Map Path: R:\Map Production\2018\P1655\Workspace\Killycard Landfill\P1655_Fig2-6_WellsAndSprings_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
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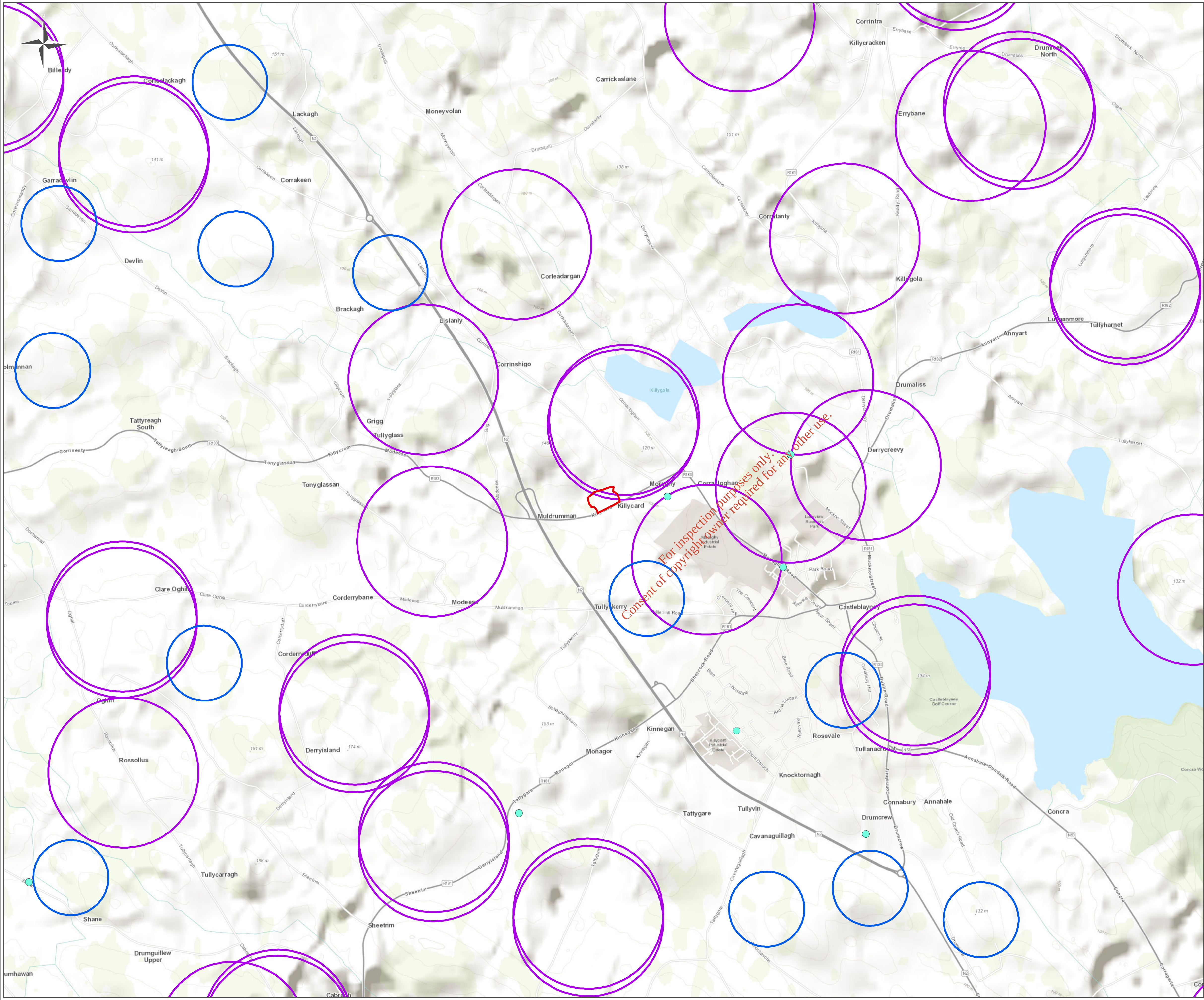

Kilometers
0 0.5 1 2

Co. Monaghan

Legend

- Site Boundary
- Groundwater Well (10-50m Accuracy)
- Groundwater Well (200-500m Accuracy)
- Groundwater Well (500m-1km Accuracy)

Figure Title	Wells And Springs Killycard
Figure No.	2.6
Project	Tier 1 Assessment of Historical Landfills in Monaghan
Client	Monaghan County Council
Scale	1:25,000
Page Size	A3
Revision	A
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2.3. Site Investigation

The site investigation comprised of a detailed site walkover by an FT Project Scientist. The site walkover was conducted on the 12th June 2018. The completed site walkover checklist, in accordance with the EPA CoP, is included in Appendix II.

