ATTACHMENT D2

Tier 2 & Tier 3 Environmental Risk Assessment

BARNAGEERAGH LANDFILL

Tier 2 and Tier 3 Environmental Risk Assessment

EPA Site Registration Number: S22-0265

MGE0755RP0001
Barnageeragh Landfill Tier 2 and Tier 3 Environmental Risk Assessment
F01
21 July 2020

rpsgroup.com

Document status

Version	Purpose of document	Authored by	Reviewed by	Approved by	Review date
A01	Draft for Client Review	GMcE, ND	Gareth McElhinney	Gareth McElhinney	22 November 2019
F01	Final	GMcE, ND	Gareth McElhinney	Gareth McElhinney	21 July 2020

Approval for issue

Gareth McElhinney	21 July 2020

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Contents

Tables

Figures

Appendices

1 INTRODUCTION

1.1 Environmental Risk Assessment

This environmental risk assessment has been completed in accordance with the EPA Code of Practice Environmental Risk Assessment for unregulated Waste Disposal Sites (EPA, 2007), hereafter the CoP. The environmental risk assessment examines the various Source-Pathway-Receptor (SPR) linkages and determines the risk posed by the historical waste body with regard to the environment and human health. The CoP defines risk categories related to the degree of environmental risk posed by the waste. The risk categories are summarised in **Table 1.1**.

Table 1.1: Risk Categories from EPA Code of Practice

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.

The CoP outlines a six-step process to be followed in undertaking an assessment of an unregulated waste disposal site. The six steps are summarised below:

- Step 1: Notification of the EPA that historical waste has been identified at the site;
- Step 2: TIER 1 Assessment including development of a conceptual site model with risk screening and prioritisation;
- Step 3: TIER 2 Assessment including detailed site investigations and verification of the site's classification;
- Step 4: TIER 3 Assessment including the refinement of the conceptual site model based on the information from the Tier 2 Assessment. A quantitative risk assessment shall be carried out on all high and moderate risk sites;
- Step 5: Site remediation proposals are to be made, if considered necessary; and
- Step 6: The Local Authority is to ensure that all reporting requirements as set out in the *Code of Practice* have been satisfied.

Step 1 and Step 2 have already been completed.

The Tier 1 Risk Assessment is presented in RPS report reference MDR1552Rp0001.

This Tier 2 and Tier 3 report completes Step 3 through Step 5 in the above sequence.

1.2 Purpose of this Report

This Environmental Risk Assessment report completes the Tier 2 and Tier 3 processes required in the CoP. This report and will be submitted by Fingal County Council in their application to the EPA for a certificate of authorisation for the unregulated waste disposal site at Barnageeragh, Skerries, Co. Dublin.

A significant amount of site investigation and analysis of the collected data has been undertaken by the developer of the site, Winsac Ltd. This information is presented in the report prepared on behalf of Winsac Ltd. by Mulroy Environmental Ltd., entitled:

- Winsac Ltd. Residential Development, Barnageeragh Cove, Skerries, Phase II Site Investigation/ DQRA & Landfill Gas Survey, Final Report, 26th February 2019.

Hereafter, the above report will be referenced as the "**DQRA**".

The information presented in this Tier 2 and Tier 3 report provides an independent review of the information presented in the Winsac Ltd. DQRA. On the basis of this information, the environmental risk of the site and the conceptual site model (CSM) can be updated from the Tier 1 report (RPS document reference MDR1552Rp0001) to facilitate the appropriate categorisation in accordance with the CoP. This will enable Fingal County Council to apply to the EPA for the certificate of authorisation for Barnageeragh Landfill.

1.3 Certificate of Authorisation

The EPA processes applications from local authorities in relation to closed landfills (or historical landfills) as required by the Waste Management (Certification of Historic Unlicensed Waste Disposal and Recovery Activity) Regulations, 2008.

In order to apply to the EPA for a certification of authorisation (Regulation 7), the local authority must have registered the landfill with the EPA (Regulation 5) and carried out a risk assessment (Regulation 6). Risk Assessments are to be carried out in accordance with the '*Code of Practice - Environmental Risk Assessment for Unregulated Waste Disposal Sites*' and the site investigation matrices published by the EPA.

The certificate of authorisation certifies compliance with the requirements of the regulations.

Under regulation 8, the local authority shall make all reasonable efforts to comply with any validated certificate issued by the EPA.

In the regulations, closed landfills are defined in as:

> "… a landfill site operated by a local authority for the recovery or disposal of waste without a waste licence on any date between 15 July 1977 and 27 March 1997 (i.e. prior to the entry into force of the Waste Management (Licensing) Regulations, 1997 (S.I. No. 133 of 1997))."

1.4 Competent and Qualified Persons

This report has been prepared by Gareth McElhinney and Noreta Daly.

Gareth McElhinney is a Technical Director in Environment and Marine and has 20 years' postgraduate experience with significant experience in landfill engineering, contaminated land and remediation projects. He holds a bachelor's degree in Civil Engineering and a master's degree in Business Studies. Gareth is a Chartered Engineer with Engineers Ireland, and is on their Register of Chartered Engineers: Historic Landfills[1] in accordance with Section 2.3 of the EPA Code of Practice.

Noreta Daly is a Senior Scientist and has 9 years' postgraduate experience with significant experience in groundwater and geological assessment projects. She holds a bachelor's degree in Earth Science and a

[1] https://www.engineersireland.ie/services/landfill-register.aspx

master's degree in Applied Environmental Geology. Noreta is a Chartered Geologist with the Institute of Geologist of Ireland and is on their Register of Professional Geologists. She is also a member of the International Association of Hydrogeologists (Irish Group).

1.5 Limitations

The following notes should be read in conjunction with this report:

- This report contains only the available factual data for the site obtained from the sources described in the text;
- The review of the site is based on documentation and information provided by FCC;
- Where data have been supplied by FCC or other sources it has been assumed that the information is correct, but no warranty is given to that effect. While reasonable care and skill has been applied in the review of this data no responsibility can be accepted by RPS for inaccuracies in the data supplied;
- During the site walkover (25th July 2019) areas where the safety and health of RPS personnel would have been jeopardised were not accessed, e.g. areas of steep slopes;

The conclusions presented in this report represent RPS's best professional judgement based on a review of the relevant information available at the time of drafting. The opinions and conclusions presented are valid only to the extent that the information provided was accurate and complete.

2 OVERVIEW OF BARNAGEERAGH LANDFILL SITE

2.1 Site Particulars

The following are the site particulars as per Regulation 7(2) of S.I. 524 of 2008, Waste Management (Certification of Historic Unlicensed Waste Disposal and Recovery Activity) Regulations, 2008:

(a) **Site Address**: Barnageeragh, Skerries, County Dublin

(b) **Owner**: Private Owner

(c) **Land Use**: This site is a privately-owned site that has been partially developed. A residential development is located to the west and north, a wastewater treatment plant to the east, and the Dublin to Belfast railway line to the south of the site. Beyond the railway line are agricultural lands.

(d) **National Grid Reference**: Refer to drawing number MGE0755-RPS-00-XX-DR-C-DG0001-01 in **Appendix A**

Overall Site Coordinates (ITM): Easting 723,131; Northing 760,830

There is one large area on the site where waste was discovered as illustrated in the drawings in **Appendix A**.

(i) The interpreted area of contamination is approximately 8,500m^2.

Centre Coordinates (ITM): Easting 723,131; Northing 760,830

(e) **Map of the Location**: Refer to drawing number MGE0755-RPS-00-XX-DR-C-DG0001-01 in **Appendix A**.

(f) **Scaled Plans and Sections:** Scaled plans and sections are provided in **Appendix A**.

(g) **Estimate of Type of Waste and Quantities:** The total area of the Barnageeragh site is approximately 1.4 hectares with the waste deposition area approximately 0.85 hectares. The depth of waste varies across the site with the maximum depth of made/ground/ waste estimated to be approximately 10.5m below ground level (bgl) near the centre of the waste body.

The type of waste present on site is a mix of municipal and C&D waste. The total volume of waste estimated to be deposited at the site is 29,677m^3 (44,516 tonnes using a factor of 1.5 t/m^3) which includes both the made ground near the surface and the waste body buried on the site. Refer to the drawing number MGE0755-RPS-01-XX-DR-C-DG0004 in **Appendix A**.

(h) **Risk Assessment**: This report completes the requirements of a Tier 2 and Tier 3 Environmental Risk Assessment in line with the *EPA Code of Practice*.

2.2 Waste Body

A geophysical investigation of the site was carried out in two phases, one in November 2017 and one in January 2018, to determine the extents and approximate volume of waste material present at the Barnageeragh site. The details of the geophysical survey are presented in the Appendix 9 of the DQRA.

The geophysical investigation confirmed the presence of two types of waste within the landfill mass, namely:

- Type 1: a layer of largely mixed C&D waste with some municipal wastes ranging in thickness from 2.0m to 7.0m.
- Type 2: a layer of largely municipal waste ranging in thickness from 1.0m to 9.0m.

The depth to bedrock across the sites ranges from approximately 5.6m to 13.8m from ground level.

The information from the boreholes drilled on-site is contained in Appendix 8 of the DQRA. From this information RPS modelled the waste body to estimate the approximate volume of waste on the site. The results are presented in drawing number MGE0755-RPS-01-XX-DR-C-DG0004 in **Appendix A**. The approximate area is 8,500m^2 with a calculated waste volume of 29,677m^3. This volume is made up of both the Type 1 and Type 2 wastes defined in the geophysical survey report included in Appendix 9 of the DQRA.

2.3 Section 22 Register

The Barnageeragh Landfill is registered with the EPA under Section 22 of the Waste Management Act 1996, as amended), EPA registration number **S22-02655**.

2.4 Eastern-Midlands Region Waste Management Plan 2015-2021

The Barnageeragh Landfill site is included in Appendix F of the Eastern-Midlands Region Waste Management Plan 2015-2021.

2.5 Development & Current Zoning

2.5.1 Development

The planning history of the site is set out in detail in Section 2 of the Tier 1 Risk Assessment (RPS document reference MDR1552Rp0001). Below is a brief summary to provide context for this report.

The waste body at Barnageeragh was previously excavated during the construction of the rising foul sewer between Balbriggan and the wastewater treatment plant located east of the Barnageeragh waste body in 2006 (**Figure 2.1 and Figure 2.2**).

In 2006, Winsac Ltd. obtained planning permission for the construction of a residential development in the area. Construction commenced in 2008. An extension to this permission was obtained in 2013. During the construction of the Hamilton Hill housing estate in 2017 the waste body was again encountered. The area of the waste body was left largely undeveloped as shown below in **Figure 2.3**.

A LiDAR survey of the area was provided to RPS by Fingal County Council. The output from this LiDAR survey has been used to generate contours of the site as illustrated in drawing number MGE0755-RPS-00-XX-DR-C-DG0001-02, in **Appendix A**.

The land slopes from a high of approximately 25.0m O.D. in the southwestern corner to a low of approximately 15.0m O.D. at the north-eastern corner. The area to the west is landscaped with pavement and footpaths adjacent to the houses in the Hamilton Hill development. The landfill site itself is a typical construction site with stockpiles of soil and other construction materials clearly visible. Flat areas for the construction compound and other site activities are evident from the topographical survey.

In October 2019, the waste body and the land to the north of the waste body was regraded and soiled by the developer (**Figure 2.4**) to provide a clean soil surface. The regraded site provides a gentle slope falling from south to north.

Currently, Winsac Ltd. has a planning application lodged with Fingal County Council (application number: F19A/0196) which will consist of the development of an area of open space at Barnageeragh which will consist of a Multi-Use Games Area (MUGA) and associated site development works to facilitate the establishment of the open space area. As of the end of October 2019, no decision has been made with regard to this planning application.

Figure 2.1 Barnageeragh Landfill During Construction of Wastewater Rising Main (view to the west, 2006).

Figure 2.2 Barnageeragh Landfill During Construction of Wastewater Rising Main (view to the east, 2005).

Figure 2.3 Barnageeragh Landfill Site (looking west) during the construction of the Hamilton Hill housing development

Figure 2.4 Regrading and Soil Spreading at Barnageeragh Landfill, October 2019

2.5.2 Current Zoning

The zoning in the vicinity of the Barnageeragh Landfill is shown in **Figure 2.5** which is an extract from the Skerries Development Plan. In summary:

- The area around the Barnageeragh Landfill is zoned RA – Residential Area (light brown colouring).
- The area to the east of the site, at the wastewater treatment plant is zoned RU – Rural (light blue).
- To the south of the landfill, is the Dublin to Belfast railway line and south of this the land is zoned as GB – Greenbelt (light green).
- To the west of the site, beyond the existing housing development, the land is zoned OS- Open Space (dark green) and includes for the provision of a cycle/ pedestrian route.
- The site lies within Master Plan area MP5.A and within the development boundary for Skerries.
- To the west of the landfill waste body are two protected structures denoted by the yellow circles 178 and 179 in **Figure 2.5**, which are national monuments, respectively: DU005-017001 – mound and DU005-016001 – cairn unclassified.
- A recorded monument also lies within the western part of the site denoted by the purple star below (national monument reference DU005-017002 Prehistoric site - lithic scatter).

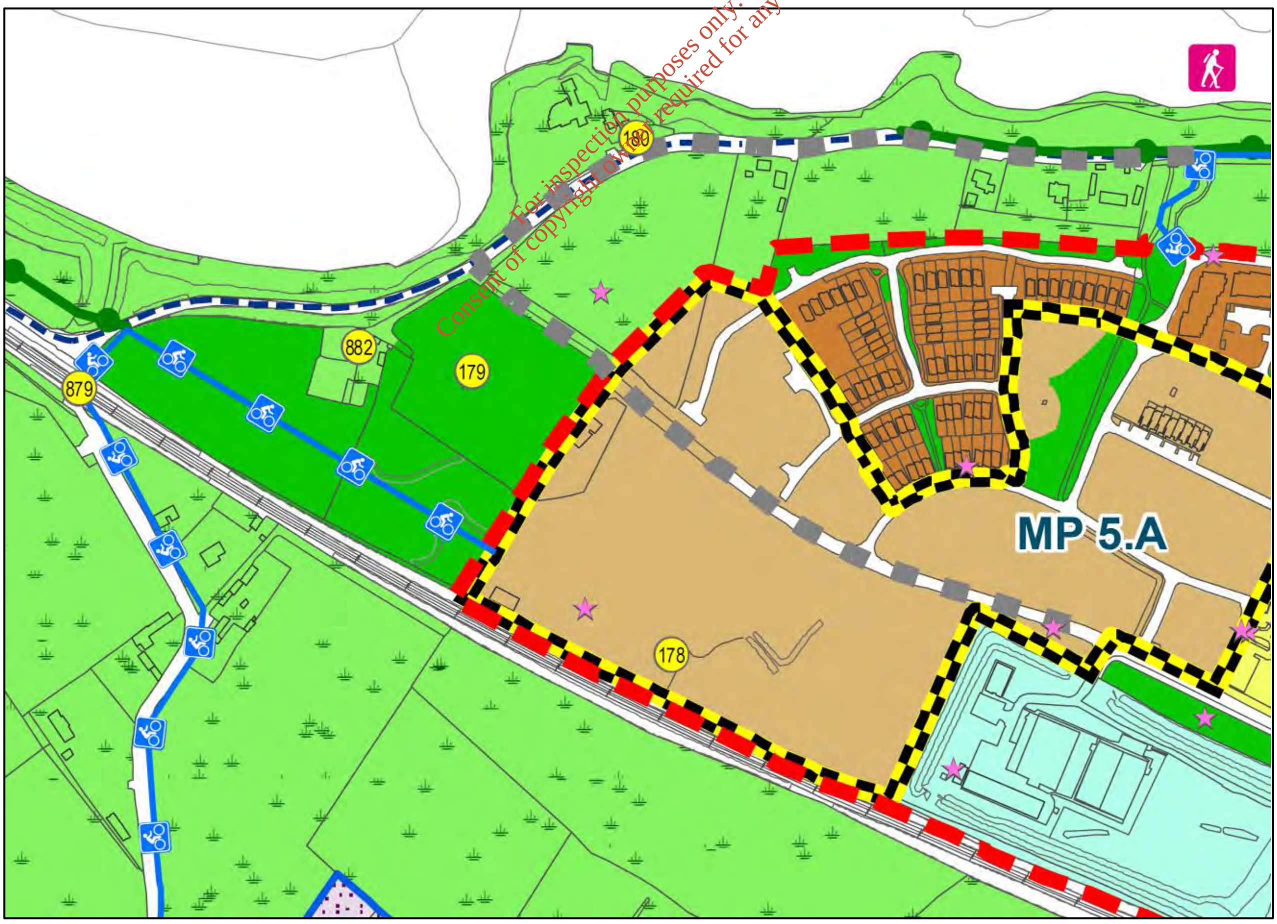


Figure 2.5 Skerries Development Plan: Barnageeragh (Fingal Development Plan 2017-2023, Sheet 5)

2.6 Proximity to Designated Sites

There are eleven European sites located within 15km of the Barnageeragh site, as follows:

1. Boyne Coast and Estuary SAC (Site Code: 001957);
2. Malahide Estuary SAC (Site Code: 000205);
3. Rogerstown Estuary SAC (Site Code: 000208);
4. Lambay Island SAC (Site Code: 000204);
5. Rockabill to Dalkey Island SAC (Site Code: 003000);
6. River Nanny Estuary and Shore SPA (Site Code: 004158);
7. Skerries Islands SPA (Site Code: 004122);
8. Rogerstown Estuary SPA (Site Code: 004015);
9. Malahide Estuary SPA (Site Code: 004025);
10. Lambay Island SPA (Site Code: 004069); and
11. Rockabill SPA (Site Code: 004014).

A screening for Appropriate Assessment (AA) report has been completed as required by the EPA for the application for a certificate of authorisation. The screening for AA report comprises the information for the EPA, in its role as the public authority under Regulation 42(2) of the European Communities (Birds and Natural Habitats) Regulations 2011 (SI No. 477/2011) as amended, to examine the likely significant effects of the proposal, individually or in combination with other plans or projects, on European sites in light of the specific Conservation Objectives (COs) of the Qualifying Interests (QIs) of SACs and Special Conservation Interests (SCI) of SPAs.

The screening for AA report concludes that Barnageeragh landfill, Skerries, Co. Dublin, either alone or in-combination with other plans and/or projects will not have significant negative effects on the integrity of European Sites in light of their conservation objectives. **Therefore, a Stage 2 Appropriate Assessment is not required**.

The screening for AA report accompanies this report (RPS document reference: MGE0755RP0002).

3 SUMMARY OF TIER 1 RISK ASSESSMENT

A Tier 1 risk assessment exercise was undertaken in accordance with the methodology outlined in Chapter 4 of the CoP (RPS report reference: MDR1552Rp0001). The Source-Pathway- Receptor (SPR) linkages were considered and assessed as part of the Tier 1 risk assessment. An initial conceptual site model was developed based on the desktop study of information and is illustrated in **Figure 3.1**.

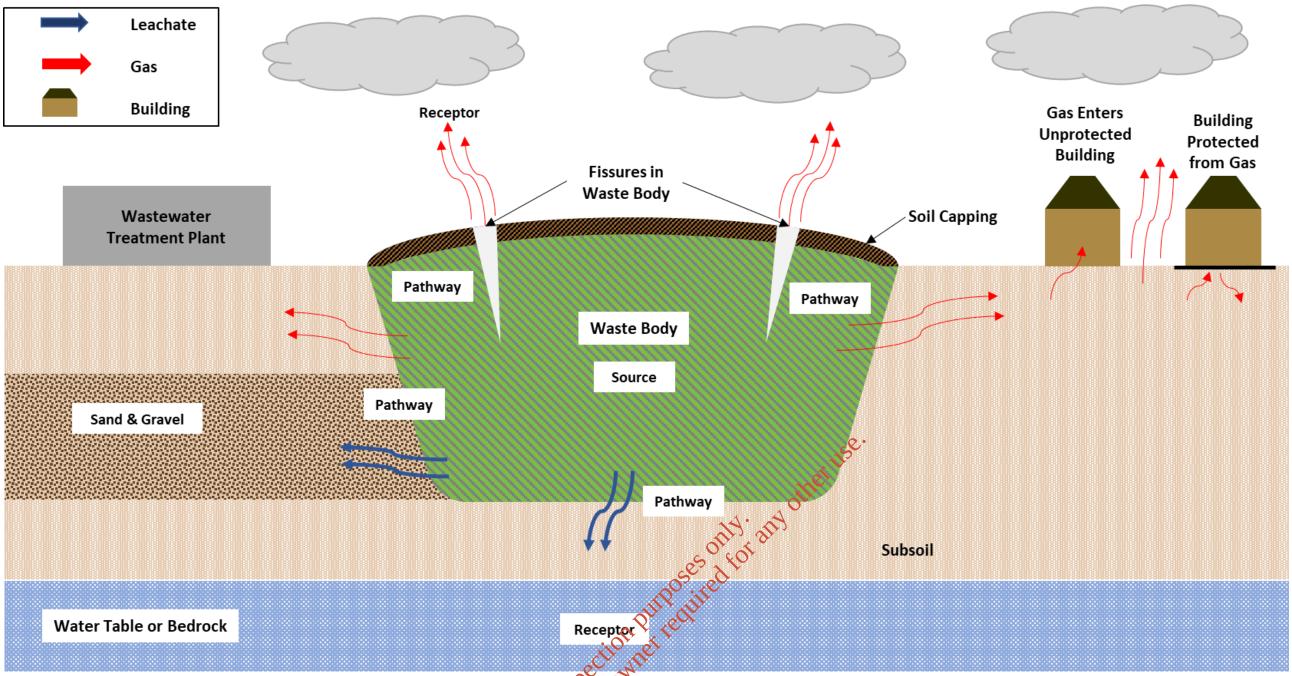


Figure 3.1 Tier 1 Conceptual Site Model

A summary of the results of the Tier 1 SPR assessment is provided below.

- Nine of the SPR linkages have a low risk (SPR 1 to 9)
- SPR 10 has a Moderate Class B risk. This SPR relates to the potential for lateral gas migration which should be investigated further due to the presence of residential housing within 50m of the site boundary.
- SPR 11 has a Moderate Class B risk. This relates to the potential for vertical gas migration which should be investigated further due to the presence of residential housing within 50m of the site boundary.
- None of the SPR matrices have a high-risk categorisation.

The Tier 1 risk assessment concluded:

- The site should be categorised as a Moderate Risk (Class B) for SPR linkages 10 and 11, both relating to landfill gas migration pathways (both lateral and vertical).

In line with the CoP, further Tier 2 ground investigation and testing are required to verify the risk status. Following the completion of the Tier 2 investigations, the Tier 3 risk assessment is required in order to refine the initial conceptual site model.

4 TIER 2 INVESTIGATIONS

4.1 EPA Site Investigation Matrices

Based on the findings of the Tier 1 environmental risk assessment (ref: MDR1552RP0001) undertaking site investigations was required. The EPA has published the following guidance for site investigation matrices which summarise 'mandatory', 'recommended' and 'should be considered' investigation techniques:

- Matrix 1 – Guidance for preliminary and exploratory investigations for all unregulated waste disposal sites; and

- Matrix 2 – Guidance for main site investigation requirements for moderate risk and high risk for unregulated waste disposal sites.

Over the course of a number of years, site investigation and monitoring works have been undertaken at Barnageeragh Landfill. These are detailed in the DQRA. The site investigations covered all SPR linkages 1 through 11, not just those deemed to be Moderate Risk (SPR linkages 10 and 11). As such, a comprehensive and complete picture of the Barnageeragh Landfill and the environmental risk posed by the landfill has been generated.

4.2 Winsac Ltd. Site Investigation and DQRA

The site Investigation works already undertaken on behalf of Winsac Ltd. include topographical mapping, a geophysical survey and intrusive ground investigation with associated environmental monitoring, gas and air quality monitoring and laboratory testing and reporting. Full details of the site investigations and testing are provided in the DQRA. This report presents a review of the information provided in the DQRA.

