WINSAC LTD.,

RESIDENTIAL DEVELOPMENT,

BARNAGEERAGH COVE, SKERRIES

PHASE II SITE INVESTIGATION/DQRA &

LANDFILL GAS SURVEY

FINAL REPORT

VOLUME I. REPORT TEXT

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EXECUTIVE SUMMARY

Winsac Ltd. are currently constructing a large residential development at Barnageeragh Cove, Skerries, Co. Dublin which commenced in 2008. It is understood that in early May, 2017 that Fingal County Council contacted Winsac Ltd. with regard to the possible presence of an historic landfill in the vicinity of their residential development. It is understood that during groundworks for the development, historic landfilled material was encountered in May, 2017 southwest of Row 3 Hamilton Hill where an access road and pathways were being constructed. Winsac uncovered some builder's rubble (i.e. blocks, timber, tree roots and polythene) which were removed before the construction of the road. Following this, Winsac requested an inspection by their structural engineer following which the ground conditions in the vicinity of the proposed access road were inspected on the 22nd May, 2017. Following the recommendation of our structural engineer, Winsac employed the services of Mulroy Environmental who inspected the site and confirmed the absence of waste material in the footprint of the residences. Following this inspection, an on-site meeting was held with Fingal C.C.'s representatives, RPS Consulting Engineers to discuss a methodology to assess the potential risk posed by the historic landfill from landfill gas and to the underlying aquifer from leachate emanating from the landfill. It was determined that the residential development was adjacent to a former sand and gravel pit which had been used historically as a domestic landfill. Mulroy Environmental Ltd. were contracted by Winsac to carry out a comprehensive site investigation and environmental risk assessment on the historic landfill. The principal objectives of this work was firstly, to assess the potential risks posed to the newly constructed residences and their occupants and secondly, to assess the risk to the underlying aquifer. A comprehensive site investigation involving the excavation of 50 trialpits was carried out. Fourteen groundwater monitoring wells, 3 deep gas monitoring wells and 4 shallow gas monitoring wells were installed on site. Three rounds of groundwater monitoring and 2 rounds of surface water sampling were carried out.

Since July 2017, up to 50 rounds of landfill gas monitoring has been carried out on the existing boreholes to date. Since the 18th September, 2017, 42 rounds of landfill gas monitoring has been carried out on residence services (i.e. radon sump and water meters). Indoor air monitoring of selected residences has also been carried out. The potential risk from landfill gas to residences has been assessed as very low risk in pathway boreholes. However, as an additional precautionary measure, further gas monitoring has been undertaken within the houses and utilities next to the houses where gas may flow along preferential pathways. The monitoring determined that methane was absent or present at trace [1] concentrations within the radon sumps and where the water supply entered the base of the house. Carbon dioxide, which occurs naturally as a result of respiration in soils, was detected at trace concentrations. This data support the findings of the risk assessment and indicated that risks posed by gas from the waste body are low. The indoor air monitoring of the residences identified a number of volatile compounds in air within the houses. However, these compounds were associated with decorating paints, glues and background

[1] ***Trace Detections*** *for the purposes of this section are defined as the detection limit of the instrument x 5. The accuracy of trace detections should not be relied upon, because they may be caused by factors such as background interference by moisture in the gas (the analyser will have been calibrated using dry gas), or instrument drift as the instrument has warmed up or been moved since the latest calibration. These factors will affect portable instruments measuring methane, carbon dioxide, carbon monoxide, hydrogen sulphide and volatile organic compounds by photo ionisation detection (PID).*

vehicle emissions. There was a noticeable odour of paints, varnishes and glues in the houses, and evidence of rubber cement tubes on the ground external to the houses during their construction.

A total of 35 groundwater samples have been taken across three monitoring rounds to date from 14 groundwater monitoring wells. No Volatile Organic Compounds (VOCs) were detected within the groundwater above the method detection limit in any of these samples. The potential pathway of volatilisation from tested groundwater into the houses is therefore incomplete. Only two VOCs, namely vinyl chloride and 1,2-dichloroethene (DCE) were detected in one soil sample. It should be noted that this sample was taken from a trial pit located 51m from the nearest residence. To asses this pathway, the Risk Based Corrective Action model (RBCA) was used to assess whether the soil detections pose any risk to downgradient receptors. The calculated risk from all exposure pathways in the RBCA model was assessed in comparison with a Hazard Index (HI). Anything over a HI of 1 requires further assessment or mitigation. The results of the RBCA model adding up all of the exposure pathways indicated that the HI is over two orders of magnitude lower (i.e., 100 times less, than a HI of 1).

The Hydrogeological Conceptual Model development relates to the identification of two possible groundwater discharge pathways at the site. The main pathway is active during periods of maximum groundwater elevation from October to May. Under this maximum groundwater elevation scenario (i.e. Scenario 1) groundwater flows east beneath the site and discharges to the stream/drain that runs along eastern site boundary. During periods of minimum groundwater elevation, the water table drops below the invert level of the eastern boundary stream/drain and discharge to this surface water feature is no longer possible. Under this minimum groundwater elevation scenario (i.e. Scenario 2) groundwater flows east beneath the site and continues flowing east beneath the boundary stream to eventually discharge to the Barnageeragh Stream to the east of the Irish Water WWTP site. Detailed Quantitative Risk Assessment (DQRA) modelling was carried out to assess the potential impact on groundwater and surface water of Substances of Concern (SOCs) that were detected in the landfill waste at the site. The SOCs modelled were representative of the contaminant groups present in the waste and comprised of DCE, ammonia, arsenic, benzo(a)pyrene, chloride, lead, mercury, naphthalene, phenol, decane and hexadecane. The DQRA model predicts that ammonia, chloride, arsenic, DCE, and naphthalene occur at slightly elevated above background concentrations in the groundwater at the downgradient site boundary and at the surface water receptors over varying timescales. The DQRA predicts that following the installation of an engineered cap at the site, there will be exceedances of EQS criteria for chloride, ammonia, arsenic, mercury, c1,2-Dichloroethene and naphthalene. There is no significant environmental impact associated with the predicted exceedances. The contaminant concentrations of groundwater at the downgradient receptors are predicted to be mitigated such that the contaminant concentrations do not result in breaches of the Groundwater and Surface Water Regulations. Based on the interpretation of all the available site data and on the outcome of the detailed groundwater quantitative risk assessment, the installation of the engineered cap is considered the best remedial option for the site and it is considered that this strategy will have no significant impact on the groundwater or surface water receptors downgradient of the site.

It should be noted that the water quality in the surface water on-site indicates that ammonia in groundwater baseflow to the site boundary stream may rapidly oxidise to nitrate. Considering this and the significant dilution

available within the Irish Sea, the impact to the 2 surface water bodies and the Irish Sea is considered to be negligible.

It is recommended that the landfill body should be capped with a suitable capping material. AGL Consulting Engineers have recommended a design of 1.0mm LLDPE geomembrane liner ($k < 1x10^{-9}$m/s), an overlying geocomposite drainage layer ($k > 1x10^{-4}$m/s) and 1.0m of cover soil comprised of 0.85m of subsoil and 0.15m of topsoil. This will reduce the penetration of precipitation through the existing waste body thus reducing the quantity of leachate produced. The principle function of the engineered landfill cap is to mitigate the potential for elevated concentrations of ammonia, chloride, arsenic, DCE, and naphthalene to occur at downgradient receptors due to contaminant migration from the waste. It is recommended that an uncapped landscaped biocover/venting area is maintained in the vicinity of BH4 where 3 passive gas venting wells are located. The purpose of this feature is to allow any residual methane in the vicinity of BH4 to vent to the atmosphere. It is recommended that 1-2 passive gas venting wells are constructed in the vicinity of BH17.

The existing passive gas venting wells should receive occasional maintenance to ensure that the cowls rotate with minimal wind speed. This is to ensure that the decrease in methane levels continues. In order to confirm that landfill gas generation is continuing to decrease over time following the introduction of the biocover/venting zone near BH4 and the passive gas venting wells, landfill gas monitoring of the existing wells, residences and services should be carried out on a monthly basis.

In order to confirm that groundwater quality is improving over time, groundwater monitoring should be carried out on selected wells on a quarterly basis. Further surface water monitoring should be carried out on both streams during high and low groundwater conditions to determine the effect of the groundwater on surface water quality.

It is proposed that both the historic landfill and the greenfield site immediately to the north of the site (i.e. site formerly proposed for petrol retail station development) are landscaped and made suitable as an open space/public park amenity for the benefit of the residents of Barnageeragh Cove (i.e. following the installation of the cap, biocover/venting areas and passive gas venting wells on the historic landfill to the south).

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1 INTRODUCTION

1.1 Project Background

Winsac Ltd. are currently constructing a large residential development at Barnageeragh Cove, Skerries, Co. Dublin (see site location in Figure 1 and existing site layouts in Figures 2 and 3). It is understood that the construction of the Barnageeragh residential development commenced with the initial phase of residences in 2008. Winsac Ltd. are currently completing a 63-house phase of the development, Hamilton Hill, which is located immediately to the east of the Dublin-Belfast Railway line and immediately to the northwest of the Skerries/Balbriggan Wastewater Treatment Plant (WWTP). The Skerries Point Shopping Centre located in the Kelly's Bay area to the east of the WWTP. An 'Educate Together' Primary School is located approximately 260m to the northeast of the development (see Figures 1-3).

It is understood that in early May, 2017 that Fingal County Council contacted Winsac Ltd. with regard to the possible presence of an historic landfill in the vicinity of their residential development. It is understood that during groundworks for the development, historic landfilled material was encountered in May, 2017 southwest of Row 3 Hamilton Hill where an access road and pathways were being constructed. Winsac uncovered some builder's rubble (i.e. blocks, timber, tree roots and polythene) which were removed before the construction of the road. Following this, Winsac requested an inspection by their structural engineer following which the ground conditions in the vicinity of the proposed access road were inspected on the 22nd May, 2017. Following the recommendation of their structural engineer, Winsac employed the services of Mulroy Environmental. On the 23rd May, 2017, Padraic Mulroy of Mulroy Environmental met on site with Malachy Clarke, Managing Director of Winsac Ltd., inspected the site and confirmed the absence of waste material in the footprint of the residences. Following this inspection, an on-site meeting was held with Fingal C.C.'s representatives, RPS Consulting Engineers to discuss a methodology to assess the potential risk posed by the historic landfill from landfill gas and to the underlying aquifer from leachate emanating from the landfill.

Plate 1. Photograph of historic landfill on 21/08/18 taken from southern boundary facing northwards with Dublin-Belfast railway line to the west, builders compound to its east and existing Hamilton Hill housing development to the northwest

It was determined that the residential development was adjacent to a former sand and gravel pit which had been used historically as a domestic landfill. Mulroy Environmental Ltd. were contracted by Winsac to carry out a comprehensive site investigation and environmental risk assessment on the historic landfill.

It was understood that a 0.58-hectare area of land to the northeast of the landfill area and current builder's compound was designated for the location of a commercial/petrol retail development and that a planning application was submitted for this development in 2017. It was understood that the application for the development was withdrawn. On the 24th May, 2017, Padraic Mulroy and Patrick McCabe of Mulroy Environmental carried out a site walkover and an aerial drone survey of the site in order to determine the footprint of the area required for investigation and to determine suitable locations for the installation of groundwater/gas monitoring boreholes and the excavation of trialpits.

1.2 Site History – Sand & Gravel Extraction

A comprehensive review of aerial photography and Ordnance Survey historical mapping has been carried out with both publically (i.e. web-based) digital mapping assessed and mapping archives visited in the Ordnance Survey, Phoenix Park. The principle purpose of this exercise was to determine when sand and gravel quarrying had commenced on site to determine if possible the relative extent of the sand and gravel pit (i.e. and possibly the extent of the landfill's footprint). A review of Ordnance Survey historical 6-inch mapping shows the position of the cairn (i.e. national monument record DU005:0017001) to the northwest of the subject site (see Plate 2 below). At the time of surveying (i.e. 1837-1842), there was some evidence of possible sand and gravel extraction to the northeast of the subject area.

Plate 2. 6-inch OS Mapping (1837-1842) showing position of Cairn and possible evidence of sand and gravel pit to east

Please see Figure 4 which indicates the actual footprint of the waste body on historical OS 6-inch mapping which was revised from 1909 to 1939. This mapping clearly shows a roadway leading to a rectangular area which was most likely the starting footprint for sand and gravel extraction in the area.

Figure 5 indicates the actual footprint of the waste body on historical OS 25-inch mapping which was revised from 1974 to 1987. This mapping shows the continuation of the roadway but also areas to the north of the site which are sloping and possibly areas for stockpiling of soil. It should also be noted that the mapping indicates that another sand and gravel pit had commenced operation to the northwest of the development area. It should be noted that this area has since been developed as a football field by Winsac Ltd. for the benefits of the residents of Barnageeragh Cove. An area to the south of the football pitch is currently being used for the storage of topsoil which is used for landscaping within the development.

A comprehensive review of available modern and historical aerial photography was carried out by RPS Consulting Engineers. This report is available in Appendix 1.

It should be noted that the earliest aerial photography available for the site is black and white photography from 1995 (see Plate 3 below). This photography pre-dates the construction of the wastewater treatment plant. The plate below illustrates a black and white aerial photograph of the site in 1995. It should be noted that 2nd afore-mentioned sand and gravel pit is visible from this photograph approximately 200m to the west.

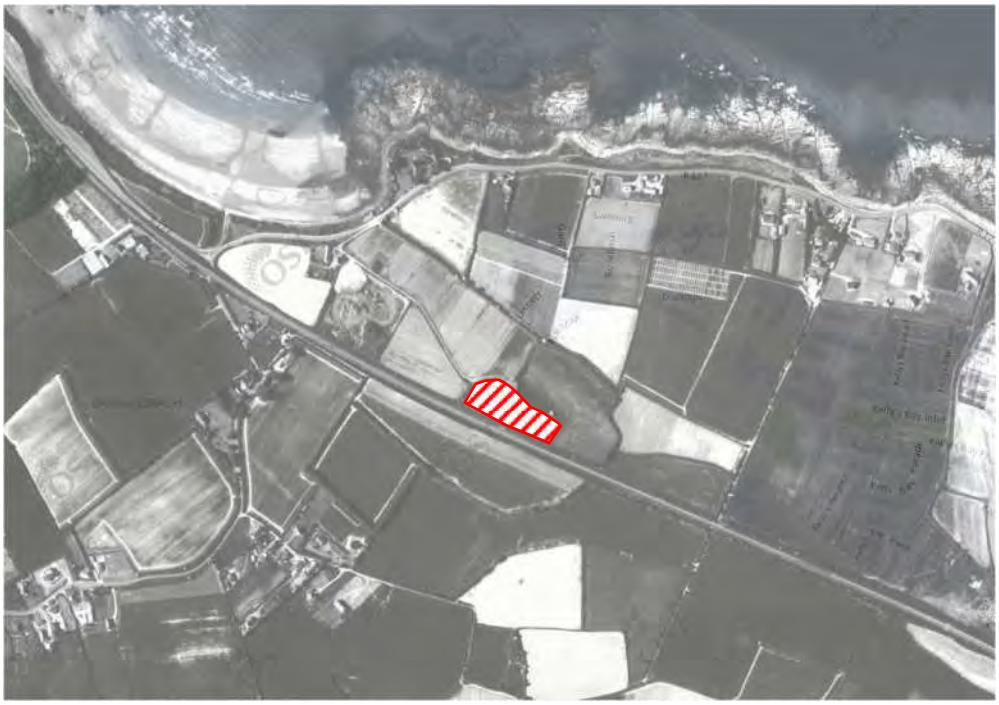

Plate 3. 1995 OS aerial photography with red boundary showing possible extent of former of sand and gravel pit to east. The sand and gravel pit to the northwest of the site is clearly visible.

1.3 Site History – Municipal Waste Landfilling

At some point in the 1950s, it is understood that the landfilling of the sand and gravel pit with local authority domestic waste commenced. It is understood that an inventory of historical municipal landfills was carried out in 1988 by Dublin City Council (see extract in Appendix 3). An extract of this inventory is presented in Plate 4 below:

5. Barnageera Map Ref. 333✓
Situated about 2¼km. North west of Skerries, on the northern side of the railway, this site became available to the Council in 1954, but most of the tipping occured between 1963 and 1983. It is believed that trade waste as well as domestic refuse was tipped here.

Plate 4. Extract of Dublin City Council 1988 report on historical landfills.

However, following consultation with the former land owner, John Ellis, it is understood that waste was not landfilled on site after 1977. During the trialpitting exercise carried out by Mulroy Environmental on the 2nd June, 2017, it should be noted that a newspaper dating from 1975 was found in trialpit, TP2 (see Plate 5 below).

Plate 5. Newspaper found in trialpit, TP2 excavated as part of the site investigation works.

An 'Environmental Risk Assessment for Unregulated Waste Disposal Site' Walkover Survey was carried out by Fingal C.C. on the landfill body in 2009 and a short summary report prepared (see Appendix 1). This report states the following:

'The site is classified as LA1 - a historic unregulated waste disposal site (closed landfills) operated by a Local Authority without a waste licence under the Act in the period between 15th July 1977 and prior to coming into operation of the Waste Management Licensing Regulations, 1997.'

It is understood from this Fingal C.C. report that the EPA have designated a Certificate of Registration Number of H0197-01 for the site and a Site Registration Number of S22-02655. Mulroy Environmental have carried out a review of the EPA website Historical Landfill Certificate of Registration application database. There is no information available for public viewing on the afore-mentioned database with regard to the subject site. As part of this work, the site was visited on the 30th July, 2009 by Fingal C.C. staff and the site was inspected from the outside (i.e. it was enclosed by palisade fencing) with photographs taken. It was stated that the site was overgrown with vegetation at the time of inspection. Five photographs were taken of the site from the eastern boundary of the site (i.e. from the WWTP) (see Appendix 1).

1.4 Site History – Site Investigation Works for Construction of Wastewater Treatment Plant

1.4.1 Site Investigation by Site Investigations Ireland

Mulroy Environmental requested any information from Fingal C.C. that may have been available on any site investigation works that had been carried out on site or in the vicinity of the site on behalf of Fingal C.C. as part of the WWTP development works located to the southeast of the site (see Figure 3). It should be noted that as part of the WWTP works a 600mm rising foul sewer main was constructed to transfer sewage from Balbriggan to the newly constructed WWTP (see location in Figure 6). It is understood that the afore-mentioned 600mm foul water rising main, which runs parallel to the Dublin-Belfast Railway line was installed on site in 2006 and that the installation involved the excavation and pulling back of historical waste within the waste body, the installation of the pipework and the re-instatement of the waste (see Plate 6 below, Plate 7 following and report in Appendix 2).

Plate 6. Photograph taken during rising main construction through waste body on 28/4/2006 (facing SE from subject site towards WWTP under construction)

As part of the construction works, a trench was excavated through the waste and piles were installed at regular intervals to support the rising main (see Plate 7 below).

Plate 7. Photograph taken during rising main construction through waste body on 23/5/2006 (facing NW from eastern boundary of site with railway line to the left)

Prior to the installation of the foul sewer rising main and given the difficult ground conditions a geotechnical/environmental borehole site investigation was carried out in October 2005 to January 2006 (see Appendix 2). This investigation involved the installation of 4 boreholes installed through a combination of shell & auger followed by air rotary drilling. Waste was found at 8.3m bgl in BH1A, 9.2m in BH2B, 8.7m bgl in BH3A and 6.0m in BH4A. During the drilling 6 soil samples were taken for laboratory testing. The results of the soils analysis indicated that for 1 soil sample, the levels of arsenic were found to be in exceedance of the Dutch Criteria Intervention Value. This was recorded from the sample taken at 5.0m bgl in BH1A. It should be noted that polyaromatic hydrocarbons were found in a number of the soil samples. However, a review of the levels found did not indicate an exceedance of current Soil Guideline Values and Soil Inert Waste Acceptance Criteria. Although piezometers were installed no groundwater samples were taken as groundwater was not reached. A single round of gas monitoring was carried out on the 23rd January 2006. Methane was not detected during this round and carbon dioxide was found at natural levels.

1.4.2 Report by Sustech Ltd. on Construction of Rising Foul Sewer Main through Historic Landfill

Prior to the construction of the foul rising main, it is understood that Sustech Ltd. were contracted by Fingal C.C.'s consulting engineers, J.B. Barry and Partners Ltd. to determine if the proposed construction was in compliance with waste management legislation at that juncture (see Appendix 2). The following conclusions were provided by Sustech Ltd. on the environmental risk posed by the waste material deposited on site:

'The filled material is very mature, and no significant evidence of residual anaerobic decomposition is visible in the exposed faces. This is understandable as any putrescible material would have been expected to have undergone anaerobic and aerobic stabilisation in the early years of the post fill maturation and would now be stable. This material would also be stabilised by the considerable proportion of construction and demolition clays present which has been a feature of landfills of this era.

The unlined nature of the fill, the fact that the site was a sand and gravel quarry with an attendance high transmissivity aquifer (demonstrated by the high yield boreholes) would also be strong presumptive evidence that leachable material has long since been eluted from the matrix particularly in the upper layers.

Similarly, the aerobic appearance of the face material and the absence of any evidence of anaerobic processes or sulphidic material and the low analytical results for related anions mean that protection from sulphidic attack is not suggested. The low sulphate values with some spots of elevated levels are more suggestive of builders' rubble containing gypsum /plaster and plasterboard than presenting a general significant sulphate attack potential. In any case this is further prevented if a recommendation on clay backfill is utilised.

The materials encountered are unexceptional for dumps of this age and type. The material is at an advanced stage of stabilisation and contains a significant quantity of inert construction and demolition waste. The recommendations are designed to ensure an environmental and occupational health and safety satisfactory execution based on good practice and current experience at similar or more challenging projects. The proposals do not include activities which require either a waste licence or waste permit as currently understood and adjudicated upon in similar circumstances.'

It should be noted that a small area of medical waste was identified during the groundworks on the 23rd March 2006. This area, which consisted of some sharps (i.e. veterinary syringes) was observed through the sides of the excavations.

1.4.3 Foul Rising Main & Repairs

It is understood that following the installation of the foul water rising main in 2006, that a fault was identified during a pressure test on the 20th June 2006 (see Appendix 1). It was determined that the fault was due to the material underneath the mid-section of a certain section of the pipe (i.e. between the pile caps) had either settled away from the pipe due to the nature of the ground or had not been compacted correctly around and over the tie beams. This had the effect of causing a point load to be applied to the pipes at each pile cap over a small bearing area. The pipe between Ch3255 & Ch3261m was cut and a section near the failed joint removed (see photographs of groundworks in report in Appendix 2).

1.5 Foul Rising Main Exclusion Zone for Mulroy Environmental Phase II Site Investigation

In order to ensure that no damage would occur during the Mulroy Environmental site investigation works (i.e. to prevent interference with the pipe or its foundations), a *'5m + 5m No Go Buffer Zone'* was placed on mapping (see Figure 6). Mulroy Environmental contacted Fingal County Council with regard to determining the 'as built'

location of the rising main and the provision of a site investigation report for work carried out by S.I Ltd. on behalf of SIAC.

1.6 Consultation with Regulator (Fingal County Council) and External Consultants (RPS Consulting Engineers)

1.6.1 Liaison with Fingal County Council and RPS Consulting Engineers on the 25th May 2017

On the 25th May, 2017, Malachy Clarke of Winsac Ltd. and Padraic Mulroy and Patrick McCabe of Mulroy Environmental met with representatives of Fingal County Council and RPS Consulting Engineers at the Fingal County Council Offices in Swords, County Dublin. The purpose of this meeting was to discuss the proposed scope of works for a Tier 2/Phase II Intrusive Site Investigation/Generic Quantitative Risk Assessment/Soil Waste Characterisation Study.

Prior to the meeting, Mulroy Environmental carried out a Tier 1 Qualitative Risk Assessment of the waste body in accordance with the EPA's *'Code of Practice, Environmental Risk Assessment for Unregulated Waste Disposal Sites'* (see Appendix 3). It was determined from the assessment that the site could be classified as a *'Moderate Risk'* site based on the potential for lateral migration of landfill gases. Given, that the site was categorised as a *'Moderate Risk (Class B)'* site, a site investigation in accordance with the EPA's Code of Practice Matrix Tables was required (see Appendix 3).

In addition, the documentation produced by RPS consulting Engineers prior to the meeting was discussed (see reports included in Appendix 1). This included:

- *RPS - Barnageeragh Site Historical Review (23rd May 2017);* and
- *RPS – Memorandum, Proposed Scope of Assessment for Barnageeragh Landfill Site.*

It was concluded from the meeting that a trialpit investigation should be conducted to determine the material within, the hazardous/non-hazardous contents and the extents of the landfill. It was agreed that a network of gas monitoring wells would be installed across the landfill site to monitor landfill gases and that the location of these boreholes would be determined following a trialpit investigation. Subsequent to the meeting, it was agreed that four of the proposed gas wells would be extended a sufficient depth below the groundwater table to allow for groundwater quality monitoring.

Following the initial landfill gas monitoring rounds and groundwater quality monitoring, a further 6 gas/groundwater monitoring wells were installed to the north of the northern landfill boundary. These were installed to assess the potential for landfill gas migration to any future development/receptor north of the waste body. A groundwater quality sample was also taken from each of these wells after installation and development.

1.6.2 Liaison with Fingal County Council and RPS Consulting Engineers from the 29th August 2017 to the 24th January 2018

On the 29th of August 2017, Mulroy Environmental submitted a Phase II Site Investigation/GQRA & Landfill Gas Survey Report to Fingal County Council for their review. This report included the results and screening assessment for each of the soil samples taken during the trialpit investigation, the groundwater samples taken from BH1 – BH4 & BH8 – BH13 and the landfill gas monitoring results taken on four separate occasions. It should be noted that all the findings and results presented within the initial Phase II Site Investigation/GQRA Report have been included within this document.

On the 10th of October 2017, Winsac Ltd. and Mulroy Environmental Ltd. met with representatives from Fingal County Council and RPS Consulting Engineers to discuss the contents of the report. The minutes of the meeting were issued on the 23rd of October 2017 with responses and comments on the proposed further site investigation and reporting requirements exchanged between Mulroy Environmental and Fingal County Council (see correspondence in Appendix 4). This included:

- The requirement for the installation of a further groundwater borehole (BH14) downgradient from the defined northern boundary of the landfill;
- The requirement to conduct a second round of groundwater quality monitoring from each of the groundwater boreholes previously installed on-site (i.e. with the first round on the newly installed borehole BH14);
- The requirement to conduct a detailed quantitative risk assessment (DQRA) for the site;
- The requirement for ongoing groundwater standing water level measurement;
- The requirement for further determination of the quantity and depths of waste within the landfill and the quantity of waste below the water table;
- The requirement to investigate the potential impact of the Barnageeragh Landfill on the adjacent surface water stream;
- The requirement for further ongoing landfill gas monitoring of the onsite gas wells, groundwater boreholes, services and radon sumps (Residence Nos. 25 – 34); and
- A discussion on potential gas migration mitigation measures (i.e. the possible requirement for a landfill gas cutoff trench at that juncture).

All parties met again on the 24th January 2018 to discuss the progress of the works to that date (see meeting minutes in Appendix 4).

1.6.3 Liaison with Fingal County Council and RPS Consulting Engineers from the 02nd February 2018 to the 21st March 2018

On the 1st March 2018, Mulroy Environmental submitted the 1st Draft of Detailed Quantitative Risk Assessment (DQRA) produced by Peter Conroy of Hidrigeolaíocht Uí Chonaire Teo (HUCT) to Fingal County Council for their review. In order to further assess the risk of landfill gas to the residences closest to the landfill, an indoor landfill gas survey was carried out by Odour Monitoring Ireland (OMI) on the closest receptors to the landfill (i.e. House Nos. 25, 26, 52 & 53). The report produced by OMI was submitted to Fingal County Council on the 21st of February 2018 (see Appendix 14).

On the 21st March 2018, Malachy Clarke of Winsac Ltd., Bernie Carroll of Carroll Estates Ltd., Padraic Mulroy and Patrick McCabe of Mulroy Environmental and Peter Conroy of HUCT met with representatives of Fingal County Council and RPS Consulting Engineers at the Fingal County Council Offices in Swords, County Dublin. The principle items on the agenda for discussion included the results and conclusion of the DQRA, the results of all landfill gas monitoring to date and the likely proposed mitigation measures required. It was concluded from the meeting that a number of further tasks were required. These included:

- The recommendations outlined in the DQRA produced by Peter Conroy of HUCT were to be implemented. These recommendations included the installation of 3 further boreholes to the northeast of the landfill boundary, in order to determine the potential of a groundwater preferential flow pathway in that area and further soil sampling for ammonia testing to provide a more robust characterization of the source concentrations of ammonia within the landfill body;
- The requirement for further surface water sampling and possibly surface water modelling;
- The requirement for the installation of a number of passive gas venting wells to reduce methane levels within the waste body and to act as a mitigation measure against possible gas migration from boreholes BH1 and BH4 towards the residences to the north, proposed public park area to the north and WWTP to the southeast;
- The requirement to assess the effectiveness of the passive gas venting wells 'post-installation' as a mitigation measure; and
- The requirement to assess the risk to human health through possible ingestion/dermal contact of contaminated soil within the landfill body (i.e. a Detailed Quantitative Risk Assessment (DQRA)).

The minutes drawn up by Fingal C.C. for the meeting held on the 21st March are included in Appendix 4.

1.6.4 Liaison with Fingal County Council and RPS Consulting Engineers from the 22nd March 2018 to the 30th August 2018

Following receipt of the minutes, further communications took place between Peter Conroy of HUCT and Paul Heaney of RPS with regard to the agreed programme of works from the meeting on the 21st March, 2018. Peter Conroy acknowledged an email from RPS on the 28th March, 2018 which clarified further what was agreed at the 21st March meeting. A comprehensive breakdown of the correspondence on the DQRA between Paul Heaney of RPS and Peter Conroy of HUCT is provided in detailed spreadsheet prepared by HUCT (see Appendix 4).

Correspondence was received by Mulroy Environmental on the 23rd May, 2018 from Fingal C.C. stating the above and requesting clarification from Mulroy Environmental on the following remedial strategies:

- The response states that timelines will be established for the MNA strategy with projected chloride concentration peaks discussed;
- Information was requested on the party responsible for the implementation and costs of the on-going relatively long-term groundwater monitoring programme;

- Further research and information on the potential for, following the introduction of a landfill cap, for the build-up of landfill gas pressure beneath the cap and the possibility of undesirable sub-surface landfill gas migration; and
- Further information on hydrogeological implications (or advantages) of a capping layer, whether the cap is required from a groundwater perspective and what the benefits are.

An Indoor Air Quality assessment of Residences Nos, 25, 26, 52 and 53 was carried out by Odour Monitoring Ireland. Following revisions, this report was submitted to Fingal C.C. on the 19th June, 2018.

Following Fingal C.C's review of the afore-mentioned report, it was agreed that a further Indoor Air Monitoring survey would be carried out on a residence within the housing development that was a significant distance from the landfill. The purpose of this survey was to compare those results with the results obtained from the previous survey where Volatile Organic Compounds were detected from surfaces that had been freshly painted with solvent based paints.

2 OBJECTIVES

The objectives of the Tier 2/Phase II Site Investigation and the Tier 3 Quantitative Risk Assessment are as follows:

- Using the field data and laboratory data gathered, delineate the inorganic and organic chemistry of the soil/overburden/waste within the area previously used as a landfill;
- Characterise the correct waste category of the landfilled waste on site and having reviewed the laboratory data, to determine the correct waste category as recognised within the waste management sector of the Rep. of Ireland;
- To determine and monitor the landfill gas concentration within the waste body at the Barnageeragh Cove site;
- To determine if landfill gas is migrating from the waste body and/or has migrated in a direction from the waste body at the Barnageeragh Cove site towards the residences currently being constructed, towards the proposed public park area (to the north) or towards the WWTP;
- To determine if landfill gas has entered the foundations (i.e. radon gas barrier sumps, etc) of the residences and/or the services within the residential development (i.e. stormwater and foul sewers, water mains, etc);
- To evaluate potential liabilities associated with historic and/or current uses of the site on the new and/or existing residences and their residents;
- To evaluate potential liabilities associated with historic and/or current uses of the site on the proposed public park area and its users (i.e. Barnageeragh residents);
- To determine the short-term and long-term impact on the underlying groundwater aquifer and possible users hydraulically downgradient of the site;
- To determine the short-term and long-term impact on the surface water bodies in the vicinity of the site and the downgradient receptor (i.e. the marine ecosystem in the vicinity of Skerries and Irish Sea if required);
- Develop a Risk Assessment to provide a basis for decision making, to ensure the safe development of the historic landfill for recreational use (i.e. landscaped amenity area, etc) and to ensure that there will be no adverse impact to the environment; and
- To formulate a Remedial Action Plan (i.e. which may include capping, passive gas wells, cut-off trenching, etc), if feasible, to allow the safe retention of the existing waste at the Barnageeragh Cove site.

3 SCOPE OF WORKS

In order to fulfil the above outlined objectives, the following scope of works were proposed:

- Task 1: Site Audit & Desk Study;
- Task 2: Site Investigation;
- Task 3: Laboratory analysis; and
- Task 4: Data assessment and reporting.

Task 1: Site Audit & Desk Study

The Preliminary Audit involved the collation and assessment of the following key information:

- Site environmental setting in terms of geology, hydrogeology, hydrology and surrounding land use;
- Site history, specifically with respect to previous unrelated land uses and operations which may have formerly been conducted prior to the construction of the residential area (i.e. sand and gravel extraction, landfilling, etc);
- The production of a Tier 1 Qualitative Risk Assessment of the waste body in accordance with the EPA's *'Code of Practice, Environmental Risk Assessment for Unregulated Waste Disposal Sites'* (see Appendix 3);
- The preliminary audit of the site involved a walk-about survey of the site to identify suitable locations for intrusive investigation (i.e. trialpits and borehole installation). Both Padraic Mulroy and Patrick McCabe of Mulroy Environmental conducted this site walkover on the 24th May 2017; and
- A number of ortho-photogrammetric surveys of the site have been carried out by Mulroy Environmental using a DJI Phantom 4 Drone since project commencement to digitally record the construction of the residences and the progression of the site investigation works. This has enabled the production of grid reference orthomosaics and 3D models to aid in the interpretation of the site's topography. Previous mapping/historical photographs available from Google Earth and/or prepared by RPS on behalf of Fingal C.C. were used to determine the approximate extent of the former sand and gravel pit and subsequently the possible extent of the waste landfilled on site (see Appendix 1). At that juncture, it was determined that the area of the former sand pit was approximately 7,659m^2 (see Figure 6). It was proposed to subdivide the area of the site under inspection into a '10m x 10m' grid. This strategy is consistent with Section 7.6.2.5 of the *BS10175, Code of Practice for the Identification of Potentially Contaminated Land and its Investigation.* This section deals with sampling density for various types of suspected contaminated sites. It was proposed to take up to two soil/waste samples from each of these plots for Waste Acceptance Criteria (WAC) and Total Pollutant testing. It was also proposed to take a composite sample from the soil stockpiles located on the south-eastern corner of the site.

Existing autocad drawings of the existing layout and underground services in the area, and digital 2500 Ordnance Survey rasters were reviewed as part of the preliminary desk study work. As standard for a brownfield industrial site, all areas chosen for drilling/excavation were checked using a cable avoidance tool (CATSCAN).

Mulroy Environmental collated drawings and mapping provided by Waterman-Moylans Consulting Engineers and documentation provided by Fingal C.C. to determine the location of a 600mm foul rising main that was

installed along the southern boundary of the site in 2005 (see Figure 6). A 5m buffer zone either side of the rising main was placed on site investigation mapping (i.e. where the proposed route for the pipe is shown) in order to prevent interference with the pipe or its foundations during the site investigation works (i.e. works involving air rotary drilling rig and excavator). Mulroy Environmental contacted Fingal County Council with regard to determining the 'as built' location of the rising main and the provision of a site investigation carried out by Site Investigation Ltd. on behalf of SIAC in 2005 and 2006. This site investigation was carried out prior to the construction of the rising main in 2006. The report for this site investigation is located in Appendix 2.

Prior to the excavation works contact was made with Eoin Halpin of Archaeological & Heritage Consultancy Ltd. to determine a safe setback distance from a mound/cairn (i.e. statutory monument) which is located to the northwest of the waste body. An archaeological report was prepared by Archaeological Development Services Ltd. for the proposed residential development during the planning stage in 2005. No archaeological trenching was carried out within the footprint of the historic landfill as all material of archaeological merit was removed during the previous sand and gravel pit operation. Two test trenches, Trench 11 and Trench 12 were excavated in the field to the north of the historic landfill. No features of archaeological significance were noted along the length of Trenches 11 and 12 (see relevant extract of Archaeological Test Trenching Report, 2005 in Appendix 5).

It should be noted that Eoin Halpin, of Archaeological Development Consultants visited the site on the 2nd June 2017 to supervise the excavation of a slit trench (MEST1) excavated to the east of the cairn (see Figures 3 and 7). The purpose of this slit trench was to determine the position of the waste material in proximity to the cairn (i.e. Statutory Monument No. DU005-017001) and to confirm that the cairn was intact and not being interfered with during the site investigation trialpitting exercise (see report in Appendix 5).

On the 29th of May 2017 and 5th June 2017, Padraic Mulroy of Mulroy Environmental carried out an inspection of 4 residences to the north of the waste body (i.e. Residences Nos. 25-28) to determine the layout of services (i.e. foul, storm, rainwater, radon gas measures, water mains, etc). The purpose of this exercise was to determine possible routes for entry of landfill gas into each residence (i.e. through the foundation slab). On these occasions, Mulroy Environmental carried out a landfill gas and Volatile Organic Compound (VOC) monitoring survey of the 4 properties. No evidence of the ingress of landfill gases into the foulwater services on site or into the building services or their foundations was observed (see Section 9.9). Methane was not detected, and carbon dioxide was at normal levels (see Tables A13.31A & A13.31B in Appendix 13).

Task 2: Site Investigation

The site investigation programme was undertaken in accordance with the *British Standard BS 10175:2011 (Investigation of potentially contaminated sites – Code of Practice).* This enabled the site investigation programme to be undertaken in a systematic manner and provided details of a process of site investigations and interpretation methodology to characterise the geological and hydrogeological setting of the site.

Trialpitting & Soil Sampling

The trialpitting work and soil sampling work was carried out over 5 separate events:

- Trialpits TP1-TP35 – These trialpits were excavated within the waste body and the greenfield area to the north and east of the waste body from the 31st May 2017 to the 3rd June 2017. Soil samples were taken to determine the levels of contamination/waste classification of the soils within and outside the boundary of the waste boundary (see Figure 7);
- Trialpits TP36-TP38 – These additional trialpits were excavated in the builder's compound area on the 4th July 2017 with soil samples taken to determine the levels of contamination/waste classification of the soil in this area;
- Trialpits TP39-TP48 – These additional trialpits were excavated in the area to the north of the builder's compound on the 11th August 2017. The purpose of this work was to confirm the absence of domestic waste within this area (i.e. to confirm its status as a greenfield site). A single soil sample was taken from TP48 to determine the levels of contamination/waste classification of the soil in this area;
- A number of soil samples were taken at various depths during the installation of the passive gas venting wells to aid in the DQRA process; and
- A final two trialpits (i.e. TP49 & TP50) were excavated on the 1st of June 2018 with a single soil sample taken from each to aid in the DQRA process (i.e. ammonia testing).

Trialpits were dug down to a maximum depth of 4.6m bgl where possible (i.e. cohesive nature of soil, presence of bedrock, etc.) for TP1 – TP48 (see Figure 7 and trialpit logs in Appendix 6). Trialpits TP49 and TP50 were excavated to a depth of 1.6m bgl, which allowed for a sample of the waste material within to be taken. Trialpits were dug using a tracked machine provided by Winsac Ltd. A single soil sample was taken from each of the trialpits TP1-TP38 with a 2nd sample taken where evidence of hydrocarbon contamination or indigenous soil was found below the waste body. A single soil sample was taken during the trialpitting exercise undertaken on the 11th of August 2017 (i.e. from trialpit TP48). A total of 40 soil samples were submitted for WAC & Total Pollutant laboratory analysis with 5 samples also analysed for VOCs and SVOCs (see soil sample inventory in Table 1). The results for these analyses are presented in Tables 2, 3, 4 and 5 and in Tables A18.1 and A18.2 in Appendix 18.