2.3.1. Site Walkover

The FT Project Engineer noted that the site is currently used for pasture and that the ground level is undulating. The walkover paid considerable attention to the surface water drainage network surrounding the site along the perimeter and the leachate collection system in place.

The site walkover noted evidence of recent erosion along large sections of the western landfill boundary with Corrinshigo lake. Waste material was found to be depositing directly into lake along the western edge of the site and also to the surface water ditch on the northern edge of the site. Waste material was found to be protruding from the soil surface along the site perimeter and throughout the site area, as shown in photos 10-14 of Appendix III.

The following infrastructural services are also present at the site:

- A concrete drainage culvert which runs underneath local road R184 to the boundary fence with the licenced facility.
- Two old wells present in grassed area of industrial unit carpark. Monaghan County Council believe these to be old methane wells.
- Overhead electricity lines along the northern boundary adjacent to local road R184.

The photos presented in Appendix III show the site itself and the type of materials encountered during the site walkover.

2.3.2. Previous Site Investigations

It is understood that no previous site investigation has been undertaken at the site of the historic landfill.

Legend

Site Boundary

Meters
0 50 100 200

Figure Title
Existing Site Layout
Killycard

Figure No. 2.7

Project
Tier 1 Assessment of Historical Landfills in Monaghan

Client
Monaghan County Council

Scale	1:2,500	**Page Size**	A3
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3. RISK ASSESSMENT

3.1. Introduction

Risk assessment considers the likelihood of occurrence and the consequence of occurrence of an event (Royal Society, 1992[1]). ERA 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 site walkover undertaken, this CSM takes the source of the contamination to be the interred waste material deposited in the historic landfill, the pathway to involve Corrinshigo Lough, surface water drainage and groundwater and the ultimate receptors to be the groundwater and surface water bodies Corrinshigo Lough to the west of site, Drumillard Lough and River Fane to the northeast of the site and all human presence nearby the former landfill.

3.2. Potential Pathways and Receptors

A pathway is a mechanism or route by which a contaminant comes into contact with, 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 unlined waste body at the historic landfill was designed as 'dilute and disperse' and lies directly on saturated bedrock. Leachate from the waste represents a direct discharge to groundwater. Therefore, the potential pathways associated with the site are:

- direct seepage into the underlying bedrock aquifer;
- contaminant migration through the bedrock aquifer to the adjacent stream to the west and north;
- waste material falling directly into Corrinshigo Lough and surface water ditch on the northern edge of the site.

3.2.1. Groundwater/Leachate Migration

The three main pathways for leachate migration 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; and,
- Surface water bodies

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

3.2.2. Landfill Gas Migration

The two main pathways for landfill gas migration are

- Lateral migration via subsoil
- Vertical migration via subsoil

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

Landfill gas has the potential to collect in confined spaces such as ducts, chambers, and manholes. As a result, the industrial units located to the east of the site is an area that may be at particular risk from landfill gas produced at the site.

3.3. Conceptual Site Model

Based on the desktop investigation and site walkover undertaken, 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 basic conceptual model to be produced, which is presented in Figure 3.1, overleaf.

LANDFILL GAS

LEACHATE MIGRATION

HISTORIC LANDFILL

APPROX AREA 2 Ha

Private Houses

Derelict Mushroom Houses

Industrial Units

Private Houses

Old Gas Wells

Corrinshigo Lake

CUTOVER/CUTAWAY PEAT SOILS

GROUNDWATER TABLE

Poorly Productive Aquifer (PI)

Groundwater Depth and Gradient Unknown

SANDSTONE BEDROCK

CROSS SECTION WEST - EAST

FIGURE 3.1 KILLYCARD HISTORIC LANDFILL CONCEPTUAL SITE MODEL

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3.4. Risk Prioritisation

Risk prioritisation enables resources to be prioritised on the highest risk facilities and on the highest source – pathway – receptor linkage potential.

The risk prioritisation process assigns a score to each linkage and the overall score is the maximum of the individual linkages for the site. The higher the score a site/linkage receives the higher the risk.

To classify the risk, scores will be applied to the information obtained during the site investigation. Where there is insufficient information available (i.e. where there is a high degree of uncertainty) the highest score is assumed.

