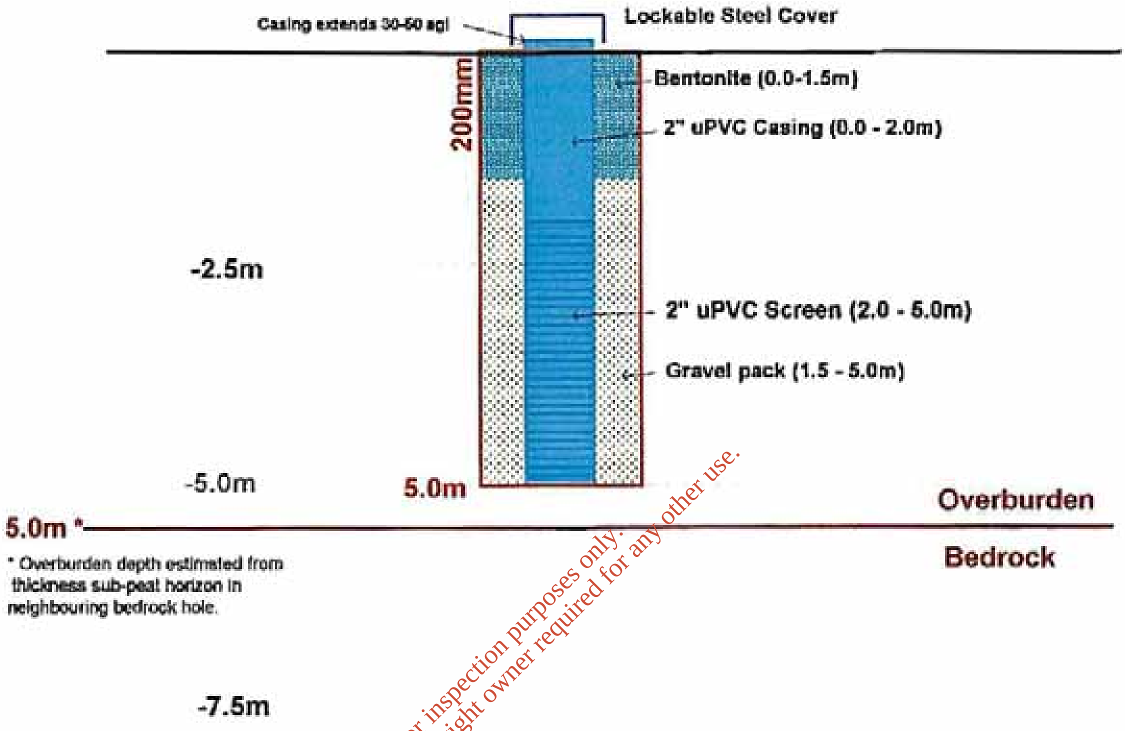
brg



MW-22 Instalation Log

Project: TES 05/03	Drawn By: D Blaney
Project No.: 10/03	Date: 8 October 2003
Map:Inst.log	Workspace: BRG/TES/Contract 3/MW22
Map Scale :1:100	Projection: Non-Earth Meters

brg

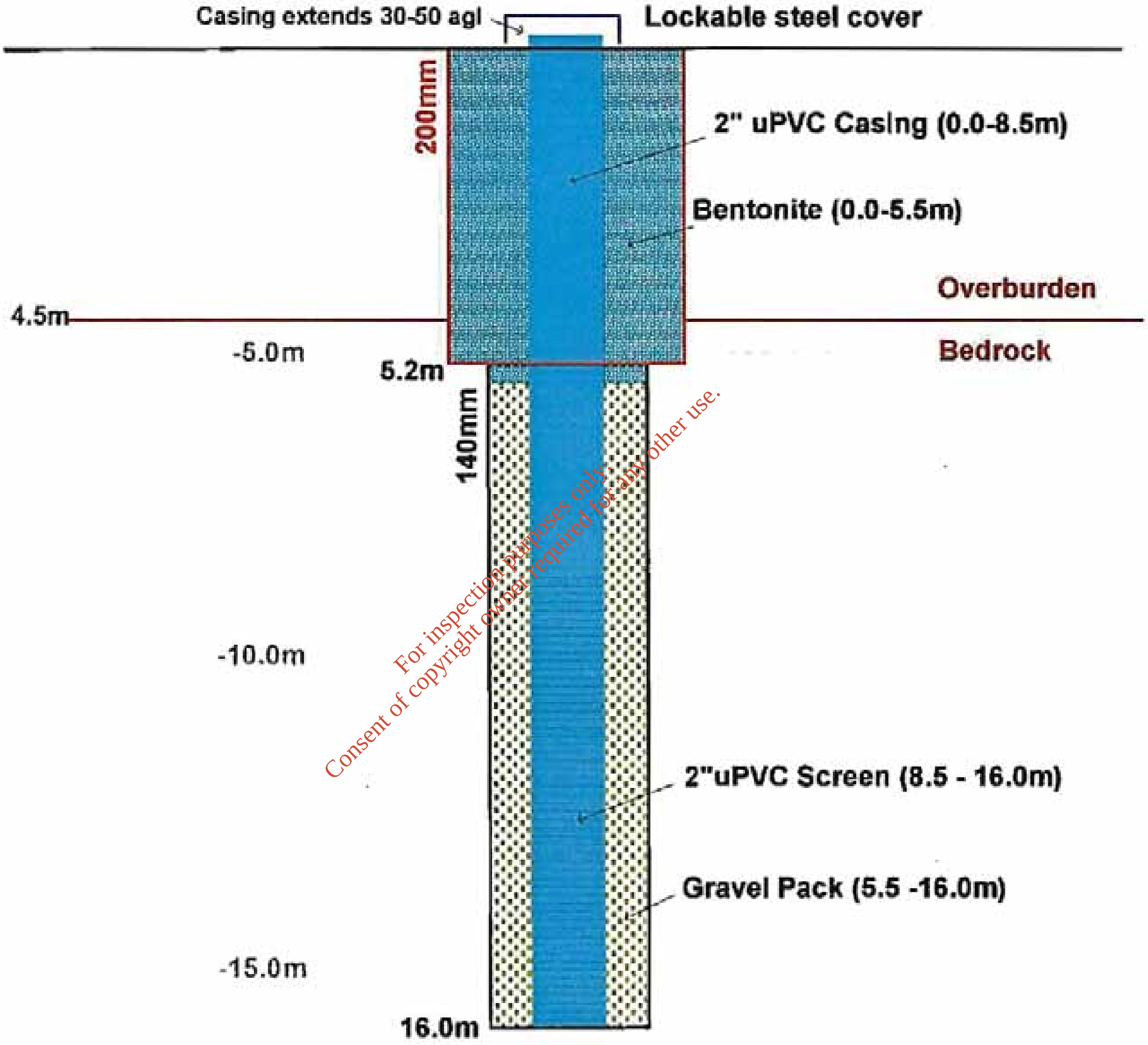


* Overburden depth estimated from thickness sub-peat horizon in neighbouring bedrock hole.

MW-23 Instalation Log

Project: TES 06/03
Drawn By: D Blaney
Project No.: 10/03
Date: 6 October 2003
Map:Instlog
WorkSpace:BRG/TES/Contract 5/MW
Map Scale :1:78
Projection: Non-Earth Metres

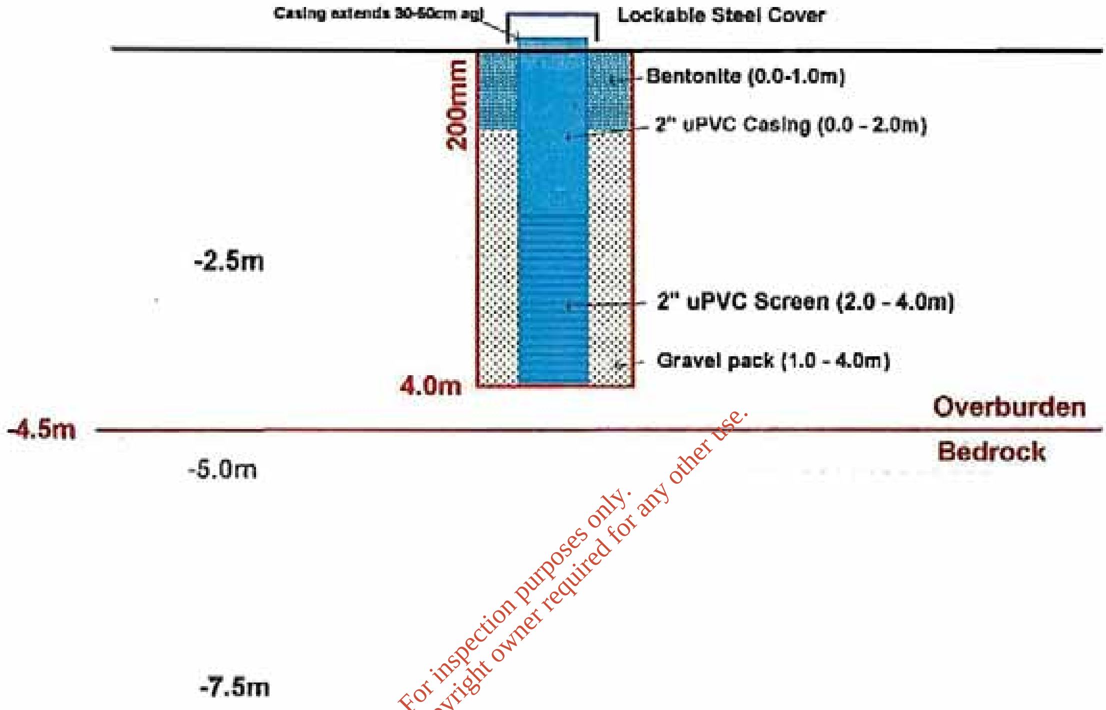
brg



MW-24 Instalation Log

Project: TES 05/03	Drawn By: D Blaney
Project No.: 10/03	Date: 6 October 2003
Map: Instlog	WorkSpace: BRO/TES/Contract 6/MW24
Map Scale: 1:100	Projection: Non-Earth Metres

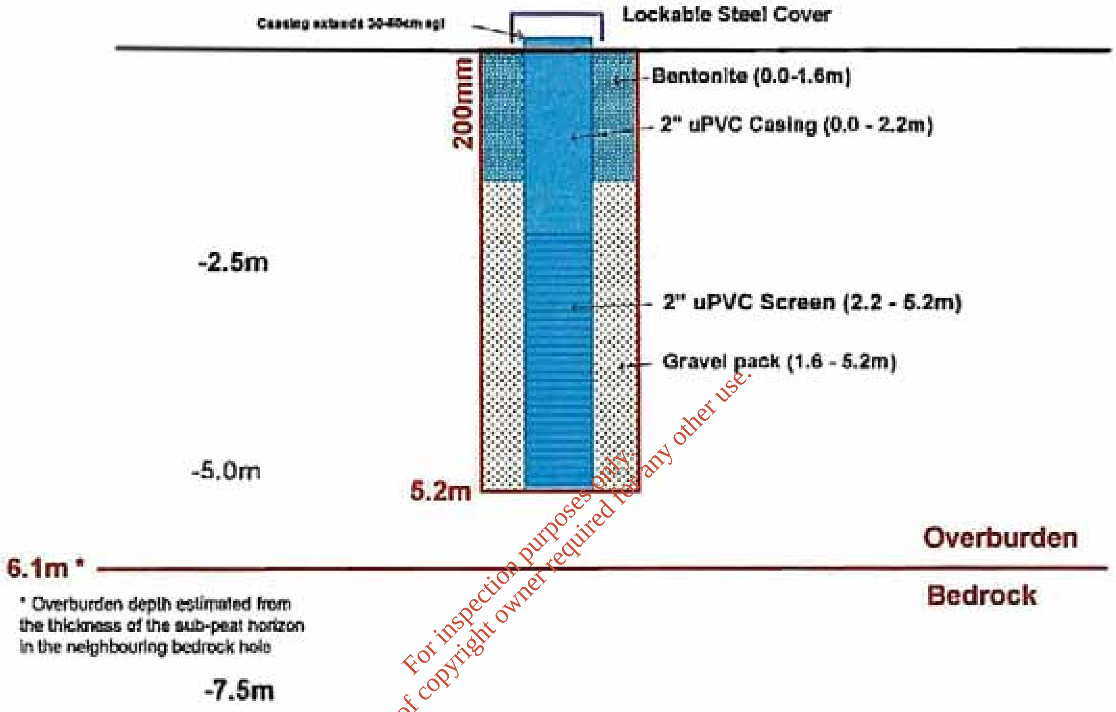
brg



MW-25 Instalation Log

Project: TEB 01/03	Drawn By: D Blaney
Project No : 10/03	Date: 8 October 2003
Map Ins/Reg	Workspace: BRD/TEB/Contract 5/MW25
Map Scale : 1:75	Projection: Non-Earth Metres