In order to facilitate the Detailed Quantitative Risk Assessment by HUCT, a total of 15 soil samples were taken from the spoil generated from the 5 passive gas venting wells (i.e. 2 from each gas venting well), the 3 additional groundwater boreholes (i.e. a single sample), BH15, BH16 and BH17 and from TP49 and TP50 (i.e. each a single sample) and analysed for a number of parameters including Total Kjeldahl Nitrogen (TKN), Cation Exchange Capacity (CEC), Major Cations, etc to further determine the soil ammonia concentrations within the body (see

full suite of parameters in Section 3 – Task 3A). The results of this additional analyses are present in Table A18.33 in Appendix 18.

The purpose of the trialpitting was to thoroughly assess the type and thickness of the made ground and/or indigenous soil on site, and subsequently the lateral and vertical extent of any contamination within the overburden on site. Following the completion of the trialpit logging and sampling, each soil and made ground layer was reinstated back into the trialpit in the correct order. Each horizon was compacted down thoroughly prior to proceeding with the next horizon. The location (i.e. 6 * 6 Irish national grid reference) of each of the 48 trialpits was recorded using a combination of Autocad 2017 topographical mapping, post-excavation 4k aerial drone photographs and a Garmin GPSMAP62st handheld GPS with a boosted aerial. Digital photographs were taken of each trialpit's soil profile and stockpile identifying any key components of the overburden encountered (see trialpit Photo Logs in Appendix 7). All photos were 'geotagged' to a 6 * 6 Irish national grid reference using the Garmin GPSMAP62st handheld GPS.

Detailed hydrogeological logging of subsurface media was carried out to *British Standard BS5930 Code of Practice for Site Investigations, 1999* and *BS 10175:2011, Code of Practice for the Identification of Potentially Contaminated Land and its Investigation, BS10175.* Any waste material encountered was assessed and identified with regard to the European Waste Catalogue and Hazardous Waste List, 2002. This enabled the site investigation programme to be undertaken in a systematic manner. If any suspected contaminated soil was identified during the exercise it was proposed to sample this as part of the composite sample and analyse for the Waste Acceptance laboratory suite. Once sampling depths were established, samples were taken from the trialpit stockpile in accordance with *British Standard BS10175:2011*. The location of each sample was dictated by the results of visual and olfactory findings. Samples were collected by hand using a fresh pair of disposable latex gloves for each sample. Trialpit logs were taken for each trialpit in accordance with BS5930. Where any evidence of contamination by volatile organic compounds was identified (i.e. gasoline/BTEX, solvents, etc), a soil vapour survey of soil samples taken in the trialpitting exercise was carried out using a MiniRae 2000 Photo-Ionisation Detector (PID) equipped with a 10.6eV bulb. This involved taking soil samples in freezer zip lock bags, equilibrating for 15 minutes to allow any VOCs to enter the headspace and analysing using a portable photoionization detector (PID). It should be noted that no asbestos containing materials (ACMs) were identified during the trialpitting exercise.

Following sampling, each sample was maintained at <4ºC in a freezer box using a combination of ice freeze packs and a mobile refrigeration unit prior to dispatch to the laboratory for analysis.

Stockpile Sampling

It should be noted that a number of soil stockpiles were located on the south-eastern corner of the site. It was noted that a number of these stockpiles which were stacked close together contained relatively high concentrations of crushed glass. In order to determine the characteristics of this material, Mulroy Environmental took 1 representative composited sample (i.e. SP1) from these stockpiles to analyse for the WAC & Total Pollutant laboratory suite.

Table 1. Inventory of Soil Samples taken from Trialpits TP1 - TP50, Soil Stockpile SP1 and Topsoil Samples at Barnageernagh Cove, Skerries, Co. Dublin

Trialpit No.	Trialpit Location	Sample ID	Sample Depth	Sample Type	Sample Suite
TP1	Located within landfill	SO-TP1-01	0 - 3.0	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
		SO-TP1-02	3.0 - 3.5	Indigenous soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP2	Located within landfill	SO-TP2-01	0 - 4.0	Waste material/soil	**WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown & VOCs & SVOCs**
TP3	Located within landfill	SO-TP3-01	1.0 - 4.2	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP4	Located within landfill	SO-TP4-01	1.0 - 4.4	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP5	Located within landfill	SO-TP5-01	1.2 - 3.5	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP6	Located within landfill	SO-TP6-01	2.5 - 4.3	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP7	Located within landfill	SO-TP7-01	1.6 - 4.6	Waste material/soil	**WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown & VOCs & SVOCs**
TP8	Located within landfill	SO-TP8-01	1.5 - 4.1	Waste material/soil	**WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown & VOCs & SVOCs**
TP9	Located within landfill	SO-TP9-01	0.3 - 2.2	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP10	Located within landfill	SO-TP10-01	1.0 - 4.5	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP11	Located within landfill	SO-TP11-01	1.2 - 4.4	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP12	Located within landfill	SO-TP12-01	0 - 2.7	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
		SO-TP12-02	2.7 - 4.6	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP13	Located within landfill	SO-TP13-01	1.5 - 4.0	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP14	Located within landfill	SO- TP14-01	1.0 - 2.3	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
		SO- TP14-02	2.3 - 4.4	Waste material/soil	**WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown & VOCs & SVOCs**
TP15	Located within landfill	SO- TP15-01	1.0 - 3.2	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
		SO- TP15-02	3.2 - 4.1	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP16	Located within landfill	SO- TP16-01	2.4 - 4.6	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP17	Located within landfill	SO-TP17-01	2.5 - 4.1	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP18	Located within landfill	SO-TP18-01	0 - 4.1	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP19	Located within landfill	SO-TP19-01	0.9 - 3.5	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
		SO-TP19-02	3.5 - 4.0	Indigenous soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP20	Located within landfill	SO-TP20-01	1.3 - 4.0	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
		SO-TP20-02	4.0 - 4.3	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP21	Located within landfill	SO-TP21-01	1.3 - 4.0	Waste material/soil	**WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown & VOCs & SVOCs**
TP22	Located within landfill	SO-TP22-01	1.6 - 4.2	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP23	Located within landfill	SO-TP23-01	3.5 - 4.0	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP25	Located to north of landfill and construction compound	SO-TP25-01	0.5 - 3.6	Waste free soil (FILL)	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP27	Located to north of landfill and construction compound	SO-TP27-01	0.5 - 3.5	Waste free soil (FILL)	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP28	Located within landfill	SO-TP28-01	2.2 - 4.0	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP29	Located to east of landfill and construction compound	SO-TP29-01	1.9 - 4.2	Waste free soil (FILL)	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP31	Located within landfill	SO-TP31-01	0 - 3.8	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP33	To west of Cairn (i.e. outside landfill boundary)	SO-TP33-01	0 - 2.3	Indigenous soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP36	Located within landfill	SO-TP36-01	0.2 - 3.2	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP37	Located within landfill	SO-TP37-01	0.2 - 3.7	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP38	Located within landfill	SO-TP38-01	0.2 - 3.6	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP48	Located to north of landfill and construction compound	SO-TP48-01	1.7 - 2.4	Indigenous soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TP49	Located within landfill	SO-TP49-01	0.2-1.55	Waste material/soil	DQRA Suite (CEC, TOM, Kjeldahl N, nitrates, nitrites, chloride, sulphide, major cations, etc)
TP50	Located within landfill	SO-TP50-01	1.1-1.55	Waste material/soil	DQRA Suite (CEC, TOM, Kjeldahl N, nitrates, nitrites, chloride, sulphide, major cations, etc)
SP1	Located on south-eastern area of landfill	SO-SP1-01	-	Waste material/soil	WAC Suite & TPH-CWG & Speciated PAHs & Total Metals & Chromium breakdown
TS1	Located within landscaped area over Type 1 Waste	SO-TS1-01	0-0.3	Topsoil	Topsoil Suite (Total Metals, Chromium Breakdown, TPH-CWG, PAHs, PCBs, Pesticides, Soil WAC, etc)
TS2	Located within landscaped area outside landfill footprint	SO-TS2-01	0-0.3	Topsoil	Topsoil Suite (Total Metals, Chromium Breakdown, TPH-CWG, PAHs, PCBs, Pesticides, Soil WAC, etc)

Groundwater Borehole / Landfill Gas Well Installation

1st Installation in June 2017

Mulroy Environmental initially proposed that 4 'deep air rotary' groundwater/gas wells be installed with a target depth of 15m depth (or sufficiently into groundwater) using an air rotary driven Coomacheo Drill rig within the waste body and along its boundary. Given the type of waste on site (i.e. domestic and C&D waste), this technique was required to get to the bottom of the waste and drill into the underlying soils and/or bedrock (i.e. if met within 15m).

Four boreholes, BH1-BH4 were installed over a period of 4 days from the 14th June to the 19th June, 2017 (see Figure 8 and borehole logs in Appendix 8). Drilling conditions were extremely difficult particularly during the drilling of borehole BH1 on the southern boundary of the site with the drilling lead bit lost on 2 occasions due to compacted sands and gravels found under the waste material. As bedrock was not encountered during the drilling of BH1, this borehole was installed to a total depth of 18.5m bgl. The other boreholes, BH2, BH3 and BH4 were installed to depths of 14.6m, 14.6m and 11.5m bgl respectively. Drilling was terminated at 11.5m bgl in BH4 as groundwater was encountered during drilling at 5.13m bgl.

Groundwater piezometers/gas wells with removable gas taps were installed in each of the 4 boreholes. Each borehole was installed with a top 1m of plain HDPE pipe with the remainder slotted HDPE pipe located underneath. Each borehole was installed with a filter sock and pea gravel filter pack. Each groundwater borehole installation included a bentonite seal, top hat cover, concrete plinth and traffic bollard.

Three 'deep air rotary' gas wells, BH5-BH7 were installed to 8m bgl depth using an air rotary driven Coomacheo Drill rig within the waste body and along its boundary from the 14th June 2017 to the 15th June 2017 (see Figure 8 and borehole logs in Appendix 8). The location for the 3 gas wells was finalised once the extent of the buried material/waste had been established following the trialpitting exercise (see Figure 7). Each standpipe consisted of 1.0m of plain HDPE pipe with up to 7m of slotted pipe. Tophats, concrete plinths and traffic bollards were installed on each of 'deep air rotary' gas wells to provide protection against construction traffic. Gas taps fittings with butyl rubber bungs were installed.

Four 'shallow window sample' gas wells were installed on the 15th of June 2017 at depths ranging from 1.5m to 4m bgl using a percussion Dando Terrier drill rig along the foot path to the south of the residences No. 25 – 34 (see Figure 8 and borehole logs in Appendix 8). The standpipe for gas well GS01 consisted of 1m of plain HDPE pipe with up to 3m of slotted tubing. The standpipe for gas wells GS02-GS04 consisted of 0.5m of plain HDPE pipe with up to 0.5m - 1.5m of slotted tubing. Gas taps fittings with butyl rubber bungs were installed. Flush manhole covers were installed on each of the 'shallow window sample' gas wells with the objective of providing long-term gas monitoring wells which will allow future landfill gas testing if deemed necessary.

2nd Installation in July/August 2017

In order to delineate the migration of methane gas moving in a northerly direction (i.e. methane was detected at approximately 12.5% in BH4 on the 12th of July 2017 (see Section 8.2)), it was decided to install 6 further

groundwater/gas monitoring wells to the north of the historic landfill. These 6 boreholes, BH8-BH13 were installed over a period of 4 days from the 31st July to the 2nd August 2017 (see Figure 8 and borehole logs in Appendix 8). Drilling conditions were again difficult due to compacted sands and gravels found under the fill material (i.e. waste free soil). Boreholes BH8 to BH12 were installed in an approximate line to the north of BH4 and the builder's compound with BH13 located further north. The 6 boreholes, BH8, BH9, BH10, BH11 and BH12 were each installed to a depth of 12m. BH13 was installed to a depth of 10m with bedrock encountered at a depth of 4.5m bgl.

As per the construction of the earlier boreholes, groundwater piezometers/gas wells with removable gas taps were installed in each of the 6 boreholes. Each borehole was installed with a top 1m of plain HDPE pipe with the remainder slotted HDPE pipe located underneath. Each borehole was installed with a filter sock and pea gravel filter pack. Each groundwater borehole installation included a bentonite seal and top hat cover, plinth and traffic bollard.

3rd Installation in October 2017

Given that there were a number of exceedances in the Groundwater Regulations Statutory Instrument No. 9 of 2010 threshold values for the groundwater quality samples taken in June/August 2017, it was determined that an additional borehole should be installed on the northern boundary of the site to assess whether groundwater contamination was migrating off site. Borehole BH14 was installed on the 26th of October 2017 (see Figure 8). As per the construction of the previous boreholes, a groundwater piezometer with removable gas tap was installed within the borehole. The borehole was installed with a top 2m of plain HDPE pipe with the remainder slotted HDPE pipe located underneath. The borehole was installed with a filter sock, pea gravel filter pack and included a bentonite seal, top hat cover, concrete plinth and traffic bollard.

4th Installation in April 2018

After the completion of the preliminary draft of the DQRA, it was recommended that 3 further boreholes (i.e. BH15, BH16 & BH17) should be installed to the north east of the waste body (see Figure 8). These 3 boreholes were installed to a depth of 10m bgl on the 17th of May 2018. BH17 was installed with a top 2.5m of plain HDPE while BH15 & BH16 were installed with a top 1m of plain HDPE. The remainder comprised of slotted HDPE pipe located underneath. As per the construction of the previous boreholes, a groundwater piezometer with removable gas tap was installed within each borehole with a filter sock, pea gravel filter pack, a bentonite seal, top hat cover, concrete plinth and traffic bollard. All boreholes and gas wells installed over the duration of the site investigation were surveyed in (i.e. ground elevation, top of casing and top of standpipe) by Tom Nesbit of Land Surveys, Dun Laoghaire County Dublin.

Geophysical Surveying

In an effort to expand upon the information retrieved from the trialpit and borehole investigation and to fully delineate the extent of the historic landfill boundary and the depths of waste within, Apex Geoservices were contracted to carry out a geophysical survey of the site (see report in Appendix 9). The geophysical survey was conducted over the course of two days (i.e. 24th November 2017 & 29th January 2018) and consisted of EM31 Ground Conductivity mapping, Electrical Resistivity Tomography (ERT), Seismic Refraction surveying and

Multi-Channel Analysis of Surface Waves (MASW). In total 8 ERT profiles were produced. The location of the ERT runs were selected on the following basis:

- ERT Profile R1 – Eastern to western cross section of the landfill body (used to confirm the eastern and western extents of the landfill);
- ERT Profiles R2 & R4 – Southern to northern cross sections of the landfill body (used to confirm northern extent of the landfill and to establish the depths of waste within the middle of the site;
- ERT Profile R3 - Eastern to western cross section directly outside of the northern boundary of the landfill body (used to confirm the northern extent of the landfill);
- ERT Profiles R5 & R6 – Cross sections running in a southern to northern direction adjacent to House Nos. 24 & 25 (i.e. used to confirm that the waste body did not extend up to the boundary of the housing development); and
- ERT Profiles R7 & R8 – Cross sections selected to confirm the north-western boundary of the landfill and to ensure that the waste body did not extend up to the boundary of the housing development

Groundwater Quality Monitoring

Three rounds of groundwater quality monitoring were conducted for the newly installed boreholes on-site. The first round of groundwater samples was taken on the 27th June 2017 (BH1 – BH4) and on the 2nd of August 2017 (BH8 – BH13). At that juncture, borehole BH14 had not been installed. The second round of monitoring was completed on the 15th November 2017 from all 14 onsite groundwater monitoring boreholes (i.e. including BH14). The third round of sampling was completed on the 24th May 2018 after boreholes, BH15 – BH17 were installed.

A leachate sample was taken from BH7 on the 21st of February 2018 and analysed solely for ammonia. This sample was taken in order to aid in the development of the DQRA for the project. No leachate was observed in BH7 on the 24th of May 2018 (i.e. during the 3rd round of groundwater monitoring).

Prior to sampling, each groundwater well was dipped with a Geotechnical Instrument Interface Probe to determine firstly if any groundwater was present, and if so, the depth of standing water level, total well depth and to determine if any floating free-phase product (i.e. Light Non-aqueous Phase Liquid (LNAPL)) or (i.e. Non-aqueous Phase Liquid (DNAPL)) are present within the aquifer on site. Groundwater was present in all 14 of the deep wells (i.e. BH1-BH4 and BH8-BH17) during monitoring events. No 'product' (i.e. solvents) was identified in any of the 14 boreholes. Monitoring well sampling logs were produced for each borehole on each sampling occasion (see Appendix 10).

Dedicated Waterra inertial lift pumps were installed in each of the 14 groundwater boreholes for sample extraction. Each well was initially developed by purging 5 well volumes after installation. Prior to each sampling round, 3 well volumes were removed as recommended by *British Standard BS 6068-6.11:1993 (ISO 5667-11:1993) Part 6: Section 6.11 Guidance on Sampling of Groundwater.* This standard provides recommendations regarding the number of well volumes and subsequently the amount of time required to purge a borehole prior to taking a water sample for laboratory analysis. The purpose of this procedure is to remove stagnant groundwater (i.e. where the well has not been sampled for an extended period and/or groundwater that may have been contaminated by the

drilling process (i.e. in order to give a representative groundwater sample). The purge water was visually examined during the purging process in a dedicated bucket for physical evidence of contamination in the form of floating product or emulsified product (i.e. sheen, droplets, etc) and/or sheen and/or taint or discoloration. The purged water was also inspected for olfactory evidence of contamination (i.e. odour). All observations were logged in the field in a 'Rite in the Rain' All Weather Notebook. Geotagged and time-stamped digital photographs were taken of purge water taken from each borehole.

Sample bottles were filled directly from the waterra outlet. Unfiltered samples were taken for each laboratory analyte with the exception of the sample taken for heavy metals analysis. A disposable 0.5µm mesh waterra in-line filter was employed to remove suspended solids from the groundwater samples. Preservatives were placed in specific containers to help in sample preservation during laboratory analysis (i.e. metal analysis). Prior to sampling for Total Coliforms, the mouth of the Waterra was flamed using a paraffin lighter to sterilise the aperture. Following sampling, each sample was maintained at <4ºC in a freezer box using a combination of ice freeze packs and a mobile refrigeration unit prior to dispatch to City Analysts, Ringsend, Dublin 4 and Chemtest Ltd. in the UK for analysis. All samples submitted to City Analysts were hand delivered by a Mulroy Environmental field scientist on the day of sampling, while all samples submitted to Chemtest Ltd. were sent on the day of sampling via overnight courier to the UK.

Groundwater Standing Water Level Monitoring

The standing water table for each of the boreholes has been regularly monitored from installation in July 2017 until August, 2018 (see Table A11.1 in Appendix 11).

Onsite Pump Testing

In order to determine the hydraulic conductivity of the groundwater aquifer on-site a rising head pump test was completed on 13 of the 14 groundwater monitoring wells onsite from the 30th January 2018 to the 2nd February 2018 and from the 31st May 2018 to 1st June 2018. On the 30th January 2018 Mulroy Environmental and Peter Conroy of HUCT carried a 4-hour duration rising head pump test on BH4. A pressure transducer was installed within the borehole to monitor groundwater levels with manual dip readings also taken to measure the level of drawdown during the test. Pressure transducers were also installed in boreholes BH8, BH9 and BH10 to observe any drawdown effect. The volume of groundwater abstracted/discharged from the borehole was measured (i.e. litres/second). The recovery of each borehole was also monitored (i.e. to within 10% of the initial standing groundwater level). From the 31st January 2018 to the 2nd February 2018, Mulroy Environmental carried out a short duration (i.e. 30 minute) rising head pump test on 9 of the remaining 10 groundwater monitoring wells onsite. Additionally, short duration (i.e. 30 minute) rising head pump tests were carried out from the 31st May 2018 to the 1st June 2018 on BH15 – BH17. Drawdown in each of the pumping wells was measured using a combination of an in-borehole pressure transducer and manual dip readings. A separate pressure transducer was installed in the closest borehole (i.e. observation well) to the pumping well to also measure any drawdown which was occurring. Additionally, the volume of groundwater abstracted/discharged from each of the boreholes was measured (i.e. litres/second).

Given that there was no drawdown observed during the short duration pumping test in BH15 and owing to the proximity of BH15 to the adjacent stream, the electrical conductivity (EC) of the stream was compared to the EC of the groundwater to determine whether the stream was contributing to the recharge of the well. On the 1st of June 2018, BH15 was pumped continuously for a 2-hour duration with a water sample collected before any water abstraction commenced and every 15 minutes thereafter. A water sample was also collected from SW4 on the same date (see Figure 11). On the day of sampling, all samples were submitted to the laboratory of City Analysts for EC analysis.

An interpretation of the pumping test data and summary of the site's aquifer properties are included in the DQRA report produced by Peter Conroy (see DQRA report in Appendix 12).

Surface Water Quality Monitoring

The hydrology of the site and alterations made as a result of the development of the Wastewater Treatment Plant and Barnageeragh Cove Residential Development are explained with the aid of 3 figures, Figures 9, 10 and 11. The hydrology of the area features a stream which rises approximately 800m to the southwest of the site. Figure 9 shows the hydrology of the site prior to the construction of the wastewater treatment plant to the east of the site with the Barnageeragh Stream starting within the WWTP site and flowing in an easterly direction. Figure 10 shows the hydrology of the site after the construction of the wastewater treatment plant which shows the afore-mentioned un-named stream re-routed along the boundary between the subject site and the WWTP and then turning to the west. Figure 10 shows the 4 surface water monitoring points locations, SW1-SW4 used for this study. Figure 11 shows the storm drainage network which carries the stream towards its marine discharge point to the north of the site. A detailed description of the hydrology of the area is provided in Section 4.4 of this report.

On the 11th of January 2018, Mulroy Environmental took a surface water sample from this stream at three locations in close proximity to the landfill (see Figure 11). This was conducted in order to investigate any potential impact the landfill may be having on the surface water body. Given that groundwater flow has been interpreted to flow radially outwards from the site in a northern, southern and eastern direction, sampling locations SW1 – SW3 can be considered to be hydraulically downgradient of the site. In an effort to determine the surface water conditions upstream of any potential influence from the landfill, a further sampling point SW4 was identified (see Figure 9). On the 15th of June 2018, a surface water quality sample was taken from SW1 and SW4. It was intended to take a sample from SW2 & SW3 on this occasion also, however the quantity of water/flow at these locations prohibited any sample collection (see plate 8 following).

Plate 8. Surface water monitoring point, SW2 which was dry during a sampling round carried out in June 2018

Each surface water grab sample was analysed for the laboratory suite given in Section 3 – Task 3C. Each sample was collected into laboratory-supplied bottles and sent in suitably chilled coolboxes by courier to the laboratories of Chemtest Ltd. (UKAS accredited laboratory) in the UK and City Analysts, Ringsend, Dublin 4 for analysis. All samples submitted to City Analysts were hand delivered by a Mulroy Environmental field technician on the day of sampling, while all samples submitted to Chemtest Ltd. were sent on the day of sampling via overnight courier to the UK.

Landfill Gas Monitoring

Borehole / Gas Well Monitoring

Following the installation of the 17 boreholes and 4 shallow gas wells, a total of 28 landfill gas monitoring rounds have been completed. It should be noted that landfill gas monitoring was conducted 22 times on borehole, BH14 with 13 monitoring rounds completed on BH15 – BH17 (i.e. as a consequence of the more recent date of installation) (see Appendix 13). Each well was surveyed using a hired GA5000 Plus Landfill Gas Analyser which was pre-calibrated by the owner, Geotech UK. Each calibration certificate issued was valid for 12 months (see Appendix 13). This is consistent with the requirements specified in *CIRIA Report C665 'Assessing risks posed by hazardous ground gases in buildings' by S. Wilson, S. Oliver, H. Mallett, H. Hutchings & G. Card. (July 2007).* The results of the ground gas monitoring events have been assessed for risk in accordance with the CIRIA C665.

During this survey, a set procedure was used where the pressure head/gas flow at each borehole was measured by the GA5000 Plus. Following this, the pump was switched on and methane, oxygen, carbon dioxide carbon monoxide and hydrogen sulphide levels were measured. Peak readings and readings after 60 seconds were measured for methane, carbon dioxide, carbon monoxide, nitrogen and hydrogen sulphide. This method is consistent with *British Standard BS8576:2013 Guidance on investigations for ground gas.* Each gas reading was

recorded in an all-weather field book by the field scientist. The atmospheric (barometric) pressure was recorded from the GA5000 Landfill Gas Analyser for each sample reading.

After each gas well was assessed for landfill gas and following a period of 2 hours (i.e. to allow gases to stabilize within each well), each well was assessed for VOCs using a MiniRae 2000 Photo-Ionisation Detector. Peak readings and readings after 60 seconds were measured for VOCs.

Climatic data (i.e. pressure, temperature, rainfall, wind speed, etc) have been collected from Dublin Airport Synoptic Meteorological Station which is located in County Dublin approximately 20km to the southeast of Barnageeragh Cove, Skerries. Data has been collected for the day of monitoring and the day preceding the gas monitoring event to determine atmospheric pressure trend (see Appendix 13). It was intended that all landfill gas readings are taken during contrasting pressure events as recommended in *British Standard BS8576:2013 Guidance on investigations for ground gas.*

Landfill Gas Probe Survey at Foul Rising Main/Landfill Body Interface

In order to determine if landfill gas from the waste body is migrating northwards towards the residential development, particularly Residences No. 52-63, along the rising foul main sewer (i.e. as a preferential pathway), it was agreed with Fingal C.C. that a gas probe survey would be carried out at the northern end of the waste body where the foul rising main exits the waste body. A gas probe survey was carried out by Mulroy Environmental on the 15th March, 2018 at the afore-mentioned location. During this survey, an electric Makita Hilti drill equipped with a 1m long 1-inch diameter auger bit and powered by a mobile generator was used to drill 16 holes (i.e. soil vapour points) for gas monitoring (see Figure 14). The 16 vapour points were laid out in 2 rows of 8 points. Each row ran parallel with and to the north and south of the foul rising main. Each of the rows was laid out at approximately 2m offsets from the centre line of the foul rising main. It should be noted that the rising main runs at approximately 2.5m below ground level (bgl) and as such, the depth proposed for the gas probe survey (i.e. 1m maximum bgl) was deemed safe for the survey. The results of the landfill gas probe survey are discussed in Section 9.7 of this report.

Landfill Gas Probe Survey at Waste Water Treatment Plant

In order to determine if landfill gas from the waste body is migrating eastwards towards the Skerries Waste Water Treatment Plant (WWTP) along the rising foul main sewer (i.e. as a preferential pathway), it was agreed with Fingal C.C. that a gas probe survey would be carried out at the southwestern corner of the WWTP where the foul rising main enters from the historic landfill to the north. A gas probe survey was carried out by Mulroy Environmental on the 27th November, 2018 at the afore-mentioned location (see Figure 14C). During this survey, an electric Makita Hilti drill equipped with a 1m long 1-inch diameter auger bit and powered by on-site mains was used to drill 9 holes (i.e. soil vapour points) for gas monitoring. The survey was carried out around the foul rising main where it enters the site. The 9 vapour points were laid out in 2 approximate rows on either side of the foul rising main. Each vapour point row was laid out at approximately 2m offset from the centre line of the foul rising main. The results of the landfill gas probe survey are discussed in Section 9.8 of this report.

Mulroy Environmental – Indoor Residence & Services Gas Monitoring

On the 29th May and the 5th June 2017, the landfill gas monitoring of the underground services of the 4 newly built residences to the north of GS01 to GS04 commenced (see Residences. Nos. 25-28 locations in Figure 6 & 13). Each house was inspected with services examined where stagnant gases had the potential to accumulate (see Plate 9 following). Five 'Building Monitoring Points (i.e. BMP1-BMP5) were identified within each building for air monitoring (see Figure 14B). This was carried out using both the GA5000 and the Photo-ionisation Detector (PID) simultaneously. During this exercise the radon gas sump to the rear of each residence was opened to determine if landfill gas had built up within the foundations of the residences (see Tables A13.31A to A13.31B in Appendix 13).

Mulroy Environmental – Outdoor Residence & Services Gas Monitoring

Following the fitting out and the closure of sale to the new house owner, the landfill gas monitoring of each residence was switched to the outdoors. Since the 18th September, 2018, the radon gas sumps to the rear of each house and the water mains meters to the front of the residences were assessed for landfill gases and VOCs (see Tables A.13.16 to 13.29 in Appendix 13). The presence of landfill gas within two stormwater manhole chambers (ST1 and ST2) to the southwest of Residences No. 25 and 26 were assessed (see Figure 13). In August, 2018, landfill gas and VOC monitoring commenced on the 2 stormwater/surface water drain access chambers (SW2 & SW3) located to the northeast of the residences.

Plate 9. Services within newly built residences which were inspected and checked for the presence of landfill gases

Odour Monitoring Ireland - Residence & Gas Well Gas Monitoring

Given that low quantities of hydrogen sulphide (H_2S) were detected (i.e. 0ppm – 3ppm) in a number of boreholes/gas wells, it was decided to conduct an indoor gas survey of Residences Nos. 25, 26, 52 & 53. This survey was carried out by Odour Monitoring Ireland (OMI). These residences were selected because they are the closest potential receptors to the landfill body (see Figure 13).

Indoor air monitoring was conducted on Residences Nos. 25, 52 and 53 on the 15th of December 2017 with monitoring carried out on Residence No. 26 and gas wells GS01 – GS04 on the 14th February 2018. In addition to H_2S monitoring within the house and gas wells, it was deemed prudent to widen the scope of the analysis suite. The complete monitoring suite included the following:

- Arsenic (House Nos. 25, 26, 52 & 53 & Gas Wells GS01 – GS04);
- Mercury (House Nos. 25, 26, 52 & 53 & Gas Wells GS01 – GS04);
- Trace Landfill Gas Screen (House Nos. 25, 26, 52 & 53 & Gas Wells GS01 – GS04);
- Formaldehyde & Acetaldehyde (House Nos. 25, 26, 52 & 53 & Gas Wells GS01 – GS04);
- Carbon Dioxide (House Nos. 25, 26, 52 & 53); and
- Methane Ground Surface Screen (House Nos. 25, 26, 52 & 53).

In order to determine the effect on similar houses which are the furthest possible distance from the landfill (i.e. a Control), it was decided to carry out another Indoor Monitoring Survey on Residence No. 47 (see Figure 13). This survey was carried out on the 27th June, 2018 by Odour Monitoring Ireland (see Appendix 14).

At a later date, it was decided to assess the volatile organic carbon (VOC) levels within the radon sumps for Residences Nos. 47, 52 and 53. It was also decided to assess the indoor levels of VOCs within residences Nos. 52 and 53 for comparative purposes. It should be noted that Residence No. 52 had been recently painted with solvent based paints at the time of surveying. This work was carried out on the 14th August, 2018.

A detailed description of the methodology used throughout both surveys is included in both OMI reports which are included in Appendix 14.

Topsoil Composite Sampling within Landscaped Area of Hamilton Hill

In order to landscape the area to the north of the historic landfill, clean topsoil was utilised by Winsac. It is understood that this topsoil was stockpiled on site (i.e. to the south of the new football pitch) following the clearance of topsoil during the ground preparation works for various phases of the residential development. It should be noted that prior to the residential development the land on the footprint of Barnageeragh Cove residential development was used for agriculture (i.e. tillage and pastureland) and as such, would have been regarded as a greenfield site. In order to determine if any potential risk exists from the topsoil used in the landscaping of the grassed area at Hamilton Hill, it was decided to take 2 composited topsoil samples from 2 areas within the landscaped area from 0-0.3m below ground level (bgl) (see Figure 14D). These areas are an area to the southeast of the cairn and overlying the footprint of the historic landfill Type 1 waste (i.e. TS1) and an area outside the footprint of the landfill, to the northwest of the cairn and which is underlain by undisturbed subsoil (i.e. TS2).

Each composited topsoil sample was made up of 10 separate subsamples taken from the upper 30cm of topsoil using a hand-held soil auger. Each of the 10 soil subsamples was placed in a clean bucket and mixed thoroughly prior to transfer to laboratory containers. The results of the topsoil composite testing are discussed in Section 7 of this report.

Passive Gas Venting Well Installation

Given that methane was detected at the highest levels in the vicinity of boreholes BH1 and BH4 during the landfill gas monitoring period, it was concluded that a number of passive gas venting wells should be installed in their vicinity to aid in the venting off of methane being generated and/or trapped in these areas. Five passive gas venting wells (GV1 – GV5) were installed onsite over a two-week period (i.e. 25th April 2018 – 3rd May 2018) (see Figure 15). Each well was installed down through the overburden and into the waste body. All 5 wells were terminated above the base of the waste body (i.e. as determined from the trialpitting, borehole drilling and geophysical survey data) (see gas venting well logs in Appendix 8). Each passive gas venting well was installed with a top 1m of plain HDPE pipe (160mm ø) with the remainder slotted HDPE pipe (160mm ø) located underneath. In addition, each well installation included a 0.5m bentonite seal, top hat cover, concrete plinth and traffic bollard. At the top of each casing, a Rotorvent rotating wind cowl was installed to increase the draw of gases up through the standpipe and into the atmosphere (see following Plate 10).

Plate 10. Gas venting well GV4 facing northwards towards builder's compound

Task 3A: Laboratory analysis (Soils)

Soil WAC, TPH-CWG, Speciated PAHs & Total Metals & Chromium breakdown

During the trialpitting exercise within the historic landfill, samples were collected into laboratory-supplied bottles and sent in suitably chilled coolboxes by courier to the laboratories of Chemtest Ltd (UKAS accredited laboratory). Precise sampling depth was recorded at each location, and strict chain of custody procedures adhered-to. In total, 40 soil samples were submitted for the following analyses.

Each of 40 soil samples were analysed initially for the Inert Waste Acceptance Criteria (WAC) full laboratory suite which involves both 'Total Pollutant' analyses and CEN leachate extraction (i.e. 10:1 liquid to solid) followed by analysis of the leachate. It was also screened for the presence of asbestos fibres.

The laboratory analyses for the leachate was as follows:

- Heavy metals analysis (i.e. antimony, arsenic, barium, cadmium, total chromium, copper, lead, mercury, molybdenum, nickel, selenium & zinc);
- Sulphates;
- Fluoride;
- Chloride;
- Total Dissolved Solids (TDS)
- Total Phenols; and
- Dissolved Organic Carbon.

The Total Pollutant Analyses laboratory suite was as follows:

- Total Petroleum Hydrocarbons (TPH) – Core Working Group (CWG);
- Benzene/Toluene/Ethylbenzene/Xylenes (BTEX);
- Total & Seventeen Individual Polyaromatic Hydrocarbons (PAHs);
- Total PCBs;
- Total Organic Carbon (%) & Loss on Ignition;
- pH analysis;
- Heavy Metals on soil (i.e. Total Pollutant); and
- Chromium III/ Chromium VI Breakdown.

Each of the 40 soil samples were screened for Asbestos using Polarised Light Microscopy (PLM). All of the above analyses were carried out by Chemtest Ltd. in the United Kingdom. Chemtest Ltd. have UKAS accreditation for all of the above. As the asbestos screening did not indicate the presence of asbestos, gravimetric testing (i.e. on a % weight basis) and qualitative analysis was not required.

Where any visual or olfactory evidence of contamination (i.e. hydrocarbon) was identified during the trialpitting exercise, soil samples for Volatile Organic Compounds (VOCs) and Semi Volatile Organic Compounds (SVOCs) analysis were also taken and submitted for analysis (see Table 1). This included samples SO-TP2-01, SO-TP7-01, SO-TP8-01, SO-TP14-02 & SO-TP21-01.

DQRA Suite (CEC, TOM, Kjeldahl N, nitrates, nitrites, chloride, sulphide, major cations, etc)

To facilitate the Detailed Quantitative Risk Assessment (DQRA) of the groundwater, 15 soil samples were taken either during the installation of 5 gas venting wells GV1 – GV5, boreholes BH15 – BH17 or during the excavation of trialpits, TP49 – TP50 for a specialist laboratory suite. The 15 samples were sent in suitably chilled coolboxes by courier to the laboratories of Southern Scientific Ltd. (INAB accredited laboratory). Precise sampling depth was recorded at each location, and strict chain of custody procedures adhered-to. The 15 soil samples were submitted and analysed for the following parameters:

- Total Kjeldhal Nitrogen;
- Organic Matter;
- Cation Exchange Capacity;
- Moisture Content;
- Major Cations;
- Nitrate;
- Nitrite;
- Chloride; and
- Sulphate.

These analyses were conducted to further characterise soil ammonia concentrations within the waste body and to allow for an improved representation of ammonia in the DQRA.

Topsoil Suite

During the topsoil sampling exercise within the landscaped area, 2 composited samples (i.e. TS1 and TS2) were taken from 0-0.3m bgl, collected into laboratory-supplied bottles and sent in suitably chilled coolboxes by courier to the laboratories of Chemtest Ltd (UKAS accredited laboratory). It should be noted that no visual or olfactory evidence of contamination (i.e. hydrocarbon) was identified during the topsoil sampling exercise. However, for reasons of thoroughness, it was decided to test both topsoil samples for Volatile Organic Compounds (VOCs) and Semi Volatile Organic Compounds (SVOCs). Given the former agricultural use of the site, it was decided to also analyse the topsoil samples for a suite of pesticides including organo-phosphorus, organo-chloride and acid herbicide pesticides.

The Total Pollutant Analyses laboratory suite is as follows:

- Heavy Metals (i.e. Total Pollutant) with Chromium III/ Chromium VI Breakdown;
- Total Petroleum Hydrocarbons (TPH) – Core Working Group (CWG);
- Volatile Organic Compounds (VOCs);
- Semi-Volatile Organic Compounds (sVOCs);
- Benzene/Toluene/Ethylbenzene/Xylenes (BTEX);
- Total & Seventeen Individual Polyaromatic Hydrocarbons (PAHs);
- Total & Seven Individual PCBs;
- Pesticides (Organo-phosphorous, Organo-chloride and Acid Herbicides);
- Total Organic Carbon (%) & Loss on Ignition; and

- pH analysis;

The laboratory analyses for the leachate was as follows:

- Heavy metals analysis (i.e. antimony, arsenic, barium, cadmium, total chromium, copper, lead, mercury, molybdenum, nickel, selenium & zinc);
- Sulphates;
- Fluoride;
- Chloride;
- Total Dissolved Solids (TDS)
- Total Phenols; and
- Dissolved Organic Carbon.

Both topsoil samples were screened for Asbestos using Polarised Light Microscopy (PLM). All of the above analyses were carried out by Chemtest Ltd. in the United Kingdom. Chemtest Ltd. have UKAS accreditation for all of the above. As the asbestos screening did not indicate the presence of asbestos, gravimetric testing (i.e. on a % weight basis) and qualitative analysis was not required.

Task 3B: Laboratory analysis (Groundwater)

Samples were collected into laboratory-supplied bottles and sent in suitably chilled coolboxes by courier to the laboratories of Chemtest Ltd. (UKAS accredited laboratory) in the UK and City Analysts, Ringsend, Dublin 4 Strict chain of custody procedures was adhered-to. The surface water suite selected is consistent with the parameters outlined in Table C.2 of the *EPA Landfill Manuals – Landfill Monitoring, 2003*. Table D.2 of the manual recommends trace organic substances that should be included in the determination. Volatile organic carbons, SVOCs, organo-nitrogen pesticides, organochlorine pesticides, herbicides and phenols were included for analysis. Tributyltin (i.e. anti-fouling paint) and organo-phosphorous pesticides (i.e. sheep dip, etc) were not deemed to be required.

