2.2.7 Hydrology

The site is located within the Newry, Fane, Glyde and Dee catchments and the sub-catchment of River Fane. The site is bounded to the southwest by the source stream for Corrinshigo Lough, to the west by Corrinshigo Lough itself and to the north by the lake outlet stream. Carrickaslane Lough stream and Devlin stream lie northeast of the site and are tributaries of the River Fane.

There are several small lakes located in the vicinity of the site. Drumillard Lough is located approximately 0.6km to the northeast of the site while an unnamed surface water area located approximately 0.5km to the east of the site. Killygola Lough and Lough Smiley are located approximately 1km northeast of the site.

2.2.8 Ecology

The site is not within or directly adjacent to any Natural Heritage Area (NHA), proposed NHA (pNHA), Special Area of Conservation (SAC) or Special Protection Area (SPA). However, the following pNHAs and NHA are located within the vicinity of the site:

Lough Smiley proposed NHA (pNHA) lies approximately 0.5km northeast of the site. Muchno Lake NHA lies approximately 1.6km east of the site.

There are no SACs or SPAs within 15km of the site. The ecologically protected areas mapping is presented in Figure 2.7.

During the site walkover, Japanese Knotweed was identified along the western banks of the site and evidence of eradication was identified, see Plate 2-1. The lake is eroding the banks of the site exposing the interred waste.

Plate 2-1: Japanese Knotweed and exposed waste material

2.2.9 Site History

The earliest historical map available on the OSI website dates from 1837-1842. OSI Historic Map identifies the land within the site boundary and the surrounding area was previously 'Bog or uncultivated land'.

The OSI Historical Mapping is presented in Figure 2.8.

2.2.10 Existing Geological Heritage

The GSI holds no records of areas of Geological Heritage within the site boundary or in the immediate vicinity of the site.

The nearest recorded of geological heritage held by the GSI is approximately 5.8km north of the site boundary at Tassan. Tassan is described as *"the largest and most productive of the Monaghan district lead mines, from c. 1840-1866"* and the geological feature of note is a *"good mixture of extant mine features, including mine buildings and solid waste".*

The geological heritage mapping is presented in Figure 2.9.

2.2.11 Existing Geotechnical Stability

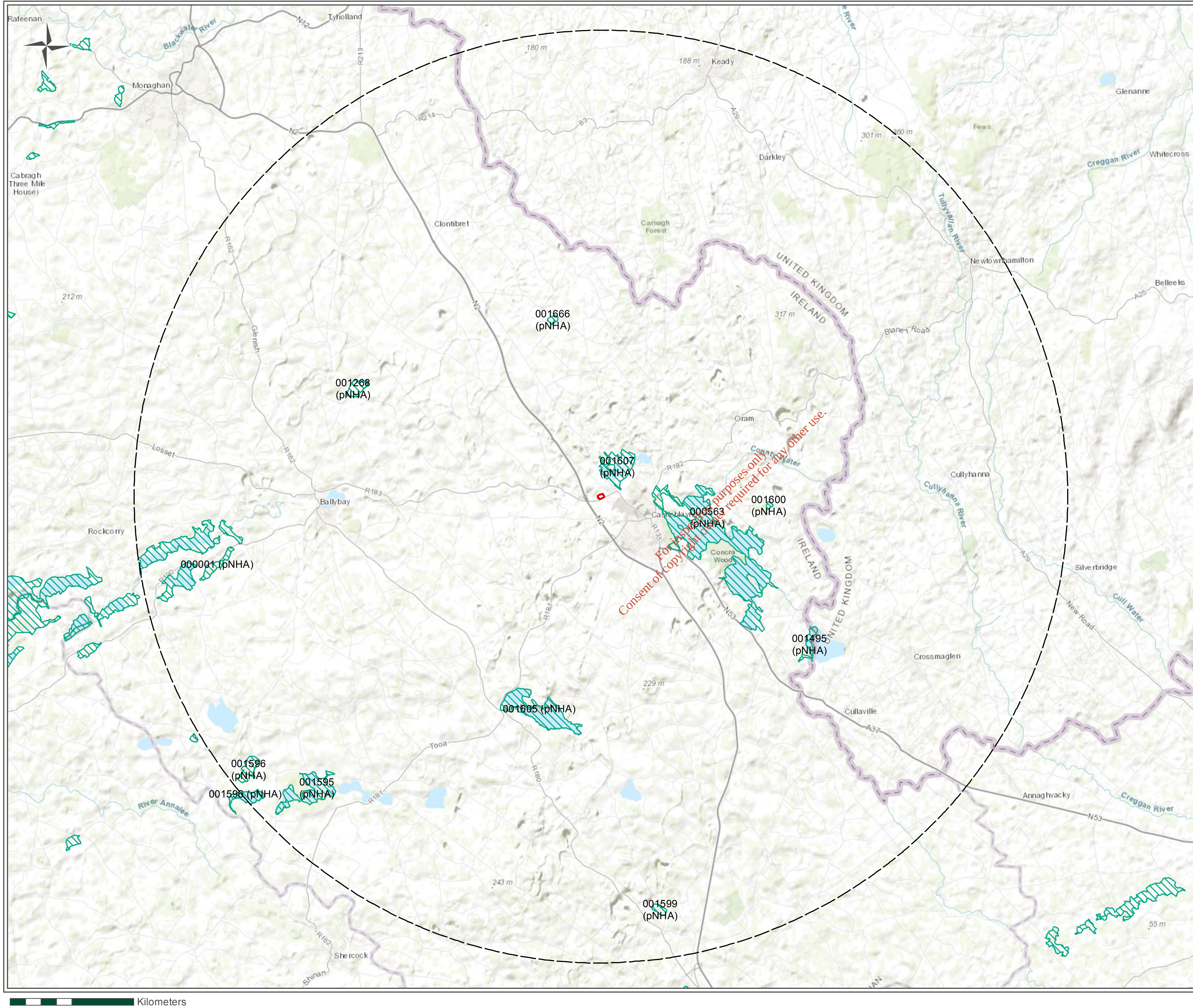
The GSI landslides database indicates that the nearest recorded geo-hazard was at Carrowmaculla, Lisnaskea Co. Fermanagh (ITM 643496 835192) in 1979, approximately 40 km west of the site boundary.

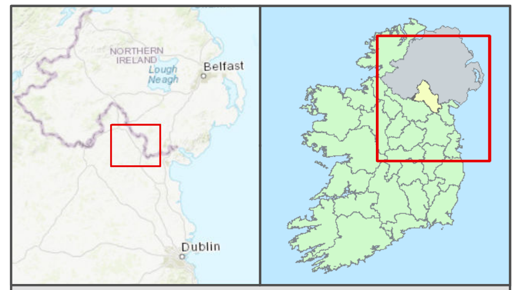
According to the GSI, the site and surrounding area is underlain by cutaway blanket peat.

2.2.12 Archaeological Heritage

There are no Archaeological Heritage sites with the site boundary according to the Heritage Ireland GSI Geological Heritage map layer.

Map Path: R:\Map Production\2018\P1724\Workspace\Killycard Landfill\P1724_Fig2-7_EcologyProtectedSites_A3.mxd





Co. Monaghan

Legend

- Site Boundary
- 15km Distance from Site Boundary

Proposed Natural Heritage Area (pNHA)

- Closest Site: 0.5km

Figure Title
Ecology: Protected Sites

Figure No. 2.7

Project
ERA of Historic Landfill at
Killycard, Co. Monaghan

Client
Monaghan County Council

Scale 1:120,000 **Page Size** A3

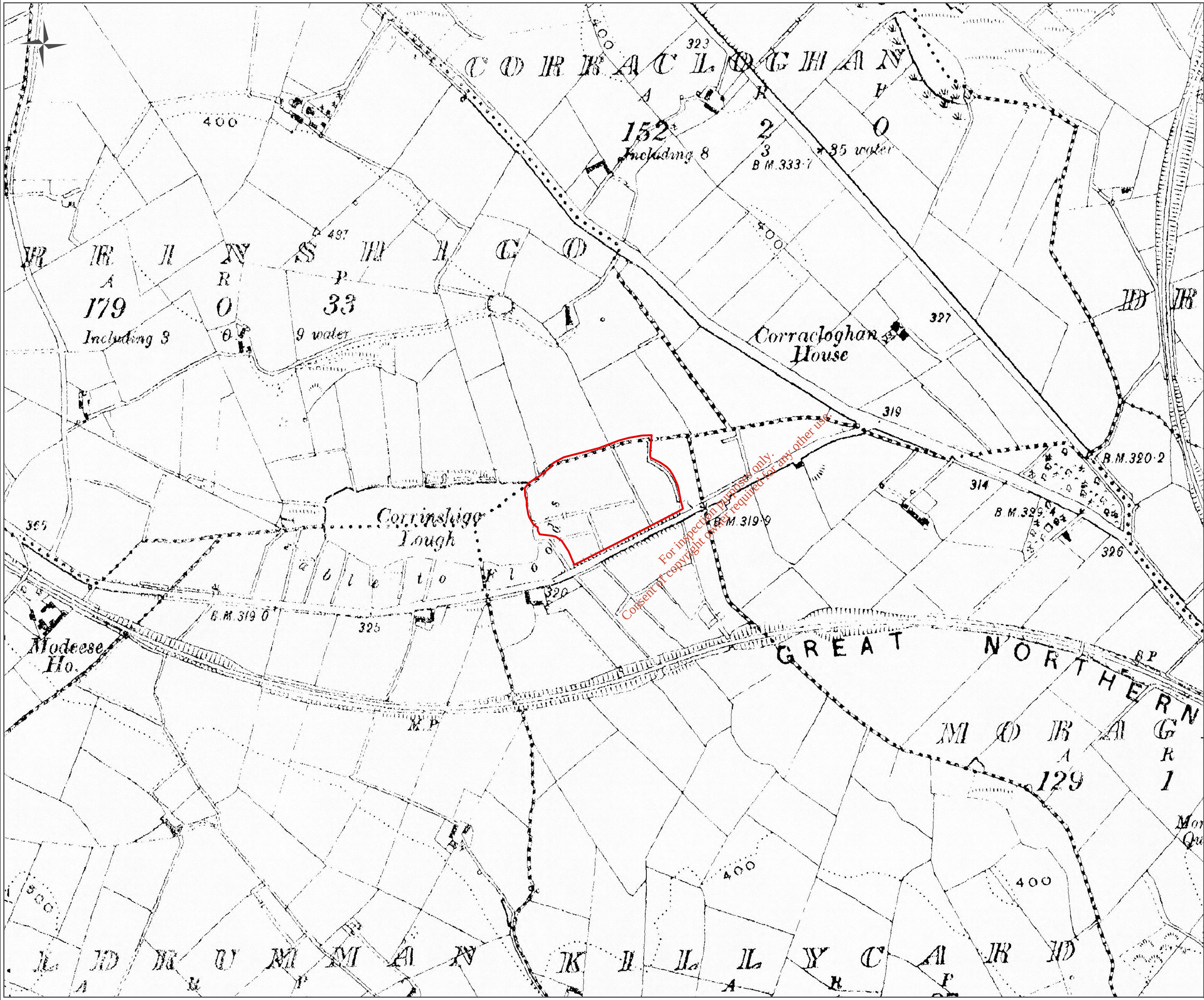
Revision A **Date** 17/10/2018

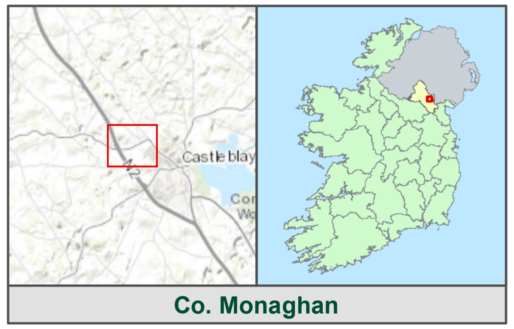
Consultants in Engineering
and Environmental Sciences

www.fehilytimoney.ie

FEHILY TIMONEY & COMPANY

Map Path: R:\Map Production\2018\P1724\Workspace\Killycard Landfill\P1724_Fig2-8_OSiHistoricalMapping_A3.mxd