4.3 Objectives of Site Investigation

The objectives of the site investigation works were to establish the following:

- The geological sequence and associated lithologies, both solid and overburden including Made Ground and waste present across the site;

- Improved understanding of the hydrogeological profile of the site and define controlled water bodies on the site;

- Improved understanding of the nature of site drainage and site hydrology;

- Determine the vertical and lateral extent of the infill area;

- Provide information on any contamination of the ground and groundwater, including the occurrence of leachate or free phase contamination, if present;

- Provide information on the concentration of any hazardous substances in soils or waters;

- Determine the landfill gas concentrations and migration patterns and provide a network for monitoring landfill gases;

- Provide a targeted monitoring network for each groundwater body present on the site; and

- Provide the dataset to underpin an environmental risk assessment.

4.4 Tier 2 Investigation Works

4.4.1 Completed Investigations

The intrusive site investigation phase of the works took place between May 2017 and April 2018. The scope of the intrusive site investigation works was as follows:

- The excavation of 50 no. trial pits (TP1 -TP50);
- The drilling of 14 deep groundwater/gas wells (BH1-BH4, BH8 -BH17);
- The drilling of 3 deep gas wells (BH5-BH7); and
- The drilling of 4 shallow gas wells (GS01-GS04).

A drawing showing the location of all site investigations undertaken in included in **Appendix A** (drawing number MGE0755-RPS-01-XX-DR-C-DG0002-01).

Non-intrusive site investigation works were also undertaken, as follows:

- Geophysical surveying was carried by Apex Geoservices over the course of two days (24th November 2017 and 29th January 2018).

Full details in relation to methodology, scheduling, construction and location of the trial pitting, borehole drilling and gas well installation details are outlined in Section 3 Scope of Works of the DQRA.

The intrusive investigation was carried out in accordance with the British Standard BS 10175:2011 (Investigation of potentially contaminated site- Code of Practice).

A summary of the various techniques employed in the site investigation are included below:

4.4.1.1 Shallow Probes/ Hand Augers

A hand-held soil auger was used to collect topsoil samples to determine if there was any potential risk associated with the topsoil. This technique is recommended as part of the EPA COP Matrix 2 as it is suitable for gas monitoring and gas migration potential. The technique involves the manual or mechanical installation of temporary probes at typical depths of 2m below ground level. The technique is used to give initial information on the soil profile and strength.

4.4.1.2 Geophysics/ Infra-red Surveys

The geophysical surveys were undertaken to determine the extent and thickness of the waste body at the site. The survey was also used to identify the presence of irregular features in the waste body, to give an estimated waste volume calculation and to propose locations of sampling points. The geophysical survey was also used to determine the depth to the top surface of the bedrock and the thickness and types of soil present between the waste body and bedrock.

4.4.1.3 Window Sampling

Four 'shallow window sample' gas wells were installed on the 15th June 2017. Two of the wells terminated at depths of 2.0 m due to refusal on cobbles/boulders, while another terminated at 1.3m for the same reason. The other well was installed to a depth of 4m, the maximum depth allowed by the drilling rig.

4.4.1.4 Air Rotary Open or Cored Hole

Four boreholes (BH1-BH7) were installed on dates between the 14th June and the 19th June 2017 using deep air rotary techniques. Difficulty was experienced during the installation of boreholes BH1-BH4 due to compacted sand and gravel present beneath the waste material. BH1-BH4 acted as groundwater/gas wells, while BH5-BH7 acted as deep gas wells. Six more groundwater and gas monitoring boreholes. BH8-BH13, were installed on dates between 31st July and 2nd August 2017.

4.4.1.5 Landfill Gas Sampling

Landfill gas monitoring was undertaken borehole locations across the site between June 2017 and January 2019. Gas sampling was carried out at boreholes BH1-BH14 and at the 4 no. shallow gas wells, GS01-GS04 from June 2017. A further four boreholes were installed at a later date, BH15-BH17. The number of monitoring rounds for landfill gas varies from 32 to 50 rounds depending on when the boreholes were installed. The main constituent gases in landfill gas were sampled: methane (CH_4), carbon dioxide (CO_2) and Carbon monoxide (CO). The levels of volatile organic carbon (VOC) was also assessed during each sampling round.

A landfill gas probe survey was carried out at the interface of the foul ring main and the landfill body on the 15th March 2018. This interface is located at the northern end of the waste body where the foul rising main exits the waste body. In the survey, 16 no. vapour points were drilled in two rows of 8 at offsets of 2m on both sides of the foul rising main. A similar probe gas probe survey was carried out at the Skerries and Balbriggan waste water treatment plant on the 27th November 2018. For this survey, nine vapour points were drilled at 2m offsets of the foul rising main.

Gas sampling was carried out on the underground services of Residence Nos. 25-28 on the 29th May and the 5th June 2018. Locations where stagnant gases were likely to accumulate were tested. The radon sump of each residence was also opened to see if a build-up of landfill gas was present within foundation. The water mains at the front of the houses were also tested.

An indoor gas survey was conducted on the 15th December 2017 at Residences Nos. 25, 52 and 53. Further monitoring took place at Residence No. 26 and each of the four shallow gas wells GS01-GS04 on the 14th February 2018. Volatile organic carbons levels were assessed within the radon sump of Residences Nos.47, 52 and 53 on the 14th August 2018. **Table 4.1** shows the parameters that were tested during the indoor air and gas well monitoring period.

Table 4.1: Parameters Assessed During Indoor Air and Gas Well Monitoring

Residence/Gas Well	No. 25	No. 26	No. 52	No. 53	GS01	GS02	GS03	GS04
Parameter								
Arsenic	✔	✔	✔	✔	✔	✔	✔	✔
Mercury	✔	✔	✔	✔	✔	✔	✔	✔
Trace Landfill Gas Screen	✔	✔	✔	✔	✔	✔	✔	✔
Formaldehyde and Acetaldehyde	✔	✔	✔	✔	✔	✔	✔	✔
Carbon dioxide	✔	✔	✔	✔	✔	✔	✔	✔
Methane ground surface	✔	✔	✔	✔	✖	✖	✖	✖
Formaldehyde and Acetaldehyde	✔	✔	✔	✔	✖	✖	✖	✖

4.4.1.6 Leachate Sampling

Leachate was analysed for heavy metals, sulphates, fluoride, chloride, total dissolved solids (TDS), total phenols and dissolved organic carbon. One leachate sample taken from BH7 on the 21st February 2018. The leachate was analysed solely for ammonia. The same borehole was observed to have no leachate on the 24th May 2018 during groundwater monitoring. Laboratory analysis of leachate was carried out on soil samples taken from Trial Pits TP1-TP48.

4.4.1.7 Soil Sampling

Trial pits were excavated at 50 locations on the Barnageeragh landfill site. These pits are denoted as TP1-TP50. The trial pits were used to classify the waste present on site and the level of contamination. Trial pits TP1 to TP35 were excavated on dates between the 31st May and the 3rd June 2017. These trial pits are located both within the waste body and the greenfield area to the north and east of the waste body. Trial pits TP36-TP38 were located in the builder's compound and were excavated on the 4th July 2017. Trial pits TP39-TP48 were located to the north of the builder's compound and were excavated on the 11th August 2017. These trial pits were used to confirm the absence of domestic waste within this area.

Ten soil samples were taken from the spoil created during the installation of the five passive gas venting wells, two samples from each well. These samples were analysed for parameters including Total Kjeldahl Nitrogen (TKN), Organic Matter, Moisture Content, Cation Exchange Capacity (CEC), Major Cations, as well as Nitrate (NO_3), Nitrite (NO_2), Chloride (Cl^-) and Sulphate (SO_4) levels.

Topsoil was stock piled during the ground preparation works for the various phases of development. Soil sampling of two composite topsoil samples were analysed to determine if any potential risk exists. Each composite sample was composed of 10 no. separate subsamples taken from different locations in the topsoil stock pile.

4.4.1.8 Asbestos Surveys

Analysis was conducted on soil samples taken during the trial pitting exercise. Both topsoil samples and forty soil samples were screened for asbestos. The screening did not indicate the presence of asbestos fibres in any of the samples analysed.

4.4.1.9 Groundwater Sampling

The majority of the groundwater boreholes were installed on dates between June 2017 and August 2017. Borehole BH1-BH4 were installed between the 14th and 19th June, BH5-BH7 between the 14th and 15th June and BH8-BH13 installed between the 31st July and the 2nd August. Borehole BH14 was installed on the later date of 26th October 2017 with BH15-BH17 being installed on the 17th May 2018. Groundwater quality monitoring was conducted over three rounds. The first round took place on the 27th June and the 2nd August. This round occurred at BH1-BH4 and BH8-BH13 respectively. The second round took place on the 15th November 2017 and was conducted on BH1 to BH14. The final round of groundwater quality monitoring took place on the 24th May 2018 and was conducted on all boreholes BH1-BH17.

4.4.1.10 Pumping Test

On-site rising head pump tests were conducted to determine the hydraulic conductivity of the groundwater aquifer. A long duration rising pump head testing took place on BH4 on the 30th January 2018. This test took place over a 4-hour period. Pressure transducers were installed on BH8-BH10 to record any drawdown effect. Short duration rising head pump tests were also conducted on BH15-BH17 on dates between the 31st May and the 1st June 2018. Pressure transducer to measure the drawdown effects were placed in the borehole closest to the one being tested. Borehole BH15 experienced no drawdown effects during its rising head pumping test, due to the adjacent stream. This borehole was pumped continuously for 2 hours on the 1st June 2018. A water sample was taken before commencement of the pump test and then at 15-minute intervals.

4.4.1.11 Surface Water Sampling

Two rounds of surface water sampling took place on the 11th January 2018 and the 15th June 2018.The sampling took place at four locations, SW1-SW4. SW1 and SW 4 are hydraulically upgradient of the site with SW2 and SW3 located downgradient. Samples were unable to be taken from SW2 and SW3 on the 15th June as the water level was too low.

4.4.2 Data Collected

The DQRA reports that the following information was ascertained from the site investigations:

- The extent and type of waste and the subsoil type and thickness was determined thorough trial pits excavation and borehole drilling;
- Samples were taken for analysis to determine the level of contamination in the soil/ waste and to classify the waste type at the site;
- Groundwater level and quality was investigated through the installation of groundwater piezometers within a network of 14 deep combined groundwater/gas wells;
- Surface water quality was sampled both upgradient and downgradient of the site;
- A total of 7 dedicated gas wells (3 'deep air rotary' and 4 'shallow window sample' gas wells) and 13 combined deep groundwater/gas wells were installed to establish the presence of landfill gas, delineate migrations and to provide a network for gas monitoring;
- The locations of trial pits were chosen to delineate the extent of the waste body;
- Gas monitoring points (GS1-GS4) were installed adjacent to the properties closest to the waste body, at Hamilton Hill, i.e. House numbers 25 to 34.
- Proper sample handling and chain of custody procedures was evident.

A summary of the investigations in included in **Table 4.2**.

Table 4.2: Tier 2 Main Investigation Completed Works

Description of the Works	Objectives
Geophysical Survey	• Provides information on the extent and thickness of the waste body in the c1.45ha site. • Identifies the presence of irregular features in the waste body. • Gives an estimated waste volume calculation. • Assists in choice of sampling points. • Provides information on depth to rock, stratification of sub-soils and waste layers.
Trial Pitting and Soil Sampling at 50 No. Locations (TP1-TP50)	• Provides information regarding the extent and type of waste. • Provides information regarding the soil type and thickness. • Provides information regarding contamination levels in the soils beneath the waste body and mobility potential of contamination found. • Identifies the lateral and vertical extent of any contamination. • Provides an examination of leachability of soils. • Information on soil composition and characteristics. • Used to confirm presences/absence of waste material within area to north of landfill site.
Borehole Drilling and Soil Sampling at 17 No. Locations (BH1-BH17)	• 14 No. combined deep groundwater/gas wells (BH1-BH4, BH8-BH17) installed to investigate groundwater level and quality. • 7 no. dedicated gas wells (3 No. 'deep air rotary' gas wells (BH5-BH7) and 4 no.

	'shallow window sample' gas wells (GS01-GS04) installed to establish the presence of landfill gas, delineate migrations and to provide a network for gas monitoring.
Gas Monitoring at 21 No. Locations	• Undertaken at this site due to the close proximity to residential dwellings to assess risk from landfill gas.
Surface Water Sampling at 4 No. Locations (SW1-SW4)	• Additional sampling to supplement information gathered in Tier 1 & 2 assessments. • Sampling undertaken both upgradient and downgradient of the waste body • Provides information on the vulnerability of receiving surface water bodies.
Groundwater Wells and Sampling – 35 samples from 14 locations	• Examination of groundwater for contamination. • Establishing groundwater levels across the site. • Determination of groundwater flow patterns. • Determination of trends in groundwater contamination.

4.4.3 EPA CoP Matrices for Moderate SPR Linkages

As noted in **Section 3**, the main pathway of concern is landfill gas as it scored a Moderate – Class B risk for SPR 10 and SPR 11.

The investigations carried out by Winsac Ltd., as detailed in the DQRA, have been compared against the CoP matrices for site investigations. Compliance with the recommended investigation techniques (R) are summarised in **Table 4.3** to **Table 4.5** including investigations that should be considered (S) and those which are not recommended (N).

Extensive site investigations have been carried out that fully meet the requirements of matrices in relation to both SPR 10 and SPR 11.

4.5 Groundwater, Surface Water & Gas Monitoring

As per the EPA CoP sampling was carried out in accordance with the British Standard BS 10175:2011 Investigation of potentially contaminated sites- Code of Practice. The following monitoring and sampling programme was carried out:

- Three rounds of groundwater monitoring were carried out during the ground investigation works during June and August 2017, November 2017 and May 2018;
- Groundwater level monitoring was conducted between July 2017 and August 2018;
- Two Rising head pump tests on 30th January to 2nd February 2018 and 31st May to 1st June 2018;
- Two surface water sampling rounds were conducted on 11th January 2018 and 15th June 2018;
- 42 rounds of landfill gas monitoring were conducted between August 2017 and January 2019;
- A gas probe survey at the northern end of the waste body; and
- Indoor and outdoor residence and services gas monitoring.

Full details of the methodologies employed for groundwater quality, groundwater level, surface water quality monitoring and gas monitoring are provided in Section 3 Scope of Works of the DQRA.

4.6 Laboratory Analysis

The laboratory analysis of the soil, groundwater, and surface water sampling are all presented in the DQRA. A discussion on the findings of the results is presented in the following section.

Table 4.3: Tier 2 Main Investigation Requirements for SPR 10 and SPR 11

SPR Linkage	Source	Pathway	Receptor	Shallow Probes/ Hand Augers	Geophysics/ Infrared Surveys	Window Sampling	Cable Percussion Boring	Air Rotary Open Or Cored Hole
SPR 10	LANDFILL GAS	Lateral Migration (Subsoil)	Human Presence	R	S	S	S	S
				X	✔	✔	X	✔
SPR 11	LANDFILL GAS	Vertical Migration (Subsoil)	Human Presence	R	S	S	S	S
				X	✔	✔	X	✔

R = Recommended technique assuming site conditions allow.
S = Should be considered but is dependent on site suitability for that methodology.
N = Not recommended but may occasionally be suitable.

Table 4.4: Tier 2 Probe and/or Borehole Sampling Requirements for SPR 10 and SPR 11

SPR Linkage	Source	Pathway	Receptor	Gas Sampling	Leachate Sampling	Soil Sampling	Surface Water Sampling	Groundwater Sampling	Pumping Test
SPR 10	LANDFILL GAS	Lateral Migration (Subsoil)	Human Presence	R/S	N	N	N	N	N
				✔	✔	✔	✔	✔	✔
SPR 11	LANDFILL GAS	Vertical Migration (Subsoil)	Human Presence	R/S	N	N	N	N	N
				✔	✔	✔	✔	✔	✔

R = Recommended technique assuming site conditions allow.
S = Should be considered but is dependent on site suitability for that methodology.
N = Not recommended but may occasionally be suitable.

Table 4.5: Tier 2 Specialist Survey Requirements for SPR 10 and SPR 11

SPR LINKAGE	SOURCE	PATHWAY	RECEPTOR	ECOLOGICAL SURVEYS	SURFACE WATER SURVEYS	ODOUR/DUST or ASBESTOS SURVEYS
SPR 10	LANDFILL GAS	Lateral Migration (Subsoil)	Human Presence	N	N	S
				X	✔	✔
SPR 11	LANDFILL GAS	Vertical Migration (Subsoil)	Human Presence	N	N	S
				X	✔	✔

R = Recommended technique assuming site conditions allow.
S = Should be considered but is dependent on site suitability for that methodology.
N = Not recommended but may occasionally be suitable.

5 RESULTS & INTERPRETATION OF LABORATORY ANALYSIS PRESENTED IN THE DQRA

5.1 Site Subdivision

From the site investigations undertaken at the site, the site was sub-divided into two distinct areas, namely:

- Area 1 – The main landfill waste body. This area is located to the south and southeast of the Hamilton Hill development.
- Area 2 – Made-ground. This area is located directly east of the Hamilton Hill development and north of the Area 1.

Figure 5.1 below presents an image from the DQRA showing the different areas. These areas have been delineated based on the information collected during the Tier 2 site investigations, including from trial pit and borehole logs.

Figure 5.1 Areas identified as containing waste materials

5.2 Site Geology

The geological logs for all intrusive investigation locations installed during the ground investigation are provided in Appendix 8 of the DQRA.

Consistent with the expected regional geology, the soil profile across much of the site consists of surface Made Ground (that is silt or clay with concrete, plastics and bricks), overlying unconsolidated Quaternary superficial deposits which in turn conceal the siltstone bedrock of the Skerries Formation (SS) at depth. A geological cross section is provided in drawing number MGE0755-RPS-00-XX-DR-C-DG0003-01 contained in **Appendix A**.

5.2.1 Made Ground & Quaternary Deposits

The sequence of Made Ground and natural superficial deposits encountered across the site comprised the following:

- Made Ground – Waste mass contained in the landfilled area;
- Made Ground – General fill material; and
- Sand and Gravel (S&G) of variable lithology across much of site.

Table 5.1 provides a summary of Made Ground and Quaternary Superficial encountered for each of the two areas described in **Section 5.1** above.

A surface horizon of Made Ground covers much of the former landfilled area (waste body) as depicted in the geological cross section (drawing number MGE0755-RPS-00-XX-DR-C-DG0003-01 contained in **Appendix A**). The Made Ground encountered is granular in nature and is typically less than 8.5 m thick. The waste mass in the south of the landfilled area is typically deepest, reaching 10.5m in BH1, and is generally described as a silt/clay unit with variable proportions of plastic, glass and timber throughout.

Outside of the landfilled area, approximately 4m of fill material covers the Quaternary superficial deposits (BH4, BH8-12). It is generally described as dark brown gravelly SILT/CLAY.

Beneath the Made ground and the Fill material the ground investigation identified a significant depth of sand and gravel deposits, ranging in depth from 2.5m to at least 9.5m, across the site that conceals bedrock at depth.

Table 5.1: Summary of Made Ground and Quaternary Superficial Deposits

Area / Location	Exploratory Hole ID	Comment	Made Ground	Made Ground- General Fill	Quaternary Superficial Deposits
Area 1 (Waste Area)	BH1, BH2, BH3 BH5, BH6, BH7 (deep gas wells)	BH1 difficult drilling conditions due to sandy gravels	Thickness: 5.5m -8.5m Silty/Clay with waste material e.g. plastic, glass, ceramics, ash, timber, red brick, blocks, gravels	-	Gravelly SAND overlying silty sandy GRAVEL and BOULDERS
Area 2 (North of the Site)	BH4, BH8-BH17	BH12 Productive water strike encountered at 9.0m	-	Thickness: 2m-5.5m (BH13) Sandy gravelly SILT/CLAY with cobbles	1-1.5m of SAND overlying 1m of CLAY overlying gravelly SAND

5.2.2 Bedrock Geology

Bedrock was proven in eleven rotary holes of the fourteen air rotary boreholes at a depth of between 3mOD and 10.5mOD. The elevation of rockhead in those boreholes implies a c. 3.0m to 10.5 m thick sequence of unconsolidated superficial deposits and Made Ground above the bedrock. From **Table 5.2** and drawing number MGE0755-RPS-00-XX-DR-C-DG0003-01 contained in **Appendix A**, it is evident that the elevation of rockhead declines in a north/north east to south/southwest direction across the site. Bedrock was not encountered within the main waste area (Area 1).

The log descriptions (provided in Appendix 8 of the DQRA) confirm that bedrock comprises siltstones and sandstones of the Skerries Formation.

Table 5.2: Bedrock Details

ID	Site Area	Rockhead		General Log Description
		mBGL	mOD	
BH4	Area 2	10.5	8.32	Blue/grey weathered bedrock
BH8	Area 2	10.4	8.03	Blue weathered SILTSTONE
BH9	Area 2	10.5	8.1	Competent blue SILSTONE
BH10	Area 2	10.0	8.64	Competent blue SILTSTONE
BH11	Area 2	8.6	10.37	Light grey/blue SANDSTONE overlying very competent dark blue SILTSTONE
BH12	Area 2	6.8	12.17	Very competent dark blue SILSTONE
BH13	Area 2	4.5	11.44	Light grey/blue SILTSTONE
BH14	Area 2	4.5	10.84	Dark grey/blue SILSTONE
BH15	Area 2	5.0	11.37	Brown grey slightly calcareous slightly weathered SILSTONE overlying brown/grey slightly calcareous slightly weathered to competent SANDSTONE
BH16	Area 2	3.0	12.74	Brown/grey competent SILSTONE overlying dark great competent SILSTONE at 10.0m
BH17	Area 2	5.0	14.23	Grey/dark grey slightly calcareous very weathered SILSTONE

5.3 Site Hydrogeology

Groundwater strikes and groundwater levels were encountered in the general fill, the Quaternary superficial deposits, weathered bedrock and bedrock. Installations constructed in boreholes primarily targeted the Quaternary superficial deposits weathered bedrock and competent bedrock. Appendix 8 of the DQRA provides details of the final installations at each monitoring location and the groundwater levels recorded in each borehole.

A detailed analysis has been carried out by HUCT which is included as Appendix 12 of the DQRA. The analysis confirmed groundwater flow discharges in an easterly direction across the site towards the eastern boundary stream and the Barnageeragh Stream and that a significant component of the waste body is below the water table at all times.

The GSI classifies groundwater vulnerability across the site as High. Excluding the area of infill, the GI encountered bedrocks at depths in general between depths of 4m to 6.5mbgl with shallower depths of between 1.5m to 4mbgl at the eastern site boundary. The natural subsoil comprises predominantly of high permeability sand and gravel confirming that the regional vulnerability rating (High) concurs with the site-specific findings.

5.4 Analytical Results

5.4.1 Soil Quality

The results of the testing of the 41 soil samples taken from the site are provided in full in Section 6 of the DQRA. A total of 40 soil samples were obtained from 50 trial pits (TP1-TP50) and 1 stockpile (SP1). Soil samples tested included Made Ground (both general fill and the landfill waste mass), and Quaternary superficial deposits underlying the Made Ground. The soil samples were also screened for asbestos. Two topsoil samples were also taken and analysed for contamination.

For description purposes the soil data has been split into the two areas as outlined in **Section 5.1**. The data presented in the following sections only includes those parameters where concentrations exceed the limit of detection. .

5.4.1.1 Area 1: Main Waste Body

Thirty-six samples of Made ground were taken from Area 1. The analytical results from the Made ground within the main waste body confirm the presence of metals (most notably antimony, arsenic, copper, lead and zinc), mineral oil (aliphatic hydrocarbons) and TPH (total petroleum hydrocarbons). The highest concentrations were found in TP4, TP5, TP7, TP8, TP10, TP11, TP14, TP15 and TP20 at the eastern half of the main waste body, corresponding to the area where the maximum depth of waste was delineated. The soil sampling results are summarised in **Table 5.3** below.