The laboratory analyses for the groundwater was as follows:

- pH;
- Electrical Conductivity (EC);
- Dissolved Oxygen (DO);
- Total Dissolved Solids (TDS);
- Total Suspended Solids (TSS);
- Chemical Oxygen Demand (COD);
- Total Alkalinity ($CaCO_3$);
- Ammonia (N);
- Ammoniacal Nitrogen;
- Nitrate (NO_3);
- Nitrite (NO_2);
- Total Organic Nitrogen (TON);
- Total Nitrogen (TN);

- Chloride (Cl^-);
- Fluoride (F^-);
- Sulphide (S^{2-});
- Sulphate (SO_4);
- Cations (i.e. Potassium (K), Sodium (Na), Calcium (Ca) & Magnesium (Mg));
- Heavy Metals (i.e. aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, nickel, manganese, mercury, molybdenum, selenium, strontium, thallium, uranium, vanadium & zinc);
- Total Cyanide;
- Total Coliforms;
- Faecal Coliforms;
- Volatile Organic Carbons (VOCs);
- Semi Volatile Organic Carbons (SVOCs);
- Organo-nitrogen Pesticides;
- Organochlorine Pesticides;
- Herbicides; and
- Phenols.

For the first monitoring round (i.e. 27th June 2017 & 2nd August 2017) all parameters were analysed by Chemtest Ltd. For the second monitoring round (i.e. 15th November 2017) all parameters were analysed by Chemtest Ltd. with the exception of faecal and total coliforms which were analysed by City Analysts. For the samples collected on the 23rd of May 2018, ammonia, COD, faecal and total coliforms were analysed by City Analysts Ltd. with the remaining parameters analysed by Chemtest Ltd.

As mentioned previously, one leachate sample was taken from BH7 on the 21st of February 2018 and analysed solely for ammonia. This sample was analysed by City Analysts.

The samples taken for Electrical Conductivity (EC) analysis during the pumping test conducted on BH15 and from SW4 on the 1st June 2018, were analysed by City Analysts.

Task 3C: Laboratory analysis (Surface Water)

Samples were collected into laboratory-supplied bottles and sent in suitably chilled coolboxes by courier to the laboratories of Chemtest Ltd. (UKAS accredited laboratory) in the UK and City Analysts, Ringsend, Dublin 4. Strict chain of custody procedures was adhered-to. The surface water laboratory suite selected is consistent with the parameters outlined in Tables C.2 & D2 of the EPA Landfill Manuals – Landfill Monitoring, 2003 and is similar to that assessed for groundwater with the addition of BOD. Ammonia, BOD, COD, faecal and total coliforms were analysed by City Analysts with the remaining parameters analysed by Chemtest Ltd.

Task 4: Data assessment & Reporting

Risk Assessment

A risk assessment is defined as a process of establishing, to the extent possible, the existence, nature and significance of risk. Risk is defined as the probability of the occurrence of, and magnitude of the consequences of, and unwanted adverse effect to a receptor.

There are 4(no.) stages involved in a risk assessment:

1. *Hazard Identification* – This will involve identifying contaminants of concern and will be achieved through a program of site investigation works and environmental monitoring;
2. *Hazard Assessment Stage* - This stage involves the development of a Conceptual Site Model;
3. *Risk Estimation Stage* – A Quantitative Risk Assessment is undertaken as part of this stage to determine risks to human health, groundwater and surface water; and
4. *Risk Evaluation Stage* – This stage involves recommendation of remedial works.

Conceptual Model

The risk to the surrounding environment was assessed based on the geological and hydrogeological information gathered through the site investigation programme. This information was used to develop a conceptual site model of the underlying environment, in terms of identifying potential contaminants, pathways and sensitive receptors.

A conceptual model is defined as a textual and/or schematic hypothesis of the nature and sources of contamination, potential migration pathways (including description of the ground and groundwater) and potential receptors, developed on the basis of the information from the preliminary investigation and refined during subsequent phases of investigation. The development of a conceptual model is an essential base component of the risk assessment process. The development of a conceptual model is an iterative process, which is progressively refined based on additional focused investigations.

The results of site investigations and the development of a conceptual model should define all known aspects of the site that could impinge upon or affect the overall environment. The conceptual model is based on the hazard – pathway – receptor concept, where:

- A hazard represents the inherently dangerous quality of a substance, procedure or event;
- A pathway is a mechanism or route by which a contaminant comes in contact with, or otherwise affects, a receptor; and
- A receptor is a human being, living organism, ecological system, controlled waters, atmosphere, structures and utilities that could be adversely affected by the hazard. Surface water channels and springs are also considered to be sensitive receptors as the groundwater environment may provide baseflow to these features.

GENERIC QUANTITATIVE RISK ASSESSMENT

A Generic Quantitative Risk Assessment uses relevant generic assessment criteria (GAC) (i.e. values which are generally applicable to an entire class or group e.g. based on proposed future land use) or guidelines.

Generic Quantitative Risk Assessment (GQRA) of Groundwater

As a precursor to the Detailed Quantitative Risk Assessment which was carried out by HUCT using the CONSIM model, to assess risk from contaminated groundwater, the following guidance has been used:

- Interim Guideline Values from EPA Towards Setting Guideline Values for the Protection of Groundwater in Ireland, 2003;
- Threshold Values from Statutory Instrument No. 9, European Communities Environmental Objectives (Groundwater) Regulations, 2010; and
- S.I. No. 122 European Communities (Drinking Water) Regulations, 2014.

Generic Quantitative Risk Assessment (GQRA) of Surface Water

To assess risk to surface water, the following legislation was used:

- S.I. No. 294 European Communities (Quality of Surface Water Intended for Abstraction of Drinking Water) Regulations, 1989;
- S.I. No. 294 European Communities (Quality of Surface Water Intended for Abstraction of Drinking Water) Regulations, 1989;
- S.I. No. 122 European Communities (Drinking Water) Regulations, 2014.

Generic Quantitative Risk Assessment (GQRA) of Soils taken from Trialpits

As a precursor to the Detailed Quantitative Risk Assessment which was carried out by Mulroy Environmental using the Risk Based Corrective Assessment (RBCA) model, to assess risk from contaminated soil, Mulroy Environmental used the following GAC for soils:

- *UK Department of Environment, Food and Rural Affairs (DEFRA) - Contaminated Land Exposure Assessment (CLEA) Model – Soil Guideline Values, 2009* - Residential with plant, Allotment and Industrial/Commercial for sandy loam soil and 6% soil organic matter (SOM) (i.e. 12 SGVs published); [1]
- *LQM/CIEH Generic Assessment Criteria for Human Health Risk Assessment, 2nd Edition, 2011* – Residential Land-use, Allotment Land-use and Commercial Land-Use at 6% Soil Organic Matter (i.e. 82 SGVs published); [2]

[1] The Contaminated Land Exposure Assessment (CLEA) Model is used to quantify the risk to the environment. CLEA is a risk-based computer model developed by the UK Department of Environment, Food and Rural Affairs (DEFRA) to aid in the determination the suitability of contaminated land sites for redevelopment/remediation. Instead of applying a set limit or standard to any one parameter, which may deem a site contaminated or unsuitable, the CLEA model takes contaminant and environmental factors into account to determine a site-specific risk. The risk of human health being affected by living or working on a site with contaminated soil would be dramatically lower in an urban setting such as an apartment surrounded by hard standing versus a house with a back garden, where children play and interact with the soil. The CLEA model takes such a risked based approach by modelling the possible effects of a number of key contaminants. Guideline values produced by the model indicate a level below which the site is considered safe. Above the guideline value, further investigation is required. Thus the CLEA guidelines provide an objective basis for decision-making, based on an assessment of risk to human health. A number of Soil Guideline Values (SGVs) have been calculated by DEFRA and have been published in an 'SGV series' of documents

[2] A joint workshop was held by the Land Quality Management Ltd. and the Chartered Institute of Environmental Health in 2009. This workshop used CLEA Model 1.04 to derive SGVs for 82 organic and inorganic common contaminants.

- *UK Department of Environment, Food and Rural Affairs (DEFRA) - Contaminated Land Exposure Assessment (CLEA) Model* – Soil Guideline Values, Pre-2008 - Residential with plant and Industrial/Commercial for sandy loam soil and 6% soil organic matter (SOM);
- *EIC/AGS/CL:AIRE Soil Generic Assessment Criteria for Human Health, 2010;* and
- *National Institute of Public Health and the Environment of The Netherlands - The Soil Protection Guidelines (Dutch Criteria*) – Intervention and Target Values. [3]

Soil laboratory results were compared to the following waste acceptance criteria (WAC) to determine the correct waste category for each soil sample:

- Inert Waste Acceptance Criteria at Walshestown Restoration Waste Facility (W0254-01) in Naas, Co. Kildare; and
- Waste Acceptance Criteria at Murphy Environmental Waste Facility (WA 129-02) in Hollywood, Co. Dublin – Inert Waste Limit.[4]

Following the collation of this data, it was necessary to carry out an analysis on the data using the Hazardous Waste Classification Tool to determine if the material required disposal as a hazardous waste (i.e. if the soil is hazardous or non-hazardous). This tool requires the input of data acquired for total metals, individual PAHs, total petroleum hydrocarbons and BTEX compounds in order to comply with the definition and characteristics of Non-Hazardous waste soil as defined by the Landfill Directive (1999/31/EC) and as stipulated for example, in the waste licence, WA165-02 currently in place at Ballinagran Landfill.

Generic Quantitative Risk Assessment (GQRA) of Topsoil taken from Landscaped Area

Mulroy Environmental used the following GAC for the topsoil samples taken from the landscaped area:

- *National Institute of Public Health and the Environment of The Netherlands - The Soil Protection Guidelines (Dutch Criteria*) – Intervention and Target Values; [3]
- *UK DEFRA C4SLs, 2015* – Public Open Space 1 (Residential) for 1% Soil Organic Matter – Given that the topsoil is located in a publicly available green space within a residential development, this category was chosen. The 1% SOM was selected based on % organic matter results obtained for the 2 topsoils; [5] and

[3] When dealing with the Due Diligence Site Assessment of brownfield sites in Ireland a set of guidelines called the Soil Protection Guidelines, produced by National Institute of Public Health and the Environment of The Netherlands is generally used. The treatment of polluted soil and groundwater depends on the nature and the concentrations of the polluted substances present in it. The Soil Protection Guidelines used in The Netherlands is built on two values. These values, consisting of different ascending levels of concentration TV and IV are differentiated according to the nature of the pollution:

- Level TV is the target value. Pollutants above the TV level should be investigated more thoroughly. The question asked is: to what extent is the nature, location, and concentration of the pollutants of such a nature that it is possible to speak of a risk of exposure to man or the environment?; and
- Level IV is the intervention value above which the pollutants should generally be treated. In order to assess the risk of any contaminants contained in the overburden on site as a result of historical practices, the results of the soils analysis are compared to the above levels with particular regard paid to Level IV.

[4] The results of the soils analysis are compared to the values taken from Section A4 'Limit values for pollutant content for inert waste landfills' of Schedule A from the Waste Licence, WA 129-1 for the Murphy Environmental Inert Landfill at Gormanstown, County Dublin. These include the 'Total Pollutant Content' limits and the 'L/S = 10 l/kg Limits'. The purpose of comparison with these limits is to determine if an inert landfill such as the landfill operated by Murphy Environmental would be capable of accepting contaminated soil from the site.

[5] These GACs are Category 4 Screening Levels that arose out of the United Kingdom Department for Environment, Farms and Rural Affairs (Defra) revision of the Statutory Guidance for Part IIA of the Environmental Protection Act (1990). The revision identified a new four category approach for classifying land affected by contamination. Category 4 represents land that would not meet the requirements for classification as contaminated under Part IIA of the Environmental Protection Act.

- *LQM/CIEH Suitable for Use Levels (S4ULs) for Human Health Risk Assessment, 2015* – Public Open Space 1 (Residential) for 1% Soil Organic Matter – Given that the topsoil is located in a publicly available green space within a residential development, this category was chosen. The 1% SOM was selected based on % organic matter results obtained for the 2 topsoils. [6]

Soil laboratory results were compared to the following waste acceptance criteria (WAC) to determine the correct waste category for each soil sample:

- Waste Acceptance Criteria at Murphy Environmental Waste Facility (WA 129-02) in Hollywood, Co. Dublin – Inert Waste Limit.[7]

Risk Assessment from Landfill Gas

The results of each of the ground gas monitoring events were assessed for risk according to *CIRIA Report C665 'Assessing risks posed by hazardous ground gases in buildings' by S. Wilson, S. Oliver, H. Mallett, H. Hutchings & G. Card. (July 2007).* The results of the ground gas monitoring events were assessed for risk in accordance with CIRIA C665. A common method for characterising a site, is through the use of the Wilson and Card Methodology (1999). The method uses both gas concentrations and borehole flow rates to define a characteristic situation for a site based on the gas screening value (GSV) for methane (CH_4) and carbon dioxide (CO_2). According to CIRIA C665, where low rise houses (i.e. with a 150mm ventilated underfloor void) exist, the characterisation method proposed by Boyle and Witherington (2007) should be used. The NHBC method proposed by Boyle and Witherington is similar to the Wilson and Card system in that GSV's are utilised. This approach categorises risk by comparing the measured gas emission rates to 'traffic light' scenarios. Given that House No. 25 & 26 at Hamilton Hill, Barnageeragh Cove have been constructed with a 150mm underfloor void and that the other houses in the development have not, both risk assessment methodologies have been used.

The risk assessment approach (i.e. the use of fractional exposure limits) adapted during the indoor gas monitoring survey completed by Odour Monitoring Ireland is contained within the 2 reports included in Appendix 14.

DETAILED QUANTITATIVE RISK ASSESSMENT (DQRA)

Two Detailed Quantitative Risk Assessments were carried out:

- *Risk to Groundwater* – This was carried out by Peter Conroy, PGeo of HUCT using CONSIM. A summary of the methodology used and its conclusions are provided in Section 12 of this report. The full DQRA by HUCT is provided in Appendix 12; and

[6] The S4ULs follow on from the previous LQM/CIEH Generic Assessment Criteria (1st and 2nd editions), which were widely used by many local authorities and private sector practitioners. The S4ULs represent updated assessment criteria in line with recent developments in UK human-health risk assessment practice, including the additional land uses and exposure assumptions presented in Defra's recent C4SL guidance. However, unlike the C4SLs, the S4ULs are all based on Health Criteria that represent minimal or tolerable levels of risks to health as described in the Environment Agency's SR2 guidance, ensuring that the resulting assessment criteria are 'suitable for use' under planning. Assessment Criteria were derived for 89 substances (including SGV substances except lead and PCBs/dioxins). (Copyright Land Quality Management Limited reproduced with permission, Publication Number S4UL3757. All rights reserved).

[7] The results of the soils analysis are compared to the values taken from Section A4 'Limit values for pollutant content for inert waste landfills' of Schedule A from the Waste Licence, WA 129-1 for the Murphy Environmental Inert Landfill at Gormanstown, County Dublin. These include the 'Total Pollutant Content' limits and the 'L/S = 10 l/kg Limits'. The purpose of comparison with these limits is to determine if an inert landfill such as the landfill operated by Murphy Environmental would be capable of accepting contaminated soil from the site.

- *Risk to Human Health* – This was carried out by Mulroy Environmental using Chemical Releases Risk Based Corrective Assessment (RBCA) Model Version 2.6. A summary of the methodology used and its conclusions are provided in Section 13 of this report. The full DQRA by Mulroy Environmental is provided in Appendix 15. It should be noted that an external review of the RBCA model has been carried out by Tom Parker of Argentum Fox (see Appendix 15).

4 ENVIRONMENTAL SETTING

4.1 Introduction

This section describes the site's environmental setting including the site's location (Section 4.2), topography (Section 4.3), hydrology (Section 4.4), soils (Section 4.5), geology (Section 4.6) and hydrogeology (section 4.6) of the area.

4.2 Site Location

As stated in the introduction, the former disused landfill site is located in Barnageeragh Cove, Skerries, Co. Dublin. A number of newly developed houses by Winsac Ltd. are located adjacent to the north-western corner of the landfilled area (see plate 11 below and Figures 1-3). A mound identified as a 'Site of Cairn' on the 1837 Ordnance Survey of Ireland 6-inch mapping is located on the western boundary with a number of newly developed houses situated further to the northwest (see Figure 3). The Dublin-Belfast railway line runs directly along the south-western boundary of the site, while a waste water treatment plant operated by Fingal County Council is situated directly to the southeast. A builder's compound/yard is located directly to the north of the elevated landfilled area. However, during the site investigation and subsequent geophysical survey by APEX Geoservices, it was determined that previously landfilled material is also located underneath the compound. It was noted during the site investigation works that the area directly north of the site compound comprised of made ground (i.e. previously disturbed filled soil) but that there was no evidence of buried waste. An area of lower elevation comprising mostly of indigenous soils is located directly to the north of this area.

Plate 11. Historic landfill with newly built residences located to the north and northeast (note that the construction of Residences No. 25 and 26 required a piled foundation prior to subsequent completion)

4.3 Topography

Following the intrusive site investigation works (i.e. trialpit excavation, borehole installation and geophysical survey) the extent of the former landfill was delineated (see Figures 6-8). The western, southern and south-eastern portions of the landfill are at higher elevation than the northern and eastern areas (i.e. where the construction compound is located). The topography slopes from the south-eastern corner (i.e. 20.02m AOD) to the western boundary of the infill (i.e. 25.28m AOD). There is a sharp drop off in elevation where the construction compound to the north is located. This area is relatively flat with elevations ranging from 18.77m AOD to 18.99m AOD, as is the area of made ground (fill material), directly to the north of the compound. There is a further sharp drop of in elevation where the proposed public park area is to be located (15.6m AOD – 15.96m AOD).

4.4 Hydrology

The site is located within the Mill Stream (Skerries) 010 WFD River Sub Basin (see Figures 9 and 10 and plate 12 following). This river water body is located within the Palmerstown_SC_010 WFD Sub-Catchment which in turn is located within the Nanny - Devlin WFD Catchment and Hydrometric Area. The hydrology of the site and alterations made as a result of the development of the Wastewater Treatment Plant and Barnageeragh Cove Residential Development are explained with the aid of 3 figures, Figures 9, 10 and 11. As can be seen from Figure 9, there are 2 streams which pass through the WWTP site.

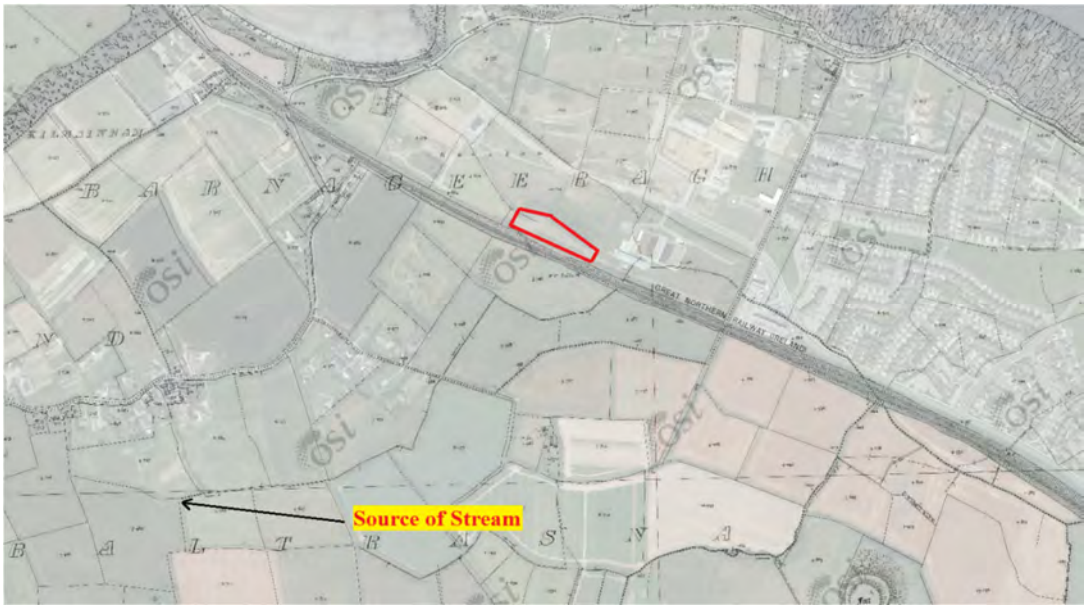

Plate 12. Map showing location of site and source of stream to southwest of site

The original route of the stream, which is based on original ordnance survey mapping, is provided in Figure 9. This shows the hydrology of the site prior to the construction of the wastewater treatment plant and the Barnageeragh Cover residential development. This stream rises approximately 800m to the south west of the site (see plate 12). From there, the stream flows in an approximate southwest to northeast direction. Approximately 900m from its source the stream is culverted underneath the Dundalk – Dublin Railway (see Figures 9). As can be seen from Figure 9, the subject stream having passed through the railway culvert, originally meandered through

the western end of the WWTP plant site and then into the north-eastern corner of the subject site. This stream then flowed in an east to west direction and discharged into the Irish Sea approximately 400m to the west of the site.

A 2nd stream, which is referred to as the Barnageeragh Stream, appears to rise within the WWTP site and flow to the northeast of the site. This stream flows eastwards towards Skerries after leaving the site and discharges into the Irish Sea, east of Skerries at a bathing area known locally as South Beach approximately 2.5km to the east of the site.

Figure 10 shows the hydrology of the area surrounding the site after the construction of the wastewater treatment plant and the Barnageeragh Cove residential development. Figure 10 shows the afore-mentioned un-named stream which has been re-routed along the boundary between the subject site (i.e. its eastern boundary) and the WWTP to facilitate the internal development of the WWTP site. The stream exits the site at the north-western corner of the WWTP and then discharges into the new stormwater drainage system constructed as part of the Barnageeragh Cove development.

Figure 11 shows in more detail the existing stormwater drainage network which carries the stream towards its marine discharge point to the north of the site. As can be seen from Figures 10 and 11, the stormwater drainage system has intercepted the stream which originally discharged on the beach to the west of the site. This stream has been diverted in a north-easterly direction via the Barnageeragh Cove stormwater drainage system and now discharges to the Irish Sea to the north of the site (see plate 13 below).

Plate 13. Drone aerial photograph of marine stormwater discharge point to north of site (see Figure 11)

Figures 10 and 11 also show the 4 surface water monitoring points locations, SW1-SW4 which were used for this study. Two hydraulically upgradient surface water monitoring points were used, SW4 and SW1. These are located to the south of the railway line with S4 being more upgradient and approximately 315m to the south of the site. The surface water monitoring point, SW4 was selected as it was found that during the months of June to August, 2018, when there was an extended period of dry weather, SW1 monitoring location was dry. The downgradient surface water monitoring locations, SW2 and SW3 were stormwater manhole chambers. It should also be noted that SW2 and SW3 were dry during the months of June to August, 2018 and could not be sampled.

The 2nd surface water body, the Barnageeragh Stream rises approximately 170m to the east of the site within the footprint of the Fingal C.C. WWTP site (see Figures 10 and 11 & Plate 14). From there, the Barnageeragh Stream is diverted to the south of Skerries Point Shopping Centre and thereafter, flows in a general south-easterly direction where it joins the Margaretstown River approximately 450m downstream. The Margaretstown River joins the Mill Stream (Skerries), which flows onto South Beach approximately 2.5km from the site. No surface water quality status has been assigned to these waterbodies as they are not currently monitored as part of Ireland's Water Framework Directive (WFD) monitoring programme.

Plate 14. Barnageeragh Stream rising within WWTP site and flowing in easterly direction towards Skerries

The Irish Sea is located approximately 400m to the north of the site. Skerries Islands Special Protection Areas (SPAs) are located approximately 3.0km to east of the site with Rockabill to Dalkey Special Area of Conservation (SAC) and SPA located 4.75km to the east of the site (see Appendix 16 and Plate 15). It should be noted that the waters off the coast of Skerries is a designated shellfish growing water (i.e. Balbriggan/Skerries Shellfish Area) (see Appendix 17 and Plate 15). This area receives a number of stormwater discharges in addition to the treated foul effluent from the Skerries/Balbriggan WWTP (see Plate 15). There are 2 designated shellfish monitoring locations off the Skerries coast (see Plate 15 following).

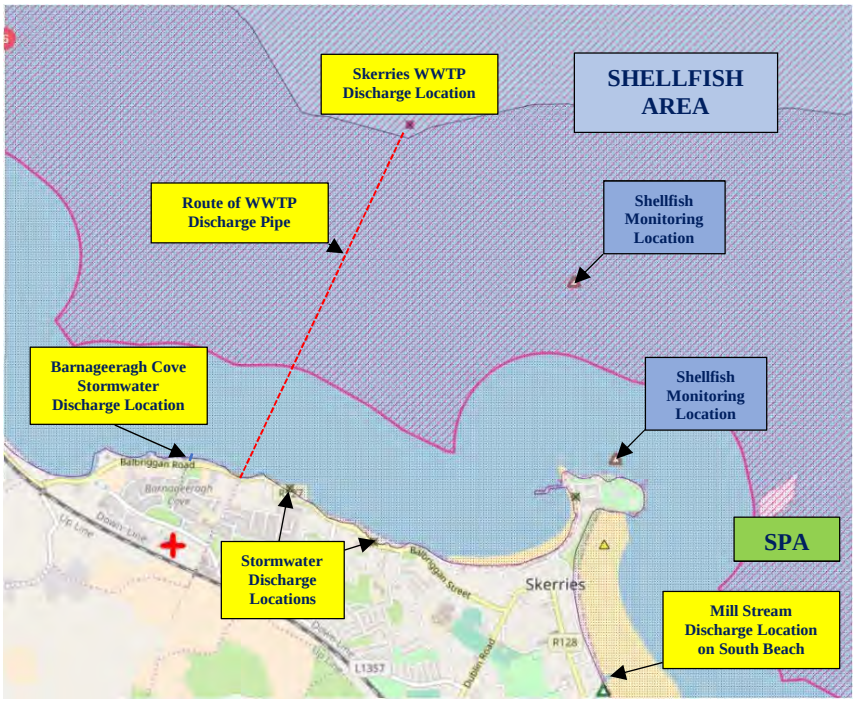

Plate 15. Skerries offshore area showing shellfish monitoring locations, WWTP discharge point

4.5 Soil

4.5.1 Soil (Top Horizon)

The formation of topsoil is known as the 'pedogenic' process. Reference to the General Soil Map of Ireland, published by An Foras Talúntais (1980) indicates that the predominant or principal soil type in the vicinity of the site is Soil Association No. 38, Grey Brown Podzolics (75%) with gleys (20%) and brown earth (5%) derived from till of Irish Sea origin with limestone and shale. A National Soil Mapping Project carried out jointly by the EPA and Teagasc have identified 2 separate soil types within the footprint of the site. This mapping indicates that the soils (i.e. topsoil) within the majority of the site, including the landfilled area comprises of *AminSW Shallow well drained mineral (Mainly acidic)* (see Appendix 16). This soil is described as *Lithosols, Regosols* derived mainly from non-calcareous parent materials. As a consequence of the sand and gravel removal and the subsequent landfilling activities on the site, this soil was removed within the sand and gravel pit area and replaced with MADE GROUND/WASTE. An area of land located to the north of the landfill body and towards the northern boundary of the proposed public park area is classified as having *AlluvMIN – Alluvial (mineral) soil.*

4.5.2 Subsoil (Quaternary) Geology

The origin of the subsoil material in this region is associated with the movement and deposition from glaciers during the last Ice Age. The ice sheets ground down the underlying bedrock, breaking the rock and grinding it to small sizes ranging from clays to boulders. The powerful erosive force of these ice sheets are considered to have moulded/sculpted the landscape in the area, with glacial features evident in the area. Glacial deposits in the area consist of tills, which were deposited at the base of moving glaciers, and to a lesser extent fluvio-glacial sand and gravels, which were deposited by glacial meltwaters. The National Soil Mapping Project carried out jointly by the EPA and Teagasc have identified the majority of the site, including the landfilled area as subsoil type *GLPSsS* –

Gravels derived from Lower Palaeozoic sandstones and shales (see Plate 16). The area of land located to the north of the landfill and on the northern boundary of the proposed public park area is classified as having *'A – Alluvium undifferentiated'* subsoil.

Plate 16. EPA/Teagasc subsoil mapping for the Barnageeragh area

4.5.3 Onsite - Subsoil

It should be noted that sands and gravels were found under the landfilled waste material in BH1 to the south of the site. It appears that these gravels were possibly marine in origin. Natural subsoils consisting of sands underlain by gravels were encountered in boreholes BH4, BH5, BH7 and BH8-BH13 to the north of the historic landfill. Given the history of the site (i.e. sand and gravel pit), the discovery of sand and gravels at depth (i.e. under the waste) is to be expected. The stratification of sands to the north of the historic landfill would indicate that they are more likely alluvial in source which is consistent with streams passing through the area.

4.6 Geology

4.6.1 Regional Geology

Based on the Geological Survey of Ireland (GSI Bedrock 1:100,000 scale digital geological map series) the bedrock formation for the site is described as the ***Skerries Formation*** (see Plate 17 below). The formation is described as comprising of laminated blue-grey sandstones and siltstones.

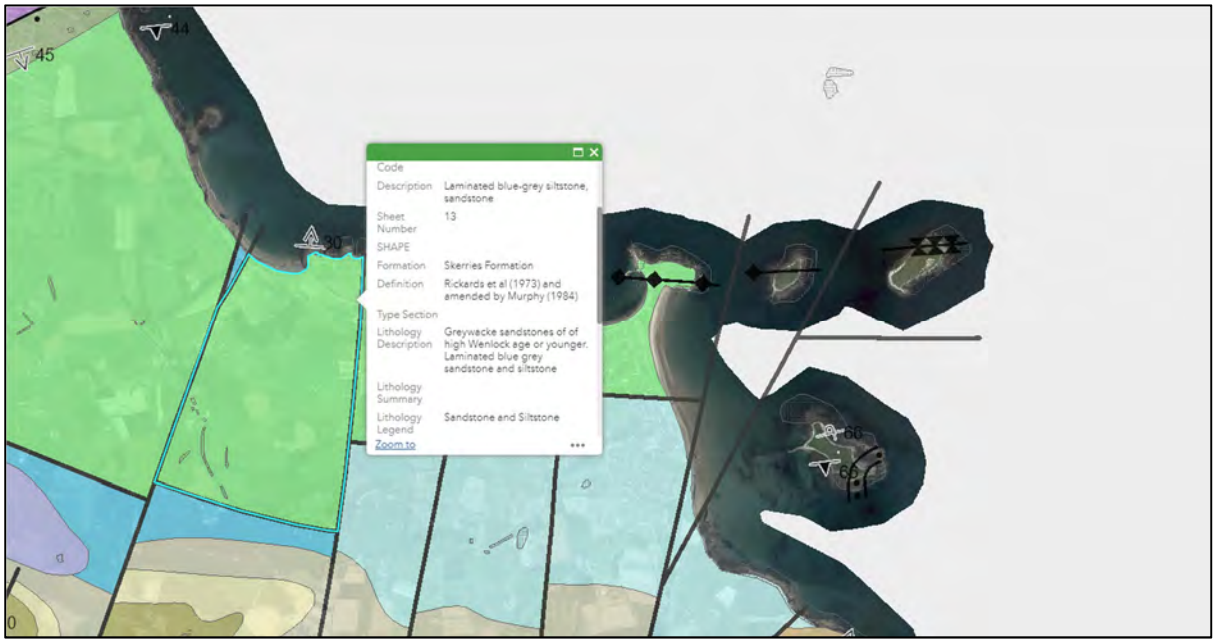

Plate 17. Bedrock mapping for Skerries Area

4.6.2 Onsite Geology

Bedrock was not encountered in 6 of those boreholes drilled within the landfill body or on its periphery. Bedrock was encountered in BH4, which is located to the north of the waste body and the later boreholes, BH8-BH14. The bedrock encountered appears to slope from north to south as can be seen in Figure 18, Section A-A'. As can be seen from the borehole logs in Appendix 8, bedrock was found at 3.5m bgl in BH13, 10m bgl in BH10 and 4.5m bgl in BH4.

However, it should be noted that bedrock also appears to be sloping in a southwest to northeast direction. As can be seen from the borehole logs in Appendix 8, bedrock was found at 7.6m bgl in BH12, 8.5m bgl in BH11 10m bgl in BH10, 10.5m bgl in BH9 and 10.5m bgl in BH8.
The bedrock was found to be either a blue weathered siltstone or a light grey blue sandstone.

4.7 Hydrogeology

4.7.1 Groundwater Aquifer

The generalised bedrock (i.e. Rock Unit Group) for the site is described as the *SMV – Silurian Metasediments and Volcanics* (see Appendix 16). According to the GSI mapping, the classification of the type of the aquifer within

the vicinity of the site is '*PI': Poor Aquifer – Bedrock which is Generally Unproductive except for Local Zones* (see Plate 18).

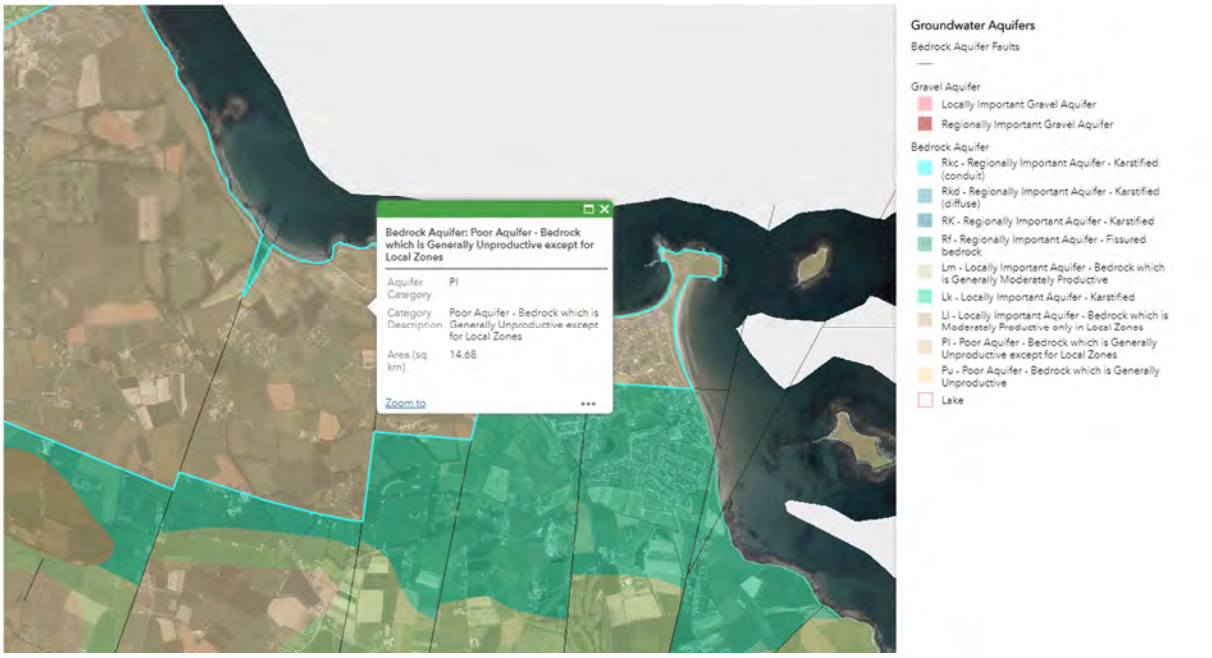

Plate 18. GSI aquifer mapping for the Skerries area

A review of the Geological Survey of Ireland groundwater well database reveals that there are no borehole records in the vicinity of the site. There are 6 boreholes located approximately 2.3km – 3.7km to the south, southeast and southwest of the site with yields ranging from 109m^3/d to 1,091m^3/d. A review of historical 25-inch mapping indicates the presence of a well located approximately 300m to the northwest of the site. This well was adjacent to what appears to be a farm complex and was most likely a dug well. A second well was recorded on the historic 25-inch mapping approximately 400m to the west. The closet groundwater drinking water protection area to the site is located in the townland of Bog of the Ring with the outer source protection area boundary for this abstraction located approximately 2.1km to the south east of the site. The closest karst landform is *'St. Movees Well'* located approximately 1.6km to the south of the site.

4.7.2 Groundwater Flow

A detailed analysis has been carried out on the groundwater gradient on site during both winter and summer periods by HUCT as part of the DQRA (see Appendix 12). Figures 18 to 21 in Volume II illustrated sections (or profiles) through the site with summer and winter groundwater levels.

4.7.3 Groundwater Vulnerability

Groundwater vulnerability is a term used to represent the intrinsic geological and hydrogeological characteristics that determine the ease with which groundwater may be contaminated by human activities. The vulnerability category is based on the relative ease with which infiltrating water and potential contaminants may reach groundwater in a vertical or sub-vertical direction. The permeability and thickness of the subsoil, which influences the attenuation capacity, are important elements in determining the vulnerability of groundwater.

The Irish GSI has produced guidelines on groundwater vulnerability mapping that aim to represent the intrinsic geological and hydrogeological characteristics that determine how easily groundwater may be contaminated by human activities. Vulnerability depends on the quantity of contaminants that can reach the groundwater, the time taken by water to infiltrate to the water table and the attenuating capacity of the geological deposits through which the water travels. These factors are controlled by the types of subsoils that overlie the groundwater, the way in which the contaminants recharge the geological deposits (whether point or diffuse) and the unsaturated thickness of geological deposits from the point of contaminant discharge.

For vulnerability assessments with regard to bedrock aquifers the relevant geological layer is the subsoil between the release point of contaminants and the top of the bedrock. Any unsaturated bedrock layer is not considered as it is assumed that bedrock has little or no attenuation capacity due to its fissure flow characteristics. Groundwater encountered in low permeability glacial tills, or other non-aquifer subsoils, is not considered to be a target. Therefore, where low permeability subsoils overlie the bedrock it is the thickness of subsoil between the release point of contaminants and bedrock that is considered when assessing vulnerability of bedrock aquifers, regardless of whether the low permeability materials are saturated or not.

The Irish GSI's vulnerability mapping guidelines allow for the assignment of vulnerability ratings from *"extreme"* to *"low"*, depending upon the subsoil type and thickness. The aquifer vulnerability for the majority of the site is described as '*H – high'*. This area largely coincides with the area of the site whereby the subsoil is *GLPSsS – Gravels derived from Lower Palaeozoic sandstones and shales* (see Plate 19 following). This vulnerability classification has been assigned on the basis that the sand and gravel overburden is estimated to be >3m in thickness (see Table 2). A small portion of land to the north-western corner of the proposed public park area is classified as *'M – Moderate'* groundwater vulnerability (see Plate 19).

Table 2. Groundwater Vulnerability Mapping Guidelines

VULNERABILITY RATING	HIGH PERMEABILITY (SAND/GRAVEL)	MODERATE PERMEABILITY (SANDY TILL, SUBSOIL)	LOW PERMEABILITY (CLAYEY SUBSOIL, CLAY, PEAT)
Extreme	0 – 3.0m	0-3.0 m	0 – 3.0m
High	>3.0m	3.0-10.0m	3.0 – 5.0m
Moderate	N/A	>10m	5.0 – 10.0m
Low	N/A	N/A	>10.0m

Plate 19. Groundwater vulnerability mapping for Barnageeragh Area

4.7.4 Regional Groundwater Quality

The site is located within the Balrothery Groundwater Body, where the water quality is classified as being of *'Good'* status (see Appendix 16). The groundwater waterbody risk score is determined to be currently under review.

5 WASTE BOUNDARY & DEPTH DELINEATION

5.1 Type of Waste

During the trialpit investigation and subsequent geophysical survey, two principle types of waste within the boundary of the landfill were discovered (see Figure 15):

- *Type 1* - consists of material with low organic, primarily C&D mixed with some municipal waste/high volume of ash, in places this layer contains sandy gravelly silt/clay mixed with minor waste; and
- *Type 2* - waste consists of municipal waste with high organic and/or metallic content.