Legend

Site Boundary

Figure Title	OSi Historical Mapping
Figure No.	2.8
Project	ERA of Historic Landfill at Killycard, Co. Monaghan
Client	Monaghan County Council
Scale	1:5,000
Page Size	A3
Revision	A
Date	17/10/2018

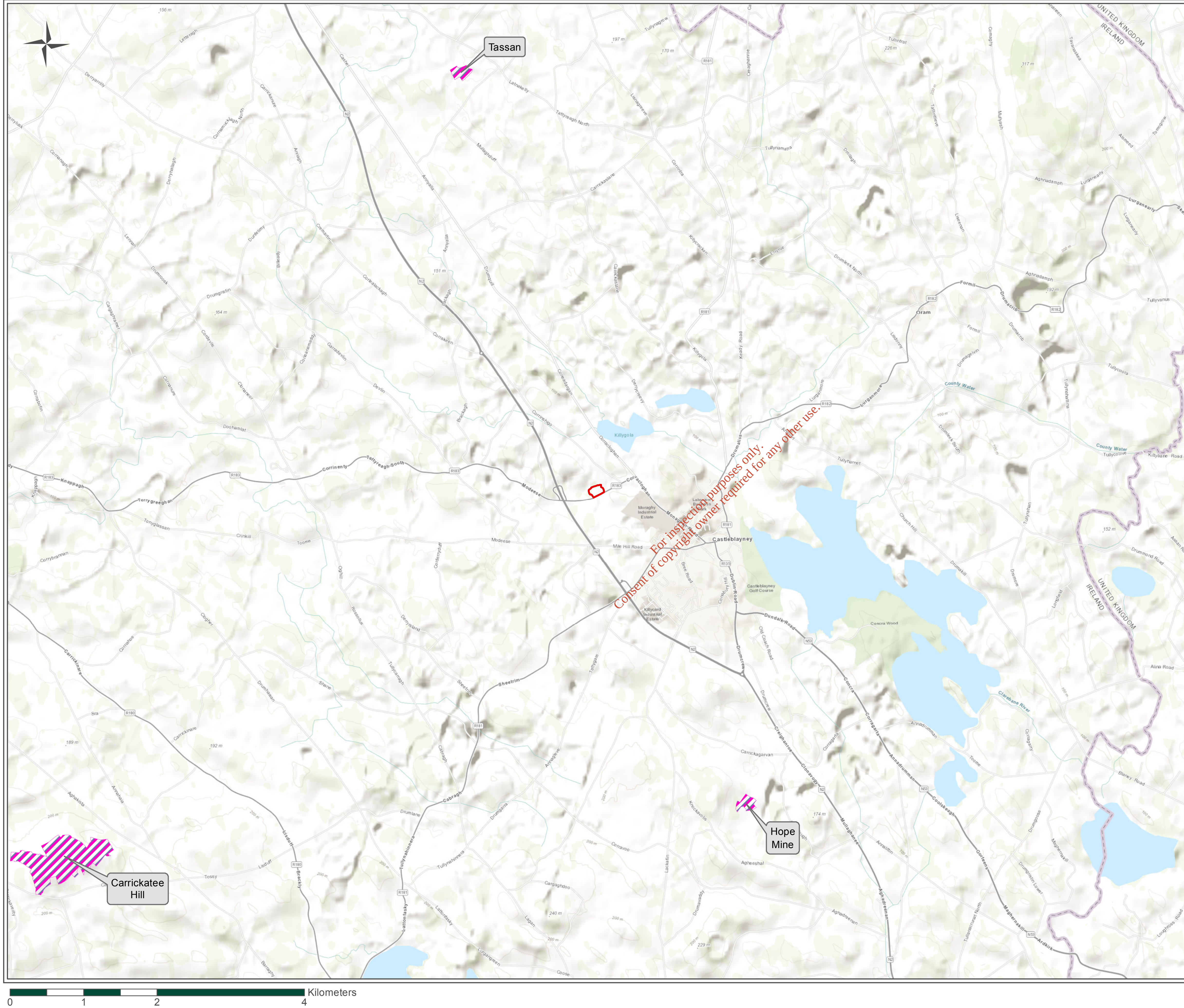
Consultants in Engineering and Environmental Sciences

www.fehilytimoney.ie

0 0.125 0.25 0.5 Kilometers

Map Path: R:\Map Production\2018\P1724\Workspace\Killycard Landfill\P1724_Fig2-9_GeologicalHeritage_A3.mxd

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community
Mapping Reproduced Under Licence from the Ordnance Survey Ireland Licence No. EN 0001218 © Government of Ireland



Co. Monaghan

Legend

- Site Boundary
- Geological Heritage Sites

Figure Title	Geological Heritage
Figure No.	2.9
Project	ERA of Historic Landfill at Killycard, Co. Monaghan
Client	Monaghan County Council
Scale	1:50,000
Page Size	A3
Revision	A
Date	17/10/2018

Consultants in Engineering and Environmental Sciences

www.fehilytimoney.ie

FEHILY TIMONEY & COMPANY

3 TIER 2 SITE INVESTIGATION

3.1 Site Investigation Works

A site investigation rationale was devised based on findings of the Tier 1 assessment, site walkover, historical aerial photography and the preliminary risk assessment which formed part of that report.

The scope of site investigation works included:

- 13 No. Trial pit excavations
- Installation and monitoring of 3 No. groundwater boreholes
- 1 No. Geophysical survey (2D resistivity and seismic refraction profiling)
- Topographical Survey
- Factual reporting

The locations of the intrusive works at the site are presented in Figure 3.1.

The site investigation included the review of the following literature sources and websites:

- EPA 2003, Landfill Manuals: Landfill Monitoring (2nd Edition)
- EPA 1999, Landfill Manuals: Site Investigations
- BS 5930: 1999, Code of Practice for Site Investigations
- BS 6068 Water Quality: Sampling (parts 6.1-6.6 and 6.11-6.12, 6.14)
- BS 8855 Soil analysis (all parts)
- CLM: Ready Reference 2002, Section 3.1 Soil sampling strategies
- CLM: Ready Reference 2002, Section 3.2 Groundwater sampling/monitoring strategies
- CLM: Ready Reference 2002, Section 3.3 Gas sampling/monitoring strategies

3.1.1 Site Walkover

A site walkover was conducted prior to site investigation works by an FT Engineer and a CGL Engineer. During the site walkover the scope of the investigative works were evaluated based on the findings in the Tier I assessment.

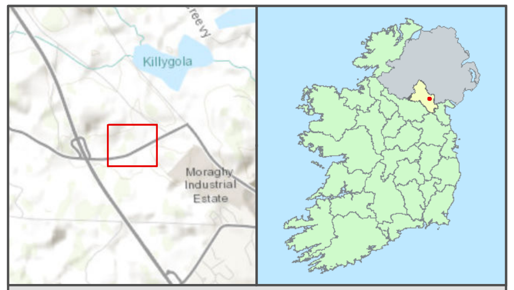
The scope was agreed based on the site walkover assessment, historic aerial photography and other information received by MCC.

During the site walkover, Japanese Knotweed was identified along the western banks of the site. Evidence of eradication efforts by means of spraying was confirmed as discussed previously in Section 2.2.8. The lake also appears to be eroding the banks of the landfill and exposing the interred waste in this area.

The site walkover also confirmed the presence of public supply water mains outside the entrances to the residential housing within 250m of the site and outside the industrial units adjacent to the site.

The site walkover checklist and photo log are included in Appendix 4.

Map Path: R:\Map Production\2018\P1724\Workspace\Killycard Landfill\P1724_Fig3-1_SiteInvestigationLocationPlan_A3.mxd



Co. Monaghan

Legend

- Groundwater Well Locations
- Trial Pit Locations
- Site Boundary

Figure Title	Site Investigation Location Plan
Figure No.	3.1
Project	ERA of Historic Landfill at Killycard, Co. Monaghan
Client	Monaghan County Council
Scale	1:1,500
Page Size	A3
Revision	A
Date	09/11/2018

Consultants in Engineering and Environmental Sciences

www.fehilytimoney.ie

FEHILY TIMONEY & COMPANY

3.1.2 Trial Pitting

A Causeway Geotech (CGL) Engineering Geologist supervised the advancement of 13 No. trial pits, shown in Figure 3.1, on the 20th September and 21st September 2018.

The trial pits (TP01 to TP13) were excavated to depths of 4.20m to 4.50m below existing ground level (bgl) using a JCB 3CX back-hoe excavator.

The geophysical survey used in conjunction with the profiles identified during trial pitting provided a picture of the underlying geology of the site and a general profile of the buried waste.

A summary of the ground conditions is presented in Table 3.1 below with photographs and exploratory hole logs provided in the CGL site investigation report, Appendix 2.

Table 3-1: Summary of Ground Conditions

Trial Pit ID	Depth of cover material (m BGL)	Depth to base of made ground/waste (m BGL)	Profile Description
TP01	0.10 (Topsoil) 0.1 – 2.2 (Made Ground) 2.2 – 3.4 (Peat) 3.4 – 4.5 (Clay)	4.5 (base of excavation)	MADE GROUND: Black waste with sandy gravelly SILT - 40% plastic, 5% glass bottles, fertiliser bags, shoes, mattress, steel pipe, cloths and 2 rolls of industrial cardboard. Spongy brown fibrous PEAT. Soft bluish grey silty CLAY.
TP02	0.10 (Topsoil) 0.1 – 2.6 (Made Ground) 2.6 – 4.2 (Peat) 4.2 – 4.5 (Clay)	4.5 (base of excavation)	MADE GROUND: Black waste with sandy gravelly SILT - 50% plastic, 5% glass bottles, planks of wood, foam, plastic, pipes, kitchen knife, metal straps, shoes, wellies. Spongy brown fibrous PEAT. Soft bluish grey silty CLAY.
TP03	0.10 (Topsoil) 0.1 – 2.3 (Made Ground) 2.3 – 3.6 (Peat) 3.6 – 4.2 (Clay)	4.2 (base of excavation)	MADE GROUND: Brownish black waste with sandy gravelly SILT - 30% office waste, shredded paper, old clothes, mattress springs, zinc, wood, shoes, tiles, blankets and fertiliser bags. Spongy brown fibrous PEAT. Soft bluish grey silty CLAY.
TP04	0.10 (Topsoil) 0.1 – 2.1 (Made Ground) 2.1 – 4.2 (Peat) 4.2 – 4.5 (Clay)	4.5 (base of excavation)	MADE GROUND: Black waste with sandy gravelly SILT - 40% plastic, fertiliser bags, 10% glass bottles, shoes, clothes. Spongy brown fibrous PEAT. Soft bluish grey silty CLAY.
TP05	0.10 (Topsoil) 0.1 – 2.2 (Made Ground) 2.2 – 3.8 (Peat) 3.8 – 4.5 (Clay)	4.5 (base of excavation)	MADE GROUND: Black waste with sandy gravelly SILT - 60% plastic, 10% clothes, 5% glass bottles, wood, plastic bottles, metal pipes. Spongy brown fibrous PEAT. Firm blue silty CLAY.