Table 5.3: Summary of Soil Analysis for Area 1 – Main Waste Body

Parameter	Units	No. Analyses	No. Analyses above LOD	Concentration Data	
				Range	Mean
pH	pH units	36	36	7.3-8.5	7.96
Total Organic Carbon	mg/kg	36	36	0.2-7.5	3.27
Total Aliphatics	mg/kg	36	12	<5.0-1200	137
Total Aromatics	mg/kg	36	15	<5.0-1600	92.4
TPH	mg/kg	36	15	<10-2800	245
Mineral Oil	mg/kg	36	11	<10-1200	139.75
Total PAH's	mg/kg	36	10	<2.0-38	2.375
Antimony	mg/kg	36	33	<2-39	7.75
Arsenic	mg/kg	36	36	15-61	26.8
Barium	mg/kg	36	36	56-770	290
Cadmium	mg/kg	36	36	0.18-5.3	1.4
Total Chromium	mg/kg	36	36	20-71	42.9
Copper	mg/kg	36	36	24-810	160
Lead	mg/kg	36	36	29-1700	324
Nickel	mg/kg	36	36	32-120	60.75
Molybdenum	mg/kg	36	30	<2.0-16	4.1
Mercury	mg/kg	36	32	<0.1.0-0.8	0.295
Selenium	mg/kg	36	3	<0.20-0.93	0.065
Zinc	mg/kg	36	36	72-3600	575

5.4.1.2 Area 2: Made Ground

Four samples of Fill material were taken from Trial pits TP25, TP27, TP33 and TP48 within Area 2. It is notable that mineral oil and TPH were only detected in one sample from TP25 and at a much lower concentration of 42mg/kg and 59mg/kg than that observed in Area 1. There is also a general absence of elevated concentrations of metals with the exception of Cadmium in TP33 at a concentration of 3.8mg/kg. The soil sampling results are summarised in **Table 5.4** below.

Table 5.4: Summary of Soil Analysis for Area 2 – Made Ground

Parameter	Units	No. Analyses	No. Analyses above LOD	Concentration Data	
				Range	Mean
pH	pH units	4	4	7.4-8.5	7.9
Total Organic Carbon	mg/kg	4	4	0.73-2.7	1.35
Total Aliphatics	mg/kg	4	1	<5.0-42	10.5
Total Aromatics	mg/kg	4	1	<5.0-17	4.25
TPH	mg/kg	4	1	<10-59	14.75
Mineral Oil	mg/kg	4	1	<10-42	10.5
Antinomy	mg/kg	4	1	<2-6.3	1.575
Arsenic	mg/kg	4	4	13-28	19.5
Barium	mg/kg	4	4	72-180	108.75
Cadmium	mg/kg	4	2	<0.1-3.8	1.2
Total Chromium	mg/kg	4	4	31-43	38.25
Copper	mg/kg	4	4	24-68	37.25
Lead	mg/kg	4	4	23-110	46.5
Nickel	mg/kg	4	4	34-51	42.5
Molybdenum	mg/kg	4	2	<2.0-6.3	2.35
Mercury	mg/kg	4	2	<0.1.0-0.15	0.0625
Selenium	mg/kg	4	1	<0.20-1.4	0.35
Zinc	mg/kg	4	4	62-240	112

5.4.2 Leachate Analysis

The results of the testing of the 40 leachate samples taken from the site are provided in full in Section 6 of the DQRA. **Table 5.5** and **Table 5.6** below summarise the results. A total of 40 soil samples were obtained from 48 trial pits (TP1-TP48) and 1 stockpile (SP1). The results give an indication of the leachable components within the soils encountered on the site. For description purposes the leachate data has been split into the two areas as outlined in **Section 5.1**. The data presented in the following sections only includes those parameters where concentrations exceed the limit of detection (LOD).

Table 5.5: Summary of Leachate Analysis for Area 1

Parameter	Units	No. Analyses	No. Analyses above LOD	Concentration Data	
				Range	Mean
Sulphate	mg/kg	36	36	22-16000	2,866
Fluoride	mg/kg	36	32	<1.0-6.7	2.08
Chloride	mg/kg	36	36	12-1600	542
Total Dissolved Solids	mg/kg	36	36	860-16,000	4,966
Dissolved Organic Carbon	mg/kg	36	36	76-350	144
Antinomy	mg/kg	36	33	<0.001-0.14	0.06
Arsenic	mg/kg	36	7	<0.05-0.11	0.017
Barium	mg/kg	36	19	<0.5-1.5	0.38
Chromium	mg/kg	36	8	<0.05-1.3	0.11
Copper	mg/kg	36	13	<0.05-0.61	0.042
Lead	mg/kg	36	6	<0.01-0.32	0.003
Mercury	mg/kg	36	6	<0.005-0.0068	0.000975
Molybdenum	mg/kg	36	22	<0.05-0.76	0.54
Selenium	mg/kg	36	29	<0.01-0.079	0.025
Zinc	mg/kg	36	4	<0.5-1.4	0.098
Nickel	mg/kg	36	6	<0.05-0.16	0.017

Table 5.6: Summary of Leachate Analysis for Area 2

Parameter	Units	No. Analyses	No. Analyses above LOD	Concentration Data	
				Range	Mean
Sulphate	mg/kg	4	4	93-200	158.25
Fluoride	mg/kg	4	4	2.1-7.7	5.05
Chloride	mg/kg	4	4	23-54	39.75
Total Dissolved Solids	mg/kg	4	4	630-1100	817.5
Dissolved Organic Carbon	mg/kg	4	4	120-210	152.5
Total Organic Carbon	mg/kg	4	4	0.73-2.7	1.35
Antinomy	mg/kg	4	3	<0.001-0.023	0.017
Arsenic	mg/kg	4	2	<0.05-0.84	0.026
Copper	mg/kg	4	4	<0.05-0.13	0.0625
Lead	mg/kg	4	2	<0.01-0.016	0.0075
Molybdenum	mg/kg	4	3	<0.05-0.32	0.13
Selenium	mg/kg	4	3	<0.01-0.02	0.013

The results are assessed against GAC for Leachate in **Section 6.1.2** below.

5.4.3 Groundwater Quality

The results of the three rounds of groundwater sampling and testing undertaken are provided in full in Section 8 of the DQRA. **Table 5.7** below summarises the results. A total of 35 groundwater samples were obtained from 14 monitoring locations. For description purposes the groundwater data has been split into the two areas as outlined in **Section 5.1**. The data presented in the following sections only includes those parameters where concentrations exceed the limit of detection.

5.4.3.1 Area 1: Waste Area

The analytical results obtained from Boreholes BH1 to BH3 located in the main Waste Area in Area 1 are summarised in **Table 5.7**.

Groundwater from the waste area is characterised by elevated electrical conductivity, total dissolved solids, ammoniacal nitrogen, chloride, sulphate, sodium, potassium and orthophosphate. BH1 is characterised by a high concentration of ammoniacal nitrogen in excess of 10 mg/l. Metals are present and are at the highest concentration in BH1, most notably a boron concentration in excess of 3,400 µg/l, and in BH3 which had a mercury concentration of 7.3 µg/l. Iron and Manganese are elevated with the highest concentrations again seen in BH1.

Coliforms were present in all boreholes with water from BH3 being the most affected by microbial contamination.

In general, the water quality from the waste area is poor with the deepest installation in borehole BH1 yielding the poorest water quality, indicative of groundwater impacted by waste leachate.

The water sample taken from BH2 at the edge of the waste area displays a lower electrical conductivity concentration as well as lower chloride and sulphate than seen in boreholes BH1 and BH3. Metals, including iron, manganese are present in the groundwater from BH2 albeit at lower concentrations than seen in the main body of the waste ground.

In general, the water quality within the sand and gravel deposits at the edge of the waste mound does not seem to suggest a large impact from the waste body, considering the water quality observed underlying the main waste body itself (BH1 and BH3). BH2 is expected to represent an upgradient borehole, showing background groundwater quality.

Table 5.7: Summary of Groundwater Analysis Area 1

Parameter	Units	No. of Analyses	No Analyses > LOD	Concentration Data	
				Range	Mean
Inorganics & Carbon					
pH	pH Units	9	9	7.5 – 8.0	7
Electrical Conductivity	µS/cm	9	9	690-10,000	30,560
Temperature	ºC	9	9	14-18	15.6
Dissolved Oxygen	mg/l	9	9	6.6-8.7	7.9
Total Dissolved Solids	mg/l	9	9	410-6100	2,055
Total Suspended Solids	mg/l	9	8	<5-38,000	6,634
Chemical Oxygen Demand	mg/l	9	4	<10-139	34
Total Alkalinity	mg/l	9	9	280-700	390
Ammonia (as free N)	mg/l	9	7	<0.010-9.44	1.16
Ammoniacal Nitrogen	mg/l	9	9	0.31-18	3.96
Nitrate (as NO3)	mg/l	9	7	<0.50-54	8.93
Nitrite (as NO2)	mg/l	9	7	0.041-0.69	0.17
Total Organic Nitrogen (TON)	mg/l	9	8	<1.0-8.2	3.3
Total Nitrogen (TN)	mg/l	9	9	2.0-26	9.3
Chloride	mg/l	9	9	30-2200	544.6
Sulphate	mg/l	9	9	55 - 3200	1,002
Fluoride	mg/l	9	8	<0.050- 0.26	0.11
Molybdate Reactive Phosphate (as P)	mg/l	9	3	<0.050-0.056	0.018
Potassium	mg/l	9	9	11 - 930	196
Sodium	mg/l	9	9	25 - 1400	298
K/Na Ratio		9	n/a	0.1 – 0.89	0.47
Calcium	mg/l	9	9	150-740	344
Magnesium	mg/l	9	9	33-950	217.7
Dissolved Metals					
Arsenic	µg/l	9	6	<1-8.2	3.07
Aluminium	µg/l	9	2	<10-95	12.4
Barium	µg/l	9	9	43-130	71.2
Boron	µg/l	9	9	160-3400	1,198
Cadmium	µg/l	9	9	<0.080-0.79	0.12
Chromium	µg/l	9	6	<1.0-16	4.5
Cobalt	µg/l	9	5	<1.0-5.6	2.7
Copper	µg/l	9	4	<1.0-9.8	2.04
Iron	µg/l	9	9	170-1200	495.5
Nickel	µg/l	9	8	<1.0-12	4.37
Manganese	µg/l	9	9	2.2-3300	1,124
Mercury	µg/l	9	2	<0.5-7.3	0.6
Molybdenum	µg/l	9	6	<0.1-5.9	1.05
Selenium	µg/l	9	9	1.2-42	21
Strontium	µg/l	9	3	<1.0-1700	278
Vanadium	µg/l	9	4	<1.0-3.6	1.14
Zinc	µg/l	9	9	Aug-64	25
Microbial					
Total Coliforms	Cfu/100ml	9	9	Feb-00	1,386
Faecal Coliforms	Cfu/100ml	9	5	<1-170	26.1

The results are assessed against GAC for groundwater in **Section 6.1.3**.

5.4.3.2 Area 2: North of the Site

The analytical results obtained from Boreholes BH4 and BH8 to BH17 located in Area 2, north of the site are summarised in **Table 5.8**.

Groundwater from the area north of the waste area is characterised by elevated electrical conductivity, ammoniacal nitrogen, chloride, sulphate and potassium. Iron and Manganese is elevated across all boreholes with the highest concentrations seen in BH4 and BH8 to BH12 which are located outside the northern boundary of the waste body. Metals are present, most notably calcium, magnesium and boron.

Water from BH16 was the most affected by microbial contamination. Results from only one round of monitoring was carried out in BH15, BH16 and BH17.

The boreholes in Area 2 will be representative of the underlying Skerries Formation aquifer that underlies the site. In general, the water quality at depth in the Siltstone bedrock does not seem to suggest a large impact from above, considering the water quality observed in the subsoil underlying the waste body itself. The mean concentrations of the downgradient boreholes (BH15-17) although elevated are notably lower than those of boreholes BH8-BH12.

Table 5.8: Summary of Groundwater Analysis Area 2

Parameter	Units	No. of Analyses	No Analyses > LOD	Concentration Data	
				Range	Mean
Inorganics & Carbon					
pH	pH Units	26	26	7.2 – 8.2	7.7
Electrical Conductivity	µS/cm	26	26	550-2600	1,250
Temperature	ºC	26	26	14-18	14.7
Dissolved Oxygen	mg/l	26	26	7.2-9.0	8.3
Total Dissolved Solids	mg/l	26	26	39-1600	686.5
Total Suspended Solids	mg/l	26	24	<5.0-30000	7,796
Chemical Oxygen Demand	mg/l	26	22	<10-181	34
Total Alkalinity	mg/l	26	26	280-790	455.5
Ammonia (as free N)	mg/l	26	26	0.010-0.9.25	1.74
Ammoniacal Nitrogen	mg/l	26	26	0.16-0.23	3.25
Nitrate (as NO3)	mg/l	26	13	<0.5-30	4.4
Nitrite (as NO2)	mg/l	26	17	<0.020-2.1	4.4
Total Organic Nitrogen (TON)	mg/l	26	21	<1.0-4.7	1.95
Total Nitrogen (TN)	mg/l	26	24	<1.0-28	6.22
Chloride	mg/l	26	26	28-180	70.46
Sulphate	mg/l	26	26	26 – 430	149.6
Fluoride	mg/l	26	26	0.1- 0.19	0.13
Molybdate Reactive Phosphate (as P)	mg/l	26	4	<0.050-0.059	0.0085
Potassium	mg/l	26	26	2.8 - 120	23
Sodium	mg/l	26	26	21 - 140	50.8
K/Na Ratio		26	n/a	0.11 – 0.86	0.34
Calcium	mg/l	26	26	120-400	220.7
Magnesium	mg/l	26	26	21-130	23
Dissolved Metals					
Antimony	µg/l	26	9	<1.0-6.2	0.85
Arsenic	µg/l	26	22	<1- 8.9	2.3
Aluminium	µg/l	26	3	<10-160	10.5
Barium	µg/l	26	26	59-330	117
Boron	µg/l	26	26	46-760	260
Cadmium	µg/l	26	9	<0.080-1	0.1
Chromium	µg/l	26	11	<1.0-4.7	1.5
Cobalt	µg/l	26	12	<1.0-4.5	1.12
Copper	µg/l	26	15	<1.0-6.2	1.6
Iron	µg/l	26	26	150-970	392
Nickel	µg/l	26	25	<1.0-20	6.3
Manganese	µg/l	26	26	9.9-3800	795.4
Mercury	µg/l	26	7	<0.5-1.1	0.2
Molybdenum	µg/l	26	21	<0.1-7.2	2.09
Selenium	µg/l	26	25	<0.1-52	7.8
Strontium	µg/l	26	7	<1.0-770	134.2
Vanadium	µg/l	26	2	<1.0-1.2	0.096
Zinc	µg/l	26	21	<1.0-8.6	4.0
Microbial					
Total Coliforms	Cfu/100ml	26	14	<1-331->2419.6	326.1
Faecal Coliforms	Cfu/100ml	26	8	<1-11	1.34

The results are assessed against GAC for groundwater in **Section 6.1.3**.

5.4.4 Surface Water Quality

Surface water quality sampling was undertaken in two rounds, one in January 2018 and the second in June 2018. Two upgradient sampling points were established, SW1 and SW4 and two downgradient sampling points SW2 and SW3. The first round of sampling, in January 2018 consisted of one upgradient sample (SW1) and two downgradient samples (SW2 and SW3). In June 2018, no downgradient samples were possible given the low flow levels in the surface water so only two upgradient samples (SW1 and SW4) were taken. Therefore, a total of five samples of surface water were taken for analysis.

The results of the surface water sampling and testing undertaken are provided in Section 9 of the DQRA. The surface water samples were tested for a range of potential contaminants as described in Section 9 and detailed in Appendix 18 of the DQRA. **Table 5.9** below summarises the results.

Table 5.9: Summary of Surface water Analysis

Parameter	Units	No. of Analyses	No Analyses > LOD	Concentration Data		
				Min (> LOD)	Max	Mean
Physico-chemical Parameters						
pH	pH Units	5	5	8.1	8.4	8.2
Electrical cond. (EC)	µS/cm	5	5	640.0	700.0	676.0
Dissolved oxygen (DO)	ºC	5	5	8.0	8.3	8.2
Standard Chemistry						
Total dissolved solids	mg/l	5	5	380.0	410.0	400.0
Total suspended solids	mg/l	5	4	16.0	330.0	130.0
Total alkalinity (as CaCO3)	mg/l	5	5	0.0	0.0	0.0
Ammonia (as NH3)	mg/l	5	4	0.017	0.039	0.030
Ammoniacal Nitrogen	mg/l	5	5	0.190	0.430	0.268
Nitrate NO3	mg/l	5	5	15.0	41.0	20.8
Nitrite NO2	mg/l	5	3	0.043	0.100	0.062
Total Organic Nitrogen	mg/l	5	5	1.8	9.0	4.7
Total Dissolved Nitrogen	mg/l	5	5	5.0	9.0	6.2
Chloride Cl-	mg/l	5	5	25.0	51.0	38.6
Flouride	mg/l	5	3	0.13	3.00	1.09
Sulphate SO4	mg/l	5	5	30.0	82.0	52.8
Sulphide S2-	mg/l	5	0	0.0	0.0	0.0
Molybdate Reactive Phosphate P		5	3	0.10	0.25	0.19
Major Cations						
Potassium K	mg/l	5	5	1.0	2.2	1.4
Sodium Na	mg/l	5	5	14.0	21.0	16.4
K/Na Ratio	-	5	5	0.060	0.110	0.082
Calcium Ca	mg/l	5	5	100.0	120.0	110.0
Magnesium Mg	mg/l	5	5	11.0	15.0	13.2
Heavy Metals						
Aluminium (Al)	µg/l	5	2	20.0	45.0	32.5
Antimony (Sb)	µg/l	5	0	<LOD	<LOD	<LOD
Arsenic (As)	µg/l	5	1	1.1	1.1	1.1
Barium (Ba)	µg/l	5	5	27.0	47.0	37.6
Beryllium (Be)	µg/l	5	0	<LOD	<LOD	<LOD
Boron (B)	µg/l	5	5	26.0	110.0	50.0
Cadmium (Cd)	µg/l	5	0	<LOD	<LOD	<LOD
Chromium (Cr)	µg/l	5	3	1.80	2.30	1.97
Cobalt (Co)	µg/l	5	0	<LOD	<LOD	<LOD

Parameter	Units	No. of Analyses	No Analyses > LOD	Concentration Data		
				Min (> LOD)	Max	Mean
Copper (Cu)	µg/l	5	0	<LOD	<LOD	<LOD
Iron (Fe)	µg/l	5	5	120.0	230.0	190.0
Lead (Pb)	µg/l	5	0	<LOD	<LOD	<LOD
Nickel (Ni)	µg/l	5	0	<LOD	<LOD	<LOD
Manganese (Mn)	µg/l	5	2	2.70	5.40	4.05
Mercury (Hg)	µg/l	5	0	<LOD	<LOD	<LOD
Molybdenum (Mo)	µg/l	5	1	1.10	1.10	1.10
Selenium (Se)	µg/l	5	4	1.00	4.20	2.48
Strontium (Sr)	µg/l	5	0	<LOD	<LOD	<LOD
Thallium (Ti)	µg/l	5	0	<LOD	<LOD	<LOD
Uranium (U)	µg/l	5	0	<LOD	<LOD	<LOD
Vanadium (V)	µg/l	5	1	4.20	4.20	4.20
Zinc (Zn)	µg/l	5	2	1.90	2.90	2.40
Oxygen Demand/Organic Carbon						
BOD	mg/l	5	2	2.0	3.0	2.5
COD	mg/l	5	4	8.0	161.0	71.8
Microbiological						
Total coliforms (i.e. Confirmed)	CFU/100ml	5	5	5.2	241,960	53,402
Faecal coliforms (i.e. Confirmed)	CFU/100ml	5	5	2.0	1,950	498
Other Analysis						
TPH (EPH C8 – C40)	µg/l	5	0	<LOD	<LOD	<LOD
PAH	µg/l	5	0	<LOD	<LOD	<LOD
Cyanides	µg/l	5	0	<LOD	<LOD	<LOD
VOC	mg/l	5	0	<LOD	<LOD	<LOD
Semi VOC	mg/l	5	0	<LOD	<LOD	<LOD
Organochlorine Pesticides & Acid Herbicides	µg/l	5	0	<LOD	<LOD	<LOD

The results are assessed against GAC for surface water in **Section 6.1.4**.

5.4.5 Landfill Gas Monitoring

5.4.5.1 Waste Body

Landfill gas monitoring was undertaken at Barnageeragh between 18 and 21 borehole locations across the site between June 2017 and January 2019. Between June 2017 and April 2018, 14 borehole locations (BH1 to BH14) were monitored alongside four shallow gas wells (GS01-GS04), located between the western edge of the waste body and the nearest houses. In May 2018, a further three boreholes were drilled (BH15-BH17) and gas monitoring undertaken at these locations also. As an interim landfill gas protection measure, five passive vents (GV1 to GV5) were also installed with cowled tops to draw landfill gas out of the waste body and vent it safely to the atmosphere.

Given the passive venting system that has been employed at the site since May 2018, the monitoring results post-installation of the vents have been considered in the analysis presented in this report. Comparison has been made against the figures pre-installation of the passive gas vents, but it is considered that the current regime is more appropriate in terms of analysing the monitoring results.

Table 5.10 summarises the monitoring undertaken at each landfill gas monitoring location and the peak concentrations of the gases recorded at each location over the duration of the monitoring period post-installation of the passive gas vents, i.e. May 2018 to January 2019. The peak readings give a worst-case measurement and should be considered highly-conservative.

Table 5.10: Summary of Landfill Gas Monitoring and Analysis in Waste Body

Location	No. of Monitoring Rounds	Flow Rate Peak (l/hr)	Methane (CH_4) Peak (v/v %)	Carbon Dioxide (CO_2) Peak (v/v %)	Carbon Monoxide (CO) Peak (v/v %)	Hydrogen Sulphide (H_2S) Peak (ppm)	VOCs Peak (ppm)
GS01	48	0.3	0.8	4.5	19	2	8.9
GS02	48	0.3	0.6	2.5	4	4	7.4
GS03	48	0.4	0.3	0.9	4	3	4.2
GS04	48	0.5	0.3	0.7	7	3	5.5
BH1	48	0.6	7.4	13.2	2	2	4.6
BH2	48	0.3	0.4	4.5	5	1	6.8
BH3	48	0.3	0.9	7.6	2	1	12.1
BH4	50	0.4	73.6	20.9	8	5	7.7
BH5	45	0.3	0.2	14.6	2	1	14
BH6	47	0.3	7.2	15.7	6	2	3.8
BH7	47	0.2	11.9	17.1	2	1	9
BH8	43	0.3	7.5	10.3	3	2	12.7
BH9	43	0.3	24.6	19.1	5	2	7.7
BH10	24	0.2	8.7	21.8	5	2	0
BH11	43	0.3	5.8	14.8	8	3	4.2
BH12	43	0.2	19.6	20.1	8	3	5
BH13	43	0.2	0.5	7.4	9	3	9.2
BH14	41	0.3	0.3	6.6	7	2	11.4
BH15	32	0.2	0.4	15.1	4	2	7.9
BH16	32	0.2	0.3	12.4	5	2	7.3
BH17	32	0.2	17.8	18.1	3	2	5.8

The results are assessed against generic assessment criteria (GAC) for landfill gas in **Section 6.1.5** below.