Type 1 waste was largely confined to the western/north-western portion of the landfill. The footprint of this area is approximately 2,041m^2. This waste typically contained a mixture of red/orange gravelly sandy SILT & CLAY intermingled with glass and ceramics with a small amount of plastics (see Plate 20 below). The soil laboratory results also indicated that the organic carbon content was low for this waste type. Lead and zinc concentrations within this waste type were found to be elevated.

Plate 20. Typical stockpile of Type 1 waste (i.e. note red/orange coloration & sand/gravel SILT & CLAY)

Type 2 waste was largely confined to the central and eastern areas of the landfill. The footprint of this area is approximately 5,659m^2 and over twice the footprint of Type 1. This waste principally consisted of very dark brown/black gravelly sandy SILT & CLAY mixed with a greater volume of municipal waste (see Plate 21 following). The soil laboratory results also indicate that the organic carbon content was higher for this waste type.

Plate 21. Typical stockpile of Type 2 waste (i.e. note grey/black coloration & high organic matter content, trialpit TP16 stockpile)

5.2 Historic Landfill Perimeter Delineation

The boundary and depths of the historic landfill has been defined through a combination of trialpitting, borehole installation and geophysical surveying (see Figure 7). A total waste body footprint of 7,659m^2 was determined. The landfill is approximately 159m in length and 58m in width (i.e. at its widest).

Plate 22. Aerial photograph of landfill body facing west with builder's yard in foreground and Dublin-Belfast Railway line on western boundary

The Dublin-Belfast Railway line borders the south-western boundary of the landfill site. This railway has been in existence prior to the sand and gravel extraction and subsequent landfilling on the site. The OSI 6-inch map details the position of the railway line, referred to within as the Great Northern Railway, in relation to the historic sand and gravel pit (see Figure 4). The landfill is bordered to southeast by Irish Water's WWTP. In was determined after the site investigation programme that the north western boundary of landfill body did not extend past the cairn/burial mound (DU005:017) located onsite (see Figure 3). On the 2nd June 2017, Dr. Eoin Halpin supervised a slit trench excavation in the vicinity of the cairn/burial mound (DU005:017) (see Appendix 5). The purpose of this excavation was to determine the extent to which the disturbed ground associated with the sand and gravel extraction extended to the west and if it had encroached on the burial mound. It was determined that the deposits which formed the western end of the trench were undisturbed and represented the limit to which ground disturbance occurred in the area.

Additionally, Mulroy Environmental excavated two trialpits (i.e. TP30 & TP33) to the west of the cairn/burial mound to investigate the presence of landfilling (see Figure 7). No waste was recorded within the trialpits (see Trialpit Logs in Appendix 6 and Trialpit Photo Log in Appendix 7). As can be seen from Plate 23 below, a SAND subsoil was identified in the area. As can be seen from Figure 7, TP30 and TP33 were excavated in the vicinity of Residences Nos. 52 and 53.

Plate 23. Stockpile of soil from trialpit, TP31 (i.e. note undisturbed indigenous SAND subsoil)

The geophysical survey of the site completed by Apex Geoservices Ltd. also indicates that the waste body does not extend past the burial mound (see Appendix 9). For instance, the electrical resistivity tomography (ERT) profiles, R1, R7 & R8 describe the ground to the west of the burial mound as *Gravelly Sand/Boulders/Completely Weathered Rock.*

It was determined that the north-eastern boundary of landfill did not extend beyond the builder's compound. Mulroy environmental excavated 4 trialpits (i.e. TP25, TP26, TP27 & TP29) directly to the north of the compound's boundary. The trialpits were observed to contain clean subsoil (i.e. made ground) deposited there as a result of clearance from other areas within the Barnageeragh Cove residential development (see Plate 24 below). Waste was not observed within these trialpits.

Plate 24. Soil profile of trialpit, TP25 excavated to the north of the builders compound (i.e. note absence of waste)

The electrical resistivity tomography (ERT) profile R3 was surveyed across the area where TP25, TP26, TP27 and TP29 were excavated. No municipal waste was detected in the ERT profile. The geophysical survey indicated that the gravelly SILT/CLAY (MADE GROUND) extended to a maximum depth of circa 7m bgl and was underlain with gravelly silty SAND. The resistivity profile readings for the fill material was interpreted as *'C&D waste with lower organic & or metallic content or waste mixed with sandy gravelly SILT/CLAY'*. The C&D waste has been attributed to small/sporadic amounts of wood fragments within the SILT/CLAY matrix (see APEX Geoservices Drawing AGL 18018_14 in Appendix 9). This is consistent with the findings of the trialpit investigation (see Plate 25).

Plate 25. Soil stockpile of trialpit, TP25 excavated to the north of the builders compound

The electrical resistivity tomography (ERT) profiles, R6 and R8 have been used to determine the north and north-western landfill boundary of the site. It can be seen from the R6 profile, that made ground was determined to extend approximately 7m to the north of BH3 with *'C&D waste with lower organic & or metallic content or waste mixed with sandy gravelly SILT/CLAY'* found to extend approximately 3m to the north of BH3. A further area of lower resistivity (i.e. <30 Ohm-m) was recorded on the R6 profile. This is not believed to be *'municipal waste with high organic & or metallic content'* but possible interference from nearby foundations.

5.3 Depth of Waste

As described previously, two principle types of waste were discovered within the boundary of the landfill. In the area where Type 1 waste was encountered, the maximum total depth of waste observed was 8.18m (see electrical resistivity tomography profiles, R1 and R7 from APEX Geophysical Survey in Appendix 9). Whereas a median waste thickness of 3.41m was calculated. No waste was observed to be below the water table at either high or low (i.e. summer or winter) elevation.

A geological section of the site, A-A' has been prepared (see Figure 17 for section position with boreholes used and section in Figure 18). This section gives an indication of the depths of Type 2 waste encountered onsite. As can be seen from Figure 18, the maximum depth of waste of 12.36m is located in the vicinity of BH6. The total depth of waste declines further north, with a maximum depth of approx. 6.5m identified in the area underneath the builder's compound. For the Type 2 waste a median waste thickness of 7.74m was calculated. Detailed characterisation of the elevation of the base of the waste and the groundwater water table elevations indicated that a large part of the base of the Type 2 waste lies below the water table (see Figures 19 – 21).

6 ENVIRONMENTAL SOIL RESULTS & GQRA

6.1 Laboratory Suite & Generic Assessment Criteria

As mentioned previously a total of 42 soil samples were analysed for the laboratory suites outlined in Section 3. An inventory of the soil samples taken is given in Table 1. The results of laboratory analyses carried out by Mulroy Environmental on the soil samples taken from trialpits TP1 – TP50 are presented in the following tables:

- Table 3. Results of Heavy Metal, Anion, Total Dissolved Solids and Phenol Laboratory Analysis on 10:1 Leachate from Soil Samples and TOC/LOI Analysis on Soil Samples taken from trialpits TP1 – TP48 at Barnageeragh Cove, Skerries;
- Table 4. Results of TPH-CWG, BTEX, Polyaromatic Hydrocarbon, PCB, pH and Sulphate (Total Pollutant) Laboratory Analysis on trialpits TP1 – TP48 at Barnageeragh Cove, Skerries;
- Table 5. Results of Heavy Metals (i.e. Total Pollutant) Laboratory Analysis on Soil Samples taken from trialpits TP1 – TP48 at Barnageeragh Cove, Skerries;
- Appendix 18 - Table A18.1. Results of Volatile Organic Compound Laboratory Analysis on Soil Samples taken from trialpits TP1 – TP48 at Barnageeragh Cove, Skerries;
- Appendix 18 - Table A18.2. Results of Semi Volatile Organic Compound Laboratory Analysis on Soil Samples taken from trialpits TP1 – TP48 at Barnageeragh Cove, Skerries; and
- Appendix 18 - Table A18.33 – Results of Kjeldahl Nitrogen, CEC, TOM, Kjeldahl N, Nitrates, Nitrites, Chloride, Sulphide, and Major Cations Analyses on 15 selected Soil Samples taken at Barnageeragh Cove, Skerries (for Detailed Quantitative Risk Assessment (DQRA)).

The results in the above tables, Tables 3 and 4, are laid out as far as achievable to determine compliance with the Inert Waste Acceptance Criteria (WAC) utilised by the Walshestown Restoration Licensed facility located in Naas, County Kildare (W0254-01). The results in the above tables are also laid out to compare the soil quality results against the generic assessment criteria described in Section 4.

6.2 Laboratory Results (WAC & Total Pollutant)

6.2.1 Asbestos screening

It should be noted that of the 40 soil samples screened for asbestos, none of the 40 samples tested positive for asbestos fibres (see Table 5).

6.2.2 Laboratory Results on Leachate

CEN leachate extraction (i.e. 10:1 liquid to solid) was carried out on each of the 40 soil samples in Table 3. It should be noted that only Waste Acceptance Criteria values are available for leachate concentration assessment and that no Dutch Criteria values, LQM/CIEH GACs or CLEA SGVs (i.e. 2009 or 2008) are available. The Waste Acceptance Criteria are for 'Clean Subsoil', inert, stable non-reactive and non-hazardous Waste. The results for TOC and LOI are also located in Table 3. These analyses are carried out directly on the soil (i.e. Total Pollutant).

Heavy Metals - As, Ba, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Sb, Se and Zn

As can be seen from Table 3, 13 of the 40 samples had one or more exceedances in the metal leachate analysis. These included:

- SO-TP7-01, SO-TP8-01, SO-TP10-01, SO-TP13-01, SO-TP14-01, SO-TP14-02, SO-TP15-01, SO-TP16-01, SO-TP21-01, SO-TP22-01, SO-TP23-01 & SO-TP37-01 had antimony (Sb) leachate concentrations ranging from 0.064mg/kg – 0.420mg/kg which exceeded the respective inert WAC limit of 0.06mg/kg;
- SO-TP13-01, SO-TP14-01 and SO-TP20-02 had chromium (Cr) leachate concentration ranging from 0.69mg/kg – 1.3mg/kg which exceeded its respective inert WAC limit of 0.5mg/kg; and
- SO-TP7-01 (0.76mg/kg) and SO-TP15-01 (0.61mg/kg) exceeded the respective molybdenum (Mo) leachate WAC limit of 0.5mg/kg.

Sulphate

Of the 40 soil samples analysed, sulphate (SO_4^{2-}) was detected within the leachate extracted in 22 of the samples above the inert WAC value of 1,000mg/kg (see Table 3). The exceedances ranged in concentration from 1,100mg/kg – 16,000mg/kg.

Fluoride (F^-)

Fluorides (F^-) were not detected in any of the samples above the respective inert WAC value of 10mg/kg (see Table 3).

Chloride (Cl^-)

Chlorides (Cl^-) were detected in 1 of the 40 soil samples above the respective inert WAC value (800mg/kg) (see Table 3). This exceedance occurred in sample SO-TP10-01 (16,000mg/kg).

Total Dissolved Solids (TDS)

Of the 40 soil samples analysed, total dissolved solids (TDS) were detected in 14 of the samples above the inert WAC value of 4,000mg/kg (see Table 3). It should be noted that the highest concentrations of TDS (16,000mg/kg) were recorded in SO-TP10-01, SO-TP11-01 and SO-TP19-01. This is consistent with the elevated levels of SO_4^{2-} in TP11 and TP19 and with the elevated levels of Cl^- in TP10.

Total Phenols

Total Phenol analysis was carried out on the leachate extracted from the soil samples (see Table 3). No Phenols were detected within the leachate extracted from the 40 soil samples submitted.

Dissolved Organic Carbon (DOC)

Dissolved Organic Carbon (DOC) was not detected in any of the 40 samples above the respective inert WAC value (500mg/kg) (see Table 3).

Table 3. Results of Heavy Metal, Anion, Total Dissolved Solids and Phenol Laboratory Analysis on 10:1 Leachate and TOC/LOI Analysis on Soil Samples taken at Barnageernagh Cove, Skerries, Co. Dublin (Part A)

CHEMICAL SUBGROUPING			Heavy Metals Leachate												Anions			TDS	Phenols	Organic/ Carbon Content of Leachate	Organic/Carbon Content of Soil (Total Pollutant)		EWC Codes	Confirmed Asbestos Free	Soil Waste Classification
			Antimony Low Level CEN 10:1 Leachate	Arsenic Low Level CEN 10:1 Leachate	Barium Low Level CEN 10:1 Leachate	Cadmium Low Level CEN 10:1 Leachate	Chromium Low Level CEN 10:1 Leachate	Copper Low Level CEN 10:1 Leachate	Lead Low Level CEN 10:1 Leachate	Mercury Low Level CEN 10:1 Leachate	Molybdenum Low Level CEN 10:1 Leachate	Nickel Low Level CEN 10:1 Leachate	Selenium Low Level CEN 10:1 Leachate	Zinc Low Level CEN 10:1 Leachate	Sulphate CEN 10:1 Leachate	Fluoride in CEN 10:1 Leachate	Chloride in CEN 10:1 Leachate	Total Dissolved Solids	Total Phenols	Dissolved Organic Carbon	Total Organic Carbon (%)	Loss on Ignition			
Source	Units	WASTE CRITERIA	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	%			
WALSHESTOWN RESTORATION LIMITED WASTE LICENCE W0254-01	WAC Values	INERT WASTE	0.06	0.5	20	0.04	0.5	2	0.5	0.01	0.5	0.4	0.1	4	1000	10	800	4000	1	500	3	-			
WASTE FRAMEWORK DIRECTIVE	WAC Values	STABLE NON-REACTIVE	0.7	2	100	1	10	50	10	0.2	10	10	0.5	50	20000	150	15000	60000	0	800	5	-			
WASTE FRAMEWORK DIRECTIVE	WAC Values	HAZARDOUS WASTE	5	25	300	5	70	100	50	2	30	40	7	200	50000	500	25000	100000	0	1000	6	-			
SOURCE	SAMPLE ID	SAMPLING DEPTH (metres BGL)																							
TP1	SO-TP1-01	0 - 3.0	0.031	< 0.050	< 0.50	< 0.010	< 0.050	0.067	< 0.010	0.0052	0.069	< 0.050	< 0.010	< 0.50	530	1.9	18	1000	< 0.30	130	1.6	3.7	17 05 04	Y	Inert
	SO-TP1-02	3.0 - 3.5	< 0.010	< 0.050	< 0.50	< 0.010	< 0.050	< 0.050	< 0.010	< 0.0050	< 0.050	< 0.050	< 0.010	< 0.50	81	1.6	12	1000	< 0.30	120	0.34	0.9	17 05 04	Y	Inert
TP2	SO-TP2-01	0 - 4.0	0.027	< 0.050	0.52	< 0.010	0.24	0.10	0.032	< 0.0050	0.13	0.050	0.011	< 0.50	2000	1.8	67	3400	< 0.30	260	3.2	7.5	17 05 04	Y	Non-Hazardous
TP3	SO-TP3-01	1.0 - 4.2	0.046	< 0.050	0.55	< 0.010	< 0.050	0.061	< 0.010	0.0055	0.15	< 0.050	0.020	< 0.50	5600	1.0	21	10000	< 0.30	120	4.4	7.6	17 05 04	Y	Non-Hazardous
TP4	SO-TP4-01	1.0 - 4.4	0.056	< 0.050	0.53	< 0.010	< 0.050	< 0.050	0.028	0.0054	0.10	< 0.050	0.065	0.65	7600	1.0	18	12000	< 0.30	110	22.0	24.0	17 05 03*	Y	Hazardous (Determined based on zinc concentrations using HazWasteOnline tool)
TP5	SO-TP5-01	1.2 - 3.5	0.012	< 0.050	< 0.50	< 0.010	0.11	< 0.050	< 0.010	0.0058	0.10	< 0.050	0.026	< 0.50	4400	1.4	37	4900	< 0.30	76	0.22	1.5	17 05 03*	Y	Hazardous (Determined based on lead & zinc concentrations using HazWasteOnline tool)
TP6	SO-TP6-01	2.5 - 4.3	0.031	< 0.050	< 0.50	< 0.010	0.13	0.051	< 0.010	< 0.0050	0.11	< 0.050	0.048	0.96	14000	< 1.0	49	14000	< 0.30	100	4.2	4.7	17 05 04	Y	Non-Hazardous
TP7	SO-TP7-01	1.6 - 4.6	0.12	< 0.050	0.70	< 0.010	< 0.050	< 0.050	0.016	< 0.0050	0.76	< 0.050	0.033	< 0.50	1300	2.0	380	3400	< 0.30	140	5.1	8.9	17 05 04	Y	Non-Hazardous
TP8	SO-TP8-01	1.5 - 4.1	0.082	0.063	1.4	< 0.010	< 0.050	< 0.050	< 0.010	< 0.0050	0.34	0.058	0.029	< 0.50	2700	2.3	230	4600	< 0.30	200	4.2	10.0	17 05 03*	Y	Hazardous (Determined based on TPH concentrations using HazWasteOnline tool)
TP9	SO-TP9-01	0.3 - 2.2	0.021	< 0.050	< 0.50	< 0.010	< 0.050	< 0.050	< 0.010	< 0.0050	0.22	< 0.050	0.029	< 0.50	1300	1.3	41	2100	< 0.30	90	1.7	3.0	17 05 04	Y	Non-Hazardous
TP10	SO-TP10-01	1.0 - 4.5	0.098	< 0.050	< 0.50	< 0.010	0.37	< 0.050	< 0.010	0.0068	0.18	< 0.050	0.079	1.4	30	< 1.0	16000	16000	< 0.30	87	7.5	11	17 05 03*	Y	Hazardous (Determined based on zinc concentrations from HazWasteOnline tool)
TP11	SO-TP11-01	1.2 - 4.4	0.040	< 0.050	< 0.50	< 0.010	< 0.050	< 0.050	< 0.010	0.0064	0.20	< 0.050	0.065	0.58	16000	< 1.0	39	16000	< 0.30	99	1.4	3.5	17 05 03*	Y	Hazardous (Determined based on lead & zinc concentrations using HazWasteOnline tool)
TP12	SO-TP12-01	0 - 2.7	0.027	< 0.050	< 0.50	< 0.010	< 0.050	< 0.050	< 0.010	< 0.0050	0.15	< 0.050	0.028	< 0.50	700	2.9	26	1500	< 0.30	100	1.2	4.5	17 05 04	Y	Inert
	SO-TP12-02	2.7 - 4.6	0.034	< 0.050	0.56	< 0.010	< 0.050	0.066	< 0.010	< 0.0050	0.15	< 0.050	0.053	< 0.50	13000	< 1.0	440	13000	< 0.30	110	4.2	7.8	17 05 04	Y	Non-Hazardous
TP13	SO-TP13-01	1.5 - 4.0	0.064	< 0.050	0.87	< 0.010	0.69	< 0.050	< 0.010	< 0.0050	0.25	< 0.050	0.023	< 0.50	1900	1.9	110	3300	< 0.30	150	3.7	6.4	17 05 04	Y	Non-Hazardous
TP14	SO- TP14-01	1.0 - 2.3	0.420	< 0.050	0.82	< 0.010	< 0.050	0.056	< 0.010	< 0.0050	0.22	< 0.050	0.023	< 0.50	1300	2.3	77	2900	< 0.30	140	1.9	5.5	17 05 04	Y	Non-Hazardous
	SO- TP14-02	2.3 - 4.4	0.200	0.051	1.5	< 0.010	1.3	< 0.050	0.011	< 0.0050	0.32	0.13	0.030	< 0.50	4000	1.8	250	6000	< 0.30	220	5.3	15	17 05 03*	Y	Hazardous (Determined based on TPH concentrations using HazWasteOnline tool)
TP15	SO- TP15-01	1.0 - 3.2	0.067	0.11	1.0	< 0.010	< 0.050	< 0.050	< 0.010	< 0.0050	0.61	0.10	0.047	< 0.50	3200	1.9	610	6500	< 0.30	350	5.5	12	17 05 03*	Y	Hazardous (Determined based on TPH concentrations using HazWasteOnline tool)
	SO- TP15-02	3.2 - 4.1	0.043	0.075	< 0.50	< 0.010	< 0.050	0.068	< 0.010	< 0.0050	0.23	< 0.050	0.033	< 0.50	1100	2.6	130	2500	< 0.30	160	2.6	3.1	17 05 04	Y	Non-Hazardous
TP16	SO- TP16-01	2.4 - 4.6	0.140	< 0.050	0.72	< 0.010	< 0.050	< 0.050	< 0.010	< 0.0050	0.26	< 0.050	0.025	< 0.50	2400	1.8	64	4100	< 0.30	150	2.8	7.6	17 05 04	Y	Non-Hazardous

Notes:

553	Values are shaded yellow and in Red bold wherever Walshestown Restoration Limited W0254-01 WAC Value is exceeded
~	'~' signifies laboratory analysis not carried out.
-	'-' signifies no Walshestown Restoration Limited W0254-01 WAC Value available.

Table 3. Results of Heavy Metal, Anion, Total Dissolved Solids and Phenol Laboratory Analysis on 10:1 Leachate and TOC/LOI Analysis on Soil Samples taken at Barnageernagh Cove, Skerries, Co. Dublin (Part B)

CHEMICAL SUBGROUPING			Heavy Metals Leachate												Anions			TDS	Phenols	Organic/ Carbon Content of Leachate	Organic/Carbon Content of Soil (Total Pollutant)		EWC Codes	Confirmed Asbestos Free	Soil Waste Classification
			Antimony Low Level CEN 10:1 Leachate	Arsenic Low Level CEN 10:1 Leachate	Barium Low Level CEN 10:1 Leachate	Cadmium Low Level CEN 10:1 Leachate	Chromium Low Level CEN 10:1 Leachate	Copper Low Level CEN 10:1 Leachate	Lead Low Level CEN 10:1 Leachate	Mercury Low Level CEN 10:1 Leachate	Molybdenum Low Level CEN 10:1 Leachate	Nickel Low Level CEN 10:1 Leachate	Selenium Low Level CEN 10:1 Leachate	Zinc Low Level CEN 10:1 Leachate	Sulphate CEN 10:1 Leachate	Fluoride in CEN 10:1 Leachate	Chloride in CEN 10:1 Leachate	Total Dissolved Solids	Total Phenols	Dissolved Organic Carbon	Total Organic Carbon (%)	Loss on Ignition			
Source	Units	WASTE CRITERIA	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	%			
WALSHESTOWN RESTORATION LIMITED WASTE LICENCE W0254-01	WAC Values	INERT WASTE	0.06	0.5	20	0.04	0.5	2	0.5	0.01	0.5	0.4	0.1	4	1000	10	800	4000	1	500	3	-			
WASTE FRAMEWORK DIRECTIVE	WAC Values	STABLE NON-REACTIVE	0.7	2	100	1	10	50	10	0.2	10	10	0.5	50	20000	150	15000	60000	0	800	5	-			
WASTE FRAMEWORK DIRECTIVE	WAC Values	HAZARDOUS WASTE	5	25	300	5	70	100	50	2	30	40	7	200	50000	500	25000	100000	0	1000	6	-			
SOURCE	SAMPLE ID	SAMPLING DEPTH (metres BGL)																							
TP17	SO-TP17-01	2.5 - 4.1	< 0.010	< 0.050	< 0.50	< 0.010	< 0.050	< 0.050	< 0.010	< 0.0050	< 0.050	< 0.050	0.013	< 0.50	22	2.8	15	880	< 0.30	97	1.8	5.2	17 05 04	Y	Inert
TP18	SO-TP18-01	0 - 4.1	0.021	< 0.050	< 0.50	< 0.010	< 0.050	0.057	< 0.010	< 0.0050	0.061	< 0.050	< 0.010	< 0.50	630	2.3	28	1800	< 0.30	160	1.3	4.4	17 05 04	Y	Inert
TP19	SO-TP19-01	0.9 - 3.5	0.017	< 0.050	< 0.50	< 0.010	< 0.050	< 0.050	< 0.010	< 0.0050	0.16	< 0.050	0.058	0.620	16000	<1.0	19	16000	< 0.30	120	0.98	3.2	17 05 04	Y	Non-Hazardous
	SO-TP19-02	3.5 - 4.0	0.032	< 0.050	< 0.50	< 0.010	< 0.050	< 0.050	< 0.010	< 0.0050	0.10	< 0.050	0.025	< 0.50	3100	1.3	14	3400	< 0.30	77	1.2	3.2	17 05 04	Y	Non-Hazardous
TP20	SO-TP20-01	1.3 - 4.0	0.041	< 0.050	0.50	< 0.010	< 0.050	< 0.050	< 0.010	< 0.0050	0.097	< 0.050	0.015	< 0.50	1300	1.9	28	2500	< 0.30	96	1.6	3.8	17 05 03*	Y	Hazardous (Determined based on zinc concentrations using HazWasteOnline tool)
	SO-TP20-02	4.0 - 4.3	< 0.010	< 0.050	< 0.50	< 0.010	1.3	0.096	< 0.010	< 0.0050	< 0.050	< 0.050	0.017	< 0.50	360	1.9	17	900	< 0.30	140	1.8	3.2	17 05 04	Y	Non-Hazardous
TP21	SO-TP21-01	1.3 - 4.0	0.095	< 0.050	0.83	< 0.010	< 0.050	< 0.050	< 0.010	< 0.0050	0.45	0.054	0.027	< 0.50	2300	1.8	160	4300	< 0.30	150	4.3	8.3	17 05 04	Y	Non-Hazardous
TP22	SO-TP22-01	1.6 - 4.2	0.10	0.055	< 0.50	< 0.010	< 0.050	< 0.050	0.011	< 0.0050	0.49	< 0.050	0.026	< 0.50	380	2.3	230	2400	< 0.30	220	4.3	9.5	17 05 03*	Y	Hazardous (Determined based on lead concentrations using HazWasteOnline tool)
TP23	SO-TP23-01	3.5 - 4.0	0.065	< 0.050	< 0.50	< 0.010	< 0.050	< 0.050	< 0.010	< 0.0050	0.16	< 0.050	< 0.010	< 0.50	650	2.0	50	2000	< 0.30	190	2.6	6.6	17 05 03*	Y	Hazardous (Determined based on zinc concentrations using HazWasteOnline tool)
TP25	SO-TP25-01	0.5 - 3.6	0.022	< 0.050	< 0.50	< 0.010	< 0.050	0.12	0.016	< 0.0050	0.087	< 0.050	0.018	< 0.50	93	7.7	37	730	< 0.30	150	1.1	3.8	17 05 04	Y	Inert
TP27	SO-TP27-01	0.5 - 3.5	0.023	0.084	< 0.50	< 0.010	< 0.050	0.13	0.014	< 0.0050	0.11	< 0.050	0.020	< 0.50	160	6.8	45	810	< 0.30	210	0.88	3.1	17 05 04	Y	Inert
TP28	SO-TP28-01	2.2 - 4.0	0.027	< 0.050	< 0.50	< 0.010	< 0.050	0.055	< 0.010	< 0.0050	0.074	< 0.050	0.011	< 0.50	260	3.3	28	1300	< 0.30	130	2.1	6.2	17 05 04	Y	Inert
TP29	SO-TP29-01	1.9 - 4.2	0.040	< 0.050	< 0.50	< 0.010	< 0.050	0.097	0.022	< 0.0050	0.066	< 0.050	0.016	< 0.50	110	6.7	38	860	< 0.30	170	1.6	4.6	17 05 04	Y	Inert
TP31	SO-TP31-01	0 - 3.8	< 0.010	< 0.050	< 0.50	< 0.010	< 0.050	< 0.050	< 0.010	< 0.0050	0.059	< 0.050	< 0.010	< 0.50	100	6.1	20	950	< 0.30	160	1.1	2.9	17 05 04	Y	Inert
TP33	SO-TP33-01	0 - 2.3	< 0.010	< 0.050	< 0.50	< 0.010	< 0.050	< 0.050	< 0.010	< 0.0050	< 0.050	< 0.050	< 0.010	< 0.50	200	3.6	23	630	< 0.30	120	2.7	6.9	17 05 04	Y	Inert
TP36	SO-TP36-01	0.2 - 3.2	0.016	< 0.050	1.1	< 0.010	< 0.050	< 0.050	< 0.010	< 0.0050	0.089	< 0.050	< 0.010	< 0.50	1200	6.1	20	3600	< 0.30	83	1.2	3.3	17 05 04	Y	Non-Hazardous
TP37	SO-TP37-01	0.2 - 3.7	0.11	0.053	0.84	< 0.010	0.097	0.13	< 0.010	< 0.0050	0.29	0.12	0.019	< 0.50	440	3.7	29	2000	< 0.30	140	4.2	4.1	17 05 04	Y	Non-Hazardous
TP38	SO-TP38-01	0.2 - 3.6	0.032	< 0.050	0.75	< 0.010	< 0.050	0.61	< 0.010	< 0.0050	0.073	0.16	< 0.010	< 0.50	4300	1.6	150	6600	< 0.30	230	2.8	8.2	17 05 04	Y	Non-Hazardous
TP48	SO-TP48-01	1.7 - 2.4	0.023	< 0.050	< 0.50	< 0.010	< 0.050	< 0.050	< 0.010	< 0.0050	0.32	< 0.050	0.017	< 0.50	180	2.1	54	1100	<0.30	130	0.73	3.4	18 05 04	Y	Inert
SP1	SO-SP1-01	-	0.035	< 0.050	0.52	< 0.010	< 0.050	< 0.050	< 0.010	< 0.0050	0.14	< 0.050	0.020	< 0.50	530	1.9	55	1100	< 0.30	99	2	4	17 05 04	Y	Inert

Notes:

553	Values are shaded yellow and in Red bold wherever Walshestown Restoration Limited W0254-01 WAC Value is exceeded
~	'~' signifies laboratory analysis not carried out.
-	'-' signifies no Walshestown Restoration Limited W0254-01 WAC Value available.

Table 4. Results of TPH-CWG, BTEX, Polyaromatic Hydrocarbon, PCB and pH (Total Pollutant) Laboratory Analysis on Samples taken from Barnageeragh, Skerries, Co. Dublin (Part A)

CHEMICAL SUBGROUPING				Aliphatics									Aromatics									TPH	
GENERIC ASSESSMENT CRITERIA	Parameter			EC >5-C6	EC >C6-C8	EC >C8-C10	EC >C10-C12	EC >C12-C16	EC >C16-C21	EC >C21-C35	EC >C35-C40	Total Aliphatics	EC >5-C7	EC >C7-C8	EC >C8-C10	EC >C10-C12	EC >C12-C16	EC >C16-C21	EC >C21-C35	EC >C35-C44	Total Aromatics	Total Petroleum Hydrocarbons	Mineral Oil
	Units			mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
DUTCH CRITERIA CRITERIA	Dutch Intervention Levels (IV)			-	-	-	-	-	-	-	-	5000	-	-	-	-	-	-	-	-	-	-	5000
	Dutch Target Level (TV)			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50
LQM/CIEH GENERIC ASSESSMENT CRITERIA	Residential			110	370	110	540 (283)^{vap}	3000 (142)^{sol}	76000	-	76000	-	280	611	151	346	593	770	1230	1230	-	-	-
	Allotment			3900	13000	1700	7300	13000	270000	-	270000	-	57	120	51	74	130	260	1600	1600	-		-
	Commercial			13000 (1150)^{sol}	42000 (736)^{sol}	12000 (451)^{vap}	49000 (283)^{vap}	91000 (142)^{sol}	1800000	-	1800000	-	90000 (4710)^{sol}	190000 (4360)^{vap}	18000 (3580)^{vap}	34500 (2150)^{sol}	37800	28000	28000	28000	-	-	-
CLEA SOIL GUIDELINE VALUES	Calculated SGV			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2009 Published SGV [1]	Residential with plant		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
		Allotment		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
		Industrial/ Commercial		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pre 2008 Published SGV [2]	Residential with plant		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Industrial		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WALSHESTOWN RESTORATION LIMITED WASTE LICENCE W0254-01	Inert WAC Values			-	-	-	-	-	-	-	-	500	-	-	-	-	-	-	-	-	-	-	500
SOURCE	SAMPLE ID	SAMPLING DEPTH (metres BGL)																					
TP1	SO-TP1-01	0 - 3.0		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	11	38	< 1.0	49	49	< 10
	SO-TP1-02	3.0 - 3.5		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 10	< 10
TP2	SO-TP2-01	0 - 4.0		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 10	< 10
TP3	SO-TP3-01	1.0 - 4.2		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 10	< 10
TP4	SO-TP4-01	1.0 - 4.4		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 10	< 10
TP5	SO-TP5-01	1.2 - 3.5		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 10	< 10
TP6	SO-TP6-01	2.5 - 4.3		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 10	< 10
TP7	SO-TP7-01	1.6 - 4.6		< 1.0	< 1.0	< 1.0	7.2	17	72	410	1.4	**510**	< 1.0	< 1.0	< 1.0	< 1.0	1.5	2.7	120	< 1.0	120	630	**510**
TP8	SO-TP8-01	1.5 - 4.1		< 1.0	< 1.0	< 1.0	7.5	57	170	810	190	**1200**	< 1.0	< 1.0	< 1.0	2.1	35	210	1200	110	1600	**2800**	**1200**
TP9	SO-TP9-01	0.3 - 2.2		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 10	< 10
TP10	SO-TP10-01	1.0 - 4.5		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 10	< 10
TP11	SO-TP11-01	1.2 - 4.4		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 10	< 10
TP12	SO-TP12-01	0 - 2.7		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 10	< 10
	SO-TP12-02	2.7 - 4.6		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 10	< 10
TP13	SO-TP13-01	1.5 - 4.0		< 1.0	< 1.0	< 1.0	3.5	20	60	270	10	360	< 1.0	< 1.0	< 1.0	< 1.0	1.3	40	370	< 1.0	410	770	360
TP14	SO- TP14-01	1.0 - 2.3		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 10	< 10
	SO- TP14-02	2.3 - 4.4		< 1.0	< 1.0	< 1.0	8.9	47	110	810	120	**1100**	< 1.0	< 1.0	< 1.0	< 1.0	16	33	220	4.3	280	**1400**	**1100**
TP15	SO- TP15-01	1.0 - 3.2		< 1.0	< 1.0	< 1.0	2.9	37	92	430	38	**600**	< 1.0	< 1.0	< 1.0	< 1.0	6.7	59	380	8.3	460	**1100**	**600**
	SO- TP15-02	3.2 - 4.1		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 10	< 10
TP16	SO- TP16-01	2.4 - 4.6		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 10	< 10
TP17	SO-TP17-01	2.5 - 4.1		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	4.3	88	< 1.0	92	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	1.2	170	< 1.0	170	260	92

Notes:

553 Values are underlined wherever Dutch-TV is exceeded

553 Values are shaded yellow and in Red **bold** wherever Dutch-IV, LIEH/LQM GAC, CLEA Soil Guideline Value or Walshestown Restoration Limited W0254-01Waste Licence WAC Value is exceeded

553 Concentration determined to be hazardous using the HazWasteOnline Tool

~ '~' signifies laboratory analysis not carried out.

- '-' signifies no Dutch Criteria, LIEH/LQM GAC, CLEA Soil Guideline Value or Walshestown Restoration Limited W0254-01 Waste Licence WAC Value available.

1. Based on a sandy loam soil as defined in Environment Agency (2009b) and 6% soil organic matter (SOM).

2. For this project, the lowest SGV values are used for mercury which are the 'Elemental Mercury'.

[sol] GAC presented exceeds the solubility saturation limit, which is presented in brackets

[vap] GAC presented exceed the vapour saturation limit, which is presented in brackets

Table 4. Results of TPH-CWG, BTEX, Polyaromatic Hydrocarbon, PCB and pH (Total Pollutant) Laboratory Analysis on Samples taken from Barnageeragh, Skerries, Co. Dublin (Part A)

CHEMICAL SUBGROUPING				GROs								PAHs																			PCBs	
GENERIC ASSESSMENT CRITERIA	Parameter			Benzene	Toluene	Ethylbenzene	o-xylene	m-xylene	p-xylene	Total Xylene	TOTAL BTEX	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Benzo(a)pyrene	Indeno(123-cd)pyrene	Dibenz(ah)anthracene	Benzo(ghi)perylene	Coronene	Total 17 EPA PAHs	PCB Total of 7 Congeners	pH Soil
	Units			µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	pH Units
DUTCH CRITERIA CRITERIA	Dutch Intervention Levels (IV)			1000	130000	50000	-	-	-	25000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dutch Target Level (TV)			10	10	30	-	-	-	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LQM/CIEH GENERIC ASSESSMENT CRITERIA	Residential			-	-	-	-	-	-	-	-	8.7	850	1000	780	380	9200	670	1600	5.9	9.3	7	-	10	1	4.2	0.9	47	-	-	-	-
	Allotment			-	-	-	-	-	-	-	-	23	160	200	160	90	2200	290	620	10	12	13		23	2.1	7.1	2.3	160	-	-	-	-
	Commercial			-	-	-	-	-	-	-	-	1100 (432)[sol]	100000	100000	71000	23000	540000	23000	54000	97	140	100	-	140	14	62	13	660	-	-	-	-
CLEA SOIL GUIDELINE VALUES	Calculated SGV			96600000	1.88E+11	6.37E+10	-		-	95100000000	3.854E+11	-	-	-	-	-	-	-	-	-	-			-	-	-	-	-	-	-	-	
	2009 Published SGV [1]	Residential with plant		330	610000	350000	250000	240000	230000	720000	-	-	-	-	-	-	-	-	-	-	-			-	-	-	-	-	-	-	-	-
		Allotment		70	120000	90000	160000	180000	160000	500000	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-
		Industrial/ Commercial		95000	4400000	2800000	3E+06	4E+06	3E+06	9300000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pre 2008 Published SGV [2]	Residential with plant		-	14,000	41,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Industrial		-	680,000	########	-	-	-	93000000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WALSHESTOWN RESTORATION LIMITED WASTE LICENCE W0254-01	Inert WAC Values			-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	1	-
SOURCE	SAMPLE ID	SAMPLING DEPTH (metres BGL)																														
TP1	SO-TP1-01	0 - 3.0		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	0.11	< 0.10	< 0.10	< 0.10	1.2	0.33	3.1	2.8	0.95	0.72	1.5	1.2	0.25	0.82	0.51	< 0.10	0.56	< 0.10	13	<0.10	8.0
	SO-TP1-02	3.0 - 3.5		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	8.4
TP2	SO-TP2-01	0 - 4.0		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	7.8
TP3	SO-TP3-01	1.0 - 4.2		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	0.19	< 0.10	0.67	0.74	0.30	0.31	1.4	1.0	0.39	0.52	0.91	< 0.10	1.0	< 0.10	6.0	<0.10	7.5
TP4	SO-TP4-01	1.0 - 4.4		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	0.43	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	7.3
TP5	SO-TP5-01	1.2 - 3.5		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	7.9
TP6	SO-TP6-01	2.5 - 4.3		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	8.0
TP7	SO-TP7-01	1.6 - 4.6		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	8.5
TP8	SO-TP8-01	1.5 - 4.1		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	0.32	< 0.10	< 0.10	0.10	2.3	0.57	6.5	5.3	3.4	3.0	7.3	5.4	1.9	**4.1**	2.5	0.47	2.2	< 0.10	38	<0.10	8.2
TP9	SO-TP9-01	0.3 - 2.2		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	7.7
TP10	SO-TP10-01	1.0 - 4.5		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	7.5
TP11	SO-TP11-01	1.2 - 4.4		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	8.0
TP12	SO-TP12-01	0 - 2.7		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	8.1
	SO-TP12-02	2.7 - 4.6		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	8.1
TP13	SO-TP13-01	1.5 - 4.0		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	8.3
TP14	SO- TP14-01	1.0 - 2.3		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	0.32	1.0	0.90	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	2.2	<0.10	8.0
	SO- TP14-02	2.3 - 4.4		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	0.15	0.85	0.10	0.89	0.69	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	2.7	<0.10	8.0
TP15	SO- TP15-01	1.0 - 3.2		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	0.11	0.86	0.23	2.5	2.2	0.79	0.56	1.10	0.78	0.32	0.76	0.50	< 0.10	0.49	< 0.10	10	<0.10	8.0
	SO- TP15-02	3.2 - 4.1		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	0.13	< 0.10	0.30	0.31	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	7.7
TP16	SO- TP16-01	2.4 - 4.6		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	0.32	0.11	0.73	0.47	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	8.1
TP17	SO-TP17-01	2.5 - 4.1		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	0.16	< 0.10	< 0.10	< 0.10	0.47	< 0.10	0.79	0.80	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	2.2	<0.10	8.1

Notes:

553 Values are underlined wherever Dutch-TV is exceeded

553 Values are shaded yellow and in Red **bold** wherever Dutch-IV, LIEH/LQM GAC, CLEA Soil Guideline Value or Walshestown Restoration Limited W0254-01Waste Licence WAC Value is exceeded

553 Concentration determined to be hazardous using the HazWasteOnline Tool

~ '~' signifies laboratory analysis not carried out.