Trial Pit ID	Depth of cover material (m BGL)	Depth to base of made ground/waste (m BGL)	Profile Description
TP06	0.10 (Topsoil) 0.1 – 2.4 (Made Ground) 2.4 – 4.0 (Peat) 4.0 – 4.5 (Clay)	4.5 (base of excavation)	MADE GROUND: Black waste with sandy gravelly SILT with fragments of red brick, pipes, plastic, steel pipes, glass bottles, ropes and metal wires. Spongy brown fibrous PEAT. Firm bluish grey silty CLAY.
TP07	0.10 (Topsoil) 0.1 – 1.9 (Made Ground) 1.9 – 3.7 (Peat) 3.7 – 4.5 (Clay)	4.5 (base of excavation)	MADE GROUND: Firm greyish black slightly sandy slightly gravelly CLAY with fragments of red brick, plastic, old wires, wood, glass bottles and milk cartons. Spongy brown fibrous PEAT. Firm bluish grey silty CLAY.
TP08	0.10 (Topsoil) 0.1 – 4.4 (Made Ground) 4.4 – 4.5 (Peat)	4.5 (base of excavation)	MADE GROUND: Firm grey slightly sandy slightly gravelly CLAY with black waste, plastic, wires and ropes. Spongy brown fibrous PEAT.
TP09	0.10 (Topsoil) 0.1 – 2.7 (Made Ground) 2.7 – 3.5 (Peat) 3.5 – 4.5 (Clay)	4.5 (base of excavation)	MADE GROUND: Brownish black waste – 60% plastic, 10% clothes, glass bottles and pipes. Spongy brown fibrous PEAT. Soft bluish grey silty CLAY.
TP10	0.10 (Topsoil) 0.1 – 1.9 (Made Ground) 1.9 – 3.2 (Peat) 3.2 – 4.5 (Clay)	4.5 (base of excavation)	MADE GROUND: Black waste with sandy gravelly SILT - 30% plastic, old clothes, glass bottles and metal pipes. Spongy brown fibrous PEAT. Soft bluish grey silty CLAY.
TP11	0.10 (Topsoil) 0.1 – 3.4 (Made Ground) 3.4 - 4.3 (Clay)	4.3 (base of excavation)	MADE GROUND: Black waste with sandy gravelly SILT - 50% plastic, 10% rubber, 15% glass bottles, washing machines, cups, springs, coal bags, clothes, nets, planks of wood and fertiliser bags. Soft blue silty CLAY.
TP12	0.10 (Topsoil) 0.1 – 2.7 (Made Ground) 2.7 – 3.7 (Peat) 3.7 – 4.5 (Clay)	4.5 (base of excavation)	MADE GROUND: Soft brown slightly sandy slightly gravelly CLAY with plastic, glass bottles, planks of wood, wire, plastic pipe, red brick, clothes and fertiliser bags. Spongy brown fibrous PEAT. Soft bluish grey silty CLAY.
TP13	0.10 (Topsoil) 0.1 – 2.4 (Made Ground) 2.4 – 3.8 (Peat) 3.8 – 4.5 (Clay)	4.5 (base of excavation)	MADE GROUND: Firm brown slightly gravelly sandy CLAY with steel pipes, 30% plastic, 10% clothes. milk cartons, glass bottles, coal bags and fertiliser bags. Spongy brown fibrous PEAT. Soft bluish grey silty CLAY.

Made ground comprising waste was encountered in all 13 No. trial pits (TP01 - TP13). The cover material at these trial pit locations comprised 0.05m to 0.10m topsoil. The shallow topsoil depth across the site do not comply with the capping design specification set out in the Landfill Design Manual. No bedrock was encountered during the trial pitting works.

Waste material was encountered between 0.1m – 3.4m in all trial pits TP01 to TP13 where natural ground was confirmed. Natural ground comprising of cut-over peat and glacial till was confirmed in all trial pits except for TP11 where Made Ground was underlain by glacial till only.

Groundwater was encountered in 10 of 13 No. trial pits as detailed in Table 3.2.

Table 3-2: Groundwater strikes encountered during trial pitting

Trial Pit ID	Water Level (mBGL)	Flow Rate
TP01	2.1	Fast Flow
TP02	1.8	Fast Flow
TP03	2.1	Seepage
TP04	4.1	Seepage
TP06	1.2	Heavy Flow
TP07	1.0	Seepage
TP10	1.6	Seepage
TP11	3.0	Fast Flow
TP12	2.8	Seepage
TP13	2.1	Fast Flow

3.1.3 Waste Sampling

A total of 2 No. samples of the made ground / waste at the site was collected from trial pits TP04 and TP08 advanced in the centre of the site.

All samples were submitted for Waste Acceptance Criteria (WAC) testing to ALS Environmental Ltd, a UKAS/MCERTS approved laboratory. Samples were collected from site under Chain of Custody procedures.

The results are provided in Appendix G of the CGL Ground Investigation report, Appendix 2 of this report.

3.1.4 Evidence of Contamination

The trial pit excavation works identified waste material tending west-east across the entire site to a maximum depth of 4.4m BGL. Evidence of waste material was identified at all trial pit locations (TP01 – TP13). The waste encountered was typically described as black bag type waste with 30% to 50% plastic, 10% rubber, 15% glass bottles, washing machines, cups, springs, coal bags, clothes, nets, planks of wood and fertiliser bags. The waste material description as described by CGLs Engineering Geologist is typical of domestically sourced Municipal Solid Waste.

The base of the waste was encountered between 2.2m – 4.4m in all trial pits advanced across the site where natural ground was confirmed.

3.1.5 Geophysical Investigation

Apex Geoservices Ltd. (Apex) were instructed by FT to undertake a geophysical investigation of the site. The survey was carried out on the 1st and 2nd November 2018.

The geophysical survey consisted of reconnaissance EM Ground Conductivity Mapping with follow-up Electrical Resistivity Tomography (ERT), Seismic Refraction profiling and the MASW (multichannel analysis of surface waves) method used to estimate shear-wave velocities (Vs) in the ground material. A total of 516m of electrical resistivity profiles were collected.

The geophysical survey calibrated against the findings of the trial pitting and borehole installations was used to estimate a general profile of the buried waste above the in-situ bedrock.

The geophysical survey delineated the survey area into zones based on an interpretation of the ground conditions across the site. The following 2 No. zones were identified:

- Zone A: made ground/waste (predominantly organic) over very soft Peat/Clay with Leachate
- Zone B: made ground/waste (mixed with Clay/Silt) over very soft Peat/Clay

A map showing a delineation of the identified zones is presented in Figure 3.2.

Seismic Refraction Profiling & Electrical Resistivity Tomography (ERT)

Apex recorded 5 no. ERT profiles data along three designated profiles. ERT profiles are named R1 through R5. The location of these profiles is given in Drawing No. AGL18164_01 and interpreted cross sections were compiled for the profiles on Drawing No. AGL18164_R1-R5.

Three seismic refraction profiles (S1-S3) were recorded across the site. The locations are shown on Drawing No. AGL18164_01 and the interpreted cross sections are presented in Drawing No. AGL18164_R1-R5.

An interpretation of the results is included in the Apex geophysical survey report, Appendix 2.

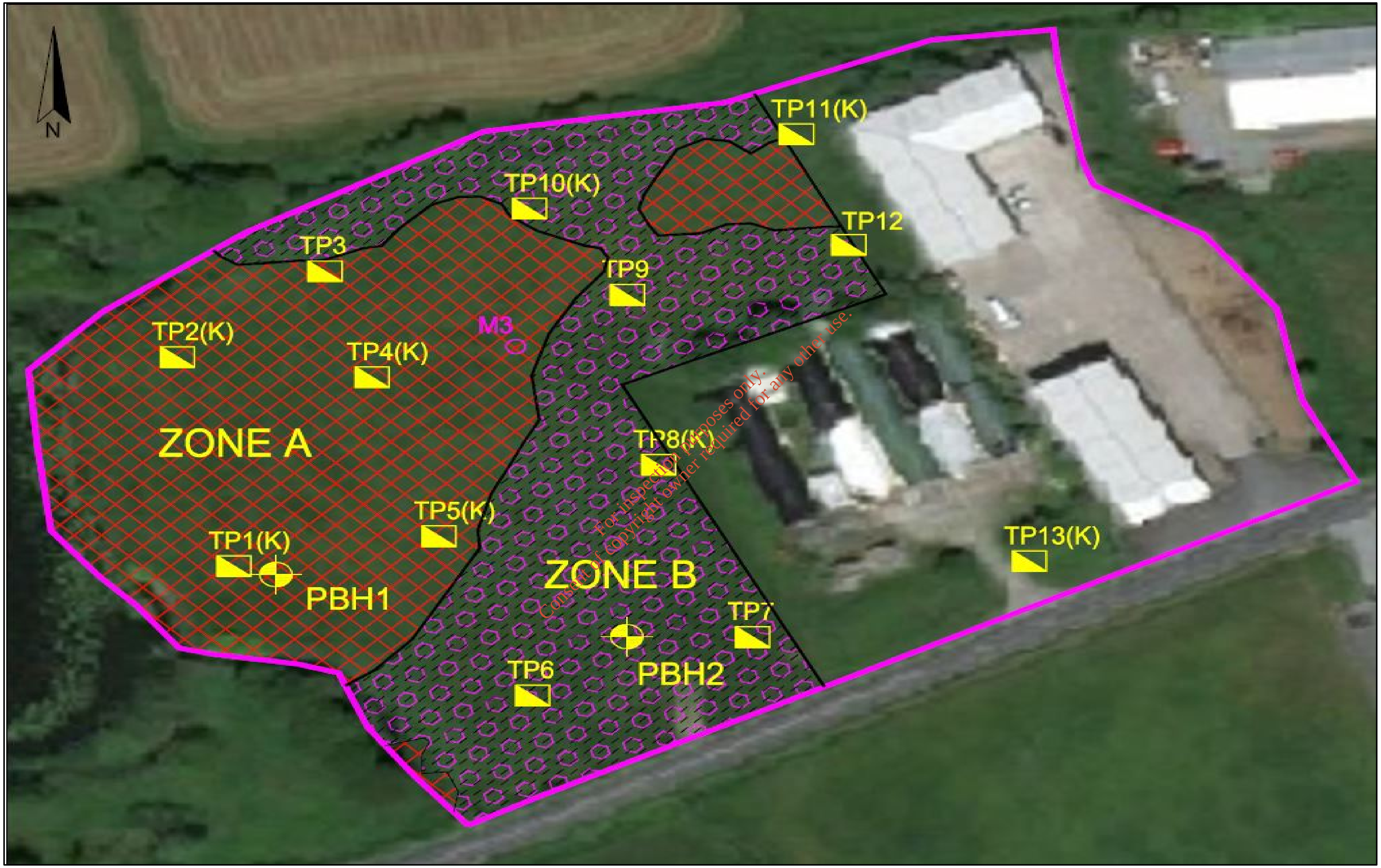


Figure 3-2: Maximum Waste Footprint

Results

The geophysical survey succeeded in validating the general location of the waste material. Both the elevated EM conductivity readings in combination with the trial pit logs show the waste to be present across the entire survey area.