The scoring matrixes are as follows:

- Leachate; Source/hazard scoring matrix, based on waste footprint
- Landfill gas: Source/hazard scoring matrix based on waste footprint
- Leachate migration: Pathway (Vertical)
- Leachate migration: Pathway (Horizontal)
- Leachate migration: Pathway (Surface water drainage)
- Landfill gas: Pathway (Lateral migration potential)
- Landfill gas: Pathway (Upwards migration potential)
- Leachate migration: Receptor (Surface water drainage)
- Leachate migration: Receptor (Human presence)
- Leachate migration: Receptor (Protected areas – SWDTE or GWDTE) (Surface water/groundwater dependent terrestrial ecosystems)
- Leachate migration: Receptor (Aquifer category – Resource potential)
- Leachate migration: Receptor (Public water supplies – other than private wells)
- Leachate migration: Receptor (Surface water bodies)
- Landfill gas: Receptor (Human presence)

Table 3.1 calculates the points awarded to each of the headings listed above.

Table 3.1: Risk Classification Calculation

EPA Ref	Risk	Points	Rationale
1a	Leachate; source/hazard scoring matrix, based on waste footprint.	7	Based on a waste footprint of >1 and ≤5 ha and a site that operated as a landfill post 1980.
1b	Landfill gas; source/hazard scoring matrix, based on waste footprint.	7	Based on a municipal waste footprint of >1 and ≤5 ha.
2a	Leachate migration: Pathway (Vertical)	3	GSI describes the groundwater vulnerability as Extreme.
2b	Leachate migration: Pathway (Horizontal)	1	The bedrock is classified by the GSI as a Poorly Productive Aquifer (Pl) – bedrock which is unproductive except in Local Zones.
2c	Leachate migration: Pathway (Surface water drainage)	2	Connection between the waste body and surface water
2d	Landfill gas: Pathway (Lateral migration potential)	3	Made ground, cutover peat
2e	Landfill gas: Pathway (Upwards migration potential)	5	Made ground, cutover peat

EPA Ref	Risk	Points	Rationale
3a	Leachate migration: Receptor (Human presence)	3	On or within 50m of the waste body.
3b	Leachate migration: Receptor (Protected areas – SWDTE or GWDTE) (Surface water/ groundwater dependent terrestrial ecosystems)	1	Greater than 250m but less than 1km from the waste body/Undesignated sites within 50m of site of the waste body.
3c	Leachate migration: Receptor (Aquifer category – Resource potential)	1	The bedrock is classified by the GSI as a Poorly Productive Aquifer (Pl) – bedrock which is unproductive except in Local Zones.
3d	Leachate migration: Receptor (Public water supplies – other than private wells)	0	Greater than 1km (no karst aquifer).
3e	Leachate migration: Receptor (Surface water bodies)	3	Surface water within 50 m of site boundary. Corrinshigo Lough adjacent to waste body.
3f	Landfill Gas: Receptor (Human presence)	5	On site or within 50m of site boundary. Industrial units present within site boundary.

Table 3.2: Normalised Score of S-P-R Linkage

Calculator		S-P-R Values	Maximum Score	Linkage	Normalised Score
Leachate migration through combined groundwater and surface water pathways					
SPR1	1a x (2a + 2b + 2c) x 3e	7 x (3+1+2) x 3 = **126**	300	Leachate => surface water	42%
SPR2	1a x (2a + 2b + 2c) x 3b	7 x (3+1+2) x 1 = **42**	300	Leachate => SWDTE	14%
Leachate migration through groundwater pathway					
SPR3	1a x (2a + 2b) x 3a	7 x (3+1) x 3 = **84**	240	Leachate => human presence	35%
SPR4	1a x (2a + 2b) x 3b	7 x (3+1) x 1 = **28**	240	Leachate => GWDTE	11.7%
SPR5	1a x (2a + 2b) x 3c	7 x (3+1) x 1 = **28**	400	Leachate => Aquifer	7%
SPR6	1a x (2a + 2b) x 3d	7 x (3+1) x 0 = **0**	560	Leachate => Surface Water	0%
SPR7	1a x (2a + 2b) x 3e	7 x (3+1) x 3 = **84**	240	Leachate => SWDTE	35%
Leachate migration through surface water pathway					
SPR8	1a x 2c x 3e	7 x 2 x 3 = **42**	60	Leachate => Surface Water	**70%**
SPR9	1a x 2c x 3b	7 x 2 x 1 = **14**	60	Leachate => SWDTE	23.3%
Landfill gas migration pathway (lateral & vertical)					
SPR10	1b x 2d x 3f	7 x 3 x 5 = **105**	150	Landfill Gas => Human Presence	**70%**
SPR11	1b x 2e x 3f	7 x 5 x 5 = **175**	250	Landfill Gas => Human Presence	**70%**
Site maximum S-P-R Score					**70%**
Risk Classification					**A - High**

Table 3.2 shows the maximum S-P-R scoring for the site is **70%** based on the potential for landfill gas migration at the site.

