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CONSULTANTS IN ENGINEERING, ENVIRONMENTAL SCIENCE & PLANNING

TIER 2 RISK ASSESSMENT

HISTORIC LANDFILL AT LISTOWEL, CO. KERRY

Prepared for: Kerry County Council

Comhairle Contae Chiarraí

Kerry County Council

Date: August 2021

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TIER 2 RISK ASSESSMENT

HISTORIC LANDFILL AT LISTOWEL, CO. KERRY

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Abstract: This report represents the findings of a Tier 2 site investigation carried out at Listowel Historic Landfill, Co. Kerry and conducted in accordance with the EPA Code of Practice for unregulated landfill sites. The site investigation was undertaken to determine the extent of the historic landfilling at the site.

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EXECUTIVE SUMMARY

The site of Listowel Historical Landfill is currently utilised as a town park, the Garden of Europe – and is an area of cultural heritage. The site covers an area of c.1.01 ha and is located at the edge of the town of Listowel with the River Feale flowing along the southern boundary of the site. The Garden of Europe contains more than 3,000 trees and shrubs, numerous pieces of sculpture artwork and the only public monument in memory of those who died in the Holocaust in Ireland.

A Tier 2 study was conducted by Fehily Timoney (FT) in accordance with the EPA CoP for Listowel Historic Landfill.

The study consisted of a desktop study, site walkover, topographical survey, geophysical survey, intrusive site investigation works and environmental monitoring. These works informed the development of the CSM and risk screening model.

The findings of the site investigation work and geophysical surveying suggest the waste material is deposited in a single infill area with the extent of the landfill is estimated at 8,900 m^2. A volume calculation based on the surveyed surface profiles for the existing ground level and the base of waste as interpreted, preliminary estimates indicate an interred waste volume of approximately 98,000 m^3 including fill material was landfilled. Information provided in the KCC Tier 1 assessment assumes a 20-year lifespan for the landfill. Available records reviewed by KCC state an annual intake of 1,850 tonnes per annum and 2 years of remaining capacity in 1986. This would equate to 37,000 tonnes of waste deposited at the site. The waste volume as estimated by the geophysical survey is significantly greater than that indicated within the Tier 1 assessment information. It is noted that that the waste thickness applied by the geophysical survey waste volume estimate includes the existing cap thickness and basal leachate, therefore the estimate 98,000 m^3 may be considered a conservative estimate of waste deposited at the site. Applying an estimated waste volume of 98,000 m^3 and an assumed waste density of 1.4 tn/m^3 this equates to 137,200 tonnes. It is therefore estimated the quantity of waste deposited at the site is between 37,000 and 137,200 tonnes.

Analysis of waste samples from the window sample holes advanced at the site, when assessed against the inert waste acceptance criteria indicated that much of the waste material within the site can be classified as typically inert. The waste classification is considered to reflect the level of degradation over time since landfilling ceased. Window sampling has confirmed the waste material is near the surface with a minimal topsoil and clay cover present across the site.

Landfill gas monitoring from perimeter wells BH01 and BH02 at the site indicates gas concentrations detected are below threshold levels set by the EPA CoP.

Analysis of groundwater samples recovered from the monitoring wells BH01 and BH02 have reported the presence of elevated ammonia and dissolved metal 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 therefore contributing to leachate migration from the site.

Analysis of groundwater samples presented elevated alkalinity and manganese concentrations which appear to be typical of localised background concentrations due to the presence of high concentrations on both monitoring wells.

Analysis of surface water samples recovered from the watercourses surrounding the site indicated no exceedances of the EQS (2019) and MAC (1989) guideline limit values. Given the determined groundwater flow direction is due south-north, detection of leachate migration from the landfill at SW1 is not considered likely.

Based on the results of the Tier 2 site assessment, the site can be classified as a **Moderate Risk Classification (Class B)**.

1. INTRODUCTION

1.1 Background

The site of Listowel Historical Landfill is currently utilised as a town park, the Garden of Europe – which is an award-winning area of cultural heritage. The site covers an area of c.1.01 ha and is located at the edge of the town of Listowel with the River Feale flowing along the southern boundary of the site. The Garden of Europe contains more than 3,000 trees and shrubs, numerous pieces of sculpture artwork and the only public monument in memory of those who died in the Holocaust in Ireland.

The topography of the site is generally relatively flat, with a gentle slope southward towards River Feale. The surroundings are composed by agricultural land to the East, pitches to the West, forestry and residential areas to the North and River Feale to the South.

The landfill area was estimated to be approximately 0.75Ha in size. Available evidence suggests that the site closed, and landfilling had ceased in 1989. The potential receptors identified were nearby houses, groundwater and the River Feale, which is located 20m South of the site boundary, flowing in an East-West direction. Previous remediation measures include installation of soil capping. No other remediation measures are known have been carried out. Information provided in the KCC Tier 1 assessment assumes a 20-year lifespan for the landfill. An Foras Forbatha records reviewed by KCC state an annual intake of 1,850 tonnes per annum and 2 years of remaining capacity in 1986. This would equate to 37,000 tonnes of waste deposited at the site.

KCC is required to complete a tiered risk assessment of unregulated waste disposal sites in accordance with the Environmental Protection Agency (EPA) code of practice for unregulated waste disposal sites.

A Tier 1 Risk Assessment was first completed by KCC in 2007. The site was assessed again in 2009 and registered utilising the EPA's Section 22 Tier 1 assessment and registration tool. KCC also conducted a review of these previous assessments producing a review report in 2013. Based on the available information, the Tier 1 Assessment determined that the overall risk score for Listowel Landfill was 44%, resulting in a risk classification of Moderate (Class B).

A copy of KCC's Tier 1 assessments is included in Appendix 1.

1.2 Scope of Works

FT's scope of work was to undertake a Tier 2 assessment of the site in accordance with the EPA Code of Practice (CoP) 2007: *Environmental Risk Assessment for Unregulated Waste Disposal Sites*. This approach required the completion of the following:

- Desk Study
- Site Walkover
- Topographical Survey
- Geophysical and surveying to estimate extents and depths of waste
- Intrusive Site Investigation
- Groundwater and Surface Water Sampling
- Environmental Risk Assessment (ERA)
- Development of a conceptual site model (CSM)

As part of the initial desk study, a review of available information was undertaken. This was followed-up with a site walkover by FT personnel. The desk study and site walkover were used to determine the locations for the intrusive site investigation.

FT appointed Causeway Geotech Limited (CGL) to conduct the intrusive site investigation which included; two boreholes by rotary drilling methods, two standpipe installations, and eight boreholes by dynamic (windowless) sampling methods.

A full geotechnical report is included in Appendix 2 to this document.

Laboratory analysis of waste, surface water and groundwater samples were conducted to assess and quantify any potential or ongoing environmental impacts. Results of waste sampling are included in Appendix F of Causeway Geotechnical Report (Appendix 2 of this report) with laboratory analytical reports for surface and groundwater presented in Appendix 3.

The site walkover checklist and accompanying photolog are included in Appendix 4 to this report.

Minerex were appointed by FT to undertake a geophysical survey of the site. Geophysical surveying including Electro Conductivity, Electro Resistivity and Seismic Refraction surveying methods.

The full geophysical survey report is included in Appendix 5 to this document.

The purpose of the geophysical study was to attempt to define the vertical and lateral extents of any waste body. Trial pits were excavated to provide a preliminary assessment of the volume, extent and type of waste infilled at the site. The groundwater monitoring boreholes were installed to assess the impact, if any, of the onsite groundwater.

The information gathered from the desk study, intrusive site investigation and geophysical survey were used to inform the development of the CSM and the Environmental Risk Assessment (ERA). This report presents the findings of the assessment.

2. DESK STUDY

2.1 Introduction

The desk study included the review of the following literature sources and websites:

- Geological Survey of Ireland, Groundwater Web Mapping: www.gsi.ie
- Environmental Protection Agency Maps: http://gis.epa.ie/Envision
- National Parks and Wildlife Service Map Viewer: www.npws.ie
- DoHPLG/EPA/Local Authority maps: www.catchments.ie
- BS 5930: 1999, Code of Practice for Site Investigations
- BS 10175: 2000, Investigation of Potentially Contaminated Sites – Code of Practice
- EPA - Assessing and Developing Natural Background Levels for Chemical Parameters in Irish Groundwater (2017)

A desktop review of available documentation for the site was conducted followed by a site walkover on 14th February 2019.

2.2 Desk Study

This section of the report presents the findings of the desk study.

2.2.1 Site Description & On-Site Conditions

The waste footprint area was estimated by KCC to be approximately 0.75Ha in size, although a previous reports and records of the site refer to it as being 1.01HA in size. As a conservative approach KCC assumed the larger area in carrying out their Tier 1 assessment.

The topography of the site is generally relatively flat, with a gentle slope southward towards River Feale. The surroundings are composed by agricultural land to the East, pitches to the West, forestry and residential areas to the North and River Feale to the South. A KCC works/storage yard is located at the south eastern boundary of the site.

Since landfilling activities have ceased has been utilised as a town park, the Garden of Europe. As outlined in Section 1.1 the Garden of Europe is an award-winning area of cultural heritage. The park contains more than 3,000 trees and shrubs, numerous pieces of sculpture artwork and the only public monument in memory of those who died in the Holocaust in Ireland.

The site covers an area of c.1.01 ha is located at the edge of the town of Listowel with the River Feale flowing along the southern boundary of the site. The site can be accessed via local roads off the N69 which runs through Listowel town centre. There are no residential dwellings located within the subject site however there is a housing development located 150m north-east of the site.

2.2.2 Previous Studies

A Tier 1 Risk Assessment was first completed by KCC in 2007 (Appendix 1). The site was assessed again in 2009 and registered utilising the EPA's Section 22 Tier 1 assessment and registration tool. KCC also conducted a review of these previous assessment producing a revised report in 2013. The Tier 1 assessment comprised the following:

- Development of a conceptual site model (CSM);
- Identification of contaminant sources, pathways of contaminant migration and potential receptors which may be vulnerable if exposed to those contaminants; i.e. the identification of Source- Pathway-Receptor (SPR) linkages; and
- The prioritisation of sites and SPR linkages based on their perceived risk.

Based on the available information, the Tier 1 Assessment determined that the overall risk score for Listowel Landfill was 50%, resulting in a risk classification of Moderate (Class B).

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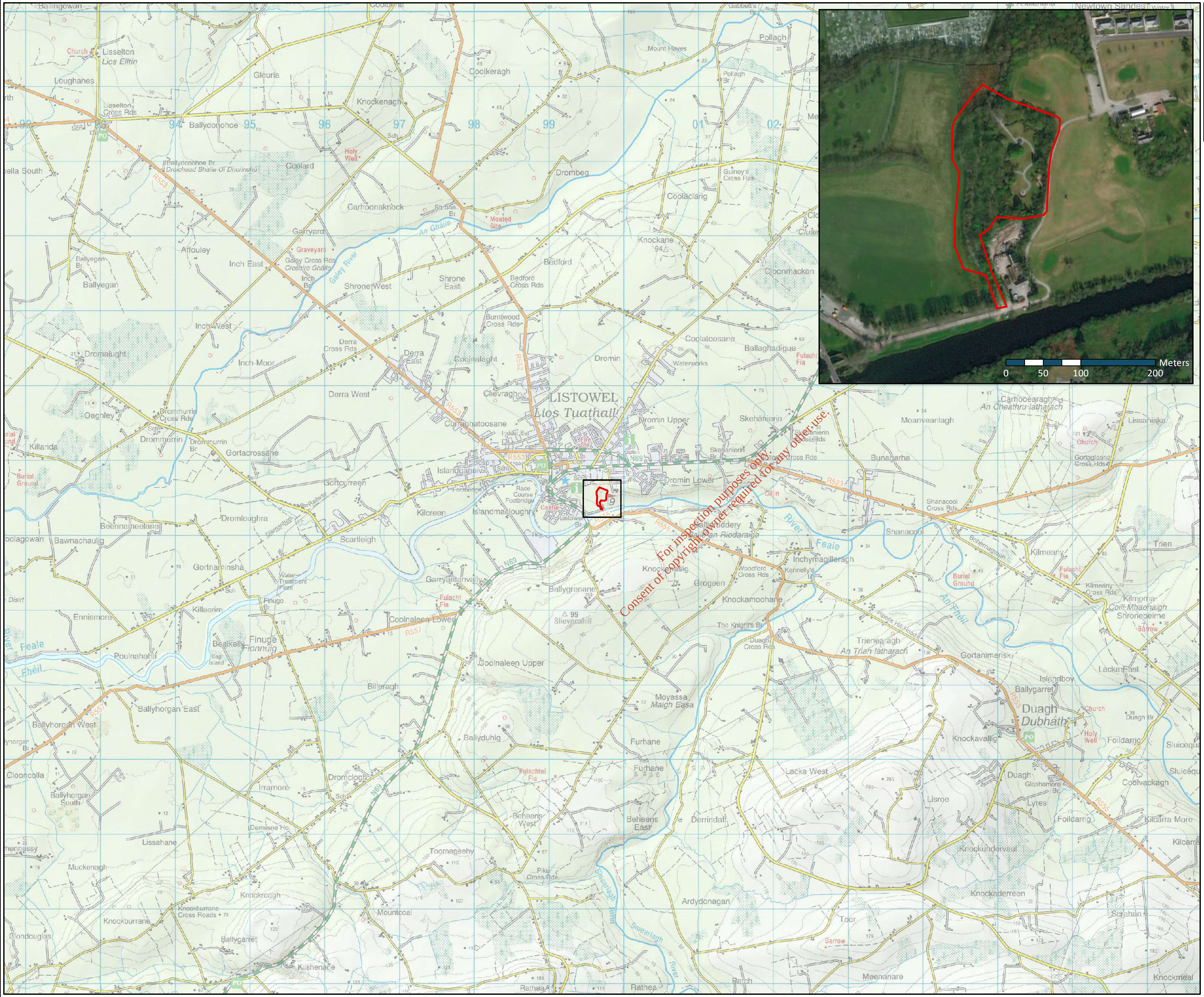

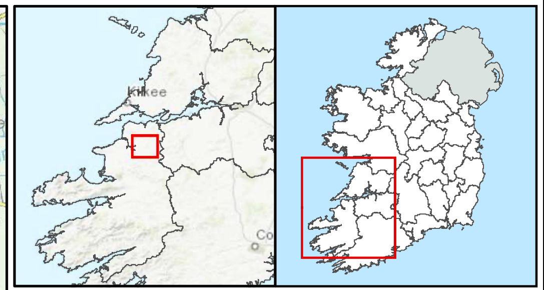

Site Boundary

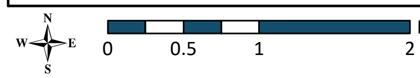

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FIGURE NO:	2.1
CLIENT:	Kerry County Council
SCALE: 1:50000	**REVISION:** 0
DATE: 25/10/2019	**PAGE SIZE:** A3

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2.2.3 Topography

The site covers an area of c.1.01 ha is located at the edge of the town of Listowel with the River Feale flowing along the southern boundary of the site. Topography of the site and surrounding environment is characterised by land gently sloping towards the River Feale.