The survey outlined an area of 0.67 ha which has been interpreted as TOPSOIL over MADE GROUND/WASTE (predominantly organic) over very soft PEAT/CLAY with LEACHATE (Zone A). This area corresponds well with the locations where trial pits encountered 'black bag type waste'.

The survey has interpreted an area of 0.65 ha as TOPSOIL over MADE GROUND/WASTE (mixed with CLAY/SILT) over very soft PEAT/CLAY (Zone B). This area corresponds with the locations where trial pits encountered brown or grey-black waste mixed with clay or silt.

The survey estimated the average thickness of the Zone A waste as 2.1m and the average thickness of the Zone B waste as 2.4m.

The geophysical results confirm the findings of the desk study and anecdotal information gathered, indicating that the site was backfilled with municipal solid waste directly atop the underlying Peat or Clay glacial till strata. The geophysical profiles indicate predominantly organic waste has been deposited in the western portion of the site towards Corrinshigo Lough and leachate is more prevalent in this area of the site.

The modelled profiles and geophysical interpretations are presented in Figure 3.2 to Figure 3.6.

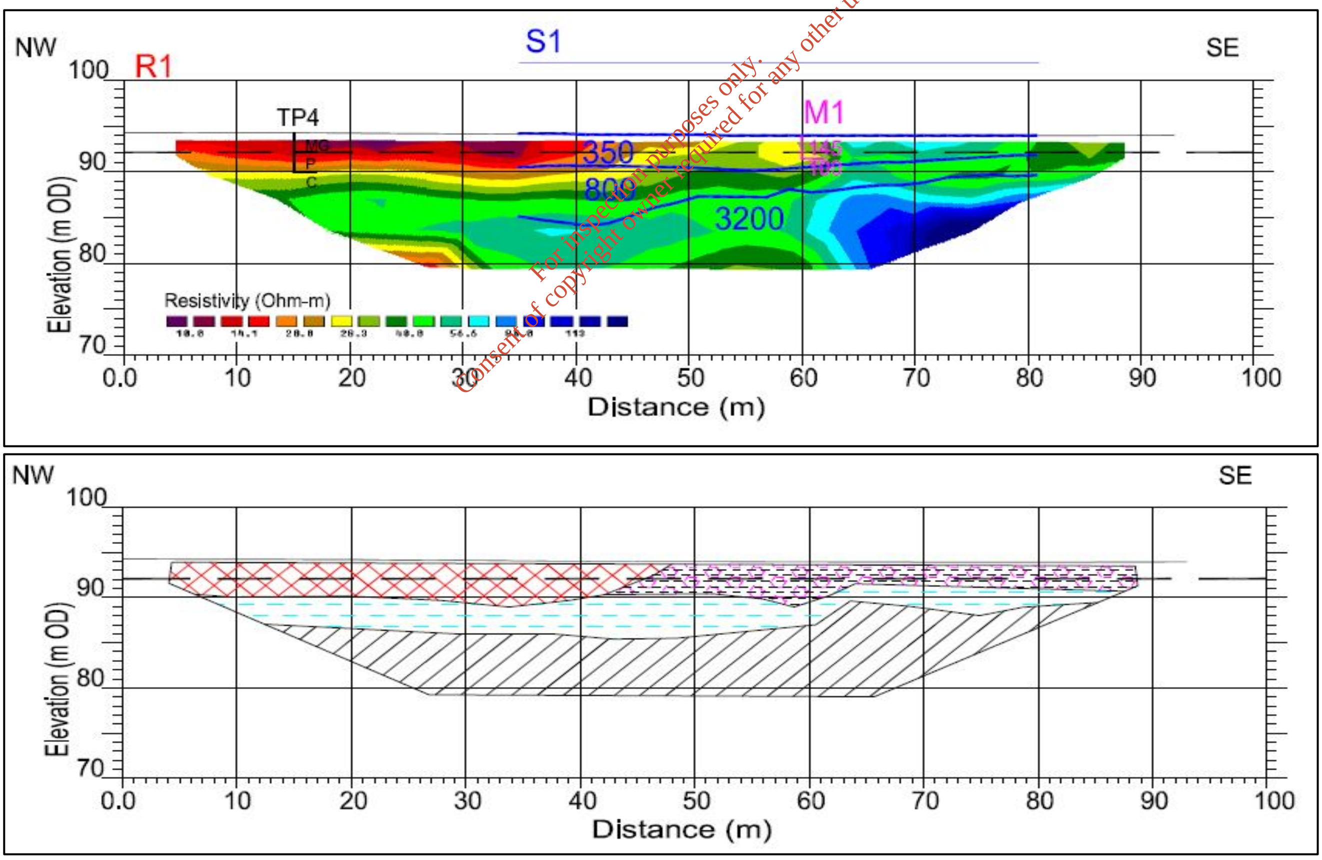


Figure 3-3: ERT Profile R1 Interpreted Cross Section

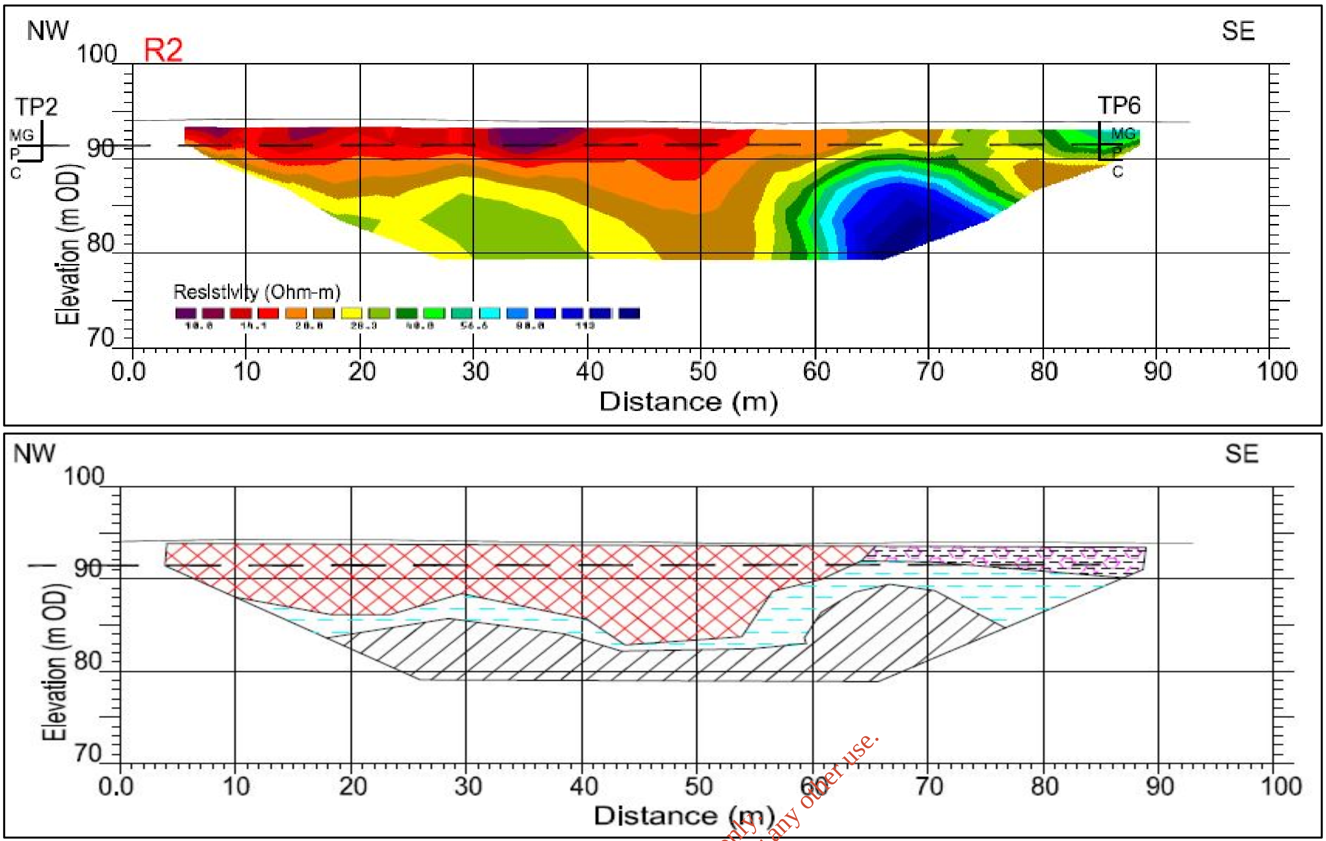


Figure 3-4: ERT Profile R2 Interpreted Cross Section

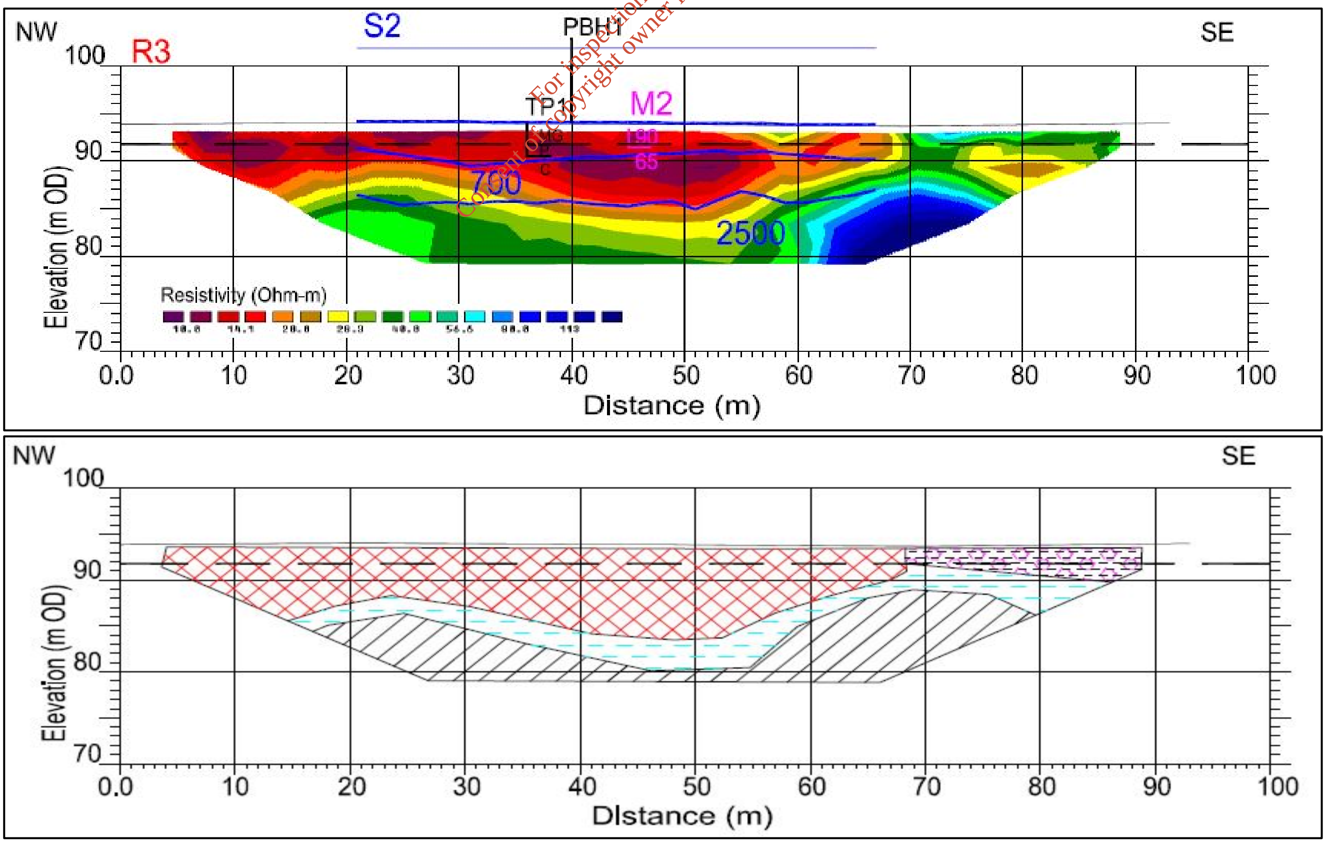


Figure 3-5: ERT Profile R3 Interpreted Cross Section

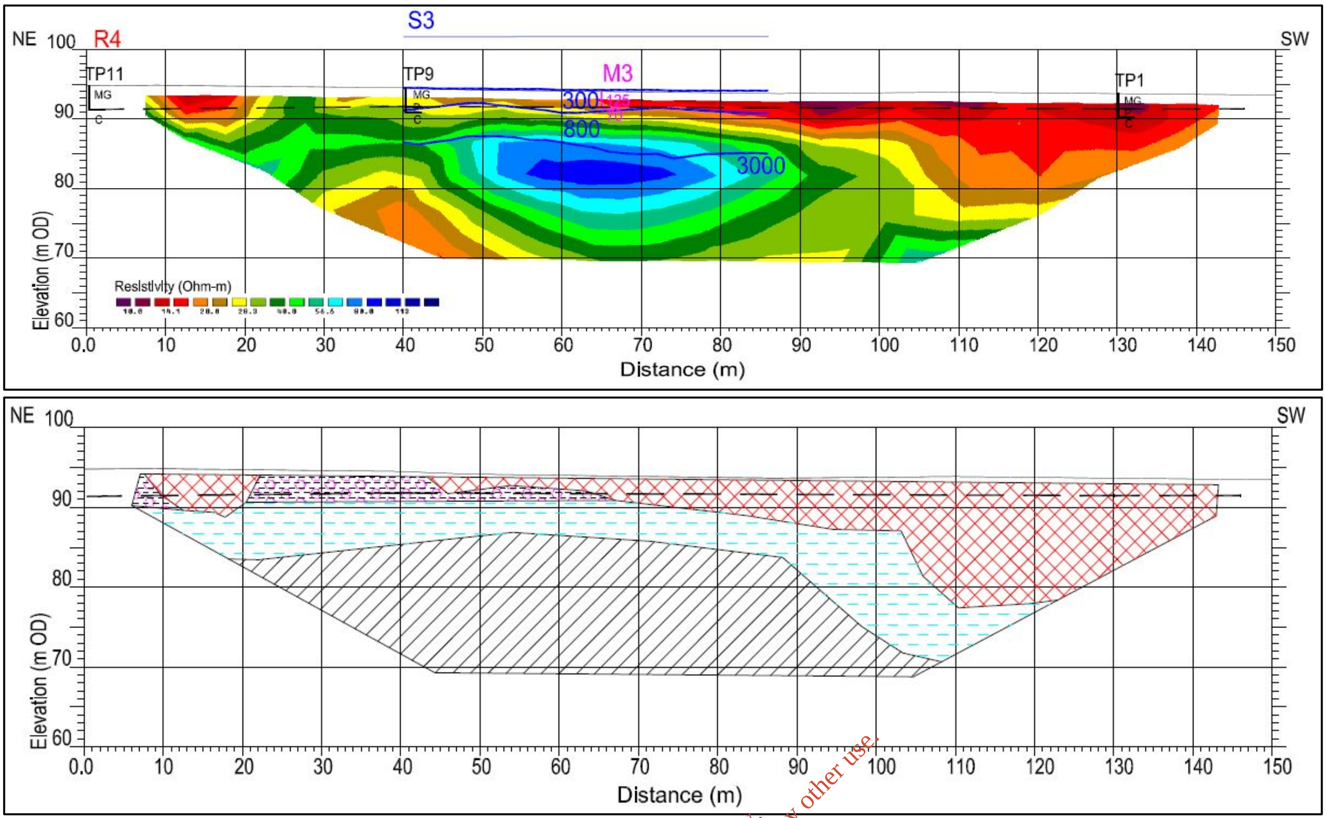


Figure 3-6: ERT Profile R4 Interpreted Cross Section

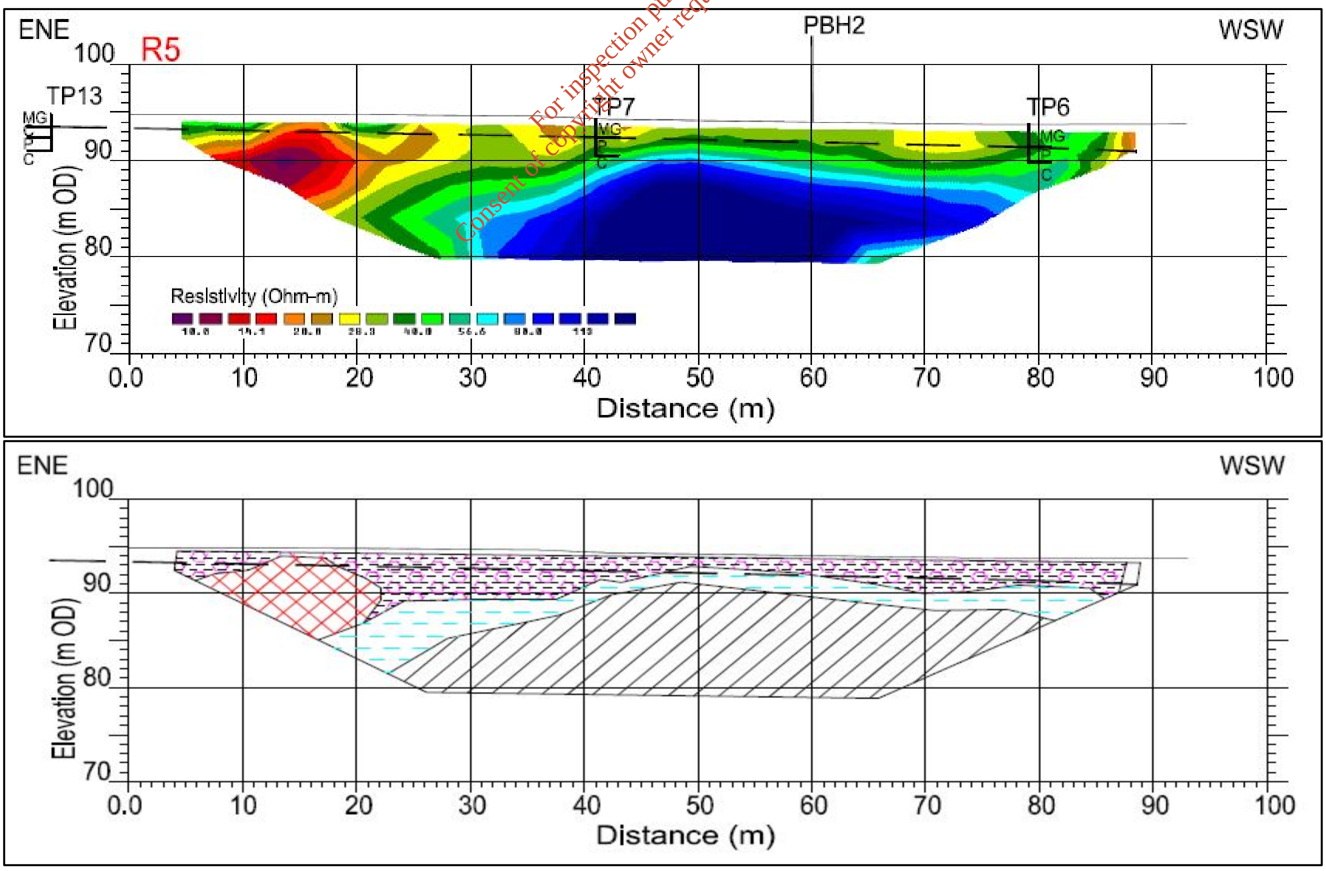


Figure 3-7: ERT Profile R5 Interpreted Cross Section

3.1.6 Waste Delineation

The combined findings of the geophysical survey and intrusive site investigation were used to interpret the aerial extent of the waste mass.

The findings of the site investigation work suggest the waste material is deposited in a single infill area tending west to east across the site and between approximately 140m in length and 120m in width.

Interpretation of the geophysical survey results indicate the presence of two waste composition types which have been designated as Zone A and Zone B. Zone A is characterised as predominantly organic waste deposited in the western portion of the site towards Corrinshigo Lough and a small pocket near the eastern site boundary. Zone B is dispersed over the remaining site footprint and is characterised as waste mixed with Clay/Silt glacial till.

The extent of the waste deposit has been interpreted by the presence of undisturbed ground encountered in 13 No. trial pits TP01 to TP13. Based on this interpretation, the maximum waste footprint is calculated to be approximately 1.15 hectares.