The following are the risk classifications applied:

- Highest Risk (Class A) Greater than 70 for any individual SPR linkage
- Moderate Risk (Class B)41-69 for any individual SPR linkage
- Lowest Risk (Class C) Less than 40 for any individual SPR linkage

Based on this, the site can be classified as a **high-risk classification (Class A)**. The EPA describes these sites as a "high risk posed to the environment or human health". Detailed site investigations are required to be carried out on all high and moderate risk sites.

4. CONCLUSIONS & RECOMMENDATIONS

A Tier 1 study was conducted by FT. The study consisted of a desktop study and a detailed site walkover. These works informed the development of the CSM and risk screening model.

The results of the Tier 1 assessment and risk model indicate that the site is a **Class A - high risk**. The EPA describes these sites as a "high risk posed to the environment or human health". Detailed site investigations are required to be carried out on all high and moderate risk sites.

Given that there is no landfill liner or capping present there remains a pathway between the leachate and the groundwater body beneath. There is also believed to be a direct pathway between the leachate and surface water seepage from the landfill.

A Tier 2 quantitative risk assessment is required for a site which is classified as high risk. FT recommend further intrusive site investigations and sampling as part of the Tier 2 assessment.

For a high-risk site, the CoP directs that the site will have to apply for a certificate of authorisation to certify compliance with Regulation 7(7) of the Waste Management (Certification of Historic Unlicensed Waste Disposal and Recovery Activity) Regulations, 2008.

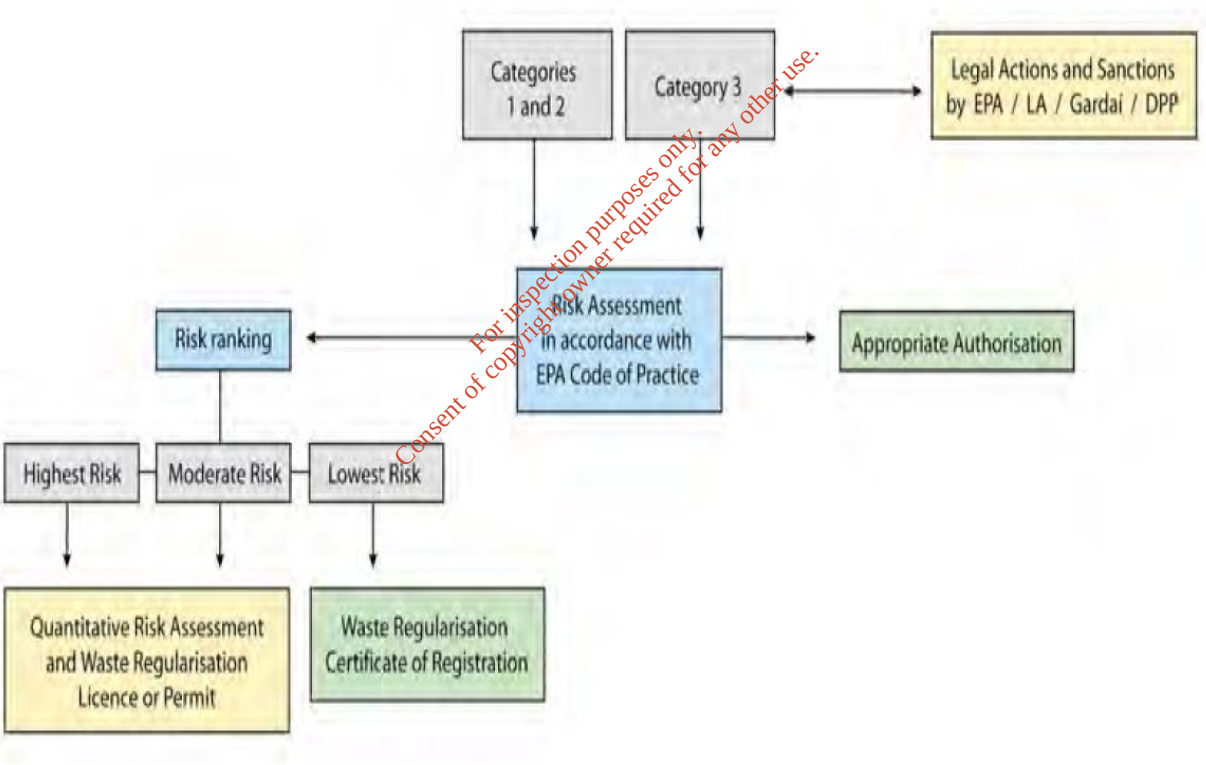


Figure 4-1: Extract from Section 1.3 of the EPA CoP

4.1. Recommendations

FT recommends intrusive site investigations will be required, using trial pits, boreholes and slit trenches to confirm waste volumes, footprint and depths, and to assess and characterise waste types and compositions. An environmental monitoring program including surface water, groundwater, leachate sampling and landfill gas migration monitoring is also recommended.