- '-' signifies no Dutch Criteria, LIEH/LQM GAC, CLEA Soil Guideline Value or Walshestown Restoration Limited W0254-01 Waste Licence WAC Value available.

1. Based on a sandy loam soil as defined in Environment Agency (2009b) and 6% soil organic matter (SOM).

2. For this project, the lowest SGV values are used for mercury which are the 'Elemental Mercury'.

[sol] GAC presented exceeds the solubility saturation limit, which is presented in brackets

[vap] GAC presented exceed the vapour saturation limit, which is presented in brackets

Table 4. Results of TPH-CWG, BTEX, Polyaromatic Hydrocarbon, PCB and pH (Total Pollutant) Laboratory Analysis on Samples taken from Barnageeragh, Skerries, Co. Dublin (Part B)

CHEMICAL SUBGROUPING				Aliphatics									Aromatics									TPH	
GENERIC ASSESSMENT CRITERIA	Parameter			EC >5-C6	EC >C6-C8	EC >C8-C10	EC >C10-C12	EC >C12-C16	EC >C16-C21	EC >C21-C35	EC >C35-C40	Total Aliphatics	EC >5-C7	EC >C7-C8	EC >C8-C10	EC >C10-C12	EC >C12-C16	EC >C16-C21	EC >C21-C35	EC >C35-C44	Total Aromatics	Total Petroleum Hydrocarbons	Mineral Oil
	Units			mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
DUTCH CRITERIA CRITERIA	Dutch Intervention Levels (IV)			-	-	-	-	-	-	-	-	5000	-	-	-	-	-	-	-	-	-	-	5000
	Dutch Target Level (TV)			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50
LQM/CIEH GENERIC ASSESSMENT CRITERIA	Residential			110	370	110	540 (283)[vap]	3000 (142)[sol]	76000	-	76000	-	280	611	151	346	593	770	1230	1230	-	-	-
	Allotment			3900	13000	1700	7300	13000	270000	-	270000	-	57	120	51	74	130	260	1600	1600	-		-
	Commercial			13000 (1150)[sol]	42000 (736)[sol]	12000 (451)[vap]	49000 (283)[vap]	91000 (142)[sol]	1800000	-	1800000	-	90000 (4710)[sol]	190000 (4360)[vap]	18000 (3580)[vap]	34500 (2150)[sol]	37800	28000	28000	28000	-	-	-
CLEA SOIL GUIDELINE VALUES	Calculated SGV			-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2009 Published SGV [1]	Residential with plant		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
		Allotment		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
		Industrial/ Commercial		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pre 2008 Published SGV [2]	Residential with plant		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Industrial		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WALSHESTOWN RESTORATION LIMITED WASTE LICENCE W0254-01	Inert WAC Values			-	-	-	-	-	-	-	-	500	-	-	-	-	-	-	-	-	-	-	500
SOURCE	SAMPLE ID	SAMPLING DEPTH (metres BGL)																					
TP18	SO-TP18-01	0 - 4.1		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	1.7	84	< 1.0	86	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	2.4	90	< 1.0	93	180	86
TP19	SO-TP19-01	0.9 - 3.5		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 10	< 10
	SO-TP19-02	3.5 - 4.0		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 10	< 10
TP20	SO-TP20-01	1.3 - 4.0		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 10	< 10
	SO-TP20-02	4.0 - 4.3		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 10	< 10
TP21	SO-TP21-01	1.3 - 4.0		< 1.0	< 1.0	< 1.0	5.2	58	110	200	< 1.0	370	< 1.0	< 1.0	< 1.0	< 1.0	5.1	14	120	< 1.0	140	510	370
TP22	SO-TP22-01	1.6 - 4.2		< 1.0	< 1.0	< 1.0	< 1.0	4.3	39	180	< 1.0	220	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	8.0	120	< 1.0	130	350	220
TP23	SO-TP23-01	3.5 - 4.0		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	9.7	150	5.2	160	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	1.9	110	< 1.0	110	270	160
TP25	SO-TP25-01	0.5 - 3.6		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	42	< 1.0	42	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	17	< 1.0	17	59	42
TP27	SO-TP27-01	0.5 - 3.5		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 10	< 10
TP28	SO-TP28-01	2.2 - 4.0		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	63	< 1.0	63	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	4.2	90	< 1.0	94	160	63
TP29	SO-TP29-01	1.9 - 4.2		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 10	< 10
TP31	SO-TP31-01	0 - 3.8		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	9.7	260	< 1.0	260	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	38	< 1.0	38	300	260
TP33	SO-TP33-01	0 - 2.3		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 10	< 10
TP36	SO-TP36-01	0.2 - 3.2		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 10	< 10
TP37	SO-TP37-01	0.2 - 3.7		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	5.1	23	3.9	32	32	< 10
TP38	SO-TP38-01	0.2 - 3.6		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	3.3	7.6	< 1.0	11	11	< 10
TP48	SO-TP48-01	1.7 - 2.4		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 10	< 10
SP1	SO-SP1-01	-		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 5.0	< 10	< 10

Notes:

553	Values are underlined wherever Dutch-TV is exceeded
553	Values are shaded yellow and in Red **bold** wherever Dutch-IV, LIEH/LQM GAC, CLEA Soil Guideline Value or Walshestown Restoration Limited W0254-01Waste Licence WAC Value is exceeded
553	Concentration determined to be hazardous using the HazWasteOnline Tool
~	'~' signifies laboratory analysis not carried out.
-	'-' signifies no Dutch Criteria, LIEH/LQM GAC, CLEA Soil Guideline Value or Walshestown Restoration Limited W0254-01 Waste Licence WAC Value available.

1. Based on a sandy loam soil as defined in Environment Agency (2009b) and 6% soil organic matter (SOM).
2. For this project, the lowest SGV values are used for mercury which are the 'Elemental Mercury'.

[sol] GAC presented exceeds the solubility saturation limit, which is presented in brackets

[vap] GAC presented exceed the vapour saturation limit, which is presented in brackets

Table 4. Results of TPH-CWG, BTEX, Polyaromatic Hydrocarbon, PCB and pH (Total Pollutant) Laboratory Analysis on Samples taken from Barnageeragh, Skerries, Co. Dublin (Part B)

CHEMICAL SUBGROUPING				GROs								PAHs																				PCBs	
GENERIC ASSESSMENT CRITERIA	Parameter			Benzene	Toluene	Ethylbenzene	o-xylene	m-xylene	p-xylene	Total Xylene	TOTAL BTEX	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(k)fluoranthene	Benzo(a)fluoranthene	Benzo(a)pyrene	Indeno(123-cd)pyrene	Dibenz(ah)anthracene	Benzo(ghi)perylene	Coronene	Total 17 EPA PAHs	PCB Total of 7 Congeners	pH Soil
	Units			µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	pH Units
DUTCH CRITERIA CRITERIA	Dutch Intervention Levels (IV)			1000	130000	50000	-	-	-	25000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Dutch Target Level (TV)			10	10	30	-	-	-	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LQM/CIEH GENERIC ASSESSMENT CRITERIA	Residential			-	-	-	-	-	-	-	-	8.7	850	1000	780	380	9200	670	1600	5.9	9.3	7	-	10	1	4.2	0.9	47	-	-	-	-
	Allotment			-	-	-	-	-	-	-	-	23	160	200	160	90	2200	290	620	10	12	13		23	2.1	7.1	2.3	160	-	-	-	-
	Commercial			-	-	-	-	-	-	-	-	1100 (432)[sol]	100000	100000	71000	23000	540000	23000	54000	97	140	100	-	140	14	62	13	660	-	-	-	-
CLEA SOIL GUIDELINE VALUES	Calculated SGV			96600000	1.88E+11	6.37E+10	-		-	95100000000	3.854E+11	-	-	-	-	-	-	-	-	-	-			-	-	-	-	-	-	-	-	
	2009 Published SGV [1]	Residential with plant		330	610000	350000	250000	240000	230000	720000	-	-	-	-	-	-	-	-	-	-	-			-	-	-	-	-	-	-	-	-
		Allotment		70	120000	90000	160000	180000	160000	500000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Industrial/ Commercial		95000	4400000	2800000	3E+06	4E+06	3E+06	9300000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pre 2008 Published SGV [2]	Residential with plant		-	14,000	41,000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
		Industrial		-	680,000	########	-	-	-	93000000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
WALSHESTOWN RESTORATION LIMITED WASTE LICENCE W0254-01	Inert WAC Values			-	-	-	-	-	-	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	1	-
SOURCE	SAMPLE ID	SAMPLING DEPTH (metres BGL)																															
TP18	SO-TP18-01	0 - 4.1		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	8.2
TP19	SO-TP19-01	0.9 - 3.5		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	7.7
	SO-TP19-02	3.5 - 4.0		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	7.7
TP20	SO-TP20-01	1.3 - 4.0		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	0.16	< 0.10	0.27	0.29	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	8.1
	SO-TP20-02	4.0 - 4.3		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	8.0
TP21	SO-TP21-01	1.3 - 4.0		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	0.30	< 0.10	0.95	0.92	0.29	0.25	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	2.7	<0.10	8.3
TP22	SO-TP22-01	1.6 - 4.2		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	0.10	< 0.10	< 0.10	< 0.10	0.60	< 0.10	1.1	0.88	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	2.7	<0.10	8.0
TP23	SO-TP23-01	3.5 - 4.0		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	7.9
TP25	SO-TP25-01	0.5 - 3.6		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	7.4
TP27	SO-TP27-01	0.5 - 3.5		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	7.5
TP28	SO-TP28-01	2.2 - 4.0		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	0.81	0.16	2.0	1.8	0.59	0.64	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	6.0	<0.10	8.2
TP29	SO-TP29-01	1.9 - 4.2		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	7.5
TP31	SO-TP31-01	0 - 3.8		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	8.0
TP33	SO-TP33-01	0 - 2.3		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	8.5
TP36	SO-TP36-01	0.2 - 3.2		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	8.2
TP37	SO-TP37-01	0.2 - 3.7		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	0.34	0.25	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	7.8
TP38	SO-TP38-01	0.2 - 3.6		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	7.7
TP48	SO-TP48-01	1.7 - 2.4		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	7.8
SP1	SO-SP1-01	-		< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 0.010	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	0.12	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 0.10	< 2.0	<0.10	8.3

Notes:

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553 Values are shaded yellow and in Red **bold** wherever Dutch-IV, LIEH/LQM GAC, CLEA Soil Guideline Value or Walshestown Restoration Limited W0254-01Waste Licence WAC Value is exceeded

553 Concentration determined to be hazardous using the HazWasteOnline Tool

~ '~' signifies laboratory analysis not carried out.

- '-' signifies no Dutch Criteria, LIEH/LQM GAC, CLEA Soil Guideline Value or Walshestown Restoration Limited W0254-01 Waste Licence WAC Value available.

1. Based on a sandy loam soil as defined in Environment Agency (2009b) and 6% soil organic matter (SOM).

2. For this project, the lowest SGV values are used for mercury which are the 'Elemental Mercury'.

[sol] GAC presented exceeds the solubility saturation limit, which is presented in brackets

[vap] GAC presented exceed the vapour saturation limit, which is presented in brackets

Table 5. Results of Heavy Metals (i.e. Total Pollutant) and Asbestos Screening Laboratory Analysis on Soil Samples taken from Barnageeragh, Skerries, Co. Dublin (Part A)

CHEMICAL SUBGROUPING				Heavy Metals (Total Pollutant)															Asbestos Screening
GENERIC ASSESSMENT CRITERIA	Parameter			Antimony Low Level	Arsenic Low Level	Barium Low Level	Cadmium Low Level	Total Chromium Low Level	Chromium (III) Low Level	Chromium (IV) Low Level	Copper Low Level	Lead Low Level	Nickel Low Level	Molybdenum Low Level	Mercury Low Level	Selenium Low Level	Zinc Low Level	Asbestos Screening
	Units			mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	-
DUTCH CRITERIA CRITERIA	Dutch Intervention Levels (IV)			15	55	625	12	380	-	-	190	530	210	200	10	100	720	-
	Dutch Target Level (TV)			3	29	160	0.8	100	-	-	36	85	35	3	0.3	0.7	140	-
LQM/CIEH GENERIC ASSESSMENT CRITERIA	Residential			-	-	-	3	-	3000	4.3	2330	-	-	-	-	-	3750	-
	Allotment			-	-	-	0.53	-	34600	2.1	524	-	-	-	-	-	618	-
	Commercial			-	-	-	348	-	30400	35	71700	-	-	-	-	-	665000	-
CLEA SOIL GUIDELINE VALUES	2009 Published SGV [1]		Residential with plant	-	32	-	10	-	-	-	-	-	130	-	1	350	-	-
			Allotment	-	43	-	1.8	-	-	-	-	-	230	-	26 [2]	120	-	-
			Industrial/ Commercial	-	640	-	230	-	-	-	-	-	1800	-	26 [2]	13000	-	-
SAMPLE LOCATION	SAMPLE ID	SAMPLING DEPTH (metres BGL)																
TP1	SO-TP1-01	0 - 3.0		2.6	19	250	0.49	36	36	< 0.50	67	110	45	< 2.0	0.17	< 0.20	210	NAD
	SO-TP1-02	3.0 - 3.5		< 2.0	16	56	0.32	20	20	< 0.50	24	32	32	< 2.0	< 0.10	< 0.20	72	NAD
TP2	SO-TP2-01	0 - 4.0		2.2	21	190	0.48	33	33	< 0.50	52	130	46	2.7	0.20	< 0.20	690	NAD
TP3	SO-TP3-01	1.0 - 4.2		**17**	**35**	**770**	1.6	64	64	< 0.50	**270**	**640**	79	8.1	0.33	< 0.20	**940**	NAD
TP4	SO-TP4-01	1.0 - 4.4		13	**59**	490	1.2	53	53	< 0.50	**260**	**740**	90	14	0.80	< 0.20	**1100**	NAD
TP5	SO-TP5-01	1.2 - 3.5		9.9	24	410	2.7	56	56	< 0.50	**810**	**1100**	86	5.6	0.16	< 0.20	**650**	NAD
TP6	SO-TP6-01	2.5 - 4.3		9.8	31	430	**5.3**	49	49	< 0.50	**630**	380	120	7.7	0.41	< 0.20	**730**	NAD
TP7	SO-TP7-01	1.6 - 4.6		13	30	470	2.0	39	39	< 0.50	**200**	310	57	4.9	0.42	< 0.20	560	NAD
TP8	SO-TP8-01	1.5 - 4.1		6.2	23	510	1.1	57	57	< 0.50	100	260	59	3.1	0.76	< 0.20	540	NAD
TP9	SO-TP9-01	0.3 - 2.2		6.4	24	300	2.9	48	48	< 0.50	80	260	59	4.3	0.73	< 0.20	570	NAD
TP10	SO-TP10-01	1.0 - 4.5		**22**	**61**	300	2.6	68	68	< 0.50	**390**	**980**	120	16	0.48	< 0.20	**1300**	NAD
TP11	SO-TP11-01	1.2 - 4.4		**17**	**46**	360	**3.9**	71	71	< 0.50	**560**	**1700**	96	14	0.36	< 0.20	**1500**	NAD
TP12	SO-TP12-01	0 - 2.7		3.2	24	130	0.39	36	36	< 0.50	44	40	50	2.3	0.17	< 0.20	97	NAD
	SO-TP12-02	2.7 - 4.6		9.7	**33**	410	2.7	51	51	< 0.50	**200**	390	85	6.5	0.24	< 0.20	**770**	NAD
TP13	SO-TP13-01	1.5 - 4.0		4.5	23	230	0.70	37	37	< 0.50	110	140	51	3.2	0.28	< 0.20	340	NAD
TP14	SO- TP14-01	1.0 - 2.3		**39**	19	160	0.36	36	36	< 0.50	52	81	41	2.1	0.19	< 0.20	200	NAD
	SO- TP14-02	2.3 - 4.4		**20**	25	310	0.72	40	40	< 0.50	120	260	50	3.5	0.32	< 0.20	320	NAD
TP15	SO- TP15-01	1.0 - 3.2		4.1	22	240	0.54	41	41	< 0.50	75	170	49	3.4	0.25	< 0.20	210	NAD
	SO- TP15-02	3.2 - 4.1		3.4	15	110	0.28	34	34	< 0.50	34	46	42	< 2.0	0.12	< 0.20	110	NAD
TP16	SO- TP16-01	2.4 - 4.6		14	23	260	0.91	40	40	< 0.50	65	150	53	3.0	0.42	< 0.20	420	NAD
TP17	SO-TP17-01	2.5 - 4.1		2.5	18	150	1.7	35	35	< 0.50	60	100	45	2.2	0.15	< 0.20	260	NAD

Notes:

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553 — Concentration determined to be hazardous using the HazWasteOnline Tool

~ — '~' signifies laboratory analysis not carried out.

Table 5. Results of Heavy Metals (i.e. Total Pollutant) and Asbestos Screening Laboratory Analysis on Soil Samples taken from Barnageeragh, Skerries, Co. Dublin (Part B)

CHEMICAL SUBGROUPING				Heavy Metals (Total Pollutant)															Asbestos Screening
GENERIC ASSESSMENT CRITERIA	Parameter			Antimony Low Level	Arsenic Low Level	Barium Low Level	Cadmium Low Level	Total Chromium Low Level	Chromium (III) Low Level	Chromium (IV) Low Level	Copper Low Level	Lead Low Level	Nickel Low Level	Molybdenum Low Level	Mercury Low Level	Selenium Low Level	Zinc Low Level	Asbestos Screening
	Units			mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	-
DUTCH CRITERIA CRITERIA	Dutch Intervention Levels (IV)			15	55	625	12	380	-	-	190	530	210	200	10	100	720	-
	Dutch Target Level (TV)			3	29	160	0.8	100	-	-	36	85	35	3	0.3	0.7	140	-
LQM/CIEH GENERIC ASSESSMENT CRITERIA	Residential			-	-	-	3	-	3000	4.3	2330	-	-	-	-	-	3750	-
	Allotment			-	-	-	0.53	-	34600	2.1	524	-	-	-	-	-	618	-
	Commercial			-	-	-	348	-	30400	35	71700	-	-	-	-	-	665000	-
CLEA SOIL GUIDELINE VALUES	2009 Published SGV [1]		Residential with plant	-	32	-	10	-	-	-	-	-	130	-	1	350	-	-
			Allotment	-	43	-	1.8	-	-	-	-	-	230	-	26 [2]	120	-	-
			Industrial/ Commercial	-	640	-	230	-	-	-	-	-	1800	-	26 [2]	13000	-	-
SAMPLE LOCATION	SAMPLE ID	SAMPLING DEPTH (metres BGL)																
TP18	SO-TP18-01	0 - 4.1		2.1	16	150	0.39	35	35	< 0.50	80	97	50	< 2.0	0.33	< 0.20	220	NAD
TP19	SO-TP19-01	0.9 - 3.5		6.8	27	320	2.3	44	44	< 0.50	120	180	82	5.0	0.13	< 0.20	750	NAD
	SO-TP19-02	3.5 - 4.0		7.2	32	290	2.6	58	58	< 0.50	170	270	80	5.5	0.11	< 0.20	640	NAD
TP20	SO-TP20-01	1.3 - 4.0		12	45	250	2.5	42	42	< 0.50	110	230	68	4.3	0.12	< 0.20	3600	NAD
	SO-TP20-02	4.0 - 4.3		2.4	22	160	0.72	48	48	< 0.50	51	60	57	2.3	< 0.10	< 0.20	220	NAD
TP21	SO-TP21-01	1.3 - 4.0		3.5	29	260	0.60	37	37	< 0.50	160	230	51	3.2	0.20	< 0.20	260	NAD
TP22	SO-TP22-01	1.6 - 4.2		4.2	25	360	0.89	38	38	< 0.50	90	1100	53	3.3	0.34	< 0.20	300	NAD
TP23	SO-TP23-01	3.5 - 4.0		3.1	26	290	1.2	38	38	< 0.50	66	130	51	2.5	0.65	< 0.20	1100	NAD
TP25	SO-TP25-01	0.5 - 3.6		< 2.0	13	72	< 0.10	31	31	< 0.50	24	24	34	< 2.0	< 0.10	< 0.20	62	NAD
TP27	SO-TP27-01	0.5 - 3.5		< 2.0	13	83	< 0.10	36	36	< 0.50	27	29	38	< 2.0	0.10	< 0.20	72	NAD
TP28	SO-TP28-01	2.2 - 4.0		2.4	17	650	0.46	49	49	< 0.50	39	600	46	2.1	0.17	< 0.20	470	NAD
TP29	SO-TP29-01	1.9 - 4.2		< 2.0	15	95	0.18	32	32	< 0.50	25	44	36	< 2.0	< 0.10	< 0.20	84	NAD
TP31	SO-TP31-01	0 - 3.8		< 2.0	22	110	0.27	39	39	< 0.50	28	30	47	< 2.0	< 0.10	< 0.20	84	NAD
TP33	SO-TP33-01	0 - 2.3		6.3	24	180	3.8	43	43	< 0.50	68	110	51	6.3	0.15	< 0.20	240	NAD
TP36	SO-TP36-01	0.2 - 3.2		2.5	22	120	0.73	26	26	< 0.50	47	45	47	2.1	0.71	0.70	110	NAD
TP37	SO-TP37-01	0.2 - 3.7		2.7	21	160	1.7	26	26	< 0.50	48	74	40	2.7	0.24	0.73	210	NAD
TP38	SO-TP38-01	0.2 - 3.6		3.9	22	210	1.4	41	41	< 0.50	97	140	53	3.1	0.44	0.93	500	NAD
TP48	SO-TP48-01	1.7 - 2.4		<2.0	28	100	1.0	43	43	< 0.50	28	23	47	3.1	< 0.10	1.40	74	NAD
SP1	SO-SP1-01	-		6.9	36	480	1.8	48	48	< 0.50	430	520	71	4.9	0.22	< 0.20	560	NAD

Notes:

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553 — Concentration determined to be hazardous using the HazWasteOnline Tool

~ — '~' signifies laboratory analysis not carried out.

- — '-' signifies no Dutch Criteria, LIEH/LQM GAC, CLEA Soil Guideline Value or Walshestown Restoration Limited Waste Licence WAC Value available.

1. Based on a sandy loam soil as defined in Environment Agency (2009b) and 6% soil organic matter (SOM).

6.2.3 Laboratory Results on Soil (Total Pollutant Analysis)

Total Petroleum Hydrocarbons (TPH)/Mineral Oil Total/Core Working Group (CWG)

As can be seen from Table 4, of the 40 samples analysed, mineral oil (i.e. aliphatic hydrocarbons) was detected above the Inert WAC limit in 4 soil samples. This occurred in samples SO-TP7-01, SO-TP8-01, SO-TP14-02 & SO-TP15-01 whereby concentrations ranged from 510mg/kg – 1,100mg/kg. The concentration of Total Petroleum Hydrocarbon was also highest in these 4 samples ranging from 630mg/kg – 2,800mg/kg.

BTEX (Benzene, Toluene, Ethylbenzene, o-, m- and p-xylenes)

Of the 4 compounds analysed, none were detected in the 40 samples tested (see Table 4).

Polyaromatic Hydrocarbons (17 speciated including Coronene)

The total polyaromatic hydrocarbon (PAH-17) concentrations (i.e. for 17 individual) ranged from <2mg/kg (i.e. Method Detection Limit) to 38mg/kg (see Table 4). In total, PAHs were detected above the method detection limit in 10 samples however no Total PAH-17 was detected in the 40 samples tested at levels above the inert WAC limit (100mg/kg).

Of the 17 individual PAHs, there was an exceedance of the Benzo(a)pyrene Residential LQM/CIEH Generic Assessment Criteria (1mg/kg) in 1 sample (see Table 4). This occurred in sample SO-TP8-01 (4.1mg/kg) which coincides with the samples where the Total PAH-17 concentration was highest.

Polychlorinated Biphenyls (PCBs - 7 congeners)

Total polychlorinated biphenyls (PCB) concentrations were below the limits of detection in all 40 samples (see Table 4).

Total Organic Carbon (%)

Total Organic Carbon (TOC) was detected above the Inert WAC limit of 3% in 14 in any of the 40 soil samples analysed (see Table 3). These exceedances ranged from 3.2% - 22%, with the highest value recorded in SO-TP4-01 (22%).

Loss on Ignition (LOI)

Loss on Ignition (LOI) analysis was also carried out on the 40 soil samples (see Table 3). Loss on Ignition values ranged from 0.9% to 24% across the samples.

Heavy Metals- As, Ba, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Sb, Se and Zn

Of the 12 total metals analysed (see Table 5):

- Antimony exceeded the Dutch Intervention Value of 15mg/kg in 5 of the 40 samples;
- Arsenic exceeded the CLEA Residential Soil Guideline Value of 32mg/kg in 7 of the 40 samples;
- Barium exceeded the Dutch Intervention Level (IV) of 625mg/kg in 2 of the 40 samples;
- Cadmium exceeded the LQM/CIEH Residential Generic Assessment Criteria Value of 3mg/kg in 3 of the 40 samples;

- Copper exceeded the Dutch Intervention Level of 190mg/kg in 9 of the 40 samples;
- Lead exceeded the Dutch Intervention Level (IV) of 530mg/kg in 7 of the 40 samples; and
- Zinc exceeded the Dutch Intervention Level (IV) of 720 mg/kg in 9 of the 40 samples.

Chromium speciation – Cr (III) and Cr (VI)

Chromium (III) ranged from 20 – 71 mg/kg in the 40 samples analysed (see Table 5). All 40 samples were below the corresponding Residential LQM/CIEH GAC. No Cr (VI) was detected in any of the 40 soil samples analysed.

pH

The pH of the 40 samples analysed ranged from 7.3 to 8.5 (see Table 4).

VOCs (Volatile organic compounds)

As stated previously, Volatile Organic Compound (VOCs) analysis was conducted on 5 of the 40 samples. No VOCs were detected above the method detection limit in 4 of the 5 samples (see Table A18.1 in Appendix 18). Vinyl Chloride and cis 1,2-Dichloroethene were detected in SO-TP21-01 at concentrations of 2.1µg/l and 11µg/l respectively.

SVOCs (Semi-volatile organic compounds)

Similarly, Semi Volatile Organic Compound (SVOCs) analysis was conducted on 5 of the 40 samples. With the exception of the PAHs discussed previously, no SVOCs were detected above the method detection limit in any of the 5 samples (see Table A18.2 in Appendix 18).

6.2.4 Hazardous Waste Assessment

An assessment of the hazardous properties of all 40 soil samples was conducted using the HazWasteOnline™ tool (see Appendix 20). The parameters assessed included the total heavy metals, speciated chromium, pH, individual PAHs, BTEX compounds, PCBs and TPH.

Ten of the 40 samples assessed using the HazWasteOnline™ tool were deemed to be Hazardous in nature based on their chemical composition:

- Samples SO-TP8-01, SO-TP14-02 & SO-TP15-01 were classified as hazardous due to their TPH concentration;
- Samples SO-TP4-01, SO-TP10-01, SO-TP20-01 & SO-TP23-01 were classified as hazardous due to their zinc concentration;
- Sample SO-TP22-01 was classified as hazardous based on its lead concentration; and
- Samples SO-TP5-01 and SO-TP11-01 were classified as hazardous based on their zinc and lead concentrations.

6.2.5 Summary of Results

Summary of Waste Classification Results

In total, 13 of the 40 soil samples analysed can be classified as Inert. All five soil samples taken outside the boundary of the landfill were found to be Inert. In addition, 7 samples taken from 6 trialpits excavated within the landfilled area and 1 sample taken from the stockpile were also classified as Inert.

Seventeen soil samples taken from 16 trialpits excavated within the landfill area were classified as Non-Hazardous (see Figure 7) based on a variety of parameters including antimony, chromium, molybdenum, sulphate, chloride, total dissolved solids, total organic carbon and mineral oil.

Ten soil samples taken from 10 individual trialpits were classified as 'Hazardous' in nature. These trialpits were located right across the landfill body and their locations do not have a discernible pattern.

It should be noted that no asbestos fibres were detected in any of the 40 samples analysed (see Figure 7).

Summary of Generic Quantitative Risk Assessment Results

Of the 40 samples analysed, there was an exceedance in the Residential CLEA Soil Guideline Value, LQM/CIEH Generic Assessment Criteria or Dutch Intervention Value in 18 samples. This included an exceedance in one or more metals in 17 samples and 1 exceedance in Benzo(a)pyrene (SO-TP8-01).

6.3 Laboratory Results (DQRA Suite (CEC, TOM, Kjeldahl N, nitrates, nitrites, chloride, sulphide, major cations, etc)

The results of the laboratory analyses on the 15 soil samples by Southern Scientific, which was completed to facilitate the Detailed Quantitative Risk Assessment of groundwater by HUCT, are presented in Table A18.33 in Appendix 18. It should be noted that for the parameters assessed, there are no comparative assessment criteria.

7 ENVIRONMENTAL TOPSOIL RESULTS & GQRA

7.1 Laboratory Suite & Generic Assessment Criteria

In order to determine if any risk exists from the topsoil used in the landscaping of the grassed area at Hamilton Hill, it was decided to take 2 composited topsoil samples from 2 areas within the landscaped area from 0-0.3m below ground level (bgl)(see Figure 14D). These areas are an area to the southeast of the cairn and overlying the footprint of the historic landfill Type 1 waste (i.e. TS1) and an area outside the footprint of the landfill, to the northwest of the cairn and which is underlain by undisturbed subsoil (i.e. TS2). Each composited topsoil sample was made up of 10 separate subsamples taken from the upper 30cm of topsoil using a hand-held soil auger. Each of the 10 soil subsamples was placed in a clean bucket and mixed thoroughly prior to transfer to laboratory containers. As mentioned previously both soil samples were analysed for the laboratory suites outlined in Section 3. An inventory of the soil samples taken is given in Table 1. The results of laboratory analyses carried out by Mulroy Environmental on the topsoil samples taken from the landscaped area are presented in the following tables which are located in Appendix 18:

- Table A18.34 Results of Heavy Metals (i.e. Total Pollutant) Laboratory Analysis on Topsoil Samples taken from Barnageeragh Cove, Skerries, Co. Dublin;
- Table A18.35 Results of TPH-CWG, BTEX, Polyaromatic Hydrocarbon, PCB and pH (Total Pollutant) Laboratory Analysis on Topsoil Samples taken from Barnageeragh Cove, Skerries, Co. Dublin;
- Table A18.36. Volatile Organic Compound (VOC) Laboratory Results on Topsoil Samples taken from Barnageeragh Cove, Skerries, Co. Dublin;
- Table A18.37. Semi-Volatile Organic Compound (sVOC) Laboratory Results for Topsoil Samples taken from Barnageeragh Cove, Skerries, Co. Dublin;
- Table A18.38. Organo-phosphorus, Organo-nitrogen and Organo-chlorine Pesticides Laboratory Results for Topsoil Samples taken from Barnageeragh Cove, Skerries, Co. Dublin; and
- Table A18.39 Results of Heavy Metal, Anion, Total Dissolved Solids and Phenol Lab. Analysis on 10:1 Leachate from Topsoil Samples and TOC/LOI Lab. Analysis on Topsoil Samples taken from Barnageeragh Cove, Skerries, Co. Dublin.

The results in the above tables are also laid out to compare the soil quality results against the generic assessment criteria for topsoil described in Section 4. It should be noted that given the end use of the topsoil in question (i.e. landscaped green 'kickabout' area within a residential estate) and the organic matter levels found in the topsoil (i.e. ranging from 1-1.4%), the ***'Public Open Space 1 (Residential) – 1% Soil Organic Matter'*** GACs for the CS4L and S4UL were selected. It should be noted that the Dutch Criteria Target Values are regarded as background values (i.e. normal levels) for soils in the Netherlands which are typically sandy estuarine soils and should be regarded as conservative for Irish soils which are typically boulder till clays with a high binding capacity (i.e. Cation Exchange Capacity (CEC).

7.2 Laboratory Results on Topsoil (Total Pollutant Analysis)

Heavy Metals- As, Ba, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Sb, Se and Zn

Of the 12 total metals analysed (see Table A18.34) only one metal exceeded a GAC:

- Nickel exceeded the Dutch Target Value of 35mg/kg in topsoil sample, TS1 (i.e. 37mg/kg).

As stated previously, the Dutch Criteria Target Values are regarded as background values (i.e. normal levels) for soils in the Netherlands which are typically sandy estuarine soils and should be regarded as conservative for Irish soils which are typically boulder till clays with a high binding capacity (i.e. Cation Exchange Capacity (CEC).

Chromium speciation – Cr (III) and Cr (VI)

Chromium (III) ranged from 25-30 mg/kg in the 2 samples analysed (see Table A18.34). Both results were significantly lower than the corresponding S4UL *'Public Open Space 1 (Residential) – 1% Soil Organic Matter'* GAC of 1,500mg/kg.

Total Petroleum Hydrocarbons (TPH)/Mineral Oil Total/Core Working Group (CWG)

As can be seen from Table A18.35 in Appendix 18, petroleum hydrocarbons were not detected within the 2 topsoil samples tested.

BTEX (Benzene, Toluene, Ethylbenzene, o-, m- and p-xylenes)

As can be seen from Table A18.35 in Appendix 18, no BTEX compounds were detected within the 2 topsoil samples tested.

Polyaromatic Hydrocarbons (17 speciated including Coronene)

As can be seen from Table A18.35 in Appendix 18, no Polyaromatic Hydrocarbons (PAH) were detected within the 2 topsoil samples tested.

Polychlorinated Biphenyls (PCBs - 7 congeners)

As can be seen from Table A18.35 in Appendix 18, no polychlorinated biphenyls (PCB) were detected within the 2 topsoil samples tested.

pH

The pH of the 2 samples analysed ranged from 8.0 to 8.1 (see Table A18.35).

VOCs (Volatile organic compounds)

No VOCs were detected above the method detection limit in the 2 topsoil samples (see Table A18.36 in Appendix 18).

SVOCs (Semi-volatile organic compounds)

No sVOCs were detected above the method detection limit in the 2 topsoil samples (see Table A18.37 in Appendix 18).

Pesticides (Organo-phosphorous, Organo-chlorine and Acid Herbicide)

No Organo-phosphorous, Organo-chlorine and Acid Herbicide pesticides were detected above the method detection limit in the 2 topsoil samples (see Table A18.38 in Appendix 18).

Total Organic Carbon (%)

Total Organic Carbon (TOC) was detected found to be below the Inert WAC limit of 3% in both topsoil samples analysed (see Table A18.39 in Appendix 18).

7.3 Laboratory Results (WAC Leachate)

7.3.1 Asbestos screening

It should be noted that both of the topsoil samples were screened for asbestos and both tested negative for asbestos fibres (see Table A18.39 in Appendix 18).

7.3.2 Laboratory Results on Leachate

CEN leachate extraction (i.e. 10:1 liquid to solid) was carried out on each of 2 topsoil samples in Table 3. It should be noted that only Waste Acceptance Criteria values are available for leachate concentration assessment and that no risk based Dutch Criteria values, C4SL or S4UL values are available. This is because Waste Acceptance Criteria are only applicable for waste assessment and, in particular on this site, for Inert Waste.

Heavy Metals - As, Ba, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Sb, Se and Zn

As can be seen from Table A18.39, neither of the topsoil samples had an exceedance of Inert waste criteria in the metal leachate analysis.

Sulphate

Of the 2 topsoil samples analysed, sulphates (SO_4^{2-}) were detected within the leachate in concentrations from 60mg/kg to 280mg/kg. These values did not exceed the Inert Value of 1000mg/kg for sulphate (see Table A18.39).

Fluoride (F^-)

Fluorides (F^-) were not detected in the 2 subsoil samples above the respective inert WAC value of 10mg/kg (see Table A18.39).

Chloride (Cl^-)

Of the 2 topsoil samples analysed, Chlorides (Cl^-) were detected within the leachate in concentrations ranging from 87mg/kg to 210mg/kg. These values did not exceed the Inert Value of 800mg/kg for Chlorides (Cl^-) (see Table A18.39).

Total Dissolved Solids (TDS)

Total dissolved solids (TDS) were detected in both topsoil samples in concentrations ranging from 1,400mg/kg to 1,900mg/kg. These values did not exceed the Inert Value of 4,000mg/kg for TDS (see Table A18.39).

Total Phenols

Total Phenol analysis was carried out on the leachate extracted from the 2 topsoil samples (see Table A18.39). No Phenols were detected within the leachate extracted from the topsoil samples submitted.

Dissolved Organic Carbon (DOC)

Dissolved Organic Carbon (DOC) was not detected in the topsoil samples above the respective inert WAC value (500mg/kg) (see Table A18.39).

7.4 Summary of Results

Summary of Generic Quantitative Risk Assessment Results

Of the 12 total metals analysed (see Table A18.34) only one metal, nickel, in topsoil sample TS1 marginally exceeded a GAC, the Dutch Target Value of 35mg/kg in topsoil sample, TS1 (i.e. 37mg/kg). As stated previously, the Dutch Criteria Target Values are regarded as background values (i.e. normal levels) for soils in the Netherlands which are typically sandy estuarine soils and should be regarded as conservative for Irish soils which are typically boulder till clays with a high binding capacity (i.e. Cation Exchange Capacity (CEC). A review of the Geochemical Atlas for Ireland indicates that soils in the North Dublin area typically contain nickel in exceedance of 37.5mg/kg (see Plate 26 below and extracts of Geochemical Atlas in Appendix 18.). It should also be noted that results for both samples for most parameters were very similar.

Summary of Waste Classification Results

Both topsoil samples analysed would be classified as Inert waste if they were ever discarded, and as expected, no asbestos fibres were found.

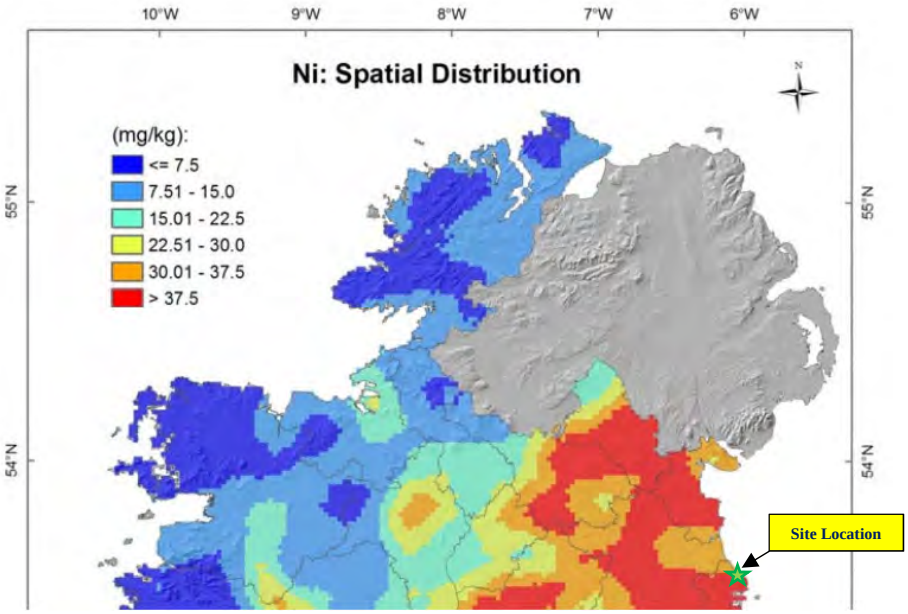

Plate 26. Nickel distribution in North Dublin area (Extract of Geochemical Atlas of Ireland)

8 ENVIRONMENTAL GROUNDWATER RESULTS & GQRA

8.1 Groundwater Sampling Rounds, Laboratory Suite & Generic Assessment Criteria

Three rounds of groundwater quality monitoring were conducted for the boreholes on-site (see Figure 8). The first round of groundwater samples was taken on the 27th June 2017 (BH1 – BH4) and on the 2nd of August 2017 (BH8 – BH13). At that juncture, borehole BH14 had not been installed. The second round of monitoring was completed on the 15th November 2017 the 11 onsite (i.e. at that juncture) groundwater monitoring boreholes (i.e. including BH14). The third round of sampling was completed on the 24th May 2018 after boreholes, BH15 – BH17 were installed. The final round of sampling involved all 14 groundwater wells being sampled.