Land to the north and south of the River Feale rises to hills and mountains with the Stack Mountains located further south of the river at the site. Review of the OSI Discovery series map indicate that site elevations range from 30 – 20 m AOD.

2.2.4 Geology

Drift/Quaternary Geology

Review of the GSI's quaternary sediments mapping shows that the site and estimated waste footprint area is comprises a combination of tills derived from Namurian sandstones and shales, bedrock outcrop or subcrop and urban made ground. Alluvium deposits are also shown to be present along River Feale. Drift/quaternary geology is shown in Figure 2.2.

During the installation of boreholes during the site investigation, the presence of made ground, silt, clay and gravel are described in the driller's logs to a depth of approximately 7.0m BGL at borehole BH01 and 11.5m BGL at borehole BH02, as referenced in the CGL borehole logs, Appendix 2.

Solid or Bedrock Geology

The GSI online 1:100,000 scale bedrock geology map shows the bedrock beneath the site to comprise two different formation the boundary of which transects the site. The site is underlain by a combination of undifferentiated visean limestones (CDVIS) and cherty mudstone/shale of the Clare Shale Formation (CNCLSH). Further to the east and south of the site are mudstone, siltstone and sandstone of the Shannon Group.

GSI mapping also indicates the presence of bedrock outcrop within the site and may cover a significant portion of the site. Bedrock outcrop is also identified directly east of the site, along the eastern boundary. A significant number of bedrock outcrops are also shown along the banks of the River Feale. Bedrock geology mapping is presented in Figure 203.

No bedrock was encountered at 11.5m and 7.0m BGL during the installation of boreholes BH01 and Bh02 as referenced in the CGL borehole logs, Appendix 2.

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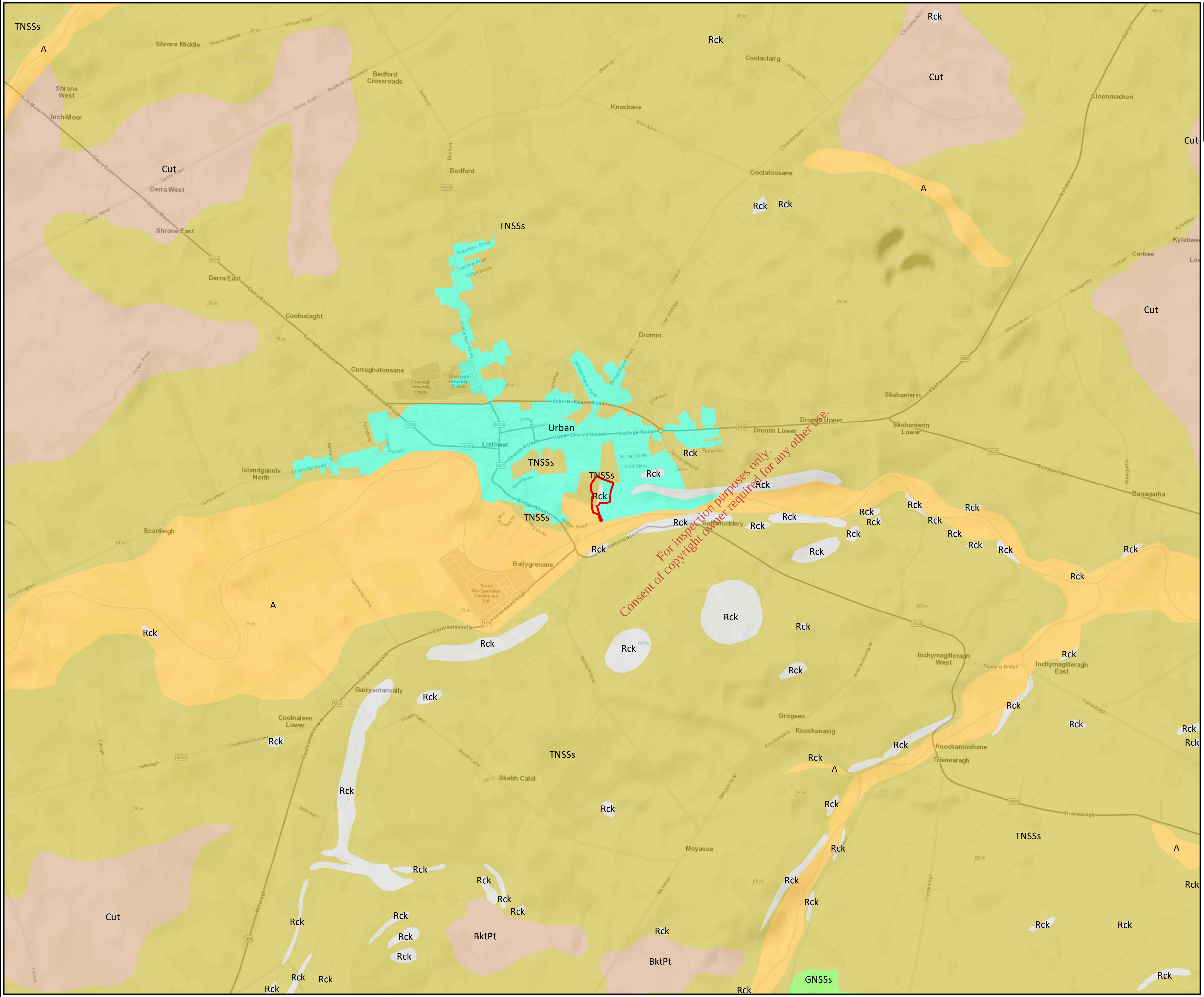

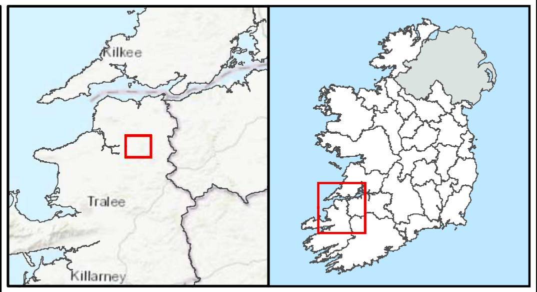

Site Boundary

Quaternary Sediments

- A, Alluvium
- BktPt, Blanket Peat
- Cut, Cut over raised peat
- GNSSs, Gravels derived from Namurian sandstones and shales
- Rck, Bedrock outcrop or subcrop
- TNSSs, Till derived from Namurian sandstones and shales
- Urban

TITLE: Quaternary Geology			
PROJECT: Environmental Risk Assessment for Listowel Landfill, Co. Kerry			
FIGURE NO:	2.2		
CLIENT:	Kerry County Council		
SCALE:	1:25000	**REVISION:**	0
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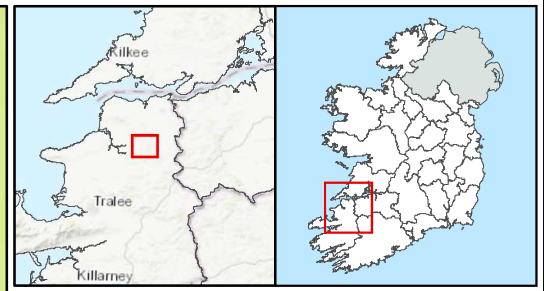

Site Boundary

Dip of bedding or main foliation, old GSI data

Strike and dip of bedding, way up unknown

Bedrock Outcrop

Bedrock Geology

Visean Limestones (undifferentiated

Central Clare Group

Clare Shale Formation

Shannon Group

TITLE: Bedrock Geology	
PROJECT: Environmental Risk Assessment for Listowel Landfill, Co. Kerry	
FIGURE NO: 2.3	
CLIENT: Kerry County Council	
SCALE: 1:25000	**REVISION:** 0
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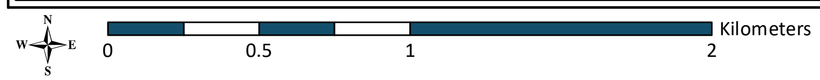

2.2.5 Hydrogeology

An examination of the national bedrock aquifer map on the GSI online mapping shows that bedrock groundwater beneath site comprises two different formations and corresponds with the different bedrock geology underlying the site. A portion of the site comprises 'Regionally important Aquifer – Karstified (diffuse) and relates to the visean limestone bedrock while groundwater underlying the remainder of the site is classified as 'Poor Aquifer – bedrock which is generally unproductive'. The bedrock aquifer mapping is presented in Figure 2.4.

There are no karst landforms identified by the GSI within the site boundary or in the wider environment.

Historical mapping for the area shows no springs within the site boundary or near the site, however a spa well 'Spa Well (Chalybeate)' is identified approximately 250m east of the site. It is noted that a portion of the site was also used a former quarry. As the site is located at the edge of an urban area there is a lower risk of unregistered private wells being in the vicinity of the site. A review of the GSI registered wells and springs database was also conducted.

Table 2.1 below presents the details of the registered boreholes and springs within 1km of the site.

Table 2.1: Borehole and Spring Descriptions near the Project Site

BH/Spring	Yield class	Yield (m^3/day)	Use	Depth (m)	Depth to Rock confidence (m)	Distance from site (km)	Date
0813SEW068	Excellent	552	Industrial	-	64	0.75	1899
0813SEW067	Excellent	500	Industrial	-	-	0.9	1899
0813SEW037	Poor	32.7	Agri & domestic	4.3	70.1	0.9	1971

There are no Groundwater Drinking Water Protection Areas within the site boundaries according to GSi. The nearest groundwater protection zone is located approximately 18.5 km north-east of the site near Glin village and is associated with the Glin Public Water Supply, it is noted however that this public water supply is no longer in use. Other groundwater protection zones are located over 20km away from the site.

The GSI mapping suggests that the groundwater body (GWB) underlying the site is the Ballybunion GWB. The Abbeyfeale GWB is also located immediately south-east of the site, the boundary of which corresponds with the boundary between the Clare Shale Formation and Shannon Group bedrock formations.

There are no recorded groundwater dependent ecosystems in the area.

GSI mapping shows groundwater recharge to be quite variable within and surrounding the site. Owing to the variation in geology i.e. areas of bedrock group, made ground and till subsoils, permeability and recharge will vary. Effective rainfall for area is 765 to 785 mm/year. Recharge co-efficient values vary from 20%, 22.5%, 85% yielding recharge rates 153 to 650 mm/year.

The GSI mapping showing approximate locations of known wells and springs is included in Figure 2.5.

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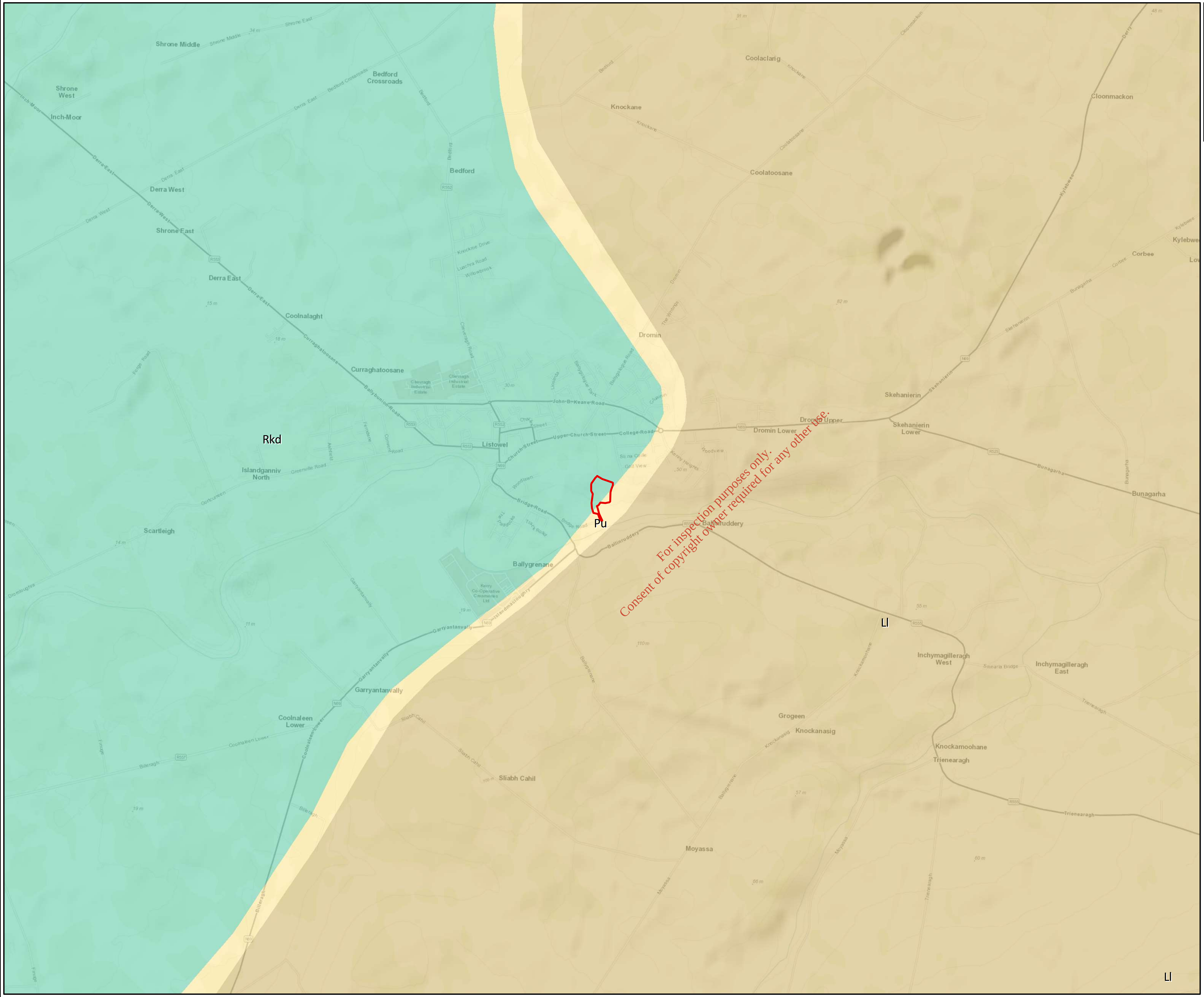

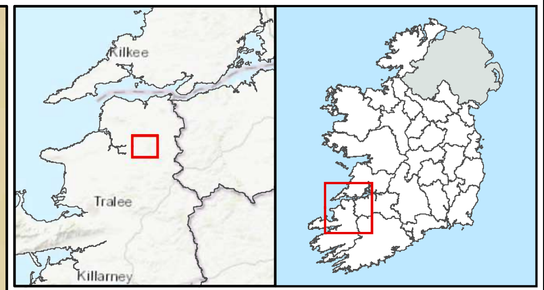

Site Boundary

Bedrock Aquifers

- Ll: Locally Important Aquifer - Bedrock Mod Productive Locally
- Pu: Poor Aquifer Bedrock Generally Unproductive
- Rkd: Regionally Important Aquifer - Karstified (diffuse)