The scope of the site investigation recommended is detailed in the following section.

4.1.1. S.I. Design

FT recommend that a site investigation in line with the Tier II CoP be undertaken at the site. It is proposed that the Site Investigation programme should consist of the following items:

- Geophysical Investigation
- Trial Pitting
- In-situ testing
- Cable Percussion with Rotary Follow-on Boreholes for the purposes of groundwater and landfill gas monitoring
- Groundwater Monitoring & Sampling
- Laboratory testing
- Factual reporting

The following sections outline the overall approach that may be adopted.

Geophysics Survey

It is recommended that a geophysical survey is undertaken to determine the full vertical and lateral extent of the interred waste body and ground conditions beneath the waste. Procurement of a suitably qualified surveyor will be required to undertake a geophysical survey of the site using EM31 conductivity, 2D resistivity profiling and seismic refraction.

Trial Pitting

Trial pits are recommended across the site to investigate the nature, vertical and horizontal extent of the interred waste material. The number and location of trial pits will depend on site access and location of existing services. FT recommends the excavation of trial pits across the target site to a maximum depth of 4.0m, or until natural ground is confirmed beyond the base of the interred waste body. All trial pits should be logged in accordance with BS5930.

Waste Quantification, Sampling and Analysis

Wastes encountered during trial pitting shall be subject to descriptive logging and bulk sampling at appropriate intervals. A proportion of the waste samples collected during trial pitting shall be subject to Waste Acceptance Criteria analysis for the purposes of classification into inert, non-hazardous or hazardous criteria.

Landfill Leachate if encountered should also be subject to sampling and suitable leachate indicator analysis. Results should be compared to reference values to assess the type and strength of the leachate encountered.

Groundwater/Landfill Gas Monitoring Boreholes

FT propose the installation of groundwater/leachate monitoring wells at the site. A minimum of three number wells is recommended. The borehole installations will be multi-purpose and allow for sampling of groundwater, landfill gas as required.

In-situ Falling/Rising head tests are recommended to assess the permeability of the underlying strata.

GPS way finders and physical markers should be used to record proposed SI locations allowing for accurate mapping and setting out of actual works.

Groundwater / Leachate / Landfill Gas Sampling and Potentiometric Mapping

The borehole installations should be multi-purpose and allow for sampling of groundwater and landfill leachate as required. Post installation and development of the wells, a minimum of two rounds of groundwater sampling should be undertaken from each of the well locations and analysed for the parameters listed in Table C.2 of the EPA Landfill Monitoring Manual (2003).

Groundwater: groundwater sampling should be designed to assess the overall groundwater quality versus the published Groundwater Regulations (2010) (SI No. 9 of 2010) groundwater threshold values (GTVs), and to allow for the detection of key leachate indicators i.e. ammonia, heavy metals etc.

Landfill Gas: borehole installations will be subject to regular monitoring as part of the proposed schedule. Landfill Gas sampling should allow for the measurement of the following parameters:

- CH4
- CO2
- O2
- N
- H2S
- Barometric Pressure (mB)
- Flow
- Balance Gases

Potentiometric Groundwater Mapping

The groundwater flow gradient on site should be determined from the groundwater depth/head information collected at the site. A standard dip meter should be used to measure the natural level of groundwater / leachate. The potentiometric groundwater head measurements should be combined to map the groundwater flow direction beneath the site. The potentiometric mapping will allow the upstream and downstream groundwater locations to be identified which will aid conceptualising the flow direction of any contaminated leachate plumes exiting the site.

Surface Water Sampling

The monitoring schedule adopted should allow at a minimum for the sampling of surface water bodies upstream, onsite and downstream of the historic landfill waste body to assess the impact (if any) of the landfill on local surface water quality.

It is envisaged to sample the upstream and downstream surface water sampling locations set out in in Table 4.1 below:

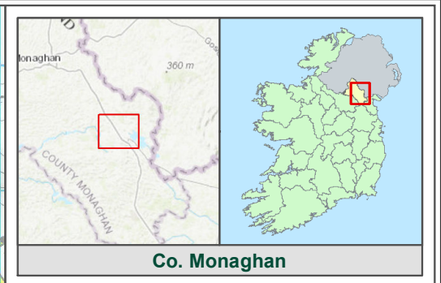
Table 4.1: Potential Surface water Sampling Locations

Site	Receiving Watercourse	Upstream Location	Onsite Location	Downstream Location
Killycard Historic Landfill	Carrickaslane Lough tributary stream.	Southwestern perimeter drainage channel	Corrinshigo Lough	Northern perimeter drainage channel

A minimum of two rounds of surface water sampling should be undertaken from each location and analysed for the parameters listed in Table C.2 of the EPA Landfill Monitoring Manual (2003). The results of the surface water monitoring will be assessed against the current published surface water standards (S.I. No. 272 of 2009).