5.4.5.2 Other Locations: Properties and Underground Services

The DQRA includes details of monitoring that was carried out at house numbers 25 to 28 in the Hamilton Hill estate from 29th May and 5th June 2017. Indoor monitoring at the properties and within underground services for landfill gas and VOCs was conducted at the properties. In September 2018 this monitoring was moved to outdoor monitoring, including the underground services. The radon sumps at the properties were also monitored. The results are included in Appendix 13 of the DQRA.

A further indoor monitoring programme was undertaken in residence numbers 25, 26, 52 and 53, the closest potential human receptors to the waste body.

A monitoring survey relating to the potential for landfill gas to migrate along the pathway of the foul rising main toward houses numbers 52 to 63 (to the west of the waste body) was carried out in March 2018. 16 vapour points (2 rows x 8 points per row) were drilled along the route of the foul main. Details are provided in Section 10.7 of the DQRA.

A further monitoring survey relating to the potential for landfill gas to migrate along the pathway of the foul rising main toward the wastewater treatment plant (to the east of the waste body) was carried out in November 2018. Nine vapour points (2 rows x 4/5 points per row) were drilled along the route of the foul main. Details are provided in Section 10.8 of the DQRA.

Table 5.11 summarises the monitoring undertaken at other landfill gas monitoring locations and the peak concentrations of the gases recorded at each location over the duration of the monitoring period, which varies for each monitoring location. The peak readings give a worst-case measurement and should be considered highly-conservative. A discussion on these results is included in **Section 6.1.5** below.

Table 5.11: Summary of Landfill Gas Monitoring and Analysis at Other Locations

Location	No. of Monitoring Rounds	Methane Peak (v/v %)	Carbon Dioxide Peak (v/v %)	Carbon Monoxide Peak (v/v %)	Hydrogen Sulphide Peak (ppm)	VOCs Peak (ppm)
House 25 (Radon Sump)	34	0.0	0.2	30.0	4.0	11.0
House 25 (Water Mains Meter)	38	0.3	1.5	7.0	4.0	12.2
House 26 (Radon Sump)	34	0.2	0.3	24.0	3.0	11.3
House 26 (Water Mains Meter)	38	0.3	0.8	5.0	4.0	12.9
House 27 (Radon Sump)	33	0.1	0.1	11.0	2.0	8.5
House 27 (Water Mains Meter)	38	0.3	1.1	5.0	4.0	27.0
House 28 (Radon Sump)	32	0.0	0.4	11.0	3.0	8.6
House 28 (Water Mains Meter)	38	0.3	0.1	7.0	4.0	12.6
House 29 (Radon Sump)	31	0.1	0.2	9.0	3.0	0.4
House 29 (Water Mains Meter)	38	0.3	0.1	11.0	4.0	13.1
House 30 (Radon Sump)	32	0.1	0.3	8.0	2.0	0.8
House 30 (Water Mains Meter)	38	0.3	0.1	12.0	4.0	20.9
House 31 (Radon Sump)	33	0.1	0.4	8.0	2.0	7.9
House 31 (Water Mains Meter)	38	0.3	0.2	15.0	4.0	17.4
House 32 (Radon Sump)	32	0.1	0.2	8.0	2.0	8.8
House 32 (Water Mains Meter)	38	0.3	0.1	18.0	4.0	12.5
House 33 (Radon Sump)	32	0.1	0.4	7.0	3.0	7.9
House 33 (Water Mains Meter)	38	0.3	0.1	18.0	4.0	9.2
House 34 (Radon Sump)	32	0.1	0.1	7.0	2.0	1.6
House 34 (Water Mains Meter)	37	0.3	0.2	20.0	4.0	12.2
House 52 (Radon Sump)	30	0.1	0.7	7.0	2.0	10.3
House 52 (Water Mains Meter)	17	0.1	0.1	10.0	2.0	22.6
House 53 (Radon Sump)	30	0.1	0.7	6.0	2.0	10.8
House 53 (Water Mains Meter)	17	0.1	0.1	7.0	2.0	16.4
House 54 (Radon Sump)	30	0.1	0.1	7.0	2.0	0.0
House 54 (Water Mains Meter)	17	0.1	0.1	3.0	2.0	9.4
House 55 (Radon Sump)	30	0.1	0.7	6.0	2.0	9.8
House 55 (Water Mains Meter)	17	0.1	0.1	7.0	2.0	126.0
House 56 (Radon Sump)	30	0.1	0.6	6.0	3.0	12.1
House 56 (Water Mains Meter)	17	0.1	0.1	14.0	3.0	22.6
House 57 (Radon Sump)	30	0.1	0.4	6.0	2.0	12.3
House 57 (Water Mains Meter)	17	0.1	0.2	5.0	2.0	18.1
House 58 (Radon Sump)	30	0.1	0.3	6.0	2.0	10.5
House 58 (Water Mains Meter)	17	0.1	0.1	4.0	2.0	20.0
House 59 (Radon Sump)	30	0.1	0.4	6.0	2.0	1.1
House 59 (Water Mains Meter)	17	0.1	0.1	10.0	3.0	41.8
House 60 (Radon Sump)	30	0.1	0.4	6.0	2.0	10.8
House 60 (Water Mains Meter)	17	0.1	0.2	11.0	2.0	27.1
House 61 (Radon Sump)	30	0.1	0.8	5.0	2.0	11.2
House 61 (Water Mains Meter)	17	0.1	0.1	7.0	2.0	33.7
House 62 (Radon Sump)	30	0.1	0.8	5.0	2.0	1.5
House 62 (Water Mains Meter)	17	0.1	0.3	6.0	2.0	55.8
House 63 (Radon Sump)	30	0.1	0.4	5.0	2.0	11.6
House 63 (Water Mains Meter)	20	0.1	0.3	4.0	2.0	14.0
House 64 (Water Mains Meter)	4	0.0	0.2	4.0	2.0	2.4
ST1 (Storm Drain)	35	0.1	0.5	15.0	3.0	7.8
ST2 (Storm Drain)	35	0.1	0.2	15.0	3.0	8.4
Surface Water Monitoring Drain (SW2)	25	0.1	0.5	5.0	2.0	7.3
Surface Water Monitoring Drain (SW3)	22	0.1	0.2	5.0	2.0	7.3
Foul Rising Main (16no. near residences)	1	0.0	0.6	5	1	n/a
Foul Rising Main (9no. near WwTP)	1	0.2	2.8	51	13	2.8

6 TIER 3 GENERIC QUANTITATIVE RISK ASSESSMENT (GQRA)

6.1 Generic Assessment Criteria (GAC)

In accordance with the CoP (EPA, 2007) and the *Guidance on the Management of Contaminated Land and Groundwater at EPA Licensed Sites* (EPA, 2013) the potential significance of contamination identified on the site (as described in **Section 5**) is evaluated by comparison with Generic Assessment Criteria (GAC). GACs represent assessment criteria relevant in the consideration of risk to water quality and human health. A Generic Quantitative Risk Assessment (GQRA) may be used at less sensitive sites and/or where the information available suggests that the level is low risk.

A GQRA uses relevant GAC which are the most appropriate for the future land use allocated to the site.

The results obtained for each area with identified exceedances when compared to the GAC screening values are summarised below. Contaminants with no generic screening values or no results exceeding the minimum detection limit of the test have been excluded from the summary tables.

6.1.1 Soil

6.1.1.1 Classification of Waste

The classification of waste is confined to two hazard classes, namely hazardous waste and non-hazardous waste. The classification assigns a code from the List of Wastes published by the EU. It should be noted that the term “inert” is only used with regard to the Waste Acceptance Criteria (WAC) for disposal of a waste to a landfill. WAC is concerned with the leachability of contaminants from the waste body. It is not concerned with the solid concentration within the waste and/or soil matrix. Therefore, this GQRA of the soil relates to the solid fraction of contaminants within the soil matrix. Leachate is discussed further in **Section 6.1.2**.

The two topsoil samples returned no exceedances of the GAC and as such are not considered further.

The asbestos screens returned no positive results and as such are not considered further.

The results from the laboratory analysis of the 41 soil samples was entered into a computer software to determine whether the soil had any hazardous properties. The results from the computer software are included in Appendix 20 of the DQRA. The results are summarised in **Table 6.1**.

Of the 41 samples, 31 were confirmed to be non-hazardous, as would be expected from largely C&D waste, and have been assigned a waste code of 17 05 04. It is known that municipal waste is also buried on the site and this waste should be coded as 20 03 01 *mixed municipal waste* or 20 03 99 *municipal wastes not otherwise specified*.

Ten of the soil samples returned a hazardous classification and have been assigned the waste code 17 05 03*. Further discussion on the hazardous waste classification is provided in the following section.

Table 6.1: Classification of Soil Samples

Sample Number	Classification	Hazard Properties	Contaminant of Concern	Concentration mg/kg	List of Waste Code
SO-TP1-01	Non-hazardous				17 05 04
SO-TP1-02	Non-hazardous				17 05 04
SO-TP2-01	Non-hazardous				17 05 04
SO-TP3-01	Non-hazardous				17 05 04
SO-TP4-01	Hazardous	HP14	zinc sulphate	1100	17 05 03*
SO-TP5-01	Hazardous	HP7, HP14	lead chromate (HP7); zinc sulphate (HP14)	1100; 650	17 05 03*
SO-TP6-01	Non-hazardous				17 05 04
SO-TP7-01	Non-hazardous				17 05 04

Sample Number	Classification	Hazard Properties	Contaminant of Concern	Concentration mg/kg	List of Waste Code
SO-TP8-01	Hazardous	HP3(i), HP7, HP11	TPH (C6-C40)	2800	17 05 03*
SO-TP9-01	Non-hazardous				17 05 04
SO-TP10-01	Hazardous	HP14	zinc sulphate	1300	17 05 03*
SO-TP11-01	Hazardous	HP7, HP14	lead chromate (HP7); zinc sulphate (HP14)	1700; 1500	17 05 03*
SO-TP12-01	Non-hazardous				17 05 04
SO-TP12-02	Non-hazardous				17 05 04
SO-TP13-01	Non-hazardous				17 05 04
SO-TP14-01	Non-hazardous				17 05 04
SO-TP14-02	Hazardous	HP3(i), HP7, HP11	TPH (C6-C40)	1400	17 05 03*
SO-TP15-01	Hazardous	HP3(i), HP7, HP11	TPH (C6-C40)	1100	17 05 03*
SO-TP15-02	Non-hazardous				17 05 04
SO-TP16-01	Non-hazardous				17 05 04
SO-TP17-01	Non-hazardous				17 05 04
SO-TP18-01	Non-hazardous				17 05 04
SO-TP19-01	Non-hazardous				17 05 04
SO-TP19-02	Non-hazardous				17 05 04
SO-TP20-01	Hazardous	HP14	zinc sulphate	3600	17 05 03*
SO-TP20-02	Non-hazardous				17 05 04
SO-TP21-01	Non-hazardous				17 05 04
SO-TP22-01	Hazardous	HP7	lead chromate	1100	17 05 03*
SO-TP23-01	Hazardous	HP14	zinc sulphate	1100	17 05 03*
SO-TP25-01	Non-hazardous				17 05 04
SO-TP27-01	Non-hazardous				17 05 04
SO-TP28-01	Non-hazardous				17 05 04
SO-TP29-01	Non-hazardous				17 05 04
SO-TP31-01	Non-hazardous				17 05 04
SO-TP33-01	Non-hazardous				17 05 04
SO-SP1-01	Non-hazardous				17 05 04
SO-TP36-01	Non-hazardous				17 05 04
SO-TP37-01	Non-hazardous				17 05 04
SO-TP36-01	Non-hazardous				17 05 04
SO-TP38-01	Non-hazardous				17 05 04
SO-TP48-01	Non-hazardous				17 05 04

The waste body is currently covered in a soil layer that ensures no pathway to receptors on the surface. Rainwater is, however, able to percolate through the soil and into the waste body and this may pose a risk to leaching of contaminants from the waste body over time. There is evidence in groundwater samples of some contaminants leaching from the waste body into the groundwater. This is discussed further in **Section 6.1.3** below.

6.1.1.2 Hazardous Waste

Hazardous waste was found in 10 out of the 41 soil samples taken from trial pits excavated during the Tier 2 Site Investigation of Barnageeragh, as summarised in **Table 6.2**. All samples were classified as 17 05 03* - soil and stones containing hazardous substances. The affected trial pits where hazardous waste was found are TP4, TP5, TP8, TP10, TP11, TP14, TP15, TP20, TP22 and TP23. For the locations of these trial pits refer to drawing number MGE0755-RPS-01-XX-DR-C-DG0002-03 in **Appendix A**.

Five of the hazardous waste samples are located in the area to the west of the waste body that is located underneath the green and road area to the south of the Hamilton Hill houses nearest the waste body. The green area and the pavement provide an effective barrier to dermal contact and rainfall infiltration.

Four of the remaining five sample are clustered around the centre and deepest part of the waste body. The remaining hazardous waste sample was taken closer to the eastern edge of the waste body.

Table 6.2: Summary of Trail Pits Founds to Contain Hazardous Waste

Location	Sample	Trial Pit Depth (m bgl)	List of Waste Code	Hazard Properties Note 1	Soil Waste Classification
TP4	SO-TP4-01	1.0 - 4.4	17 05 03*	HP 14	Hazardous due to zinc concentrations
TP5	SO-TP5-01	1.2 - 3.5	17 05 03*	HP 7, HP 14	Hazardous due to lead and zinc concentrations
TP8	SO-TP8-01	1.5 - 4.1	17 05 03*	HP 3(i), HP 7, HP 11	Hazardous due to TPH concentrations
TP10	SO-TP10-01	1.0 - 4.5	17 05 03*	HP 14	Hazardous due to zinc concentrations
TP11	SO-TP11-01	1.2 - 4.4	17 05 03*	HP 7, HP14	Hazardous due to lead and zinc concentrations
TP14	SO- TP14-02	2.3 - 4.4	17 05 03*	HP 3(i), HP 7, HP 11	Hazardous due to TPH concentrations
TP15	SO- TP15-01	1.0 - 3.2	17 05 03*	HP 3(i), HP 7, HP 11	Hazardous due to TPH concentrations
TP20	SO-TP20-01	1.3 - 4.0	17 05 03*	HP 14	Hazardous due to zinc concentrations
TP22	SO-TP22-01	1.6 - 4.2	17 05 03*	HP 7	Hazardous due to lead concentrations
TP23	SO-TP23-01	3.5 - 4.0	17 05 03*	HP 14	Hazardous due to zinc concentrations

Note 1: Hazard Properties:
HP 3(i): Flammable “flammable liquid waste: liquid waste having a flash point below 60°C or waste gas oil, diesel and light heating oils having a flash point >55°C and <=75°C”
HP 7: Carcinogenic “waste which induces cancer or increases its incidence”
HP 11: Mutagenic “waste which may cause a mutation, that is a permanent change in the amount or structure of the genetic material in a cell”
HP 14: Ecotoxic “waste which presents or may present immediate or delayed risks for one or more sectors of the environment”

There is a layer of soil covering this material which will prevent dermal contact for users of the site. However, the soil layer will permit the percolation of rainwater into the waste body thereby increasing the potential for contaminants leaching from the waste body. Therefore, consideration must be given to a longer-term solution to ensure that the hazardous waste in this area does not become exposed and to prevent the possibility of leaching of the contaminants of concern.

6.1.1.3 Conclusion

The existing soil layer overlaying the site ensures that there is no exposed waste and therefore this pathway to receptors does not exist. However, the long-term use of the area needs to be considered, particularly where the potential exists for the waste to become exposed on the surface over time or through human activity. In addition, there is evidence of groundwater contamination resulting from the leaching of contaminants from the waste body into the groundwater and from there into surface water receptors. Therefore, measures are required in order to mitigate this risk.

6.1.2 Leachate

GAC for leachate were applied to the results of the leachate samples summarised in **Section 5.4.2** above. For the purpose of the GQRA the analytical results for leachate will be screened against:

- Waste Acceptance Criteria as set out in the 2018 Waste Framework Directive (2018/851/EC)

For screening purposes, the concentration data ranges presented in the tables have been used to establish whether the leachate from the materials analysed would conform to the Waste Acceptance Criteria (WAC) limits for inert, non-hazardous or hazardous waste. In addition to the Waste Framework Directive the DQRA also screens the leachate results against the more stringent Walshestown Restoration Limited Waste Licence WAC values. The results are detailed in Section 6 of the DQRA.

Table 6.3 and **Table 6.4** below provide a summary of the exceedances of the GAC recorded in the leachate samples for Area 1 and Area 2, respectively.

Table 6.3: Summary of Soil Leachate Analysis for Area 1 – Main Waste Body

Parameter	Units	No. Analyses	No. Analyses above LOD	Range	Concentration Data		
					WAC Values (Inert Waste)	WAC Values (Hazardous Waste)	Walshestown Restoration Ltd. WL W0254-01
Sulphate	mg/l	36	36	22-**16,000**	20,000	50,000	1,000
Fluoride	mg/l	36	32	<1.0-6.7	150	500	10
Chloride	mg/l	36	36	12-**1,600**	15,000	25,000	800
Total Dissolved Solids	mg/l	36	36	860-**16,000**	60,000	10,000	4,000
Dissolved Organic Carbon	mg/l	36	36	76-350	800	1,000	500
Antimony	mg/l	36	33	<0.001-**0.14**	0.7	5	0.06
Arsenic	mg/l	36	7	<0.05-0.11	2	25	0.5
Barium	mg/l	36	19	<0.5-1.5	100	300	20
Chromium	mg/l	36	8	<0.05-**1.3**	10	70	0.5
Copper	mg/l	36	13	<0.05-0.61	50	100	2
Lead	mg/l	36	6	<0.01-0.32	10	50	0.5
Mercury	mg/l	36	6	<0.005-0.0068	0.2	2	0.01
Molybdenum	mg/l	36	22	<0.05-**0.76**	10	30	0.5
Nickel	mg/l	36	6	<0.05-0.16	10	40	0.4
Selenium	mg/l	36	29	<0.01-0.079	0.5	7	0.1
Zinc	mg/l	36	4	<0.5-1.4	50	200	4

Exceedances of WAC value marked in **bold**

Table 6.4: Summary of Soil Leachate Analysis for Area 2 – Made Ground

Parameter	Units	No. Analyses	No. Analyses above LOD	Range	Concentration Data		
					WAC Values (Inert Waste)	WAC Values (Hazardous Waste)	Walshestown Restoration Ltd. WL W0254-01
Sulphate	mg/kg	4	4	93-200	2,000	5,000	1,000
Flouride	mg/kg	4	4	2.1-7.7	150	500	10
Chloride	mg/kg	4	4	23-54	15,000	25,000	800
Total Dissolved Solids	mg/kg	4	4	630-1,100	60,000	10,000	4,000
Dissolved Organic Carbon	mg/kg	4	4	120-210	800	1,000	500
Antinomy	mg/kg	4	3	<0.001-0.023	0.7	5	0.06
Arsenic	mg/kg	4	2	<0.05-0.084	2	25	0.5
Copper	mg/kg	4	4	<0.05-0.13	50	100	2
Lead	mg/kg	4	2	<0.01-0.016	10	50	0.5
Molybdenum	mg/kg	4	3	<0.05-0.32	10	30	0.5
Selenium	mg/kg	4	3	<0.01-0.02	0.5	7	0.1

Leachability tests were undertaken on thirty-six samples of Made Ground from Area 1 the results of which are summarised in **Table 6.3**. These confirm the potential of the waste mass to generate contaminants of concern, most notably heavy metals i.e. antimony, chromium and molybdenum.

The following contaminants were recorded in the Made Ground within the waste body at concentrations exceeding the GAC.

- Sulphate (compared to 1,000mg/kg) in TP2-TP9, TP11, TP12-TP16, TP19-TP21, TP36, TP38.
- Chloride (compared to 800mg/kg) in TPTP10.
- Total Dissolved Solids (compared to 4,000mg/kg) in TP3-TP6, TP8, TP10-TP12, TP14-16, TP19, TP21, TP22, TP38.
- Antinomy (compared to 0.06mk/kg) in TP7, TP8, TP10, TP13-TP16, TP21, TP22, TP23, TP37.
- Chromium (compared to 0.5mk/kg) in TP13, TP14 and TP20.
- Molybdenum (compared to 0.5mk/kg) in TP7 and TP15.

Leachability tests were undertaken on four samples of Fill material from Area 2. There were no exceedances of the GAC in the leachate samples taken from Area 2.

6.1.3 Groundwater

6.1.3.1 Screening Values

The principal controlled-water receptors that will be considered as part this groundwater GQRA are:

- Groundwater contained in aquifer units that underlie the site and/or in continuity therewith; and
- Adjacent surface water stream and Barnageeragh Stream.

The GQRA provides the mechanism to interpret the contamination status shown by the water quality dataset for a specific water body and allow the qualitative assessment of potential risk to other receptors to be strengthened on the basis of pollutant (source-pathway-receptor) linkages defined by the CSM developed for the site.

For the purpose of this controlled water GQRA the analytical results for groundwater will be screened against:

- "Threshold Values" published in Schedule 5 of the European Union Environmental Objectives (Groundwater) (Amendment) Regulations 2016 (Statutory Instrument No 366) as initial screening criteria. "Threshold values" have been established for pollutants that are causing a risk to groundwater bodies.
- EPA Interim Guideline Values, Towards Setting Guideline Values for the Protection of Groundwater in Ireland, 2003
- S.I. No. 122/2014 European Union (Drinking Water) Regulations 2014.

The results of the groundwater analyses based upon the different strata types encountered are summarised in **Section 5.4.2**. Further assessment based upon the results obtained for differing strata in each of the investigation areas is presented in the tables below, together with an indication of exceedances of 'groundwater threshold values' where applicable.

As detailed in previous sections of this report, for management and assessment of the ground investigation findings for the GQRA, the site has been subdivided into two discrete areas principally on the basis of the extent and delineation of the waste mass (see **Section 5.1**). For groundwater the results have been assessed in relation to the main identified hydrogeological units (i.e. made ground, natural subsoil and bedrock) underlying the site.

6.1.3.2 Area 1: Waste Area

A summary of those parameters in water samples taken from the waste area that exceed the assessment criteria is provided in **Table 6.5**.

Table 6.5: Area 1 Groundwater Exceedances - Waste body (BH1-BH3)

Contaminant	Substance Classification (EPA 2010)	Units	No of Results	Concentration Range	Mean	GTV*	Exceedances
Electrical Conductivity	Undetermined	mg/l	9	690-**10,000**	30,560	1000	**BH1(x3) BH3(x3)**
Total Dissolved Solids	-	mg/l	9	410-**6100**	2,055	1000	**BH1(x2) BH3(x2)**
Ammoniacal Nitrogen	Non Hazardous	mg/l	9	**0.31-18**	3.96	0.15	**BH1(x3) BH2(x3) BH3(x3)**
Nitrate	-	mg/l	9	<0.50-**54**	8.93	25	**BH3(x1)**
Nitrite	Non Hazardous	mg/l	9	0.041-**0.69**	0.17	0.1	**BH3(x1)**
Chloride	Undetermined	mg/l	9	**30-2200**	544.6	30	**BH1(x3) BH2(x3) BH3(x3)**
Sulphate	Undetermined	mg/l	9	55 - **3200**	1,002	200	**BH1(x3) BH3(x3)**
Orthophosphate	-	mg/l	9	<0.050-**0.056**	0.018	0.03	**BH1(x1) BH2(x1) BH3(x1)**
Potassium	Undetermined	mg/l	9	**11 - 930**	196	5	**BH1(x3) BH2(x3) BH3(x3)**
Sodium	Undetermined	mg/l	9	25 - **1400**	298	150	**BH1(x3)**
Calcium	Undetermined	mg/l	9	150-**740**	344	200	**BH1(x3) BH3(x3)**
Magnesium	Undetermined	mg/l	9	33-**950**	217.7	50	**BH1(x3) BH3(x3)**
Arsenic	Hazardous		9	<1.0-**8.2**	2.3	7.5	**BH1(x1)**
Barium	Non Hazardous	µg/l	9	43-**130**	71.2	100	**BH1(x1)**
Boron	Non Hazardous	µg/l	9	160-**3400**	1,198	1000	**BH1(x3)**
Iron	Non Hazardous	µg/l	9	170-**1200**	495.5	200	**BH1(x3) BH3(x3)**
Manganese	Undetermined	µg/l	9	2.2-**3300**	1,124	50	**BH1(x3) BH2 (x2) BH3(x2)**
Mercury	Hazardous	µg/l	9	<0.5-**7.3**	0.6	1	**BH1(x1) BH3(x1)**
Selenium	-	µg/l	9	<0.1-**52**	7.8	10	**BH1(x3) BH3(x2)**
Total Coliforms	-	Cfu/100ml	9	**2-8300**	1,386	0	**BH1(x3) BH2 (x3) BH3(x3)**
Faecal Coliforms	-	Cfu/100ml	9	<1-**11**	1.34	0	**BH1(x2) BH3(x3)**

* Groundwater Threshold Values (GTV) for Chemical Status Tests – Assessment of general quality of groundwater and ability to support human uses; Exceedances marked in **bold#**

Ammoniacal Nitrogen, chloride and potassium exceed their respective assessment criteria on every occasion. Metals exceeded their relevant assessment criterial on multiple occasions. Borehole BH2 represents upgradient groundwater at the site. The groundwater at BH2 appears to be significantly less impacted than that observed in BH1 and BH3, which are located within the main waste body.