TITLE: Aquifer Classification	
PROJECT: Environmental Risk Assessment for Listowel Landfill, Co. Kerry	
FIGURE NO: 2.4	
CLIENT: Kerry County Council	
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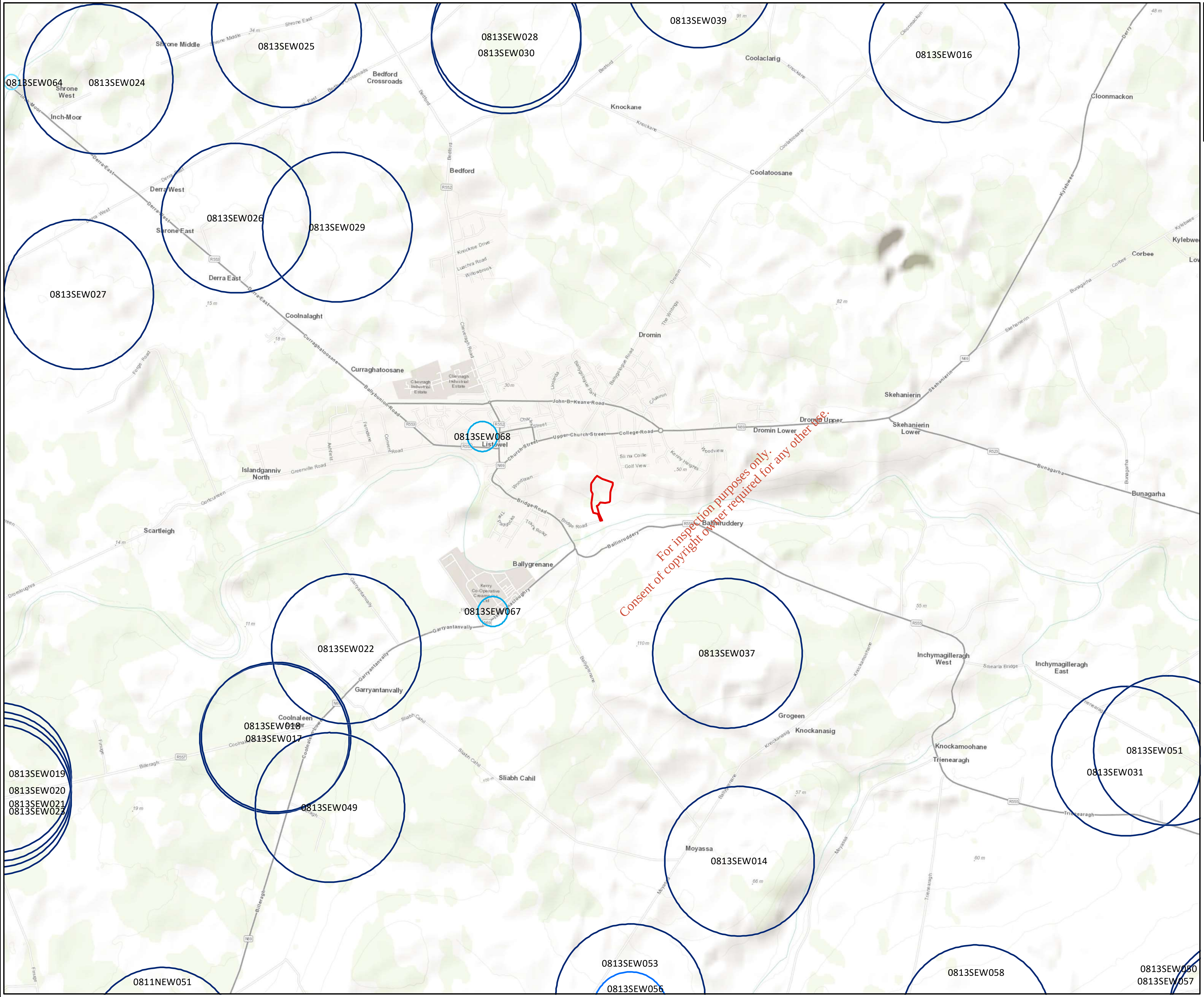

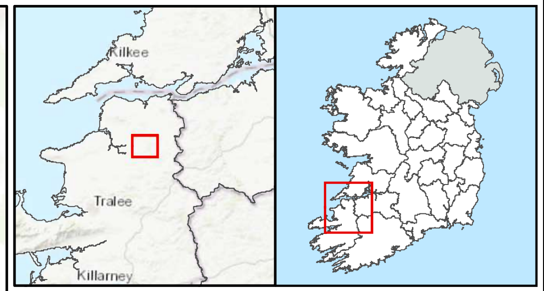

- Site Boundary
- Wells and Springs (50-100m Accuracy)
- Wells and Springs (100-200m Accuracy)
- Wells and Springs (200-500m Accuracy)
- Wells and Springs (500m-1km Accuracy)

TITLE: GSI Wells and Springs	
PROJECT: Environmental Risk Assessment for Listowel Landfill, Co. Kerry	
FIGURE NO: 2.5	
CLIENT: Kerry County Council	
SCALE: 1:25000	**REVISION:** 0
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2.2.6 Groundwater Vulnerability

Groundwater vulnerability, as defined by the GSI, is the term used to represent the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities.

The factors used in assessing groundwater vulnerability include subsoil type and thickness and recharge type as indicated in Table 2.2. The GSI procedure whereby groundwater protection is assessed is outlined in the EPA-GSI publication *Groundwater Protection Schemes* (DELG/EPA/GSI, 1999).

The GSI Online mapping data set identifies the vulnerability of groundwater to contamination within the site area is classified as being primarily extreme with an area classified having rock at or near the surface. Groundwater vulnerability does vary considerably in the area changing from extreme to low, west of the site. The groundwater vulnerability mapping is presented in Figure 2.6.

Table 2.2: GSI Guidelines – Aquifer Vulnerability Mapping

Vulnerability Rating	Hydrogeological Conditions		
	Subsoil Permeability (Type) and Thickness		
	High Permeability (Shallow Bedrock)	Moderate Permeability (e.g. Sandy soil)	Low Permeability (e.g. Clayey subsoil, clay, peat)
Extreme (E)	0 - 3.0 m	0 - 3.0 m	0 - 3.0 m
High (H)	>3.0 m	3.0 -10.0 m	3.0 - 5.0 m
Moderate (M)	N/A	>10.0 m	5.0 - 10.0 m
Low (L)	N/A	N/A	>10 m

Notes:

N/A = Not Applicable

Precise permeability values cannot be given at present

Path: R:\Map Production\2019\P1766\Workspace\Listowel\Tier 2 ERA Report\P1766_Fig2-6_GroundwaterVulnerability_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), (c) OpenStreetMap contributors, and the GIS User Community
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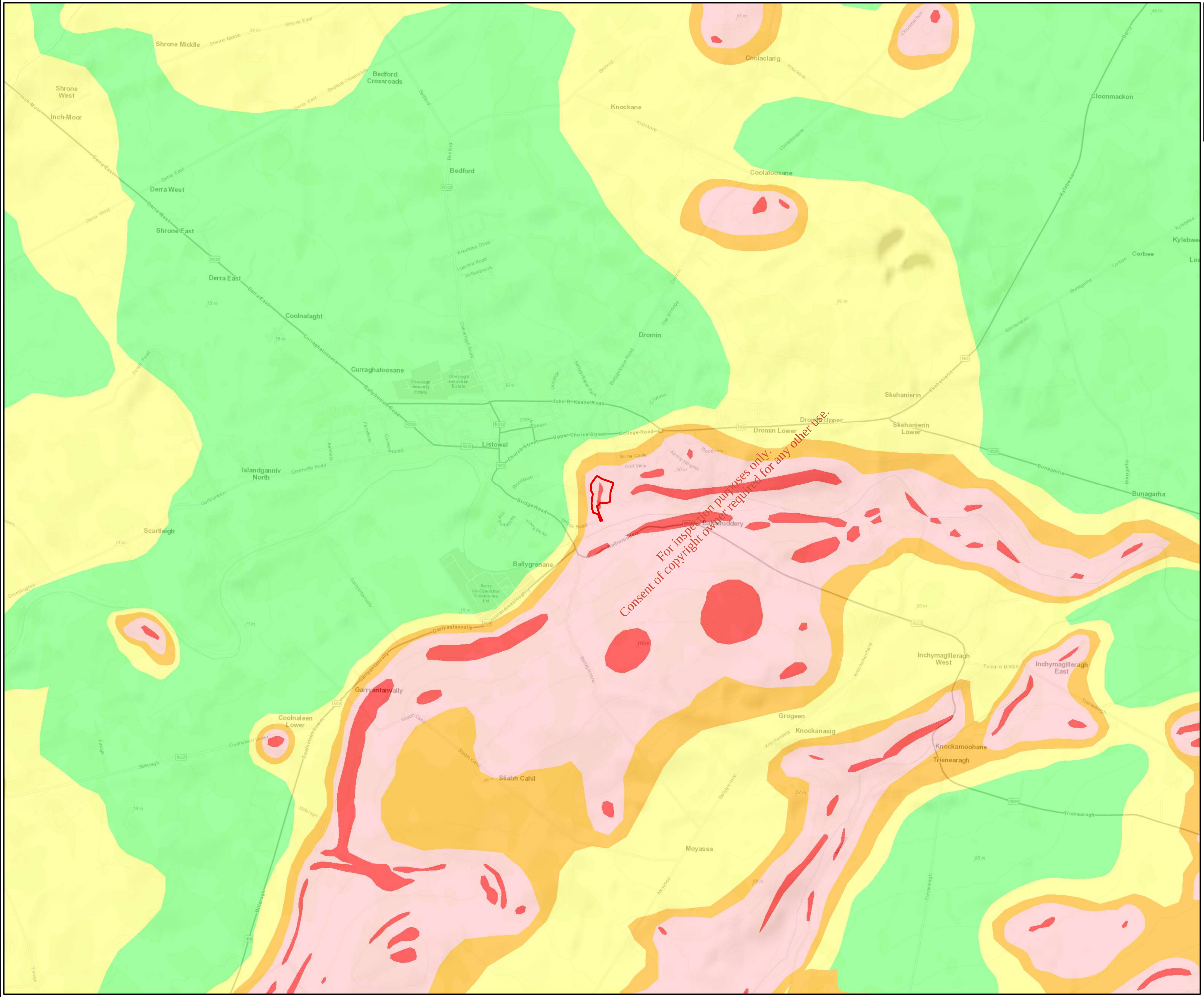

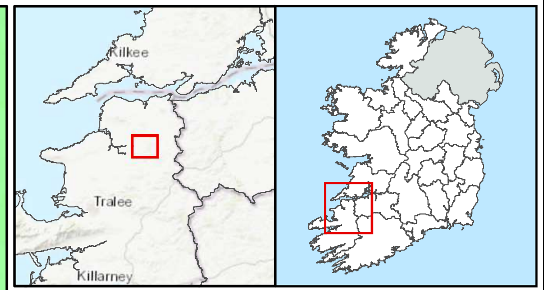

Site Boundary

Groundwater Vulnerability

- E - Extreme
- H - High
- M - Moderate
- L - Low
- X - Rock Near Surface or Karst

TITLE:	Groundwater Vulnerability		
PROJECT:	Environmental Risk Assessment for Listowel Landfill, Co. Kerry		
FIGURE NO:	2.6		
CLIENT:	Kerry County Council		
SCALE:	1:25000	**REVISION:**	0
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2.2.7 Hydrology

The site is located within the Tralee Bay-Feale catchment (Hydrometric Area: 23), Feale_SC_040 sub-catchment and Feale_090 sub-basin. The River Feale is the most significant water feature near the site, being <200m south of the site and estimated waste footprint area. Review of available mapping does indicate that there is no direct surface water connection e.g. land drains, ditches etc. between the landfill area and the River Feale. The River Feale flows in a westerly direction past Listowel converging the River Brick and Galey River downstream of Listowel before eventually discharging to the Atlantic, at Kilmore, south of Ballybunion.

Surface water quality monitoring has historically been conducted at Listowel Bridge c. 330m away and downstream of the site. The most recent biological Q-Rating for surface water quality at this location (2017) was Q4, Good status. Upstream monitoring close to the site has not been historically conducted. The nearest EPA surface water monitoring station is located between 5-6km upstream of Listowel Bridge, and the most recent q-rating assigned was Q4/Good in 2017.

2.2.8 Ecology

The site is not located within any Natural Heritage Area (NHA), proposed NHA (pNHA), Special Area of Conservation (SAC) or Special Protection Area (SPA). The River Feale however is part of the Lower River Shannon SAC (Site Code: 002165) and is located <200m from the site. The River Feale is also a designated salmonid river. The River Feale eventually forms the Cashen River downstream and Cashen Estuary which is a pNHA (Site Code: 001340).

The ecology protected areas mapping is presented in Figure 2.7

2.2.9 Site History

The earliest historical map available on the OSI website dates from 1837-1842. Review of this map shows that portions of the site were historically used for quarrying. These areas correspond with area of bedrock outcrop shown on geological mapping discussed above. A fort or mound is also indicated to be present within the southern portion of the site between the two quarrying areas. The latter 1888-1913 OSI historical mapping also display quarrying activity at the site, primarily along the eastern boundary and northern portion of the site. The remainder of the site is characterised as being mixed coniferous and deciduous woodland. A water reservoir (Listowel Water Works) was historically located directly south of the site, close to the River Feale.

OSI historical mapping presented in Figure 2.8.

2.2.10 Existing Geological Heritage

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

The geological heritage mapping is presented in Figure 2.9.

2.2.11 Existing Geotechnical Stability

The GSI landslides database indicates that there are no recorded geo-hazards within the site boundary or in the surrounding area or region.

2.2.12 Archaeological Heritage

Review of the 1837-1842 and 1888-1913 OSI historical maps for the area do not indicate the presence of any significant archaeological features. The 1837-1842 mapping did indicate the presence of a fort or mound however this was no longer displayed on the 1888-1913 maps. A disused lime kiln was located <10m east of the site. A historical reservoir identified as Listowel Water Works were also located directly south of the site. Review of the Department of Arts, Heritage, Regional, Rural and Gaeltacht Affairs' online historic environment viewer/database indicates the presence of a ringfort – rath within the site. This corresponds with the fort/mound shown in the 1837-1842 OSI map. The historic environment viewer does note that the site was completely destroyed, and a quarry was developed in its place.