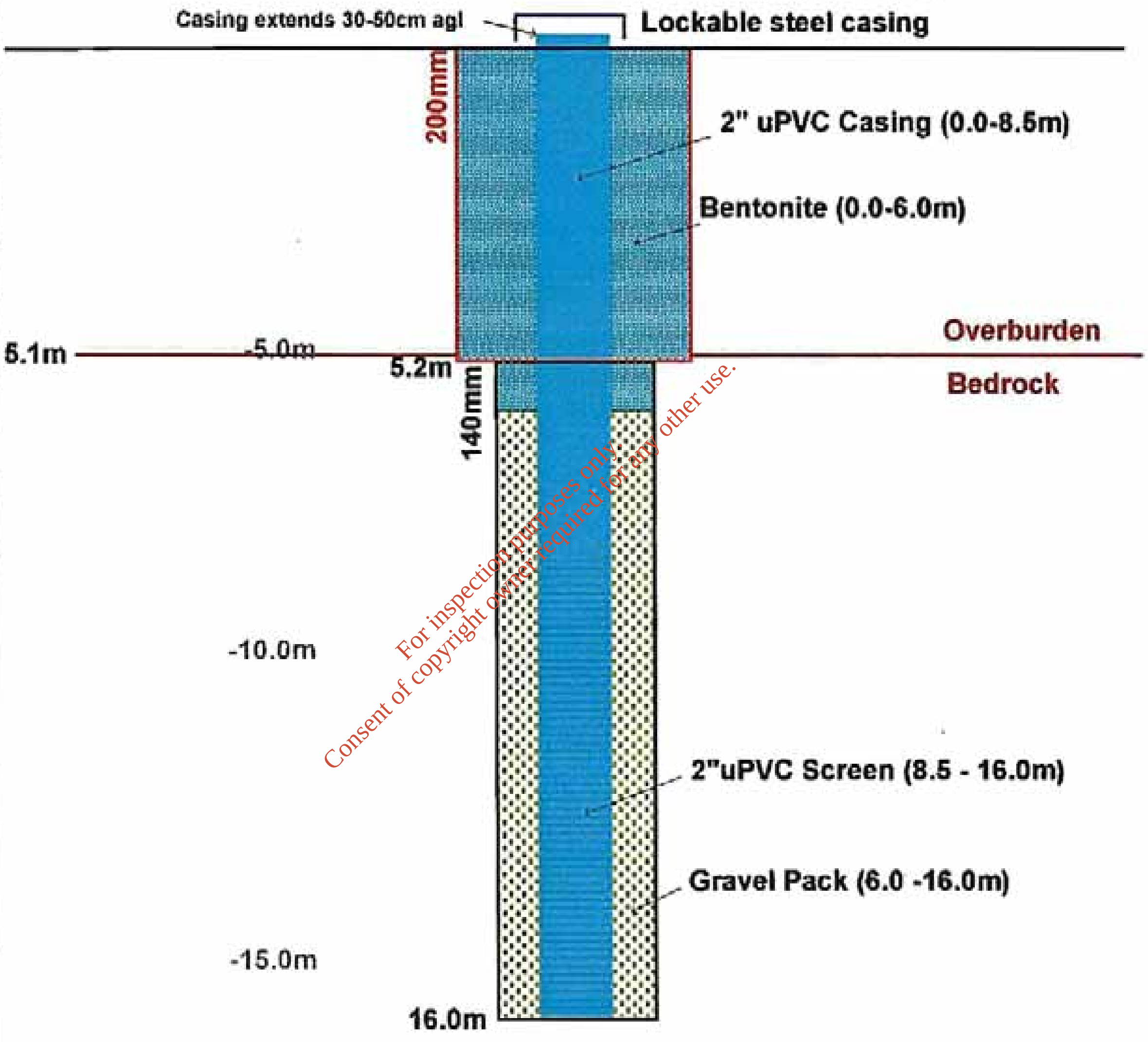
brg



MW-26 Instalation Log

Project: TES 08/03
Drawn By: D Blaney
Project No.: 10/03
Date: 6 October 2003
MapInfoRef
WorkSpace: BRG/TES/Contract 5/M
Map Scale: 1:75
Projection: Non-Earth Metres

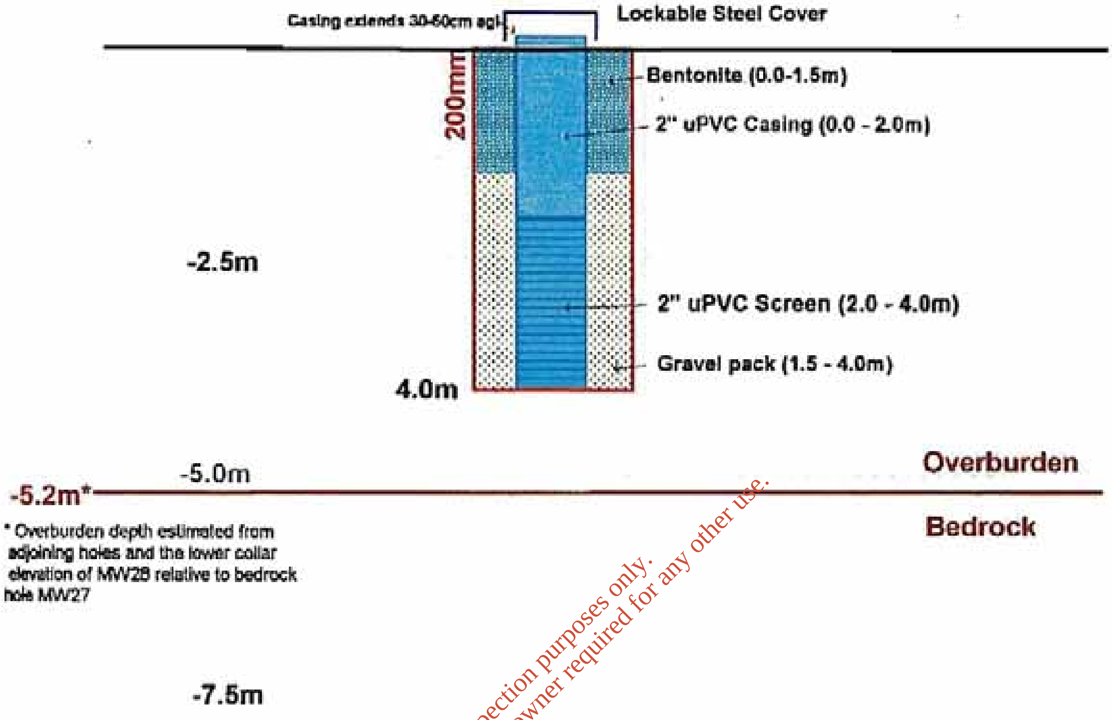
brg



MW-27 Instalation Log

Project: TES 06/03	Drawn By: D Blaney
Project No.: 10/03	Date: 6 October 2003
Map:instlog	WorkSpace:BRG/TES/Contract 5/MW
Map Scale :1:100	Projection: Non-Earth Metres

brg



* Overburden depth estimated from adjoining holes and the lower collar elevation of MW28 relative to bedrock hole MW27

MW-28 Instalation Log

Project: TES 05/03	Drawn By: D Blaney
Project No.: 10/03	Date: 6 October 2003
Map:instlog	WorkSpace:BRG/TES/Contract 5/MW2
Map Scale :1:75	Projection: Non-Earth Metres

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Borehole No
MW-17
Sheet 1 of 2

Project Name: TES-Derrinumera-Co Mayo
Project No.: TES2
Co-ords: 104530E - 293558N
Hole Type: PD

Engineer: TES Consulting Engineers Ltd.
Drilling Company: Dullea Well Drilling
Level: -
Azimuth: - 90
Scale: 1:50

Client: Mayo County Council
Driller: Pat Dullea
Dates: 30/09/2003
Logged By: D Blaney

Well	Water Strikes	Samples & In Situ Testing Depth (m)	Type	Results	Depth (m)	Level (m AOD)	Legend	Stratum Description
							▩	Aggregate / Fill - Limestone boulders and gravel
					0.90		▒	PEAT
					5.00		▤	Soft, pale purple/pink, Clayey SAND, occasional sub-rounded gravel
					7.30		░	Red / brown SANDSTONE, cuttings dominantly medium grained rounded quartz grains minor millimetric scale sub-rounded translucent grey quartzite fragments. Water strike at 7.9m.
					9.50		▤	Red/pink SANDSTONE, balls of pale pink clay. More rapid penetration by drill.

Type Results

Continued next sheet

Remarks: Site D - Bedrock hole, outside of the cut-off wall. Located by a handheld 'Garmin 12' GPS Accurate to +/-8.0m.

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Borehole No
MW-17
Sheet 2 of 2

Project Name TES-Derrinumera-Co Mayo	Project No. TES2	Co-ords: 104530E - 293558N		Hole Type PD
Engineer: TES Consulting Engineers Ltd.	Drilling Company Dullea Well Drilling	Level: -	Azimuth - 90	Scale 1:50
Client: Mayo County Council	Driller Pat Dullea	Dates: 30/09/2003		Logged By D Blaney

Well	Water Strikes	Samples & In Situ Testing			Depth (m)	Level (m AOD)	Legend	Stratum Description
		Depth (m)	Type	Results				
					10.00			CONGLOMERATIC SANDSTONE, pink/purple sandstone with fragments of quartz upto 0.5mm in diameter.
					13.30			Red/purple medium grained SANDSTONE, grains of rounded quartz
					15.70			Dominantly SANDSTONE red/purple sand with occasional larger (0.5-1.0cm) cuttings of pale grey sandstone/quartzite and black/red mudstone, more rapid penetration of drill.
					16.50			CONGLOMERATE, becomes coarser grained with tabular fragments of pale sandstone and quartzite with black/red mudstone fragments.
					19.00			End of Borehole at 19.00 m

Type Results

Remarks: Site D - Bedrock hole, outside of the cut-off wall. Located by a handheld 'Garmin 12' GPS
Accurate to +/-8.0m.

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Project Name TES-Derrinumera-Co Mayo	Project No. TES2	Co-ords: 104536E - 293563N	Hole Type PD
Engineer: TES Consulting Engineers Ltd.	Drilling Company Dullea Well Drilling	Level: - Azimuth - 90	Scale 1:50
Client: Mayo County Council	Driller Pat Dullea	Dates: 30/09/2003	Logged By D Blaney

Well	Water Strikes	Samples & In Situ Testing Depth (m)	Type	Results	Depth (m)	Level (m AOD)	Legend	Stratum Description
								Aggregate/fill - limestone boulders and gravel.
					0.80			PEAT
					4.10			Soft, dark purple brown Sandy CLAY, with occasional, fine to medium grained, sub-rounded gravel
					5.10			End of Borehole at 5.10 m

Type Results

Remarks: Site D - Overburden hole outside of the cut-off wall. Located with a handheld 'Garmin12' GPS - accurate to +/-8m

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Borehole No
MW-19
Sheet 1 of 1

Project Name TES-Derrinumera-Co Mayo	Project No. TES2	Co-ords: -		Hole Type PD
Engineer: TES Consulting Engineers Ltd.	Drilling Company Dullea Well Drilling	Level: -	Azimuth - 90	Scale 1:50
Client: Mayo County Council	Driller Pat Dullea	Dates: 30/09/2003		Logged By D Blaney

Well	Water Strikes	Samples & In Situ Testing Depth (m)	Type	Results	Depth (m)	Level (m AOD)	Legend	Stratum Description
								Aggreagate/fill - Limestone boulders and gravel
					0.70			PEAT
					5.50			Soft, dark to medium brown, Sandy CLAY, with occasional sub-rounded gravel
					6.80			End of Borehole at 6.80 m

Type Results

Remarks: Site D - Overburden hole inside of the cut-off wall.

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Project Name TES-Derrinumera-Co Mayo	Project No. TES2	Co-ords: -	Hole Type PD
Engineer: TES Consulting Engineers Ltd.	Drilling Company Dullea Well Drilling	Level: -	Azimuth - 90
Client: Mayo County Council	Driller Pat Dullea	Dates: 01/10/2003	Scale 1:50
			Logged By D Blaney

Borehole No
MW-20
Sheet 1 of 2

Well	Water Strikes	Samples & In Situ Testing			Depth (m)	Level (m AOD)	Legend	Stratum Description
		Depth (m)	Type	Results				
					0.50			Aggregate/Fill - Limestone boulders and gravel
					5.10			PEAT
					7.40			Loose - Medium dense, purple/brown Clayey SAND, with occasional rounded to sub-rounded gravel (quarz, quartzite and sandstone)
					8.30			SANDSTONE - fragments up to 3cm in dia of coarse grained red/grey/green sandstone. Water strike at c.8.0m vis. est <50gal/hr
								CONGLOMERATE - Coarse cuttings of quartz, quartzite, brown sandstone and minor green volcanic clasts with brown medium grained sand that probably formed the matrix of the conglomerate

Type Results

Continued next sheet

Remarks: Site C, Bedrock hole outside of the cut-off wall

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Borehole No
MW-20
Sheet 2 of 2

Project Name TES-Derrinumera-Co Mayo	Project No. TES2	Co-ords: -		Hole Type PD
Engineer: TES Consulting Engineers Ltd.	Drilling Company Dullea Well Drilling	Level: -	Azimuth - 90	Scale 1:50
Client: Mayo County Council	Driller Pat Dullea	Dates: 01/10/2003		Logged By D Blaney

Well	Water Strikes	Samples & In Situ Testing Depth (m)	Type	Results	Depth (m)	Level (m AOD)	Legend	Stratum Description
					10.00			Cuttings become finer grained, either fine grained conglomerate or coarse sandstone. Cuttings dominated by brown/white rounded quartz grains with minor pale grey quartzite and red brown mudstone
					14.00			Possible water strike? - slight increase in water return
					15.50			Returns become paler with more rapid pentration, cutting contain small 'balls' of pink clay, - possible thin clay gouge.
					15.60			Dominantly red/brown, medium to coarse grained, rounded quartz grains, minor rounded fragments of white quartz and red/brown quartzite. Drill labouring slightly at 17m possibly a thin conglomeratic band
					19.00			End of Borehole at 19.00 m

Type Results

Remarks: Site C, Bedrock hole outside of the cut-off wall

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Project Name	Project No.	Co-ords:		Borehole No
TES-Derrinumera-Co Mayo	TES2	-		**MW-21**
				Sheet 1 of 1
				Hole Type
				PD
Engineer:	Drilling Company	Level:	Azimuth	Scale
TES Consulting Engineers Ltd.	Dullea Well Drilling	-	- 90	1:50
Client:	Driller	Dates:		Logged By
Mayo County Council	Pat Dullea	01/10/2003		D Blaney

Well	Water Strikes	Samples & In Situ Testing Depth (m)	Type	Results	Depth (m)	Level (m AOD)	Legend	Stratum Description
					0.50			Aggregate/Fill - Limestone boulders and gravel
					5.20			PEAT
					5.90			Loose, reddish, brown, coarse grained clayey SAND with gravel, rounded to sub-rounded medium grained (0.5-2cm dia.) Minor water strike at 5.2m.
					6.60			SANDSTONE - Red/ grey, coarse grained sandstone.

