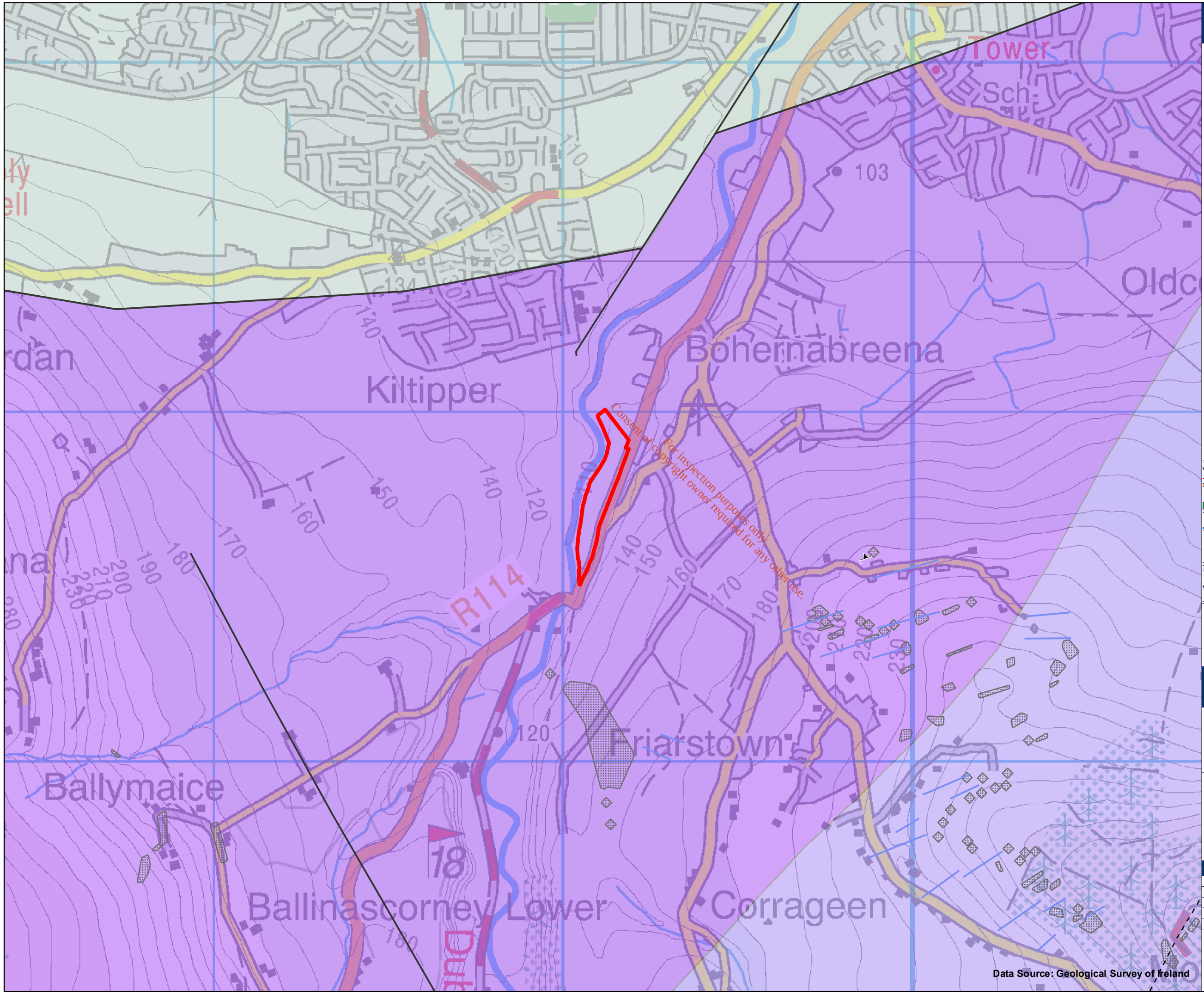


Legend

- Site Boundary

Bedrock Units (1:100k)

- Lucan Formation
- Nt2p - Type 2p microcline porphyritic (Northern and Upper Liffey Valley Plutons)
- Aghfarrell Formation
- Butter Mountain Formation
- Pollaphuca Formation

Bedrock Outcrop

- Bedrock Outcrop

Bedrock Stratigraphic and Structural Lines (1:100k)

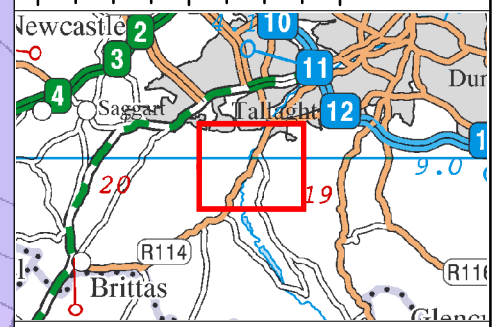
- Area
- Dyke
- Fault

Bedrock Structural Symbols (1:100k)

- Strike and dip of first foliation

N

0 100 200 400 Meters



Client

Comhairle Contae Átha Cliath Theas
South Dublin County Council

Project

Bohernabreena Landfill Environmental Risk Assessment

Title

Bedrock Geology of the Site and Surrounding Area

Figure: 3.3

RPS

West Pier Business Campus,
Dun Laoghaire,
Co. Dublin,
Ireland.

T: +353 (0) 1 4882900
E: ireland@rpsgroup.com
W: rpsgroup.com/ireland

Issue Details

Drawn By: HF		**Project No.** MDR1489	
Checked By: BMcP		**File Ref:**	
Approved By: BMcP		MDR1489Arc0004D01	
Scale: 1:10,000 @ A3		**Drawing No.**	**Rev:**
Date: 19/12/2018		Arc0004	D01

NOTE:

1. This drawing is the property of RPS Group Ltd. It is a confidential document and must not be copied, used, or its contents divulged without prior written consent.
2. All levels are referred to Ordnance Datum, Malin head.
3. Ordnance Survey Ireland Licence EN 0005018 ©Copyright Government of Ireland.

Data Source: Geological Survey of Ireland

2.4.3 Hydrogeology & Hydrology

2.4.3.1 Hydrogeology

Aquifer Characteristics

According to the GSI the aquifer beneath the site and the surrounding vicinity is designated as a Poor Aquifer (Pl) which is described as bedrock which is generally unproductive except for local zones (**Figure 2.6**).

The aquifer is assigned to the Kilcullen Groundwater Body (GWB) (IE_EA_G_003) which is characterised predominantly by a poorly productive flow regime. Most groundwater flow occurs in a shallow upper weathered zone; deeper groundwater flow is possible along fractures, joints and major faults. Recharge occurs diffusely through the subsoils and via outcrops. Typical groundwater flow paths are likely to be in the order of a couple of hundred metres and discharging to the closest surface water features which in this case is the River Dodder which runs along the western boundary of the site.

The majority of groundwater flow will occur in the top couple of metres. In some instances, a greater degree of structural deformation may provide a fracture network, which will allow groundwater movement at greater depths. Only flow in isolated fractures is expected below 30 metres.

According to the GSI there are no gravel aquifers within the vicinity of the site. However, according to historical maps there are several gravel pits within the vicinity of the site and along the River Dodder.

Aquifer Vulnerability

According to the GSI the aquifer vulnerability at the majority of the site is classified as High, with a small portion of the site at the south classified as Extreme (**Figure 2.7**). Assuming a moderate permeability of the subsoil due to the presence of sand and gravels, the depth to bedrock, based on the GSI classification is expected to be between 3 to 5 metres.

Groundwater Quality

According to the EPA the status of the groundwater within the Kilcullen GWB located beneath the site and the surrounding area is classified as “Good Status” (EPA, catchments.ie, 2018). The Water Framework Directive (WFD) groundwater risk of the groundwater is projected as “Not at Risk”.

The hydro-chemical signature of the GWB is slightly hard water (100-150 mg/l ($CaCO_3$)) and electrical conductivity values of 300-500 µS/cm. the groundwater has very low alkalinity (generally less than 50 mg/l).