A leachate sample was taken from one of the 3 shallow leachate wells, BH7 on the 21st of February 2018 and analysed solely for ammonia. This sample was taken in order to aid in the development of the DQRA for the project. An attempt was made to collect leachate from BH7 on the 24th May, 2017. However, no leachate was observed (i.e. during the 3rd round of groundwater monitoring).

It should be noted that the borehole logs for the 21 installed groundwater wells and gas monitoring wells are located in Appendix 8.

The groundwater well monitoring logs for each of the 14 groundwater monitoring wells are located in Appendix 10.

Samples were collected into laboratory-supplied bottles, and sent in suitably chilled coolboxes by courier to the laboratories of Chemtest Ltd. (UKAS accredited laboratory) in the UK and City Analysts, Ringsend, Dublin 4 Strict chain of custody procedures was adhered-to. The surface water suite selected is consistent with the parameters outlined in Table C.2 of the *EPA Landfill Manuals – Landfill Monitoring, 2003*. Table D.2 of the manual recommends trace organic substances that should be included in the determination. Volatile organic carbons, SVOCs, organo-nitrogen pesticides, organochlorine pesticides, herbicides and phenols were included for analysis. Tributyltin (i.e. anti-fouling paint) and organo-phosphorous pesticides (i.e. sheep dip, etc) were not deemed to be required. The laboratory suite is detailed in Task 3B of Section 3.

The following table, Table 6 represent the results of the inorganic and microbiological analyses on the groundwater. The results of the organic compound analyses (i.e. TPH, BTEX & PAHs), the Volatile Organic Compound (VOC), Semi-volatile Organic Compound (sVOC) and Organo-chlorine pesticide analyses are located in Tables A18.3 to A18.22 in Appendix 18. Ion balance calculations for each of the sampling rounds is located on Appendix 18.

The results in the above Table 6 are laid out to compare the groundwater quality results against the generic assessment criteria described in Section 4.

Table 6. Results of Inorganic and Microbiological Laboratory Analysis on Samples taken from Groundwater Monitoring Wells BH1 to BH4 and BH8 – BH17 at Barnegeeragh Cove, Skerries, Co. Dublin

Parameter	Units	*S.I. No. 122 of 2014 European Union (Drinking Water) Regulations 2014* *Parametric & Indicator Values*	*EPA Guideline Values - From Interim Report on 'Towards Setting Guideline Values for the Protection of Groundwater in Ireland'.* *Interim Guideline Values*	*EC Environmental Objectives (Groundwater Regulations) Statutory Instrument No. 9, 2010.* *Threshold Values*	Analytical Results: ON-SITE BOREHOLES																																
					BH1 (June 2017)	BH1 (Nov. 2017)	BH1 (May.2018)	BH2 (June 2017)	BH2 (Nov. 2017)	BH2 (May.2018)	BH3 (June 2017)	BH3 (Nov. 2017)	BH3 (May.2018)	BH4 (June 2017)	BH4 (Nov. 2017)	BH4 (May.2018)	BH8 (August 2017)	BH8 (Nov. 2017)	BH8 (May.2018)	BH9 (August 2017)	BH9 (Nov. 2017)	BH9 (May.2018)	BH10 (August 2017)	BH10 (Nov. 2017)	BH10 (May.2018)	BH11 (August 2017)	BH11 (Nov. 2017)	BH11 (May.2018)	BH12 (August 2017)	BH12 (Nov. 2017)	BH12 (May.2018)	BH13 (August 2017)	BH13 (Nov. 2017)	BH13 (May.2018)	BH14 (Nov. 2017)	BH14 (May.2018)	BH15 (May.2018	BH16 (May.2018)	BH17 (May.2018)
Physico-Chemical Parameters																																				
pH		-	*6.5<pH<9.5*	-	7.5	7.9	8.0	7.6	7.8	8.0	7.8	7.6	7.9	7.7	7.3	7.7	8.1	7.9	7.9	8.2	7.8	8.1	7.5	7.4	7.3	8.1	7.2	7.5	8.1	7.6	7.9	8.2	7.7	7.9	7.9	7.2	8	7.8	8.1
Electrical cond. (EC)	µS/cm	*2500*	*1000*	*800-1875*	**5500**	**10000**	**7800**	950	690	720	**1300**	**1800**	**1800**	**1200**	**1900**	**1900**	880	**1000**	**1100**	760	**1100**	**1200**	**1100**	**1400**	**1500**	**1300**	**2100**	**2600**	**1100**	**1400**	**1500**	550	960	820	680	**1800**	710	**1100**	850
Temperature	°C	-	-	-	18.0	15.0	14.0	18.0	15.0	14.0	18.0	15.0	14.0	18.0	15.0	14.0	15.0	15.0	14.0	15.0	15.0	14.0	15.0	15.0	14.0	15.0	15.0	14.0	15.0	15.0	14.0	15.0	15.0	14.0	15.0	14.0	14.0	14.0	14.0
Dissolved oxygen (DO)	mg/l	-	-	-	7.2	8.3	8.3	6.6	8.3	8.7	7.4	8.3	8.7	7.2	8.3	8.8	8.0	8.4	8.9	8.0	8.3	9.0	7.9	8.3	8.5	7.8	8.2	8.3	7.9	8.3	8.6	7.9	8.2	8.7	8.4	8.8	8.6	8.4	8.6
Standard Chemistry																																				
Total Dissolved Solids (TDS)	mg/l	-	*1000*	-	**3300**	**6100**	**4700**	570	410	430	790	**1100**	**1100**	39	**1200**	**1200**	520	630	660	450	660	710	650	840	890	800	**1200**	**1600**	650	820	880	330	580	490	410	**1100**	430	680	510
Total Suspended Solids (TSS)	mg/l	-	-	-	11	38000	8900	23000	9400	3700	< 5.0	6100	4800	< 5.0	3500	7600	59000	6600	5900	25000	30000	3100	26000	2600	4300	2900	260	400	8000	130	180	780	2700	4500	1800	250	4300	2900	<5.0
Chemical Oxygen Demand (COD)	mg/l	-	-	-	21	47	139	< 10	< 10	<10	< 10	< 10	99	26	32	181	< 10	11	52	20	25	60	28	15	84	34	30	45	19	10	14	< 10	< 10	37	< 10	69	27	53	11
Total alkalinity (as $CaCO_3$)	mg/l	-	-	-	360	500	700	340	280	340	300	330	360	490	650	850	350	310	400	390	390	500	510	460	630	660	640	790	480	360	430	370	330	360	280	640	340	450	370
Ammonia (as free N)	mg/l	-	-	-	0.089	0.88	9.44	0.019	0.039	<0.010	0.023	0.019	<0.010	0.063	0.081	9.25	0.015	0.043	0.046	0.016	0.030	0.552	0.010	0.017	0.185	0.83	0.16	25.99	0.18	0.076	1.9	0.020	0.033	0.013	0.043	0.051	5.28	0.056	0.399
Ammoniacal Nitrogen (NH3-N)	mg/l	-	*0.15*	*0.065-0.175*	**4.0**	**18.0**	**10.0**	**0.66**	**0.86**	**0.59**	**0.55**	**0.72**	**0.31**	**1.9**	**5.5**	**7.8**	**0.19**	**0.86**	**0.30**	**0.16**	**0.71**	**0.65**	**0.45**	**0.93**	**0.71**	**11**	**14**	**23**	**2.0**	**2.6**	**3.4**	**0.21**	**0.86**	**0.60**	**0.86**	**4.7**	**0.33**	**0.19**	**0.49**
Nitrate (NO_3)	mg/l	*50*	*25*	*37.5*	< 0.50	< 0.50	0.93	3.5	3.8	5.6	2.6	10	**54**	< 0.50	< 0.50	0.99	21	0.73	1.70	< 0.50	< 0.50	<0.50	0.52	< 0.50	<0.50	< 0.50	< 0.50	<0.50	3.2	6.5	23	0.59	1.50	**30**	< 0.50	13	<0.50	<0.50	12
Nitrite (NO_2)	mg/l	*0.5*	*0.1*	*0.375*	0.042	**0.16**	**0.13**	**0.31**	< 0.020	<0.020	**0.16**	**0.690**	0.041	0.037	< 0.020	<0.020	**0.30**	**0.10**	<0.020	**0.29**	< 0.020	0.250	0.087	< 0.020	0.094	**0.23**	< 0.020	0.04	**0.43**	0.022	0.052	0.068	0.097	<0.020	0.028	**2.1**	0.032	<0.020	<0.020
Total Organic Nitrogen (TON)	mg/l	-	-	-	2.1	8.2	6.7	1.8	2.6	<1.0	1.3	1.8	5.5	2.2	1.5	3.0	2.9	1.1	<1.0	2.8	1.9	<1.0	2.8	1.4	2.3	4.0	3.0	4.7	< 1.0	1.1	4.4	2.5	1.0	1.6	1.4	3.4	<1.0	<1.0	1.8
Total Nitrogen (TN)	mg/l	-	-	-	6.1	26.0	17.0	3.2	4.3	2.0	2.4	4.8	18.0	4.1	7.1	11.0	7.7	2.1	1.0	3.1	2.6	1.0	3.4	2.3	3.0	15.0	17.0	28.0	3.2	5.1	13.0	2.8	2.2	9.0	2.2	11.0	<1.0	<1.0	5.0
Chloride Cl^-	mg/l	*250*	*30*	*24-187.5*	**1100**	**2200**	**1300**	**30**	**37**	**40**	**55**	**72**	**68**	**81**	**120**	**90**	**56**	**61**	**62**	**67**	**58**	**64**	**62**	**58**	**47**	**110**	**140**	**180**	**82**	**71**	**86**	**39**	**37**	28	**32**	**80**	**35**	**42**	**44**
Sulphide S^{2-}	mg/l	-	-	-	< 0.050	< 0.050	<0.050	< 0.050	< 0.050	<0.050	< 0.050	< 0.050	<0.050	< 0.050	< 0.050	<0.050	< 0.050	< 0.050	<0.050	< 0.050	< 0.050	<0.050	< 0.050	< 0.050	<0.050	0.056	< 0.050	<0.050	< 0.050	< 0.050	<0.050	< 0.050	< 0.050	<0.050	< 0.050	<0.050	<0.050	<0.050	<0.050
Sulphate SO_4	mg/l	*250*	*200*	*187.5*	**1700**	**3200**	**2400**	110	55	64	**400**	**490**	**600**	180	110	130	**190**	**200**	180	120	100	120	80	73	26	180	**230**	**430**	**220**	**240**	**300**	61	110	50	39	**230**	45	150	97
Flouride (F-)	mg/l	*0.8*	1	-	< 0.050	0.26	0.11	0.10	0.14	0.13	0.11	0.09	0.11	0.14	0.13	0.16	0.13	0.11	0.13	0.16	0.13	0.14	0.14	0.10	0.12	0.13	0.11	0.12	0.12	0.10	0.11	0.19	0.12	0.12	0.12	0.16	0.13	0.12	0.14
Molybdate Reactive Phosphate (as P)	mg/l	-	*0.03*	*0.035*	**0.055**	< 0.050	<0.20	**0.051**	< 0.050	<0.20	**0.056**	< 0.050	<0.20	**0.059**	< 0.050	<0.20	**0.051**	< 0.050	<0.20	**0.054**	< 0.050	<0.20	< 0.050	< 0.050	<0.20	< 0.050	< 0.050	<0.20	< 0.050	< 0.050	<0.20	**0.057**	< 0.050	<0.20	< 0.050	<0.20	<0.20	<0.20	<0.20
Major Cations																																				
Potassium (K)	mg/l	-	*5*	-	**210**	**930**	**510**	**6.6**	**21**	**6.5**	**11**	**30**	**40**	**26**	**50**	**6.2**	**7.9**	**7.2**	**6**	**6.1**	**5.8**	4.7	**8.1**	**7.6**	**5.2**	**63**	**91**	**120**	**38**	**32**	**27**	**6.8**	**6.5**	3.1	**5**	**51**	4	**6.9**	2.8
Sodium (Na)	mg/l	*200*	*150*	*150*	**380**	**1400**	**570**	42	47	25	110	57	57	95	83	48	45	44	44	41	40	43	38	43	32	74	100	140	55	51	58	32	30	21	25	67	23	26	23
K/Na Ratio					0.55	0.66	0.89	0.16	0.45	0.26	0.10	0.53	0.70	0.27	0.60	0.13	0.18	0.16	0.14	0.15	0.15	0.11	0.21	0.18	0.16	0.85	0.91	0.86	0.69	0.63	0.47	0.21	0.22	0.15	0.20	0.76	0.17	0.27	0.12
Calcium (Ca)	mg/l	-	*200*	-	**440**	**740**	**360**	160	150	190	**290**	**340**	**430**	**250**	**340**	**210**	170	180	180	160	190	**200**	**200**	**280**	**330**	**210**	**350**	**400**	**200**	**210**	**240**	120	190	170	130	**320**	130	**220**	160
Magnesium (Mg)	mg/l	-	*50*	-	**280**	**950**	**410**	40	41	33	**91**	**60**	**53**	**83**	**99**	48	42	44	45	42	**50**	**55**	38	38	40	**68**	**100**	**130**	**52**	46	49	26	33	20	29	**74**	28	44	21
Heavy Metals																																				
Aluminium (Al)	µg/l	*200*	*200*	*150*	< 10	< 10	17	95	< 10	<10	< 10	< 10	<10	87	< 10	<10	< 10	< 10	<10	< 10	< 10	<10	< 10	< 10	<10	27	< 10	<10	< 10	< 10	**160**	< 10	< 10	<10	< 10	<10	<10	<10	<10
Antimony (Sb)	µg/l	*5*	-	-	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	1.0	< 1.0	<1.0	1.7	< 1.0	<1.0	1.4	< 1.0	<1.0	< 1.0	< 1.0	<1.0	1.3	< 1.0	<1.0	**6.2**	2.1	1.2	2.0	<1.0	2.1	4.1	<1.0
Arsenic (As)	µg/l	10	*10*	7.5	6.5	**8.2**	6.0	1.6	< 1.0	<1.0	4.1	1.3	<1.0	**8.9**	6.3	3.5	1.7	2.5	<1.0	1.6	4.1	3.1	2.3	3.2	1.6	1.8	1.8	1.4	1.9	1.4	<1.0	2.0	2.3	<1.0	3.6	1.6	2.4	1.6	<1.0
Barium (Ba)	µg/l	-	*100*	-	**130**	69	48	75	43	53	71	90	62	**230**	**270**	**330**	83	64	81	93	**120**	96	**190**	**180**	**170**	86	93	96	61	69	68	64	83	87	86	99	**110**	59	73
Beryllium (Be)	µg/l	-	-	-	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	<1.0	<1.0	<1.0	<1.0
Boron (B)	µg/l	*1000*	*1000*	*750*	**1800**	**3400**	**3300**	140	320	160	690	650	330	410	680	500	97	49	220	71	63	79	160	170	110	530	680	**760**	450	430	450	73	49	110	52	380	51	46	88
Cadmium (Cd)	µg/l	*5*	*5*	*3.75*	< 0.080	0.18	0.79	0.14	< 0.080	<0.080	< 0.080	< 0.080	<0.080	< 0.080	< 0.080	<0.080	< 0.080	< 0.080	<0.080	< 0.080	< 0.080	<0.080	< 0.080	0.092	0.30	0.39	0.37	1.00	0.13	0.19	0.20	< 0.080	< 0.080	<0.080	< 0.080	0.08	<0.080	<0.080	<0.080
Chromium (Cr)	µg/l	*50*	*30*	*37.5*	12	16	<1.0	6.8	1.6	<1.0	1.4	2.7	<1.0	3.6	4.7	<1.0	< 1.0	< 1.0	<1.0	< 1.0	2.7	<1.0	2.7	4.5	<1.0	2.7	7.1	<1.0	1.7	3.6	<1.0	< 1.0	1.8	<1.0	3	<1.0	<1.0	<1.0	<1.0
Cobalt (Co)	µg/l	-	-	-	4.8	5.6	4.5	2.2	< 1.0	<1.0	1.3	< 1.0	<1.0	1.9	4.5	3.3	< 1.0	< 1.0	<1.0	< 1.0	1.2	<1.0	1.4	2	3.1	2.1	3.2	3.4	1.5	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	1.7	<1.0	<1.0	<1.0
Copper (Cu)	µg/l	*2000*	*30*	*1500*	3.4	6.5	9.8	1.3	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	1.3	< 1.0	<1.0	1.4	3.9	1.6	2.4	1.7	6	6.2	3.1	4.4	2.5	1.5	1.6	< 1.0	< 1.0	<1.0	< 1.0	4.3	<1.0	1.0	<1.0
Iron (Fe)	µg/l	*200*	*200*	-	**1200**	**590**	**590**	**360**	170	190	**450**	**470**	**440**	**970**	**430**	**430**	**560**	150	**280**	**410**	**220**	**260**	**790**	**360**	**460**	**660**	**380**	**420**	**630**	**290**	**500**	**280**	170	**240**	170	**400**	180	**300**	**260**
Lead (Pb)	µg/l	*10*	*10*	*7.5*	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	<1.0	<1.0	<1.0	<1.0
Nickel (Ni)	µg/l	*20*	*20*	*15*	5.1	12	10	5.7	1.5	1.4	< 1.0	2.4	1.3	3.9	**15**	**20**	2.4	< 1.0	2.1	2.7	2.7	2.5	5.3	4.8	7.7	11	12	10	13	3.6	3.5	5.1	5.0	3.9	2.6	10	3.7	9.6	1.6
Manganese (Mn)	µg/l	*50*	*50*	-	**2900**	**3300**	**2100**	**580**	**250**	38	**720**	**230**	2.2	**1700**	**2600**	**2500**	**250**	**370**	**63**	**210**	**830**	**360**	**720**	**1900**	**3800**	**400**	**1700**	**1700**	**140**	**290**	38	**63**	**150**	**56**	**320**	**91**	**130**	**290**	9.9
Mercury (Hg)	µg/l	*1*	*1*	*0.75*	**2.2**	< 0.50	<0.50	< 0.50	< 0.50	<0.50	**7.3**	< 0.50	<0.50	0.65	< 0.50	<0.50	< 0.50	< 0.50	<0.50	< 0.50	< 0.50	<0.50	0.71	**1.10**	<0.50	**0.89**	0.73	**0.83**	0.51	< 0.50	<0.50	< 0.50	< 0.50	<0.50	< 0.50	<0.50	<0.50	<0.50	<0.50
Molybdenum (Mo)	µg/l	-	-	-	4.7	3.0	5.0	5.2	1.1	<1.0	5.9	< 1.0	<1.0	7.2	2.0	2.7	6.7	1.1	1.5	5.8	1.9	1.3	4.2	1.0	1.2	2.0	1.1	<1.0	1.3	< 1.0	<1.0	4.2	1.4	1.0	2.2	<1.0	2.4	2.3	<1.0
Selenium (Se)	µg/l	*10*	-	-	**40**	**35**	**42**	2.5	4.6	1.2	6.6	**15**	**42**	6.8	5.5	6.1	2.3	2.3	1.8	4.5	3.6	2	9.8	5.1	**12**	**52**	4.6	5.8	**14**	**11**	8.2	3.6	4	<1.0	1.2	**16**	3.6	4.1	**14**
Strontium (Sr)	µg/l	-	-	-	1700	< 1.0	<1.0	380	< 1.0	<1.0	510	< 1.0	<1.0	670	< 1.0	<1.0	400	< 1.0	<1.0	330	< 1.0	<1.0	770	< 1.0	<1.0	580	< 1.0	<1.0	530	< 1.0	<1.0	210	< 1.0	<1.0	< 1.0	<1.0	<1.0	<1.0	<1.0
Thallium (Ti)	µg/l	-	-	-	< 0.10	< 0.10	<0.10	< 0.10	< 0.10	<0.10	< 0.10	< 0.10	<1.0	< 0.10	< 0.10	<0.10	< 0.10	< 0.10	<1.0	< 0.10	< 0.10	<0.10	< 0.10	< 0.10	<0.10	< 0.10	< 0.10	<0.10	< 0.10	< 0.10	<0.10	< 0.10	< 0.10	<0.10	< 0.10	<0.10	<0.10	<0.10	<0.10
Uranium (U)	µg/l	-	*20*	-	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	<1.0	<1.0	<1.0	<1.0
Vanadium (V)	µg/l	-	-	-	3.6	3.6	<1.0	2.1	< 1.0	<1.0	1.0	< 1.0	<1.0	1.2	< 1.0	<1.0	< 1.0	< 1.0	<1.0	1.3	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	< 1.0	<1.0	< 1.0	<1.0	<1.0	<1.0	<1.0
Zinc (Zn)	µg/l	-	*100*	*75*	54	59	64	6.4	2.3	4.6	13	8	14	6.2	2.8	6.8	4.5	< 1.0	4.6	2.9	5.8	4.2	5.1	< 1.0	2.5	8.6	6	10	8.1	< 1.0	7.4	1.6	< 1.0	2.1	< 1.0	6.1	1.5	4.9	2.5
Microbiology																																				
Total Coliforms (i.e. Confirmed)	cfu/100ml	*0*	-	-	**2700**	**588**	**2**	**11**	**331**	**2**	**8300**	**331**	**52.9**	**11**	**311**	<1	0	**228**	**3**	0	**3076**	**179.3**	0	**387.3**	<1	0	**152.9**	<1	0	**>2419.6**	<1	0	**3**	<1	**57.6**	<1	**47.4**	**1553.1**	**49.6**
Faecal coliforms (i.e. Confirmed)	cfu/100ml	*0*	-	-	**32**	**12**	<1	0	<1	<1	**170**	**5**	**16**	0	<1	<1	0	**6**	<1	0	**2**	**11**	0	**1**	<1	0	**6**	<1	0	**5**	<1	0	<1	<1	**2**	<1	<1	**2**	<1

Note:

450	Red & bold font with yellow highlight indicates where SI 9, 2010 or SI 366, 2016 (Amendment) Threshold Values are exceeded
450	Red & bold Font indicates where EPA Interim Guideline Values or SI 122, 2014 Indicator or Parametric Values are exceeded

< = Less than

'-' = No EPA Interim Guideline Values, SI 9, 2010 Threshold Values or SI 122, 2014 Indicator or Parametric Values are available

~' = No analysis conducted on sample

8.2 Laboratory Results on Groundwater

8.2.1 Physicochemical Analysis

The pH values (7.2 – 8.2) at all 14 locations on each monitoring occasion were within the Groundwater Interim Guideline Value (>6.5 and <9.5). The highest pH value of 8.2 was recorded at BH9 and BH13 with the lowest value of 7.2 recorded at BH11 (see Table 6).

Electrical conductivity values ranged from 550µS/cm – 10,000µS/cm across all samples (see Table 6). The value of 10,000µS/cm recorded at BH1 exceeded the Groundwater Regulations Threshold Value of 1,875µS/cm. Seven samples exceeded the Groundwater Regulations Threshold Value of 1,875µS/cm. An exceedance was observed on all 3 sampling occasions at BH1, 2 out of 3 sampling occasions in BH4 and 2 out of 3 sampling occasions in BH11.

Dissolved oxygen concentrations ranged from 6.6mg/l – 9.0mg/l across the 14 boreholes. The lowest value of 6.6mg/l, was obtained at BH2 and the highest value of 9.0mg/l obtained at BH9 in May 2018 (see Table 6).

Chemical Oxygen Demand (COD) concentrations varied across the 14 boreholes ranging from <10.0mg/l – 139mg/l (see Table 6).

Total Alkalinity ranged from 280mg/l at BH2 and BH14 to 850mg/l at BH4 (see Table 6).

8.2.2 Total Dissolved Solids & Suspended Solids

Total dissolved solid (TDS) concentrations ranged from 39mg/l in BH4 to 6,100mg/l in BH1 (see Table 6). Ten samples exceeded the TDS Groundwater Interim Guideline Value of 1,000mg/l. All 3 groundwater samples taken from BH1 and samples taken from BH3, BH4, BH11 and BH14 exceeded the guideline value. Total Suspended Solid concentrations varied across the 14 boreholes ranging from <5.0mg/l – 59,000mg/l (see Table 6).

8.2.3 Ammonia, Ammoniacal Nitrogen, Nitrate & Nitrite

The results obtained within all 14 boreholes on the 3 sampling occasions for Ammoniacal Nitrogen exceeded the Groundwater Regulations Threshold Value of 0.065mg/l (see Table 6).

The highest concentrations of Ammoniacal Nitrogen were detected in BH1 (18mg/l) and BH11 (23mg/l).

Ammonia (NH_3) concentrations varied across the 14 boreholes ranging from <0.01mg/l – 25.99mg/l (see Table 6).

Nitrate concentrations varied across the 14 boreholes ranged from <0.50mg/l to 54mg/l (see Table 6). The May 2018 sample from BH3 exceeded the Groundwater Regulations Threshold Value of 37.5mg/l for NO_3.

Nitrite concentrations varied across the 14 boreholes ranged from <0.02mg/l to 2.1mg/l (see Table 6). There were three exceedances of the Groundwater Regulations Threshold Value of 0.375mg/l for NO_2. These occurred in the

sample taken from BH12 (0.43mg/l) in August, 2017, the sample taken from BH3 (0.69mg/l) in November, 2017 and the sample taken from BH14 (2.1mg/l) in May, 2018.

8.2.4 Total Organic Nitrogen & Total Nitrogen

Total Organic Nitrogen concentrations ranged from <1.0mg/l at BH2, BH8, BH9, BH12, BH15 and BH16 to 8.2mg/l at BH1 (see Table 6). Total Nitrogen concentrations ranged from <1mg/l at BH15 and BH16 to 28mg/l at BH11 (see Table 6). The highest concentrations of both TON and TN were recorded in the sample taken from BH11.

8.2.5 Anions (Chloride (Cl^-), Fluoride (F^-), Sulphate (SO_4^{2-}) and Sulphides (S^{2-}))

The results obtained within the groundwater samples for chloride ranged from 30mg/l in BH2 to 2,200mg/l in BH1 (see Table 6). All 3 groundwater samples taken from BH1 (i.e. ranging from 1,100mg/l to 2,200mg/l) exceeded the Groundwater Regulations Threshold Value of 187.5mg/l for Cl^-. All the remaining samples with the exception of the sample taken from BH2 in June 2017 exceeded the Groundwater Interim Guideline Value of 30mg/l.

The results obtained within the groundwater samples for fluoride ranged from <0.050mg/l to 0.26mg/l (see Table 6). There were no exceedances in the F^- Groundwater Interim Guideline Value of 1mg/l.

Sulphate (SO_4^{2-}) concentrations varied across the 14 boreholes ranging from 26mg/l to 3,200mg/l (see Table 6). The Groundwater Regulations Threshold Value of 187.5mg/l for $SO4^{2-}$ was exceeded in 14 samples. Sulphate concentrations were exceeded on all 3 monitoring rounds in boreholes BH1, BH3 and BH12. Sulphate concentrations were exceeded in 2 of the 3 monitoring rounds in boreholes BH8 and BH11.

Sulphides were not detected above the method detection limit in any of groundwater samples taken (see Table 6).

8.2.6 Phosphate (as P)

Seven samples taken on the first round of groundwater quality monitoring exceeded the Groundwater Regulations Threshold Value of 0.035mg/l for P (see Table 6). It should be noted that all 11 samples taken on the 2nd round of monitoring had a P concentration below the method detection limit and that all 14 samples taken on the 3rd round of monitoring had a P concentration below the method detection limit.

8.2.7 Major Cations

The results obtained within the groundwater samples for potassium ranged from 5mg/l in BH14 to 930mg/l in BH1 (see Table 6). All samples with the exception of BH14 exceeded the Groundwater Interim Guideline Value of 5mg/l for K.

The results obtained for sodium (Na) ranged from 23mg/l in BH15 to 1,400mg/l in BH1 (see Table 6). The results obtained for BH1 (380mg/l, 1,400mg/l and 570mg/l) exceeded the Groundwater Regulations Threshold Value of 150mg/l for Na, while the results obtained for the remaining 13 boreholes were below each of the groundwater screening values.

The results obtained for calcium (Ca) ranged from 120mg/l to 740mg/l (see Table 6). Twenty one samples exceeded the Groundwater Interim Guideline Value of 200mg/l for Ca. Calcium concentrations were exceeded on all 3 monitoring rounds in boreholes BH1, BH3, BH4 and BH11.

The results obtained for magnesium (Mg) ranged from 20mg/l to 950mg/l across the 14 boreholes (see Table 6). Fifteen samples exceeded the Groundwater Interim Guideline Value of 50mg/l for Mg. Magnesium concentrations were exceeded in all 3 monitoring rounds in boreholes BH1, BH3, BH4 and BH11.

8.2.8 Heavy Metals

Of the 22 heavy metals analysed (see Table 6), the reported concentrations for all parameters were within their corresponding generic assessment criteria values with the exception of:

- *Arsenic (As)*

The value obtained from BH4 was 8.9µg/l in June 2017. This value exceeded the corresponding Groundwater Regulations Threshold Value of 7.5µg/l. The As concentration recorded in November 2017 in BH4 was 6.3µg/l which was the below the threshold value. An As exceedance was also observed in November 2017 in BH1 (8.2µg/l). This concentration was a slight increase from that observed in June 2017 (6.5µg/l). Arsenic was not detected in any of the water samples taken in May 2018.

- *Barium (Ba)*

Nine samples exceeded the barium Groundwater Interim Guideline Value of 100µg/l. The Ba concentrations were exceeded in boreholes BH4 and BH10 on all 3 sampling rounds, while the Ba concentration was exceeded in BH1, BH9 and BH15 on one occasion.

- *Boron (B)*

The values obtained for boron from the samples taken from BH1 were 1,800µg/l, 3,400µg/l and 3,300µg/l respectively. These 3 values exceeded the corresponding Groundwater Regulations Threshold Value of 750µg/l. A single exceedance of 760µg/l were observed in borehole BH11.

- *Iron (Fe)*

The values obtained from all samples analysed from the 14 boreholes ranged from 150µg/l to 1,200µg/l. In total, 29 samples exceeded the corresponding Groundwater Interim Guideline Value of 200µg/l.

- *Manganese*

The values obtained from all groundwater samples analysed ranged from 2.2µg/l to 3,300µg/l. In total, 31 samples exceeded the corresponding Groundwater Interim Guideline Value of 50µg/l.

- *Mercury (Hg)*

Five samples were observed to exceed the Groundwater Regulations Threshold Value of 0.75µg/l for mercury. This included an exceedance in BH1 (2.2µg/l), BH3 (7.3µg/l) and BH11 (0.89µg/l) for samples taken in

Table 7A. Results of Inorganic and Microbiological Laboratory Analyses on Surface Water Samples (SW1-SW3) taken from Adjacent Stream on the 11.01.18

Parameter	Units	*S.I. No. 294, European Communities (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations, 1989* *MACs* *1.*	*S.I. No. 278, European Communities Environmental Objectives (Drinking Water) (No. 2) Regulations, 2007* *Interim Guideline Values*	*S.I. No. 272, European Communities Environmental Objectives (Surface Water) Regulations, 2009)* *Threshold Values* *2.*	UPGRADIENT	DOWNGRADIENT	
					SW1 (18/1/2018)	SW2 (18/1/2018)	SW3 (18/1/2018)
Physico-Chemical Parameters							
pH		*5.5 - 8.5*	-	*6..0<pH<9..0*	8.4	8.3	8.1
Electrical cond. (EC)	µS/cm	*1000*	*2500*	-	670	680	640
Dissolved oxygen (DO)	mg/l	-	-	-	8.2	8.2	8.2
Standard Chemistry							
Total dissolved solids	mg/l	-	*1000*	-	400.0	410.0	380.0
Total suspended solids	mg/l	*50*	-	-	24	16	< 5.0
Total alkalinity (as $CaCO_3$)	mg/l	-	-	-	250.0	250.0	240.0
Ammonia (as NH_3)	mg/l	-	-	*0.065*	0.034	0.028	0.039
Ammoniacal Nitrogen	mg/l	*0.2*	*0.3*	-	**0.26**	0.19	**0.23**
Nitrate NO_3	mg/l	*50*	*50*	-	41.0	18.0	15.0
Nitrite NO_2	mg/l	-	*0.5*	-	0.1	< 0.050	< 0.050
Total Organic Nitrogen	mg/l	-	-	-	9	5	5
Total Dissolved Nitrogen	mg/l	-	-	-	9	5	5
Chloride Cl^-	mg/l	*250*	*250*	-	51.0	25.0	27.0
Flouride	mg/l	*1*	-	*0.5*	< 0.050	< 0.050	**3**
Sulphate SO_4	mg/l	*200*	*250*	-	33	81	82
Sulphide S^{2-}	mg/l	-	-	-	< 0.050	< 0.050	< 0.050
Molybdate Reactive Phosphate P	mg/l	*0.5*	-	*0.035*	**0.1**	< 0.050	< 0.050
Major Cations							
Potassium K	mg/l	-	-	-	1.1	1.0	1.0
Sodium Na	mg/l	-	*200*	-	15.0	15.0	14.0
K/Na Ratio					0.07	0.06	0.07
Calcium Ca	mg/l	-	-	-	100.0	110.0	100.0
Magnesium Mg	mg/l	-	-	-	11.0	14.0	12.0
Heavy Metals							
Aluminium (Al)	µg/l	-	*200*	-	45	< 10	< 10
Antimony (Sb)	µg/l	-	*5*	-	< 1.0	< 1.0	< 1.0
Arsenic (As)	µg/l	50	*10*	25	< 1.0	< 1.0	< 1.0
Barium (Ba)	µg/l	100	-	-	42	27	31
Beryllium (Be)	µg/l	-	-	-	< 1.0	< 1.0	< 1.0
Boron (B)	µg/l	*2000*	*1000*	-	26	32	29
Cadmium (Cd)	µg/l	*5*	*5*	-	< 0.080	< 0.080	< 0.080
Chromium (Cr)	µg/l	*50*	-	*3.4*	2.3	1.8	1.8
Cobalt (Co)	µg/l	-	-	-	< 1.0	< 1.0	< 1.0
Copper (Cu)	µg/l	*50*	*2000*	*30*	< 1.0	< 1.0	< 1.0
Iron (Fe)	µg/l	*200*	*200*	-	**230**	**210**	**230**
Lead (Pb)	µg/l	*50*	*10*	*7.2*	< 1.0	< 1.0	< 1.0
Nickel (Ni)	µg/l	-	*20*	*20*	< 1.0	< 1.0	< 1.0
Manganese (Mn)	µg/l	*50*	*50*	-	2.7	< 1.0	< 1.0
Mercury (Hg)	µg/l	*1*	*1*	-	< 0.50	< 0.50	< 0.50
Molybdenum (Mo)	µg/l	-	-	-	< 1.0	< 1.0	< 1.0
Selenium (Se)	µg/l	*10*	*10*	-	1.4	4.2	3.3
Strontium (Sr)	µg/l	-	-	-	< 1.0	< 1.0	< 1.0
Thallium (Ti)	µg/l	-	-	-	< 0.10	< 0.10	< 0.10
Uranium (U)	µg/l	-	-	-	< 1.0	< 1.0	< 1.0
Vanadium (V)	µg/l	-	-	-	< 1.0	< 1.0	< 1.0
Zinc (Zn)	µg/l	*3000*	-	*100*	< 1.0	< 1.0	< 1.0
Oxygen Demand/Organic Carbon							
BOD	mg/l	5	-	2.2	<2	<2	<2
COD	mg/l	40	-	-	**42**	<8	8
Microbiological							
Total coliforms (i.e. Confirmed)	CFU/100ml	*0*	*0*	-	**142.1**	**5.2**	**13.5**
Faecal coliforms(i.e. Confirmed)	CFU/100ml	*0*	*0*	-	**34**	**4**	**2**

Note:

450	Values are shaded yellow and in RED bold where S.I. No. 272 Surface Water Reg. Threshold Levels are exceeded
450	Values are in RED bold where SI No. 294 of 1989 MACs, SI No. 278 of 2007 Parametric Values are exceeded

< = Less than

'-' signifies analysis not carried out on sample or no SI No.293 of 1988 WQS, SI No. 294 of 1989 MACs, SI No. 278 of 2007 Parametric Values, or S.I. No. 272 Surface Water Reg. Threshold Levels are available.

1. Thresholds have been determined based on A1 Category surface waters as defined by S.I. No. 294 of 1989 MACs. Where limits for A1 Category are not defined A2 or A3 limts have been applied

2. Nutrient thresholds have been determined based on Good Status (mean) limits. Specific pollutants have been determined based on MAC - EQS for inland surface waters. Ammonia Threshold Value refers to Total Ammonia (mg N/l) mean value

Table 7B. Results of Inorganic and Microbiological Laboratory Analyses on Surface Water Samples (SW1-SW3) taken from Adjacent Stream on the 15.06.18

Parameter	Units	Statutory Limits			Off-Site Surface Water	
					UPGRADIENT	
		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*	*S.I. No. 272, European Communities Environmental Objectives (Surface Water) Regulations, 2009)*	SW1 (15/6/2018)	SW4 (15/6/2018)
		MACs 1.	*Parametric Values*	*Threshold Values* 2.		
Physico-Chemical Parameters						
pH	-	*5.5 - 8.5*	-	*6..0<pH<9..0*	8.1	8.2
Electrical cond. (EC)	µS/cm	*1000*	*2500*	-	700	690
Dissolved oxygen (DO)	mg/l	-	-	-	8.3	8.0
Standard Chemistry						
Total Dissolved Solids	mg/l	-	-	-	410	400
Total suspended solids	mg/l	*50*	-	-	**330**	**150**
Total alkalinity (as $CaCO_3$)	mg/l	-	-	-	290	300
Ammonia (N)	mg/l	-	-	*0.065*	<0.010	0.017
Ammoniacal Nitrogen	mg/l	*0.2*	*0.3*	-	**0.23**	**0.43**
Nitrate NO_3	mg/l	*50*	*50*	-	15	15
Nitrite NO_2	mg/l	-	*0.5*	-	0.043	0.044
Total Organic Nitrogen (TON)	mg/l	-	-	-	1.8	2.7
Total Nitrogen (TN)	mg/l	-	-	-	5.4	6.5
Chloride Cl^-	mg/l	*250*	*250*	-	47	43
Fluoride F^-	mg/l	*1*	-	*0.5*	0.14	0.13
Sulphate SO_4	mg/l	*200*	*250*	-	38	30
Sulphide S^{2-}	mg/l	-	-	-	<0.050*	<0.050*
Phosphate as P	mg/l	*0.5*	-	*0.035*	0.23	0.25
Major Cations						
Potassium K	mg/l	-	-	-	2.20	1.90
Sodium Na	mg/l	-	*200*	-	21	17
Potassium K/Sodium Na Ratio	-	-	-	-	0.10	0.11
Calcium Ca	mg/l	-	-	-	120	120
Magnesium Mg	mg/l	-	-	-	15	14
Heavy Metals						
Aluminium Al	µg/l	-	*200*	-	20	<10
Antimony	µg/l	-	*5*	-	<1.0	<1.0
Arsenic	µg/l	*50*	*10*	*25*	1.1	<1.0
Barium (Ba)	µg/l	*100*	-	-	41	47
Beryllium (Be)	µg/l	-	-	-	<1.0	<1.0
Boron	µg/l	*2000*	*1000*	-	110	53
Cadmium Cd	µg/l	*5*	*5*	-	<0.080	<0.080
Chromium Cr	µg/l	*50*	-	*3.4*	<1.0	<1.0
Cobalt (Co)	µg/l	-	-	-	<1.0	<1.0
Copper	µg/l	*50*	*2000*	*30*	<1.0	<1.0
Iron (Fe)	µg/l	*200*	*200*	-	120	160
Lead Pb	µg/l	*50*	*10*	*7.2*	<1.0	<1.0
Nickel Ni	µg/l	-	*20*	*20*	<1.0	<1.0
Manganese Mn	µg/l	*50*	*50*	-	5.4	<1.0
Mercury Hg	µg/l	*1*	*1*	-	<0.50	<0.50
Molybdenum (Mo)	µg/l	-	-	-	1.1	<1.0
Selenium	µg/l	*10*	*10*	-	<1.0	1.0
Strontium (Sr)	µg/l	-	-	-	<1.0	<1.0
Thallium (Ti)	µg/l	-	-	-	<0.10	<0.10
Uranium (U)	µg/l	-	-	-	<1.0	<1.0
Vanadium (V)	µg/l	-	-	-	4.2	<1.0
Zinc Zn	µg/l	*3000*	-	*100*	2.9	1.9
Oxygen Demand/Organic Carbon						
BOD	mg/l	*5*	-	*2.2*	2	**3**
COD	mg/l	*40*	-	-	**76**	**161.0**
Microbiology						
Total coliforms (i.e. Confirmed)	CFU/100ml	*0*	*0*	-	**24890**	**241960**
Faecal coliforms (E. coli)	CFU/100ml	*0*	*0*	-	**1950**	**500**

Note:

450	Values are shaded yellow and in RED bold where S.I. No. 272 Surface Water Reg. Threshold Levels are exceeded
450	Values are in RED bold where SI No. 294 of 1989 MACs, SI No. 278 of 2007 Parametric Values are exceeded

< = Less than

'-' signifies analysis not carried out on sample or no SI No.293 of 1988 WQS, SI No. 294 of 1989 MACs, SI No. 278 of 2007 Parametric Values, or S.I. No. 272 Surface Water Reg. Threshold Levels are available.