End of Borehole at 6.60 m

Type Results

Remarks: Site C - Outside the cut off wall. This was designed as an overburden hole, but it penetrated bedrock. The bedrock intercept was sealed with bentonite 0.4m back from rockhead into the overburden

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Borehole No
MW-22
Sheet 1 of 2

Project Name	Project No.	Co-ords:		Hole Type
TES-Derrinumera-Co Mayo	TES2	104625E - 293729N		PD
Engineer:	Drilling Company	Level:	Azimuth	Scale
TES Consulting Engineers Ltd.	Dullea Well Drilling	0.00 m AOD	- 90	1:50
Client:	Driller	Dates:		Logged By
Mayo County Council	Pat Dullea	30/09/2003		D Blaney

Well	Water Strikes	Samples & In Situ Testing			Depth (m)	Level (m AOD)	Legend	Stratum Description
		Depth (m)	Type	Results				
								Aggregate/Fill - Limestone boulders and gravel
					0.50	-0.50		PEAT, woody texture
					3.00	-3.00		Soft, pale purple/brown, Sandy CLAY, with sub-angular to sub-rounded gravel. Minor water strike between 4.2 and 4.3m.
					4.50	-4.50		CONGLOMERATE, 0.5 -1.0cm sized clasts of pale grey quartzite, red sandstone and red brown mudstone. Water strike at 6.9m - c.100gal/hr.

Type Results

Continued next sheet.

Remarks: Site C - Bedrock hole inside the cut-off wall. Located with handheld GPS - accurate to +/-8m

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Borehole No
MW-22
Sheet 2 of 2

Project Name TES-Derrinumera-Co Mayo	Project No. TES2	Co-ords: 104625E - 293729N	Hole Type PD
Engineer: TES Consulting Engineers Ltd.	Drilling Company Dullea Well Drilling	Level: 0.00 m AOD Azimuth - 90	Scale 1:50
Client: Mayo County Council	Driller Pat Dullea	Dates: 30/09/2003	Logged By D Blaney

Well	Water Strikes	Samples & In Situ Testing Depth (m)	Type	Results	Depth (m)	Level (m AOD)	Legend	Stratum Description
					10.00	-10.00		CONGLOMERATE - becoming slightly finer grained, red/brown sand with fine gravel sized fragments of quartzite, sandstone and mudstone. Slight increase in water return.
					12.20	-12.20		SANDSTONE - pale purple sand, very few cuttings returned that are greater than sand sized.
					16.00	-16.00		End of Borehole at 16.00 m

11
12
13
14
15
16
17
18
19

Type Results

Remarks: Site C - Bedrock hole inside the cut-off wall. Located with handheld GPS - accurate to +/-8m

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Project Name TES-Derrinumera-Co Mayo	Project No. TES2	Co-ords: 104629E - 293721N		Borehole No **MW-23** Sheet 1 of 1
				Hole Type PD
Engineer: TES Consulting Engineers Ltd.	Drilling Company Dullea Well Drilling	Level: -	Azimuth - 90	Scale 1:50
Client: Mayo County Council	Driller Pat Dullea	Dates: 30/09/2003-01/10/2003		Logged By D Blaney

Well	Water Strikes	Samples & In Situ Testing Depth (m)	Type	Results	Depth (m)	Level (m AOD)	Legend	Stratum Description
								Aggregate/fill - limestone boulders and gravel
					0.50			PEAT
					4.00			Soft, purple brown, Sandy CLAY, occasional sub-angular to sub-rounded gravel.
					5.00			End of Borehole at 5.00 m

Type Results

Remarks: Site C - Overburden hole inside the cutt-off wall. Hole has been located with a handheld 'Garmin 12' GPS accurate to +/- 8.0m.

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Borehole No
MW-24
Sheet 1 of 2

Project Name	Project No.	Co-ords:		Hole Type
TES-Derrinumera-Co Mayo	TES2	0E - 0N		PD
Engineer:	Drilling Company	Level:	Azimuth	Scale
TES Consulting Engineers Ltd.	Dullea Well Drilling	0.00 m AOD	- 90	1:50
Client:	Driller	Dates:		Logged By
Mayo County Council	Pat Dullea	01/10/2003		D Blaney

Well	Water Strikes	Samples & In Situ Testing Depth (m)	Type	Results	Depth (m)	Level (m AOD)	Legend	Stratum Description
								Aggrate/fill - Limestone boulders and gravel
					0.70	-0.70		PEAT
					3.40	-3.40		Medium dense to loose, reddish/brown, medium grained SAND, occasional gravel, sub-rounded to rounded clasts of red medium grained sandstone. Water strike at 3.4m - low flow rate.
					4.50	-4.50		CONGLOMERATIC SANDSTONE, dominant return is fine to medium grained red/brown/white quartz grains (rounded), occasional larger cuttings (up to 1.5cm dia.) of white sandstone and translucent white grey quartzite. Tabular fragments of red brown mudstone, minor clay balling noted. Increased water return at 6.0m vis. est. c.100-150gal/hr.
					9.00	-9.00		Slightly more rapid penetration

Type Results

Continued next sheet

Remarks: Site B - Bedrock Hole outside of the cut-off wall. Driller reported easier than normal penetration - possibly softer or more fractured sandstones.

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Project Name TES-Derrinumera-Co Mayo	Project No. TES2	Co-ords: 0E - 0N		Borehole No **MW-24** Sheet 2 of 2 Hole Type PD
Engineer: TES Consulting Engineers Ltd.	Drilling Company Dullea Well Drilling	Level: 0.00 m AOD	Azimuth - 90	Scale 1:50
Client: Mayo County Council	Driller Pat Dullea	Dates: 01/10/2003		Logged By D Blaney

Well	Water Strikes	Samples & In Situ Testing Depth (m)	Type	Results	Depth (m)	Level (m AOD)	Legend	Stratum Description
								Slightly more rapid penetration
					11.00	-11.00		Faster penetration, returns are a darker red colour, increased mudstone content noted.
					11.50	-11.50		CONGLOMERATIC SANDSTONE, Coarse sand grains, clasts of rounded quartz, quartzite and red sandstone.
					15.00	-15.00		CONGLOMERATE, sand with up to 30% cuttings of tabular white sandstone/quartzite up to 1cm in dia.
					16.00	-16.00		End of Borehole at 16 00 m

Type Results

Remarks: Site B - Bedrock Hole outside of the cut-off wall. Driller reported easier than normal penetration - possibly softer or more fractured sandstones.

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Project Name TES-Derrinumera-Co Mayo	Project No. TES2	Co-ords: 0E - 0N		Borehole No **MW-25** Sheet 1 of 1 Hole Type PD
Engineer: TES Consulting Engineers Ltd.	Drilling Company Dullea Well Drilling	Level: 0.00 m AOD	Azimuth - 90	Scale 1:50
Client: Mayo County Council	Driller Pat Dullea	Dates: 01/10/2003		Logged By D Blaney

Well	Water Strikes	Samples & In Situ Testing Depth (m)	Type	Results	Depth (m)	Level (m AOD)	Legend	Stratum Description
								PEAT
					2.50	-2.50		Loose - medium dense, red/brown, medium grained SAND and GRAVEL, gravel generally sub-rounded clasts. Minor water strike at 2.5m.
					4.00	-4.00		End of Borehole at 4.00 m

Type Results

Remarks: Site B - Overburden hole outside of the cut-off wall.

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Borehole No
MW-26
Sheet 1 of 1

Project Name	Project No.	Co-ords:		Hole Type
TES-Derrinumera-Co Mayo	TES2	-		PD
Engineer:	Drilling Company	Level:	Azimuth	Scale
TES Consulting Engineers Ltd.	Dullea Well Drilling	-	- 90	1:50
Client:	Driller	Dates:		Logged By
Mayo County Council	Pat Dullea	01/10/2003		D Blaney

Well	Water Strikes	Samples & In Situ Testing Depth (m)	Type	Results	Depth (m)	Level (m AOD)	Legend	Stratum Description
								Aggregate/fill - limestone boulders and gravel
					1.00			PEAT
					3.60			Loose to medium dense, reddish brown Clayey SAND, with sub-rounded to sub-angular, medium grained gravel
					5.20			End of Borehole at 5.20 m

Type Results

Remarks: Site A - Overburden hole outside the cut-off wall.

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Borehole No
MW-27
Sheet 1 of 2

Project Name TES-Derrinumera-Co Mayo	Project No. TES2	Co-ords: -		Hole Type PD
Engineer: TES Consulting Engineers Ltd.	Drilling Company Dullea Well Drilling	Level: -	Azimuth - 90	Scale 1:50
Client: Mayo County Council	Driller Pat Dullea	Dates: 01/10/2003		Logged By D Blaney

Well	Water Strikes	Samples & In Situ Testing Depth (m)	Type	Results	Depth (m)	Level (m AOD)	Legend	Stratum Description
					1.00			Aggregate/fill - limestone boulders and gravel.
					1.30			PEAT
					2.50			Loose to medium dense, pale yellow brown, medium grained SAND.
					5.10			Loose - medium dense, reddish/brown Clayey SAND with sub-rounded to sub-angular gravel, becoming markedly stiffer towards base. Water strike at 3.0m
					7.50			SANDSTONE - cuttings primarily consist of pale grey/red sandstone and red/brown/white sand. Water intersected at rockhead c.100gal/hr
								SANDSTONE / CONGLOMERATE red brown sand with sub rounded fragments of translucent white/green quartzite clasts.

Type Results

Continued next sheet

Remarks: Site A - Bedrock hole outside of the cut-off wall.

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Borehole No
MW-27
Sheet 2 of 2

Project Name	Project No.	Co-ords:		Hole Type
TES-Derrinumera-Co Mayo	TES2	-		PD
Engineer:	Drilling Company	Level:	Azimuth	Scale
TES Consulting Engineers Ltd.	Dullea Well Drilling	-	- 90	1:50
Client:	Driller	Dates:		Logged By
Mayo County Council	Pat Dullea	01/10/2003		D Blaney

Well	Water Strikes	Samples & In Situ Testing Depth (m)	Type	Results	Depth (m)	Level (m AOD)	Legend	Stratum Description
							⁚⁚⁚	SANDSTONE / CONGLOMERATE red brown sand with sub rounded fragments of translucent white/green quartzite clasts.
					11.00		☰	MUDSTONE, more rapid drill penetration, cuttings of red mudstone with minor sandstone.
					11.50		⁚⁚⁚	SANDSTONE - cuttings of predominantly red/brown medium grained sand / sandstone with minor small white/green quartzite and white sandstone fragments
					15.30		- - -	More rapid drill penetration, returns of small rounded balls of pink / purple clay.
					15.60		○○○	CONGLOMERATE, fine grained red & white quartz gains with small clasts of white quartz and quartzite. A few small fragments of bright green mudstone. Larger cuttings of quartzite tend to have a flat/tabular nature.
					16.00			End of Borehole at 16.00 m

Type Results

emarks: Site A - Bedrock hole outside of the cut-off wall.

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Borehole No
MW-28
Sheet 1 of 1

Project Name TES-Derrinumera-Co Mayo	Project No. TES2	Co-ords: -	Hole Type PD
Engineer: TES Consulting Engineers Ltd.	Drilling Company Dullea Well Drilling	Level: -	Azimuth - 90
Client: Mayo County Council	Driller Pat Dullea	Dates: 01/10/2003	Logged By D Blaney

Scale
1:50

Well	Water Strikes	Samples & In Situ Testing Depth (m)	Type	Results	Depth (m)	Level (m AOD)	Legend	Stratum Description
					0.50			Sand and gravel fill
					4.00			PEAT very soft and water-logged
								End of Borehole at 4.00 m

Type Results

Remarks: Site A - Overburden hole inside the cut-off wall

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APPENDIX 10

Leachate Characterisation Report

[TES, 2003]

1. INTRODUCTION

This interim report on leachate characteristics and the effectiveness of current treatment at Castlebar WWTP can be broken into the following sections:

- Purpose of the Report
- Stakeholders and their Concerns;
- Existing Leachate Management System;
- Methodology;
- Laboratory Suite Rationale;
- Relevant Regulatory Standards,

1.1 Purpose of the Report

At present the leachate generated at Derrinumera landfill is first collected in a lagoon. From here it is pumped to, and stored in, 3 large identical precast concrete collection tanks on site. Each tank has a volume of 297m^3 (i.e. 10.4m diameter with a working depth of the order of 4m). As a condition of the Landfill Waste Licence No. 21-1 issued by the EPA for Derrinumera, leachate is transported by tanker from Derrinumera to Castlebar WWTP for treatment. An Bord Pleanála, in certifying the EIS for expansion of the Castlebar WWTP, has on the other hand made it a condition of such Treatment Plant expansion that the importation of leachate there is discontinued when the new Castlebar WWTP is in place.

In order to assess the 'treatability' of the leachate produced at Derrinumera Landfill with the aim of constructing an on-site leachate treatment system (e.g. Sequence Batch Reactor (SBR), reverse osmosis system etc), a 'Leachate Characterisation Study' was carried out.

As a separate matter, and in order to provide an indication of the efficiency of a conventional secondary treatment plant to co-treat this leachate with municipal wastewater, the current performance of the municipal wastewater treatment plant in Castlebar in treating this same leachate has been monitored, and samples have been taken of the treated wastewater there, and analysed for the presence of trace elements typical of the leachate.