Path: R:\Map Production\2019\P1766\Workspace\Listowel\Tier 2 ERA Report\P1766_Fig2-7_EcologicallyProtectedAreas_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), (c) OpenStreetMap contributors, and the GIS User Community
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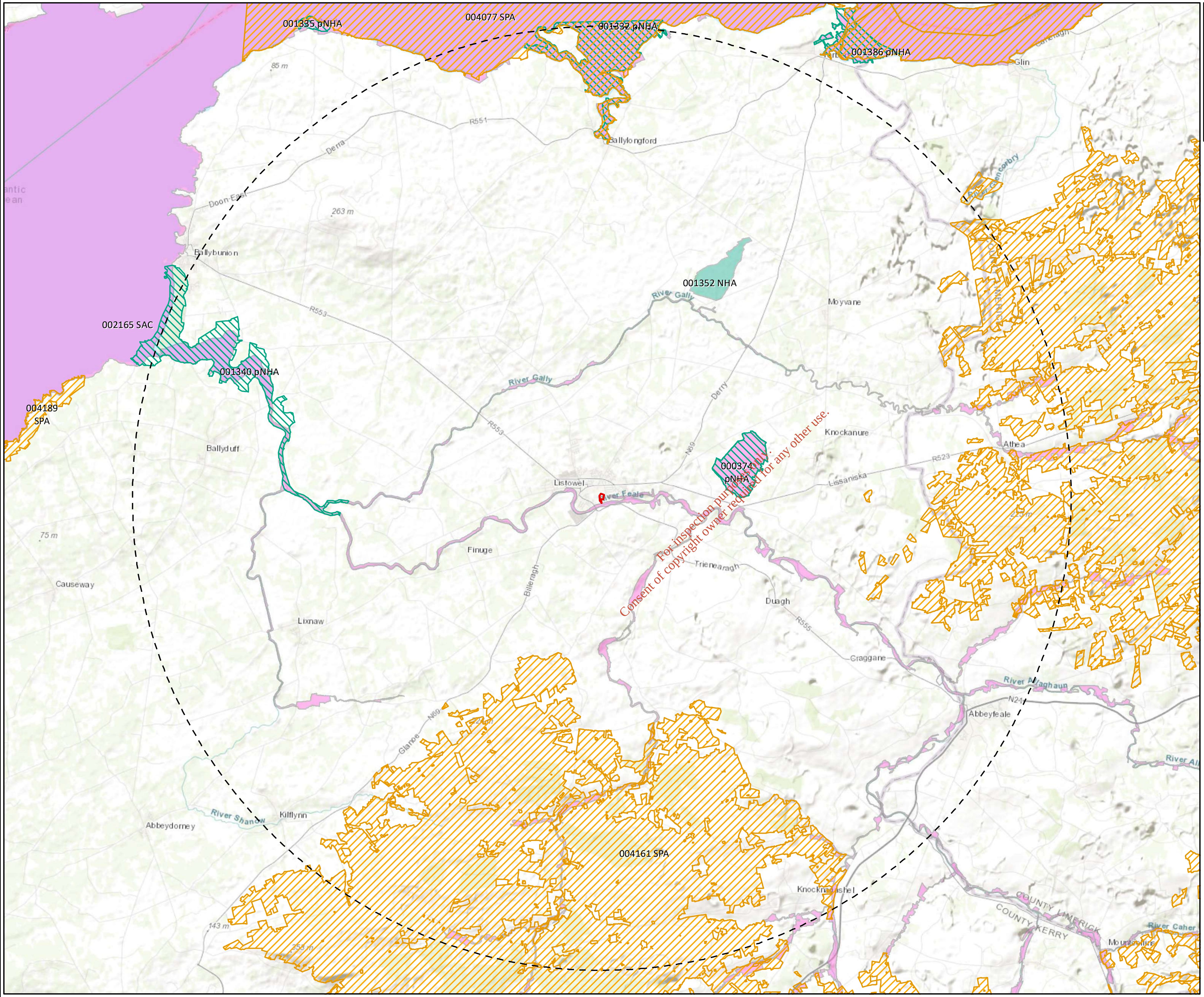

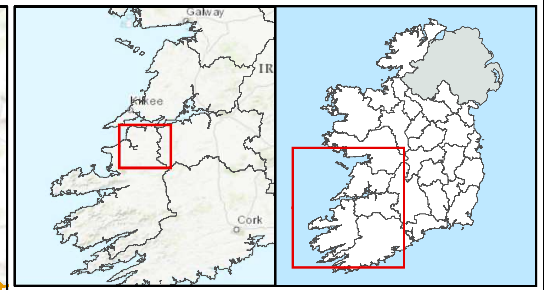

Legend
Site Boundary
15km Distance from Site Boundary
Special Protection Area (SPA)
Proposed Natural Heritage Area (pNHA)
Special Area of Conservation (SAC)
Natural Heritage Area (NHA)

TITLE: Ecologically Protected Areas

PROJECT: Environmental Risk Assessment for Listowel Landfill, Co. Kerry

FIGURE NO:	2.7		
CLIENT:	Kerry County Council		
SCALE:	1:120000	**REVISION:**	0
DATE:	25/10/2019	**PAGE SIZE:**	A3

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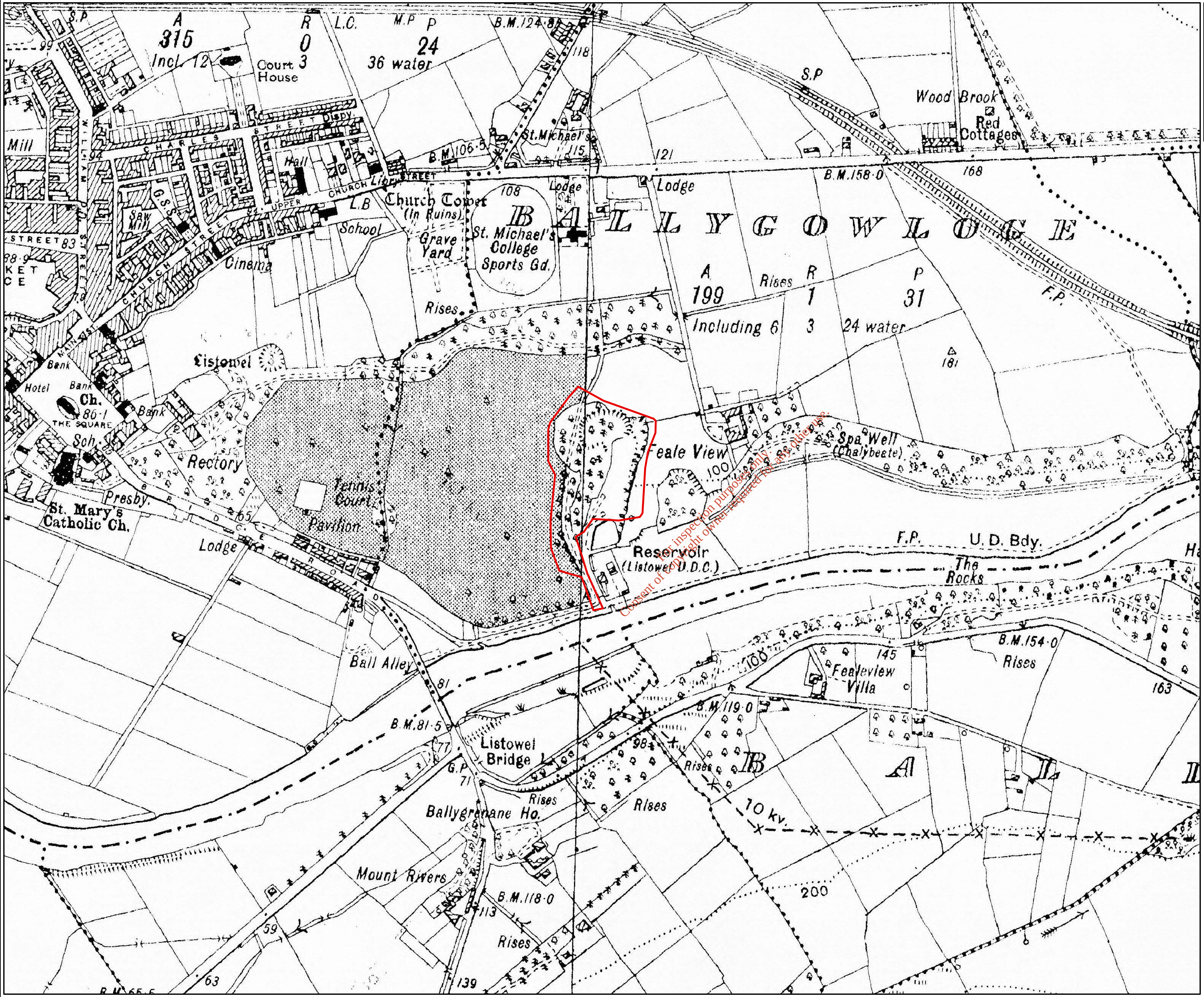

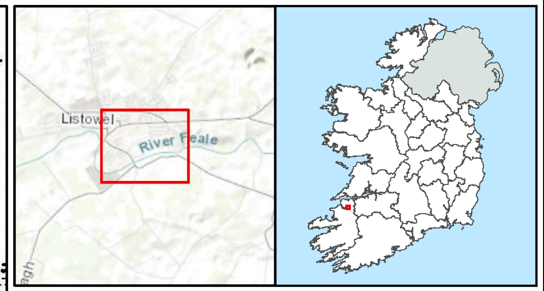

Site Boundary

TITLE:	OSi Historical Mapping
PROJECT:	Environmental Risk Assessment for Listowel Landfill, Co. Kerry
FIGURE NO:	2.8
CLIENT:	Kerry County Council
SCALE: 1:5000	**REVISION:** 0
DATE: 25/10/2019	**PAGE SIZE:** A3

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Meters
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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), (c) OpenStreetMap contributors, and the GIS User Community
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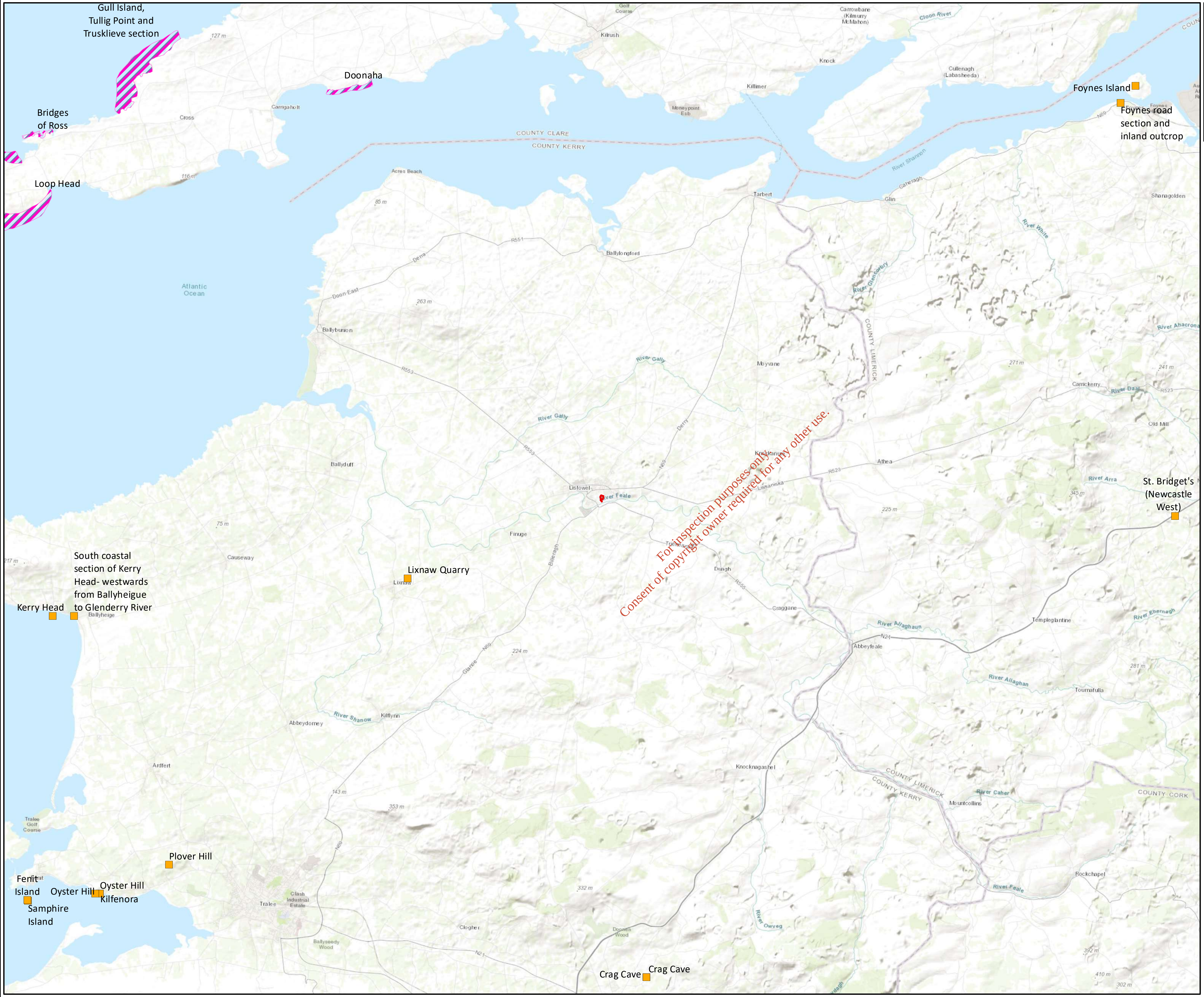

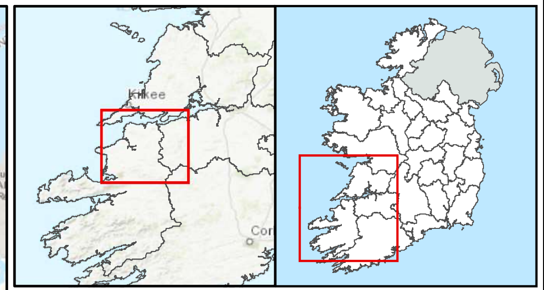

Geological Heritage Sites

Geological Heritage Sites (Audited)

Site Boundary

TITLE: Geological Heritage	
PROJECT: Environmental Risk Assessment for Listowel Landfill, Co. Kerry	
FIGURE NO: 2.9	
CLIENT: Kerry County Council	
SCALE: 1:175000	**REVISION:** 0
DATE: 25/10/2019	**PAGE SIZE:** A3

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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:

- 2 No. boreholes by rotary drilling methods
- 2 No. standpipe installations
- 8 boreholes by dynamic (windowless) sampling methods
- 1 No. Geophysical survey (2D resistivity, EM31 Ground Conductivity and seismic refraction profiling)
- Topographical Survey
- Factual reporting

The locations of the intrusive works at the site are presented in **Error! Reference source not found.**.