Groundwater Use and Protection

There are no groundwater wells on the site. The closest wells according to GSI are 2921NEW001 located approximately 3km northwest of the site, GSI well 2921NEW006 located approximately 2.3km

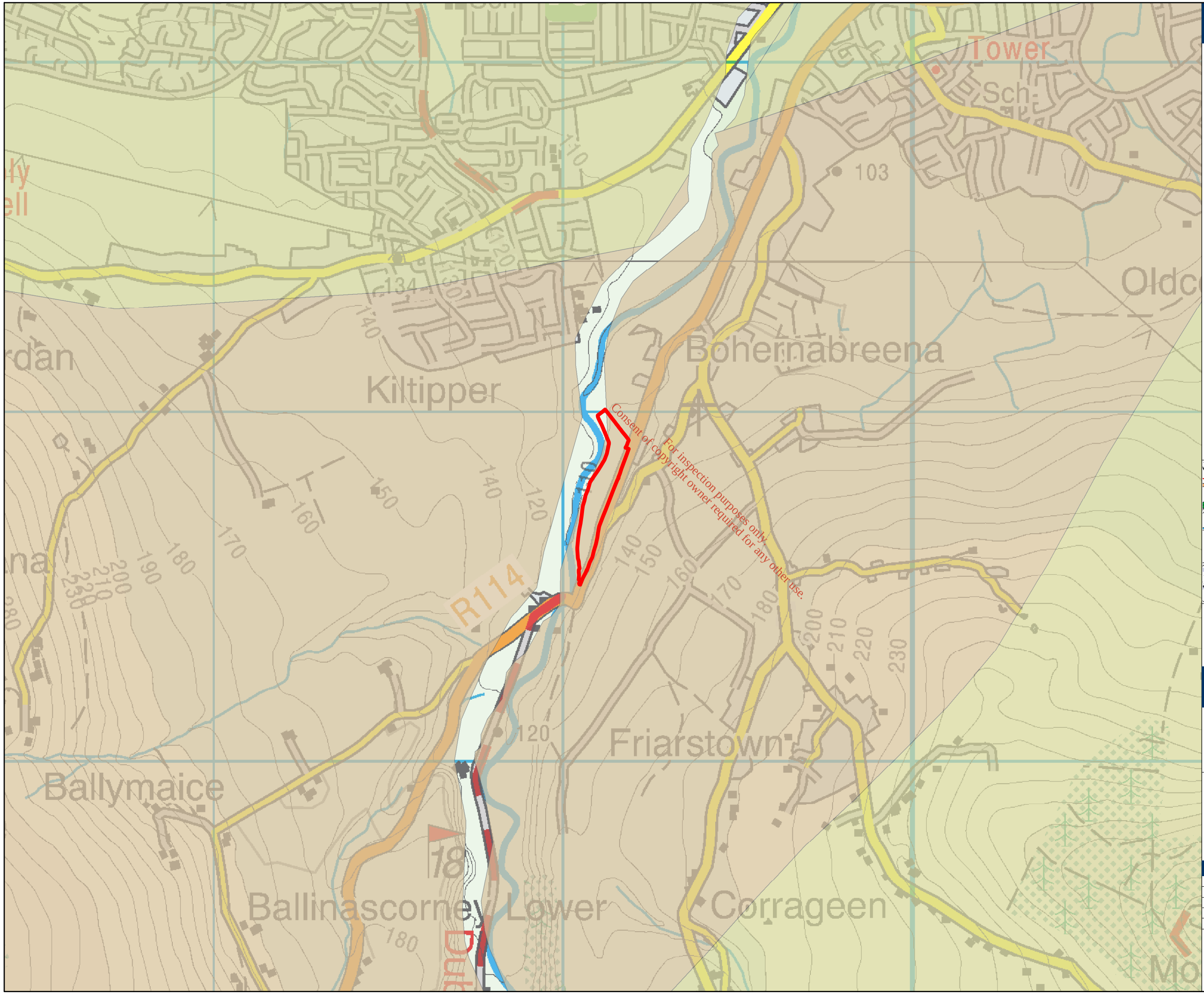
south of the site and GSI well 2921NEW011 located approximately 4km southeast of the site (**Figure 2.8**). A summary of well use and yields are presented in **Table 2.3.**

Table 2.3 GSI Wells

GSI Wells	Drill Date	Well Use	Yield Class
2921NEW006	1899	Agricultural & domestic use	Poor (32.7m^3/d)
2921NEW011	1986	Unknown	Poor (19.6m^3/d)
2921NEW001	1976	Industrial use	Excellent (513m^3/d)*

*Note this well is located within the Lucan Formation.

There are no Public Supply Source Protection Areas within the site or proximity of the site, the nearest is located at Kilteel approximately 8.5km southwest of the site.



Legend

Site Boundary

Aquifer Classification

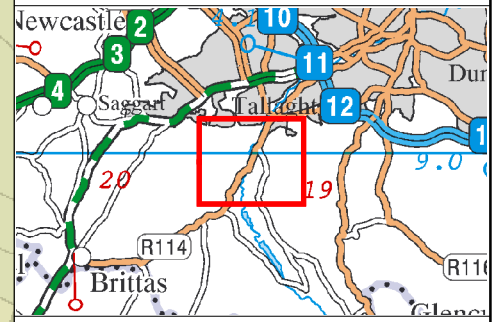
Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones

Poor Aquifer - Bedrock which is Generally Unproductive except for Local Zones

N

Data Source: Geological Survey of Ireland

0 100 200 400 Meters



Client

Comhairle Contae Átha Cliath Theas
South Dublin County Council

Project

Bohernabreena Landfill Environmental Risk Assessment

Title

Aquifer Classification beneath the Site and Surrounding Area

Figure: 3.4

RPS

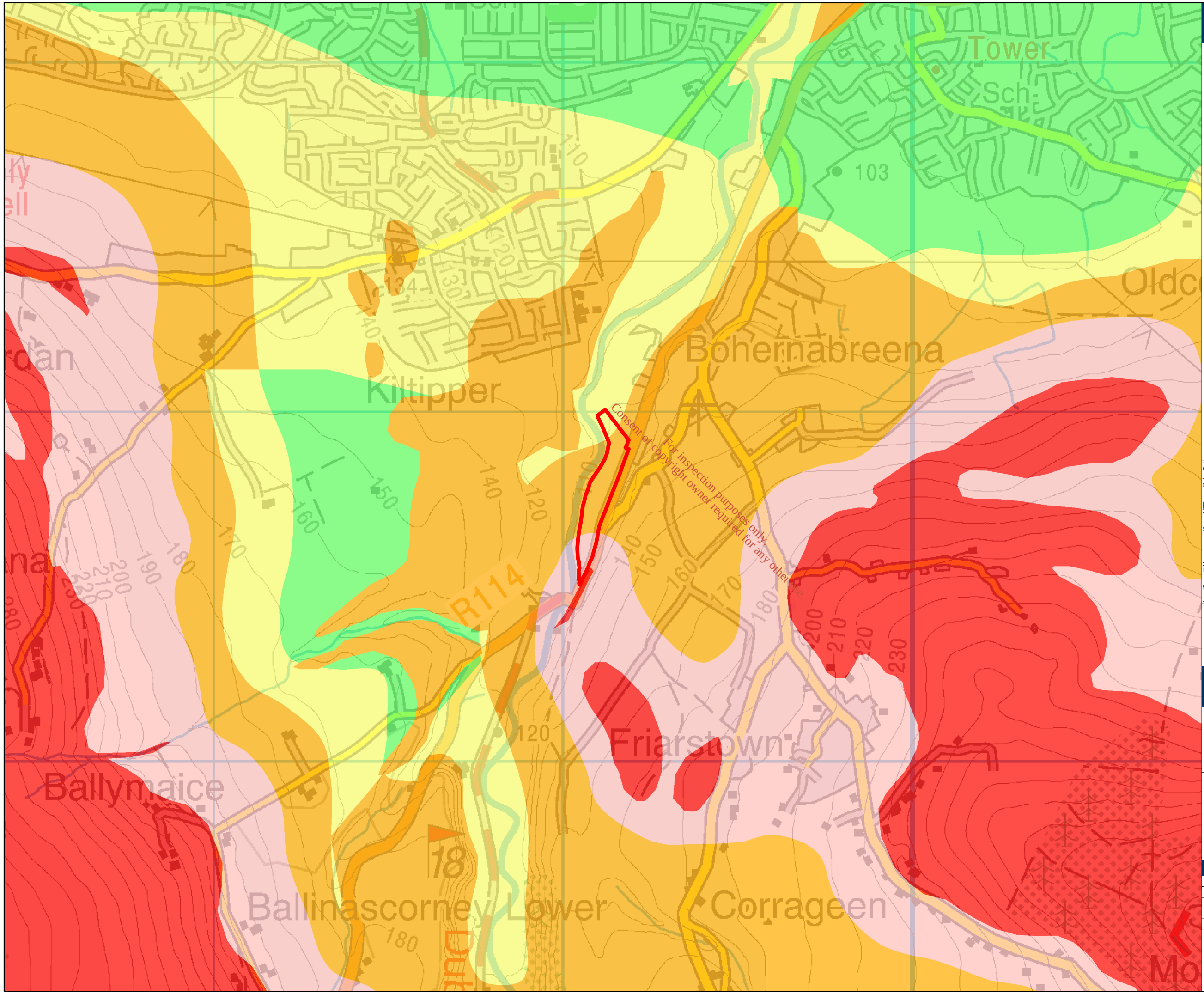
West Pier Business Campus,
Dun Laoghaire,
Co. Dublin,
Ireland.