1.2 Relevant Stakeholders' and their Concerns

A consultative forum was held at the offices of Mayo County Council on December 5th, 2002. Following this forum, a number of submissions have been made to Mayo C.C. in relation to the Marine Discharge of treated leachate from Derrinumera Landfill Site to Newport, and ultimately Clew Bay. The concerns relate primarily to the impact of the proposals on the existing Mariculture and Finfish farming in Clew Bay, with submissions having been received from the Clew Bay Oyster Coop Society Ltd. and the Clew Bay Marine Forum Ltd. These stakeholders have identified a number of issues that they would like to have addressed so that a full assessment of the impact of the treated leachate discharge on the bay can be made as follows:

- Impact of the temporary treatment of leachate at Westport in advance of a long-term solution being realised;
- Standards of treatment that will be required to achieve compliance with the Quality of Shellfish Regulations;
- Full and independent characterisation of what is contained in leachate, what treatment will be carried out, what will be removed and what will be left after treatment;
- Comparisons of the best available technology in leachate treatment;
- Assessment of the risk of bio-accumulation and toxic contamination in the shellfish in the bay; and
- Assessment of the risks of interruption to the biology and reproductive cycles of the shellfish in the bay.

1.3 Existing Leachate Management System

The waste body at Derrinumera has been surrounded by a 1.3km long 600mm wide Bentonite Cut-Off wall, keyed into bedrock, which prevents loss of leachate from the permeable deposits in the enclosed area and diverts upland surface water around the unlined waste. This leachate flows to a balancing lined lagoon at present, with a floor area of 860m^2 and a volume in the region of 3600m^3. This lagoon balances peaks in leachate production, which broadly mirrors rainfall, and provides a measure of settlement. Leachate is pumped from the lagoon to three holding tanks, each 10.4 m diameter and with a working depth of the order of 4m. These in turn feed the tankers through a gantry loading system.

The volumes to be handled, and the strength of the constituents in the leachate, vary from winter to summer. Looking at the experience of 2001, 125m^3 approximately was transported in May and June and 130m^3 was tankered in September. Over the year an average daily leachate flow of 258m^3/d was recorded, ranging from a minimum of 125m^3/d to a maximum of 358m^3/d. In 2002, which had been exceptionally wet, volumes as high as 650m^3/d were removed in February and in November. In the future, these volumes will change as cells are filled and capped off, with the maximum volume of leachate expected over the design life of the landfill peaking at 700m^3/d. This figure has been used for design purposes, and the site records of leachate volumes transported are attached as Appendix No 2.

Leachate will contain elements of all substances in the landfill that have not been broken down by microbiological activity within it and which are soluble in water. A landfill undergoes two distinct stages of biological waste decomposition during the cycle of breakdown of waste, namely the acetogenic and the methanogenic stages. Both of these stages can coexist in the one landfill, because the ages of the waste in the landfill can vary from place to place. The following describes these stages:

Acetogenic Stage

In the early stages following waste emplacement, acetogenic liquors containing high amounts of BOD and COD (consisting mainly of soluble organic compounds such as volatile fatty acids) together with high concentrations of Ammoniacal Nitrogen dominate the characteristics of the leachate.

Methanogenic Stage

In the later methanogenic stage of decomposition, although ammoniacal nitrogen levels remain, these soluble organic compounds are converted to landfill gas. In the methanogenic stage, leachate typically contains relatively low amounts of biodegradable organic material.

The concentrations of various constituents of the leachate also varies greatly depending on whether it is sampled in the waste body itself or from the holding tanks. Leachate monitoring at Derrinumera has shown that leachate sampled from the Holding Tanks tends not to have the same levels of BOD, COD, SS and Ammonia as leachate sampled from the Waste Body itself does. The following table compares the various mean concentrations found in the leachate sampled from the lagoon (L1) and the holding tanks (L5).

Table 1. Mean Concentrations Found in the Leachate Sampled from the Lagoon (L1) and the Holding Tanks (L5).

Sampling Point	BOD (mg/l)	COD (mg/l)	Suspended Solids (mg/l)	Ammonia (mg/l)
Lagoon (L1)	110	513	147	241
Holding Tanks(L5)	171	654	2237	123

Readings of suspended solids in the holding tanks are heavily biased by a small number of very high results, themselves likely to be influenced by the mixing conditions at the sampling point. Overall we would interpret the above readings as indicating that the concentrations of elements and compounds in the leachate generally remains unchanged during transfer from the lagoon to the Holding Tanks, and with careful attention to the decanting system at the lagoon, and the mixing at the sampling point in the holding tanks, the suspended solids result would at least remain unchanged. It is possible that the reduction in ammoniacal N concentration is a significant result, since contaminated stormwater would tend to dilute the contents of the holding tank. It is the constituents in the leachate as it enters the Holding Tanks that is relevant in determining a suitable leachate treatment system.

1.4 Methodology

Five grab samples of leachate were taken from the No. 2 leachate storage tank once a week for 5 weeks between 29th July 2003 and the 27th August 2003. Standard quality assurance procedures were taken to prevent contamination of the sample (i.e. disposable gloves, etc). A 2-gallon bucket attached to a chord was used to take each sample with the bucket being cleaned thoroughly with deionised water prior to and after use. Field parameters (i.e. pH, Temperature, Dissolved Oxygen and electrical conductivity measurement) were taken in the field by a TES Field Engineer using a Dr. Lange Multimeter (see results of field parameters in Table 1 of Appendix 1). Following field testing, samples of leachate were taken using specifically design containers supplied by Alcontrol Geochem with preservatives to impede the breakdown of any compounds within the leachate taken.[1] The containers were packed carefully and stored within 2 freezer boxes containing freezer ice packs to insure a maximum temperature of 4°C was maintained during transit. Samples were collected within 2 hours of sampling by Alcontrol Geochem field sample collection vehicle and delivered to Alcontrol Geochem Laboratories in Dublin approximately 4 hours later. These samples were unpacked on arrival and analysed for the chemical parameters as shown in the Tables 1-5 of Appendix 1. The raw results of the analyses carried out by Alcontrol Geochem are located in Appendix 2. Samples were also sent the same day by courier to Shannon Toxicity Laboratory for toxicity testing (see results in Table 6 of Appendix 1).

1.5 Laboratory Suite Rationale & 'Endocrine Disruptors'

These parameters in the chosen laboratory suite are based on the recommended leachate assessment laboratory suite as stipulated in Tables D1 and D2 of the *Draft* Landfill Monitoring Manual November 2002. Given that it is eventually proposed to discharge the treated leachate to the head manhole of the Newport WWTP treated effluent outfall, itself discharging to Clew Bay and that requests were made by stakeholders to test for the presence of 'endocrine disrupters', a review of available literature was carried out to ascertain the identity of known endocrine disrupters of aquatic life.[2] Some of the most pertinent 'endocrine disrupters' with regard to marine aquatic life are:

- *Lead & Cadmium*

These heavy metals have suspected endocrine disruption capabilities and are examined in a heavy metals-specific analysis (see Table 1A & 1B)[2];

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[1] For samples taken for Volatile Organic Compound Analysis, air tight vials with screw caps and teflon line septa were used with hydrochloric acid preservative to prevent volatilisation of any volatile compounds within the samples taken.

[2] Endocrine Disrupters are synthetic (i.e. man-made chemicals) which are thought to mimic natural hormones, inhibit the action of hormones, or alter the normal regulatory function of the immune, nervous, and endocrine systems.

- *Alkylphenols (e.g. Nonylphenol, Bisphenol-A, etc)*

Alkylphenols, such as Nonylphenol, are commonly used as antioxidants and also are degradates of the biodegradation of a family of non-ionic surfactants (such as APE) during sewage treatment (Jobling and Sumpter, 1993).[3] Nonylphenol and other alkylphenols have been reported to leach from plastics used in food processing and packaging, such as food grade polyvinyl chloride (Junk et al., 1974; Brotons et al., 1995). The presence of these compounds was examined as part of the semi-volatile organic compound analysis (sVOC) (see Table 3A & 3B);

- *2,3,7, 8 – TCDD and 2,3,7,8-tetrachlorodibenzo-furan (TCDF)*

These are byproducts of the paper, wood, and herbicide industries and are formed in the incineration of some chlorinated organic compounds (Schmidt, 1992). The presence of these compounds was examined as part of the semi-volatile organic compound analysis (sVOCs) (see Table 3A & 3B);

- *Methoprene, Precocene, Diflubenzuron, Tebufenoxide and Fenocarb*

The endocrine systems of insects have been intentionally targeted for insecticidal activity. These chemicals include juvenile hormone mimics (e.g., methoprene), antijuvenile hormone analogs (e.g., precocene), chitin synthesis inhibitors (e.g., diflubenzuron), ecdysone analogs (e.g., tebufenozide), and molting disruptants (e.g. fenoxycarb). These insect growth regulators were developed to be not only efficient pesticides, but also to be highly specific to insects without risk to other nontarget animals, especially vertebrates. The presence of these compounds was examined as part of the semi-volatile organic compound analysis (sVOCs) (see Table 3A & 3B);

- *PCBs*

Polychlorinated Biphenyls (PCBs) are a class of compounds that have approximately 113 congeners present in the environment. PCBs, which disrupt hormone pathways involved in, for example, male fertility (Sager, 1983), were banned from further production in the United States in 1976 under the Toxic Substances Control Act, but these agents were used widely between 1930 and 1970 as additives in products such as paints, plastics, rubber, adhesives, printing ink, and insecticides (Peakall and Lincer, 1970). [2] While 31% of total PCBs manufactured are currently estimated to be present in the global environment, only 4% of cumulative world production can be accounted for as degraded or incinerated. Many PCBs are still in use in older electrical equipment (e.g. transformers), in containment storage, or in dumps or landfills. Releases from these sources can result in continuing PCB pollution for years to come (Tanabe, 1988). The presence of these compounds was examined as in a PCB specific analysis (see Table 4);

- *Chlorinated Pesticides – Alachlor, Chlordane, DDT, Dicofol, Methoxychlor, Trifluralin, etc.*

These chlorinated pesticides have suspected endocrine disruption capabilities and are examined in a Chlorinated Pesticide-specific analysis (see Table 4);

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[3] Special Report on Environmental Endocrine Disruption: An Effects Assessment and Analysis Prepared for the Risk Assessment Forum, U.S. Environmental Protection Agency, Washington, D.C. 20460 EPA/630/R-96/012 February 1997.

- *Organophosphorous Pesticides – Malathion, Parathion, etc.*

These Organophosphorous pesticides have suspected endocrine disruption capabilities and are examined in a Organophosphorous Pesticide-specific analysis (See Table 5); and

- *Organotin Compounds – Tributyltin, Triphenyltin & Dibutyltin*

Tributyltin (TBT) has in other countries been found in bivalve molluscs and fish species eaten by man, although levels of these residues in edible tissues (e.g., 0.08 to 0.9 mg/kg in salmon in the United States, and < 10 to 5600 µg/kg in Chesapeake Bay oysters) are considered to be "safe" levels (Fent, 1996). [2] These compounds have suspected endocrine disruption capabilities and are examined in an Organotin Compound-specific analysis (see Table 5).

The leachate samples taken were also submitted to Shannon Toxicity Laboratory for toxicity testing by Microtox™ which is a 5-30 minute acute toxicity test which measures the inhibition of light emission in *Vibrio fischeri* (see results in Table 6 of Appendix 1). This test is recommended for testing the inhibition of wastewater treatment plant microflora (i.e. inhibition of respiration and nitrification).[4] The Sequence Batch Reactor (SBR) is a variant of an aerobic biological system. Unlike a conventional activated sludge plant with presettlement, an SBR system is worked entirely by bacteria and as such, the Microtox test is the toxicity test most suited to assessing any toxic shock and subsequent negative performance effect, which the leachate could have on the system.

1.6 Guidelines & Relevant Legislation

There are no specific guidelines dealing with the quality of landfill leachate prior to or after treatment. In order to assess the level of contaminants commonly tested for in raw untreated leachate (i.e. heavy metals, BOD, COD, NH_3 and suspended solids), the results obtained (see Tables 1A &1B) were compared with the Mean Concentrations for Typical Leachate taken from Table 3, Typical Leachate Composition of 30 Samples from UK/Irish Landfills accepting Mainly Domestic Waste, *EPA Landfill Operational Practices Manual.*

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[4] Toxicity/inhibition tests are carried out by exposing a group of test organisms in a series of dilutions of the test substance or mixture, under conditions, which are controlled. On the basis of the recorded effect frequencies in the various dilutions, the effect concentrations (Effective Concentration (EC) or Lethal Concentration (LC)) are usually calculated for the 10, 50 and 90% mortality or effect level in the population. Example: If the results from a 24-hour EC_{50} toxicity test is 20% v/v, this means that 200ml of wastewater made up to a litre with water had a specified effect on 50% of the test species, in 24 hours. To avoid confusion and to report increasing toxicity with a correspondingly increasing number (i.e. the more toxic the wastewater, the higher the numerical TU number assigned to it), the result is expressed as a function of the undiluted sample (100%). This form of expression is known as the Toxic Unit (Tu) and is defined as follows:

$$\boxed{Tu = \frac{100}{EC_{50}}}$$

The most relevant legislation with regard to assessing the standard and inorganic chemical concentrations within the discharge from Castlebar WWTP are:

- S.I. No. 200, Quality of Shellfish Waters Regulations, 1994. These regulations specify indirect standards for a discharge. The discharge must not cause the receiving water (i.e. in the vicinity of the outfall) to exceed certain levels. i.e. these values need to be back calculated on the basis of dilution factors and tidal currents and are not possible to ascertain at this stage. However, a pH of between 7 and 9 is specified in these regulations for the discharge;
- S.I. No. 254, Urban Wastewater Treatment Regulations, 2001. These regulations specify the minimum discharge standards required of municipal wastewater treatment plants; and
- Discharge limits otherwise set for the Newport WWTP on the basis of the environmental impact assessment which was carried out there.