Appendix I

GSI Information Mapping



Legend

Site Boundary

Figure Title	Site Location Killycard
Figure No.	2.1
Project	Tier 1 Assessment of Historical Landfills in Monaghan
Client	Monaghan County Council
Scale	1:25,000
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Kilometers
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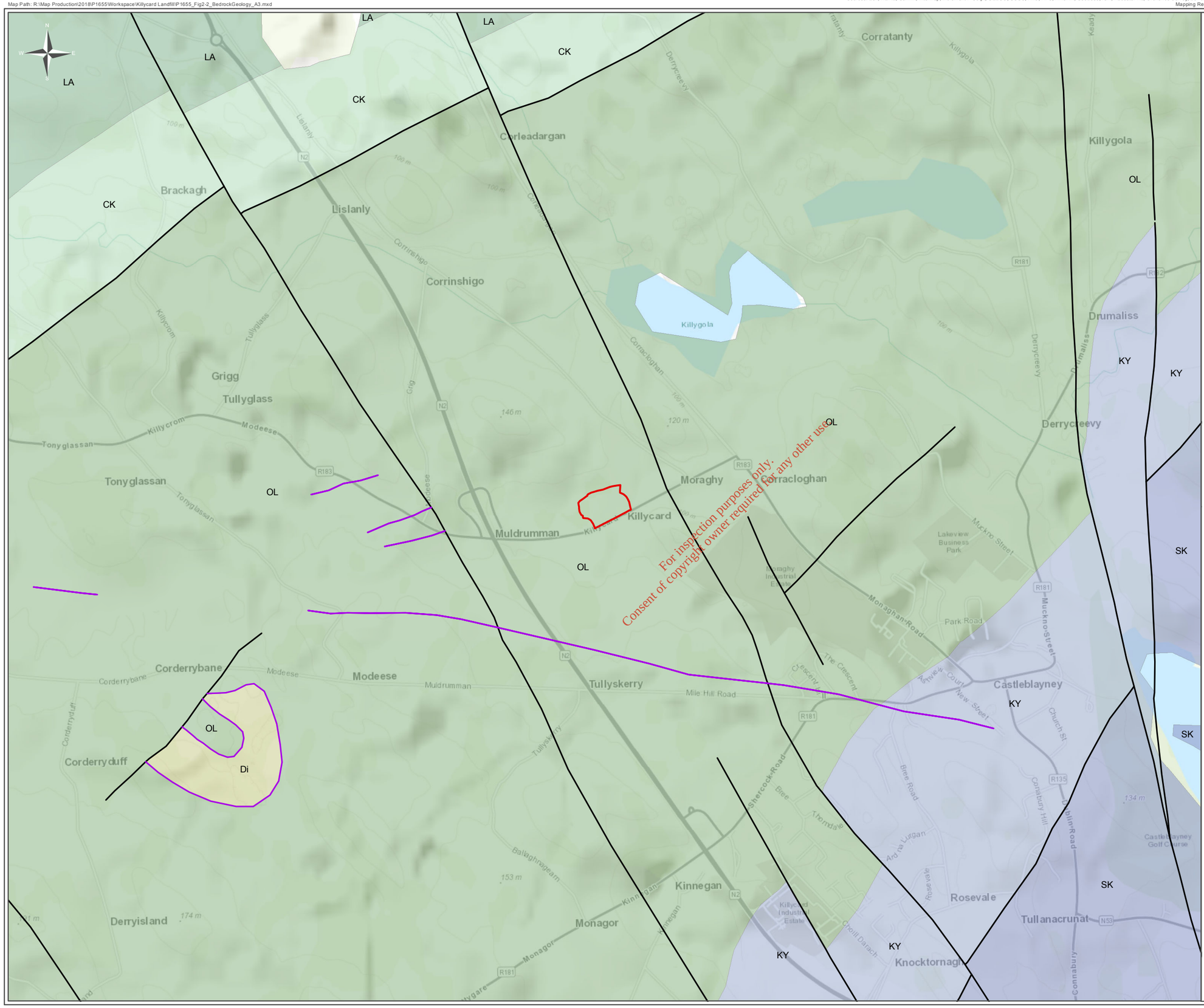