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 at 14TH February 2019, prior to site investigation works by an FT 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 KCC.

Since landfilling activities have ceased has been utilised as a town park, the Garden of Europe. As outlined in Section 1.1 the Garden of Europe is an award-winning area of cultural heritage. The park contains more than 3,000 trees and shrubs, numerous pieces of sculpture artwork and the only public monument in memory of those who died in the Holocaust in Ireland.

The site covers an area of c.1.01 ha is located at the edge of the town of Listowel with the River Feale flowing along the southern boundary of the site. There are no residential dwellings located within the subject site however there is a housing development located 150m north-east of the site.

The KCC works/storage yard at the south east of the site was noted during the site walkover noted to contain machinery and equipment. Leachate seepage was noted on the ground surface within the KCC works/storage yard with photos provided in Appendix 4 of this report.

No immediate wetland, protected areas, public water supplies or other buildings identified, however local usage private wells might be present.

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

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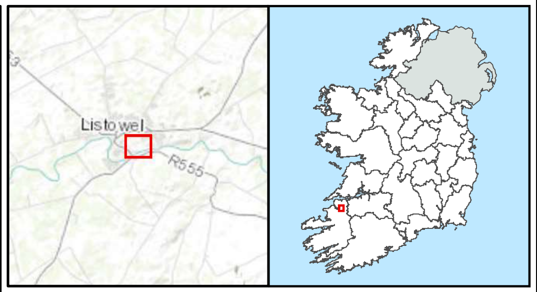

Borehole

Site Boundary

TITLE:	Site Investigation Location Plan
PROJECT:	Environmental Risk Assessment for Listowel Landfill, Co. Kerry
FIGURE NO:	3.1
CLIENT:	Kerry County Council
SCALE: 1:2500	**REVISION:** 0
DATE: 13/11/2019	**PAGE SIZE:** A3

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3.1.2 Window Samples

A Causeway Geotech (CGL) Engineering Geologist supervised the advancement of 8 No. window samples, shown in Figure 3.1, between 13th and 15th August 2019.

The window sampling technique was chosen for this site due to its currently land use as a town park.

The window samples (WS01 to WS08) were advanced to depths of between 3.3m to 6.0m below existing ground level (BGL) using a Dando Terrier dynamic sampling rig. Hand dug inspection pits were carried out between ground level and 1.20m depth to ensure window samples were put down clear of services or subsurface obstructions.

The geophysical survey used in conjunction with the profiles identified during window sampling 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 Condition

Window Sample ID	Depth of cover material (m BGL)	Depth to base of made ground/waste (m BGL)	Profile Description
WS01	0.0 – 0.15 (Topsoil) 0.15 – 0.60 (Made Ground) 0.6 – 1.20 (Clay) 1.20 – 2.0 (Gravel) 1.0 – 3.0 (Gravel) 3.0 – 4.20 (Gravel)	4.20 (base of excavation - terminated due to very dense gravel)	Topsoil; Sandy silty GRAVEL of mixed lithologies; Very soft slightly gravelly sandy CLAY; Sandy GRAVEL of mixed lithologies; Sandy silty GRAVEL of mixed lithologies; Sandy silty GRAVEL of mixed lithologies.
WS02	0.0 – 0.10 (Topsoil) 0.10 – 1.0 (Made Ground) 1.0 – 3.0 (Made Ground) 3.0 – 6.0 (Made Ground)	6.0 (base of excavation – terminated at scheduled depth)	Topsoil; Sandy gravelly CLAY with fragments of timber, plastic and glass; Plastic, cotton, rubber and ceramic with bands of SILT, (no recovery) and a very strong hydrocarbon odour present; Soft sandy gravelly SILT with fragments of concrete, plastic, glass and rope.
WS03	0.0 – 0.10 (Topsoil) 0.10 – 1.20 (Made Ground) 1.20 – 2.50 (Made Ground)	5.0 (base of excavation – terminated due to obstruction)	Topsoil; Sandy gravelly Clay with fragments of glass and plastic; Plastic, glass, rope, wire with bands of SILT (poor recovery) and strong hydrocarbon odour present;

Window Sample ID	Depth of cover material (m BGL)	Depth to base of made ground/waste (m BGL)	Profile Description
	2.50 – 5.0 (Made Ground)		Sandy gravelly SILT with fragments of plastic and glass.
WS04	0.0 – 0.20 (Topsoil) 0.20 – 1.20 (Silt) 1.20 – 2.0 (Silt) 1.0 – 3.0 (Silt) 3.0 – 3.80 (Silt)	3.80 (base of excavation – terminated due to obstruction)	Topsoil; Slightly gravelly sandy SILT; Sandy gravelly SILT; Slightly gravelly sandy SILT; Sandy gravelly SILT.
WS05	0.0 – 0.10 (Topsoil) 0.10 – 1.0 (Made Ground) 1.0 – 6.0 (Made Ground)	6.0 (base of excavation – terminated at scheduled depth)	Topsoil; Sandy gravelly CLAY with fragments of plastic and glass and a very strong hydrocarbon odour present; Plastic, glass, metal and heavy hydrocarbon with a SILT matrix (very poor recovery).
WS06	0.0 – 0.20 (Topsoil) 0.20 – 0.50 (Sand) 0.50 – 1.20 (Silt) 1.20 – 2.0 (Silt) 2.0 – 3.30 (Silt)	3.30 (base of excavation – terminated due to obstruction)	Topsoil; Gravelly silty fine to medium SAND; Stiff sandy gravelly SILT; Stiff sandy gravelly SILT; Very stiff slightly gravelly sandy SILT.
WS07	0.0 – 0.15 (Topsoil) 0.15 – 1.0 (Made Ground) 1.0 – 6.0 (Made Ground)	6.0 (base of excavation – terminated at scheduled depth)	Topsoil; Very soft sandy gravelly CLAY with fragments of plastic and glass, with a very strong hydrocarbon odour present; Plastic, glass, copper and wire in a SILT matrix (very poor recovery).
WS08	0.0 – 0.10 (Topsoil) 0.10 – 1.0 (Made Ground) 1.0 – 3.80 (Made Ground) 3.8 – 5.0 (Silt) 5.0 – 6.0 (Silt)	6.0 (base of excavation – terminated at scheduled depth)	Topsoil; Very soft sandy gravelly CLAY with fragments of bitmac, red brick, glass and plastic; Timber, plastic, wool and glass in a SILT matrix (very poor recovery); Very soft slightly sandy gravelly SILT; Soft to firm slightly gravelly very sandy SILT.

Made ground comprising waste was encountered in 5 No. window samples (WS02, WS03, WS05, WS07 and WS08). No bedrock encountered.

Waste material was encountered between 0.10m – 6.0m in window samples WS02, WS03, WS05, WS07 and WS08. No groundwater was encountered.

Natural ground comprising of quaternary glacial till was confirmed in 2 No. window samples (WS04 and WS06).

3.1.3 Waste Sampling

A total of 2 No. samples of the made ground / waste at the site was collected from window samples WS03 (southern portion of the site) and WS08 (advanced in the northern portion of the site).

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

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

The results are discussed in Section 4.2.

3.1.4 Evidence of Contamination

The window samples excavation works identified waste material tending to the eastern site boundary with thicknesses ranging from 0.10 – 6.0m BGL. Evidence of waste material was identified in 5 No. window samples locations (WS02; WS03; WS05; WS07 and WS08). The waste encountered was described as timber, plastic, glass, cotton, rubber, ceramic, concrete, rope, wire, metal, fragments of bitmac, red brick and wool.

Waste was not encountered in the perimeter window samples WS01, WS04 and WS06 advanced in the west and south of the site. The base of the waste material was reached only in window sample WS08 at the termination depth of 3.8m BGL. The other samples (WS02, WS05 and WS07) waste material was found up to 6.0m BGL and window sample WS03 at 5.0m BLG, where the excavations terminated.

As noted, most of the Made Ground waste material encountered comprised sandy gravelly Clay and sandy gravelly Silt mixed with waste material.

3.1.5 Geophysical Investigation

Minerex Geophysics Ltd (MGX) were instructed by FT to undertake a geophysical investigation of the site. The survey was carried out on the 3rd and 12th of April 2019. The MGX geophysical survey report is included in Appendix 5.

The geophysical survey consisted of reconnaissance EM Ground Conductivity Mapping with follow-up 2D Resistivity Profiling (RT) and Seismic Refraction Profiling. A total of 330m for Resistivity Profiling (RT) and 327m for Seismic Refraction Profiling of geophysical profiles were collected. The geophysical survey was used to estimate a general profile of the buried waste above the in-situ bedrock.

The survey located a waste body within an historic quarry in the NE of the site.

The extent of the historic landfill is estimated at 8,900 m^2, its depth is about 11m below ground level which gives a total volume of 98,000 m^3 including fill material placed on top of the landfill and basal leachate. The low resistivities and seismic velocities measured were noted as consistent with commercial and domestic waste rather than C&D type.

MGX recorded RT profiles data along 3 designated profiles due to the elongated nature of the site. RT profiles named R1, R2 and R3, and three seismic refraction profiles (S1- S3) were recorded across the site. See Figure 3.2.

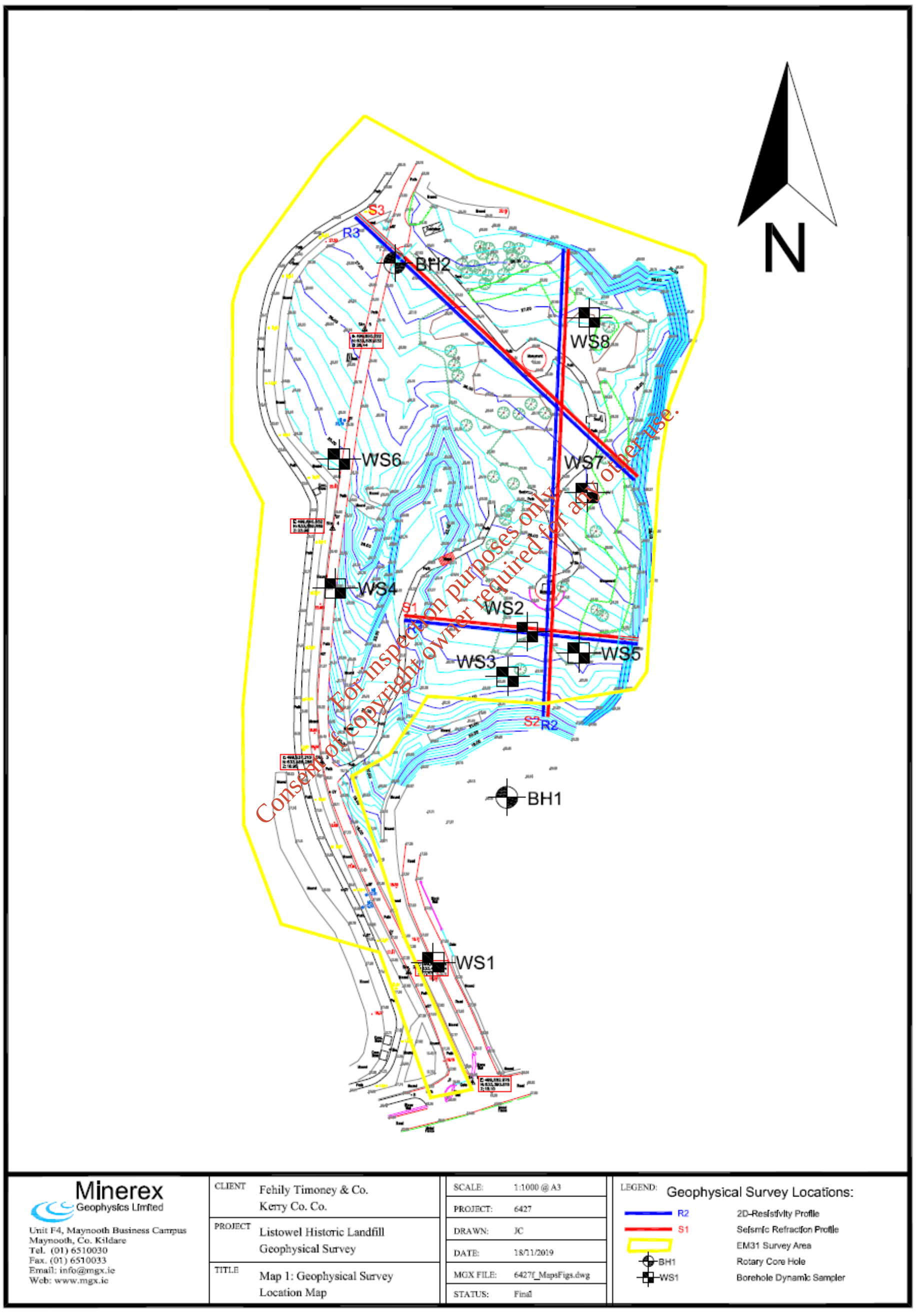


Figure 3.2: Geophysical Survey Location Map

Results

The geophysical survey succeeded in validating the general location of the waste material. Both the elevated EM conductivity readings in combination with the window sample logs show the waste to be present within most of the survey area.

There is a clear area in the middle of the site where conductivity is above 30 mS/m. Most of the surrounding area has a conductivity range of 10 – 30 mS/m while in some areas the conductivity drops below 10 mS/m. The area with conductivities above 30 mS/m indicates waste material while the surrounding area with conductivities of 10 – 30 mS/m may consist of waste material or clay rich overburden. Areas where conductivities are below 10 mS/m are likely natural overburden or man-made overburden without typical waste material.

Throughout most of the three profiles to a depth of roughly 11m below ground level the resistivities are below 125 Ohmm which would indicate waste material. In some areas such as the start and end of profile R1 and the start of profile R3 there are resistivities of between 125 and 350 Ohmm which likely shows natural overburden or non-waste manmade overburden.

At the beginning of profile R1, the resistivities decrease with depth before increasing again. This may be due to leachate within the overburden but may also be waste material with overburden fill above it. Below 11 m throughout the three profiles, resistivities rise rapidly above 350 Ohmm which would indicate fresh limestone.

As the profiles do not extend past the edge of the landfill, no information lateral leachate has been obtained.

A layered ground model was created from the modelled seismic data (See Figure 3.5):

Layer 1 has a seismic velocity range of 200 m/s and 250 m/s and is found in most of the survey area. This velocity would represent landfill material which has a lower velocity than the surrounding natural ground.

Layer 2 has a seismic velocity range of 400 and 2200 m/s. This layer in interpreted as natural overburden material, in this case sandy gravelly Clay or Silt and it is found only in some areas, such as start and end of profile R1 and start of profile R3.

Layer 3 is interpreted as fresh Limestone and is found in most of the survey area, under layers 1 and 2. This layer has N/A seismic velocity.