1. Thresholds have been determined based on A1 Category surface waters as defined by S.I. No. 294 of 1989 MACs. Where limits for A1 Category are not defined A2 or A3 limts have been applied

2. Nutrient thresholds have been determined based on Good Status (mean) limits. Specific pollutants have been determined based on MAC - EQS for inland surface waters. Ammonia Threshold Value refers to Total Ammonia (mg N/l) mean value

June/August 2017 and an exceedance in BH10 (1.1µg/l) in November, 2017and in BH11 (0.83µg/l) in May, 2018. No borehole was found to exceed the threshold value on all 3 monitoring occasions.

- *Selenium (Se)*

No Groundwater Threshold Value or Interim Guideline Value has been set for selenium. Therefore, the Se concentrations were screened against the Drinking Water Regulations Parametric Value of 10µg/l. Eleven samples were found to exceed the parametric value including all 3 samples taken from BH1.

8.2.9 Total Petroleum Hydrocarbons (EPH (C8-C40)) /Mineral Oil

The results of the Total Petroleum Hydrocarbons (EPH (C8-C40))/Mineral Oil analysis for groundwater samples are located in 4 tables, Tables A18.3, A18.8, A18.13 and A18.18 in Appendix 18. As can be seen from the four tables, TPH's were not detected above the method detection limit of <10µg/l in any of the samples analysed during each monitoring round.

8.2.10 Polyaromatic Hydrocarbons (PAHs)

The results of the Polyaromatic Hydrocarbons analysis for groundwater samples are located in 4 tables, Tables A18.3, A18.8, A18.13 and A18.18 in Appendix 18. As can be seen from the 4 tables, Polyaromatic Hydrocarbons were not detected above the method detection limit of <0.10µg/l in any of the samples analysed during each monitoring round.

8.2.11 Total Cyanide

The results of the Total Cyanide analysis for groundwater samples are located in 4 tables, Tables A18.3, A18.8, A18.13 and A18.18 in Appendix 18. As can be seen from the 4 tables, Cyanides were not detected within any of the groundwater samples taken on site.

8.2.12 Total Phenols

The results of the Total Phenol analysis for groundwater samples are located in 4 tables, Tables A18.3, A18.8, A18.13 and A18.18 in Appendix 18. Phenols were not detected within any of the groundwater samples taken on site.

8.2.13 Benzene, Toluene, Ethylbenzene, Xylenes (BTEX) & MTBE

The results of the BTEX and MTBE analysis for groundwater samples are located in 4 tables, Tables A18.3, A18.8, A18.13 and A18.18 in Appendix 18. As can be seen from the 4 tables, all of the MTBE/BTEX compounds analysed were below their respective Method Detection Limits.

8.2.14 Volatile Organic Compounds

The results of the volatile organic compound analysis for groundwater samples are located in 4 tables, Tables A18.4, A18.9, A18.14 and A18.19 in Appendix 18. As can be seen from the 4 tables, all of the VOC compounds analysed were below their respective Method Detection Limits.

8.2.15 Semi-Volatile Organic Compounds (sVOC)

The results of the semi-volatile organic compound analysis for groundwater samples are located in 4 tables, Tables A18.5, A18.10, A18.15 and A18.20 in Appendix 18. As can be seen from the 4 tables, all of the sVOC compounds analysed were below their respective Method Detection Limits.

8.2.16 Organochlorine Pesticides & Acid Herbicides

The results of the Organochlorine Pesticide and Acid Herbicide analysis for groundwater samples are located in 4 tables, Tables A18.6, A18.11, A18.16 and A18.21 in Appendix 18. As can be seen from the 4 tables, all of the VOC compounds analysed were below their respective Method Detection Limits.

8.2.17 Microbiology

Total coliforms were detected in 23 of the groundwater samples (see Table 6). The highest result included a colony count of 8,300cfu/100ml in BH3 and a colony count of 3,076cfu/100ml in BH9.

Faecal coliforms (i.e. Thermotolerant *E. coli*) were detected in 13 of the groundwater samples. Faecal coliforms were detected in all 3 samples from borehole, BH3.

The highest colony counts detected included a concentration of 170cfu/100ml in BH3 and 32cfu/100ml in BH1. Faecal coliforms were not detected in any of the samples taken from BH2, BH4, BH13, BH15 or BH17.

8.2.18 Summary of Results

The ammonia, sulphate, mercury, phosphate, iron and manganese results are typical of groundwater which has been impacted by landfill leachate in the past.

9 ENVIRONMENTAL SURFACE WATER RESULTS

9.1 Surface Water Sampling Rounds, Laboratory Suite & Generic Assessment Criteria

Mulroy Environmental carried out the following surface water sampling on the unnamed stream adjacent to the site:

- At 3 locations, SW1(Upgradient), SW2 (Downgradient) and SW3 (Downgradient) on the 11th January 2018; and
- At 2 locations, SW4 (Upgradient) and SW1 (Upgradient) on the 15th June 2018. It was intended to take a sample from SW2 & SW3 on this occasion also, however the quantity of water/flow at these locations prohibited any sample collection.

The results of the physico-chemical, inorganic, major cation, oxygen demand analyses and microbiological analysis are included in the following tables, Table 7A and Table 7B.

The results of the TPH-CWG, BTEX, Polyaromatic Hydrocarbon (PAH) and Total Cyanide analyses are located in Table A18.23 and Table A18.28 in Appendix 18.

The results of the Volatile Organic Compound (VOC) analyses are located in Table A18.24 and Table A18.29 in Appendix 18.

The results of the Semi-volatile Organic Compound (VOC) analyses are located in Table A18.25 and Table A18.30 in Appendix 18.

The results of the Organochlorine Pesticide and Acid Herbicide analyses are located in Table A18.26 and Table A18.31 in Appendix 18.

These results are compared against the following Generic Assessment Criteria/statutory limits:

- S.I. No. 293, European Communities (Quality of Salmonid Waters) Regulations, 1988;
- 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.

9.2 Laboratory Results on Surface Water

9.2.1 Physicochemical Analysis

The pH of the 5 surface water samples although slightly alkaline, are relatively consistent throughout (8.1 – 8.4) and are within normal range (see Tables 7A & 7B). The electrical conductivity (EC) of the surface water samples also appears to be relatively consistent throughout (640µS/cm - 700µS/cm) and are within normal range (see Tables 7A & 7B). The dissolved oxygen (DO) concentration of the 5 surface water samples ranged from 8.0mg/l to 8.2mg/l.

9.2.2 Total Suspended Solids (TSS) & Total Dissolved Solids (TDS)

The results obtained for total suspended solids (TSS) ranged from <5.0mg/l to 330mg/l (see Tables 7A & 7B). The values recorded for S1 and SW4 in the 2nd round of monitoring were greater than the 50mg/l standard outlined in S.I. No. 294, European Communities (Quality of Surface Water Intended for Abstraction of Drinking Water) Regulations, 1989. The total dissolved solids (TDS) concentrations for the 5 samples ranged from 380mg/l to 410mg/l.

9.2.3 Total Alkalinity ($CaCO_3$)

The total alkalinity ($CaCO_3$) values recorded at the 5 sampling locations ranged from 240mg/l to 300mg/l (see Tables 7A & 7B).

9.2.4 Ammonia (NH_3), Ammonium (NH_4), Nitrates (NO_3) and Nitrites (NO_2)

Ammonia concentrations were recorded at values ranging from <0.01mg/l to 0.039mg/l (see Tables 7A & 7B). These values were below the 0.065mg/l standard outlined in S.I. No. 272, European Communities (Surface Water) Regulations, 2009. Ammoniacal nitrogen concentrations ranged from 0.19mg/l to 0.43mg/l across the 5 sampling locations. Sample SW1 and SW3 were in exceedance of the 0.2mg/l maximum allowable concentration (MAC) stipulated in S.I. No. 294, European Communities (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations, 1989.

The nitrate (NO_3) concentrations recorded from the 3 surface water samples ranged from 15mg/l to 41mg/l (see Table 7) and were below the 50mg/l MAC stipulated in S.I. No. 294, European Communities (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations, 1989. The nitrite (NO_2) concentrations ranged from <0.020mg/l to 0.026mg/l at the 3 monitoring points. Each of these values exceeded were below the Surface Water Regulations Threshold Value of 0.5mg/l.

9.2.5 Total Organic Nitrogen (TON) & Total Nitrogen (TN)

Total Organic Nitrogen concentrations ranged from <1.0mg/l in SW1 and SW2 to 2.7mg/l in SW4 (see Tables 7A & 7B). Total Nitrogen concentrations ranged from 4.7mg/l in SW2 to 9.3mg/l in SW1 (see Tables 7A & 7B).

9.2.6 Phosphate (as P)

The samples taken at the 4 monitoring points (i.e. SW1–SW4) had phosphate (P) concentrations ranging from <0.05mg/l in SW2 and SW3 to 0.25mg/l in SW4 (see Tables 7A & 7B). Consequently, the mean threshold limit

for *'Good Status'* waters according to S.I. No.272, 2009 was exceeded in SW1 for both rounds and in SW4 for the June 2018 sampling round.

9.2.7 Chloride (Cl^-), Sulphate (SO_4^{2-}), Sulphide (S^{2-}) and Fluoride (F^-)

The results obtained for the surface water sample for chloride (Cl^-) ranged from 25mg/l to 51mg/l across the 5 samples taken. These values are substantially lower than the S.I. No. 278 (Drinking Water) Parametric value of 250mg/l for Cl^- (see Tables 7A & 7B).

The results obtained for the surface water samples for sulphate (SO_4^{2-}) ranged from 33mg/l to 82mg/l across the 5 samples taken. These values are substantially lower than the S.I. No. 278 (Drinking Water) Parametric value of 250mg/l for SO_4^{2-} (see Tables 7A & 7B). Sulphide (S^{2-}) concentrations were below the method detection limit (<0.05mg/l) in all of the 5 samples (see Tables 7A & 7B).

Fluoride (F^-) concentrations ranged from <0.05mg/l to 2.7mg/l across the 5 samples (see Tables 7A & 7B). The samples taken from SW1 and SW2 in January 2018 were below the 0.5mg/l threshold value outlined in the S.I. No.272, 2009, Surface Water Thresholds. However the sample taken from SW3 in January, 2018 exceeded the threshold value (see Table 7A).

9.2.8 Potassium (K), Sodium (Na), Calcium (Ca) and Magnesium (Mg)

The results of the major cation analysis obtained within the 5 surface water samples taken from the adjacent stream are included in Tables 7A and 7B. Potassium (K) concentrations ranged from 0.97mg/l – 2.2mg/l, sodium (Na) concentrations ranged from 14mg/l to 21mg/l, calcium (Ca) concentrations ranged from 100mg/l to 120mg/l, while magnesium (Mg) concentrations ranged from 11mg/l to 15mg/l. The K/Na ratio was relatively consistent (i.e. 0.06 – 0.11) across the 5 samples indicating that the surface water is not being impacted by landfill type waste.

9.2.9 Heavy Metals

Of the 22 heavy metals analysed, the reported concentrations for all parameters were within their respective generic assessment criteria values with the exception of iron which was found during the January 2018 sampling round at 230mg/l, 210mgl and 230mg/l in SW1, SW2 and SW3 respectively (see Tables 7A & 7B). It should be noted that the concentration of arsenic (As) and mercury (Hg) were below their respective method detection limits for 4 out of the 5 samples. Arsenic was detected marginally over the Method Detection Limit at 1.1µg/l in SW1 during the second surface water sampling round.

9.2.10 Oxygen Demand

Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) analyses were carried out on each of the 5 surface water samples (see Tables 7A & 7B). For BOD analysis, a concentration of <2mg/l was recorded for 4 out of the 5 samples which were below the 2.2mg/l threshold value outlined in S.I. No. 272, European Communities Environmental Objectives (Surface Water) Regulations 2009. A marginal exceedance of the BOD Threshold Value was found in the sample taken from SW4 (i.e. 3mg/l) during the July 2018 round.

Chemical Oxygen Demand concentrations ranged from <8mg/l to 161mg/l across the 5 samples. Both samples taken from SW1 and the July 2018 sample taken from SW4 exceeded the S.I. 294 European Communities (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations, 1989 Maximum Allowable Concentration (MAC) for COD.

9.2.11 Microbiological Analysis

Total coliforms were detected in all of the 5 samples at colony counts ranging from 5.2cfu/100ml to 24,890cfu/100ml (see Tables 7A & 7B). Faecal coliforms (i.e. Thermotolerant *E. coli*) were detected in each of the 5 surface water samples at colony counts ranging from 2cfu/100ml to 1,950cfu/100ml (see Tables 7A & 7B).

9.2.12 Total Petroleum Hydrocarbons (EPH (C8-C40))

The results of the Total Petroleum Hydrocarbons (EPH (C8-C40))/Mineral Oil analysis for the surface water samples are located in 2 tables, Tables A18.23 and A18.28 in Appendix 18. As can be seen from the 2 tables, TPH's were not detected above the method detection limit of <10µg/l in any of the 5 samples analysed between the 2 monitoring rounds.

9.2.13 Polyaromatic Hydrocarbons (PAHs)

The results of the Polyaromatic Hydrocarbons analysis for surface water samples are located are located in 2 tables, Tables A18.23 and A18.28 in Appendix 18. As can be seen from the 2 tables, Polyaromatic Hydrocarbons were not detected above the method detection limit of <0.10µg/l in any of the 5 samples analysed between the 2 monitoring rounds.

9.2.14 Total Cyanide

The results of the Total Cyanide analysis for surface water samples are located in 2 tables, Tables A18.23 and A18.28 in Appendix 18. As can be seen from the 2 tables, Cyanides were not detected in any of the 5 samples analysed between the 2 monitoring rounds.

9.2.15 Volatile Organic Compounds

The results of the Volatile Organic Compounds analysis for the surface water samples are in 2 tables, Tables A18.24 and A18.29 in Appendix 18. As can be seen from the 2 tables, VOCs were not detected in any of the 5 samples analysed between the 2 monitoring rounds.

9.2.16 Semi-Volatile Organic Compounds (sVOC)

The results of the Semi-volatile Organic Compounds analysis for the surface water samples are in 2 tables, Tables A18.25 and A18.30 in Appendix 18. As can be seen from the 2 tables, sVOCs were not detected in any of the 5 samples analysed between the 2 monitoring rounds.

9.2.17 Organochlorine Pesticides & Acid Herbicides

The results of the Organochlorine Pesticide and Acid Herbicide analysis for the surface water samples are in 2 tables, Tables A18.26 and A18.31 in Appendix 18. As can be seen from the 2 tables, neither pesticides nor herbicides were not detected in any of the 5 samples analysed between the 2 monitoring rounds.

9.2.18 Summary of Results

The ammonia, phosphate, iron, COD and coliform results are typical of surface waters within agricultural catchments. The exceedances observed may have arisen as a result of horizontal run-off of organic and/or inorganic fertilizers upgradient of the site.

10 LANDFILL GAS RISK ASSESSMENT

10.1 Field Work

As stated in Section 3, Mulroy Environmental supervised the installation of 2 types of gas monitoring wells, ***'deep air rotary'*** gas wells and ***'shallow window sample'*** gas wells (see Figure 8).

'Shallow Window Sample' Gas Wells

Four 'shallow window sample' gas wells were installed at depths ranging from 1.5m to 4m total depth using a percussion Dando Terrier drill rig along the foot path to the southwest of the residences being construction to the north of the waste body (see Figure 8 and borehole logs in Appendix 8). The standpipe for gas well GS01 consisted of 1m of plain HDPE pipe with up to 3m of slotted pipe. The standpipe for gas wells GS02-GS04 consisted of 0.5m of plain HDPE pipe with up to 1.5m of slotted pipe.

'Deep Air Rotary' Gas Wells

Three 'deep air rotary' gas wells, BH5-BH7 were installed to 8m depth using an air rotary driven Coomacheo Drilling rig within the waste body and along its boundary (see Figure 8 and borehole logs in Appendix 8). The location for these 3 gas wells was finalised once the extent of the buried material/waste had been established following the trialpitting exercise (see Figure 7). Each of the 3 deep gas wells were installed with slotted pipe to within 1m to 2.5m of the ground surface to facilitate transference of landfill gas.

Groundwater Monitoring/Gas Wells

It should be noted that each of the 14 groundwater monitoring boreholes were equipped with a landfill gas tap to allow for landfill gas monitoring. Each of these wells were installed with slotted pipe to within 1m to 2.5m of the ground surface to facilitate transference of landfill gas.

Residence Radon Sump, Water Mains Meter & Stormwater Sewer Monitoring

The following landfill gas and VOC survey work was carried out on the residences and infrastructure within the residential estate (see Figure 13):

- Radon sumps of Residences Nos. 25–63 on 18 occasions (i.e. from 17/9/2017 to 21/1/2019);
- Water mains meters for Residences Nos. 25–34 on 8 occasions (i.e. from 26/11/2017 to 21/1/2019);
- Two storm sewer access chambers (ST1 & ST2) located to the south of Residences Nos. 28–30 on 8 occasions (i.e. from 26/11/2018 to 21/1/2019); and
- Two storm sewer access chambers through which the stream runs (i.e. SW2 and SW3) were monitored on 23 occasions (i.e. from 13/8/2018 to 21/1/2019).

The above surveys were normally carried out immediately after the groundwater monitoring and gas well surveys.

Landfill Gas Probe Survey at Foul Rising Main/Landfill Body Interface

In order to determine if landfill gas from the waste body was migrating northwards towards the residential development, particularly Residences No. 52-63, along the rising foul main sewer (i.e. as a preferential pathway), it was agreed with Fingal C.C. that a gas probe survey would be carried out at the northern end of the waste body

where the foul rising main exits the waste body. A gas probe survey was carried out by Mulroy Environmental on the 15th March, 2018 at the afore-mentioned location. During this survey, an electric Makita Hilti drill equipped with a 1m long 1-inch diameter auger bit and powered by a mobile generator was used to drill 16 holes (i.e. soil vapour points) for gas monitoring (see Figure 14). The 16 vapour points were laid out in 2 rows of 8 points. Each row ran parallel with and to the north and south of the foul rising main. Each of the rows was laid out at approximately 2m offsets from the centre line of the foul rising main. It should be noted that the rising main runs at approximately 2.5m below ground level (bgl) and as such, the depth proposed for the gas probe survey (i.e. 1m maximum bgl) was deemed safe for the survey. The results of the gas probe survey are discussed in the following section, Section 10.7 of this report.

10.2 Gas Well & Groundwater Well Landfill Gas Readings

The results of the landfill gas and VOC monitoring for the groundwater and gas monitoring wells are summarised in Tables A13.1 to A13.34 in Appendix 13. As can be seen from Tables A13.1 to A13.34, the peak levels of methane (CH_4), carbon dioxide (CO_2), carbon monoxide (CO), oxygen (O_2), and Hydrogen Sulphide were measured and also a steady reading was recorded after 3 minutes. A separate methane and carbon dioxide progression chart has been prepared for all groundwater and gas monitoring wells with 48 rounds of landfill gas monitoring graphed for the original 7 boreholes, BH1-BH7 and 4 gas wells, GS01-04 (i.e. from 27/6/2018 to 21/1/2019). Each graph contains atmospheric pressure (i.e. recorded by the GA5000 landfill gas meter) and rainfall events as recorded at Dublin Airport meteorological synaptic station during the study.

After each gas well was assessed for landfill gas, following a period of 2 hours (i.e. to allow gases to stabilize within each well), each well was assessed for volatile organic compounds using a MiniRae3000 Photo-Ionisation Detector (PID). Peak readings and readings after 60 seconds were measured for VOCs (see Tables A13.1 to A13.34 in Appendix 13). Volatile Organic Compound (VOCs) measurements were not taken on days where heavy rainfall persisted given that there are limitations on the use and accuracy of a Photo-ionisation Detector during high humidity and rainfall.

Climatic data (i.e. pressure, temperature, rainfall, wind speed, etc) was collected from Dublin Airport Meteorological Station which is located approximately 18kms from the site. Data was collected for the day of the monitoring event and the day preceding the gas monitoring event to determine the atmospheric pressure trend (see Appendix 13). In addition, the atmospheric (barometric) pressure was recorded from the GA5000 Landfill Gas Analyser for each sample reading. Monitoring was achieved during both periods of high and low pressure as recommended in BS8576:2013.

10.2.1 GS01 Gas Monitoring

As can be seen from Tables A13.1 to A13.34 in Appendix 13 and the methane chart for GS01, CH_4 concentrations were recorded on 48 occasions (i.e. June 2017 – January 2019) in GS01 with concentrations found to be consistently low (i.e. 0.2% – 0.8%), while CO_2 levels ranged from 0.3% - 1.4%. Hydrogen sulphide concentrations were detected in trace concentrations (i.e. 0ppm – 2ppm) with CO concentrations also ranging from 0ppm – 19ppm. The highest concentration of VOCs (8.9ppm) was recorded on the 1st October 2018, with mostly 0ppm recorded for all subsequent readings.

10.2.2 GS02 Gas Monitoring

As can be seen from Tables A13.1 to A13.34 in Appendix 13 and the methane chart for GS02, CH_4 concentrations were recorded on 48 occasions (i.e. July 2017 – January 2019) in GS02 with concentrations found to be consistently low (i.e. 0% – 0.6%), while CO_2 levels ranged from 0% to 1%. Hydrogen sulphide concentrations were detected in trace concentrations (i.e. 0ppm – 2ppm) with CO concentrations detected in concentrations (i.e. 0ppm – 4ppm). The highest concentration of VOCs (7.4ppm) was recorded on the 1st October, 2017, with 0ppm recorded for most monitoring events after this date.

10.2.3 GS03 Gas Monitoring

As can be seen from Tables A13.1 to A13.34 in Appendix 13 and the methane chart for GS03, CH_4 concentrations were recorded on 48 occasions (i.e. July 2017 – January 2019) in GS03 with concentrations found to be consistently very low (i.e. 0% – 0.2%), while CO_2 levels ranged from 0% - 0.9%. Hydrogen sulphide concentrations were detected in trace concentrations (i.e. 0ppm – 2ppm) with CO concentrations also detected in concentrations from 0ppm – 4ppm). The highest concentration of VOCs (4.2ppm) was recorded on the 1st October 2018, with 0ppm recorded for most monitoring events after this date.

10.2.4 GS04 Gas Monitoring

As can be seen from Tables A13.1 to A13.34 in Appendix 13 and the methane chart for GS04, CH_4 concentrations were recorded on 48 occasions (i.e. July 2017 – January 2019) in GS04 with concentrations found to be consistently very low (i.e. 0% – 0.1%), while CO_2 levels ranged from 0.1% - 0.7%. Hydrogen sulphide concentrations were detected in trace concentrations (i.e. 0ppm – 3ppm) with CO concentrations also detected in concentrations ranging from 0ppm – 7ppm. The highest concentration of VOCs (5.5ppm) was recorded on the 1st October 2018, with 0ppm recorded for most monitoring events after this date.

10.2.5 BH1 Gas Monitoring

As can be seen from Tables A13.1 to A13.34 in Appendix 13 and the methane chart for BH1, CH_4 concentrations were recorded on 48 occasions (i.e. June 2017 – January 2019) in BH1 with concentrations ranging from 0% - 7.4%. As can be seen from the methane chart for BH1, concentrations have varied over the monitoring period with no obvious trend identified until the introduction of the gas venting wells on the 3rd May, 2018. Thereafter, a drop in methane to almost 0% was observed with an occasion where methane rose momentarily to 7%. It should be noted that a reading of 4% methane was observed on the last round. This reading may have occurred due to a sudden observed drop in barometric pressure and increased rainfall in the days leading up to the reading.

Carbon dioxide levels (CO_2) ranged from 0.1% - 13.2%, with concentrations consistently observed above 6%. As can be seen from the carbon dioxide chart for BH1, concentrations have varied over the monitoring period with no obvious trend identified until the introduction of the gas venting wells on the 3rd May, 2018. Thereafter, a drop in carbon dioxide to normal atmospheric levels was observed where after the Carbon dioxide levels fluctuated between 6% to 11.5%.

Both CO and H_2S were detected at trace (i.e. detection limit x 5) concentrations (i.e. 0ppm – 2ppm). The highest concentration of VOCs (4.6ppm) was recorded on the 11th August 2017. This would generally be expected given

that most polymers used to construct well casing will emit VOCs from phthalate plasticisers which are used in the plastic manufacturing industry (i.e. extrusion process). The level of VOCs was found to decrease steadily with time as a result of natural weathering.

10.2.6 BH2 Gas Monitoring

As can be seen from Tables A13.1 to A13.34 in Appendix 13, CH_4 concentrations were recorded on 48 occasions (i.e. June 2017 – January 2019) in BH2 with concentrations found to be consistently low (i.e. 0% – 0.4%). While CO_2 levels ranged from 0.8% - 4.5%. Hydrogen sulphide concentrations were detected in trace concentrations (i.e. 0ppm – 1ppm) with CO concentrations ranging from 0ppm – 5ppm. Like BH1, VOC concentrations peaked at 6.8ppm on the 11th August 2017 and reduced to 0ppm thereafter.

10.2.7 BH3 Gas Monitoring

As can be seen from Tables A13.1 to A13.34 in Appendix 13, CH_4 concentrations were recorded on 48 occasions (i.e. June 2017 – January 2019) in BH3 with concentrations found to be consistently low (i.e. 0% – 0.9%). While CO_2 levels ranged from 0.2% - 7.6%. Hydrogen sulphide and CO concentrations were both detected in trace concentrations (i.e. 0.1ppm – 0.3ppm). Volatile Organic Compounds were only detected on one occasion (i.e. 6.1ppm on the 27th June 2017).

10.2.8 BH4 Gas Monitoring

As can be seen from Tables A13.1 to A13.34 in Appendix 13, CH_4 concentrations were recorded on 50 occasions (i.e. June 2017 – January 2019) in BH4 with concentrations ranging from 11.4% to 65.1%. As can be seen from the chart for methane, concentrations increased from 11.4% on the first monitoring round to 65.1% on the 21st January 2019.

Following the septic tank removal on the December, 2017, and the introduction of the 3 gas venting wells in close proximity to BH4 on the 3rd May, 2018, following an initial increase in methane, after the 1st June, 2018, methane concentrations reduced steadily to below 20%. However, like in 2017, methane concentrations increased during the winter months of 2018 and peaked at 65.1% on the 21st January, 2019.

There was no strong correlation observed between concentration and barometric pressure.

Maximum CO_2 concentrations were observed in December 2017 (20.1%). Following the removal of the septic tank and the introduction of the gas venting wells, CO_2 concentrations generally decreased with concentration appearing to stabilise after June, 2018. Hydrogen sulphide concentrations were detected in trace concentrations (i.e. 0ppm – 3ppm) with CO concentrations ranging from 0ppm – 8ppm. The highest concentration of VOCs (7.7ppm) was recorded on the 1st October 2018, with VOC levels fluctuating from 5.2ppm on the 26th November, 2018 to 0.1ppm on the 8th January, 2019.

10.2.9 BH5 Gas Monitoring

As can be seen from Tables A13.1 to A13.34 in Appendix 13, CH_4 concentrations were recorded on 48 occasions (i.e. June 2017 – January 2019) in BH5. As can be seen from the chart for methane, concentrations of CH_4 were consistently very low throughout the monitoring period ranging from 0% - 0.2%.

As can be seen from the chart for carbon dioxide, levels of CO_2 ranged from 0.1% to 14.6%, with concentrations in excess of 5% recorded on two occasions only. Following the introduction of the gas venting wells in May, 2018, carbon dioxide concentrations appear to have stabilized. Carbon monoxide was detected in trace concentrations (i.e. 0ppm – 2ppm) with H_2S also detected in trace concentrations (i.e. 0ppm – 1ppm). The highest concentration of VOCs (14ppm) was recorded on the 12th July 2017, with concentrations reducing to 0-0.2ppm (i.e. trace) on all monitoring conducted up to the 27th of August 2017.

10.2.10 BH6 Gas Monitoring

As can be seen from Tables A13.1 to A13.34 in Appendix 13, CH_4 concentrations were recorded on 48 occasions (i.e. June 2017 – January 2019) in BH6 with concentrations ranging from 0% to 7%. As can be seen from the methane chart, a strong positive correlation was observed between rising barometric pressure and declining CH_4 concentrations. Following the septic tank removal in December, 2017 and the introduction of the 3 gas venting wells in close proximity to BH6 on the 3rd May, 2018, following an initial increase in methane, methane concentrations reduced steadily to negligible levels.

As can be seen from the carbon dioxide chart, CO_2 levels ranged from 0.1% to 15.6%, with concentrations consistently observed above 5% (i.e. on 12 monitoring occasions). Like methane, following the introduction of the gas venting wells, CO_2 concentrations reduced steadily to negligible levels.

Hydrogen sulphide concentrations were detected in trace concentrations (i.e. 0ppm – 2ppm) with CO concentrations ranging from 0ppm – 6ppm. The highest concentration of VOCs (3.8ppm) was recorded on the 11th August 2017, with readings ranging from 0 to 2.6ppm for subsequent readings. Like with BH1, the level of VOCs was found to decrease steadily with time as a result of natural weathering.

10.2.11 BH7 Gas Monitoring

As can be seen from Tables A13.1 to A13.34 in Appendix 13, CH_4 concentrations were recorded on 48 occasions (i.e. June 2017– January 2019) in BH7 with concentrations ranging from 0% to 11.9%. As can be seen from the methane chart, a strong positive correlation was observed between rising barometric pressure and declining CH_4 concentrations. Following the introduction of the 3 gas venting wells on the 3rd May, 2018, following an initial increase in methane, methane concentrations reduced steadily to negligible levels.

As can be seen from the carbon dioxide chart, CO_2 levels ranged from 0.5% to 17.1%, with concentrations consistently observed above 5% (i.e. on 9 monitoring occasions). However, like methane, following the introduction of the gas venting wells, CO_2 concentrations for the most part reduced steadily to negligible levels with some fluctuations (e.g. 1st October, 2018).

Hydrogen sulphide concentrations were detected in trace concentrations (i.e. 0ppm – 1ppm) with CO concentrations also ranging from 0ppm – 2ppm. The highest concentration of VOCs (i.e. 9ppm) was recorded on the 12th July 2017, with 0.1ppm recorded on the 14th January, 2019.

10.2.12 BH8 Gas Monitoring

As can be seen from Tables A13.2 to A13.15 in Appendix 13, CH_4 concentrations were recorded on 43 occasions (i.e. August 2017 – January 2019) in BH8 with concentrations ranging from 0% to 7.5%. The highest concentration was recorded on the first monitoring round (i.e. 11th August 2018) with levels reducing to 0% to 0.3% following the monitoring conducted on the 18th September 2017. There was an isolated increase (i.e. 4.5ppm) in methane levels on the 30th October, 2018.

As can be seen from the carbon dioxide chart, CO_2 levels ranged from 0.5% to 10.3%, with the highest concentrations observed on the earlier monitoring rounds. Hydrogen sulphide concentrations were detected in trace concentrations (i.e. 0ppm – 2ppm) with CO concentrations also low ranging from 0ppm – 3ppm. Volatile Organic Compounds were detected at a peak of 12.7ppm on the 1st October, 2018 and decreased to 0.3ppm on the 14th January, 2019.

10.2.13 BH9 Gas Monitoring

As can be seen from Tables A13.12 to A13.34 in Appendix 13, CH_4 concentrations were recorded on 43 occasions (i.e. August 2017 – January 2019) in BH9 with concentrations ranging from 0% to 23.9%. The highest concentrations were recorded on the first two monitoring rounds (i.e. 11th August 2017 and 18th September 2017) with levels reducing to 0% - 4.3% for the succeeding monitoring events.

As can be seen from the carbon dioxide chart, CO_2 levels ranged from 0.2% to 19.1%, with the highest concentrations also observed on the first two monitoring rounds. Hydrogen sulphide concentrations were detected in trace concentrations (i.e. 0ppm – 2ppm) with CO concentrations also ranging from 0ppm to 5ppm. Volatile Organic Compounds were detected at a peak of 7.7ppm on the 1st October, 2018 and decreased to 0.2ppm on the 14th January, 2019.

10.2.14 BH10 Gas Monitoring

It should be noted that, due to earthworks in the vicinity of BH10, it was not accessible for gas monitoring purposes after the 27th August, 2018 (i.e. there is no data from the 27th August, 2018 to the 21st January, 2019). As can be seen from Tables A13.2 to A13.34 in Appendix 13, CH_4 concentrations were recorded on 24 occasions (i.e. August 2017 – January 2019) in BH10 with concentrations ranging from 0% to 8.5%. The highest concentrations were recorded in the earlier monitoring rounds with levels reducing to 0-0.1% after the 6th December 2017.

As can be seen from the carbon dioxide chart, CO_2 levels ranged from 2.8% to 21.8%.

Hydrogen sulphide concentrations were detected in trace concentrations (i.e. 0ppm – 2ppm) with CO concentrations also ranging from 0ppm – 5ppm. No VOCs were detected in BH10 on any of the pre-mitigation gas monitoring rounds.

10.2.15 BH11 Gas Monitoring

As can be seen from Tables A13.2 to A13.15 in Appendix 13 and the methane chart for BH11, CH_4 concentrations were recorded on 43 occasions (i.e. August 2017 – January 2019) in BH11 with concentrations generally at 0% for the duration of the monitoring period with the exception of a single reading taken on the 2nd July, 2018 when it rose to 5.8%. Following this round, methane levels were found to return to 0.1%.

As can be seen from the carbon dioxide chart, CO_2 levels ranged from 4% to 13.2%, with concentrations consistently observed above 5%. Hydrogen sulphide concentrations were detected in trace concentrations (i.e. 0ppm – 2ppm) with CO concentrations also ranging from 0ppm – 8ppm. Volatile Organic Compounds readings were found to range from a peak of 4.2ppm on the 1st October, 2018 to 0.2ppm on the 21st January, 2019.

10.2.16 BH12 Gas Monitoring

As can be seen from Tables A13.2 to A13.34 in Appendix 13 and the methane chart for BH12, CH_4 concentrations were recorded on 43 occasions (i.e. August 2017 – January 2019) in BH12 with concentrations ranging from 0% - 19.6%. The highest concentrations were recorded on the earlier monitoring rounds with levels reducing to 0% - 0.7% in the succeeding monitoring rounds. Methane was found to increase to 7.6% in the monitoring round on the 27th August, 2018, drop to 4.9% on the 8th October, 2018 and increase to 5.9% again on the 26th November, 2018.

As can be seen from the carbon dioxide chart, CO_2 levels ranged from 3.6% - 20%, with concentrations consistently observed above 5%. Hydrogen sulphide concentrations were detected in trace concentrations (i.e. 0ppm – 3ppm) with CO concentrations also ranging from 0ppm – 9ppm. Volatile Organic Compounds readings were found to range from a peak of 5ppm on the 26th November, 2018 to 0.3ppm on the 21st January, 2019.

10.2.17 BH13 Gas Monitoring

As can be seen from Tables A13.2 to A13.34 in Appendix 13 and the methane chart for BH13, CH_4 concentrations were recorded on 43 occasions (i.e. August 2017 – January 2019) in BH13 with concentrations found to be consistently low (i.e. 0% – 0.5%). As can be seen from the CO_2 chart for BH13, CO_2 levels ranged from 0.1% - 7.4%. Hydrogen sulphide concentrations were detected in trace concentrations (i.e. 0ppm – 3ppm) with CO concentrations ranging from 0ppm – 2ppm. Volatile Organic Compounds readings were found to range from a peak of 9.2ppm on the 1st October, 2018 to 0.3ppm on the 21st January, 2019.

10.2.18 BH14 Gas Monitoring

As can be seen from Tables A13.3 to A13.34 in Appendix 13 and the methane chart for BH14, CH_4 concentrations were recorded on 42 occasions (i.e. December 2017 – January 2019) in BH14 with concentrations found to be consistently very low (i.e. 0% – 0.1%).

As can be seen from the CO_2 chart for BH13, CO_2 levels ranged from 0.2% - 6.6% with the highest reading observed on the 11th June, 2018. Hydrogen sulphide concentrations were detected in trace concentrations (i.e. 0ppm – 1ppm) with CO concentrations ranging from 0ppm – 7ppm. Volatile Organic Compounds readings were found to range from a peak of 11.4ppm on the 1st October, 2018 to 0.2ppm on the 11th December, 2019.

10.2.19 BH15 Gas Monitoring

As can be seen from Tables A13.9 to A13.34 in Appendix 13 and the methane chart for BH15, CH_4 concentrations were recorded on 32 occasions (i.e. May 2018 – January 2019) in BH15 with concentrations found to be consistently very low (i.e. 0% – 0.1%).

As can be seen from the CO_2 chart for BH15, CO_2 levels ranged from 0.9% to approximately 11.9% with the highest reading observed on the 16th July, 2018. Hydrogen sulphide concentrations were detected in trace concentrations (i.e. 0ppm – 1ppm) with CO concentrations ranging from 0ppm – 4ppm. Volatile Organic Compounds readings were found to be generally low throughout with VOC levels rising to 7.9ppm on the 27th August, 2018.

10.2.20 BH16 Gas Monitoring

As can be seen from Tables A13.9 to A13.34 in Appendix 13 and the methane chart for BH16, CH_4 concentrations were recorded on 32 occasions (i.e. May 2018 – January 2019) in BH16 with concentrations found to be consistently very low (i.e. 0% – 0.1%).

As can be seen from the CO_2 chart for BH16, CO_2 levels ranged from 0.2% - 12% with the highest reading observed on the 9th July, 2018. Hydrogen sulphide concentrations were detected in trace concentrations (i.e. 0ppm – 2ppm) with CO concentrations ranging from 0ppm – 5ppm. Volatile Organic Compounds readings were found to range from a peak of 7.3ppm on the 1st October, 2018 to 0.5ppm on the 14th January, 2019.

10.2.21 BH17 Gas Monitoring

As can be seen from Tables A13.9 to A13.34 in Appendix 13 and the methane chart for BH17, CH_4 concentrations were recorded on 32 occasions (i.e. May 2018 – January 2019) in BH17 with concentrations found to vary considerably (i.e. 0% to 17.6%). Methane was found to increase to 17.6% in the monitoring round of 14th January, 2018.