Tables 2 to 6 in this report summarises the results of the trace organic analyses. For the set of parameters examined in Tables 2-6, it should be noted that it is expected that the parameters examined in the raw (i.e. untreated) leachate and in the WWTP discharge would exceed the Guideline Values and Maximum Allowable Concentration (MAC) values which are used for groundwater or drinking water. The purpose of this comparison is purely to assess the relative levels of the contaminants in the untreated leachate and to assess their levels after treatment in the Castlebar WWTP and before discharge to the Castlebar River. The most useful standards with regard to assessing the relative levels of the trace organics in the leachate and WWTP discharge sampled are listed below:

- S.I. No. 12, Discharge of Dangerous Substances to Water Regulations, 2001. The EU Directive on the discharge of dangerous substances to water has been implemented under Regulations S.I.12 of 2001 made under the Water Pollution Act. In the marine environment, the Regulations cover the obligations under the Directive by setting limits on the concentration of each parameter. These limits themselves result from extensive testing of the toxicity of these compounds to marine life, not just at the adult stage, but at the juvenile or larval stage as well;
- *The Dutch Soil Protection Guidelines*, National Institute of Public Health and the Environment, 1994. To date there is no legislation or guidelines in Ireland governing the classification, remediation or disposal/treatment of contaminated soil or groundwater. When dealing with the assessment of risks of groundwater pollution from contaminated sites in Ireland, a set of guidelines called the Soil Protection Guidelines, produced by National Institute of Public Health and the Environment of The Netherlands have generally been used. As no data are available for surface water, the groundwater target and intervention values have been used where available for this assessment.

The following guidelines and regulations are strictly applicable only to groundwater and drinking water but are used in this report to assess the relative levels of trace organics found in the raw leachate and WWTP discharge.

- The EPA Interim Report, *Towards Setting Guideline Values for the Protection of Groundwater in Ireland*, 2003. The EPA Interim Report presents proposals for the setting of environmental quality objectives and standards for groundwaters through the use of 'guideline' values'; and
- S.I. No. 81, Drinking Water Standards for Human Consumption, 1988. In order to assess the data for parameters not covered by S.I.12 of 2001, the values were also compared to their respective MAC values, where available in S.I. No. 81.

2. RESULTS

2.1 Untreated Leachate Characteristics

Table 1 summarises the field testing carried out on the 5 untreated leachate samples taken. Again it must be emphasized, these are untreated values, before any process other than settlement in the leachate lagoon has been brought to bear on the constituents. The electrical conductivity results for the 5 leachate samples gave a mean sampled value of 3129μS/cm (see Table 1A). It should be noted that even the maximum conductivity in the samples barely exceeded half of the 'Mean Concentrations for Typical Leachate Value' in the EPA Report, which was 7789 μS/cm.

2.1.1 Heavy Metals & Major Cations

The levels of manganese, potassium, sodium and magnesium found in the leachate are typical of landfill leachate in general and are consistent with the relatively high electrical conductivity readings. Again it should be noted that none of Heavy Metals or Major Cations levels exceeded their respective 'Mean Concentrations for Typical Leachate Values', and were typically half of the value quoted by the EPA as typical of landfill leachates in Ireland.

2.1.2 BOD

The mean BOD value for the 5 leachate samples was approximately 309mg/l. It should be noted that again this value was significantly less than its respective 'Mean Concentration for Typical Leachate Value' of 798mg/l, which is taken from the EPA Landfill Operational Practices Manual. These values are typical of municipal leachate and are to be expected given that domestic waste is the principal waste type accepted at Derrinumera Landfill (see Table 1A). The strength of the raw leachate is not greatly in excess of domestic wastewater, and while the COD levels are higher than domestic wastewater,they are at maximum less than one sixth of the figure given in the EPA manual as typical of the mean COD in Irish landfills. It is clear from the discussion up to this point, that the

Derrinumera leachate is quite significantly lower in strength by comparison with the generality of municipal landfill leachates in Ireland.

2.1.3 Ammonia

Elevated levels of ammonia were observed in the 5 leachate samples with a mean value of 100mg/l, and a maximum of 137 mg/l. It should be noted however, that this value was significantly less than its respective Mean Concentration for Typical Leachate Value of 491mg/l in the EPA sampling of landfill leachates in Ireland. These values, in conjunction with the results of the nitrate and nitrite analyses, are typical of landfill leachate and are consistent with the type of waste accepted and anaerobic conditions within the landfill (see Table 1A).

2.1.4 Coliforms

The results of the total and faecal coliform analyses are consistent with the level of values typically found in a municipal landfill and are to be expected given that domestic waste is the principal waste type accepted at Derrinumera Landfill (see Table 1A).

2.1.5 Volatile Organic Compounds

The results of the volatile organic compound analysis of the leachate samples show that no volatile organic compounds were detected in the leachate sampled (see Table 2). This contrasts notably with the values in the UK Landfill report, where almost all leachate samples had detectable amounts of at least one VOC, as might be expected given the differences in industrial profile of the catchment communities being compared.

2.1.6 Semi-volatile Organic Compounds

The results of the semi-volatile organic compound analysis of the leachate samples show that 6 polyaromatic hydrocarbons (PAHs), Naphthalene, Anthracene, Phenanthrene, Fluoranthrene, Benzo(a)anthracene and Chrysene were detected at concentrations above the Dutch Criteria Target Value in 4 of the 5 leachate samples collected (see Table 3A), but the detected concentrations were well within limits that would call for intervention under the Dutch standards. Only two of these compounds, Naphthalene and Phenanthrene, were detected in the raw leachate at concentrations slightly above their respective S.I. 81 MAC values, but given that the treated leachate stream will join a treated wastewater at least as voluminous at Newport, then even on the assumption of no reduction in these parameters in a secondary treatment process, the overall discharge from the outfall will comply with SI 81, and the current discharge from Castlebar WWTP already does. Phenanthrene was also detected in the raw, untreated leachate at concentrations 2.6 times their respective EPA Interim Guideline Value for groundwater protection, but again this gives compliance when dilutions of the

DWF at Castlebar WWTP is taken into account, and reductions in a secondary treatment process are ignored.

It is important to note, given the concerns of the stakeholders in this respect, that no endocrine disruptors were detected in the leachate samples. It should be noted that the limit of detection for the semi-volatile organic compounds was 1 parts per billion (ppb) (or 0.001 part per million), and at this level of sensitivity, not one parameter in the sample results would call for intervention under the Dutch guidelines.

2.1.7 Polychlorinated Biphenyl (PCBs), Chlorinated Pesticides and Diesel Range Organics

The results of the Polychlorinated Biphenyl (PCBs), chlorinated pesticides and Diesel Range Organic analyses are presented in Table 4. No PCB congeners or chlorinated pesticides were detected in the leachate samples. It should be noted that the limits of detection for the PCB congeners or chlorinated pesticides were 0.01 parts per billion (ppb) (or 0.00001 part per million). However, low concentrations of diesel range organics were detected in the first leachate sample taken. The Mineral Oil fraction concentration of the Diesel Range Organics was above its respective EPA Interim Guideline Value, S.I. 81 MAC and Dutch Criteria Target Value. However, it should be noted that these MAC values are for protection of groundwater and not strictly applicable to raw untreated leachate. The laboratory interpretation of the chromatogram indicated that highly biodegraded diesel was the source.

2.1.8 Acid Herbicides, Triazine Herbicides and Nitrile Herbicides, Organophosphorous Pesticides, and Organotin Compounds

The results of the Acid, Triazine and Nitrile Herbicides, Organophosphorous Pesticides, and Organotin analyses are presented in Table 5. Again it is important to note that no Acid, Triazine and Nitrile Herbicides, or Organophosphorous pesticides were detected in the leachate samples taken. However, low concentrations (i.e. 0.41 parts per billion) of Triphenyltin were detected in the third leachate sample taken, where all others were less than 5 parts per billion. This as an average concentration would put the total estimated Triphenyltin load close to the UK reporting limit of 5 grams annually if applied to the largest year of leachate production volume, in 2002.

2.1.9 Toxicity Testing

The results of the Toxicity Testing on the leachate samples submitted are summarised in Table 6. A Toxicity Unit level of 2.2 Tu is regarded as the background level for Microtox^{TM}, and the results were everywhere less than this. This represents a dilution of greater than 45% volume of leachate per volume of saline solution, which is the threshold or starting dilution used in the test. If the results from a 5 minute EC50 is 20% v/v, this means that 200ml of leachate made up to a litre with water had a specified effect on 50% of the test species in 5 minutes. This would mean that dilution by a factor of five would be required to reduce the potency of the sample to a level where only 50% of the bacterial population were inhibited. In all leachate samples, the requisite level of impact on the bacteria could not be produced, even by the least possible dilution of raw leachate that the test allows.

Footnote 4 explains the background behind leachate testing.

2.2 Wastewater Treatment Plant Discharge Results

Two samples were taken of the discharge from the WWTP to the Castlebar River: one on the 5th August, 2003 and the other on the 27th August, 2003. It should be noted that leachate was being drawn by tanker at an average rate of 5 tanker units per day in July (volume 22m^3) and 4 units per day in August prior to the time of sampling and that weather conditions were dry at the time. The purpose of the afore-mentioned sampling of the final effluent at the Castlebar WWTP was to assess the ability of this type of plant to remove contaminants from the leachate, so as to provide a design context for leachate treatment at Derrinumera, and so that interim treatment at Ballinrobe WWTP or Westport WWTP with similar technology can be confidently performed once importation to Castlebar is no longer possible.

As with the leachate samples, field parameters (i.e. pH, Temperature, Dissolved Oxygen and electrical conductivity measurement) were taken in the field by a TES Field Engineer (see results of field parameters in Table 1 of Appendix 1). Samples were collected and analysed for the chemical parameters as shown in the Tables 1-5 of Appendix 1. The treated wastewater samples taken were also submitted for toxicity testing (see results in Table 6 of Appendix 1). As expected, both samples were within their respective S.I. 200 (Quality of Shellfish Water Regulations, 1994) range for pH.

2.2.1 *Heavy Metals & Major Cations*

The results of the heavy metals analyses show that all heavy metals were below their respective detection limits in the laboratory (i.e. they were too low to be detected).

Although no standards are available for assessing heavy metal concentration or major cation concentration in treated wastewater, the results of the major cation analyses show levels which are typical of a municipal wastewater treatment plant discharge (see Table 1b).

2.2.2 *BOD & COD*

There was no exceedance of the S.I. 254 MAC value (i.e. 25mg/L) for BOD for both treated wastewater samples. There was an exceedance of the S.I. 254 MAC value (i.e. 125mg/L) for COD for the first treated wastewater sample. However, the second sample recorded a COD concentration of 30mg/l was well below the MAC. As can be seen from Table 1a., the S.I. 254 MAC values and the proposed discharge limits for Newport WWTP for BOD, COD and suspended solids are the same (see Table 1b). Given that we know that COD levels in the untreated leachate are not particularly high, and given the very much larger dilution of Dry Weather Flow at Castlebar compared to the volume of leachate, we can confidently say that COD exceedances in the final effluent are in all probability due to industrial discharges in Castlebar itself, and due to the general state of overload of that Plant which has necessitated its imminent upgrade.

2.2.3 Ammonia

There was no exceedance of the proposed Ammoniacal Nitrogen discharge limit for leachate discharged to the outfall of Newport WWTP (i.e. 5mg/l) for both treated wastewater samples (see Table 1b). Thus, while the raw leachate is high in Ammonia, dilution effects in the municipal DWF at Castlebar, and nitrification of the ammoniacal nitrogen in the influent to Nitrate takes place very efficiently in the Castlebar plant, despite its current overload. It is likely that the very same effects would limit the ammoniacal N levels in Ballinrobe, or Westport , if the leachate were discharged to either of these plants on an interim basis.

2.2.4 Suspended Solids

There was an exceedance of the S.I. 254 MAC value (i.e. 35mg/L) for suspended solids for the second treated wastewater sample. However, the first sample recorded a suspended solids concentration below the detection. As can be seen from Table 1a, the S.I. 254 MAC values and the discharge limits for Newport WWTP for suspended solids are the same (see Table 1b). These suspended solids at Castlebar are not related to the leachate load, but are due to the high Sludge MLSS which is maintained at the Plant, which in turn is related to difficulties of sludge wasting, dewatering and sludge drying which are experienced there.

2.2.5 Coliforms

As can be seen from Table 1B, the S.I. 254 MAC values and the proposed discharge limit for Newport WWTP for faecal coliforms are the same (see Table 1B). There was an exceedance of the this value (i.e. 2000 mpn/100ml) for faecal coliforms for both treated wastewater samples at Castlebar, but it is clear from the raw leachate sample results that leachate is not the origin of this problem. The mean value for faecal coliforms, (i.e. 7410mpn/100ml) is significantly below what would be regarded as a typical WWTP discharge faecal coliform count.

2.2.6 Volatile Organic Compounds

The results of the volatile organic compound analysis of the leachate samples show that no volatile organic compounds were detected in the 2 treated wastewater samples taken (see Table 2).

2.2.7 *Semi-volatile Organic Compounds*

The results of the semi-volatile organic compound analysis of the leachate samples show that 3 polyaromatic hydrocarbons (PAHs), Naphthalene, Anthracene and Phenanthrene, were detected at concentrations above their respective S.I. 81 MAC values and Dutch Criteria Target Values in one of the treated wastewater samples collected (see Table 3B). Two of these compounds, Naphthalene and Phenanthrene were detected at concentrations above their respective EPA Interim Guideline Value. However, it should be noted that the S.I. 81 MAC values, EPA Interim Guideline Values and Dutch Criteria Target Values are for drinking water and groundwater quality assessment. No endocrine disruptors were detected in the treated wastewater samples.

2.2.8 *Polychlorinated Biphenyl (PCBs), Chlorinated Pesticides and Diesel Range Organics*

The results of the Polychlorinated Biphenyl (PCBs), chlorinated pesticides and Diesel Range Organic analyses are presented in Table 4. No PCB congeners, no chlorinated pesticides or diesel range organics were detected in the treated wastewater sampled at Castlebar WWTP.