T: +353 (0) 1 4882900
E: ireland@rpsgroup.com
W: rpsgroup.com/ireland

Issue Details

Drawn By: HF	**Project No.** MDR1382		
Checked By: BMcP	**File Ref:**		
Approved By: BMcP	MDR1382Arc0005D01		
Scale: 1:10,000 @ A3	**Drawing No.**	**Rev:**	
Date: 19/12/2018	Arc0005	D01	

NOTE:
1. This drawing is the property of RPS Group Ltd. It is a confidential document and must not be copied, used, or its contents divulged without prior written consent.
2. All levels are referred to Ordnance Datum, Malin head.
3. Ordnance Survey Ireland Licence EN 0005017 ©Copyright Government of Ireland.



Legend

- Site Boundary

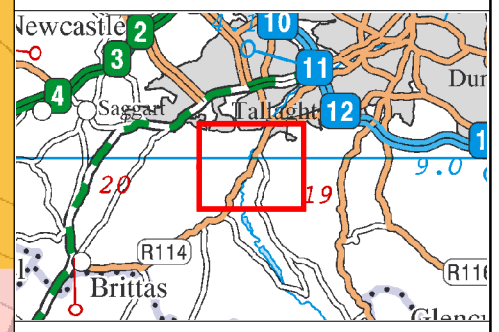
Vulnerability Rating

- Extreme (Rock Near Surface/Karst)
- Extreme
- High
- Moderate
- Low
- Water

N

Data Source: Geological Survey of Ireland

0 100 200 400 Meters



Client

Comhairle Contae Átha Cliath Theas
South Dublin County Council

Project

Bohernabreena Landfill Environmental Risk Assessment

Title

Groundwater Vulnerability of the Site and Surrounding Area

Figure: 3.5

RPS

West Pier Business Campus,
Dun Laoghaire,
Co. Dublin,
Ireland.

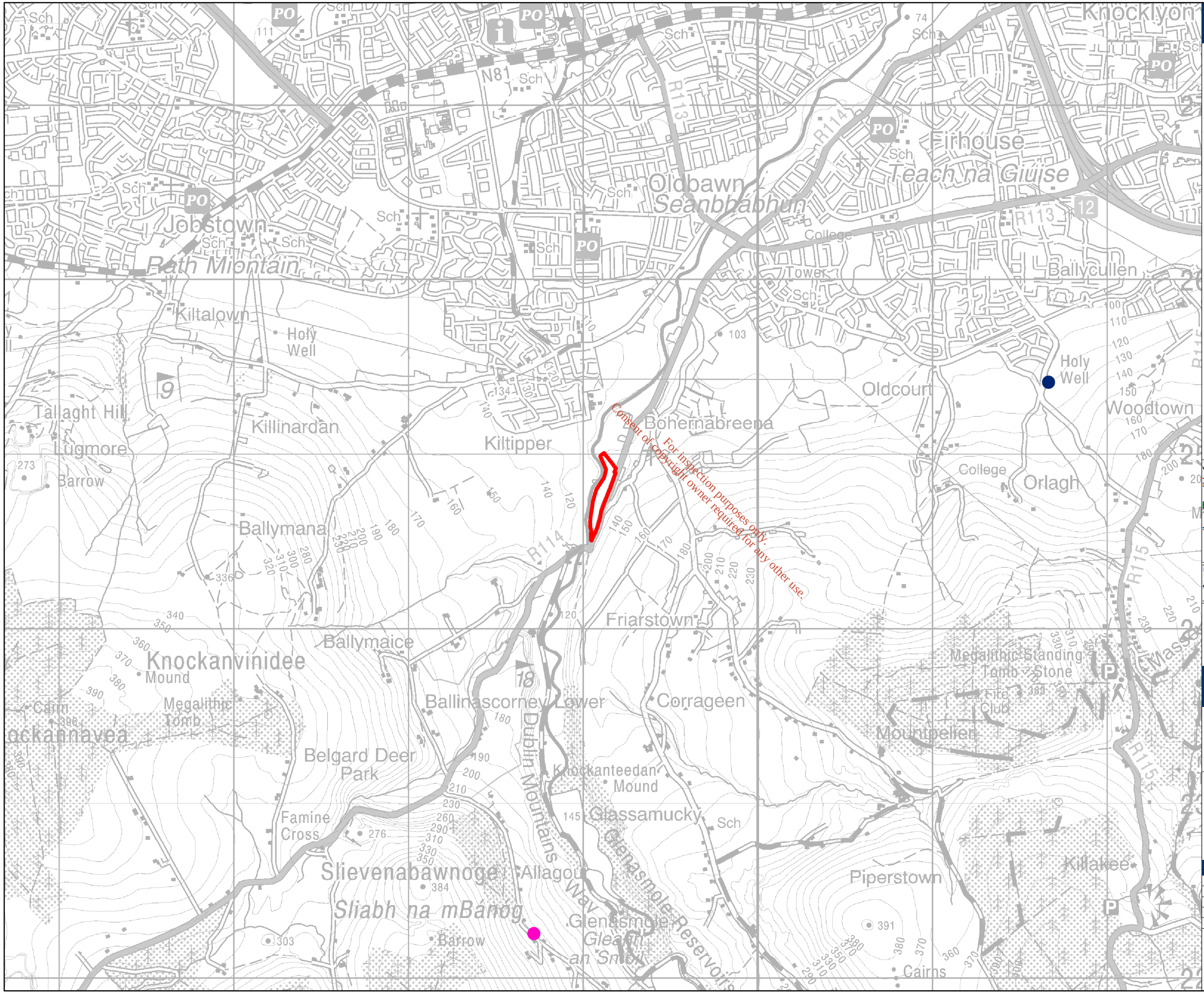
T: +353 (0) 1 4882900
E: ireland@rpsgroup.com
W: rpsgroup.com/ireland

Issue Details

Drawn By:	HF	**Project No.**	MDR1489
Checked By:	BMcP	**File Ref:**	
Approved By:	BMcP		MDR1489Arc0006D01
Scale:	1:10,000 @ A3	**Drawing No.**	**Rev:**
Date:	19/12/2018	Arc0006	D01

NOTE:

1. This drawing is the property of RPS Group Ltd. It is a confidential document and must not be copied, used, or its contents divulged without prior written consent.
2. All levels are referred to Ordnance Datum, Malin head.
3. Ordnance Survey Ireland Licence EN 0005018 ©Copyright Government of Ireland.



Legend

- Site Boundary

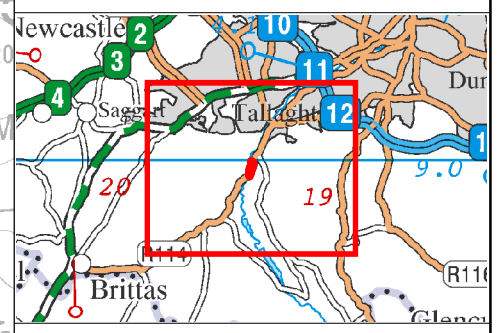
Well Type

- Borehole
- Spring

N

Data Source: Geological Survey of Ireland

0 200 400 800 Meters



Client

Comhairle Contae Átha Cliath Theas
South Dublin County Council

Project

Bohernabreena Landfill Environmental Risk Assessment

Title

Boreholes in the vicinity of the Site

Figure: 3.6

RPS

West Pier Business Campus,
Dun Laoghaire,
Co. Dublin,
Ireland.

T: +353 (0) 1 4882900
E: ireland@rpsgroup.com
W: rpsgroup.com/ireland

Issue Details

Drawn By:	HF	**Project No.** MDR1489	
Checked By:	BMcP	**File Ref:**	
Approved By:	BMcP	MDR1489Arc0007D01	
Scale:	1:20,000 @ A3	**Drawing No.**	**Rev:**
Date:	19/12/2018	Arc0007	D01

2.4.3.2 Hydrology

Hydrological Features

There are no water courses on the site with the exception of a diverted spring which has been utilised as a cattle water feeder at the north of the site. The location of the spring and surrounding water courses is indicated in **Figure 2.9**.

The site is within the Eastern River Basin District, the River Dodder which originates in the Wicklow Mountains runs along the western perimeter of the site, flowing north-easterly towards the Liffey Estuary Lower, approximately 12.5km north east of the site (**Figure 2.9**).

The River Dodder is considered a heavily modified water body (Eastern River Basin District, 2009), the river has been impounded upstream to form two reservoirs which supply water to south Dublin, there is a bridge apron at Font Bridge at the southern boundary of the site (**Plate 2.3**) and SDCC had constructed rock armour as flood defences at locations along the boundary of the site (**Plate 2.4**). Under the River Basin Management Plan for Ireland 2018 – 2021 the River Dodder is listed as a Prioritised Area for Action.

Plate 2.3 Bridge apron upgradient of the site

Plate 2.4 River armour along the site river bank

Surface Water Quality

According to the EPA the surface water quality at the nearest monitoring point immediately south of the site upstream (Dodder- Fort Bridge [ID:RS09D010200]) is reported as a linear value of Q4-Q5 which indicates a High Status (EPA, 2017). No chemical information is available for this station.