A volume calculation was conducted based on the surveyed surface profiles for the existing ground level and the base of waste as interpreted, estimates indicate an interred waste volume of approximately 29,700 m^3 at the site. This is in line with MCCs estimate which was in the region of 30,000 cubic meters.

The maximum anticipated waste footprint is presented in Figure 3-2. Eight trial pits record 'black bag type waste' on the logs have been designated with a 'K' after the trial pit number, also on Figure 3.2.

3.1.7 Borehole Installation and Groundwater Sampling

Three boreholes (GW01, GW02 and GW03) were drilled to a total depth of 10.0m bgl at the site. The boreholes were drilled for installing groundwater monitoring installations.

All exploratory holes were advanced near the boundary of the deposited waste as identified during the desk study and site walkover. Based on the findings of the geophysical survey and trial pitting, the boreholes are installed within the waste body and screened within the bedrock aquifer below the site. The purpose of the boreholes was to intercept and define the groundwater flow direction upstream and downstream of the identified waste body.

It is noted that the monitoring boreholes were installed within the waste body due to the restricted space available within the site.

Groundwater monitoring was undertaken in boreholes GW01 – GW03 on 2nd and 9th October 2018. Prior to sampling, the standpipe wells were purged and developed with Waterra groundwater sampling pipework/ foot valves and gas caps installed by CGL on the 1st October 2018 in preparation for groundwater monitoring to be undertaken by FT.

All samples were appropriately bottled (using prepared laboratory bottle ware) and packaged for submission to the laboratory. The samples were submitted for laboratory testing to ALS Environmental Ltd. The analysis results are contained in Appendix 3 and are further discussed in the proceeding sections.

3.2 Geotechnical Analysis

3.2.1 In-situ Capping Permeability Testing

Bulk disturbed soil samples from TP02, TP07 and TP13 were submitted for geotechnical analysis by Causeway Geotech Ltd for analysis of moisture content, Atterberg limits and particle size distribution (PSD). The results of the geotechnical analysis are included in the Intrusive Site Investigation Report prepared by Causeway Geotech in Appendix 2. This testing was undertaken to assess the suitability of the existing capping material at minimising rapid rainfall infiltration and preventing leachate generation within waste body.