2.2.9 *Acid Herbicides, Triazine Herbicides and Nitrile Herbicides, Organophosphorous Pesticides, and Organotin Compounds*

The results of the Acid, Triazine and Nitrile Herbicides, Organophosphorous Pesticides, and Organo-tin compound analyses are presented in Table 5. No Acid, Triazine and Nitrile Herbicides, Organophosphorous pesticides or organo-tin compounds were detected in the treated wastewater samples taken. Since many of these compounds are only detected in the raw leachate at concentrations close to the limit of detectability, it is not surprising that straight dilution effects alone with municipal DWF would result in no detected presence in the treated effluent.

2.2.10 *Toxicity Testing*

The results of the Toxicity Testing on the treated wastewater samples submitted are summarised in Table 6. As can be seen, both of the treated wastewater samples gave toxicity levels less than 2.2Tu for both the 5-minute EC50 and the 15-minute EC50. It should be noted that the EPA guideline value for discharge of effluent to a sewer by a licensed facility is 10Tu, which is significantly greater that the values obtained for the treated wastewater, and indeed for the raw leachate itself.

3. DISCUSSION OF SAMPLING RESULTS

Taking the raw leachate data initially, it is clear that when the Derrinumera Leachate results are compared to their respective Mean Concentrations for Typical Leachate values of 20 samples taken from Irish/UK Landfills (see Table 1), the field results (i.e. electrical conductivity), heavy metals (i.e. iron & manganese), major cations, BOD, COD, ammonia, phosphate, chloride and boron mean levels detected at Derrinumera are all significantly less than their respective UK/Irish means.[5] This raw leachate at Derrinumera is much thinner than average in Ireland, and lacks most of the more troublesome trace elements typical of leachates from more industrialised areas in the UK.

It should be noted that the Polyaromatic hydrocarbons (PAHs), which are commonly found in landfill leachate, and which were detected in the raw leachate were detected at trace levels (i.e. they were present in the raw leachate at concentrations less than one part per billion). These are a group of lipophilic substances that are ubiquitous in the environment. They are almost insoluble in water and are commonly sorbed on to airborne particles. They enter the environment from the following sources: tobacco smoke, incomplete combustion of coal, especially lignite, gas and oil-fired heating systems, wood fires, exhaust from petrol and diesel engines and the run-off from bitumen road surfaces. One of the most common points of entry of PAHs into a landfill would be through fire ash and cinders. With regard to the PAHs that were detected in the discharge from the Castlebar WWTP, it is probable that municipal, commercial or industrial sewage within the Castlebar catchment contained the source of the afore-mentioned compounds that were detected, because dilution effects, related to the levels found in the raw leachate, could not explain the levels found in the Castlebar WWTP discharge, which were in any case very low.

With regard to the traces of Diesel Range Organics detected in one leachate sample, it is possible that diesel contaminated soil or another diesel contaminated waste source may have been accepted into the landfill unknowingly and caused these levels.

With regard to the Triphenyl Tin detected in the raw leachate sample, it should be noted that this concentration was well within its respective EPA Interim Guideline Value. Triphenyl Tin was used as a constituent in marine anti-fouling paint. However, its use has discontinued as a result of an international ban. It is possible that old paint cans containing anti-fouling paint may have been accepted into the landfill unknowingly and caused the trace levels detected.

As can be seen, all of the leachate samples and both of the discharge samples from the Castlebar WWTP gave toxicity levels less than 2.2Tu for both the 5-minute EC50 and the 15-minute EC50 (see Table 6). It should be noted that the EPA guideline value for discharge of effluent to sewer by a licensed facility is 10Tu, which is significantly greater that the values obtained for the leachate.

In summary, the Derrinumera Leachate, even when sampled in August at its most concentrated likely condition, is of weaker strength than average landfill leachates in Ireland.

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[5] Table 3. Typical Leachate Composition of 30 Samples from UK/Irish Landfills accepting Mainly Domestic Waste, *EPA Landfill Operational Practices Manual.*

Aerobic biological secondary treatment processes are unlikely to be inhibited by any toxicity effects, as the toxicity tests show, and so the full range of treatment systems outlined below are to be expected suitable for consideration by Contractors tendering for leachate treatment as part of a DBO process.

4. IMPLICATIONS FOR LEACHATE TREATMENT TECHNOLOGIES

The most commonly used leachate treatment technologies include:

- Air stripping/aeration in lagoons or SBR processes;
- Reed beds;
- Rotating biological contactors;
- Reverse osmosis; and
- Oxidation and other chemical treatment.

The above listed treatment methods cover the likely range of treatment technologies to be offered in a DBO Contract procurement process. The choice of treatment process should be a function of the nature of the leachate to be treated, which in itself is dependent on the composition and volume of the leachate and the selected discharge medium and its location. Looking at the constituents of the leachate, it is clear that BOD, COD, ammonia and suspended solids have to be removed as the principal targets. Because of the anaerobic character of leachate, aeration is also necessary to increase the oxygen levels of the treated leachate. Aerobic forms of treatment are the most suitable form of biological treatment. It is the most frequently applied technology in the world with respect to leachate treatment, and it is a proven technology. This form of leachate treatment is basically aimed at decreasing the oxygen demand (i.e. BOD, COD, etc) of the leachate, the removal of suspended solids and the increase of oxygen levels in the treated effluent. With the removal of suspended solids, heavy metals and micro-pollutants will also be removed. The Sequencing Batch Reactor technology (SBR) is a typical form of aerobic treatment and is a robust and simple aeration system with good process flexibility.

By comparison with leachates elsewhere, the leachate concentrations across a range of parameters at Derrinumera Holding Tanks are relatively low. However, it is expected that heavy metal removal efficiencies in low strength leachate must be expected to be lower. There is a significant variation in the BOD and COD levels of the raw leachate. However, examining the ratio of COD/BOD it is concluded that a substantial part of the COD is inert. This in turn means that a significant portion of the COD will be poorly biodegradable.

For the Sequence Batch Reactor treatment system, the oxidation of nitrogen from Ammonia to the oxidised forms of Nitrogen is the most critical biochemical process. The design of an SBR system therefore is likely to be based on nitrogen loading as the limiting factor. The volume of the 3 holding tanks at Derrinumera, if converted to SBR Units, are adequate to allow complete nitrification and to reduce the risk of wash out of suspended solids. In an SBR system, settlement is achieved by periodic switching off of the aeration system and decanting of the top clarified layer after a period of settlement. The 3 holding tanks have adequate area for settlement.

Given the presence of polyaromatic hydrocarbons (PAHs) and Triphenyl Tin in the raw leachate sampled at Derrinumera, but at levels only marginally above those permissible in a treated leachate, it is possible that an activated carbon filtration system may be required to 'polish' the post-SBR treated leachate with respect to these two elements. Again Activated Carbon treatment is a proven technology in the removal of hydrophobic trace organics, and can be provided for provisionally in design, and added at a later stage if the actual full scale performance of an SBR system needs this polishing stage.

Table 1A. Standard Inorganic and Wet Chemistry Laboratorty Suite for Leachate Generated at Derrinumera and Water Samples taken at Castlebar Wastewater Treatment Plant

Parameter	Units	Leachate Results								Mk. ~ Concentrations for Typical Leachate - From EPA Landfill Operational Practices Manual
		WA-LCH-01	WA-LCH-02	WA-LCH-03	WA-LCH-04	WA-LCH-05	Mean	Maximum	Standard Deviation	
FIELD RESULTS										
pH	units	7.76	7.97	7.30	8.06	7.62	7.742	8.06	0.30	7.20
Temperature	Degree Celsius	10.00	11.00	10.50	10.75	11.00	10.65	11.00	0.42	-
Electrical conductivity (EC)	µS/cm	2727	2908	3779	3206	3027	3129	3779	402.89	7789.00
Dissolved oxygen (DO)	mg/l	1.40	5.80	8.40	8.00	2.70	5.26	8.40	3.13	-
LAB RESULTS										
Heavy Metals										
Arsenic (As)	mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	0.00	0.000	0.000	-
Cadmium (Cd)	mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	0.00	0.000	0.000	<0.01
Chromium (Cr)	mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	0.00	0.000	0.000	0.070
Copper (Cu)	mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	0.00	0.000	0.000	0.040
Iron (Fe)	mg/l	0.13	22.00	0.10	0.09	0.15	4.49	22.000	9.786	54.500
Lead (Pb)	mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	0.00	0.000	0.000	0.100
Manganese (Mn)	mg/l	0.15	0.14	0.94	0.58	0.58	0.48	0.940	0.338	1.990
Mercury (Hg)	mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	0.00	0.000	0.000	0.000
Nickel (Ni)	mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	0.00	0.000	0.000	0.100
Zinc (Zn)	mg/l	<0.05	<0.05	0.30	<0.05	0.07	0.07	0.300	0.163	0.580
Major Cations										
Calcium (Ca)	mg/l	174.30	195.40	112.00	125.30	171.10	155.62	195.40	35	250
Magnesium (Mg)	mg/l	42.80	46.07	43.01	51.32	51.10	46.86	51.32	4	151
Potassium (K)	mg/l	88.00	128.00	152.00	118.00	122.00	121.60	152.00	23	491
Sodium (Na)	mg/l	82.00	158.00	228.00	310.00	212.00	198.00	310.00	85	904
Standard Water Chemistry										
Biochemical oxygen demand (BOD)	mg/l	80.00	33.00	730.00	21.00	31.00	179.00	730.00	308.86	>798
Chemical oxygen demand (COD)	mg/l	329.00	39.00	435.00	496.00	237.00	307.20	496.00	179.80	3078.00
Total organic carbon (TOC)	mg/l	71.00	154.00	4.00	99.00	90.00	83.60	154.00	54.15	717.00
Total Hardness (mg/l $CaCO_3$ equivalent)	mg/l	614.08	680.46	459.21	527.08	640.67	584.30	680.46	89.77	-
Total alkalinity (as $CaCO_3$)	mg/l	900.00	1010.00	1200.00	520.00	1140.00	954.00	1200.00	269.04	3438.00
Total oxidised nitrogen (TON)	mg/l	0.40	0.30	2.90	9.20	<0.3	2.56	9.20	4.18	-
Nitrite (NO_3)	mg/l	0.48	0.21	4.90	15.40	0.50	4.30	15.40	6.51	0.20
Nitrate (NO_2)	mg/l	1.00	1.20	6.00	19.20	0.30	5.54	19.20	7.96	2.40
Ammoniacal nitrogen (NH_4-N)	mg/l	113.00	7.70	124.00	137.00	120.00	100.34	137.00	52.52	491.00
Phosphate (PO_4	mg/l	0.63	1.20	0.29	0.47	<0.05	0.52	1.20	0.39	0.98
Sulphate (SO_4)	mg/l	211.00	186.00	278.00	192.00	137.00	200.80	278.00	51.07	136.00
Chloride (Cl)	mg/l	195.00	190.00	230.00	640.00	220.00	295.00	640.00	193.58	1256.00
Cyanide (Total)	mg/l	<0.05	<0.05	<0.05	<0.05	<0.05	0.00	0.00	0.00	<0.05
Fluoride	mg/l	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.00	_
Boron	mg/l	0.79	0.87	0.82	1.04	0.95	0.89	1.04	0.10	7.00
Total Suspended Solids	mg/l	52.00	<10	52.00	36.00	32.00	34.40	52.00	10.52	_
Total Dissolved Solids	mg/l	1390.00	1219.00	1440.00	1534.00	1339.00	1384.40	1534.00	117.18	_
Dissolved Methane	mg/l	0.221	0.332	0.006	0.006	0.396	0.19	0.40	0.18	_
MBAS Surfactant	mg/l	<0.2	<0.2	<0.2	<0.2	<0.2	0.000	0.00	0.00	_
Bacterial Analysis										
Faecal coliforms	(mpn/100mls)	3000	1248	195	60	2480	1397	3000	1323	_
Total coliforms	(mpn/100mls)	13000	2000	15600	180	3000	6756	15600	7503	_

Note: '-' signifies no Mean Values from EPA Landfill Operational Practices Manual are available, < = Less than

Table 1B. Standard Inorganic and Wet Chemistry Laboratorty Suite for Leachate Generated at Derrinumera and Water Samples taken at Castlebar Wastewater Treatment Plant