6.1.3.3 Area 2: North of the Site

A summary of those parameters in water samples taken from Area 2 that exceed the assessment criteria is provided in **Table 6.6**.

Table 6.6: Area 2 Groundwater Exceedances – North of the site

Contaminant	Substance Classification (EPA 2010)	Units	No of Results	Concentration Range	Mean	GTV*	Exceedances
Electrical Conductivity	Undetermined	mg/l	26	550-**2600**	1,250	1000	**BH4(x3) BH8(x2) BH9(x2) BH10(x3) BH11(x3) BH11(x3) BH12(x3) BH14(x1) BH16(x1)**
Total Dissolved Solids	-	mg/l	26	39-**1600**	686.5	1000	**BH4(x2) BH11(x2) BH14(x1)**
Ammoniacal Nitrogen	Non Hazardous	mg/l	26	0.16-**0.23**	3.25	0.15	**BH4(x3) BH8(x3) BH9(x3) BH10(x3) BH11(x3) BH11(x3) BH12(x3) BH13(x3) BH14(x2) BH15(x1) BH16(x1) BH17(x1)**
Nitrate	-	mg/l	26	<0.5-**30**	4.4	25	**BH13(x1)**
Nitrite	Non Hazardous	mg/l	26	<0.020-**2.1**	4.4	0.1	**BH8(x2) BH9 (x1) BH11(x1) BH12(x1) BH14(x1)**
Chloride	Undetermined	mg/l	26	28-**180**	70.46	30	**BH4(x3) BH8(x3) BH9(x3) BH10(x3) BH11(x3) BH12(x3) BH13(x2) BH14(x2) BH15(x1) BH16(x1) BH17(x1)**
Sulphate	Undetermined	mg/l	26	26 – **430**	149.6	200	**BH8(x2) BH11(x2) BH12(x3) BH14(x1)**
Orthophosphate	-	mg/l	26	<0.050-**0.059**	0.0085	0.03	**BH4(x1) BH8 (x1) BH9(x1) BH13(x1)**
Potassium	-	mg/l	26	2.8 - **120**	23	5	**BH4(x3) BH8 (x3) BH9(x2) BH10(x3) BH11(x3) BH12(x3) BH13(x2) BH14(x2)**

Contaminant	Substance Classification (EPA 2010)	Units	No of Results	Concentration Range	Mean	GTV*	Exceedances
							BH16(x1)
Calcium	Undetermined	mg/l	26	120-**400**	220.7	200	BH4(x3) BH9(x1) BH10(x3) BH11(x3) BH12(x3) BH14(x1) BH16(x1)
Magnesium	Undetermined	mg/l	26	21-**130**	23	50	BH4(x2) BH9(x2) BH11(x3) BH12(x1) BH14(x1)
Aluminium	-	mg/l	26	<10-**95**	12.4	150	BH12(x1)
Antimony	Non Hazardous	µg/l	26	<1.0-**6.2**	0.85	5	BH13(x1)
Arsenic	Hazardous	µg/l	26	<1- **8.9**	2.3	7.5	BH4(x1)
Barium	Non Hazardous	µg/l	26	59-**330**	117	100	BH4(x3) BH9(x1) BH10(x3) BH15(x1)
Boron	Non Hazardous	µg/l	26	46-**760**	260	750	BH11(x1)
Iron	Undetermined	µg/l	26	150-**970**	392	200	BH4(x3) BH8(x2) BH9(x3) BH10(x3) BH11(x3) BH11(x3) BH12(x3) BH13(x2) BH14(x1) BH16(x1) BH17(x1)
Manganese	Undetermined	µg/l	26	9.9-**3800**	795.4	50	BH4(x3) BH8(x3) BH9(x3) BH10(x3) BH11(x3) BH11(x3) BH12(x2) BH13(x3) BH14(x2) BH15(x1) BH16(x1)
Nickel	Non Hazardous	µg/l	26	<1.0-**20**	6.3	15	BH4(x2)
Mercury	Hazardous	µg/l	26	<0.5-**1.1**	0.2	0.75	BH10(x1) BH11(x2)
Selenium	-	µg/l	26	<0.1-**52**	7.8	10	BH10(x1) BH11(x1) BH12(x2) BH14(x1) BH17(x1)
Total Coliforms	-	Cfu/100ml	26	<1->**2419.6**	326.1	0	BH4(x2) BH8(x2) BH9(x2) BH10(x1) BH11(x1) BH12(x1) BH13(x1) BH14(x1) BH15(x1) BH16(x1) BH17(x1)
Faecal Coliforms	-	Cfu/100ml	26	<1-**11**	1.34	0	BH8(x1) BH9(x2)

Contaminant	Substance Classification (EPA 2010)	Units	No of Results	Concentration Range	Mean	GTV*	Exceedances
							BH10(x1) BH11(x1) BH12(x1) BH14(x1) BH16(x1)

Ammoniacal Nitrogen, chloride and potassium exceed their respective assessment criteria on multiple occasions. There were no exceedances of sodium recorded. Iron and manganese exceeded their relevant assessment criterial on multiple occasions. There were some exceedances for selenium, mercury and arsenic. On one occasion each; exceedances of nickel, aluminium, antimony, arsenic and boron were recorded.

Boreholes BH12 and BH15-17 represent downgradient groundwater, i.e. groundwater discharging to the eastern boundary stream and to the Barnageeragh Stream.

6.1.3.4 Conclusion

From the groundwater sample analyses it is clear that there is contamination present in the groundwater beneath the waste body, while the groundwater quality at the edge of the waste mound does not seem to suggest a large impact from the waste body, considering the water quality observed underlying the main waste body itself (BH1 and BH3). The contamination is indicative of the degradation of waste material and leachate generation.

Although an impact on groundwater has been identified from the waste mass, quality data in the downgradient boreholes show a much-reduced impact on groundwater.

6.1.4 Surface Water

6.1.4.1 Screening Values

The principal controlled-water receptor that will be considered as part this surface water GQRA is:

- Surface water stream at the eastern boundary of the site, flowing northwards to existing stormwater infrastructure.

There is no pathway for surface water from the site to connect to the Barnageeragh stream located in the wastewater treatment plant.

For the purpose of this controlled water GQRA the analytical results for surface water have been screened against:

- S.I. No. 294, European Communities (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations, 1989;
- S.I. No. 278, European Communities Environmental Objectives (Drinking Water) (No. 2) Regulations, 2007; and
- S.I. No. 272, European Communities Environmental Objectives (Surface Water) Regulations, 2009.

GAC for surface waters were applied to the results of the surface water samples. The results are summarised in Section 9 and detailed in Appendix 18 of the DQRA. **Table 6.7** below provides a summary of the exceedances of the GAC recorded in the surface water samples.

Total suspended solids in SW1 and SW4 exceeded the limit of 50mg/l set in S.I. No. 294 European Communities (Quality of Surface Water Intended for Abstraction of Drinking Water) Regulations, 1989. These samples are both upgradient of the landfill.

Ammoniacal nitrogen in SW1, SW3 and SW4 exceeded the limit of 0.2mg/l set in S.I. No. 294 European Communities (Quality of Surface Water Intended for Abstraction of Drinking Water) Regulations, 1989. SW1 and SW4 are upgradient of the landfill.

In SW3, the fluoride level exceeded the limit of 1mg/l set in S.I. No. 294 European Communities (Quality of Surface Water Intended for Abstraction of Drinking Water) Regulations, 1989. SW3 is downgradient of the landfill.

Phosphate in SW1 and SW4 exceeded the limit of 0.035mg/l set in S.I. No. 272 European Communities Environmental Objectives (Surface Water) Regulations, 2009. Both samples are upgradient of the landfill.

Iron was the only heavy metal that exceeded the limit of 200 µg/l set in S.I. No. 294 European Communities (Quality of Surface Water Intended for Abstraction of Drinking Water) Regulations, 1989. This was recorded in SW1, SW2 and SW3 in January 2018. No exceedance was recorded in June 2019. SW1 is upgradient of the landfill while SW2 and SW3 are downgradient.

The Biochemical Oxygen Demand (BOD) in SW4 showed a minor exceedance of the limit of 2.2mg/l set in S.I. No. 272 European Communities Environmental Objectives (Surface Water) Regulations, 2009. SW 4 is upgradient of the landfill.

The Chemical Oxygen Demand (COD) in SW1 (2nr. Samples) and SW4 showed exceedances of the limit of 40mg/l set in S.I. No. 294 European Communities (Quality of Surface Water Intended for Abstraction of Drinking Water) Regulations, 1989. Both SW1 and SW4 are upgradient of the landfill.

Table 6.7: Summary of Surface Water Analysis

Parameter	Units	Limit	Jan-18			Jun-18	
			Upgradient	Downgradient		Upgradient	
			SW1	SW2	SW3	SW1	SW4
Total suspended solids	mg/l	50	24.0	16.0	< 5.0	330.0	150.0
Ammoniacal Nitrogen	mg/l	0.2	0.26	0.19	0.23	0.23	0.43
Flouride	mg/l	1	< 0.050	< 0.050	3.0	0.1	0.1
Molybdate Reactive Phosphate P	mg/l	0.035	0.1	< 0.050	< 0.050	0.23	0.25
Heavy Metals							
Iron (Fe)	µg/l	200	230.0	210.0	230.0	120.0	160.0
Oxygen Demand/Organic Carbon							
BOD	mg/l	5	<2	<2	<2	2.0	3.0
COD	mg/l	40	42.0	<8	8.0	76.0	161.0
Microbiological							
Total coliforms (i.e. Confirmed)	CFU/100ml	0	142.1	5.2	13.5	24,890	241,960
Faecal coliforms (i.e. Confirmed)	CFU/100ml	0	34.0	4.0	2.0	1,950	500

6.1.4.2 Surface Water Connectivity to Groundwater

As detailed in the DQRA, Appendix 12, there is hydraulic connectivity between groundwater and surface water at the site.

6.1.4.3 Conclusion

From the surface water sample analyses it is clear that there is some contamination present in the surface waters. The contamination is representative of an agricultural setting and appears both upgradient and downgradient of the landfill.

However, from the groundwater modelling, there is hydraulic connectivity between groundwater and surface water at the site. Therefore, there is a potential pathway for contamination to leach from the waste body into groundwater and thereby into surface waters.

6.1.5 Landfill Gas

6.1.5.1 Screening Values

The main cause of landfill gas results from the decomposition of the waste over a time period. It should be noted that ground gases can also occur naturally in soils from the microbial decay of organic materials, particularly in made ground. These soils may contain methane concentrations of up to 20% and carbon dioxide concentrations of up to 10% (Wilson et al., 2007, Table 2.1).

The constituent gases in landfill gas are typically methane and carbon dioxide with numerous other trace gases including hydrogen sulphide and VOCs. The biodegradable fraction of waste in particular is the main source of methane and carbon dioxide. These can typically range in level up to 64%v/v for methane and 34%v/v for carbon dioxide (EPA, Table E.1, 2000). Methane is flammable and can be an asphyxiant. It has a Lower Explosive Limit (LEL) of 5%v/v and an Upper Explosive Limit (UEL) of 15%v/v. Carbon dioxide is an asphyxiant. The occupational exposure limits for carbon dioxide are short term (15 minutes) 1.5% and long term (8 hours) 0.5% by volume in air.

For the purpose of this landfill gas GQRA the analytical results for methane and carbon dioxide have been screened using the following standard:

- British Standard BS8485:2015+A1:2019 Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings.

This standard sets out the process for assessing the risk posed by methane and carbon dioxide to buildings in proximity to areas producing ground gases. The results from on-site monitoring are used to determine a gas screening value (GSV) for each location. This is a function of the measured flow rate and the methane and carbon dioxide concentrations. The GSV is thus a semi-quantitative risk assessment derived from measured data rather than a risk assessment based on heuristics. In all cases the highest GSV has been chosen for this GQRA to determine a “worst-case” scenario. This is an overly conservative approach and can result in a “disproportionately high” gas hazard prediction (BS8485:2015+A1:2019, p.16) and this must be borne in mind when considering the results of the GQRA.

Using the GSVs, a characteristic situation (CS) is assigned to each location. The possible CS ranges are from CS1 (very low hazard potential) to CS6 (very high hazard potential). Based on the CS values, mitigation measures can be designed into the construction of new buildings to ensure that the hazard posed by methane and carbon dioxide is reduced to acceptable levels. It should be noted that the retrospective design of protection measures for completed buildings and the design of retrospective protection measures after completion of building construction are not covered in BS8485:2015+A1:2019.

The GSV and CS for methane and carbon dioxide used in this GQRA are summarised in **Table 6.8** which is extracted from Table 2, BS8485:2015+A1:2019, p.18.

Table 6.8: Methane and Carbon Dioxide Screening Values for Relevant GSV and CS

Gas Screening Value (GSV) l/h	Additional Considerations	Characteristic Situation	
		CS	Hazard Potential
<0.07	Typically <1% Methane concentration and <5% carbon dioxide concentration. If exceeded, consider increasing to CS2 Note 1	CS1	Very low
0.07 to <0.7	Typically measured flow rate <70l/h (otherwise consider increasing to CS3)	CS2	Low
0.7 to <3.5	-	CS3	Moderate
3.5 to <15	-	CS4	Moderate to high
15 to <70	-	CS5	High
>70	-	CS6	Very high

Note 1: The 1%v/v methane and 5%v/v carbon dioxide levels are applied based on the presence of housing adjacent to the site. This is in accordance with BS8485:2015+A1:2019 and The Ground Gas Handbook (p.93).

The following sections assess the characteristic situations for both methane and carbon dioxide.

With regard to trace gases, the Ground Gas Handbook notes (p.94): "*the classification and design of protection measures based on methane and carbon dioxide flows is usually more than adequate to provide protection against the acute effects from other gases*." It does, however, also state that the chronic effects from trace gases or vapours may also need to be considered in relation to human health effects. Therefore, both hydrogen sulphide and VOCs have also been considered in this GQRA.

6.1.5.2 Methane GSV and CS

The DQRA includes all monitoring results for methane in Appendix 13 to that report. These results have been assessed to determine if there is an issue with methane by using the GSV and CS calculations as set out in BS8485:2015+A1:2019.

The worst-case results for methane from the monitoring programme are summarised in **Table 6.9**.

Table 6.9: Analysis of Methane GSV and CS

Monitoring location	Peak Flow Rate	Methane Peak Concentration	GSV	Characteristic Situation	
	l/h	% v/v			
GS01	0.3	0.8	0.00240	CS1	Very Low Hazard
GS02	0.3	0.3	0.00090	CS1	Very Low Hazard
GS03	0.4	0.3	0.00120	CS1	Very Low Hazard
GS04	0.5	0.3	0.00150	CS1	Very Low Hazard
BH1	0.6	7.4	0.04440	CS2 Note 1	Low Hazard
BH2	0.3	0.2	0.00060	CS1	Very Low Hazard
BH3	0.2	0.2	0.00040	CS1	Very Low Hazard
BH4	0.4	73.6	0.29440	CS2	Low Hazard
BH5	0.3	0.2	0.00060	CS1	Very Low Hazard
BH6	0.3	3.9	0.01170	CS2 Note 1	Low Hazard
BH7	0.2	11.9	0.02380	CS2 Note 1	Low Hazard
BH8	0.2	0.8	0.00160	CS1	Very Low Hazard
BH9	0.3	4.7	0.01410	CS2 Note 1	Low Hazard
BH10	0.2	0.3	0.00060	CS1	Very Low Hazard
BH11	0.3	5.8	0.01740	CS2 Note 1	Low Hazard
BH12	0.2	8.4	0.01680	CS2 Note 1	Low Hazard
BH13	0.2	0.3	0.00060	CS1	Very Low Hazard
BH14	0.2	0.3	0.00060	CS1	Very Low Hazard
BH15	0.2	0.4	0.00080	CS1	Very Low Hazard
BH16	0.2	0.3	0.00060	CS1	Very Low Hazard
BH17	0.2	17.8	0.03560	CS2 Note 1	Low Hazard

Note 1: Although the GSVs for these boreholes equate to CS1, the methane concentration is greater than 1%v/v (cells highlighted grey). In line with the guidance in BS8485:2015+A1:2019 and the Ground Gas Handbook (p.93), and given the proximity of housing, the CS has been increased to CS2.

From the GSV calculations above, it is evident that only one of the boreholes, BH4, is automatically assigned a CS2 rating, i.e. low hazard. All other boreholes result in a CS1 rating, i.e. very low hazard. However, as per the guidance note for BS8485:2015+A1:2019, where the methane concentration is above 1%, consideration can be given to raising the CS up to CS2. What is particularly relevant to the considerations for this site is the proximity of the waste mass to the houses and the made ground that covers most of the site. In light of these and taking an overly conservative approach, the CS rating has been increased one level from CS1 to CS2 for a further seven locations. CS2 is considered to be a low hazard situation and it must be considered alongside the very low peak flow rates measured at each borehole.

6.1.5.3 Carbon Dioxide GSV and CS

The DQRA includes all monitoring results for carbon dioxide in Appendix 13 to that report. These results have been assessed to determine if there is an issue with carbon dioxide by using the GSV and CS calculations as set out in BS8485:2015+A1:2019.

The worst-case results for carbon dioxide from the monitoring programme are summarised in **Table 6.10**.

Table 6.10: Analysis of Carbon Dioxide GSV and CS

Monitoring location	Peak Flow Rate	Carbon Dioxide Peak Concentration	GSV	Characteristic Situation	
	l/h	% v/v			
GS01	0.3	4.5	0.0135	CS1	Very Low Hazard
GS02	0.3	2.5	0.0075	CS1	Very Low Hazard
GS03	0.4	0.7	0.0028	CS1	Very Low Hazard
GS04	0.5	0.3	0.0015	CS1	Very Low Hazard
BH1	0.6	11.5	0.069	CS2 Note 1	Low Hazard
BH2	0.3	3.9	0.0117	CS1	Very Low Hazard
BH3	0.2	4.5	0.009	CS1	Very Low Hazard
BH4	0.4	20.9	0.0836	CS2	Low Hazard
BH5	0.3	3.3	0.0099	CS1	Very Low Hazard
BH6	0.3	11.6	0.0348	CS2 Note 1	Low Hazard
BH7	0.2	13.3	0.0266	CS2 Note 1	Low Hazard
BH8	0.2	6.6	0.0132	CS2 Note 1	Low Hazard
BH9	0.3	8.8	0.0264	CS2 Note 1	Low Hazard
BH10	0.2	13.7	0.0274	CS2 Note 1	Low Hazard
BH11	0.3	14.8	0.0444	CS2 Note 1	Low Hazard
BH12	0.2	14.7	0.0294	CS2 Note 1	Low Hazard
BH13	0.2	6.7	0.0134	CS2 Note 1	Low Hazard
BH14	0.2	6.6	0.0132	CS2 Note 1	Low Hazard
BH15	0.2	15.1	0.0302	CS2 Note 1	Low Hazard
BH16	0.2	12.4	0.0248	CS2 Note 1	Low Hazard
BH17	0.2	18.1	0.0362	CS2 Note 1	Low Hazard

Note 1: Although the GSVs for these boreholes equate to CS1, the carbon dioxide concentration is greater than 5%v/v (cells highlighted grey). In line with the guidance in BS8485:2015+A1:2019 and the Ground Gas Handbook (p.93), and given the proximity of housing, the CS has been increased to CS2.

From the GSV calculations above, it is evident that only one of the boreholes, BH4, is automatically assigned a CS2 rating, i.e. low hazard. All other boreholes result in a CS1 rating, i.e. very low hazard. However, as per the guidance note for BS8485:2015+A1:2019, where the carbon dioxide concentration is above 5% consideration can be given to raising the CS up to CS2. What is particularly relevant to the considerations for this site is the proximity of the waste mass to the houses and the made ground that covers most of the site. In light of these and taking an overly conservative approach, the CS rating has been increased one level from CS1 to CS2 for a further thirteen locations. CS2 is considered to be a low hazard situation and it must be considered alongside the very low peak flow rates measured at each borehole.

6.1.5.4 Other Trace Gases

6.1.5.4.1 Hydrogen Sulphide

The occupational exposure limit value (OELV) for hydrogen sulphide is 5 ppm for an 8-hour reference period and 10 ppm for a 15-minute reference period (HSA, 2018, p.23).

The DQRA includes all monitoring results for hydrogen sulphide in Appendix 13 to that report. These results have been assessed to determine if there is an issue with hydrogen sulphide. From the results of the monitoring, and as summarised in **Table 5.10**, only one borehole, BH4, had a peak reading of 5ppm and that was on one occasion only. The average measured hydrogen sulphide reading from BH4 is 0.6ppm with no hydrogen sulphide recorded 64% of the time. Furthermore 86% of the results were at or less than 1ppm. Considering all of the hydrogen sulphide monitoring results, the average reading was 0.36ppm with 93% less than or equal to 1ppm.

Based on the monitoring results included in Appendix 13 and the OELV of 5ppm for hydrogen sulphide, the hazard from hydrogen sulphide is considered to be very low to negligible.

6.1.5.4.2 Volatile Organic Compounds

VOCs in soil gas migrate typically through diffusion in the unsaturated zone, i.e. movement from areas of high concentration to areas of low concentration (Environment Agency, 2009; Evans et al., 2002 as cited in Welburn et al., 2012, p.9). Advective flow may also be a factor particularly with the presence of other landfill gases, i.e. “carrier gases” (ibid.).

Soil samples were tested for the presence of VOCs (5 out of 40 samples) with 4 of the 5 samples recorded as having no VOCs present or below the limit of detection. Vinyl Chloride and cis 1,2-Dichloroethene were detected in SO-TP21-01 at concentrations of 2.1µg/l and 11µg/l respectively. This trial pit is located toward the middle of the southern boundary of the waste body.

Appendix 15 of the DQRA provides a site-specific risk based corrective assessment (RBCA) model for chemical releases. This is supplemented with a detailed peer review undertaken by Argentum Fox also included in Appendix 15 of the DQRA.

Based on the monitoring results included in Appendix 13 and the reports presented in Appendix 15 of the DQRA, the hazard from VOCs is considered to be very low.

6.1.5.5 Other Monitoring Locations: Properties and Underground Services

The DQRA includes all monitoring results the other locations in Appendix 13 to that report. These results have been assessed to determine if there is an issue with landfill gases.