The PSD analysis determined the soil samples comprised the following gravel, sand, silt and clay content, shown in Table 3.3.

Table 3-3: Soil Sample Classification

Sample Proportions	% Dry Mass		
	TP02	TP07	TP13
Cobbles	0	0	0
Gravel	42	38	34
Sand	30	42	35
Silt	25	17	26
Clay	3	4	5

Hazen's relationship[1] for sands in a loose condition was used to estimate the permeability of the soils sampled. Hazen's relationship is calculated as follows:

$$k = CD_{10}{}^{2}\ m/s$$

Where,

D_{10} is the effective size, mm

C is the coefficient 0.01 to 0.015.

The permeability of the three samples calculated using Hazen's relationship is shown in Table 3.4. The k value calculated for each of the samples classifies the existing capping material between a sandy gravelly SILT and a sandy gravelly silty CLAY.

Table 3-4: Permeability by Hazen's Relationship

Sample ID	C	D_{10} (mm)	K (m/s)
TP02	0.01	0.00461	2.13×10^{-7}
TP07	0.01	0.00692	4.78×10^{-7}
TP13	0.01	0.00369	1.36×10^{-7}

In accordance with the EPA Landfill Site Design Manual an engineered capping material -should have a permeability less than or equal to 1×10^{-9} m/s to minimise infiltration of rainwater into the waste body. The permeability estimated for the three samples analysed at the Killycard site are all greater than the EPA guidance and is not suitable as a low permeability capping material.

The shallow topsoil depth of 0.05 to 0.1m across the site and the high permeability values do not comply with the capping design specification set out in the Landfill Design Manual. The existing soil cover is not sufficient at preventing rainfall ingress which is contributing to leachate generation within the waste body or providing sufficient protection to site users from the interred waste.

[1] Graham Barnes 2010, Soil Mechanic Principles and Practice, 3rd Edition. Chapter 3: Permeability and Seepage.

3.2.2 Variable Head Permeability Testing

The permeability of the limestone bedrock aquifer was assessed by undertaking variable head permeability tests at three installed groundwater wells; GW01 to GW03. The permeability tests undertaken at the site were undertaken in accordance with B.S. 5930:1999.

The results of the permeability testing including the horizontal permeability factor at boreholes GW01 to GW03 are presented in Table 3.5. The test data and associated infiltration graphs are presented in the Causeway site investigation report, Appendix 2.

Table 3-5: In-Situ Permeability Test Results

Test No.	Test Depth (m BGL)	Total Head (m)	Test Time (min)	Permeability Factor (k)
GW01	0.74 – 1.48	1.82	60	3.36×10^{-7} m/s
GW02	0.90 – 2.17	2.38	90	2.54×10^{-7} m/s
GW03	0.35 – 0.96	1.21	90	5.11×10^{-8} m/s

The permeability recorded at GW01, GW02 and GW03 ranged from, 2.54×10^{-7} m/s to 5.11×10^{-8} m/s. According to the CGL borehole logs (Appendix 2), the permeability testing at each borehole GW01 to GW03 was carried out within the overburden which comprised of Made Ground / Waste material and Peat.

4 ENVIRONMENTAL ASSESSMENT

4.1 Chemical Assessment Criteria

- Council Decision 2003/33/EC – Waste Acceptance Criteria
- European Communities, Environmental Objectives (Groundwater)(Amendment) Regulations, 2016 (S.I. No. 366 of 2016)
- Interim Guideline Values (IGV) set out in the EPAs Groundwater *Towards Setting the Guideline Values for the Protection of Groundwater in Ireland*.
- European Communities Environmental Objectives (Surface Waters) (Amendment) Regulations, 2012 (S.I. No. 327 of 2012)
- European Communities Environmental Objectives (Surface Waters) Regulations, 2009 (S.I No. 272 of 2009)
- European Communities (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations, 1989 (S.I. No. 294/1989).

The results of the environmental assessment at the Killycard Historic Landfill site are presented in the following sections.

4.2 Waste/ Made Ground Assessment

The waste / made ground samples analysed during this assessment have been compared against Waste Acceptance Criteria (WAC) to determine the appropriate waste classification rating associated with the interred waste. WAC screening is chosen for this assessment to suitably categorise the interred waste as inert, non-hazardous or hazardous material.

4.2.1 Chemical Results for waste / made ground Samples

The waste/ made ground samples analysed from the site investigations were assessed against the Waste Classification Assessment Criteria. A summary of the results for Killycard Landfill is outlined in Table 4.1 below, while the laboratory reports are presented in Appendix 3.

Table 4-1: Waste Sampling Results – Solid Waste Analysis

Parameter	Units	Inert Waste Acceptance Criteria	Non-Hazardous Waste Acceptance Criteria	Hazardous Waste Acceptance Criteria	Sampling Results - Sample ID	
					TP04 (0.5m)	TP08 (0.5m)
Asbestos in soil	--	**Detected**	**Detected**	**Detected**	ND	ND
Arsenic	$mg.kg^{-1}$	**0.5**	**2**	**25**	0.054	<0.050
Barium	$mg.kg^{-1}$	**20**	**100**	**300**	<0.50	<0.50
Cadmium	$mg.kg^{-1}$	**0.04**	**1**	**5**	<0.010	<0.010
Chromium	$mg.kg^{-1}$	**0.5**	**10**	**70**	<0.050	<0.050
Copper	$mg.kg^{-1}$	**2**	**50**	**100**	<0.050	<0.050
Mercury Dissolved	$mg.kg^{-1}$	**0.01**	**0.2**	**2**	<0.0050	<0.0050
Molybdenum	$mg.kg^{-1}$	**0.5**	**10**	**30**	<0.050	<0.050
Nickel	$mg.kg^{-1}$	**0.4**	**10**	**40**	0.051	<0.050
Lead	$mg.kg^{-1}$	**0.5**	**10**	**50**	0.14	<0.010
Antimony	$mg.kg^{-1}$	**0.06**	**0.7**	**5**	<0.010	<0.010
Selenium	$mg.kg^{-1}$	**0.1**	**0.5**	**7**	<0.010	<0.010
Zinc	$mg.kg^{-1}$	**4**	**50**	**200**	<0.50	<0.50
Chloride	$mg.kg^{-1}$	**800**	**15000**	**25000**	<10	<10
Fluoride	$mg.kg^{-1}$	**10**	**150**	**500**	1.3	1.3
Sulphate	$mg.kg^{-1}$	**1000**	**20000**	**50000**	49	65
Total Dissolved Solids	$mg.kg^{-1}$	**4000**	**60000**	**100000**	300	290
Total Monohydric Phenols	$mg.kg^{-1}$	**1**	**--**	**--**	<0.50	<0.50
Dissolved Organic Carbon	$mg.kg^{-1}$	**500**	**800**	**1000**	130	68
Sum of BTEX	$mg.kg^{-1}$	**6**	**--**	**--**	<0.010	<0.010
Total Organic Carbon *	%	**3**	**5**	**6**	3.0	0.92
Moisture Content ratio	%	**--**	**--**	**--**	16	14
Mineral Oil	$mg.kg^{-1}$	**500**	**--**	**--**	<10	<10

Parameter	Units	Inert Waste Acceptance Criteria	Non-Hazardous Waste Acceptance Criteria	Hazardous Waste Acceptance Criteria	Sampling Results - Sample ID	
					TP04 (0.5m)	TP08 (0.5m)
PCBs (Sum of 7)	$mg.kg^{-1}$	**1**	**--**	**--**	<0.10	<0.10
PAH (Sum of 17)	$mg.kg^{-1}$	**100**	**--**	**--**	<2.0	<2.0
pH	pH units	**>6 or <9**	**>6**	**--**	7.6	7.8
Loss on ignition	%	**--**	**--**	**10**	7.4	3.0

* Hazardous Waste Landfill Criteria: >6% TOC

4.2.2 Waste Laboratory Analysis Discussion

As can be seen in Table 4.1, based on the 2 No. samples submitted for laboratory analysis, waste material encountered within the site are typically inert in terms of their leachate production indicating a high level of degradation over time since landfilling activities ceased at the site.

4.3 Groundwater Analysis

Two rounds of groundwater quality monitoring were undertaken at the site on the 2nd October and 9th October 2018. The findings from the monitoring and an interpretation of the results are presented in the following sections.

4.3.1 Groundwater Depth Analysis

Groundwater depth analysis was undertaken on one occasion following the installation of the rotary core standpipes. Static groundwater levels from the 2nd October 2018 are calculated below.

Table 4-2: Groundwater Depth Analysis

Borehole ID	Location Gradient	Top of Casing (mAOD)	Dip (m) 2/10/18	Groundwater Level (mAOD)
GW01	Upgradient	95.39	1.77	93.61
GW02	Cross-gradient	95.84	2.42	93.43
GW03	Down gradient	94.22	1.11	93.03

*Note: Location gradient is in reference to the identified waste deposition area

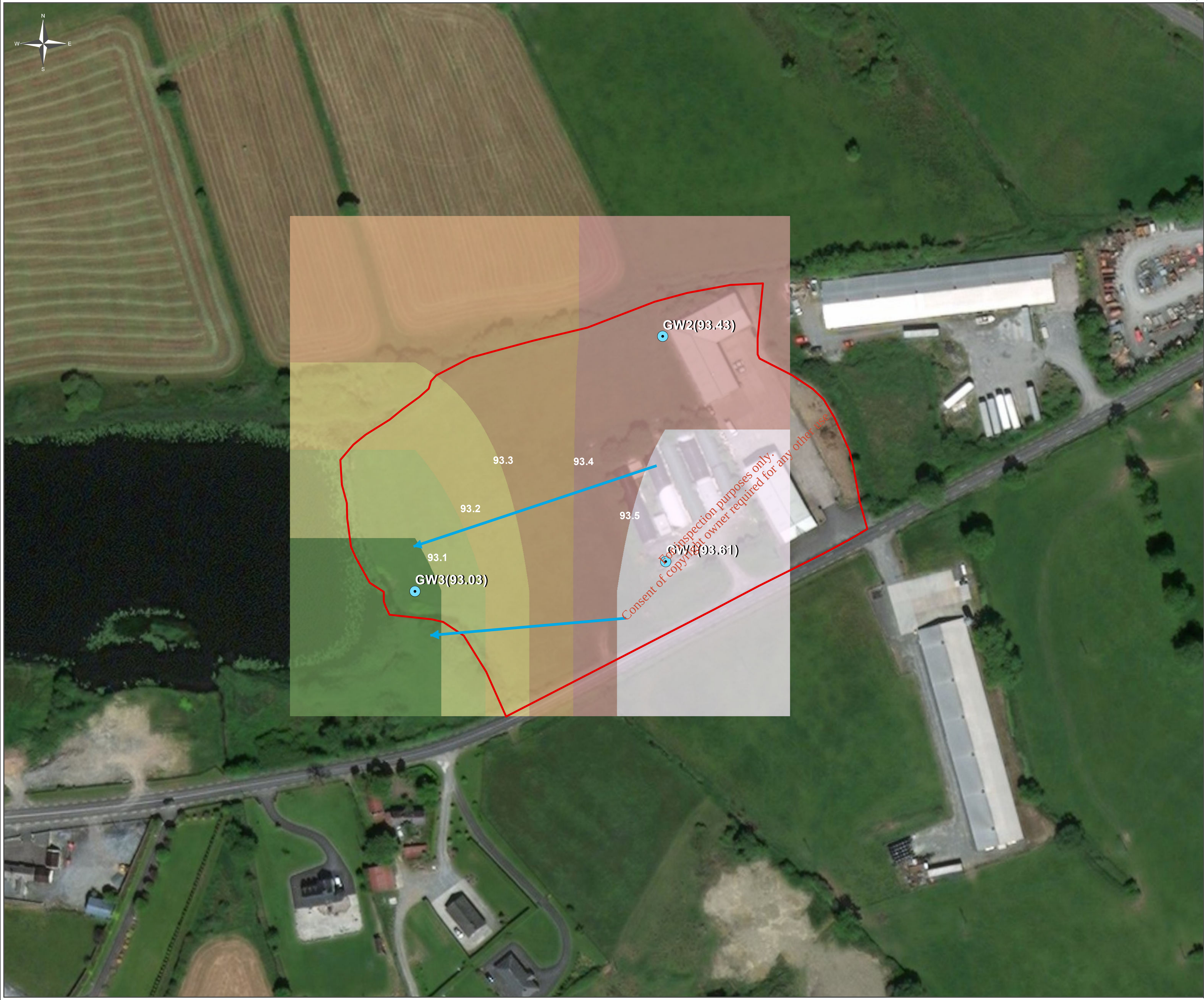
Based on the above field survey measurements, the groundwater flow direction is assumed to be west-south-west. A potentiometric map illustrating the hydraulic gradient and the direction of groundwater flow is presented in Figure 4.1.