Parameter	Units	Newport WWTP Discharge Limit Values	S.I. No. 254, Urban Wastewater Treatment Regulations, 2001. (MACs)	S.I. No. 200, Quality of Shellfish Waters Regulations, 1994. (MACs)	Treated Wastewater Results				
					WA-WWTP-01	WA-WWTP-02	Mean	Maximum	Standard Deviation
FIELD RESULTS									
pH	units	-	-	≥ 7 < 9	7.53	7.05	7.29	7.53	0.34
Temperature	Degree Celsius	-	-	-	7.00	9.00	8.00	9.00	1.41
Electrical conductivity (EC)	µS/cm	-	-	-	800.00	1025.00	912.50	1025.00	159.10
Dissolved oxygen (DO)	mg/l	-	-	-	7.20	5.10	6.15	7.20	1.48
LAB RESULTS									
Heavy Metals									
Arsenic (As)	mg/l	-	-	-					
Cadmium (Cd)	mg/l	-	-	-	<0.05	<0.05	<0.05	<0.05	0.000
Chromium (Cr)	mg/l	-	-	-	<0.05	<0.05	<0.05	<0.05	0.000
Copper (Cu)	mg/l	-	-	-	<0.05	<0.05	<0.05	<0.05	0.000
Iron (Fe)	mg/l	-	-	-	<0.05	<0.05	<0.05	<0.05	0.000
Lead (Pb)	mg/l	-	-	-	<0.05	<0.05	<0.05	<0.05	0.000
Manganese (Mn)	mg/l	-	-	-	<0.05	<0.05	<0.05	<0.05	0.000
Mercury (Hg)	mg/l	-	-	-	<0.05	<0.05	<0.05	<0.05	0.000
Nickel (Ni)	mg/l	-	-	-	<0.05	<0.05	<0.05	<0.05	0.000
Zinc (Zn)	mg/l	-	-	-	<0.05	<0.05	<0.05	<0.05	0.000
Major Cations									
Calcium (Ca)	mg/l	-	-	-	68.77	60.94	64.86	68.77	6
Magnesium (Mg)	mg/l	-	-	-	5.88	5.88	5.88	5.88	0
Potassium (K)	mg/l	-	-	-	10.00	12.20	11.10	12.20	2
Sodium (Na)	mg/l	-	-	-	63.00	128.00	95.50	128.00	46
Standard Water Chemistry									
Biochemical oxygen demand (BOD)	mg/l	25	25	-	2.000	16.000	9.00	16.00	9.90
Chemical oxygen demand (COD)	mg/l	125	125	-	**300.000**	30.000	165.00	300.00	190.92
Total organic carbon (TOC)	mg/l	-	-	-	6.000	10.000	8.00	10.00	2.83
Total Hardness (mg/l $CaCO_3$ equivalent)	mg/l	-	-	-	196.425	176.850	186.64	196.43	13.84
Total alkalinity (as $CaCO_3$)	mg/l	-	-	-	160.000	230.000	195.00	230.00	49.50
Total oxidised nitrogen (TON)	mg/l	-	-	-	15.100	10.200	12.65	15.10	3.46
Nitrite (NO_2)	mg/l	-	-	-	0.610	0.150	0.38	0.61	0.33
Nitrate (NO_3)	mg/l	-	-	-	65.000	44.1	54.55	65.00	14.78
Ammoniacal nitrogen (NH_4-N)	mg/l	5	-	-	3.400	2.800	3.10	3.40	0.42
Phosphate (PO_4)	mg/l	-	-	-	0.810	0.230	0.52	0.81	0.41
Sulphate (SO_4)	mg/l	-	-	-	75.000	60.000	67.50	75.00	10.61
Chloride (Cl)	mg/l	-	-	-	129.000	182.000	155.50	182.00	37.48
Cyanide (Total)	mg/l	-	-	-	<0.05	<0.05	<0.05	<0.05	0.00
Fluoride	mg/l	-	-	-	0.500	0.500	0.50	0.50	0.00
Boron	mg/l	-	-	-	0.090	0.100	0.10	0.10	0.01
Total Suspended Solids	mg/l	35	35	-	<10	**184.000**	**92.00**	184.00	130.11
Total Dissolved Solids	mg/l	-	-	-	498.000	574.000	536.00	574.00	53.74
Dissolved Methane	mg/l	-	-	-	0.002	<0.001	0.00	0.00	0.00
MBAS Surfactant	mg/l	-	-	-	<0.2	<0.2	<0.2	0.00	0.00
Bacterial Analysis									
Faecal coliforms	(mpn/100mls)	2000	-	-	3120	11700	7410	11700	6067
Total coliforms	(mpn/100mls)	-	-	-	9000	44000	26500	44000	24749

Note: M.A.C = Maximum Admissable Concentration, ○ signifies MAC exceeded, < = Less than
Values are shaded wherever Newport WWTP Discharge Limit Values, S.I. No. 254, Urban Wastewater Treatment Regulations, 2001, S.I. No. 200 or Quality of Shellfish Waters Regulations, 1994 MACs are exceeded.
'-' signifies no S.I.81 or S.I. 12MAC Values are available.

Table 2. Volatile Organic Compound Laboratorty Suite for Leachate Generated at Derrinumera and Water Samples taken at Castlebar Wastewater Treatment Plant

Compound	LPA Interim Guideline Values Groundwater Protection	Dutch Criteria (mg/l) TV (TARGET)	Dutch Criteria (mg/l) IV (INTERVENTION)	SI 12, 2001 Water Quality (Dangerous Substances) MAC	Leachate Results WA-LCH-01	WA-LCH-02	WA-LCH-03	WA-LCH-04	WA-LCH-05	Wastewater Results WA-WWTP-01	WA-WWTP-02
Dichlorodifluoromethane	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chloromethane	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Vinyl Chloride	-	-	0.0007	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Bromomethane	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chloroethane	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Trichlorofluoromethane	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
trans-1,2-Dichloroethene	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Dichloromethane	0.00004	0.00001(d)	1.00	0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Carbon disulphide	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,1-Dichloroethene	0.03	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,1-Dichloroethane	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
tert-butyl methyl ether	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
cis-1,2-Dichloroethene	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Bromochloromethane	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chloroform	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
2,2-Dichloropropane	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,2-Dichloroethane	0.003	0.00001(d)	0.40	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,1,1-Trichloroethane	0.5	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,1-Dichloropropene	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Benzene	0.001	0.0002	0.03	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Carbontetrachloride	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Dibromomethane	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,2-Dichloropropane	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Bromodichloromethane	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Trichloroethene	0.07	0.00001(d)	0.50	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
cis-1,3-Dichloropropene	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
trans-1,3-Dichloropropene	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,1,2-Trichloroethane	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Toluene	0.010	0.0002	1.00	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,3-Dichloropropane	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Dibromochloromethane	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,2-Dibromoethane	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Tetrachloroethene	0.04	0.00001(d)	0.04	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,1,1,2-Tetrachloroethane	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chlorobenzene	0.001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Ethylbenzene	0.01	0.0002	0.15	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
p/m-Xylene	0.01	0.0002	0.07	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Bromoform	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Styrene	-	0.0005	0.30	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,1,2,2-Tetrachloroethane		-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
o-Xylene	0.01	0.0002	0.07	0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,2,3-Trichloropropane	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Isopropylbenzene	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Bromobenzene	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
2-Chlorotoluene	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Propylbenzene	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
4-Chlorotoluene	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,2,4-Trimethylbenzene	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
4-Isopropyltoluene	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,3,5-Trimethylbenzene	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,2-Dichlorobenzene	0.01	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,4-Dichlorobenzene	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,3-Dichlorobenzene	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Total Dichlorobenzenes	-	0.00001	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
sec-Butylbenzene	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
tert-Buylbenzene	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
n-Butylbenzene	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,2-Dibromo-3-chloropropane	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,2,4-Trichlorobenzene	0.4	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
1,2,3-Trichlorobenzene	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Total Trichlorobenzenes	-	0.00001	0.01	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Naphthalene	0.001	0.0001	0.07	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Hexachlorobutadiene	0.0001	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Note: M.A.C = Maximum Admissable Concentration, < = Less than
Values are shaded wherever EPA Interim Guideline Values, Dutch TV, Dutch-IV or SI 12 MAC Values are exceeded
'-' signifies analysis not carried out on sample or no Dutch Criteria or S.I. 12 MACs available.

Table 3A. Semivolatile Organic Compounds (Phenols, PAH's, etc) Laboratorty Suite for Leachate Generated at Derrinumera

Semi-Volatile Organic Compounds (sVOCs)	EPA Interim Guideline Values Groundwater Protection	Dutch Criteria (mg/l) TV (TARGET)	Dutch Criteria (mg/l) IV (INTER-VENTION)	SI 81, 1988 Water Quality (Human Consumption)	Leachate Results							
					WA-LCH-01	WA-LCH-02	WA-LCH-03	WA-LCH-04	WA-LCH-05	Mean	Maximum	Standard Deviation
ENDOCRINE DISRUPTORS												
Nonyl-phenol	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Bisphenol A	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Alachlor	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Chlordane	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Dicofol	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Methoprene	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Precocene	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Diflubenzuron	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Tebufenoxide	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Fenocarb	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
2,3,7,8-TCDD	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0 001
2,3,7,8-TCDF	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Phenol	0.0005	0.0002	2	0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
2-Chlorophenol	0.2	0.00025	0.1	0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
2,4-Dichlorophenol	-	-	-	0.0005	<0.001	<0.001	<0.001	<0 001	<0.001	<0.001	<0.001	<0.001
TOTAL DICHLOROPHENOLS (sum of 2)	-	0.00008	0.03		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-
2,4,6-Trichlorophenol	0.2	-	-	0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
2,4,5-Trichlorophenol	-			0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
TOTAL TRICHLOROPHENOLS (sum of 2)	-	0.02500	0.01000		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-
2-Methylphenol	-	-	-	0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00000
4-Methylphenol	-	-	-	0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00000
2-Nitrophenol	-	-	-	0.0005	<0.001	<0 001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00000
4-Nitrophenol	-	-	-	0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00000
2,4-Dimethylphenol	-	-	-	0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00000
4-Chloro-3-methylphenol	-	-	-	0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00000
Pentachlorophenol	0.002	0.00002	0.003	0.0005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00000
Nitrobenzene	0.01	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00000
Azobenzene	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00000
Acenaphthylene	-	-	-	0.0002	0.000015	<0.00001	<0.00001	0.000041	<0.00001	0.000011	0.000041	0.00002
Acenaphthene	-	-	-	0.0002	0.000065	<0.00001	0.000022	0.000085	0.000059	0.000046	0.000085	0.00003
Fluorene	-	-	-	0.0002	0.000095	<0.00001	0.00004	0.000075	0.000083	0.000059	0.000095	0.00002
Pyrene	-	-	-	0.0002	0.000053	<0.00001	<0.00001	0.000047	0.000016	0.000023	0.000053	0.00002
Benzo(b)fluoranthrene	0.0005	-	-	0.0002	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
Dibenzo(a,h)anthracene	-	-	-	0.0002	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
1,3-Dichlorobenzene	-	-	-	0.1	<0.00001	<0.00001	<0.00001	<0 00001	<0.00001	<0.00001	<0.00001	0.00000
1,4-Dichlorobenzene	-	-	-	0.1	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
1,2-Dichlorobenzene	-			0.1	<0.00001	<0.00001	<0.00001	<0.00001	<0 00001	<0.00001	<0.00001	0.00000
TOTAL DICHLOROBENZENES (sum of 3)	-	0.00001	0.05000		0.000000	0.000000	0.000000	0.000000	0.000000	0.0000	0.000000	-
1,2,4-Trichlorobenzene		0.00001	0.01	0.1	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
Hexachlorobenzene	0.00003	0.00001	0.0005		<0.00001	<0 00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
Naphthalene	0.001	0.0001	0.07	0.0002	0.00027	<0.00001	0.000359	0.000164	0.000118	0.000182	0.000359	0.000108
Anthracene	10	0.00002	0.005	0.0002	0.000082	<0.00001	0.000013	0.000023	0.000029	0.000029	0.000082	0.000031
Phenanthrene	0.0001	0.00002	0.005	0.0002	0.000265	<0.00001	0.00004	0.000113	0.000128	0.000109	0.000265	0.000094
Fluoranthrene	0.001	0.000005	0.001	0.0002	0.000057	<0.00001	<0.00001	0.000038	0.000024	0.000024	0.000057	0.000017
Benzo(a)anthracene	0.0001	0.000002	0.0005	0.0002	<0.00001	<0.00001	<0.00001	0.000068	<0.00000	0.000014	0.000068	0.000030
Chrysene	0.0001	0.000002	0.0005	0.0002	<0.00001	<0.00001	<0.00001	0.000032	<0.00000	0.000006	0.000032	0.000014
Benzo(a)pyrene	0.00001	0.000001	0.0005	0.0002	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Benzo(ghi)perylene	0.00005	0.0000002	0.0005	0.0002	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Benzo(k)fluoranthrene	0.00005	0.0000002	0.0005	0.0002	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Indeno(1,2,3-cd)pyrene	0.0005	0.0000004	0.0005	0.0002	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Dimethyl phthalate	-	-	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Diethyl phthalate	-	-	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Di-n-butylphthalate	-	-	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Di-n-octylphthalate	-	-	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Bis(2-ethylhexyl)phthalate	-	-	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Butylbenzylphthalate			-		<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
TOTAL PHTHALATES (sum of 6)	0.00500	0.00050	0.00500	-	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-
2-Chloronaphthalene	-	-	-	0.0002	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
2-Methylnaphthalene	-	-	-	0.0002	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Carbazole	-	-	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Isophorone	-	-	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Dibenzofuran	-	-	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
4-Chloroaniline	-	-	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
2-Nitroanaline	-	-	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
3-Nitroaniline	-	-	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
4-Nitroaniline	-	-	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
2,4-Dinitrotoluene	-	-	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
2,6-Dinitrotoluene	-	-	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Bis(2-chloroethyl)ether	-	-	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
4-Bromophenylphenylether	-	-	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
4-Chlorophenylphenylether	-	-	-	0.1	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Hexachloroethane	-	-	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Hexachlorobutadiene	-	-	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Hexchlorocyclopentadiene	-	-	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Bis(2-chloroethoxy)methane	-	-	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
N-nitrosodi-n-propylamine	-	-	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	0.000000

Values are shaded wherever EPA Interim Guideline Values, Dutch-TV, Dutch-IV or S.I.81 MAC Values are exceeded.
'-' signifies no Dutch-TV, Dutch-IV or S.I.81 MAC Values are available, ⬭ signifies MAC exceeded.