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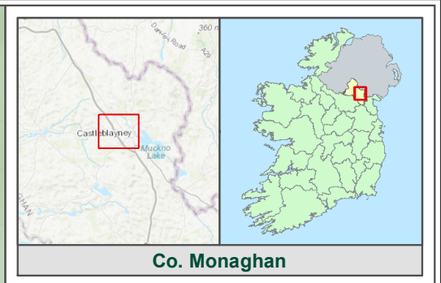

Legend

- Site Boundary
- Dip of Bedding in Degrees
- Stratigraphical Linework
- Structural Linework

Bedrock Geology

- CK: Carrickatee Formation
- Di: Diorite
- KY: Kehernaghkilly Formation
- LA: Lough Avaghon
- OL: Oghill Formation
- SK: Shercock Formation

Figure Title	Bedrock Geology Killycard
Figure No.	2.2
Project	Tier 1 Assessment of Historical Landfills in Monaghan
Client	Monaghan County Council
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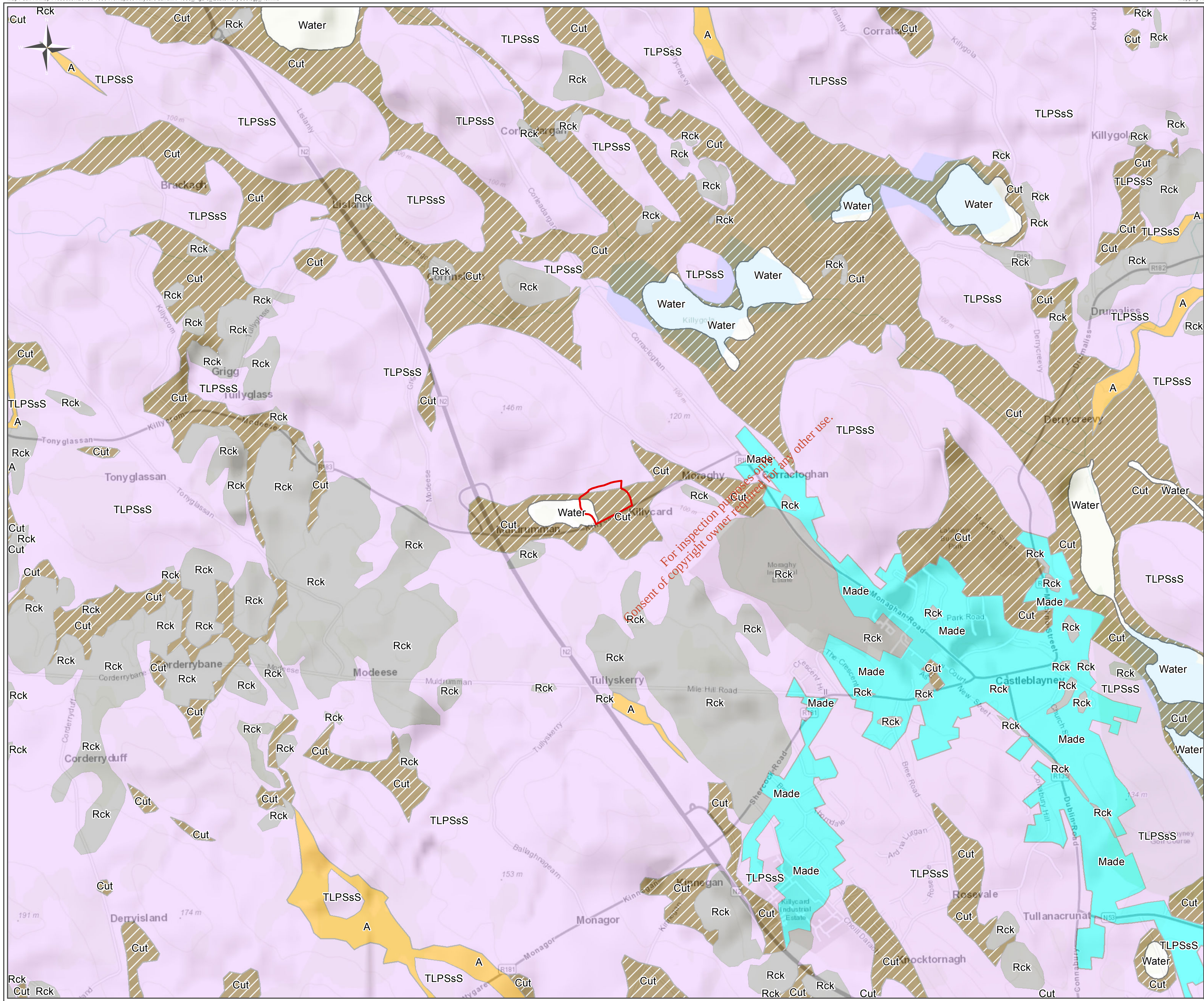