Approximately 1.4km downstream north east of the site at the Old Bawn Bridge (RS09D010300) a linear value of Q3-Q4 was reported (EPA, 2017) which indicates a Moderate Status. Surface water levels of Ammoniacal Nitrogen Ammoniacal Nitrogen for 2010 – 2015 exceed the statutory threshold levels in the river as summarised in **Table 2.4.**

Table 2.4 EPA Ammoniacal Nitrogen – Total Data

Year	Aggregation Type	Period	Total Results	Threshold (mg/l)	Value
2007	Mean	Annual	4	0.065	0.083
2008	Mean	Annual	4	0.065	0.073
2009	Mean	Annual	4	0.065	0.105
2010	Mean	Annual	3	0.065	0.123
2011	Mean	Annual	1	0.065	0.030
2012	Mean	Annual	2	0.065	0.140
2013	Mean	Annual	4	0.065	0.031
2014	Mean	Annual	4	0.065	0.107
2015	Mean	Annual	4	0.065	0.087

Grey shading indicating exceedance of statutory limits

The Water Framework Directive (WFD) status 2010-2015 of the River Dodder is assigned as “Good”, and the WFD risk is still under review (for the Dodder_030).

Surface Water Protection

According to the NPWS website, there is a Special Area of Conservation (SAC), the Glensamole Valley SAC (Site Code: 001209) immediately upstream of the site. As this SAC is within the same Catchment Management Unit as the landfill there is hydrological connectivity but it is noted that the SAC is upstream of the landfill. The site is a SAC selected for the following habitats and species listed on Annex I/II of the E.U. Habitats Directive:

- [6210] Orchid-rich Calcareous Grassland*
- [6410] Molinia Meadows
- [7220] Petrifying Springs*

Asterisk denotes priority habitats and/or species and numbers in brackets are Natura 2000 codes.

The Glensamole Valley is also a proposed Natural Heritage Area (pNHA) (Site Code: 001209).

According to the NPWS, the non-calcareous bedrock of the Glensamole Valley has been overlain by deep drift deposits which now line the valley sides. These are partly covered by scrub and woodland, and on the less precipitous parts, by a herb-rich grassland. There is much seepage through the deposits, which brings to the surface water rich in bases, which induces local patches of calcareous fen and, in places, petrifying springs..

The Appropriate Assessment Screening and Natura Impact Statement (**Appendix C**) assesses the ecological aspects of the site in more detail.

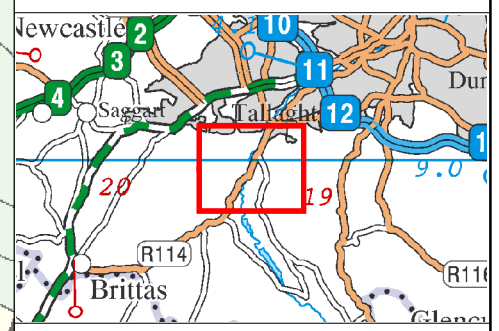
Legend

- Site Boundary
- Watercourse

N

Data Source: EPA (River Waterbodies)

0 100 200 400 Meters



Client

Comhairle Contae Átha Cliath Theas
South Dublin County Council

Project

Bohernabreena Landfill Environmental Risk Assessment

Title

EPA Watercourses within the vicinity of the Site

Figure: 3.7

RPS

West Pier Business Campus,
Dun Laoghaire,
Co. Dublin,
Ireland.

T: +353 (0) 1 4882900
E: ireland@rpsgroup.com
W: rpsgroup.com/ireland

Issue Details

Drawn By: HF	Project No. MDR1489		
Checked By: BMcP	File Ref:		
Approved By: BMcP	MDR1489Arc0008D01		
Scale: 1:10,000 @ A3	Drawing No.	Rev:	
Date: 19/12/2018	Arc0008	D01	

NOTE:
1. This drawing is the property of RPS Group Ltd. It is a confidential document and must not be copied, used, or its contents divulged without prior written consent.
2. All levels are referred to Ordnance Datum, Malin head.
3. Ordnance Survey Ireland Licence EN 0005018 ©Copyright Government of Ireland.

2.5 TIER I – CONCEPTUAL SITE MODEL

2.5.1 Initial Conceptual Site Model and Tier 1 Risk Screening

A review of the available information was completed to develop an initial CSM and identify any gaps for which further data was required. The initial CSM is based on the concept of pollutant (source-pathway-receptor) linkages which are detailed below.

2.5.2 Source

Four principal potential contamination sources for the site have been identified for the initial CSM:

- S1 – Leachate;
- S2 - Waste;
- S3 - Asbestos Containing Material; and
- S4 - Landfill Gas.

2.5.3 Pathways

A number of pathways have been identified that potentially connect the sources of contamination and potential receptors. These include:

- P1 - Vertical migration to groundwater then horizontal flow through Surface Water (SW) drainage channels into the River Dodder;
- P2 - Vertical migration to groundwater and horizontal (lateral) flow through saturated groundwater / aquifer;
- P3 - Surface Water drainage system;
- P4 - Direct dermal contact, ingestion of dust and soil or inhalation of dust;
- P5 - Lateral migration of landfill gas through subsoils, resulting in inhalation and/ or explosion;
- P6 - Lateral migration of dissolved phase landfill gas through groundwater;
- P7 - Vertical migration of landfill gas through subsoil; and
- P8 - Migration of landfill gas through existing &/or proposed services routes.

2.5.4 Receptors

A variety of receptors have been identified with respect to the site environmental setting and human health including the following:

- R1 - WFD Surface Water Body – River Dodder;
- R2 - Surface Water Protected Area – Glensamole Valley SAC;
- R3 - Private Wells – Groundwater abstraction sources;

- R4 - Groundwater Dependent Terrestrial Ecosystem (GWDTE) - Glensamole Valley SAC;
- R5 - Aquifer – Kilcullen groundwater body (R5);
- R6 - Public Supply Well (R6);
- R7 - Human health receptors current Site Users;
- R8 - Adjacent Buildings and Structures; and
- R9 - Non-designated land.

Table 2.5, **Table 2.6** and **Table 2.7** detail the classification of probability, classification of consequence and risk matrix taken from CIRIA C552 (Contaminated Land Risk Assessment) (CIRIA, 2001) that was used in the development of the initial CSM.

The initial CSM developed from this review is presented in **Table 2.8** and addresses the Source, Pathway and Receptor elements across the site. In order to complete **Table 2.8** the worst case scenario for each element was chosen.

Table 2.5 Classification of Probability

Probability/ Classification	Definition
High Likelihood	There is a pollution linkage and an event that either appears very likely in the short term and almost inevitable over the long term, or there is evidence at the receptor of harm or pollution.
Likely	There is a pollution linkage and all the elements are present and in the right place, which means that it is probable that an event will occur. Circumstances are such that an event is not inevitable, but possible in the short term and likely over the long term.
Low Likelihood	There is a pollution linkage and circumstances are possible under which an event could occur. However, it is by no means certain that even over a longer period such event would take place and is less likely in the shorter term.
Unlikely	There is a pollution linkage but circumstances are such that it is improbable that an event would occur even in the very long term.

Table 2.6 Classification of Consequence

Classification	Definition	Examples
Severe	Short-term (acute) risk to human health likely to result in "significant harm" as defined by the Environment Protection Act 1990, Part IIA. Short-term risk of pollution (note: Water Resources Act contains no scope for considering significance of pollution) of sensitive water resource. Catastrophic damage to buildings/ property. A short-term risk to a particular ecosystem or organisation forming part of such ecosystem (note: the definitions of ecological systems within the Draft Circular on Contaminated Land, DETR, 2000)	High concentrations of cyanide on the surface of an informal recreation area. Major spillage of contaminants from site into controlled water. **Explosion, causing building collapse (can also equate to a short-term human health risk if buildings are occupied).**
Medium	Chronic damage to Human Health ("significant harm" as defined by DETR, 2000). Pollution of sensitive water resources (note: Water Resources Act contains no scope for considering significance of pollution). A significant change in a particular ecosystem or organism forming part of such ecosystem (note: the definitions of ecological systems within Draft Circular on Contaminated Land, DETR, 2000).	Concentration of a contaminant from site exceeds the generic or site-specific assessment criteria. Leaching of contaminants from a site to a major or minor aquifer. Death of a species within a designated mature reserve. **Lesser toxic and asphyxiate effects of carbon dioxide**
Mild	Pollution of non-sensitive water resources. Significant damage to crops, buildings, structures and services ("significant harm" as defined in the Draft Circular on Contaminated Land, DETR, 2000). Damage to sensitive buildings/ structures/ services or the environment.	Pollution of non-classified groundwater. Damage to building rendering t unsafe to occupy (e.g. foundation damage resulting in instability).
Minor	Harm, although not necessarily significant harm, which may result in a financial loss or expenditure to resolve. Non-permanent health effects to human health (easily prevented by means such as personal protective clothing, etc.). Easily, repairable effects of damage to buildings, structures and services.	The presence of contaminants at such concentrations that protective equipment is required during site works. The loss of plants in a landscaping scheme. Discolouration of concrete