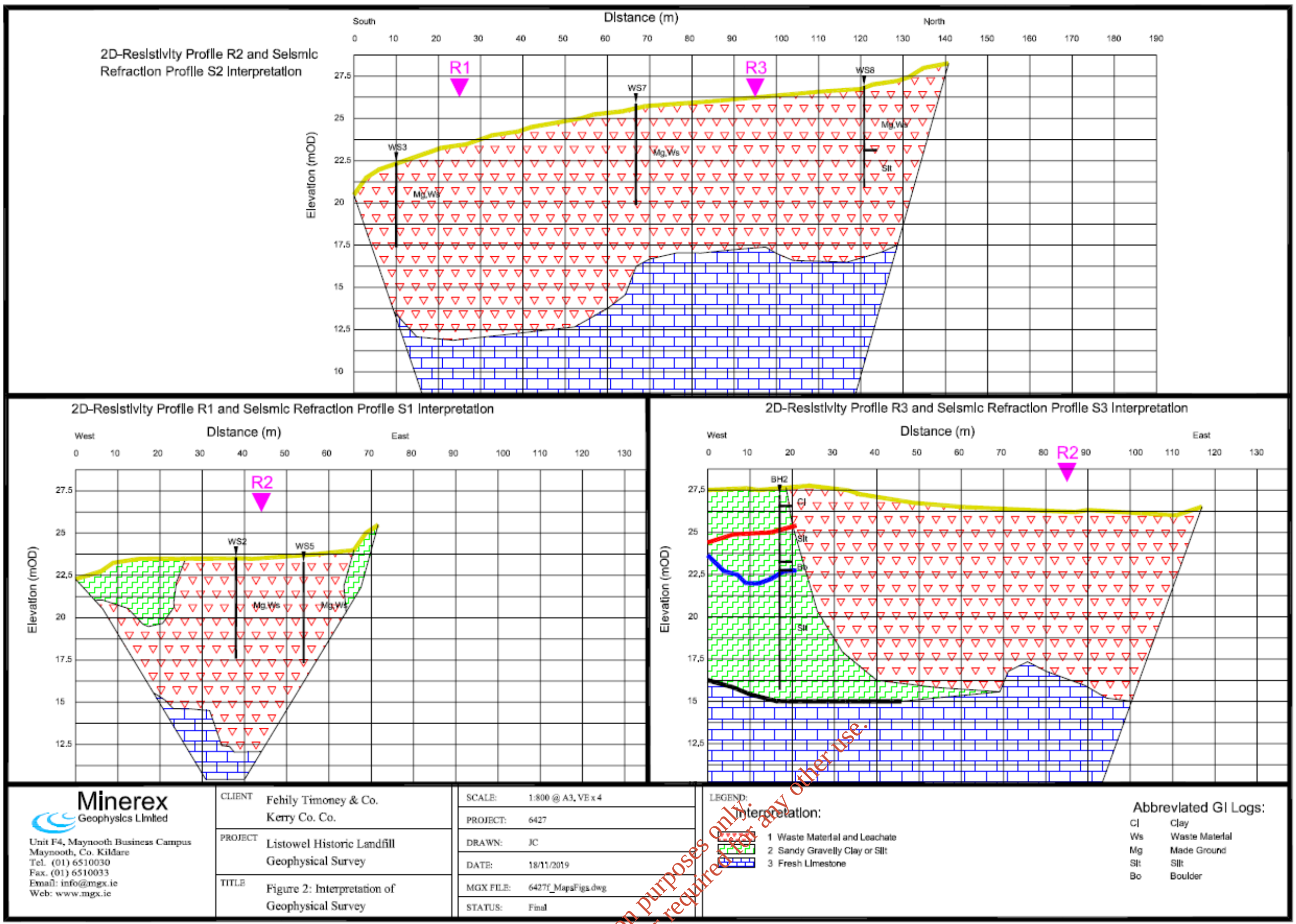


Figure 3.3: Interpretation of Geophysical Survey

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 ground conductivity and 2D-Resistivity show the area where landfill material is present. The interpreted landfill extent covers an area of approx. 8,900 m^2.

The depth of waste has been estimated from 2D-Resistivity, an average thickness of 11m has been calculated for the landfill material. The estimate includes capping or natural fill material on top of the main waste body and basal leachate and therefore may be considered estimate.

An initial volume calculation based on site investigation estimates an interred waste volume of approximately 98,000m^3 at the site. Assuming a waste density of 1.4 tonne/m^3 this equates to approximately 137,200 tonnes of waste. Information obtained and provided by KCC within the Tier 1 risk assessment suggests the deposition of c.37,000 tonnes at the site.

The maximum anticipated waste footprint is presented in Figure 3.3.

MGX note that possible leachate movement was identified at the start of profile R1 where low resistivities below higher resistivities were found.

As the profiles do not extend past the edge of the landfill, no information lateral leachate has been obtained. The limestone below the landfill generally has high resistivities which indicates that there is little or no leachate movement below the landfill. Closer to the surface leachate may move through the overburden.

3.1.7 Borehole Installation and Groundwater Sampling

Two boreholes (BH01 and BH02) were drilled to depths of, respectively, 7.0m bgl and 11.50m BGL at the site. The boreholes were drilled for installing groundwater monitoring installations.

The purpose of the boreholes was to intercept and define the groundwater flow direction upstream and downstream of the identified waste body.

Groundwater monitoring was undertaken in boreholes BH01 and BH02 on 3rd September 2019. 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 13th and 15th August 2019 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 sample from WS08 was 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 CGL in Appendix 2 of this report.

Permeability testing by triaxial compression was also completed on soil sample submitted from window sample WS08. 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 result of the permeability testing is shown below in Table 3.2:

Table 3.2: Permeability Results

Sample ID	K (m/s)
WS08	$1.5x10^{-10\ m/s}$

In accordance with the EPA Landfill Site Design Manual an engineered capping material should have a permeability less than or equal to 1 x 10^{-9} m/s to minimise infiltration of rainwater into the waste body. The permeability result of the capping material at site is below the EPA guidance however only minimal depths are noted and not in all window sample locations.

4. ENVIRONMENTAL ASSESSMENT

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

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, 2019 (S.I. No. 77 of 2019).
- European Communities Environmental Objectives (Surface Waters) (Amendment) Regulations, 2015 (S.I. No. 386 of 2015).
- 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).

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 being either inert, non-hazardous or hazardous material.

4.2.1 Chemical Results for Waste 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 Listowel Historic Landfill is outlined in Table 4.1 below, while the laboratory reports are presented in Appendix F of the CGL Ground Investigation report, Appendix 2 of this report.

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	
					WS03 (2.5m)	WS08 (3.8m)
Arsenic	l.kg^{-1}	**0.5**	2	25	0.0022	< 0.0010
Barium	l.kg^{-1}	**20**	100	300	0.14	0.0065
Cadmium	l.kg^{-1}	**0.04**	1	5	< 0.00010	< 0.00010
Chromium	l.kg^{-1}	**0.5**	10	70	0.0013	< 0.0010
Copper	l.kg^{-1}	**2**	50	100	0.0015	0.0027
Mercury Dissolved	l.kg^{-1}	**0.01**	0.2	2	< 0.00050	< 0.00050
Molybdenum	l.kg^{-1}	**0.5**	10	30	0.031	0.0065
Nickel	l.kg^{-1}	**0.4**	10	40	0.0057	0.0011
Lead	l.kg^{-1}	**0.5**	10	50	< 0.0010	< 0.0010
Antimony	l.kg^{-1}	**0.06**	0.7	5	0.0042	< 0.0010
Selenium	l.kg^{-1}	**0.1**	0.5	7	0.0028	0.0016
Zinc	l.kg^{-1}	**4**	50	200	0.020	< 0.0010
Chloride	l.kg^{-1}	**800**	15000	25000	16	1.9
Fluoride	l.kg^{-1}	**10**	150	500	0.23	0.35
Sulphate	l.kg^{-1}	**1000**	20000	50000	440	20
Total Dissolved Solids	l.kg^{-1}	**4000**	60000	100000	780	150
Phenol Index	l.kg^{-1}	**1**	--	--	< 0.030	< 0.030
Dissolved Organic Carbon	l.kg^{-1}	**500**	800	1000	35	20
Total Organic Carbon	%	3	5	6	15	0.23
Loss on Ignition	%	--	--	10	25	2.9
Total BTEX	mg/kg	**6**	--	--	< 0.010	< 0.010
Total PCBs (7 Congeners)	mg/kg	**1**	--	--	< 0.10	< 0.10
TPH Total WAC (Mineral Oil)	mg/kg	**500**	--	--	< 10	< 10
Total (Of 17) PAH's	mg/kg	**100**	--	--	< 2.0	< 2.0
pH		--	>6	--	8.1	7.8
Acid Neutralisation Capacity	mol/kg	--	To evaluate	To evaluate	0.010	0.0070

* Hazardous Waste Landfill Criteria: >6% TOC

* Items in **bold** are in exceedance of the Inert WAC limit value

* Items shaded in **green** are in exceedance of the Non-Hazardous WAC limit value

* Items shaded in **orange** are in exceedance of the Hazardous WAC limit value

4.2.2 Waste Classification

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, except for TOC and Loss on Ignition, indicating a high level of degradation over time since landfilling activities ceased at the site. The Total Organic Carbon and Loss on Ignition results indicate a higher presence of organic material within this sample. Organic carbon may be present from natural decay of organic matter present (waste or naturally occurring) or from anthropogenic sources (materials, chemicals) containing organic carbon (waste). However, it cannot be confirmed exactly what type of waste or what material may have been present that could give rise to an elevated TOC and Loss on Ignition result.

4.3 Groundwater Analysis

One round of groundwater quality monitoring was undertaken at the site on the 3rd September 2019. 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 3rd September 2019 are calculated below.

Table 4.2: Groundwater Depth Analysis

Borehole ID	Location Gradient	Dip (m) 03/09/19	Groundwater Level (m AOD)
BH01	Down gradient	0.61	17.55
BH02	Upgradient	7.8	19.41

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

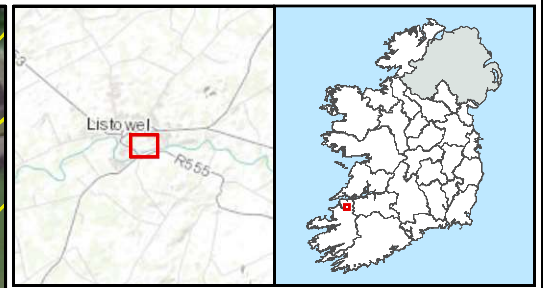
Based on the above field survey measurements, the groundwater flow direction is assumed to be north to south. A potentiometric map illustrating the hydraulic gradient and the direction of groundwater flow is presented in Figure 4.1.

4.3.2 Groundwater Borehole Position

The location of the groundwater boreholes installed at the site where based on the anticipated groundwater flow direction. A desktop analysis of the site in tandem with a site walkover estimated that the likely groundwater flow direction was North to South based on the location of the Feale River.

The results of groundwater monitoring indicate a north to south groundwater flow direction.

Path: R:\Map Production\2019\P1766\Workspace\Listowel\Tier 2 ERA Report\P1766_Fig4-1_GWFlowDirection_A3.mxd



- Borehole Locations
- Groundwater Flow Direction
- Site Boundary
- 1m Contours

TITLE: Groundwater Flow Direction	
PROJECT: Environmental Risk Assessment for Listowel Landfill, Co. Kerry	
FIGURE NO: 4.1	
CLIENT: Kerry County Council	
SCALE: 1:2500	**REVISION:** 0
DATE: 31/10/2019	**PAGE SIZE:** A3

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4.3.3 Groundwater Quality Monitoring

The results of groundwater samples analysed from the 2 No. boreholes (BH01 and BH02) at the site have been assessed against the EPAs Interim Guideline Values (IGVs) and S.I No. 9 of the European Communities Environmental Objectives (Groundwater) Regulations 2010 (amended). A summary of the maximum results reported for each parameter for the monitoring rounds 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 2010 Standards [2]	BH01	BH02
pH	pH units	**6.5 - 9.5**	**--**	7.67	7.93
Conductivity	mS/cm	**1**	**1.875**	**1.49**	0.424
Dissolved solids, Total (meter)	mg/l	**1000**	**--**	**1170**	343
Dissolved Oxygen	mg/l	**no abnormal change**	**--**	3.31	8.63
Alkalinity as CaCO3	mg/l	**200**	**--**	**660**	**320**
Ammoniacal Nitrogen as N	mg/l	**0.15**	**0.175**	**26.1**	**0.313**
Total Coliforms	cfu/100 ml	**0**	**--**	-	-
Nitrite as N	mg/l	**--**	**0.375**	-	-
BOD	mg/l	**--**	**--**	-	-
COD	mg/l	**--**	**--**	-	-
Sodium	mg/l	**150**	**150**	119	22.8
Sulphate as SO4	mg/l	**200**	**250**	-	-
Total Oxidised Nitrogen	mg/l	**--**	**--**	<0.1	<0.1
Total Organic Carbon	mg/l	**--**	**--**	24.5	9.49
Arsenic	µg/l	**7.5**	**10**	**12.4**	0.934
Barium	µg/l	**--**	**100**	164	8.61
Boron	µg/l	**750**	**1000**	189	197
Cadmium	µg/l	**3.75**	**5**	<0.08	<0.08
Calcium	mg/l	**--**	**200**	156	64.5
Chloride	mg/l	**30**	**24**	**214**	22.5
Chromium	µg/l	**30**	**37.5**	<1	<1
Copper	µg/l	**30**	**1500**	<0.3	2.46
Cyanide	mg/l	**0.01**	**0.038**	<0.05	<0.05
Fluoride	mg/l	**0.8**	**1**	<0.5	<0.5
Iron	mg/l	**0.2**	**--**	**12.3**	0.171

Parameter	Units	EPA IGV Standards [1]	S.I. No. 9 of 2010 Standards [2]	BH01	BH02
Lead	µg/l	**10**	**7.5**	0.261	0.473
Magnesium	mg/l	**50**		48.2	6.66
Manganese	µg/l	**50**	**--**	**1310**	**1250**
Mercury	µg/l	**1**	**0.75**	<0.01	-
Nickel	µg/l	**20**	**15**	3.79	1.72
Phosphorus	µg/l	**--**	**--**	20.1	32.1
Potassium	mg/l	**5**	**--**	**29.7**	1.42
Uranium	mg/l	**0.009**	**--**	-	-
Zinc	µg/l	**100**	**75**	8.6	8.03
Mineral Oil	µg/l	**10**	**--**	<100	**3340**
MTBE	µg/l	**30**	**10**	<1	<1
Semi-Volatile Organic Compounds (SVOCs)					
1,2,4-Trichlorobenzene	µg/l	**0.40**	**--**	<0.01	<0.01
2,4,6-Trichlorophenol	µg/l	**200**	**--**	<2	<20
2-Chlorophenol	µg/l	**200**	**--**	<2	<20
Benzo(k)fluoranthene	µg/l	**0.05**	**--**	<2	<20
Hexachlorobenzene	µg/l	**0.03**	**--**	<2	<20
Hexachlorobutadiene	µg/l	**0.1**	**--**	<2	<20
Nitrobenzene	µg/l	**10**	**--**	<2	<20
n-Nitroso-n-dipropylamine	µg/l	**--**	**--**	<2	<20
Pentachlorophenol	µg/l	**2**	**--**	<2	<20
Phenol	µg/l	**0.5**	**--**	<2	<20
Combined Pesticides / Herbicides					
Aldrin	µg/l	**0.01**	**--**	<0.01	<0.01
Atrazine	µg/l	**1**	**0.075**	<0.01	<0.01
Chlorfenvinphos	µg/l	**5**	**--**	<0.01	<0.01
Dichlorvos	µg/l	**0.001**	**--**	<0.01	<0.01
Dieldrin	µg/l	**--**	**0.075**	<0.01	<0.01
Permethrin I	µg/l	**20**	**--**	<0.01	<0.01
Permethrin II	µg/l	**20**	**--**	<0.01	<0.01
Simazine	µg/l	**1**	**0.075**	<0.01	<0.01
4,4 – DDT	µg/l	**--**	**0.075**	-	-
Organics					
Benzo(alpha)pyrene	µg/l	**0.01**	**0.0075**	<2	<20
Vinyl Chloride	µg/l	**0.375**	**0.375**	<1	<1

Parameter	Units	EPA IGV Standards [1]	S.I. No. 9 of 2010 Standards [2]	BH01	BH02
Benzene	µg/l	1	0.75	<1	<1
Total Trichloroethane	µg/l	500	--	<1	<1
Total Tetrachloroethene	µg/l	40	7.5	<1	<1
1,2-Dichloroethane	µg/l	3	2.25	<1	<1
Volatile Organic Compounds (VOCs)					
Naphthalene	µg/l	1	0.075	**1.29**	<1

[1] IGV-Interim Guideline Values, from EPA, Towards Setting Guideline Values for the Protection of Groundwater in Ireland, 2003.