Table 3B. Semivolatile Organic Compounds (Phenols, PAH's, etc) Laboratorty Suite for Water Samples taken at Castlebar Wastewater Treatment Plant

Semi-Volatile Organic Compounds (sVOCs)	EPA Interim Guideline Values Groundwater Protection	Dutch Criteria (mg/l) TV (TARGET)	Dutch Criteria (mg/l) IV (INTER-VENTION)	SI 81, 1988 Water Quality (Human Consumption)	Wastewater Results				
					WA-WWTP-01	WA-WWTP-02	Mean	Maximum	Standard Deviation
ENDOCRINE DISRUPTORS									
Nonyl-phenol	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001
Bisphenol A	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001
Alachlor	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001
Chlordane	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001
Dicofol	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001
Methoprene	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001
Precocene	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001
Diflubenzuron	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001
Tebufenoxide	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001
Fenocarb	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001
2,3,7,8-TCDD	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001
2,3,7,8-TCDF	-	-	-	-	<0.001	<0.001	<0.001	<0.001	<0.001
Phenol	0.0005	0.0002	2	0.0005	<0.001	<0.001	<0.001	<0.001	<0.001
2-Chlorophenol	0.2	0.00025	0.1	0.0005	<0.001	<0.001	<0.001	<0.001	<0.001
2,4-Dichlorophenol	-	-	-	0.0005	<0.001	<0.001	<0.001	<0.001	<0.001
TOTAL DICHLOROPHENOLS (sum of 2)	-	0.00008	0.03		0.0000	0.0000	0.0000	0.0000	0.0000
2,4,6-Trichlorophenol	0.2	–	–	0.0005	<0.001	<0.001	<0.001	<0.001	<0.001
2,4,5-Trichlorophenol	-			0.0005	<0.001	<0.001	<0.001	<0.001	<0.001
TOTAL TRICHLOROPHENOLS (sum of 2)	-	0.02500	0.01000		0.0000	0.0000	0.0000	0.0000	0.0000
2-Methylphenol	-	-	-	0.0005	<0.001	<0.001	<0.001	<0.001	0.00000
4-Methylphenol	-	-	-	0.0005	<0.001	<0.001	<0.001	<0.001	0.00000
2-Nitrophenol	-	-	-	0.0005	<0.001	<0.001	<0.001	<0.001	0.00000
4-Nitrophenol	-	-	-	0.0005	<0.001	<0.001	<0.001	<0.001	0.00000
2,4-Dimethylphenol	-	-	-	0.0005	<0.001	<0.001	<0.001	<0.001	0.00000
4-Chloro-3-methylphenol	-	-	-	0.0005	<0.001	<0.001	<0.001	<0.001	0.00000
Pentachlorophenol	0.002	0.00002	0.003	0.0005	<0.001	<0.001	<0.001	<0.001	0.00000
Nitrobenzene	0.01	–	–	–	<0.001	<0.001	<0.001	<0.001	0.00000
Azobenzene	-	–	–	–	<0.001	<0.001	<0.001	<0.001	0.00000
Acenaphthylene	-	–	–	0.0002	<0.00001	<0.00001	<0.001	<0.001	0.00000
Acenaphthene	-	–	–	0.0002	<0.00001	0.000031	0.000016	0.000031	0.00002
Fluorene	-	–	–	0.0002	<0.00001	0.00004	0.000020	0.00004	0.00003
Pyrene	-	–	–	0.0002	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
Benzo(b)fluoranthrene	0.0005	–	–	0.0002	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
Dibenzo(a,h)anthracene	-	–	–	0.0002	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
1,3-Dichlorobenzene	-	–	–	0.1	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
1,4-Dichlorobenzene	-	–	–	0.1	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
1,2-Dichlorobenzene	-			0.1	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
TOTAL DICHLOROBENZENES (sum of 3)	-	0.00001	0.05000	-	0.0000	0.000000	0.000000	0.000000	-
1,2,4-Trichlorobenzene		0.00001	0.01	0.1	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
Hexachlorobenzene	0.00003	0.00001	0.0005		<0.00001	<0.00001	<0.00001	<0.00001	0.00000
Naphthalene	0.001	0.0001	0.07	0.0002	<0.00001	0.000128	0.000064	0.000128	0.000091
Anthracene	10	0.00002	0.005	0.0002	<0.00001	0.000014	0.000007	0.000014	0.000010
Phenanthrene	0.0001	0.00002	0.005	0.0002	<0.00001	0.000070	0.000035	0.000070	0.000049
Fluoranthrene	0.001	0.000005	0.001	0.0002	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Benzo(a)anthracene	0.0001	0.000002	0.0005	0.0002	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Chrysene	0.0001	0.000002	0.0005	0.0002	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Benzo(a)pyrene	0.00001	0.000001	0.0005	0.0002	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Benzo(ghi)perylene	0.00005	0.0000002	0.0005	0.0002	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Benzo(k)fluoranthrene	0.00005	0.0000002	0.0005	0.0002	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Indeno(1,2,3-cd)pyrene	0.0005	0.0000004	0.0005	0.0002	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Dimethyl phthalate	-	-	-	-	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Diethyl phthalate	–	–	-	–	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Di-n-butylphthalate	–	–	-	–	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Di-n-octylphthalate	–	–	-	–	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Bis(2-ethylhexyl)phthalate	–	–	-	–	<0.00001	<0.00001	<0.00001	<0.00001	0.000000
Butylbenzylphthalate			-		<0.00001	<0.00001	<0.00001	<0.00001	0.000000
TOTAL PHTHALATES (sum of 6)	0.00500	0.00050	0.00500	-	0.0000	0.0000	0.0000	0.0000	-
2-Chloronaphthalene	-	–	–	0.0002	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
2-Methylnaphthalene	-	–	–	0.0002	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
Carbazole	-	–	–	–	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
Isophorone	-	–	–	–	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
Dibenzofuran	-	–	–	–	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
4-Chloroaniline	-	–	–	–	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
2-Nitroanaline	-	–	–	–	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
3-Nitroaniline	-	–	–	–	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
4-Nitroaniline	-	–	–	–	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
2,4-Dinitrotoluene	-	–	–	–	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
2,6-Dinitrotoluene	-	–	–	–	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
Bis(2-chloroethyl)ether	-	–	–	–	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
4-Bromophenylphenylether	-	–	–	–	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
4-Chlorophenylphenylether	-	–	–	0.1	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
Hexachloroethane	-	–	–	–	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
Hexachlorobutadiene	-	–	–	–	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
Hexchlorocyclopentadiene	-	–	–	–	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
Bis(2-chloroethoxy)methane	-	–	–	–	<0.00001	<0.00001	<0.00001	<0.00001	0.00000
N-nitrosodi-n-propylamine					<0.00001	<0.00001	<0.00001	<0.00001	0.00000

Values are shaded wherever EPA Interim Guideline Values, Dutch-TV, Dutch-IV or S.I.81 MAC Values are exceeded.
'-' signifies no Dutch-TV, Dutch-IV or S.I.81 MAC Values are available, ⬭ signifies MAC exceeded.

Table 4. Polychlorinated Biphenyl (PCBs), Chlorinated Pesticides and Diesel Range Organics (DRO) Laboratory Results for Leachate Generated at Derrinumera and Water Samples taken at Castlebar Wastewater Treatment Plant

					Leachate Results					Wastewater Results	
Parameters	SI 81, 1988 Water Quality (Human Consumption) MAC mg/l	EPA Interim Guideline Values Groundwater Protection	Dutch Criteria (mg/l) TV (TARGET)	Dutch Criteria (mg/l) IV (INTER-VENTION)	WA-LCH-01	WA-LCH-02	WA-LCH-03	WA-LCH-04	WA-LCH-05	WA-WWTP-01	WA-WWTP-02
PCBs											
PCB Congener 52	0.1	0.00001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB Congener 101	0.1	0.00001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB Congener 118	0.1	0.00001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB Congener 153	0.1	0.00001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB Congener 138	0.1	0.00001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB Congener 180	0.1	0.00001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
PCB Total of 7 Congeners	0.1	-	0.00001	0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
CHLORINATED PESTICIDES											
Tecnazene	0.1	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Trifluralin	0.1	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
alpha-HCH(Lindane)	0.1	0.0001	0.00001	0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Hexachlorobenzene	0.1	0.0001	0.00001	0.00050	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
beta-HCH(Lindane)	0.1	0.0001	0.00001	0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
gamma-HCH(Lindane)	0.1	0.0001	0.0000002	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Quintozene (PCNB)	0.1	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Triallate	0.1	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Chlorothalonil	0.1	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Heptachlor	0.1	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Aldrin	0.1	0.00001	0.00001	0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Triadimefon	0.1	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Pendimethalin	0.1	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Heptachlor Epoxide	0.1	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
o,p'-DDE	0.1	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Endosulfan I	0.1	0.000001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
p,p'-DDE	0.1	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Dieldrin	0.1	0.00001	0.0000002	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
p,p'-TDE(DDD)	0.1	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Endrin	0.1	0.0001	0.00001	0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Endosulfan II	0.1	0.000001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
o,p'-TDE	0.1	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
o,p'-DDT	0.1	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
p,p'-DDT	0.1	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Endosulfan Sulphate	0.1	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
o,p'-Methoxychlor	0.1	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
p,p'-Methyoxychlor	0.1	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Permethrin	0.1	0.02	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
DIESEL RANGE ORGANICS (DRO)	-	-	-	-	0.205 [1]	0.038	<0.010	<0.010	<0.010	0.027	<0.010
Mineral Oil	0.01	0.01	0.05000	0.60000	0.082	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
% Mineral Oil					40	0	0	0	0	0	0

Note: M.A.C = Maximum Admissable Concentration, < = Less than
Values are shaded wherever EPA Interim Guideline Values, Dutch-TV, Dutch-IV or S.I.81 MAC Values are exceeded.
'-' signifies no Dutch-TV, Dutch-IV or S.I.81 MAC Values are available, ○ signifies MAC exceeded.
[1] The laboratory interpretation of the chromatogram indicates that a highly degraded diesel was detected within the leachate.

Table 5. Acid, Triazine and Nitrile Herbicides, Organophosphorous Pesticides, and Organotin Compound Laboratorty Suite for Leachate Generated at Derrinumera and Water Samples taken at Castlebar Wastewater Treatment Plant

Parameters	SI 12, 2001 Water Quality (Dangerous Substances) MAC	EPA Interim Guideline Values for Groundwater Protection	Dutch Criteria (mg/l) TV (TARGET)	Dutch Criteria (mg/l) IV (INTER-VENTION)	Leachate Results					Wastewater Results	
					WA-LCH-01	WA-LCH-02	WA-LCH-03	WA-LCH-04	WA-LCH-05	WA-WWTP-01	WA-WWTP-02
ACID HERBICIDES											
Clopyralid	-	0.0001	-	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Picoram	-	0.0001	-	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
2,4,6- TBA	-	0.0001	-	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Dicamba	-	0.0001	-	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Benazolin	-	0.0001	-	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
4-CPA	-	0.0001	-	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Bentazone	-	0.0001	-	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
2,4-D	-	0.0001	-	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
MCPA	-	0.0001	-	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
2,4-DP	-	0.0001	-	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Triclopyr	-	0.0001	-	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Mecoprop	-	0.01	-	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
2,4,5-T	-	0.0001	-	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
2,4-DB	-	0.0001	-	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
MCPB	-	0.0001	-	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Fenoprop (2,4,5-TP)	-	0.0001	-	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Diclofop	-	0.1	-	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Pentachlorophenol	-	0.0001	-	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
TRIAZINE HERBICIDES											
Atrazine	0.001	0.001	0.0000075	0.15	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Simazine	0.01	0.001	-	-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
NITRILE HERBICIDES											
Bromoxymil	-	0.005	-	-	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
ORGANOPHOSPHOROUS PESTICIDES											
Diclorvos	-	0.000001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Mevinphos	-	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Dimethoate	-	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Parathion	-	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Methyl Parathion	-	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Propetamphos	-	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Diazinon	-	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Etrimphos	-	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Chlorpyrifos-methyl	-	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Pirimiphos Methyl	-	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Fenitrothion	-	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Malathion	-	0.00001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Fenthion	-	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Chlorpyrifos	-	0.009	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Chlorfenvinphos	-	0.005	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Ethion	-	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Triazophos	-	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Carbophenothion	-	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Phosalone	-	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Azinophos ethyl	-	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
Azinophos ethyl	-	0.0001	-	-	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001	<0.00001
ORGANOTIN COMPOUNDS											
Tributyltin	0.000001	0.0007 [1]	-	-	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Triphenyltin	-	0.0007 [1]	-	-	<0.00005	<0.00005	<0.00005	0.00041	<0.00005	<0.00005	<0.00005
Dibutyltin	-	0.0007 [1]	-	-	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005

Note: M.A.C = Maximum Admissable Concentration, < = Less than

Values are shaded wherever EPA Interim Guideline Values, Dutch-TV, Dutch-IV, S.I. 12 or S.I.81 MAC Values are exceeded.

'-' signifies no Dutch-TV, Dutch-IV, S.I. 12 or S.I.81 MAC Values are available.

1. As Sn.

Table 6. Toxicity Testing Results for Leachate Generated at Derrinumera and Water Samples taken at Castlebar Wastewater Treatment Plant

Parameters	Units	Leachate Results					Wastewater Results	
		WA-LCH-01	WA-LCH-02	WA-LCH-03	WA-LCH-04	WA-LCH-05	WA-WWTP-01	WA-WWTP-02
5 minute EC $_{50}$	No. of Toxic Units	<2.2	<2.2	<2.2	<2.2	<2.2	<2.2	<2.2
	Test Result	>45% vol./vol.	>45% vol./vol.	>45% vol./vol.	>45% vol./vol.	>45% vol./vol.	>45% vol./vol.	>45% vol./vol.
15 minute EC $_{50}$	No. of Toxic Units	<2.2	<2.2	<2.2	<2.2	<2.2	<2.2	<2.2
	Test Result	>45% vol./vol.	>45% vol./vol.	>45% vol./vol.	>45% vol./vol.	>45% vol./vol.	>45% vol./vol.	>45% vol./vol.

Note:

If the results from a 5 minute EC_{50} is 20% v/v, this means that 200ml of leachate made up to a litre with water had a specified effect on 50% of the test species in 5 minutes.
To avoid confusion and to report increasing toxicity with a correspondingly increasing number, the result is expressed as a funciton of the undiluted sample (100%).
This form of expression is known as the Toxicity Unit (Tu) and is defined as follows:

$$\boxed{Tu = \frac{100}{EC_{50}}}$$