Table 2.7 Risk Matrix - Comparison of Consequence and Probability

Probability/ Classification		Definition	Consequence			
			Severe	Medium	Mild	Minor
Probability	High Likelihood	High Likelihood	Very high risk	High risk	Moderate risk	Moderate/ low risk
	Likely	Likely	High risk	Moderate risk	Moderate/ low risk	Low risk
	Low Likelihood	Low Likelihood	Moderate risk	Moderate/ low risk	Low risk	Very low risk
	Unlikely	Unlikely	Moderate/ low risk	Low risk	Very low risk	Very low risk

Table 2.8 Conceptual Site Model

Source		Pathway		Receptor		Likelihood of Occurrence	Severity of Consequence	Risk Classification	Comments
Controlled Waters									
S1	Leachate	P1	Vertical to groundwater then horizontally through SW drainage channels into the river	R1	Surface Water Body	Likely	Medium	Moderate risk	Potential for leachate to migrate to River Dodder
				R2	Surface Water Protected Area	Likely	Low	Low risk	South Dublin Bay SAC (000210) and South Dublin Bay and River Tolka SPA (004024) approximately 12.4km north east from the site. Potential hydrogeological link.
		P2	Vertical & Horizontal through Groundwater	R3	Private Wells	Unlikely	Medium	Low risk	There are no residential properties or private wells down gradient of the site.
				R4	Ground Water Dependent Terrestrial Ecosystems	Unlikely	Medium	Moderate risk	Tufa deposits along the River Dodder within the vicinity of the site
				R5	Aquifer	Unlikely	Medium	Low risk	The underlying bedrock is poorly productive
				R6	Public Supply Well	None	Minor	No risk	There are no public water supply wells in the area.
				R1	Surface Water Body	Unlikely	Medium	Moderate risk	The River Dodder
		P3	SW Drainage	R1	Surface Water Body	Likely	Medium	Moderate risk	Potential for leachate to migrate to the River Dodder
				R2	Surface Water Protected Area	Likely	Low	Low risk	
Human Health									

Source		Pathway		Receptor		Likelihood of Occurrence	Severity of Consequence	Risk Classification	Comments
S2	Waste	P4	Direct dermal contact Ingestion dust and soil Inhalation of dust	R7	Current Site Users	Unlikely	Low	Low risk	Site is currently used as pasture from grazing, no soil is exposed.
S3	ACM	P4	Direct dermal contact Ingestion dust and soil Inhalation of dust	R7	Current Site Users	Unlikely	Low	Low risk	Site is currently used as pasture from grazing, no soil is exposed.
S4	Landfill Gas	P5	Lateral Migration Subsoil Inhalation and/ or explosion	R7	Current Site Users	Unlikely	Low	Low risk	Potential for ingress to existing buildings and structures.
				R8	Adjacent Buildings and Structures	Unlikely	Low	Low risk	
				R9	Vegetation Stresses/Ecology	None	None	No risk	
S4	Landfill Gas	P6	Lateral Migration Groundwater	R7	Current Site Users	Unlikely	Low	Low risk	Potential for ingress to existing buildings and structures.

Source		Pathway		Receptor		Likelihood of Occurrence	Severity of Consequence	Risk Classification	Comments
				R8	Adjacent Buildings and Structures	Unlikely	Low	Low risk	
S4	Landfill Gas	P7	Vertical Migration Subsoil	R7	Current Site Users	Unlikely	Low	Low risk	The lack of an engineered cap will enable vertical migration of gas and atmospheric dispersion and dilution at surface.
				R8	Adjacent Buildings and Structures	Unlikely	Low	Low risk	
				R9	Vegetation Stresses/Ecology	None	None	No risk	
S4	Landfill Gas	P8	Existing & Proposed Services Routes	R8	Adjacent Buildings and Structures	Unlikely	Low	Low risk	No offsite gas monitoring known to have been completed.

2.6 TIER I – RISK SCREENING AND CLASSIFICATION

The EPA CoP identifies eleven SPR linkages that should be considered within the conceptual model and assessed as part of the Tier I risk assessment. Each of these linkages can be scored using the scheme provided in the CoP in order to provide an overall risk categorisation for the site.

An initial model was developed based on the information available with consideration given to the eleven SPR linkages identified in the CoP. During Tier 1, each aspect of each SPR linkage can be assessed according to particular criteria as defined within the CoP. The CoP uses a separate scoring matrix for each aspect of an SPR linkage, which are defined within Tables 1a to 3f of the CoP. Where an individual aspect is not present or not relevant within the context of the conceptual model it is given a score of 0.

The score of each linkage is normalised with respect to 100 by dividing the score for each linkage by the maximum available points for that linkage to express as a percentage. The overall score for the site is taken as the maximum of the individual normalised scores. The site can then be placed in a prioritisation category depending upon the potential level of risk identified. Sites with a higher score represent those with either a higher level of risk, which may require remediation, or a high level of uncertainty, which requires further intrusive investigation. If a high score is due to a high level of uncertainty then the assessment should proceed to Tier 2 (Site Investigation and Testing) to refine the risk assessment.

The risk prioritisation and classification is summarised in **Table 2.9**. The risk category bands relating to the site scores as defined in the CoP are presented in **Table 2.10** and the risk classification and prioritisation of the Bohernabreena site are shown in **Table 2.11**.

Table 2.9 Risk Category and Prioritisation Class

Score	Priority Class	Risk Category	Definition
> 70%	A	High	High risk/high uncertainty sites. Further investigation required to confirm status. Presents potentially high risk to environment in current condition. Remediation / mitigation will be necessary. Highest priority with Regulating Authority.
40% to 70%	B	Moderate	Moderate risk/moderate uncertainty sites. Further investigation required to confirm status. Presents potentially moderate risk to environment in current condition. Remediation / mitigation may be required.
< 40%	C	Low	Low risk sites. Not considered to present risk to environment in current condition however further investigation may be required in case of change of land use.

Table 2.10 Scoring Rationale

Source Assessment	Score Matrix	Site Score	Rational/Comments
Leachate	1a	2	>1 ≤5 ha Pre 1977 Site (Site is 2.2ha and closed in 1974)
Gas	1b	0.75	>1 ≤5 ha Pre 1977 Site (Site is 2.2ha and closed in 1974)
Leachate Migration Pathway Assessment	**Score Matrix**	**Site Score**	**Rational/Comments**
Vertical Pathway (Aquifer Vulnerability)	2a	3	Extreme Vulnerability
Horizontal Pathway (Groundwater Flow Regime)	2b	1	LI poorly productive bedrock
Surface Water Pathway	2c	2	Direct linkage to the Dodder River
Gas Migration Pathway Assessment	**Score Matrix**	**Site Score**	**Rational/Comments**
Assuming lateral migration (assuming receptor within 250m of source)	2d	3	Made ground
Vertical migration (assuming receptor located above source)	2e	0	No receptors located above waste body
Receptor Assessment	**Score Matrix**	**Site Score**	**Rational/Comments**
Residential dwellings with potential for private water supply	3a	3	Domestic dwellings located within 50m of waste body
Protected Areas	3b	3	Glensamole Valley SAC (001209) 12m south east of waste body
Aquifer	3c	1	Poor Aquifer
Public Water Supplies	3d	0	No public water supplies within 1km of waste body
Surface Water Bodies	3e	3	Dodder within 50m of site boundary
Buildings and enclosed spaces used by humans or livestock	3f	5	Within 50m of site boundary

Table 2.11 Risk Classification and Prioritisation

SPR No.	Equation	SPR Linkage Score	% Score	Risk Classification
Leachate migration through combined surface water and groundwater pathways				
SPR1 Surface Water Body	1a X (2a+2b+2c) X 3e 2 X (3+1+2) X 3	36	12%	Low
SPR 2 Protected Area (SWDTE)	1a X (2a+2b+2c) X 3b 2 X (3+1+2) X 3	36	12%	Low
Leachate migration through groundwater pathway				
SPR 3 Human Presence (Private well)	1a X (2a+2b) X 3a 2 X (3+1) X 3	24	10%	Low
SPR 4 Protected Area (GWPTE)	1a X (2a+2b) X 3b 2 X (3+1) X 3	24	10%	Low
SPR 5 Aquifer Category	1a X (2a+2b) X 3c 2 X (3+1) X 1	8	2%	Low
SPR 6 Public Supply (well)	1a X (2a+2b) X 3d 2 X (2+1) X 0	0	0%	Low
SPR 7 Surface Water Body	1a X (2a+2b) X 3e 2 X (2+1) X 3	24	10%	Low
Leachate migration through surface water pathways only				
SPR 8 Surface Water Body	1a X 2c X 3e 2 X 2 X 3	12	20%	Low
SPR 9 Protected Area (SWDTE)	1a X 2c X 3b 2 X 2 X 3	12	20%	Low
Landfill gas migration pathways				
SPR 10 Lateral Migration to Human Presence	1b X 2d X 3f 0.75 X 3 X 5	11.25	8%	Low
SPR 11 Vertical Migration to Human Presence	1b X 2e X 3f 0.75 X 0 X 5	0	0%	Low

Risk Classification	
High	≥70% for any individual SPR linkage
Moderate	Between 40-79% for any individual SPR linkage
Low	≤40% for any individual SPR linkage

2.6.1 Tier I – Risk Summary

According to the EPA CoP risk prioritisation and methodology the site is classified as a Low Risk (Class C). However, direct impact on the River Dodder has been observed from leachate discharging from the site into the river. Available chemical data indicates the leachate contains high levels of Ammoniacal Nitrogen. The potential risk from leachate to the River Dodder needs to be investigated further.