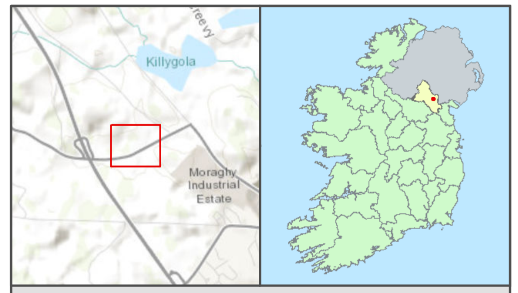
4.3.2 Groundwater Borehole Position

The location of the groundwater boreholes installed at the site where based on the anticipated groundwater flow direction. The potentiometric mapping indicates the likely groundwater flow direction is west to south-west.

GW03 is located to the west of the waste mass i.e. downgradient.

Map Path: R:\Map Production\2018\P1724\Workspace\Killycard Landfill\P1724_Fig4-1_GroundwaterFlowDirection_A3.mxd





Co. Monaghan

Legend

- Dipped Water Level (mAOD)
- Groundwater Flow Direction
- Site Boundary

Interpolated Dipped Water Level (mAOD)

- 93.03 - 93.09
- 93.1 - 93.19
- 93.2 - 93.29
- 93.3 - 93.39
- 93.4 - 93.49
- 93.5 - 93.6

Figure Title	Groundwater Flow Direction
Figure No.	4.1
Project	ERA of Historic Landfill at Killycard, Co. Monaghan
Client	Monaghan County Council
Scale 1:1,500	**Page Size** A3
Revision A	**Date** 09/11/2018

Consultants in Engineering and Environmental Sciences

www.fehilytimoney.ie

FEHILY TIMONEY & COMPANY

0 25 50 100 Meters

4.3.3 Groundwater Quality Monitoring

The results of groundwater samples analysed from the 3 No. boreholes (GW01 – GW03) at the site have been assessed against the EPAs Interim Guideline Values (IGVs) and the European Groundwater Regulations (2010) assessment criteria. A summary of the maximum results reported for each parameter over two monitoring rounds undertaken on the 2nd and 9th October is outlined in Table 4.3, while the laboratory reports are presented in Appendix 3.

Table 4-3: Groundwater Sampling Results

Parameter	Units	EPA IGV Standards [1]	S.I. No. 9 of 2016 Standards [2]	GW01	GW02	GW03
				US	CG	DS
pH	pH units	**6.5 - 9.5**	**--**	7.66	7.68	7.59
Conductivity	mS/cm	**1**	**1.875**	0.736	0.473	0.708
Dissolved Oxygen	mg/l	**no abnormal change**	**--**	7.76	6.01	8.34
Alkalinity as CaCO3	mg/l	**200**	**--**	**377**	**305**	**405**
Ammoniacal Nitrogen as N	mg/l	**0.15**	**0.175**	**19.2**	**1.13**	**4.1**
Total Coliforms	cfu/100ml	**0**	**--**	**1990**	**549**	**2420**
Nitrite as N	mg/l	**--**	**0.375**	<0.0152	<0.0152	<0.0152
BOD	mg/l	**--**	**--**	2.7	2.04	<1
COD	mg/l	**--**	**--**	48.7	115	9.93
Sodium	mg/l	**150**	**150**	59.4	17.1	64.8
Sulphate as SO4	mg/l	**200**	**250**	49.7	4.4	15.3
Total Oxidised Nitrogen	mg/l	**--**	**--**	0.119	0.203	0.111
Total Organic Carbon	mg/l	**--**	**--**	12.3	4.66	3.15
Arsenic	mg/l	**0.01**	**0.0075**	**0.0147**	0.00367	0.00215
Barium	mg/l	**0.1**	**--**	**0.294**	0.0761	**0.119**
Boron	mg/l	**1.0**	**0.75**	0.106	0.0283	0.0161
Cadmium	mg/l	**0.005**	**0.005**	<0.0008	<0.0008	<0.0008
Calcium	mg/l	**200**	**--**	115	71.2	105
Chloride	mg/l	**30**	**187.5**	42.3	15.2	15.5
Chromium	mg/l	**0.03**	**0.05**	<0.001	<0.001	<0.001
Copper	mg/l	**0.2**	**2**	0.00077	0.00148	0.00236
Cyanide	mg/l	**0.01**	**0.0375**	<0.01	<0.01	<0.01
Fluoride	mg/l	**1.0**	**0.8**	<0.5	1.04	<0.5
Iron	mg/l	**0.2**	**--**	**6.22**	0.0546	0.0936
Lead	mg/l	**0.01**	**0.025**	0.00052	**0.168**	**0.0743**
Magnesium	mg/l	**50**	**--**	20.2	21.5	21
Manganese	mg/l	**0.05**	**--**	**1.92**	**0.172**	**0.36**
Mercury	mg/l	**0.001**	**0.001**	<0.00001	<0.00001	<0.00001
Nickel	mg/l	**0.02**	**0.02**	**0.0228**	0.00452	0.00579
Phosphorus (ortho as PO4)	mg/l	**0.03**	**0.035**	<0.05	<0.05	<0.05

Parameter	Units	EPA IGV Standards [1]	S.I. No. 9 of 2016 Standards [2]	GW01	GW02	GW03
				US	CG	DS
Potassium	mg/l	5	--	**15.6**	3.49	3.59
Uranium	mg/l	0.009	--	0.0017	<0.001	0.0053
Zinc	mg/l	0.1	--	0.0387	0.0683	0.025
Mineral Oil	mg/l	--	0.01	<0.1	**0.181**	<0.1
MTBE	mg/l	--	--	<0.001	<0.001	<0.001
Semi-Volatile Organic Compounds (SVOCs)						
1,2,4-Trichlorobenzene	µg/l	0.40	--	<0.01	<0.01	<0.01
2,4,6-Trichlorophenol	µg/l	200	--	<10	<10	<10
2-Chlorophenol	µg/l	200	--	<10	<10	<10
Benzo(k)fluoranthene	µg/l	0.05	--	<0.01	<0.01	<0.01
Hexachlorobenzene	µg/l	0.03	--	<0.01	<0.01	<0.01
Hexachlorobutadiene	µg/l	0.1	--	<0.01	<0.01	<0.01
Nitrobenzene	µg/l	10	--	<1	<1	<1
n-Nitroso-n-dipropylamine	µg/l	--	--	<1	<1	<1
Pentachlorophenol	µg/l	2	--	<0.01	<0.01	<0.01
Phenol	µg/l	0.5	--	<0.01	<0.01	<0.01
Combined Pesticides / Herbicides						
Aldrin	µg/l	0.01	--	<0.01	<0.01	<0.01
Atrazine	µg/l	--	0.075	<0.01	<0.01	<0.01
Chlorfenvinphos	µg/l	5	--	<1	<1	<1
Dichlorvos	µg/l	0.001	--	<0.01	<0.01	<0.01
Dieldrin	µg/l	--	0.075	<0.01	<0.01	<0.01
Permethrin I	µg/l	20	--	<1	<1	<1
Permethrin II	µg/l	20	--	<1	<1	<1
Simazine	µg/l	--	0.075	<0.01	<0.01	<0.01
4,4 – DDT	µg/l	--	0.075	<0.01	<0.01	<0.01
Organics						
Benzo(alpha)pyrene	µg/l	--	7.5	<1	<1	<1
Vinyl Chloride	µg/l	--	0.375	<0.01	<0.01	<0.01
Benzene	µg/l	--	0.75	<0.01	<0.01	<0.01
Total Trichloroethane	µg/l	--	7.5	<1	<1	<1
Total Tetrachloroethene	µg/l	--	7.5	<1	<1	<1
1,2-Dichloroethane	µg/l	--	2.25	<1	<1	<1

[1] EPA - Towards Setting Guideline Values for the Protection of Groundwater in Ireland (2003) – Interim Guideline Values

[2] European Communities Environmental Objectives (Groundwater) Regulations (2016) – SI No. 366 of 2016

* Items shaded in **bold** are in exceedance of both EPA IGV Standards

* Items shaded in **orange** are in exceedance of the Drinking Water Regulations

4.3.4 Groundwater Analysis Discussion

The results of the groundwater monitoring from GW01 – GW03 have reported several exceedances of the IGVs and European Groundwater limit values.

Samples recovered monitoring wells GW01, GW02 and GW03 reported elevated ammonia concentrations of 19.2 mg/l, 1.13 mg/l and 4.1 mg/l respectively, which exceed guideline threshold values. Given that all monitoring wells were installed within the waste body and screened in bedrock, it is considered that the landfill is contributing to a deterioration in groundwater quality locally.

The presence of peat underlying the waste body across the site may also be contributing to the elevated ammonia concentrations detected in the groundwater locally. The combined presence of elevated ammonia and coliform concentrations in all monitoring wells GW01 to GW03 may also be evidence of localised contamination due to agricultural land spreading or poorly functioning septic tanks in the area.

Based on the presence of elevated ammonia concentrations typical of landfill leachate, the shallow soil cap is not considered suitable at preventing rainfall infiltration into the waste body. The groundwater table also appears to be intersecting the waste body and contributing to leachate migration from the landfill.

The detection of elevated lead concentrations of 0.168 mg/l and 0.0743 mg/l at monitoring locations GW02 and GW03 and slightly elevated nickel concentration at GW01 are considered to be evidence of the localised groundwater hydrochemistry based on the presence of historical lead mining north of Castleblayney. Reference is made to several small metallic mineral deposits, most notably lead and zinc, located near Castleblayney as detailed in the EPA's Historic Mine Sites - Inventory and Risk Classification (2009). Despite the detection of lead in the localised groundwater, the elevated lead concentrations at GW02 and GW03 may also be attributable to the landfill.