[2] OTV-Overall threshold value, European Communities Environmental Objectives (Groundwater) Regulations, 2010 (S.I. No. 9 of 2010) as amended in 2011, 2012, 2016.

* Items shaded in **bold** are in exceedance of the 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 BH01 and BH02 have reported several exceedances of the IGVs and European Groundwater limit values.

Samples recovered monitoring wells BH01 and BH02 reported ammonia concentrations of 26.1 mg/l and 0.313 mg/l respectively, which exceed guideline threshold values. Ammonia concentration at upgradient borehole BH02 (0.313 mg/l) is considered representative of background levels possibly due to agricultural activities. Considering that the ammonia concentration of 26.1 mg/l recorded at BH01 is significantly greater than upgradient levels, the historic landfill is impacting downgradient water quality due to the significant ammonia concentration differences between upgradient and downgradient monitoring locations.

Iron concentration of 12.3 mg/l at borehole BH01 is significantly greater than the groundwater threshold values, which is also observed for Chloride (214 mg/l), Potassium (29.7 mg/l), Arsenic (12.4 µg/l) and Naphthalene (1.29 µg/l). The high concentrations of inorganic and metals on borehole BH01 (downstream) could be a result of leachate migration from the landfill, due to its location within the waste body.

Elevated alkalinity ($CaCO_3$) is found on both sampling locations and could be a factor of local bedrock hydrochemistry, as well as conductivity and dissolved solids. Elevated manganese concentrations of 1310 µg/l to 1250 µg/l on both BH01 and BH02 monitoring wells is considered to be a background value and the source could not be identified.

Mineral oil is 33-times above the limit in the upgradient borehole BH02. A such it is considered the source is not due to landfill leachate migration and its source could not be identified. A potential source of hydrocarbon contamination at the site could be attributed to the use of maintenance plant and machinery within the site.

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.

Based on the presence of elevated ammonia and dissolved metal 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 therefore contributing to leachate migration from the landfill.

4.4 Landfill Gas Monitoring

FT carried out monitoring of landfill gas (LFG) parameters at each monitoring borehole location (BH01 and BH02) as indicated on Figure 3.1. In accordance with the EPA CoP, methane, carbon dioxide, oxygen and atmospheric pressure were analysed at the 2 No. groundwater monitoring wells located outside 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 perimeter borehole are summarised in Table 4.4.

Table 4.4: Perimeter Well Monitoring Results October 2019

Date: 23/10/2019						
Sample Station	CH_4	CO_2	O_2	Atmospheric Pressure	Staff Member	Weather
	(% v/v)	(% v/v)	(% v/v)	(mbar)		
BH01	0.6	0.4	24.5	1005	Emily Archer	Overcast, heavy rain showers, 10-14°C
BH02	0.4	0.3	23.6			

As can be seen in Table 4.4, concentrations of both CO_2 and CH_4 at both monitoring boreholes BH01 and BH02 were below the threshold values set by the CoP during both monitoring rounds.

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 upstream location on Feale river to the south of the landfill. Monitoring location SW2 samples a downstream point of the Feale river.

One round of surface water monitoring was carried out on the 3rd September 2019. The surface water sampling locations at the site are presented in Figure 4.2.

4.5.2 Monitoring Parameters

The results of surface water sampling analysed from the 2 No. sampling locations (SW01 and SW02) at the site have been assessed against the Maximum Admissible Concentration (MAC) Regulations (1989) and the Environmental Quality Standard (EQS) for Surface Waters Regulations (2019) assessment criteria.

A summary of the maximum values reported for each parameter from the monitoring round 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]	Upstream	Downstream
				SW01	SW02
				03.09.2019	03.09.2019
Inorganics					
Ammoniacal Nitrogen as N	mg/l	--	**≤0.140 (95%ile)**	<0.2	<0.2
Conductivity @ 20 deg.C	mS/cm	**1**	--	0.113	0.119
Fluoride	mg/l	**0.5**	--	<0.5	<0.5
Dissolved Oxygen	mg/l	--	**95%ile>80% saturation, 95%ile<120% saturation**	10.8	10.5
pH	pH Units	--	**6.0-9.0**	7.19	7.1
Phosphate (Ortho as PO4)	mg/l	**0.5**	--	<0.05	<0.05
Chloride	mg/l	**40**	--	19.3	19.2
COD, unfiltered	mg/l	**250**	--	41.3	45.3
Total Cyanide	mg/l	**0.01**	--	<0.05	<0.05
BOD, unfiltered	mg/l	--	**≤2.6 (95%ile)**	-	-
Total Alkalinity as CaCO3	mg/l	--	--	24.4	18.7
Total Suspended Solids	mg/l	**50**	--	<4	4.47
Total Oxidised Nitrogen as N	mg/l	**2**	--	0.997	1.15
Sulphate (soluble) as S	mg/l	**200**	--	<1	1.73
Total Organic Carbon	mg/l	**NAC****	--	13	15.8
Dissolved Metals (Filtered)					
Mercury (diss.filt)	µg/l	--	**0.07**	<0.01	<0.01
Arsenic (diss.filt)	µg/l	--	**25**	<0.5	<0.5
Barium (diss.filt)	µg/l	**1**	--	2.92	2.86
Boron (diss.filt)	µg/l	**2**	--	<10	10.5
Cadmium (diss.filt)	µg/l	**0.45**	**0.08**	<0.08	<0.08

Parameter	Units	MAC[1]	EQS[2]	Upstream SW01 03.09.2019	Downstream SW02 03.09.2019
Chromium (diss.filt)	µg/l	**32**	**4.7**	<1	<1
Copper (diss.filt)	µg/l	**100**	**30**	3.13	2.97
Lead (diss.filt)	µg/l	--	**7.2**	0.31	0.349
Manganese (diss.filt)	µg/l	**300**	--	38.3	38.2
Nickel (diss.filt)	µg/l	--	**20**	2.18	2.18
Phosphorus (diss.filt)	µg/l	--	**0.075**	29	28.4
Selenium (diss.filt)	µg/l	**0.01**	--	<1	<1
Thallium (diss.filt)	µg/l	--	--	<2	<2
Zinc (diss.filt)	µg/l	--	**100**	11.3	11.2
Sodium (Dis.Filt)	mg/l	**200**	--	10.7	10.8
Magnesium (Dis.Filt)	mg/l	--	--	2.64	2.62
Potassium (Dis.Filt)	mg/l	--	--	1.57	1.55
Calcium (Dis.Filt)	mg/l	--	--	7.29	7.19
Iron (Dis.Filt)	mg/l	**0.2**	--	0.631	0.668
Mineral Oil / Oils & Greases					
Mineral oil >C10 C40 (aq)	µg/l	--	--	<100	<100
PCB's					
PCB congener 28	µg/l	--		<0.015	<0.015
PCB congener 52	µg/l	--		<0.015	<0.015
PCB congener 101	µg/l	--		<0.015	<0.015
PCB congener 118	µg/l	--		<0.015	<0.015
PCB congener 138	µg/l	--		<0.015	<0.015
PCB congener 153	µg/l	--		<0.015	<0.015
PCB congener 180	µg/l	--		<0.015	<0.015
Sum of detected EC7 PCB's	µg/l	--	--	<0.105	<0.105
Semi-Volatile Organic Compounds (SVOCs)					
1,2,4-Trichlorobenzene	µg/l	--	**0.4**	<4	<1
1,2-Dichlorobenzene	µg/l	--	--	<4	<1
2,4,6-Trichlorophenol	µg/l	--	--	<4	<1
2-Chlorophenol	µg/l	--	--	<4	<1
Anthracene	µg/l	0.4	**0.1**	<4	<1
Bis(2-Ethylhexyl) phthalate	µg/l	--	--	<8	<2
Benzo(b)fluoranthene	µg/l		**0.03**	<4	<1
Benzo(k)fluoranthene	µg/l		**0.03**	<4	<1

Parameter	Units	MAC[1]	EQS[2]	Upstream SW01 03.09.2019	Downstream SW02 03.09.2019
Benzo(a)pyrene	µg/l	0.1	0.05	<4	<1
Benzo(g,h,i)perylene	µg/l		0.002	<4	<1
Indeno(1,2,3-cd)pyrene	µg/l		0.002	<4	<1
n-Dibutyl phthalate	µg/l	--	--	<4	<1
Fluoranthene	µg/l	--	--	<4	<1
Hexachlorobenzene	µg/l	0.05	0.01	<4	<1
Hexachlorobutadiene	µg/l	0.6	0.1	<4	<1
Nitrobenzene	µg/l	--	--	<4	<1
Naphthalene	µg/l	--	2.4	<4	<1
Pentachlorophenol	µg/l	1	0.4	<4	<1
Phenol	µg/l	46	8	<4	<1
Volatile Organic Compounds (VOCs)					
Dichlorodifluoromethane	µg/l	--	--	<1	<1
Vinyl chloride	µg/l	0.5	--	<1	<1
Trichlorofluoromethane	µg/l	--	--	<1	<1
1,1-Dichloroethene	µg/l	--	10	<1	<1
Dichloromethane	µg/l	--	20	<3	<3
Methyl tertiary butyl ether (MTBE)	µg/l	--	--	<1	<1
1,1,1-Trichloroethane	µg/l	--	10	<1	<1
Carbontetrachloride	µg/l	--	--	<1	<1
1,2-Dichloroethane	µg/l	--	10	<1	<1
Benzene	µg/l	50	10	<1	<1
Trichloroethene	µg/l	--	--	<1	<1
Toluene	µg/l	--	10	<1	<1
Tetrachloroethene	µg/l	--	10	<1	<1
Chlorobenzene	µg/l	--	--	<1	<1
Ethylbenzene	µg/l	--	--	<1	<1
m,p-Xylene	µg/l	--	10	<1	<1
o-Xylene	µg/l	--	10	<1	<1
4-iso-Propyltoluene	µg/l	--	--	<1	<1
1,2-Dichlorobenzene	µg/l	--	--	<1	<1
1,2,4-Trichlorobenzene	µg/l	--	--	<1	<1
Hexachlorobutadiene	µg/l	0.6	0.1	<1	<1
Combined Pesticides / Herbicides					

Parameter	Units	MAC[1]	EQS[2]	Upstream SW01 03.09.2019	Downstream SW02 03.09.2019
1,2,4-Trichlorobenzene	µg/l	--	--	<0.01	<0.01
Aldrin	µg/l	--	--	<0.01	<0.01
Alachlor	µg/l	--	--	<0.01	<0.01
Atrazine	µg/l	--	--	<0.01	<0.01
Chlorfenvinphos	µg/l	--	--	<0.01	<0.01
Chlorpyriphos	µg/l	--	--	<0.01	<0.01
Dichlobenil	µg/l	--	--	<0.01	<0.01
Dichlorvos	µg/l	--	--	<0.01	<0.01
Dieldrin	µg/l	--	--	<0.01	<0.01
Endosulphan I	µg/l	--	--	<0.01	<0.01
Endosulphan II	µg/l	--	--	<0.02	<0.02
Hexachlorobenzene	µg/l	--	--	<0.01	<0.01
Hexachlorobutadiene	µg/l	--	--	<0.01	<0.01
Malathion	µg/l	--	--	<0.01	<0.01
Parathion	µg/l	--	--	<0.01	<0.01
Pentachlorobenzene	µg/l	--	--	<0.01	<0.01
Permethrin I	µg/l	--	--	<0.01	<0.01
Permethrin II	µg/l	--	--	<0.01	<0.01
Prometryn	µg/l	--	--	<0.01	<0.01
Simazine	µg/l	--	--	<0.01	<0.01
Trifluralin	µg/l	--	--	<0.01	<0.01
4,4 – DDT	µg/l	--	--	<0.01	<0.01

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 **bold** are in exceedance of the European Communities MACs

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

** * NAC – no abnormal change

4.5.3 Surface Water Analysis Discussion

The 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.

Results show very little variation in parameter levels was observed between upstream and downstream sampling locations.

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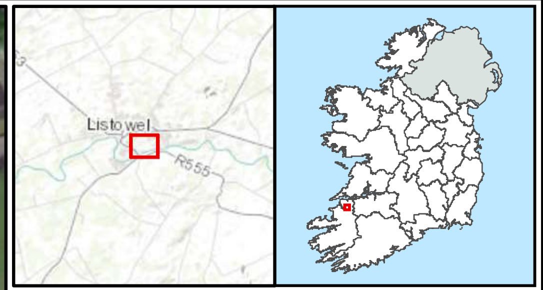
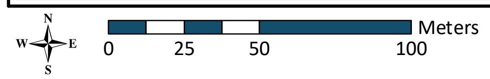


Surface Water Sampling Locations

Site Boundary



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PROJECT: Environmental Risk Assessment for Listowel Landfill, Co. Kerry			
FIGURE NO:	4.2		
CLIENT:	Kerry County Council		
SCALE:	1:2500	**REVISION:**	0
DATE:	31/10/2019	**PAGE SIZE:**	A3

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5. RISK ASSESSMENT

5.1 Introduction

Risk assessment considers the likelihood of occurrence and the consequence of occurrence of an event (Royal Society, 1992[1]). 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 lateral or vertical migration of landfill gas to human receptors.