2.6.2 Identified Gaps

- Waste characterisation unknown. Chemical analysis and leachability testing of waste material not completed.
- Limited SI completed in the vicinity of the waste bodies to determine vertical and lateral extent of waste bodies.
- Limited or no monitoring locations available within the relevant waste bodies. Where boreholes are present, logs are unavailable therefore borehole construction and integrity are unknown.
- No offsite gas monitoring locations have been installed to investigate potential lateral migration.
- Gas monitoring is limited, no reference to methodology utilised during monitoring, no flow measurements, atmospheric conditions not recorded.
- Limited or no leachate monitoring locations, sampling and analysis. Lack of information regarding leachate quality and quantity.
- Limited information available regarding the thickness of the existing clay cap and no analysis completed to determine composition.
- Limited or no groundwater quality data available. Groundwater monitoring to be completed following establishment of potential contaminants of concern.
- Limited information available on location of springs within the SAC and therefore mapping and sampling of these is required to determine potential impacts on spring water quality and flow.
- Limited dataset available for surface water quality.

3 TIER II EXPLORATORY AND MAIN PHASE

3.1 INTRODUCTION

The section presents the Tier II Exploratory and Main Phase Site Investigations and results. The site investigations were carried out in a phased manner with the results presented together.

3.2 PROJECT OBJECTIVE

The objective of the Tier II Site Investigations were to confirm the initial CSM and risk classification of the site by characterising the extent of the waste body and determine if the current condition of the site is causing a risk to the environment and human health.

3.3 SCOPE OF WORKS

For the purpose of this Tier II Site Investigations RPS undertook the following scope of works:

- Excavation of 8 No. trial pits to characterise the extent and composition of any waste and assess the ground conditions of the site;
- Installation of 6 No. gas/leachate monitoring boreholes to investigate for the presence, volume and composition of leachate;
- Installation of 2 No. groundwater monitoring boreholes to assess groundwater quality of the aquifer within the vicinity of the site;
- Gas monitoring to determine the presence and concentration of landfill gas;
- Groundwater, leachate and surface water sampling and analytical testing to determine any environmental risk;
- Soil sampling and analytical testing to determine the risk to human health;
- Geophysical survey to determine the extent of the waste across the site;
- Topographical survey of the site and to survey site investigation locations; and
- Interpretation and report of findings in a comprehensive report.

The investigations were carried out in accordance with EPA CoP and the accompanying Matrix I: *Guidance for Preliminary and Exploratory Investigations for all Unregulated Waste Disposal Sites* and the following relevant guidelines:

- BS 10175:2011+A1:2013, Investigation of potentially contaminated sites - Code of Practice;
- BS 5930:2015, Code of practice for ground investigation;
- Applicable CEN and ISO Standards for Analysis and Sampling;
- Environment Agency (EA) Guidance on Assessment of Risks from Landfill Sites;
- CIRIA C665, Assessing Risks Posed by Hazardous Ground Gases (2007); and

- All relevant Health and Safety Regulations and Guidance (including the Health, Safety and Welfare at Work Act 2005, and Safety, Health and Welfare at Work (Construction) Regulations 2006 as amended).

3.4 LIMITATIONS

- Inaccessible conditions along the River Dodder restricted the frequency and location of surface water samples.
- The presence of waste across the entire site and topography of the site restricted the number of groundwater monitoring wells which were installed across the site.

3.5 METHODOLOGY

3.5.1 Non-Intrusive Site Works

3.5.1.1 Geophysical Survey

A geophysical survey was completed at the site on the 2nd November 2018 by Apex Geoservices (refer to **Appendix D**). The objectives of the geophysical survey were as follows:

- Identify the lateral extent of the waste body;
- Identify the thickness of the waste body and presence of any anomalous features;
- Determine the type of waste;
- Determine the volume of waste;
- Identify any leachate plumes outside of or below the waste body; and
- Assist in the development of the CSM sections for the landfill.

The location points are indicated in **Figure 3.1**. The survey was carried out using the following methods:

- EM ground conductivity mapping operates on the principle of inducing currents in conductive substrata and measuring the resultant secondary electro-magnetic field. The strength of this secondary EM field is calibrated to give apparent ground conductivity in milliSiemens/metre (mS/m). This technique will provide information on the shallow (0-6m below ground level) variation of the superficial deposits and outline the extent of any shallow bedrock.
- ERT soundings image the resistivity of the materials in the subsurface along a profile to produce a pseudo-section showing the variation in resistivity to depths dependent on the length of the profile. Each pseudo-section is interpreted to determine the material type along the profile based on the typical resistivities returned for Irish ground materials.
- Seismic Refraction Profiling measures the P-wave velocity of refracted seismic waves through the overburden and rock material and allows an assessment of the thickness and quality of the materials present to be made. Stiffer and stronger materials usually have higher seismic velocities while soft, loose or fractured materials have lower velocities. This method profiles the depth to

the top of the stiff soils and bedrock and provides information on the quality/strength of the bedrock.

The MASW method is used to estimate shear-wave velocities (Vs) in the ground material. Overburden material with a Vs <175 m/s is generally classified as soft/loose. The geophysical results were used in conjunction with borehole and trial pit logs for an integrated approach to determining the subsurface conditions.