According to the EPA publication *'Assessing and Developing Natural Background Levels for Chemical Parameters in Irish Groundwater'*, barium concentrations have been recorded throughout Ireland over four orders of magnitude and appears to be controlled by both lithology and location. The study shows that high concentrations tend to be associated with the Dinantian Sandstones and shales derived from those parent materials, which the Killycard site is founded on. Similar to the naturally occurring lead levels in groundwater, the barium concentration detected at monitoring locations GW01 and GW03 are considered to be evidence of the localised groundwater hydrochemistry.

The slightly elevated manganese concentrations ranging from 0.172 mg/l to 1.92 mg/l across all monitoring wells are considered to be typical of the local bedrock hydrochemistry.

The iron concentration of 6.22 mg/l detected in upgradient borehole GW01 is 30-times the groundwater threshold value and is likely a result of leachate from the waste body. The elevated arsenic concentration of 0.0147 mg/l at GW01 is twice the GTV and may also be an indication of leachate migration from the waste body to this location.

The elevated potassium concentrations of 15.6 mg/l detected in upgradient borehole GW01 exceeds the guideline threshold value. The significant concentration difference between the upgradient and downgradient monitoring locations suggests that the waste body is contributing to the increased potassium concentrations in groundwater quality at this location.

The results of groundwater monitoring have returned one slight exceedance of the groundwater threshold value for mineral oil at monitoring location GW02. Mineral oil was detected at a concentration of 0.181 mg/l which exceeds the guideline threshold value of 0.01 mg/l.

Elevated alkalinity ($CaCO_3$) is consistent across all three sampling locations. The alkaline groundwater quality within the range 305 mg/l to 405 mg/l is considered to be a factor of local bedrock hydrochemistry.

The results of groundwater monitoring when assessed against typical leachate constituents (List 1 and List 2 substances – SVOCs, pesticides, herbicides, organics) shows all results are below the laboratory limit of detection in all assessments across all three sampling locations.

4.4 Landfill Gas Monitoring

FT carried out monitoring of landfill gas (LFG) parameters at each monitoring borehole location (GW01 – GW03) as indicated on Figure 4.1. In accordance with the EPA CoP, methane, carbon dioxide, oxygen and atmospheric pressure were analysed at the 3 No. groundwater monitoring wells located within the waste body using a geotechnical instrument GEM5000 Landfill Gas analyser.

4.4.1 Monitoring Results

In accordance with the CoP, the trigger level for methane outside the waste body is 1% v/v and for carbon dioxide is 1.5% v/v. The monitoring results for methane, carbon dioxide and oxygen levels for the monitoring boreholes are summarised in Table 4.4.

Table 4-4: Perimeter Well Monitoring Results September & October 2018

Date: 2-10-2018						
Sample Station	CH_4	CO_2	O_2	Atmospheric Pressure	Staff Member	Weather
	(% v/v)	(% v/v)	(% v/v)	(mbar)		
GW01	0.8	1.2	21.8	1028	Daniel Hayden	Cloudy with light wind N-NE, 12°C - 14°C
GW02	0.2	0.1	22.3	1028		
GW03	0.4	0.6	22.0	1028		

Date: 9-10-2018						
Sample Station	CH_4	CO_2	O_2	Atmospheric Pressure	Staff Member	Weather
	(% v/v)	(% v/v)	(% v/v)	(mbar)		
GW01	**1.5**	1.3	20.1	1005	Daniel Hayden	Cloudy with light wind N - NE, 14°C - 16°C
GW02	0.2	0.5	21.3	1005		
GW03	0.8	0.9	21.3	1005		

As can be seen in Table 4.5, concentrations of both CO_2 and CH_4 at all monitoring boreholes GW01 to GW03 were generally recorded below the threshold values set by the CoP during both monitoring rounds. However, one exception is the detection of a slightly elevated methane concentration of 1.5% v/v at upgradient sampling location GW01. Gas concentrations at these levels are an indication of the stabilised nature of the interred MSW at the site.

It is noted that the monitoring boreholes have been installed within the identified waste body due to the restricted space available within the site.

4.5 Surface Water Monitoring

4.5.1 Monitoring Locations

The surface water monitoring locations were selected upstream and downstream of the landfill footprint, as shown on Figure 4-2. Monitoring location SW1 was selected as the sampling location upstream of the waste body and samples the Corrinshigo Lough to the west of the landfill. Monitoring location SW2 is located along the northern boundary of the landfill and samples from a drainage channel downstream of the landfill.

Two surface water monitoring rounds were carried out on the 2nd October and 9th October 2018.

4.5.2 Monitoring Parameters

The results of surface water sampling analysed from the 2 No. sampling locations (SW1 and SW2) at the site have been assessed against the Maximum Admissible Concentration (MAC) Regulations (1989) and the Environmental Quality Standard (EQS) for Surface Waters Regulations (2009) assessment criteria.

A summary of the maximum values reported for each parameter from the two monitoring rounds is outlined in Table 4.5, while the laboratory reports are presented in Appendix 3.

Table 4-5: Surface Water Sampling Results

Parameter	Units	MAC [1]/EQS [2]	2nd – 9th October 2018	
			SW1 Upstream	SW2 Downstream
pH (Laboratory)	pH Units	6.0<pH<9.0[2]	7.84	7.43
Dissolved Oxygen	mg/l	<9 – 6 [1]	9.9	9.04
Conductivity	µS/cm	1 [1]	0.421	0.434
BOD, unfiltered	mg/l	≤2.6 (95%ile)[2]	**3.73**	<1
COD, unfiltered	mg/l	40 [1]	35.5	20.8
Sulphate	mg/l	200 [1]	7.63	7.40
Chloride	mg/l	250 [1]	46.9	46.6
Ammoniacal Nitrogen as N	mg/l	≤0.140(95%ile) [2]	**0.318**	<0.140
Potassium	mg/l	--	5.02	5.07
Sodium	mg/l	200 [1]	33.4	30.4

Notes:

1 Maximum Admissible Concentration (MAC), as classified by European Communities (Quality of Surface Water intended for abstraction of drinking water) Regulations 1989 (S.I No. 294 of 1989)

2 Environmental Quality Standard (EQS), European Communities Environmental Objectives (Surface Waters) Regulations 2009 (S.I No. 272 of 2009)

* Items shaded in **orange** are in exceedance of the 2009 EQS Regulations

4.5.3 Surface Water Analysis Discussion

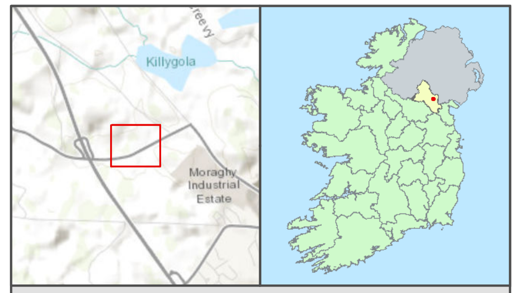
The results of the surface water monitoring from SW1 and SW2 show 2 No. exceedances of the EQS (2009) guideline limit values for ammonia and BOD. Results from sampling location SW1 detected an ammonia and BOD concentrations of 0.318 mg/l and 3.73 mg/l respectively. Given that the determined groundwater flow direction is west-south-west from the waste body, the detected ammonia and BOD at these levels may be evidence of impact from the landfill.

The presence of ammonia and BOD at these levels may also be an indication of slurry spreading runoff from the surrounding agricultural fields in the area, rather than direct impact from the landfill. Surface water runoff from the steep agricultural fields north of the landfill feed into Corrinshigo Lough and may be deteriorating water quality in the lake.

The remaining results of the surface water laboratory analysis as presented in Table 4.5, when assessed against the MAC (1989) and EQS (2009) quality standards were found to be below the guideline values in all assessments.

Map Path: R:\Map Production\2018\P1724\Workspace\Killycard Landfill\P1724_Fig4-2_SurfaceWaterSampling_A3.mxd

Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, © OpenStreetMap contributors, and the GIS User Community
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Mapping Reproduced Under Licence from the Ordnance Survey Ireland Licence No. EN 0001218 © Government of Ireland



Co. Monaghan

Legend

- Surface Water Sampling Locations
- Site Boundary

Figure Title	Surface Water Sampling
Figure No.	4.2
Project	ERA of Historic Landfill at Killycard, Co. Monaghan
Client	Monaghan County Council
Scale 1:1,500	**Page Size** A3
Revision A	**Date** 09/11/2018

Consultants in Engineering and Environmental Sciences

www.fehilytimoney.ie

FEHILY TIMONEY & COMPANY

0 25 50 100 Meters

5 RISK ASSESSMENT

5.1 Introduction

Risk assessment considers the likelihood of occurrence and the consequence of occurrence of an event (Royal Society, 1992[2]). ERA (Environmental Risk Assessment) is based on the development of a Conceptual Site Model (CSM) which is used to determine the potential exposure of a vulnerable receptor to a contaminant. The CSM is used as the basis for the risk assessment. It is used to identify all possible sources (S), pathways (P) and receptors (R) as well as the processes that are likely to occur along each of the source-pathway-receptor (S-P-R) linkages and uncertainties.

Based on the desktop investigation and completed site investigation, this CSM assumes the source to be the made ground containing waste deposit, the pathway to involve the migration of landfill gas, surface water and groundwater and the ultimate receptors to be the surface water features, groundwater, groundwater abstraction well and all human presence near the waste material.

5.2 Potential Pathways and Receptors

A pathway is a mechanism or route by which a contaminant encounters, or otherwise affects, a receptor. Contaminants associated with deposited waste may include leachate generated from groundwater/rainwater infiltration into the waste material and/or the generation of landfill gas from the degradation of the biodegradable fraction of deposited waste.

The potential pathways associated with the Killycard site are:

- Groundwater migration; and
- Surface water infiltration;

5.2.1 Groundwater/Leachate Migration

According to the EPA CoP, there are three main pathways for leachate migration. These are:

- Vertically to the water table or top of an aquifer, where groundwater is the receptor
- Vertically to an aquifer and then horizontally in the aquifer to a receptor such as a well, spring, stream or in this case, the adjacent coastline
- Horizontally at the ground surface or at shallow depth to a surface receptor

The migration and attenuation of leachate from the site depends on the permeability and thickness of subsoil and on both the bedrock permeability value and type. These elements are encompassed in groundwater vulnerability, groundwater flow regime and surface water drainage. The main receptors to leachate migration from this site are:

- Aquifer;
- Surface water features; and
- Human presence nearby the site

5.2.2 Landfill Gas Migration

According to the EPA CoP, there are two main pathways for landfill gas migration. These are:

- Lateral migration via subsoil
- Vertical migration via subsoil

[2] Royal Society 1992, Risk: Analysis, Perception and Management. The Royal Society, London (ISBN 0-85403-467-6).

The migration of landfill gas from the site depends on the nature of the material deposited and the nature, permeability and thickness of the surrounding subsoil or bedrock.

The main receptors to potential landfill gas migration from this site are:

- Human Presence/Buildings nearby the waste body

5.3 Conceptual Site Model

Based on the review of the Tier 1 assessment and site investigation works undertaken for Killycard Historic Landfill, an assessment of the risk is made to confirm the source – pathway – receptor (S-P-R) linkages identified in the preliminary investigation. The results and analysis of the investigation has enabled a revised conceptual model to be produced for the site, which is presented in Figure 5.1, overleaf.