As no flow measurements were recorded at these locations it is not possible to apply the GSV and CS calculations as set out in BS8485:2015+A1:2019.

As can be seen from **Table 5.11**, the peak concentration recorded for methane was 0.3%v/v with an average peak concentration of 0.1%v/v across all monitoring results.

For carbon dioxide, the peak concentration recorded in the underground services was 1.5%v/v measured at one location on one occasion with an average peak concentration of 0.3%v/v across all monitoring results. A further result of 2.8%v/v was recorded in one of the probe points drilled along the route of the foul rising main.

Hydrogen sulphide was recorded at a peak concentration of 4ppm in watermains meters with an average peak concentration of 2.5ppm across all monitoring results. A single hydrogen sulphide result of 13ppm was detected in one of the probe points drilled in close proximity to the foul rising main.

The results of the VOC monitoring show levels up to a peak concentration of 126ppm recorded in the water mains meter for house number 55. The average peak concentration of VOCs was 15.7ppm across all monitoring results. These concentrations of VOCs can be explained by noting that the service pipes would contain phthalate plasticisers which can emit VOCs (refer to Section 10.3 of the DQRA). In Appendix 14 of the DQRA, analysis of frost protection caps is presented which demonstrates that VOCs are being emitted along with hydrogen sulphide.

Based on the monitoring results included in Appendix 13, and the reports included in Appendices 14 and 15 of the DQRA, the hazard to residential receptors from landfill gases is considered to be very low.

6.1.5.6 Conclusion

The hazard presented by landfill gas at the Barnageeragh site has been assessed using the risk assessment set out in British Standard BS8485:2015+A1:2019 *Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings*. Taking an overly-precautionary approach the characteristic situation (CS) for the landfill has been raised from CS1 to CS2 to account for the elevated levels of methane and carbon dioxide in a number of the boreholes and the proximity of the waste body to houses. CS2 is a low hazard potential.

The CS ratings at each borehole are illustrated in drawing number MGE0755-RPS-01-XX-DR-C-DG0002-02 in **Appendix A**.

Outside of the waste body, comprehensive monitoring has been undertaken adjacent to the residences. The results of this monitoring indicate a very low hazard associated with landfill gas.

7 TIER 3 REVISED CONCEPTUAL MODEL

7.1 Revised Risk Assessment Process

Given the proximity of the waste body to receptors, the Tier 2 Site Investigation targeted all sources and pathways for further investigation including soil, leachate, groundwater, surface water and landfill gas. The information detailed in the DQRA and summarised in this report has been used to verify assumptions made in the Tier 1 risk assessment and, where relevant, update the risks based on the Tier 2 site investigation. On the basis of the information presented in **Section 5** and **Section 6** of this report, the CSM and risk assessment for the site can be updated.

7.2 Sources

The approximate extent of the landfill waste body based upon the trial hole and exploratory hole descriptions of the Made Ground encountered is shown as Area 1 in the drawings contained in **Appendix A**. The area of the waste body has increased from 0.71ha to 0.85ha.

The risk matrices for leachate and landfill gas remain unchanged from the Tier 1 risk assessment. However, it must be considered that the site was active prior to 1977 and that the waste body is a mix of both C&D and municipal waste. Therefore, the scores set out in **Table 7.1** and **Table 7.2** should be considered as conservative.

Table 7.1: Leachate: Source/ Hazard Scoring Matrix 1a

Waste Type	Waste Footprint (ha) Matrix Score		
	≤1ha	> 1 ≤ 5ha	> 5ha
C&D	0.5	1	1.5
Municipal	5	7	10
Industrial	5	7	10
Pre-1977 sites	1	2	3

Table 7.2: Landfill Gas: Source/ Hazard Scoring Matrix 1b

Waste Type	Waste Footprint (ha) Matrix Score		
	≤1ha	> 1 ≤ 5ha	> 5ha
C&D	0.5	0.75	1
Municipal	5	7	10
Industrial	3	5	7
Pre-1977 sites	0.5	0.75	1

7.3 Pathways

Made Ground varies between 5.5m to 8.5m in thickness and has been identified as mainly waste material within a Silt/Clay matrix, which is likely to inhibit vertical migration of potentially contaminated water but recharge will infiltrate the waste body, dissolving contaminants while continuing to infiltrate vertically until it reaches the subsoil and the groundwater table.

Underlying the Made Ground the natural ground comprises sands and gravels with variable silt content and cobbles and boulders. There is potential for the granular nature of these deposits to allow migration of contaminated waters both vertically and laterally. If the sand and gravel deposits form a lateral continuous water body they could provide a pathway when discharging to the eastern boundary stream and further eastwards to the Barnageeragh Stream.

The transmissivity rate of the underlying Skerries Formation bedrock has proven to be low therefore groundwater flow paths are expected to be short. However pumping tests at boreholes BH15 and BH17 at the eastern site boundary indicated high transmissivity within the upper weathered portion of sandstone which can be interpreted as a potential preferential pathway.

Landfill gas has the potential to migrate both vertically and horizontally from a waste body. This requires a pressure gradient to exist which enables the gas to move from areas of high pressure to low pressure. Landfill gas monitoring across the site has clearly demonstrated that there is very little flow in the boreholes and not enough to displace balance gases.

The following tables outline the scoring matrices for the pathways of contamination based on the results of SI at the site.

The SI confirmed the Vulnerability classification of the site as High (3-5m of high permeability subsoil).

Table 7.3: Leachate Migration: Pathways Scoring Matrix 2a

Groundwater Vulnerability (Vertical Pathway)	Matrix Score
Extreme Vulnerability	3
High Vulnerability	2
Moderate Vulnerability	1
Low Vulnerability	0.5
High - Low Vulnerability	2

Pumping tests carried out by HUCT recorded low Transmissivity rates within the competent bedrock, however high transmissivity rates were recorded within the weathered portion of the bedrock at the eastern site boundary. Therefore, the matrix score has increased from 1 to 3.

Table 7.4: Leachate Migration: Pathways Scoring Matrix 2b

Groundwater Flow Regime (Horizontal Pathway)	Matrix Score
Karstified Groundwater Bodies (Rk) Vulnerability	5
Productive Fissured Bedrock Groundwater Bodies (Rf and Lm)	3
Gravel Groundwater Bodies (Rg and Lg)	2
Poorly Productive Bedrock Groundwater Bodies (Ll, Pl, Pu)	1

A review of the surface water systems on site showed a direct connection from groundwater to surface water streams. Also, there is a culverted surface water stream on-site that discharges to the local storm network. Therefore, the matrix score as increased from 0 to 2.

Table 7.5: Leachate Migration: Pathways Scoring Matrix 2c

Surface Water Drainage (Surface Water Pathway)	Matrix Score
Is there direct connection between drainage ditches associated with the waste body and adjacent surface water body? Yes	2
If no direct connection	0

The SI confirmed the presence of Made Ground, Fill and sand and gravel Quaternary deposits across the site. However, the site is also covered in a layer of clay that is well compacted from site activities during the construction of the housing estate. In addition, landfill gas flow rates from the boreholes clearly show that there is not enough pressure to displace balance gases and therefore the risk of migration is very low. For this reason this pathway matrix has been downgraded from 3 to 1.5 (moderate permeability).

Table 7.6: Landfill Gas: Pathways Scoring Matrix 2d (receptor within 250m)

Landfill Gas Lateral Migration Potential	Matrix Score
Sand and Gravel, made ground, urban, karst	3
Bedrock	2
All other Tills (including limestone, sandstone etc. – moderate permeability	1.5
All Numerian or Irish Sea Tills (low permeability)	1
Clay, Alluvium, Peat	1

Similar to Matrix 2d above, the score for the matrix has been revised downward based on the assumption of a moderate permeability for the site. Therefore, this pathway matrix has been downgraded from 5 to 2.

Table 7.7: Landfill Gas: Pathways Scoring Matrix 2e (receptor above source)

Landfill Gas Vertical Migration Potential	**Matrix Score**
Sand and Gravel, made ground, urban, karst	5
Bedrock	3
All other Tills (including limestone, sandstone etc. – moderate permeability	2
All Numerian or Irish Sea Tills (low permeability)	1
Clay, Alluvium, Peat	1

7.4 Receptors

The following receptors are considered relevant to the environmental risk assessment for the site and will be used in the updated CSM:

- **Groundwater:** The Skerries Formation Bedrock Aquifer (poorly productive bedrock aquifer)
- **Surface Water:** Eastern boundary stream and the Barnageeragh Stream - High Sensitivity (WFD At Risk Water Body)
- **Human Health**: Construction workers, potential future end users of the site and residents within the buildings/ structures of the adjacent housing estate. In addition, it is assumed that the site will be subject to future development as an open park/ recreation area that will attract casual users.

This section deals specifically with the location of the contamination on or close to residential dwellings or industrial facilities.

The risk matrices shown in **Table 7.8** to **Table 7.11** below remain unchanged from the Tier 1 assessment.

Table 7.8: Leachate Migration: Receptors Scoring Matrix 3a

Human Presence (presence of a house indicates potential private wells)	Matrix Score
On or within 50m of the waste body	3
Greater than 50m but less than 250m of the waste body	2
Greater than 250m but less than 1km of the waste body	1
Greater than 1km of the waste body	0

Table 7.9: Leachate Migration: Receptors Scoring Matrix 3b

Protected Areas (SWDTE or GWDTE)	Matrix Score
Within 50m of the waste body	3
Greater than 50m but less than 250m of the waste body	2
Greater than 250m but less than 1km of the waste body	1
Greater than 1km of the waste body	0
Undesignated sites within 50m of the waste body	1
Undesignated sites greater than 50m but less than 250m of the waste body	0.5
Undesignated sites greater than 1km of the waste body	0

Table 7.10: Leachate Migration: Receptors Scoring Matrix 3c

Aquifer Category (resource potential)	Matrix Score
Regionally Important Aquifers (Rk, Rf, Rg)	5
Locally important aquifers (Ll, Lm, Lg)	3
Poor Aquifers (Pl, Pu)	1

Table 7.11: Leachate Migration: Receptors Scoring Matrix 3d

Public Water Supplies (other than private wells)	Matrix Score
Within 100m of the site boundary	7
Greater than 100m but less than 300m or within Inner SPA(SI) for SW supplies	5
Greater than 300m but less than 1km or within Outer SPA (SO) for GW supplies	3
Greater than 1km (karst aquifer)	3
Greater than 1km (no karst aquifer)	0

The risk matrix for surface water bodies has been increased to "within 50m of the site boundary" as groundwater monitoring on-site has demonstrated that in certain periods of high groundwater, there is connectivity between groundwater from the waste body and surface waters. Although this risk is considered to be low, as demonstrated in the DQRA, the connectivity exists and dilution is considered in the DQRA as a process whereby the impact is reduced.

Table 7.12: Leachate Migration: Receptors Scoring Matrix 3e

Surface Water Bodies	Matrix Score
Within 50m of the site boundary	3
Greater than 50m but less than 250m	2
Greater than 250m but less than 1km	1
Greater than 1km	0

Table 7.13: Landfill Gas: Receptors Scoring Matrix 3f

Human Presence	Matrix Score
On site or within 50m of the site boundary	5
Greater than 50m but less than 150m	3
Greater than 150m but less than 250m	1
Greater than 250m	0.5

7.5 Summary of Matrix Scores

Table 7.14 provides a summary of the matrix scores for each of the Source Pathway Receptor matrices discussed in the foregoing sections.

Table 7.14: Tier 3 Matrix Scores

Matrix No.	Category	Score	Max. Score possible
1a	Municipal, <1ha	5	10
1b	Municipal, <1ha	5	10
2a	High Vulnerability	2	3
2b	Productive Fissured Bedrock Groundwater Bodies (Rf and Lm)	3	5
2c	Direct connection to surface water body	2	2
2d	All other Tills (including limestone, sandstone etc. – moderate permeability	1.5	3
2e	All other Tills (including limestone, sandstone etc. – moderate permeability	2	5
3a	On or within 50m of the waste body	3	3
3b	Greater than 1km of the waste body	0	3
3c	Poor Aquifers (Pl, Pu)	1	5
3d	Greater than 1km (karst aquifer)	3	7
3e	Within 50m of the site boundary	3	3
3f	On site or within 50m of the site boundary	5	5

7.6 Revised SPR Linkages

The results from Matrix 1a through Matrix 3f have been used to calculate the respective Source-Pathway-Receptor (SPR) linkages using the equations from Figure 9 to Figure 12 of the CoP. The revised Tier 3 results of the SPR linkage calculations are summarised in **Table 7.15**.

From this it can be seen that the landfill gas linkages SPR 10 and SPR 11 have been downgraded from Moderate – Class B to Low – Class C. This is due to the low flow rate of landfill gas measured on-site and is supported by the low CS2 categorisation of the site for methane and carbon dioxide, the principal gases present in landfill gas (refer to drawing number in Appendix A

However, SPR 8 Surface Water Body has now increased from Low – Class C to Moderate – Class B. This is due to the fact that there is direct connectivity from the groundwater to the surface waters.

Table 7.15: Updated Risk Category and Prioritisation Class

SPR No.	Equation	SPR Linkage Score	% Score	Risk Classification	Max Score
Leachate migration through combined surface water and groundwater pathways					
SPR1 Surface Water Body	1a x (2a+2b+2c) x 3e 5 x (2+3+2) x 3	105	35%	Low – Class C	300
SPR 2 Protected Area (SWDTE)	1a x (2a+2b+2c) x 3b 5 x (2+3+2) x 0	0	0%	Low – Class C	300
Leachate migration through groundwater pathway					
SPR 3 Human Presence (Private well)	1a x (2a+2b) x 3a 5 x (2+3) x 3	75	31%	Low – Class C	240
SPR 4 Protected Area (GWPTE)	1a x (2a+2b) x 3b 5 x (2+3) x 0	0	0%	Low – Class C	240
SPR 5 Aquifer Category	1a x (2a+2b) x 3c 5 x (2+3) x 1	25	6%	Low – Class C	400
SPR 6 Public Supply (well)	1a x (2a+2b) x 3d 5 x (2+3) x 3	75	13%	Low – Class C	560
SPR 7 Surface Water Body	1a x (2a+2b) x 3e 5 x (2+3) x 3	75	31%	Low – Class C	240
Leachate migration through surface water pathways only					
SPR 8 Surface Water Body	1a x 2c x 3e 5 x 2 x 3	30	50%	Moderate – Class B	60
SPR 9 Protected Area (SWDTE)	1a x 2c x 3b 5 x 2 x 0	0	0%	Low – Class C	60
Landfill gas migration pathways					
SPR 10 Lateral Migration to Human Presence	1b x 2d x 3f 5 x 1.5 x 5	37.5	25%	Low – Class C	150
SPR 11 Vertical Migration to Human Presence	1b x 2e x 3f 5 x 2 x 5	50	20%	Low – Class C	250

7.7 Revised CSM

On the basis of the information presented in the DQRA, and this Tier 2 and Tier 3 risk assessment, the CSM developed in Tier 1 has been updated. The key elements of the CSM for the site include the following:

- Landfilled waste mass (Made Ground and general fill);
- Quaternary deposits;
- Bedrock of the Skerries Formation;
- Groundwater;
- Surface waters including the surface water stream culverted on-site and the Barnageeragh stream; and
- Proximity of human receptors (residents, workers and future users).

The principal contaminants identified by laboratory analysis as being present within the waste body that are of concern are summarised in **Table 7.16**.

Table 7.16: Summary of Sources of Contamination

Area	Source	Principal Contaminants of Concern	Comment
Waste Body including C&D and municipal waste.	Leachate to groundwater	Inorganic and general parameters that include Ammoniacal Nitrogen, Chloride, Sulphate, potassium, sodium, calcium and magnesium. Heavy Metals that include Fe, Mn, Hg, Ba and BO.	Water quality data is indicative of the degradation of waste material and leachate generation. There are a number of exceedances of GACs, most notably ammonia.
	Leachate to surface waters	Total suspended solids, ammoniacal nitrogen, fluoride, Iron, COD, and coliforms.	Water quality data is indicative of agricultural setting with the quality of water impacted both upgradient and downgradient of the waste body. However, a pathway exists from the groundwater to surface waters.
	Landfill gas	Methane (CH_4) Carbon Dioxide (CO_2) Hydrogen Sulphide (H_2S) VOCs	The site has an overall CS2 hazard (low risk) based on the flow rates of methane and carbon dioxide. Similarly, very low levels of H_2S and VOCs were detected.
	Soil	TPH, zinc sulphate, lead chromate.	The majority of the soil samples returned a waste classification of non-hazardous. However, hazardous waste was encountered in 10 soil samples. The waste with the hazardous properties is buried under Made Ground and clean soil. Leachate from the waste body is contaminating groundwater.

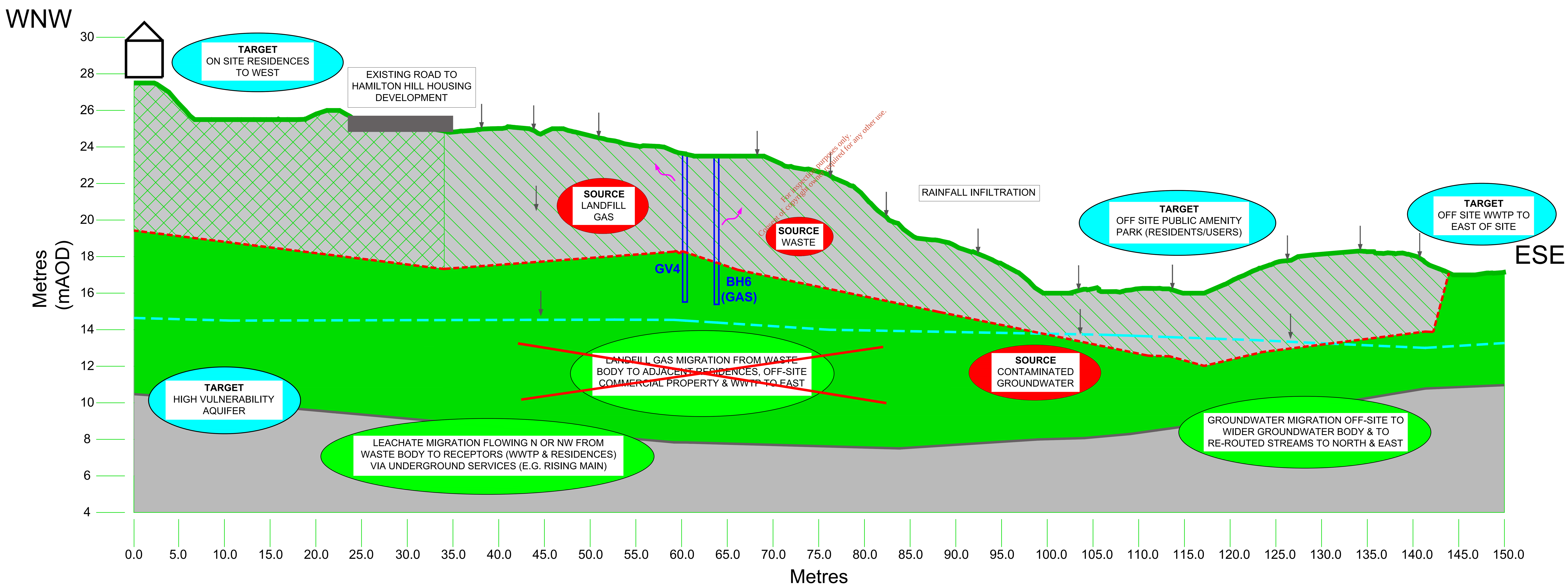
The revised CSM for the site is illustrated in **Figure 7.1**. This CSM does not include mitigation measures. The overall conclusion is that the site poses a low risk for all SPR linkages except SPR 8 Surface Water Bodies which has increased to a Moderate – Class B risk.

Remediation is therefore deemed necessary in order to reduce the environmental risk for SPR 8 Surface Water Body. The post-remediation CSM is presented in **Figure 7.2**. This demonstrates how the fully engineered landfill cap will remove the pathway for SPR 8, that is, stop the infiltration of rainwater through the waste body generating leachate which can then migrate through the groundwater to surface water bodies.

LEGEND:

- SOURCE — SOURCE
- PATHWAY — PATHWAY
- TARGET — TARGET
- EXISTING GROUND
- BEDROCK
- TYPE 1 WASTE
- TYPE 2 WASTE
- SOIL FILL (1m DEEP)
- BARRIER LAYER
- EXTENT OF WASTE
- GROUNDWATER LEVEL
- RECHARGE/INFILTRATION
- GAS MOVEMENT

Site Plan (Scale 1:1000)



Conceptual Site Model without Mitigation Measures (Not to scale)

Client: Comhairle Contae Fhine Gall / Fingal County Council

General Notes

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Rev	Date	Drn Chk	Amendment / Issue	App
F01	21.07.20	DN GMcE	FINAL ISSUE	GMcE