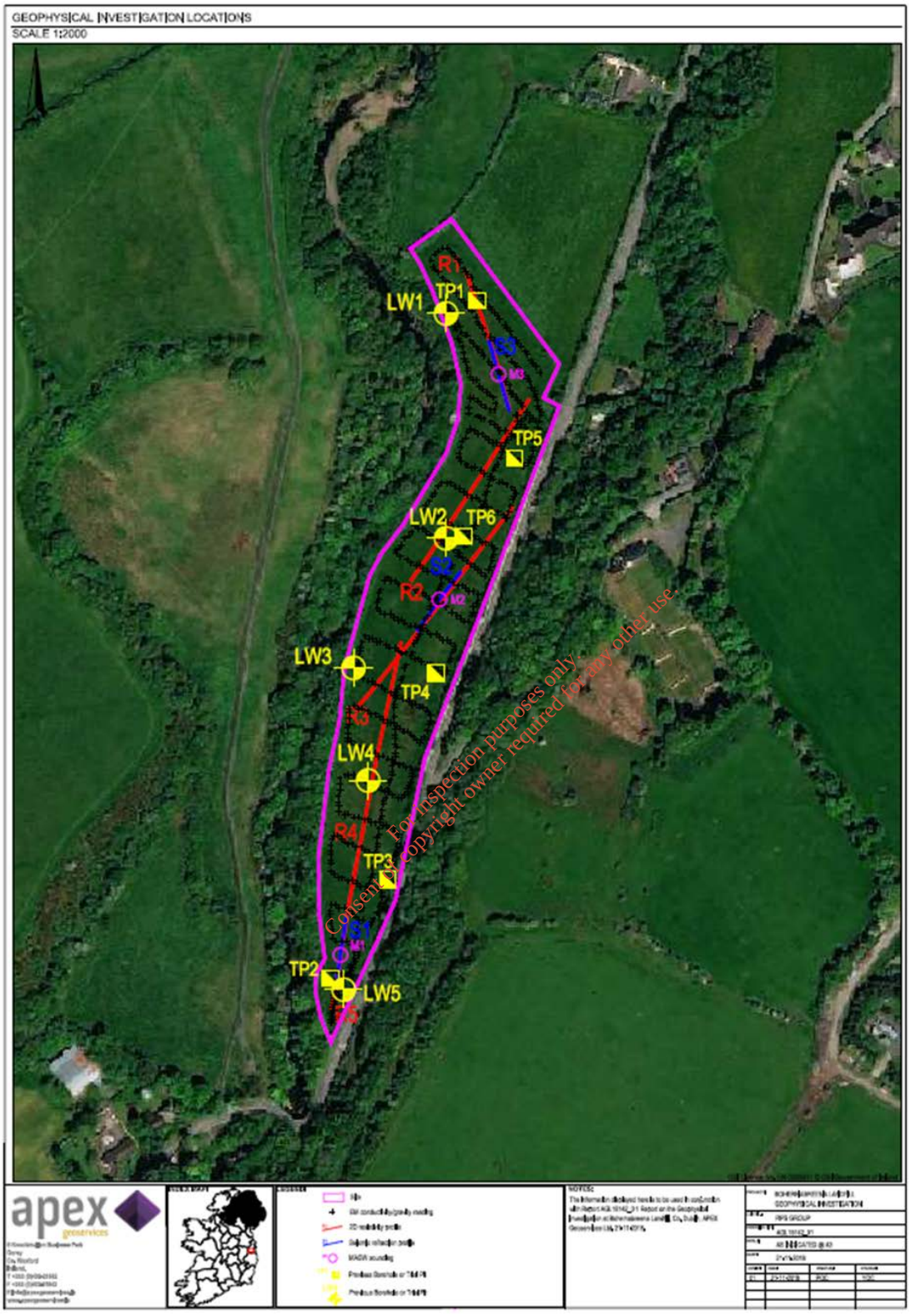


Figure 3.1 Location of Geophysical Survey Points

3.5.2 Topographical Survey

A topographical survey was completed at the site on the 18th October 2018 by Murphy Surveys Ltd. (refer to **Appendix E**). The survey was based on the installed survey control and related to the Ordnance Survey ITM (15) Grid and Malin Head Datum. Locations of all trial pits and monitoring boreholes were also surveyed.

3.6 INTRUSIVE SITE WORKS

3.6.1 Underground Utilities

Prior or any intrusive site works being undertaken underground utilities were identified. Utility maps from Eircom, ESB Networks, Bord Gais and SDCC were requested. No utilities were located on the site, however, surface water drainage and overhead power lines ran adjacent to the site along the road.

3.6.2 Trial Pit Excavations

A total of 8 No. trial pits (TP01 – TP8) were excavated on 2nd and 8th October 2018 by Priority Geotech Ltd. using a tracked excavator. Refer to **Figure 3.2** for trial pit locations. Trial pits were excavated to the depth of waste where possible. Trial pits were logged by an RPS engineer (refer to **Appendix F** for trial pit geological logs). Following completion of the trial pit, excavations were backfilled and photographed.

3.6.3 Monitoring Borehole Installation

A total of 6 No. gas/leachate (LW01 – LW06) and 2 No. groundwater monitoring boreholes (GW01-GW02) were installed across the site between the 2nd and 26th October 2018. For monitoring borehole locations refer to **Figure 3.2**. A targeted approach for the location of the monitoring boreholes was taken based on the findings of Tier I Environmental Risk Assessment.

Gas/leachate monitoring boreholes were drilled using a shell and auger drill rig and were installed and screened within the waste body. To prevent migration of any potential leachate to the bedrock aquifer, drilling was completed to the base of any encountered waste.

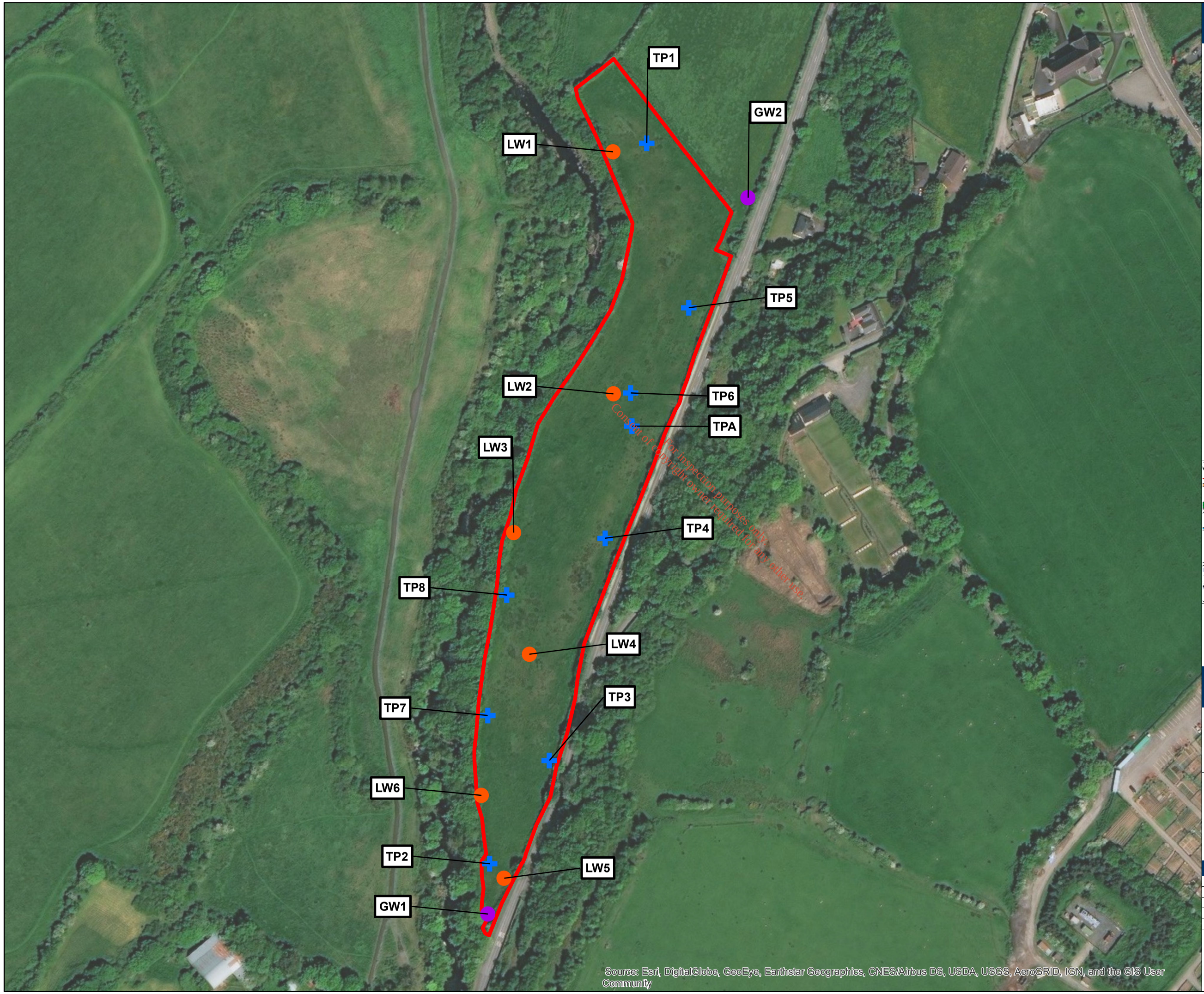
Due to access constraints and as waste was encountered across the majority of the site, only one onsite location suitable for installation of a groundwater well (GW1) was determined. An additional groundwater well was installed offsite to the north of the site (GW2).

Groundwater monitoring boreholes were drilled using a track-mounted air rotary rig and were installed within the bedrock aquifer. Temporary casing was used to maintain stability while drilling through the overburden.

All monitoring borehole installations were completed with 50mm diameter PVC standpipe. Clean pea gravel was used as a gravel pack around the monitoring wells. Monitoring well installation were designed in order to prevent any conduit for contamination from the overburden to the aquifer and the well annulus above the slotted screen section was sealed with bentonite.

All monitoring boreholes were fitted with upright steel covers. Sampling the groundwater at the monitoring borehole was undertaken using an inertial pump. The gas/leachate monitoring boreholes were fitted with a gas tap. The installation was logged by an engineer and supervised by RPS, the installation details are presented in **Appendix G**.

Monitoring borehole installation details are summarized in **Table 3.1**.



Legend

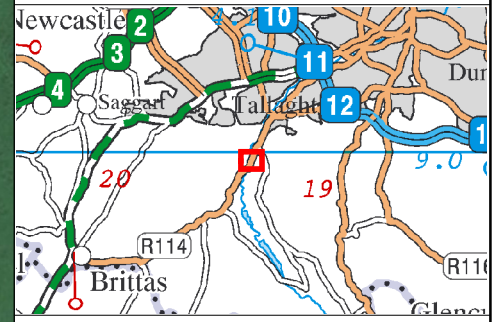
- Site Boundary

Site Investigation Locations

- Groundwater Borehole Locations
- Gas/Leachate Monitoring Well Locations
- Trial Pit Locations

N

0 20 40 80 Meters



Client

Comhairle Contae Átha Cliath Theas
South Dublin County Council

Project

Bohernabreena Landfill Environmental Risk Assessment

Title

Site Investigation Locations

Figure: 3.2

RPS

West Pier Business Campus,
Dun Laoghaire,
Co. Dublin,
Ireland.