Co. Monaghan

Legend

- Site Boundary

Subsoils Data

- A, alluvium
- Cut, cutover peat
- Made, made ground
- Rck, bedrock at surface
- TLPSsS, sanstone and shales till - Lower Paleozoic
- Water, water

Figure Title	Quaternary Geology Killycard
Figure No.	2.3
Project	Tier 1 Assessment of Historical Landfills in Monaghan
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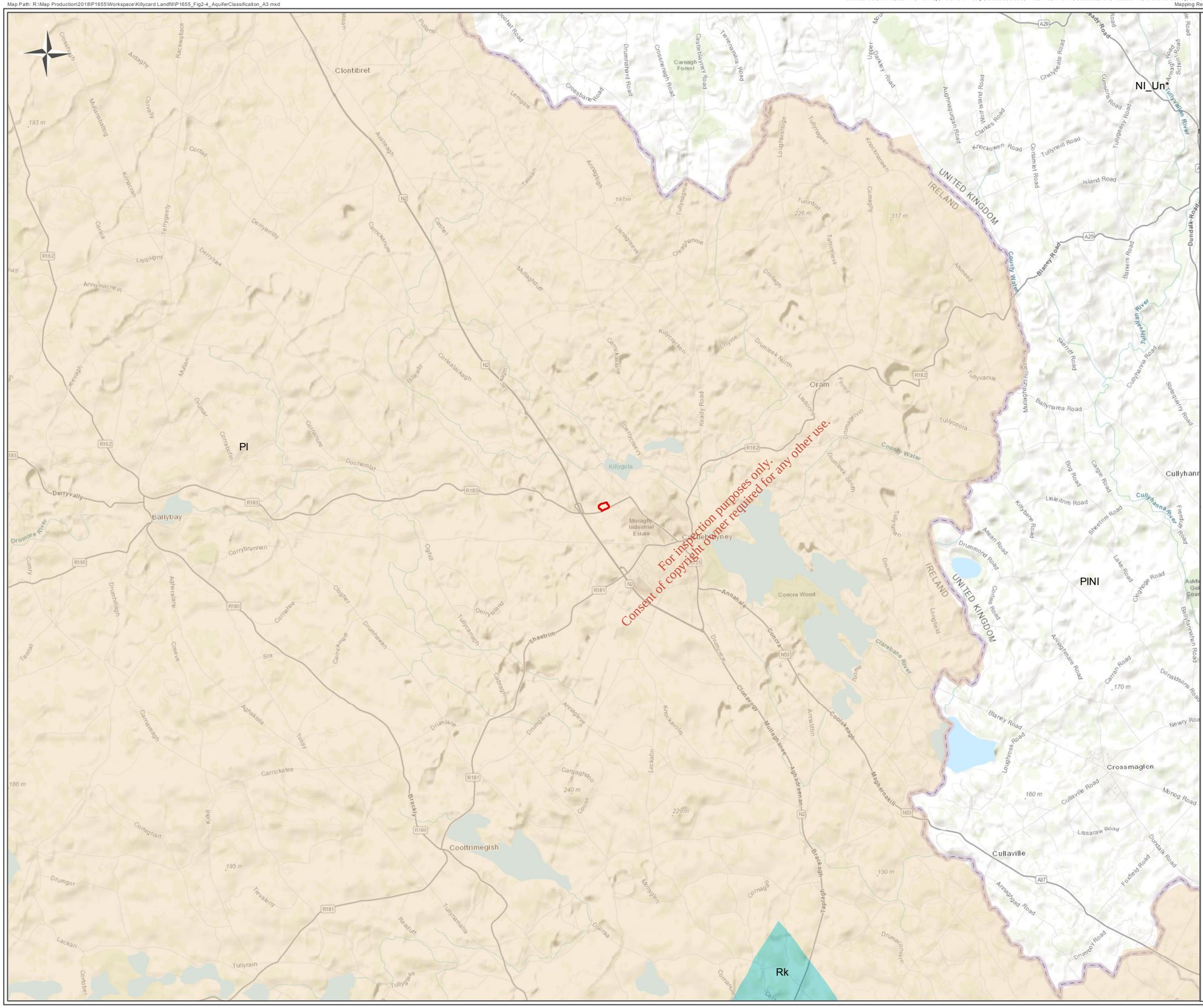
0 0.5 1 2 Kilometers



Legend

- Site Boundary
- Pl: Poor Aquifer Bedrock Generally Unproductive Except Locally
- Rk: Regionally Important Aquifer - Karstified

0 0.5 1 2 Kilometers

Figure Title
Aquifer Classification
Killycard

Figure No. 2.4

Project
Tier 1 Assessment of Historical Landfills in Monaghan

Client
Monaghan County Council

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