The potential pathways associated with the Listowel site are:

- Groundwater; and
- Bedrock

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

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

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

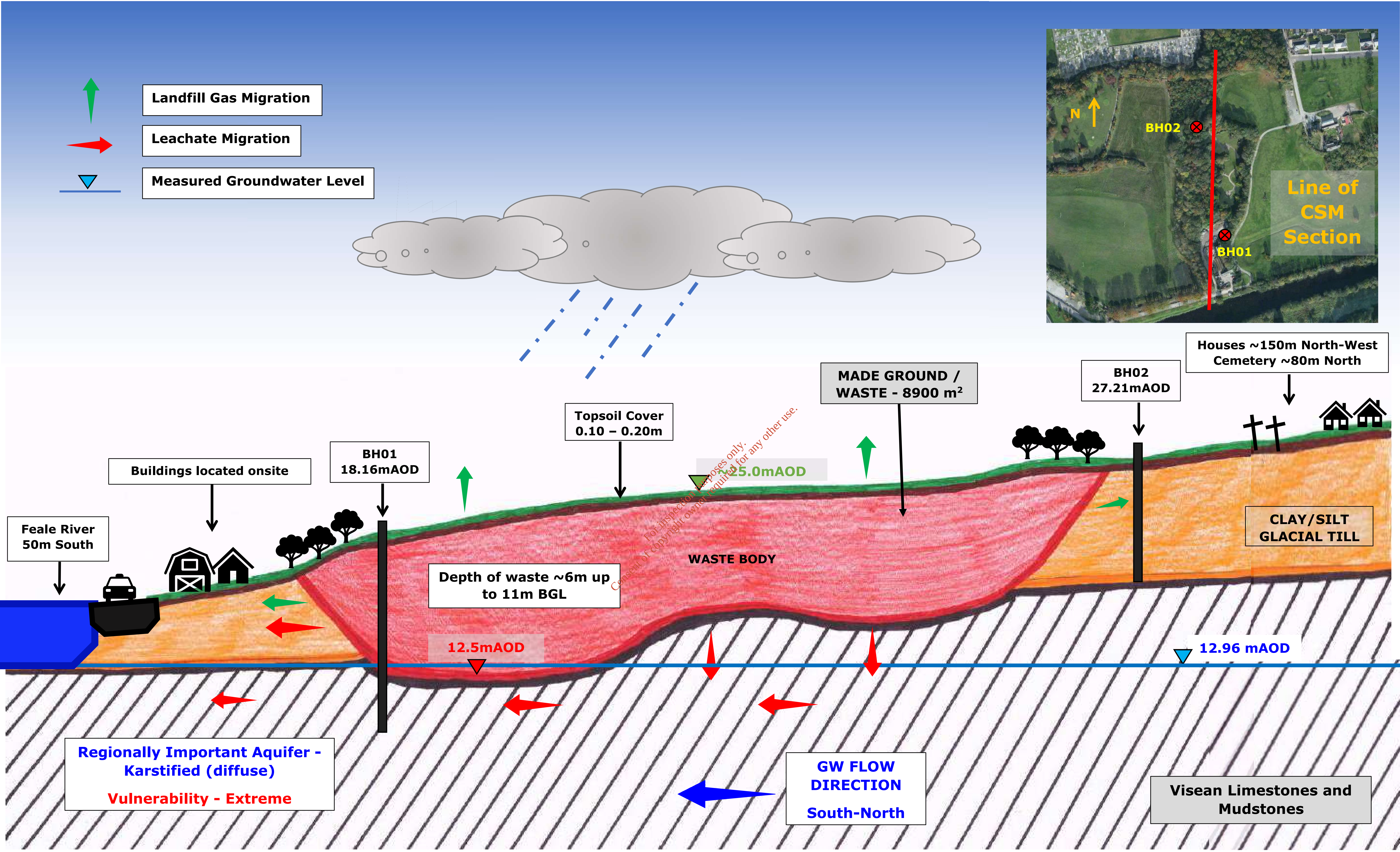
The migration of landfill gas from the site depends on the nature of the material deposited and the nature, permeability and thickness of the surrounding subsoil or bedrock.

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 Listowel 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.



CROSS SECTION NORTH-SOUTH

FIGURE 5.1 Listowel HISTORIC LANDFILL

CONCEPTUAL SITE MODEL

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5.4 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 of Listowel Historic Landfill. Where there is insufficient information available (i.e. where there is a high degree of uncertainty) the highest score is assumed.

In accordance with the EPA CoP (2007) the scoring matrices 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 5.1 calculates the points awarded to each of the headings listed above.

Table 5.1: Risk Classification Calculation – Listowel Landfill

EPA Ref	Risk	Points	Rationale
1a	Leachate; source/hazard scoring matrix, based on waste footprint.	5	Based on a waste footprint of 1.1 ha and the presence of municipal waste the score of 5 is being maintained.
1b	Landfill gas; source/hazard scoring matrix, based on waste footprint.	5	Based on a waste footprint of 1.1 ha and the presence of municipal waste the score of 5 is being maintained.
2a	Leachate migration: Pathway (Vertical)	3	GSI describes the groundwater vulnerability as X (Rock near surface) and waste above possible bedrock as indicated during trial pitting.
2b	Leachate migration: Pathway (Horizontal)	5	The groundwater vulnerability is classified by the GSI as a Regionally Important Aquifer - Karstified - diffuse (Rkd) (West) and as a Poor Aquifer – bedrock which is generally unproductive (East).
2c	Leachate migration: Pathway (Surface water drainage)	0	No land drains are present at the site, no direct surface water pathway to the Feale river as verified during site walkover.
2d	Landfill gas: Pathway (Lateral migration potential)	3	A significant portion of the site is underlain by Regionally Important Aquifer – Karstified (Rkd).
2e	Landfill gas: Pathway (Upwards migration potential)	0	No buildings or structure are located directly above estimated waste footprint area.
3a	Leachate migration: Receptor (Human presence)	3	No buildings or structures are located directly above estimated waste footprint area. Nearest residential dwellings are located 150m north-east of the waste body.
3b	Leachate migration: Receptor (Protected areas – SWDTE or GWDTE) (Surface water/ groundwater dependent terrestrial ecosystems)	2	Feale river is part of the Lower River Shannon SAC (Site Code: 002165) and it is located around 100m south of the waste body.
3c	Leachate migration: Receptor (Aquifer category – Resource potential)	5	Regionally Important Aquifer - Karstified - diffuse (Rkd) (West) and Poor Aquifer – bedrock which is generally unproductive (East).
3d	Leachate migration: Receptor (Public water supplies – other than private wells)	0	Glin Public Water Supply is located 18.5 km north-east of the site and it is noted, however, that this public water supply is no longer in use.
3e	Leachate migration: Receptor (Surface water bodies)	3.	Feale river is located within 50m of the site boundary.

EPA Ref	Risk	Points	Rationale
3f	Landfill Gas: Receptor (Human presence)	3	No landfill gas recorded, and no buildings or structures are located directly above estimated waste footprint area. Nearest residential dwellings are located 150m north-east of the waste body.

Table 5.2: 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	**120**	300	Leachate => surface water	40%
SPR2	1a x (2a + 2b + 2c) x 3b	**80**	300	Leachate => SWDTE	27%
Leachate migration through groundwater pathway					
SPR3	1a x (2a + 2b) x 3a	**120**	240	Leachate => human presence	**50%**
SPR4	1a x (2a + 2b) x 3b	**80**	240	Leachate => GWDTE	33%
SPR5	1a x (2a + 2b) x 3c	**200**	400	Leachate => Aquifer	**50%**
SPR6	1a x (2a + 2b) x 3d	**0**	560	Leachate => Surface Water	0%
SPR7	1a x (2a + 2b) x 3e	**120**	240	Leachate => SWDTE	**50%**
Leachate migration through surface water pathway					
SPR8	1a x 2c x 3e	**0**	60	Leachate => Surface Water	0%
SPR9	1a x 2c x 3b	**0**	60	Leachate => SWDTE	0%
Landfill gas migration pathway (lateral & vertical)					
SPR10	1b x 2d x 3f	**45**	150	Landfill Gas => Human Presence	30%
SPR11	1b x 2e x 3f	**0**	250	Landfill Gas => Human Presence	0%
Site maximum S-P-R Score					**50%**
Risk Classification					**Class B**

Table 5.2 shows the maximum S-P-R scoring for the site is **50%.**

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 **Moderate Risk Classification (Class B)**. The principal risk identified on the site is the risk posed to the aquifer from migration of leachate and to human receptors from migration of landfill gas from the waste material encountered at the site.

6. CONCLUSION

A Tier 2 study was conducted by FT in accordance with the EPA CoP for Listowel Historic Landfill. The study consisted of a desktop study, geophysical survey and intrusive site investigation works. These works informed the development of the CSM and risk screening model.

The findings of the site investigation work and geophysical surveying suggest the waste material is deposited in a single infill area with the extent of the landfill is estimated at 8,900 m^2.

A volume calculation based on the surveyed surface profiles for the existing ground level and the base of waste as interpreted, preliminary estimates indicate an interred waste volume of approximately 98,000 m^3 including fill material placed on top of the landfill. Assuming a waste density of 1.4 tonne/m^3 this equates to approximately 137,200 tonnes of waste. Information obtained and provided by KCC within the Tier 1 risk assessment suggests the deposition of c.37,000 tonnes at the site. It is therefore estimated the quantity of waste deposited at the site is between 37,000 and 137,200 tonnes.

Analysis of waste samples from the window sample holes advanced at the site, when assessed against the inert waste acceptance criteria indicated that much of the waste material within the site can be classified as typically inert. The waste classification is considered to reflect the level of degradation over time since landfilling ceased. Window sampling and site walkovers have confirmed the waste material is near the surface with a minimal topsoil and clay cover present across the site.

Landfill gas monitoring from perimeter wells BH01 and BH02 at the site indicates gas concentrations detected are below threshold levels set by the EPA CoP. Considering the low gas concentrations measured at the perimeter wells and the identified building receptors within 150m of the waste body, a low-risk score of 30% for SPR10 and 0% SPR11 has been generated. The pathway between the waste body and the on and offsite building receptors will require further investigation to verify the risk, if any, to these receptors.

Analysis of groundwater samples recovered from the monitoring wells BH01 and BH02 have reported ammonia concentrations which exceed guideline threshold values. Ammonia concentration at upgradient boreholes BH02 is considered representative of background levels possibly due to agricultural land spreading. However, given the ammonia concentration of 26.1 mg/l recorded at BH02 is significantly greater than upgradient levels, the landfill is impacting downgradient water quality due to the significant ammonia concentration differences between upgradient and downgradient monitoring locations.

Based on the presence of elevated ammonia and dissolved metal 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 therefore contributing to leachate migration from the landfill.

Analysis of groundwater samples presented elevated alkalinity and manganese concentrations which appear to be typical of localised background concentrations due to the presence of high concentrations on both monitoring wells.

Analysis of surface water samples from the River Feale found all results to be below the MAC (1989) and EQS (2019) guideline limit values in all assessments. The results indicate the landfill is not having an impact on surface water quality. This would indicate that the local groundwater and surface water regimes are not hydrologically linked at this location.

Based on the results of the Tier 2 site assessment, the site can be classified as a **Moderate Risk Classification (Class B)**. The principal risks identified on the site are the risk posed to underlying groundwater aquifer from the migration of leachate from the waste body.

6.1 Recommendations

Based on the results of the initial Tier 2 assessment the site is classified as Moderate Risk. For a moderate risk site, the CoP indicates that a Tier 3 Environmental risk analysis be undertaken including a Detailed Quantitative Risk Assessment (DQRA) The purpose of the DQRA will be to quantitatively assess the primary S-P-R linkage identified i.e. leachate migration to the Karst aquifer.

It is therefore recommended by FT that a Tier 3 DQRA be undertaken for the site in conjunction with an application for a Certificate of Registration for this site.

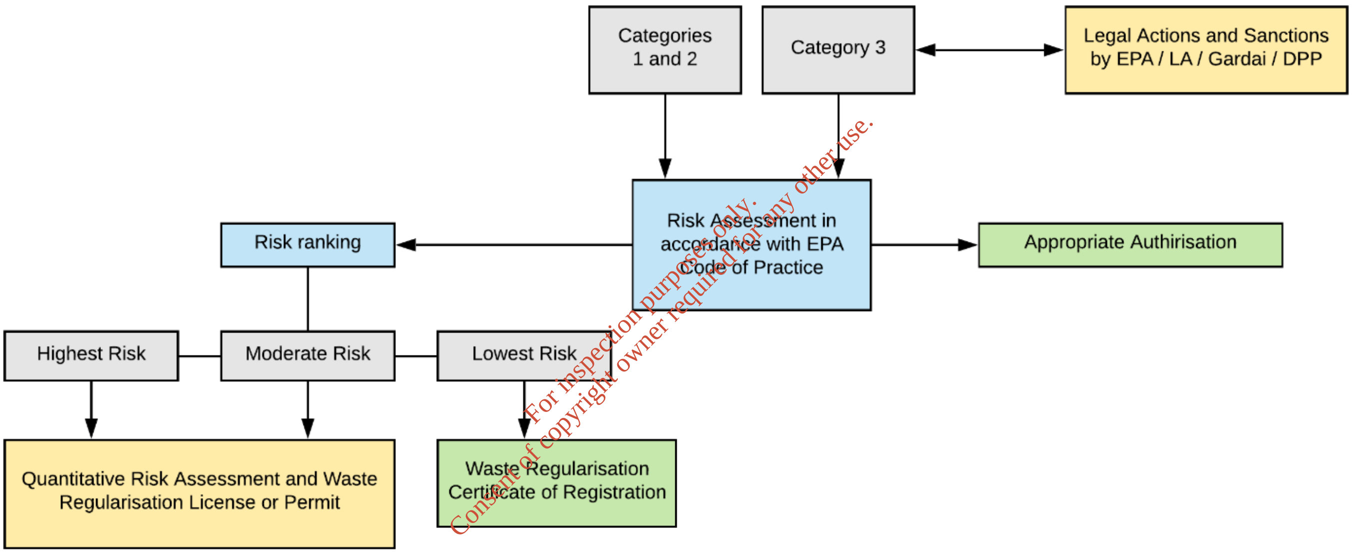

Figure 6.1: Extract from Section 1.3 of the EPA Code of Practice