T: +353 (0) 1 4882900
E: ireland@rpsgroup.com
W: rpsgroup.com/ireland

Issue Details

Drawn By: HF	**Project No.** MDR1489		
Checked By: BMcP	**File Ref:**		
Approved By: BMcP	MDR1489Arc0009D01		
Scale: 1:2,000 @ A3	**Drawing No.**	**Rev:**	
Date: 19/12/2018	Arc0009	D01	

NOTE:

1. This drawing is the property of RPS Group Ltd. It is a confidential document and must not be copied, used, or its contents divulged without prior written consent.
2. All levels are referred to Ordnance Datum, Malin head.
3. Ordnance Survey Ireland Licence EN 0005018 ©Copyright Government of Ireland.

Table 3.1 Borehole Installation Details

Borehole ID	Monitoring Borehole type	Northing	Easting	Borehole Ground level (mAOD)	Drilling Method	Total Drilled depth (mbgl)	Screening Interval (mbgl)	Screening Lithology
LW1	Gas/leachate	709047.253	724980.314	111.078	Shell & Auger	8	1-8	Waste
LW2	Gas/leachate	709047.414	724841.703	113.532	Shell & Auger	4	2- 4	Waste
LW3	Gas/leachate	708990.253	724762.282	115.469	Shell & Auger	5	1.5 - 5	Waste
LW4	Gas/leachate	708999.309	724692.704	116.603	Shell & Auger	8.5	1.5 – 8.5	Waste
LW5	Gas/leachate	708984.826	724564.522	118.947	Shell & Auger	4	1-4	Waste
LW6	Gas/leachate	708971.725	724611.862	56.57	Shell & Auger	6	1-6	Waste
GW1	Groundwater	708975.5	724544	117.083	Rotary Drilling	21	19-21	Bedrock
GW2	Groundwater	709124.6	724954	111.536	Rotary Drilling	18	16-18	Bedrock

3.7 ENVIRONMENTAL MONITORING

3.7.1 Borehole Leachate Sampling

Leachate samples were collected on 9th, 14 and 17th November 2018. A representative sample was only recovered from LW4 (LW1, LW2, LW3, LW5 and LW6 were dry).

The leachate samples were collected within dedicated laboratory supplied sample containers and shipped to Exova Jones Environmental Ltd. (UKAS Accredited), Deeside Industrial Park, Flintshire, England. To minimise cross contamination between sampling locations new sampling equipment was used to collect each discrete sample.

Leachate samples were tested for the parameters listed in Table C2 of EPA landfill monitoring manual and also additional selected parameters:

- Temperature;
- pH;
- Electrical Conductivity;
- Redox;
- Ammonia;
- Total oxidised nitrogen;
- Biochemical oxygen demand;
- Chemical oxygen demand;
- Total Organic Carbon;
- Total Dissolved Solids;
- Total Suspended Solids;
- Metals (calcium, magnesium, sodium, potassium, iron (total), manganese, cadmium, chromium (total), copper, nickel, lead, zinc, arsenic, boron and mercury);
- Sulphate;
- Sulphide;
- Chloride;
- Fluoride;
- Molybdate Reactive Phosphorus;
- Alkalinity;
- Phenols;
- Cyanide;
- Pesticides (Organochlorine Pesticides and Organophosphorus Pesticides);
- Coliforms;
- Faecal Coliforms; and
- E.coli.

Results were compared to EPA groundwater Interim Guidelines Values. In the absence of these guidelines the results were compared to Groundwater Regulations. A copy of the laboratory results is included in **Appendix H**.

3.7.2 Trial Pit Leachate Sampling

During trial pit excavation, 3 No. soil samples; TP1 (2.5 mbgl), TP7 (4.5 mbgl) and TP8 (2.5mbgl) were collected for soil leachate analysis to assess the risk from leachate generation from waste. Samples were tested using the NRA Leachability test and analyses for a range of contaminants including;

- pH;
- Electrical Conductivity;
- Redox;
- Ammonia;
- Total oxidised nitrogen;
- Biochemical oxygen demand;
- Chemical oxygen demand;
- Dissolved Organic Carbon;
- Total Dissolved Solids;
- Metals (calcium, magnesium, sodium, selenium, potassium, iron, manganese, cadmium, chromium, copper, nickel, lead, zinc, arsenic, antimony, barium, boron, molybdenum and mercury);
- PAHs (Aliphatics, Aromatics);
- Fluoride;
- Sulphate;
- Chloride;
- Nitrite;
- Molybdate Reactive Phosphorus Ortho Phosphate;
- Cyanide;
- Phenols;
- Phthalates;
- SVOCs; and,
- VOCs.

Results were compared to EPA groundwater Interim Guidelines Values. In the absence of these guidelines the results were compared to Groundwater Regulations. A copy of the laboratory results is included in **Appendix H**.

3.7.3 Soil Sampling for Human Health

During trial pit excavation, 4 No. soil samples; TP1 (0.4 mbgl), TP4 (0.4 mbgl), TP6 (0.2 mbgl) and TP7 (0.2 mbgl) were collected for soil analysis to assess the risk to human health.

- pH;
- Natural Moisture Content;
- Fraction Organic Carbon;
- Dissolved Metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc);
- PAHs;

- Phenols;
- VOC;
- SVOC; and
- Phthalates

Results were compared to EPA groundwater Interim Guidelines Values. In the absence of these guidelines the results were compared to Groundwater Regulations. A copy of the laboratory results is included in **Appendix H**.

3.7.4 Borehole Groundwater Sampling

A total of 4 No. groundwater samples were collected on 9th and 14th October 2018 from 2 No. groundwater monitoring borehole (GW1 and GW2).

The groundwater samples were collected within dedicated laboratory supplied sample containers and shipped to Exova Jones Environmental Ltd. (UKAS Accredited), Deeside Industrial Park, Flintshire, England. All groundwater samples were obtained following purging a minimum of three well volumes prior to sample collection. To minimise cross contamination between sampling locations dedicated sampling equipment was used to collect each sample.

Groundwater samples were tested for the parameters listed in Table C2 of EPA landfill monitoring manual included the following;

- Temperature;
- pH;
- Electrical Conductivity;
- Radox;
- Total dissolved solids;
- Total suspended solids;
- Biochemical oxygen demand;
- Chemical oxygen demand;
- Phenols;
- PAHs;
- Phthalates;
- SVOC;
- VOC;
- Ammonia;
- Total oxidised nitrogen;
- Total organic carbon;
- Pesticides (Organochlorine Pesticides and Organophosphorus Pesticides);
- Metals (arsenic, boron, cadmium, calcium, chromium (total), copper, iron (total), lead, magnesium, manganese, mercury, nickel, potassium, sodium and zinc);
- Alkalinity;
- Sulphate;

- Chloride;
- Molybdate Reactive Phosphorus;
- Cyanide (Total);
- Fluoride;
- Coliforms;
- Faecal Coliforms; and
- E.coli.

Results were compared to EPA groundwater Interim Guidelines Values. In the absence of these guidelines the results were compared to Groundwater Regulations. A copy of the laboratory results is included in **Appendix H**.

3.7.5 Surface Water Sampling

A total of 9 No. surface water samples were collected on 25th and 30th October 2018 from 7 No. locations shown in **Figure 3.3.** as outlined in the **Table 3.2**.

Table 3.2 Surface Water Locations

Sample ID	Location
SW1	River Dodder upgradient of site – Font Bridge
SW2	River Dodder downgradient of the site
SW3	River Dodder middle of the site
Spring 1	Cattle feeder on the site
Spring 2	Leachate on the river bank
Road Run Off	Road drainage from the Friarstown Leachate Tank
Pipe Outflow	Pipe from the Friarstown Leachate Tank

All surface water grab samples were obtained by placing the dedicated laboratory sampling bottles directly into the surface water body. The sample inlet was placed below the surface flow while care was taken not to disturb the base/bed of the surface water body. Surface water samples were analysed for a range of parameters including;

- Temperature;
- pH;
- Electrical Conductivity;
- Radox;
- Sulpahte;
- Chloride;
- Phenols;
- Cyanide;
- Molybdate Reactive Phosphorus;
- Total Oxidises Nitrogen;

- Ammoniacal;
- Alkalinity;
- Sulphide;
- Biological oxygen demand;
- Chemical oxygen demand;
- Total organic Carbon;
- Total dissolved solids;
- Total suspended solids;
- Dissolved Metals (arsenic, boron, cadmium, calcium, chromium (total), copper, iron (total), lead, magnesium, manganese, mercury, nickel, potassium, sodium and zinc);
- PAH;
- VOC;
- SVOC;
- Phthalates; and
- Pesticides (Organochlorine Pesticides and Organophosphorus Pesticides).

Results were compared to Surface Water Guidelines. A copy of the laboratory results is included in **Appendix H**.