Scale: AS SHOWN @ A1, AS SHOWN @ A3

Created on: 15/07/2020

Sheets: 01 of 02

Project: BARNAGEERAGH HISTORIC LANDFILL TIER 2 AND TIER 3

Title: BARNAGEERAGH HISTORICAL LANDFILL FIGURE 7.1 CONCEPTUAL SITE MODEL WITHOUT MITIGATION MEASURES

Model File Identifier: MGE0755-RPS-00-XX-DR-C-DG0005

File Identifier: MGE0755-RPS-00-XX-DR-C-DG0005-01

Status: S0

Rev: F01

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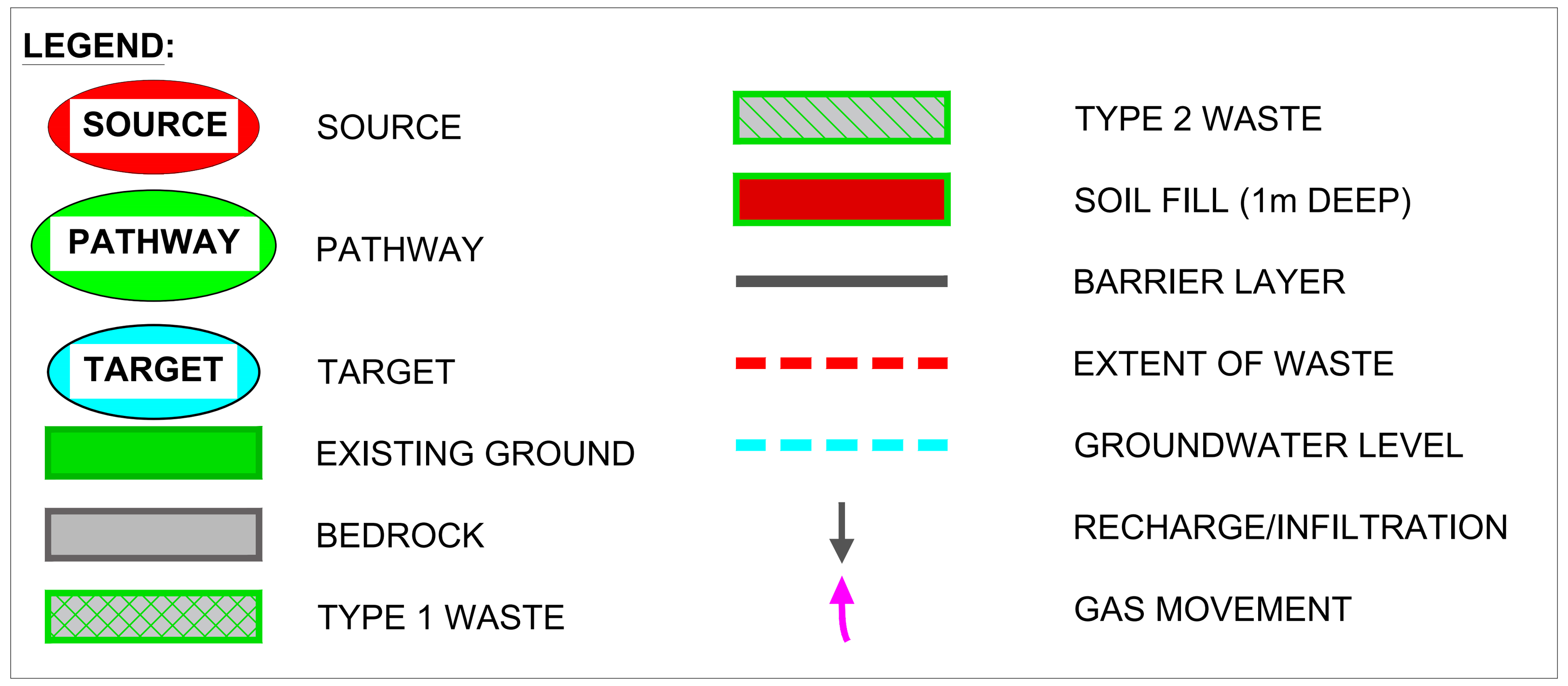
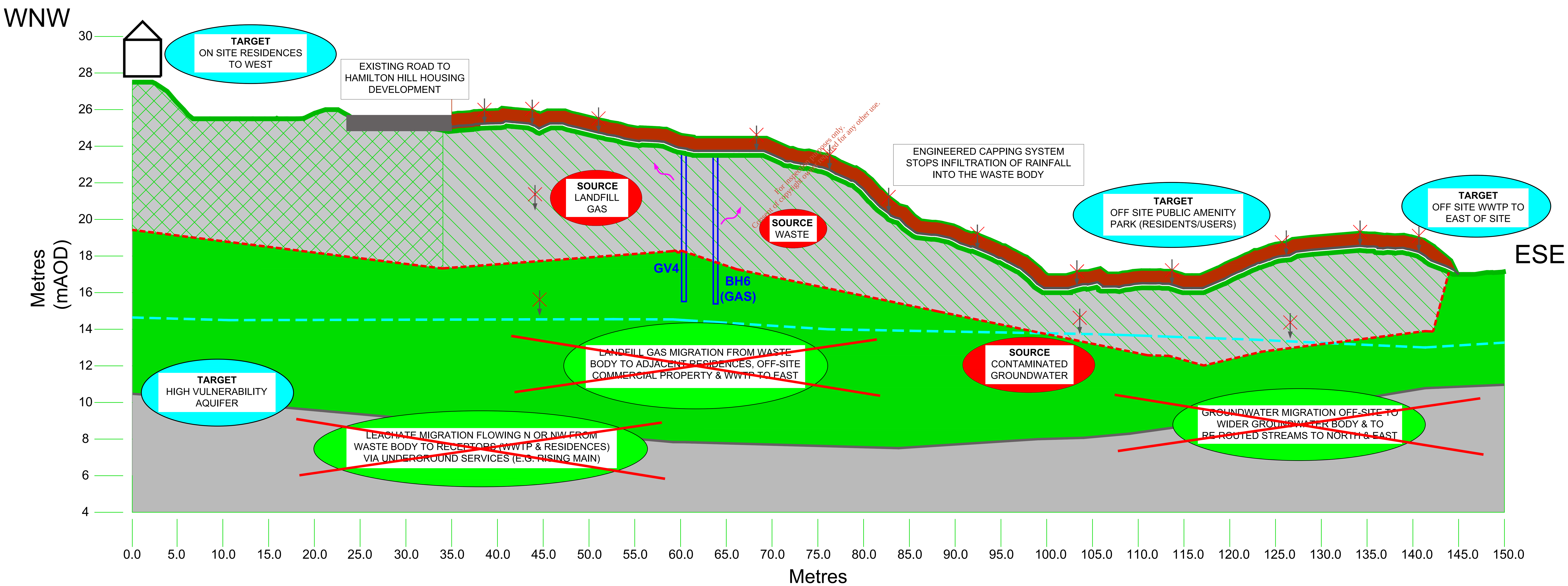


Site Plan (Scale 1:1000)



Conceptual Site Model with Mitigation Measures (Not to scale)

Client

Comhairle Contae Fhine Gall
Fingal County Council

General Notes

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Rev	Date	Drn Chk	Amendment / Issue	App
F01	21.07.20	DN GMcE	FINAL ISSUE	GMcE

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Scale	AS SHOWN @ A1 / AS SHOWN @ A3
Created on	16/07/2020
Sheets	02 of 02
Project	BARNAGEERAGH HISTORIC LANDFILL TIER 2 AND TIER 3
Title	BARNAGEERAGH HISTORICAL LANDFILL FIGURE 7.2 CONCEPTUAL SITE MODEL WITH MITIGATION MEASURES
Model File Identifier	MGE0755-RPS-00-XX-DR-C-DG0005
File Identifier	MGE0755-RPS-00-XX-DR-C-DG0005-02
Status	S0
Rev	F01

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8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

A detailed site investigation, monitoring programme and associated risk assessment have been delivered for the assessment site located at Barnageeragh, Skerries, Co. Dublin. These works have significantly enhanced the understanding of the site in terms of its ground model, hydrogeology and contamination status. This in turn has enabled the risk to key receptors (humans and controlled water) to be evaluated and the CSM to be updated.

The site investigations and the analysis of the data have revealed a ground model that typically comprises a surface horizon of Made Ground and general Fill material, above Sand and Gravel deposits that conceals the bedrock of the Skerries Formation at depth. The continuity of these granular deposits represents a potentially important pathway for the movement of groundwater principally where situated beneath the Made Ground. The bedrock is characterised of competent bedrock with an upper weathered horizon of at the eastern boundary of the site, coinciding with a higher transmissivity zone which is considered a potential preferential pathway for contaminant migration off site. Flow in the deeper bedrock aquifer is likely to be influenced by a more regional discharge path discharging to the coast.

Contamination of groundwater has been identified with the most significant contamination occurring under the main waste mass in the southern portion of the site.

The soil and groundwater data for areas impacted by landfilling indicate that contaminants of concern relevant to site include:

- Ammoniacal nitrogen and chloride;
- Heavy metals that include arsenic, mercury and lead; and
- Microbial contamination.

The works have confirmed that the groundwater beneath the mass of the waste body at the south is the most contaminated area of the site. The groundwater quality is characterised by elevated concentrations of key inorganic parameters (ammonia, nitrite, chloride, sulphate, potassium, sodium, calcium and magnesium), the presence of metals at elevated concentrations including mercury and selenium, and the general absence of organic compounds. The area to the north of the waste mass is generally characterised by the presence of the same suite of site-specific contaminants of concern, albeit at substantially lower concentrations.

The analysis has shown that there is direct connectivity, and therefore a pathway, between groundwater and surface water. This direct connectivity has resulted in an updating of the risk assessment for surface waters from low risk to moderate risk.

Landfill gases (in the form of methane and carbon dioxide) at the site are present in concentrations above GSV levels. However, the flow rate of these gases as measured in the boreholes and taking the worst case scenario has shown that these pose a low to very low risk.

8.2 Recommendations

To break the pathway between the infiltrating recharge (which infiltrates the waste body, dissolving contaminants and continues to infiltrate vertically through the subsoil until it reaches the groundwater table) and the source contaminants the modelling of key contaminants carried out by HUCT (see Appendix 12 of the DQRA) an engineered landfill capping system must be installed over the waste body.

8.3 Area-Specific Recommendations

8.3.1 Area 1: Main Waste Area

The site is considered to pose a low to very low risk to human receptors. However, a moderate risk exists for surface waters as a result of connectivity to groundwater. An engineered landfill cap, to include a low permeability barrier, is considered necessary in order to prevent the leaching of contaminants of concern (COC) from the waste body into the groundwater and thereby into adjacent surface water bodies. The low permeability barrier will also provide a barrier to landfill gas emissions. These measures, combined with other surface water, landfill gas and landscaping management measures will ensure that the environmental risk posed by the landfill is reduced significantly. The most appropriate engineered capping system is the non-hazardous landfill capping system as recommended in Chapter 10 of the EPA Landfill Site Design manual, 2000. The landfill capping system shall comprise the following:

- Regrading of the site is required in order to provide safe slopes on which to construct the landfill capping system and also for future use of the land. It is recommended that side slopes be regraded to a 1 in 3 slope where possible. In certain areas it may not be possible to achieve this grading (e.g. along the slopes adjacent to the railway line and overlying the rising main sewer) and consideration should be given to fencing this area to prevent the public accessing these slopes. The site shall be mounded to ensure surface water run-off is achieved with no flat spots.

- Regulation layer – a 300mm regulation layer shall be placed over the waste body to provide a smooth and safe surface on which the landfill capping layers can be placed.

- Gas drainage layer – this is not considered absolutely necessary given the very low level of landfill gas encountered on the site. However, it has been decided that a gas drainage geocomposite will be installed to provide a protective layer between the regulation layer and the LLDPE liner. This also ensures compliance with the suggested non-hazardous landfill capping system as set out in the Landfill Site Design Manual (EPA, 2000). A network of passive gas vents should be installed to extract landfill gas from areas identified as having high concentrations of methane and carbon dioxide.

- Low permeability barrier layer (permeability to be less than or equal to 1 x 10^{-9} m/s). It is recommended that the low permeability layer be a geomembrane, e.g. 1mm LLDPE (textured LLDPE for areas with a slope of greater than or equal to 10 degrees, smooth LLDPE for areas with a slope less than 10 degrees). Not only will this achieve the required permeability, it will also act as a marker layer to denote the separation of the clean subsoil and the waste body.

- Surface water drainage geocomposite to intercept surface water and direct the clean flow to surface water drains to be constructed around the perimeter of the landfill.

- A surface water drain shall be constructed around the perimeter of the capped landfill area to collect surface water and discharge it to the surface water drain along the eastern boundary of the site.

- A minimum of one metre thick soil layer comprising 850mm of clean subsoil overlain by 150mm clean topsoil. The materials to be imported should be either virgin soil or equivalent, or by-product soil so determined by the EPA. Where trees are likely to be planted in the soil layer, a minimum of 1.5m of soil shall be placed to prevent damage to the geomembrane.

- The topsoil shall be landscaped as required.

- In the area surrounding BH4 and BH9, the DQRA proposes that a biowindow/ passive venting area be constructed to oxidise the landfill gases. No LLDPE liner is to be constructed over this area. It is recommended that this option be given further consideration during the detailed design phase of the remediation of the site, especially with regard to the intended future use and users of the area.

As an alternative solution, consideration should be given to connecting all locations of high landfill gas concentrations to a network of pipes located underneath the geomembrane. These pipes can then be connected to a passive gas venting area located in a secure and cordoned off area of the site, situated at the furthest point from receptors, i.e. the southern and eastern edges of the waste body. This would limit the number of venting areas and facilitate maintenance of one area only.

8.3.2 Area 2: Residential and Grass Area

The residential and grass area is at very low risk. An impermeable barrier has been constructed over part of this area with the construction of the access road and pavement. In terms of remediation, it is not considered necessary to construct a landfill cap over this area.

8.3.3 Timeframe for Remediation

The developer, Winsac, commenced regrading works on-site in Q3 2020. This work has provided the surface over which the landfill capping system will be constructed.

It is proposed that the engineered landfill capping works will commence in August 2020 and be completed within 16 weeks.

8.3.4 Aftercare Monitoring

It is recommended that the following monitoring regime be implemented post-restoration of the landfill.

Table 8.1: Recommended Post-restoration Monitoring

Item	Frequency	Location	Parameters
Surface Water	Quarterly	SW1 (upstream) and SW3 (downstream)	Temperature, pH, electrical conductivity, total organic carbon, dissolved oxygen, ammonia, total oxidised nitrogen, total alkalinity, sulphate, chloride, cyanide, fluoride, calcium, magnesium, sodium, potassium, iron, manganese, cadmium, chromium, copper, nickel, lead, zinc, arsenic, boron, mercury and total petroleum hydrocarbons & BTEX
Groundwater	Quarterly	BH 2 (upgradient) and BH10, BH11, BH12, BH15 and BH17 (downgradient).	Groundwater level, temperature, pH, electrical conductivity, ammonia, total oxidised nitrogen, total organic carbon, calcium, magnesium, sodium, potassium, iron, manganese, cadmium, chromium, copper, nickel, lead, zinc, arsenic, boron, mercury, total alkalinity, sulphate, chloride, cyanide, fluoride, F. Coliforms, T. Coliforms, total petroleum hydrocarbons & BTEX.
Landfill Gas	Biannual	GS01, GS02, GS03, GS04, BH 1, BH4, BH7, BH12, BH14, BH16 and BH17.	Flow rate, methane, carbon dioxide, oxygen, carbon monoxide, hydrogen sulphide, atmospheric pressure, temperature
Visual assessment	Annually		A visual inspection of the landfill to ensure that the condition of the landfill has not deteriorated. This shall include slope stability where slopes are greater than 1V : 3H.

It is recommended that the above regime be re-assessed after two years following evaluation of the monitoring results.

9 REFERENCES

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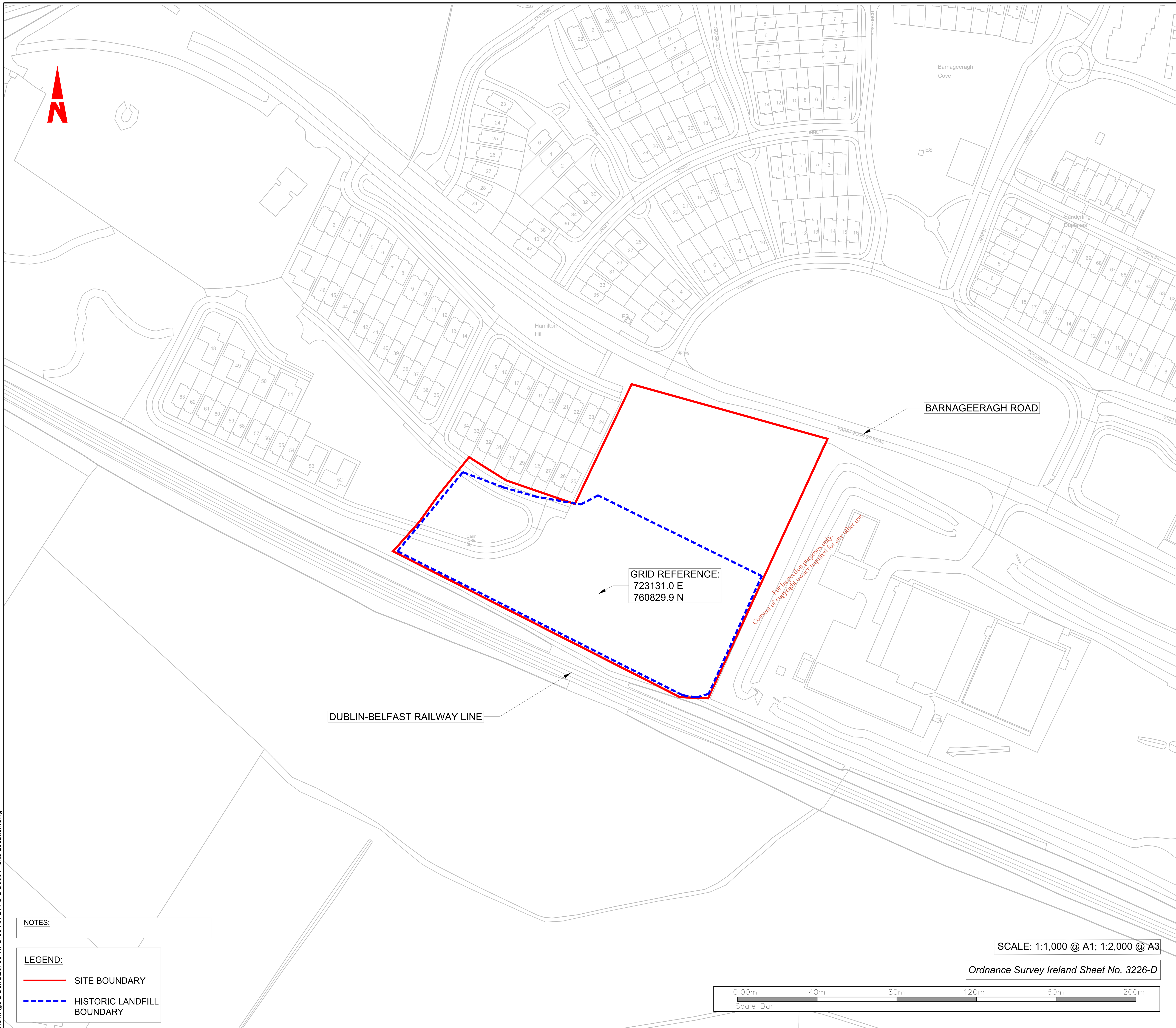
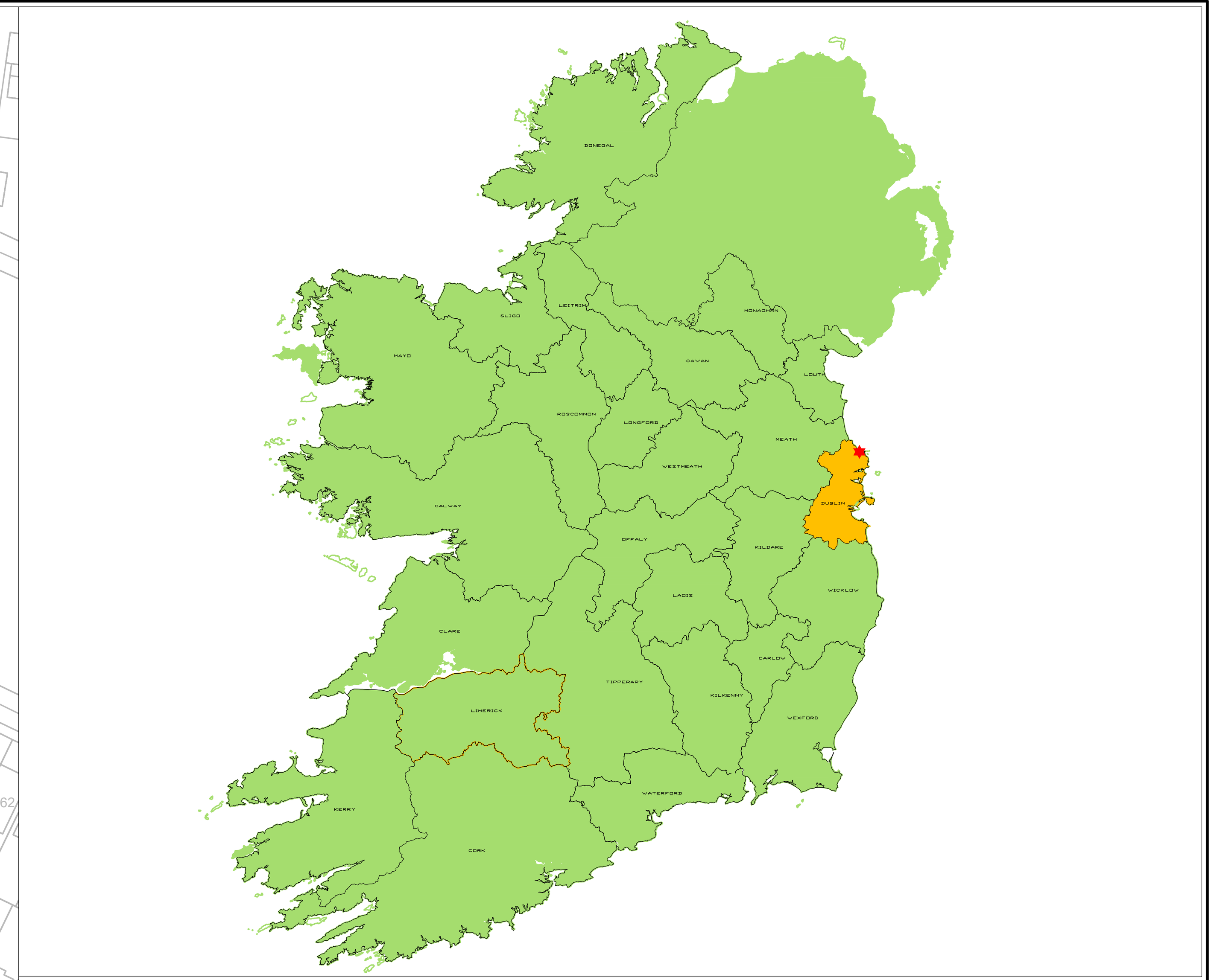
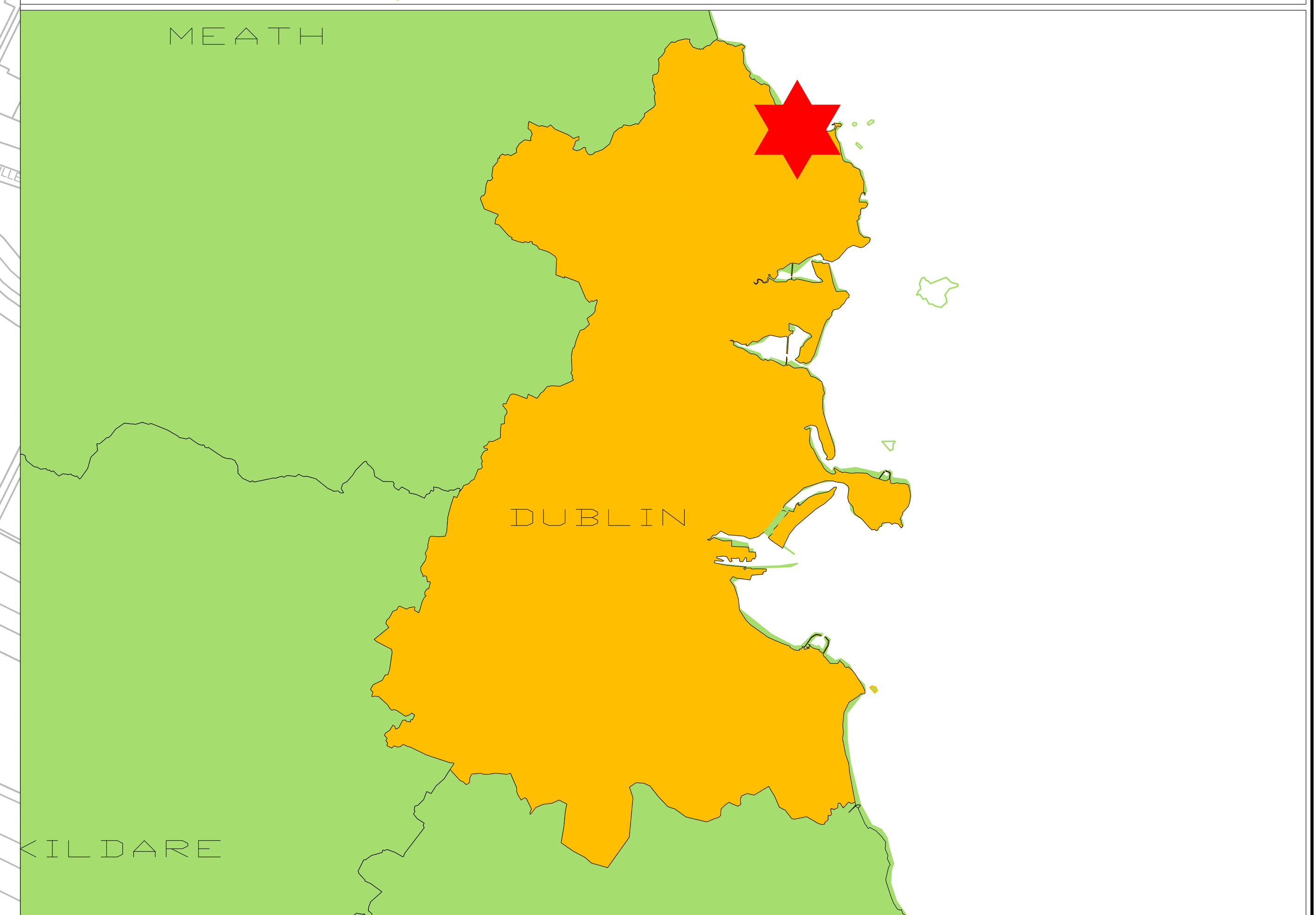
Appendix A Drawings







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D01	20.11.19	DN / GMcE	Issue for Approval	GMcE

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Scale: AS SHOWN @ A1; AS SHOWN @ A3

Created on: 21/10/2019

Sheets: 01 of 02

Project: BARNAGEERAGH HISTORIC LANDFILL TIER 2 AND TIER 3

Title: BARNAGEERAGH HISTORICAL LANDFILL SITE LOCATION MAP

Model File Identifier: MGE0755-RPS-00-XX-DR-C-DG0001

File Identifier: MGE0755-RPS-00-XX-DR-C-DG0001-01

Status: S0

Rev: D01

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Project
BARNAGEERAGH HISTORIC LANDFILL
TIER 2 AND TIER 3

Title
BARNAGEERAGH HISTORIC LANDFILL
BOREHOLE AND TRIAL PIT LOCATIONS

Model File Identifier
MGE0755-RPS-01-XX-DR-C-DG0002

File Identifier
MGE0755-RPS-01-XX-DR-C-DG0002-01

Created on	Sheets	
21/10/2019	1 of 3	
Scale	**Status**	**Rev**
1:250 @ A1 1:500 @ A3	S0	D01

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LEGEND:

- DEEP GROUNDWATER/GAS WELL
- DEEP GAS WELL
- SHALLOW GAS WELL
- ADDITIONAL MONITORING WELL
- CHARACTERISTIC SITUATION 1
- CHARACTERISTIC SITUATION 2
- OUTLINE OF TYPE 1 WASTE BODY
- OUTLINE OF TYPE 2 WASTE BODY

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Project
BARNAGEERAGH HISTORIC LANDFILL TIER 2 AND TIER 3

Title
BARNAGEERAGH HISTORIC LANDFILL BOREHOLE CHARACTERISTIC SITUATIONS

Model File Identifier
MGE0755-RPS-01-XX-DR-C-DG0002

File Identifier
MGE0755-RPS-01-XX-DR-C-DG0002-02

Created on	Sheets
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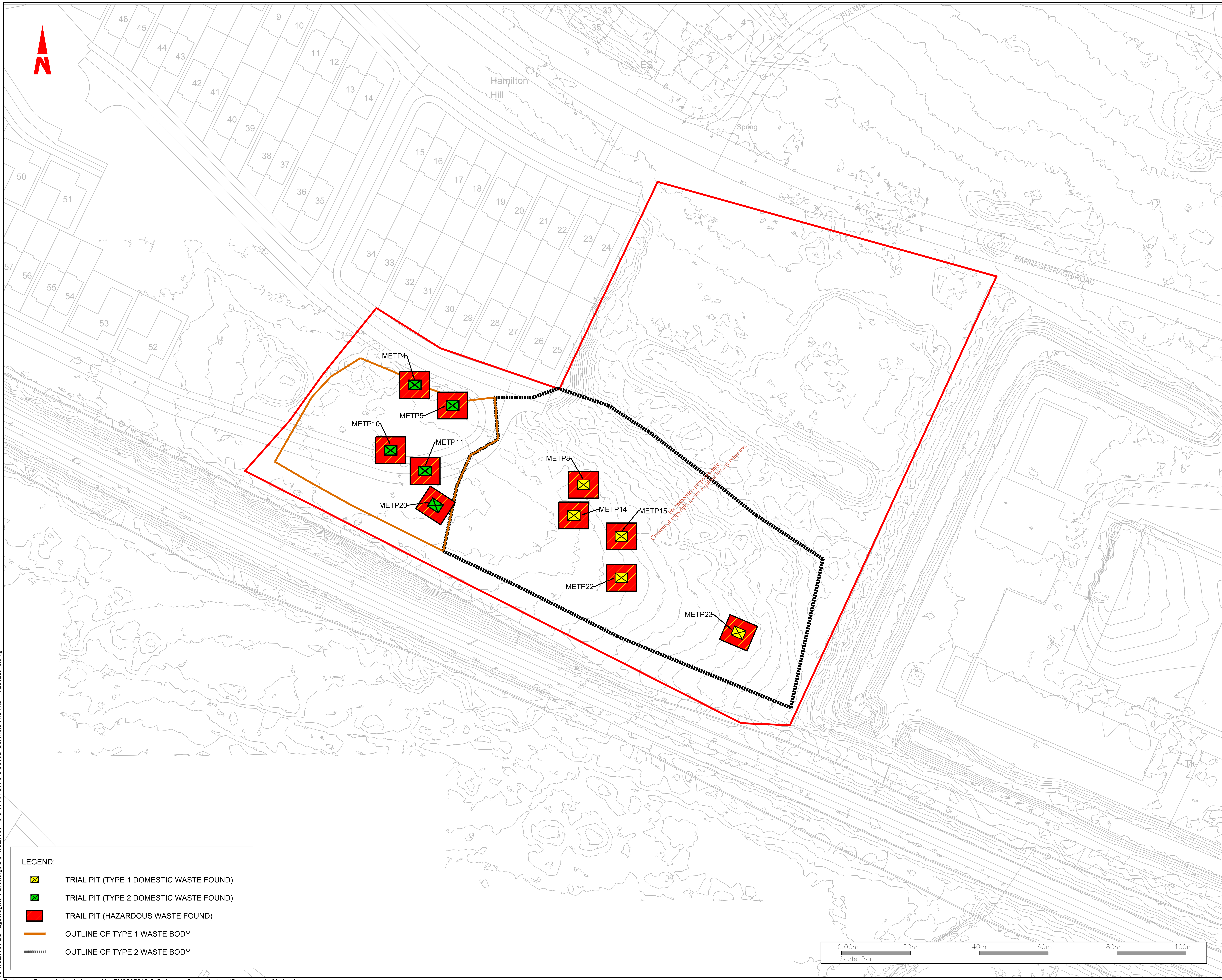

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Project
BARNAGEERAGH HISTORIC LANDFILL TIER 2 AND TIER 3

Title
BARNAGEERAGH HISTORIC LANDFILL HAZARDOUS WASTE TRIAL PIT LOCATIONS

Model File Identifier
MGE0755-RPS-01-XX-DR-C-DG0002

File Identifier
MGE0755-RPS-01-XX-DR-C-DG0002-03

Created on	Sheets	
21/10/2019	3 of 3	
Scale	**Status**	**Rev**
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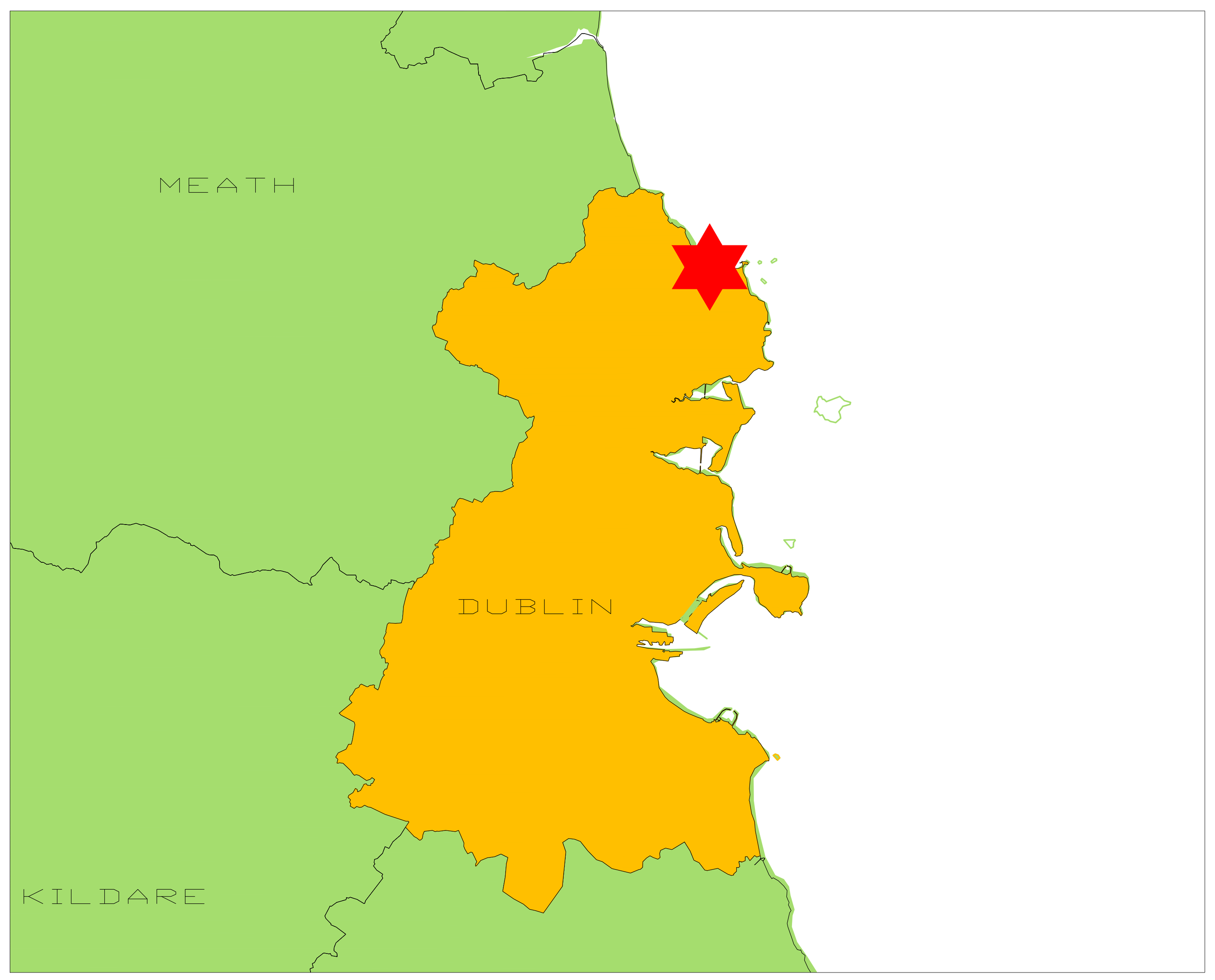
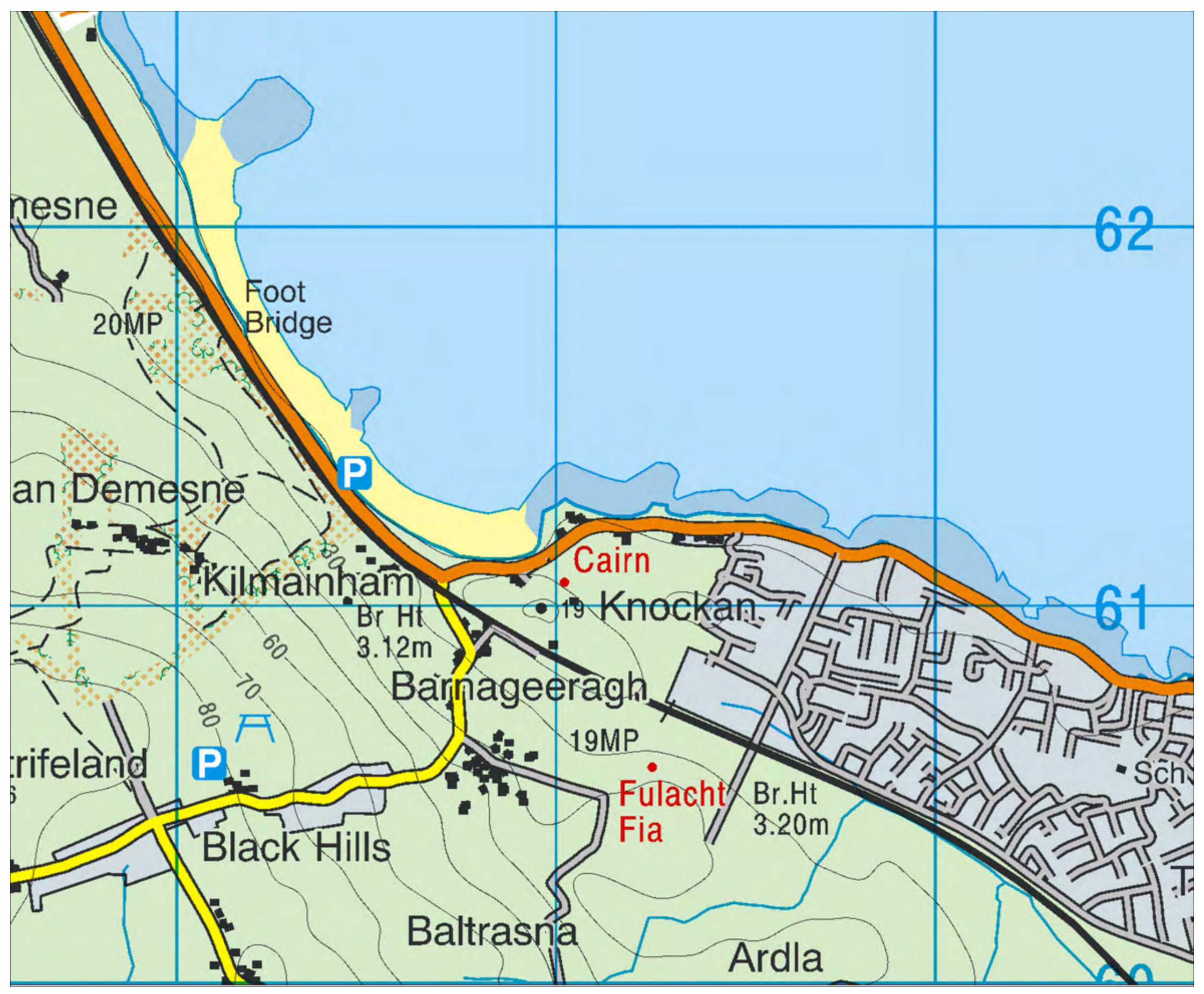
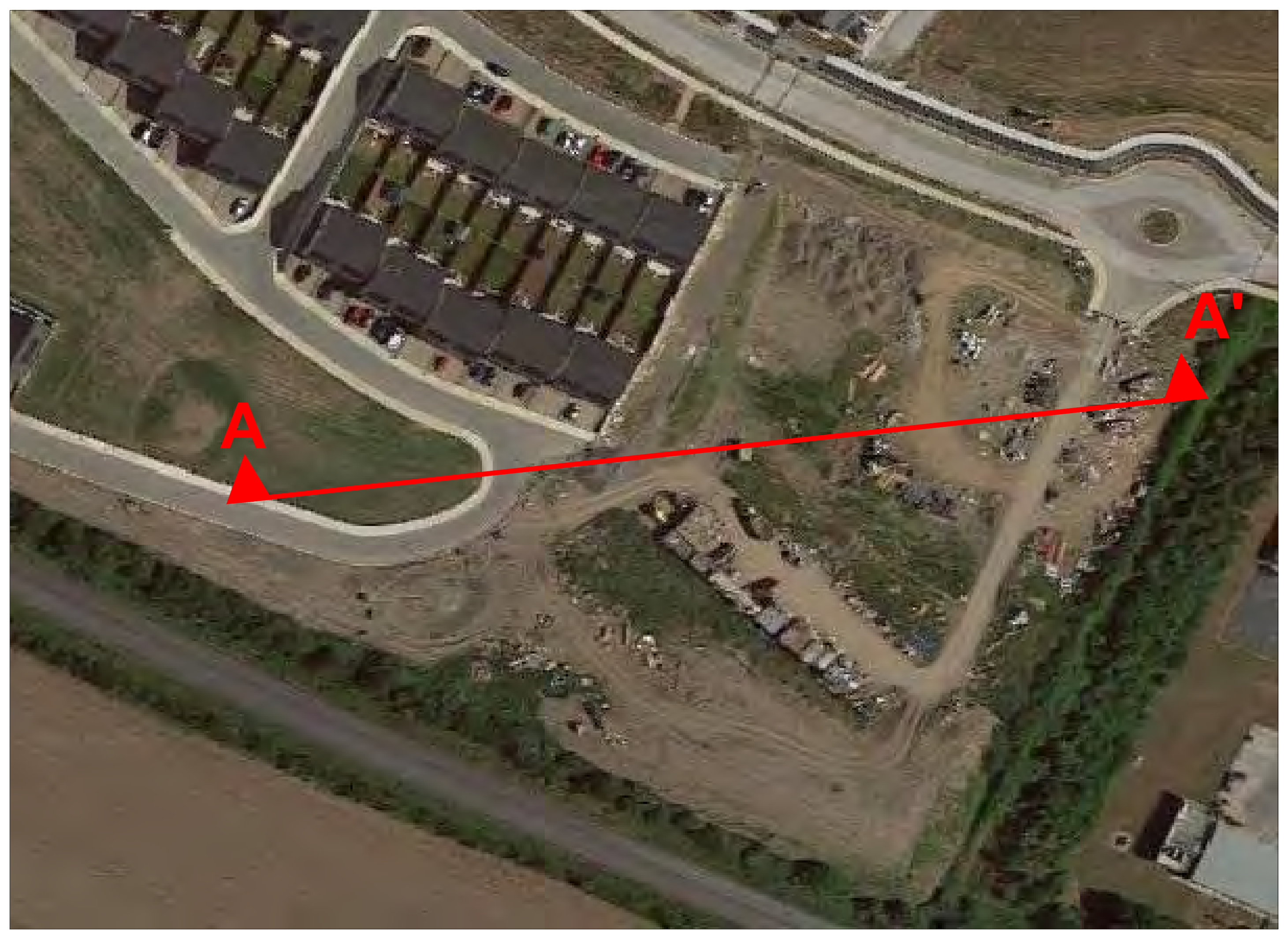
SECTION A-A'







LEGEND:

- MADE GROUND
- FILL MATERIAL
- SAND AND GRAVEL DEPOSITS
- WEATHERED SKERRIES FORMATION SS
- SKERRIES FORMATION SS
- GROUNDWATER LEVEL MAY 2018
- TOPOGRAPHY

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Rev	Date	Drn / Chk	Amendment / Issue	App
P01.01	06/11/19	DN / ND	DRAFT ISSUE	

Model File Identifier: MGE0755-RPS-00-XX-DR-C-DG0003

Scale: NTS @ A1, NTS @ A3
Created on: 06/11/2019
Sheets: 01 of 01

Project: BARNAGEERAGH HISTORIC LANDFILL TIER 2 AND TIER 3

Title: BARNAGEERAGH HISTORICAL LANDFILL GROUNDWATER BOREHOLE CROSS SECTION

File Identifier	Status	Rev
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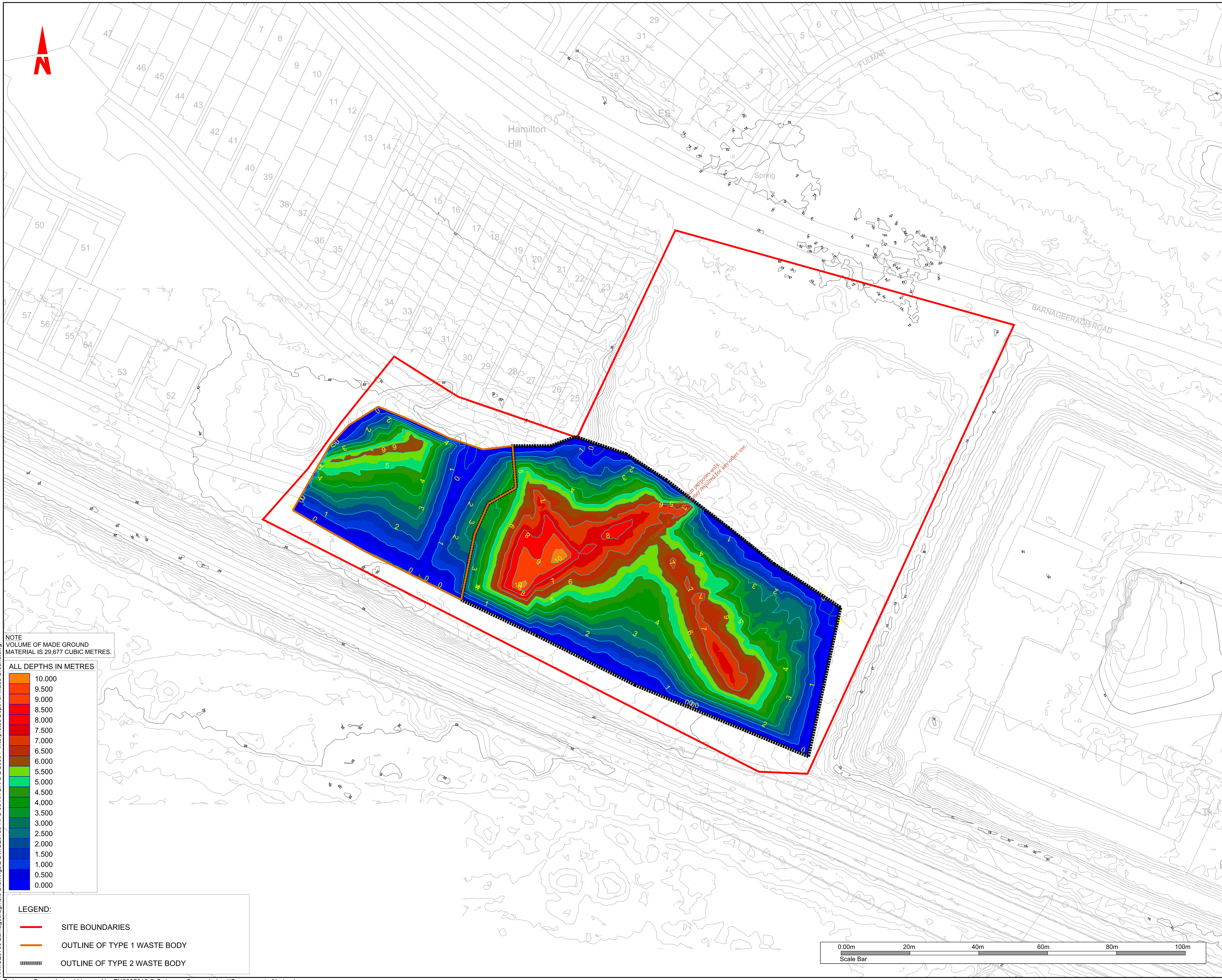

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P01	15/11/19	PH / KG	Work in Progress	GMcE

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Project

BARNAGEERAGH HISTORIC LANDFILL TIER 2 AND TIER 3

Title

BARNAGEERAGH HISTORIC LANDFILL INTERPRETED DEPTH OF MADE GROUND

Model File Identifier

MGE0755-RPS-01-XX-DR-C-DG0004

File Identifier

MGE0755-RPS-01-XX-DR-C-DG0004-01

Created on	Sheets
15/11/19	1 of 1

Scale	Status	Rev
1:250 @ A1 1:500 @ A3	S0	P01

ATTACHMENT D3

Detailed Quantitiative Risk Assessment

ATTACHMENT D3: DETAILED QUANTITATIVE RISK ASSESSMENT

A significant amount of site investigation and analysis of the collected data has been undertaken by the developer of the site, Winsac Ltd. This information is presented in the detailed quantitative risk assessment (DQRA) report prepared on behalf of Winsac Ltd. by Mulroy Environmental Ltd., entitled:

- Winsac Ltd. Residential Development, Barnageeragh Cove, Skerries, Phase II Site Investigation/ DQRA & Landfill Gas Survey, Final Report, 26th February 2019.

There is a large volume (~890 MB and 1,884 pages) of information contained in the DQRA and supporting documents. As such Attachment D3 is being provided in electronic format only. A printed hardcopy of the file can be provided to the EPA on request.