As can be seen from the CO_2 chart for BH17, CO_2 levels ranged from 10.5% to 18.1% with the highest reading observed on the 27th August, 2018.

Hydrogen sulphide concentrations were detected in trace concentrations (i.e. 0ppm – 1ppm) with CO concentrations ranging from 0ppm – 3ppm. Volatile Organic Compounds readings were found to range from a peak of 5.8ppm on the 26th November, 2018 to 0.4ppm on the 17th December, 2018.

10.3 Radon Sump Gas Monitoring

Tables A13.35 to A13.67 in Appendix 13 show the results obtained for the outdoor landfill gas and VOC monitoring of residence's radon sumps from September, 2017 to January, 2019 (see Figure 13).

As can be seen from Tables A13.35 to A13.67, CH_4 concentrations were mostly recorded at 0% during the entirety of the monitoring period. On a single occasion (i.e. 14th February 2018), a very low CH_4 concentration of 0.2% was detected at House No. 25. Methane concentrations of 0.1% was recorded for a number of houses on the 1st August 2018 and on 7th August 2017. Carbon dioxide levels were at or below 0.4% on all monitoring rounds. The low levels of methane and carbon dioxide found within the sumps should be regarded as 'trace detections'. Trace detections are defined as *'the detection limit of the instrument x 5'*. The accuracy of trace detections should not be relied upon, because they may be caused by factors such as background interference by moisture in the gas (the analyser will have been calibrated using dry gas), or instrument drift as the instrument has warmed up or been moved since the latest calibration. These factors will affect portable instruments measuring methane, carbon dioxide, carbon monoxide, hydrogen sulphide and volatile organic compounds by photo ionisation detection (PID) (see *'Potential Linkage A–Landfill Gas'* of Argentum Fox external review report in Appendix 15).

It should be noted that trace concentrations of VOCs were found within a number of the service pipes. However, this would generally be expected given that most polymers will emit VOCs from phthalate plasticisers which are used in the plastic manufacturing industry (i.e. extrusion process). The level of VOCs were found to decrease steadily with time as a result of natural weathering.

10.4 Water Meter Chamber Gas Monitoring

Tables A13.35 to A13.67 in Appendix 13 show the results obtained for the outdoor landfill gas and VOC monitoring of residence's water mains chamber from November, 2017 to January, 2019 (see Figure 13).

As can be seen from Tables A13.35 to A13.67, CH_4 concentrations were recorded at or below 0.2% during the entirety of the monitoring period (i.e. November 2017 – January, 2019). Carbon dioxide levels were mostly at or below 0.4%. On two monitoring events (11th June 2018 and 9th July 2018), low CO_2 concentrations ranging from of 1.2% to 1.5% were detected at the water mains for Residences Nos. 25 & 27. As with the results obtained during the radon sump monitoring, the low levels of methane and carbon dioxide found within the water mains should be regarded as 'trace detections' (see *'Potential Linkage A–Landfill Gas'* of Argentum Fox external review report in Appendix 15).

Since the start of the water mains chamber monitoring by Photo-Ionisation detector (PID) on the 24th November, 2017, VOCs have been observed at varying concentrations. The highest concentrations of VOCs within the water mains chambers were observed on the 21st January, 2019 when VOCs were detected in 19 of the 22 water mains manholes at concentrations varying from 0.5ppm to 80.4ppm. This is a slight increase on the number found to have VOCs in the previous round of the 14th January, 2019. In order to determine if the VOCs found in the water mains chambers were caused by the presence of the Frost Protection Cap, Mulroy Environmental carried out a vapour emission assessment of a frost protection cap that was borrowed from the site. As part of this assessment, headspace testing was carried out and it was concluded that VOCs were being emitted from the frost protection

cap (see Appendix 14). Following this, in January, 2019, 2 frost protection caps were borrowed from the site and submitted to Odour Monitoring Ireland to carry out a comprehensive VOC emissions assessment. The report for the afore-mentioned assessment by OMI is expected in February, 2019. The outcomes of this VOC emissions assessment are pending but are expected to confirm Mulroy Environmental's preliminary findings.

10.5 Stormwater Sewer (ST1 & ST2) Gas Monitoring

Tables A13.35 to A13.67 in Appendix 13 show the results obtained for the outdoor landfill gas and VOC monitoring of the 2 stormwater drain access chambers to the south west of residences Nos. 25 and 26 from November, 2017 to January, 2019 (see Figure 13).

As can be seen from Tables A13.35 to A13.67, CH_4 levels within stormwater access chambers, ST1 or ST2 were below 0.1% during the entirety of the monitoring period (i.e. November 2017 – January, 2019). Carbon dioxide levels were at or below 0.3% on all monitoring rounds.

10.6 Stormwater/Surface Water Sewer (SW2 & SW3) Gas Monitoring

Tables A13.47 to A13.67 in Appendix 13 show the results obtained for the outdoor landfill gas and VOC monitoring of the 2 stormwater/surface water drain access chambers (SW2 and SW3) which are located to the northeast of the development from August, 2018 to January, 2019 (see Figures 11 & 13).

As can be seen from A13.47 to A13.67, CH_4 levels within stormwater access chambers, SW2 and SW3 were below 0.1% during the entirety of the monitoring period (i.e. November 2017 – January, 2019). Carbon dioxide levels were at or below 0.1% on all monitoring rounds.

10.7 Landfill Gas Probe Survey at Foul Rising Main/Landfill Body Interface

Tables A13.68A in Appendix 13 shows the results obtained for the landfill gas probe survey that was carried out on the 15th March, 2018 in the north-western end of the landfill where the foul rising main exits the landfill (see Figures 13 and 14A). As can be seen from Tables A13.68A, CH_4 levels were below 0.2% for all 16 gas probe locations. Carbon dioxide levels ranged from 0.1% to 0.8% for all 16 gas probe locations. Carbon monoxide levels varied from 0ppm to 51pppm with H_2S levels varying from 0ppm to 13ppm.

10.8 Landfill Gas Probe Survey at Foul Rising Main/Waste Water Treatment Plant

Tables A13.68B in Appendix 13 shows the results obtained for the landfill gas probe survey that was carried out on the 28th November, 2018 at the south-western corner of the Waste Water Treatment Plant located to the east of the waste body (see Figure 14C). As can be seen from Tables A13.68B, CH_4 was not detected in any of the survey points. Carbon dioxide levels ranged from 0.1% to 0.2% for all 9 gas probe locations. Carbon monoxide levels varied from 0ppm to 5pppm with H_2S levels varying from 0ppm to 1ppm.

10.9 Indoor Residence Landfill Gas & VOC Survey of Indoor Services & Outdoor Radon Sump

On the 29th May and the 5th June, 2017, the 4 nearest residences to the landfill, Residences Nos. 25 to 28, were inspected and 5 internal gas monitoring points, BMP1-5 were identified for landfill gas and VOC monitoring (see Figure 14B). It should be noted that, at the time of the assessment, all 4 residences were in the middle of the

internal fit-out phase of their construction. These 5 points were each 110mm uPVC pipes that had rubber end caps/seals to prevent material entering them until connected up to utilities (i.e. wash hand basins, water closets, kitchen sinks, etc). As such, they were effectively trapping any gases that may have entered the pipework external to the house. The newly installed radon sumps for each of the 4 houses was also monitored (see previous Plate 9). This work was carried out using both a GA2000 and the Photo-ionisation Detector (PID) simultaneously. During this exercise the newly installed radon gas sump to the rear of each residence was opened and monitored. The results of this survey are presented in 2 tables, Tables A13.69A and A13.69B located in Appendix 13.

As can be seen from Tables A13.69A and A13.69B, on both monitoring events, CH_4 levels were below 0.1% for all 5 monitoring locations and each radon sump in each of the 4 houses. Carbon dioxide levels ranged from 0.1% to 0.3% for all 5 monitoring locations and each radon sump. Carbon monoxide levels varied from 0ppm to 3pppm with H_2S levels varying from 0ppm to 1ppm.

10.10 Landfill Gas Readings (Post-Passive Gas Venting Well (GV01-05) Installation on 3rd May, 2018)

In total, 33 landfill gas monitoring rounds have been conducted on the boreholes and gas wells on site following the installation of the passive gas venting wells on the 3rd May, 2018. It should be noted that boreholes BH15 – BH17 were installed on the 17th of May 2018 and as a consequence 32 monitoring rounds in total have been carried out on these boreholes.

10.10.1 Methane

Prior to the installation of the passive gas venting wells, CH_4 concentrations were found to be very low within boreholes BH2, BH3, BH5, GS01, GS02, GS03 & GS04. Methane concentrations continued to be very low during the subsequent monitoring rounds. Similarly, CH_4 concentrations were found to have reduced to very low levels in BH8 and BH10 – BH14 prior to the installation of the passive gas venting wells. Methane concentrations continued to be very low during the subsequent monitoring rounds.

After the installation of the passive gas venting wells, CH_4 concentration appeared to have continually reduced for most of the gas wells. However, like in 2017, with the onset of the winter months (i.e. October to November) and increased rainfall the levels of CH_4 increased noticeably in BH4 and BH17 and to a lesser extent on other boreholes (i.e. BH1, BH5 and BH6).

The highest steady reading for methane on site (i.e. 65.1%) was obtained in BH4 on the 21st January, 2019 with nitrogen being reduced to 23.8%. The next highest steady reading for methane on site (i.e. 17.6%) was obtained in BH17 on the 14th January, 2019 with nitrogen being reduced to 71.8%. However, it should be noted that methane levels in BH17 have decreased with a reduction to 8.8% on the 21st January, 219. It is likely that this pattern is caused by increased precipitation over the winter months (see Argentum Fox external report in Appendix 15).

It is expected that, for 2019, that CO_2 levels will follow the same pattern observed in 2018 during the spring and summer months where methane concentrations gradually declined.

10.10.2 Carbon Dioxide

After the installation of the passive gas venting wells, carbon dioxide concentration trends were as follows:

- CO_2 concentrations were found to be low in BH2, BH3, BH5, BH14, GS01, GS02, GS03 & GS04, with low concentrations continuing to be observed after the installation of the passive gas venting wells;
- After the installation of the passive gas venting wells, CO_2 concentration appear to have continually reduced within BH1, BH6 & BH7; and
- Like in 2017, with the onset of the winter months (i.e. October to November) and increased rainfall, the levels of CO_2 increased steadily. CO_2 concentrations were found in excess of 5% in BH1, BH4, BH7, BH11, BH12, BH15 and BH17 on the 21st January, 2019.

It is expected that, for 2019, that CO_2 levels will follow the same pattern observed in 2018 during the spring and summer months where CO_2 concentrations gradually declined.

10.11 Landfill Gas Risk Assessment

10.11.1 Preliminary Assessment

The results of each of the ground gas monitoring events were assessed for risk according to *CIRIA Report C665 'Assessing risks posed by hazardous ground gases in buildings' by S. Wilson, S. Oliver, H. Mallett, H. Hutchings & G. Card. (July 2007).* The results of the ground gas monitoring events were assessed for risk in accordance with CIRIA C665. A common method for characterising a site, is through the use of the Wilson and Card Methodology (1999). The method uses both gas concentrations and borehole flow rates to define a characteristic situation for a site based on the gas screening value (GSV) for methane (CH_4) and carbon dioxide (CO_2) (see Table 8 below). According to CIRIA C665, where low rise houses (i.e. with a 150mm ventilated underfloor void) exist, the characterisation method proposed by Boyle and Witherington (2007) should be used. The NHBC method proposed by Boyle and Witherington is similar to the Wilson and Card system in that GSV's are utilised. This approach categorises the risk by comparing the measured gas emission rates to *'traffic light'* scenarios (see Table 9 following). Given that Residences Nos. 25 and 26 at Hamilton Hill, Barnageeragh Cove have been constructed with a 150mm underfloor void and that the other houses in the development have not, both risk assessment methodologies have been used. The risk assessment data derived from the landfill gas monitoring data (i.e. pre and post passive gas venting well installation) are presented in the following tables, Tables 10 and 11. Initially, the calculation is carried out for carbon dioxide and methane with the worst-case scenario identified during the monitoring period, adopted.

Table 8. Modified Wilson and Card Classification (CIRIA 665)

CHARACTERISTIC SITUATION (CIRIA REPORT 665)	RISK CLASSIFICATION	GAS SCREENING VALUE (GSV) (CH_4 OR CO_2) (L/HR) THRESHOLD	ADDITIONAL FEATURES
1	Very Low Risk	<0.07	Typical Methane <1%v/v and or Carbon Dioxide <5%v/v. Otherwise consider increase to Situation 2
2	Low Risk	<0.7	Borehole flow rate not to exceed 70l/hr. Otherwise consider increase to Situation 3
3	Moderate Risk	<3.5	_
4	Moderate to High Risk	<15	Quantitative risk assessment required to evaluate scope of protective measures
5	High Risk	<70	_
6	Very High Risk	>70	_

Table 9. NHBC Traffic Light System for 150mm void (CIRIA 665)

Traffic light	Methane[1]		Carbon dioxide[1]	
	Typical maximum concentration[5] (% v/v)	Gas screening value (GSV)[2,4,6] (litres per hour)	Typical maximum concentration[5] (% v/v)	Gas screening value (GSV)[2,3,4,5] (litres per hour)
Green	1	0.16	5	0.78
Amber 1	5	0.63	10	1.56
Amber 2	20	1.56	30	3.13
Red				

10.11.2 Pre-Passive Gas Venting Well Assessment

Based on a worst-case scenario the CIRIA R149 Characteristic Situation '1' (very low risk) was applied to 6 of the 18 boreholes on site. Please note that BH15 to BH17 were installed after the installation of the passive gas venting wells. This applied to the four boreholes (GAS1 – GAS4) installed directly to the south of the newly developed houses, BH2 which is located towards the western boundary of the landfill and BH14 which was located to the north of the waste body (see Table 10).

The modified Wilson and Card Classification system detailed in CIRIA665 indicates for a *'very low risk classification'* to apply, CO_2 values should be typically <5.0%, while CH_4 values should be typically <1.0%. While no GSV above <0.07 (i.e. very low risk threshold) was determined in any of the 21 boreholes, an exceedance of 5.0% for CO_2 and/or 1.0% for CH_4 was observed in 12 of the 18 boreholes and were therefore classified as *'low risk'*.

Based on a worst-case scenario the NHBC *'Green Light'* risk classification was applied to 6 of the 18 boreholes on site. This applied to the same 6 boreholes assigned a 'very low risk' using the Wilson & Card Methodology. Two boreholes were assigned an *'Amber 1'* classification given an exceedance of either / or the 1% CH_4 limit and 5% CO_2 limit. Eight boreholes were assigned an 'Amber 2' classification given an exceedance of either / or the 5% CH_4 limit and 10% CO_2 limit. Two boreholes namely BH4 and BH9 were given a 'Red' classification due to the CH_4 concentration in excess of 20%.

10.11.3 Post-Passive Gas Venting Well Assessment

Based on a worst-case scenario, the CIRIA R149 Characteristic Situation '1' (very low risk) was applied to 7 of the 21 boreholes on site. The modified Wilson and Card Classification system detailed in CIRIA665 indicates for a *'very low risk classification'* to apply, CO_2 values should be typically <5.0%, while CH_4 values should be typically <1.0% while the GSV should not exceed 0.07. This applied to the four boreholes (GAS1 – GAS4) installed directly to the south of the newly developed houses, BH2 which is located towards the western boundary of the landfill, BH3 which is located within the waste body and BH5 which is located on the north western end of the landfill (see Table 11).

An exceedance of 5.0% for CO_2 and/or 1.0% for CH_4 was observed in 14 of the 21 boreholes and those boreholes were therefore automatically classified as the next risk level higher i.e., *'low risk'* (i.e. even though 13 of the 14 GSVs did not exceed 0.07). For BH4, the maximum (worst case) methane and CO_2 concentrations were 73.6% and 20.9% respectively, which combined with worst case flow measurement, results in GSVs of 0.29 for methane and 0.08 for CO_2. Because the methane GSV was less than 0.7 this borehole is classed as *'low risk'* using this methodology.

Based on a worst-case scenario the alternative NHBC risk classification methodology was also applied, with 7 of the 21 boreholes on site achieving a *'Green Light' status*. This applied to the same 7 boreholes assigned a 'very low risk' using the Wilson & Card Methodology. Four boreholes were assigned an *'Amber 1'* classification because of an exceedance of either the 1% CH_4 limit and/or the 5% CO_2 limit for this category. Eight boreholes were assigned an *'Amber 2'* classification given an exceedance of either the 5% CH_4 limit and/or the 10% CO_2 limit for this category. Borehole BH4 was given a *'Red'* classification under this methodology due to the CH_4 concentration in excess of 20%. It should be noted that BH9 which was previously classified as *'Red'*, was classified as 'Amber 1' following the installation of the passive gas venting wells.

Given that GSVs are calculated using both concentration and flow, the flow readings provide important context. The maximum flow recorded over the monitoring period was 0.4l/hr. Consequently, neither the Wilson & Card *'very low risk'* GSV of <0.07 nor the NHBC '*Green*' GSV of 0.16 for CH_4 or 0.78 CO_2 was exceeded for 20 of the 21 boreholes. The NHBC '*Green*' GSV of 0.16 for CH_4 was exceeded in BH4 (0.29), but was assigned as '*Red'* due to the elevated methane concentration.

10.11.4 Revised / Detailed Assessment

British Standard BS 8485:2015 *Code of Practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings* states that *'Adopting a GSV based on Q_{hg} calculated from peak flow measurements might result in a disproportionately high gas hazard prediction and assignment of an over-precautionary CS'*. Similarly, CIRIA C665 *Assessing risks posed by hazardous ground gases to buildings* states that '*It is important to recognise that the GSV is a guideline value and not an absolute threshold. That is, the GSV quoted in Table 8.5 can be exceeded in certain circumstances should the conceptual site model indicate it is safe to do so'.*

Table 10: Summary of GSVs and Associated Risk Classifications from Monitoring Data recorded at Gas Wells GS01 to GS04 and BH1 to BH14 in Barnageernagh Cove, Skerries (Pre-Passive Gas Venting Well Installation)

MONITORING POINT	DATE OF MAX VALUE OF FLOW	FLOW l/hr	MAXIMUM VALUE RECORDED DURING MONITORING EVENTS [1]				GAS SCREENING VALUE (l/hr) [2]		WILSON & CARD METHODOLOGY		'SITUATION B" NHBC TRAFFIC LIGHT SYSTEM	JUSTIFICATION FOR RISK SCORE
			DATE OF MAX VALUE OF CH4	CH4 (%)	DATE OF MAX VALUE OF CO2	CO2 (%)	CH4	CO2	"SITUATION A" CHARACTERISTIC SITUATION [3]	RISK CLASSIFICATION		
GS01	12/07/2017	0.2	20/12/2017	0.8	11/08/2017	1.4	0.0016	0.0028	1	Very Low Risk	GREEN	-
GS02	12/07/2017	0.3	24/04/2018	0.6	11/08/2017	1.4	0.0018	0.0042	1	Very Low Risk	GREEN	-
GS03	06/12/2017	0.2	18/09/2017	0.2	18/09/2017	0.9	0.0004	0.0018	1	Very Low Risk	GREEN	-
GS04	12/07/2017	0.1	04/05/2018	0.3	12/07/2017	0.7	0.0003	0.0007	1	Very Low Risk	GREEN	-
BH1	14/02/2017	0.2	26/02/2018	7.4	15/03/2018	13.2	0.0148	0.0264	2	Low Risk	AMBER 2	SITUATION A - Low Risk given that CH4 concentration is above 1%, CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Amber 2, given that CH4 concentration is above 5%, CO2 concentration is above 10% while Green GSV's are not exceeded
BH2	11/08/2017	0.3	27/06/2017	0.4	13/12/2017	4.5	0.0012	0.0135	1	Very Low Risk	GREEN	-
BH3	14/02/2018	0.2	13/12/2017	0.9	02/08/2017	7.6	0.0018	0.0152	2	Low Risk	AMBER 1	SITUATION A - Low Risk given that CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Amber 1 given that CO2 concentration is above 5% while Green GSV's are not exceeded
BH4	24/01/2018	0.2	20/12/2017	58.7	06/12/2017	20.2	0.1174	0.0404	2	Low Risk	RED	SITUATION A - Low Risk given that CH4 concentration is above 1%, CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Red given that CH4 concentration is above 20%
BH5	15/02/2018	0.1	24/04/2018	4.6	11/08/2017	14.6	0.0046	0.0146	2	Low Risk	AMBER 2	SITUATION A - Low Risk given that CH4 concentration is above 1%, CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Amber 2 given that CO2 concentration is above 10% while Green GSV's are not exceeded
BH6	26/02/2017	0.2	14/02/2018	7.2	02/08/2017	15.7	0.0144	0.0314	2	Low Risk	AMBER 2	SITUATION A - Low Risk given that CH4 concentration is above 1%, CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Amber 2 given that CH4 concentration is above 5%, CO2 concentration is above 10% while Green GSV's are not exceeded
BH7	14/02/2018	0.2	23/11/2017	5.5	13/12/2017	17.1	0.011	0.0342	2	Low Risk	AMBER 2	SITUATION A - Low Risk given that CH4 concentration is above 1%, CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Amber 2 given that CH4 concentration is above 5%, CO2 concentration is above 10% while Green GSV's are not exceeded
BH8	14/02/2018	0.3	11/08/2017	7.5	18/09/2017	10.3	0.0225	0.0309	2	Low Risk	AMBER 2	SITUATION A - Low Risk given that CH4 concentration is above 1%, CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Amber 2 given that CH4 concentration is above 5%, CO2 concentration is above 10% while Green GSV's are not exceeded
BH9	20/12/2017	0.2	11/08/2017	24.6	11/08/2017	19.1	0.0492	0.0382	2	Low Risk	RED	SITUATION A - Low Risk given that CH4 concentration is above 1%, CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Red given that CH4 concentration is above 20%
BH10	26/02/2018	0.2	23/11/2017	8.7	18/09/2017	21.8	0.0174	0.0436	2	Low Risk	AMBER 2	SITUATION A - Low Risk given that CH4 concentration is above 1%, CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Amber 2 given that CH4 concentration is above 5%, CO2 concentration is above 10% while Green GSV's are not exceeded
BH11	20/12/2017	0.2	23/11/2017	3.6	18/09/2017	13.2	0.0072	0.0264	2	Low Risk	AMBER 2	SITUATION A - Low Risk given that CH4 concentration is above 1%, CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Amber 2 given that CO2 concentration is above 10% while Green GSV's are not exceeded
BH12	11/08/2017	0.1	18/09/2017	19.6	18/09/2017	20.1	0.0196	0.0201	2	Low Risk	AMBER 2	SITUATION A - Low Risk given that CH4 concentration is above 1%, CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Amber 2 given that CH4 concentration is above 5%, CO2 concentration is above 10% while Green GSV's are not exceeded
BH13	11/08/2017	0.1	18/09/2017	0.5	18/09/2017	7.4	0.0005	0.0074	2	Low Risk	AMBER 1	SITUATION A - Low Risk given that CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Amber 1 given that CO2 concentration is above 5% while Green GSV's are not exceeded
BH14	11/08/2017	0.1	15/03/2018	0.1	06/12/2017	1.8	0.0001	0.0018	1	Very Low Risk	GREEN	-

Note:

1 Maximum concentrations recorded during all monitoring periods utilised in the calculation

2 GSV = (concentration/100) x flow rate

3 *Situation A'* All other development types. *'Situation B'* refers to Low rise housing with ventillation under floor void.

Table 11: Summary of GSVs and Associated Risk Classifications from Monitoring Data recorded at Gas Wells GS01 to GS04 and BH1 to BH17 in Barnageernagh Cove, Skerries (Post-Passive Gas Venting Well Installation)

MONITORING POINT	DATE OF MAX VALUE OF FLOW	FLOW l/hr	MAXIMUM VALUE RECORDED DURING MONITORING EVENTS [1]				GAS SCREENING VALUE (l/hr) [2]		WILSON & CARD METHODOLOGY		'SITUATION B" NHBC TRAFFIC LIGHT SYSTEM	JUSTIFICATION FOR RISK SCORE
			DATE OF MAX VALUE OF CH4	CH4 (%)	DATE OF MAX VALUE OF CO2	CO2 (%)	CH4	CO2	"SITUATION A" CHARACTERISTIC SITUATION [3]	RISK CLASSIFICATION		
GS01	18/06/2018	0.3	11/12/2018	0.2	11/06/2018	4.5	0.0006	0.0135	1	Very Low Risk	GREEN	-
GS02	18/06/2018	0.3	30/07/2018	0.1	11/06/2018	0.9	0.0003	0.0027	1	Very Low Risk	GREEN	-
GS03	23/07/2018	0.4	30/07/2018	0.1	11/06/2018	0.7	0.0004	0.0028	1	Very Low Risk	GREEN	-
GS04	23/07/2018	0.5	16/07/2018	0.8	03/09/2018	0.3	0.004	0.0015	1	Very Low Risk	GREEN	-
BH1	09/07/2018	0.6	18/06/2018	7.4	08/10/2018	11.5	0.0444	0.069	2	Low Risk	AMBER 2	SITUATION A - Low Risk given that CH4 concentration is above 1%, CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Amber 2, given that CH4 concentration is above 5%, CO2 concentration is above 10% while Green GSV's are not exceeded
BH2	25/06/2018	0.3	16/07/2018	0.2	18/06/2018	3.9	0.0006	0.0117	1	Very Low Risk	GREEN	-
BH3	17/09/2018	0.2	14/01/2019	0.1	09/07/2018	4.5	0.0002	0.009	1	Very Low Risk	GREEN	-
BH4	16/07/2018	0.4	14/01/2019	73.6	28/05/2018	20.9	**0.2944**	0.0836	2	Low Risk	**RED**	SITUATION A - Low Risk given that CH4 concentration is above 1%, CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Red given that CH4 concentration is above 20%
BH5	18/06/2018	0.3	30/07/2018	0.2	03/09/2018	3.3	0.0006	0.0099	1	Very Low Risk	GREEN	-
BH6	25/06/2018	0.3	08/10/2018	3.9	24/09/2018	11.6	0.0117	0.0348	2	Low Risk	AMBER 2	SITUATION A - Low Risk given that CH4 concentration is above 1%, CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Amber 2 given that CO2 concentration is above 10% while Green GSV's are not exceeded
BH7	24/09/2018	0.2	17/12/2018	11.9	21/01/2019	13.3	0.0238	0.0266	2	Low Risk	AMBER 2	SITUATION A - Low Risk given that CH4 concentration is above 1%, CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Amber 2 given that CH4 concentration is above 5%, CO2 concentration is above 10% while Green GSV's are not exceeded
BH8	13/11/2018	0.2	08/01/2019	0.8	11/06/2018	6.6	0.0016	0.0132	1	Low Risk	AMBER 1	SITUATION A - Low Risk given that CH4 concentration is below 1% but CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Amber 1 given that CH4 concentration is below 1% but CO2 concentration is above 5% while Green GSV's are not exceeded
BH9	11/06/2018	0.3	05/11/2018	4.7	05/11/2018	8.8	0.0141	0.0264	2	Low Risk	AMBER 1	SITUATION A - Low Risk given that CH4 concentration is above 1% and CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Amber 1 given that CH4 concentration is above 1% and CO2 concentration is above 5% while Green GSV's are not exceeded
BH10	11/06/2018	0.2	09/07/2018	0.3	23/07/2018	13.7	0.0006	0.0274	2	Low Risk	AMBER 2	SITUATION A - Low Risk given that CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Amber 2 given that CO2 concentration is above 10% while Green GSV's are not exceeded
BH11	11/06/2018	0.3	09/07/2018	5.8	05/11/2018	14.8	0.0174	0.0444	2	Low Risk	AMBER 2	SITUATION A - Low Risk given that CH4 concentration is above 1%, CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Amber 2 given that CH4 concentration is above 5%, CO2 concentration is above 10% while Green GSV's are not exceeded
BH12	21/01/2019	0.2	08/01/2019	8.4	27/08/2018	14.7	0.0168	0.0294	2	Low Risk	AMBER 2	SITUATION A - Low Risk given that CH4 concentration is above 1%, CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Amber 2 given that CH4 concentration is above 5%, CO2 concentration is above 10% while Green GSV's are not exceeded
BH13	21/01/2019	0.2	11/12/2018	0.1	01/10/2018	6.7	0.0002	0.0134	2	Low Risk	AMBER 1	SITUATION A - Low Risk given that CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Amber 1 given that CO2 concentration is above 5% while Green GSV's are not exceeded
BH14	08/01/2019	0.2	09/07/2018	0.2	11/06/2018	6.6	0.0004	0.0132	2	Low Risk	AMBER 1	SITUATION A - Low Risk given that CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Amber 1 given that CO2 concentration is above 5% while Green GSV's are not exceeded
BH15	17/09/2018	0.2	08/01/2019	0.3	03/09/2018	15.1	0.0006	0.0302	2	Low Risk	AMBER 2	SITUATION A - Low Risk given that CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Amber 2 given that CO2 concentration is above 10% while Green GSV's are not exceeded
BH16	13/08/2018	0.3	28/05/2018	0.3	09/07/2018	12.4	0.0009	0.0372	2	Low Risk	AMBER 2	SITUATION A - Low Risk given that CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Amber 2 given that CO2 concentration is above 10% while Green GSV's are not exceeded
BH17	14/01/2019	0.2	14/01/2019	17.8	27/08/2018	18.1	0.0356	0.0362	2	Low Risk	AMBER 2	SITUATION A - Low Risk given that CH4 concentration is above 1%, CO2 concentration is above 5% while GSV's are below 0.7 SITUATION B - Amber 2 given that CH4 concentration is above 5%, CO2 concentration is above 10% while Green GSV's are not exceeded

Note:

1 Maximum concentrations recorded during all monitoring periods utilised in the calculation

2 GSV = (concentration/100) x flow rate

3 *Situation A'* All other development types. *'Situation B'* refers to Low rise housing with ventillation under floor void.

Landfill gas migration generally occurs when gas is generated within a waste body, then pushes out the air entrained within the pore space which then subsequently moves along the path of least resistance via advection / diffusion to areas of low pressure and / or low concentration. Based on the landfill gas monitoring data taken to date, the balance gas (inert nitrogen in the soil pore-spaces) is similar to atmospheric air concentrations in almost all wells, indicating that there is insufficient gas generation to push out the air entrained and diffusing into the unsaturated zone. The only location where the balance gas concentration is less than atmospheric air is in BH4. However, the balance gas concentrations of inert nitrogen do not suggest significant gas generation in BH4, so it is not interpreted to be a major 'source' of landfill gas. In addition, given that BH4 is situated approx. 40m from the nearest house, it is interpreted that the statement in BS 8485:2015 '*the assignment of the GSV based on the application of the Qhg obtained from the source is inappropriate'* is relevant to data from this well. In essence, applying a worse case GSV from the BH4 'source' well to assess potential risk to the houses is not appropriate.

A number of wells (i.e. GS1 – GS4, BH2, BH3 & BH5) have been installed within the pathway between the waste body/source and the houses to the west and the north. Gas wells GS1 – GS4 which are located in closest proximity to the residences were found to have a *'very low risk' / 'Green'* classification both before and after the passive gas venting wells were installed. Boreholes BH2, BH3 and BH5 were also found to have a *'very low risk' / 'Green'* classification after the installation of the passive gas venting wells. The results of the indoor residential gas monitoring also provide evidence that no gas linkage exists between the landfill and residential properties. It therefore can be concluded that there is a very low risk of gas migration associated with the Barnageeragh landfill.

11 INTERNAL AIR QUALITY MONITORING

Even though the risk has been assessed as very low risk in the pathway boreholes, Odour Monitoring Ireland was initially commissioned to undertake further gas monitoring within the closest residences (i.e. Residences Nos. 25, 26, 52 & 53) to the waste body and within the gas wells opposite to the closest receptor (i.e. GS1 – GS4) (see Figure 13). In addition to methane and carbon dioxide monitoring, a number of other parameters/suites including arsenic, mercury, formaldehyde, acetaldehyde and trace landfill gas screen were analysed. The 1st OMI report can be found in Appendix 14.

With regards to the CO_2 levels, the monitored concentrations were normal for the environment they were monitored within *(ASHRAE Standard 62.1 – 2004).* In relation to the surface emissions Methane/VOC screen, the levels detected were approximately background and were no greater than 1.74 mg/Nm^3 indication that landfill gas is not migrating from the waste body.

With regards to Residences Nos. 25 and 26, trace concentrations of Benzene, Carbon tetrachloride, Dichloromethane, Styrene, Toluene, Formaldehyde and Acetaldehyde were detected in the headspace of both houses, with 1,2 Dichloroethylene (DCE) and Dimethyl sulphide also detected in House No. 26 (see Figure 13). There was a noticeable odour of paints, varnishes and glues in the house. All detected compounds were well within the 8hr occupational exposure limits for the each of the respective compounds. When compound concentrations were compared to fractional exposure limit values (i.e. to represent 24hr exposure), the detected concentration levels of Formaldehyde were in excess of the fractional exposure limit value for both houses with benzene levels also in excess for Residence No. 26.

With regards to Residences Nos. 52 and 53, trace concentrations of Benzene, Toluene, Carbon tetrachloride, Mercury and Hydrogen sulphide were detected in the headspace of the house. These houses were not finished and had no windows present and therefore were, more susceptible to outside influences from compounds in the ambient environment. The concentration levels of these compounds were trace and well within their respective 8hr occupational exposure limits. When compound concentrations were compared to fractional exposure limit values (i.e. to represent 24hr exposure), the detected concentration levels of Mercury (i.e. fractional limit value 0.0001 mg/Nm^3) were in excess of the fractional exposure limit value. However, it is not believed that these mercury levels are associated with the landfill. Note the Environment Agency report P1-491 *Quantification of trace components in landfill gas* noted that *'There are now sufficient data to demonstrate that mercury is not present in significant amounts and does not warrant inclusion on the main priority list.'* This was a reference in relation to mercury within modern landfill gas. Gas from an older waste deposit such as found at this site would not be expected to be a significant source of volatile mercury compounds.

With regards to gas wells GS1, GS2, GS3 and GS4, trace concentrations of Benzene, Carbon tetrachloride, Toluene and Formaldehyde were detected in the headspace of the well. Benzene and Toluene are ubiquitous in the environment as a result of traffic related sources and therefore these trace amounts can be attributed to this source. Carbon tetrachloride is a common constituent of paints and varnishes. It is likely that the concentrations of carbon tetrachloride identified within the 4 gas wells to the west of the residences is as a result of a spillage

and/or poor management of solvent based paints during the fit-out phase of construction. Formaldehyde is a basic constituent of rubber cement products which are used on building sites as either sealants and or glues. Empty rubber cement tubes were observed outside some of the residences during the fit-out phase of construction. In addition, in the waste deposited soils, the only volatile organic compounds identified were cis-1,2-dichloroethene (DCE) and vinyl chloride. Neither of these compounds were detected in the sorbent tubes/thermal desorption/capillary gas chromatography analysis conducted for GS01 – GS04, which is a further line of evidence to indicate that they are not migrating from the landfill towards the houses.

As it is believed that the VOCs identified within the residences are as a result of the freshly painted interiors, OMI were commissioned to carry out further rounds of gas monitoring at Residence No. 47 on the 27th June 2018 and 14th August 2017 (see Figure 13). Residence No. 47 was selected as it is located approx. 120m from the western boundary of the waste body and believed to be far enough removed from the landfill so as to act as a control site.

With regards to Residence 47–Locations 1 and 2, trace concentrations of Benzene, Chloroethane, Styrene, Toluene, Mercury, Formaldehyde and Acetaldehyde were detected in the headspace of the house. All detected compounds were well within the 8hr occupational exposure limits for the each of the respective compounds. When compound concentrations were compared to fractional exposure limit values (i.e. to represent 24hr exposure), the detected concentration levels of Formaldehyde (i.e. fractional exposure limit value 0.0026mg/Nm^3) were in excess of the fractional exposure limit value. Therefore, considering that similar compounds were identified within the 'control' site and those houses located closer to the waste body, it is likely that that the compounds were present as a result of the building materials used within the house (i.e. paints and varnishes).

12 GROUNDWATER DETAILED QUANTITIVE RISK ASSESSMENT (DQRA)

Due to an exceedance of the Groundwater Regulations Threshold Values for a number of parameters (i.e. ammonia, arsenic, mercury) at the landfill body at Barnageeragh Cove in Skerries and given that a quantity of waste was found below the water table at the site, Peter Conroy, PGeo was commissioned to carry out a Hydrogeological Detailed Quantitative Risk Assessment (DQRA) for the site (see Appendix 12 for Hydrogeological DQRA Report).

Detailed Quantitative Risk Assessment (DQRA) modelling was carried out using the probabilistic quantitative risk assessment software package CONSIM 2.5. The software was used to assess the potential impact on groundwater and surface water from Substances of Concern (SOCs) that were detected in the landfill waste at the site. The SOCs modelled were representative of the contaminant groups present in the waste and comprised of Dichloroethene (DCE), ammonia, arsenic, benzo(a)pyrene, chloride, lead, mercury, naphthalene, phenol, decane and hexadecane.

The site hydrogeological conceptual model was developed using indicators from regional scale data and on-site investigation work carried out over a number of months by Mulroy Environmental. This included information from:

- Trialpit investigation and soil waste classification analysis (i.e. TP1 – TP48);
- Geophysical and topographical surveying;
- Borehole and gas well installation (i.e. GS1 – GS4 and BH1 – BH17);
- Groundwater quality monitoring (i.e. 3 rounds);
- Surface water quality monitoring (i.e. 2 rounds);
- Passive gas venting well installation (i.e. GV1- 5);
- TKN soil analysis from samples taken from gas venting wells (GV1- 5), groundwater monitoring boreholes (BH15 – BH17) and trialpits (TP49 – TP50);
- Aquifer pump tests; and
- On-site groundwater level monitoring from July 2017 to July 2018.

Depending on the water table elevation, two specific groundwater pathway scenarios were observed:

- The maximum groundwater elevation occurs during the high-water table period from the months of October to May when the groundwater flowing beneath the waste body discharges to the eastern boundary stream; and
- The minimum groundwater elevation occurs during the period of June to September, where the groundwater flowing beneath the waste body passes beneath the eastern boundary stream and continues eastwards to discharge at the Barnageeragh Stream to the east of the WWTP site.

Therefore, both streams can be considered as receptors (see Figures 9 to 11 and full DQRA report and associated figures in Appendix 12).

The DQRA model predicts that ammonia, chloride, arsenic, DCE, and naphthalene occurr at slightly elevated above background concentrations in the groundwater at the downgradient site boundary and at the surface water receptors over varying timescales.

The DQRA predicts no exceedances of the arsenic EQS in groundwater at the site downgradient boundary or adjacent to downgradient surface water receptors under maximum and minimum water table scenarios until at least a 500-year period has elapsed. This indicates that the current observed occasional slightly elevated arsenic concentrations in the groundwater downgradient of the waste are unlikely to derive from arsenic mobilised within the waste body. It is more likely that the observed arsenic in groundwater derives from naturally occurring arsenic in the subsoil deposits that has been mobilised by the plume of reducing groundwater emanating from beneath the waste (i.e. elevated arsenic concentrations were observed in the indigenous soil samples analysed) (see full DQRA report and associated figures in Appendix 12).

The DQRA predicts that following the installation of an engineered cap at the site, there will be exceedances of EQS criteria for chloride, ammonia, arsenic, mercury, c1,2-Dichloroethene and naphthalene. There is no significant environmental impact associated with the predicted exceedances. The contaminant concentrations of groundwater at the downgradient receptors are predicted to be mitigated such that the contaminant concentrations do not result in the breaches of the Groundwater and Surface Water Regulations.

Based on the interpretation of all the available site data and on the outcome of the detailed groundwater quantitative risk assessment, the installation of the engineered cap is considered the best remedial option for the site and it is considered that this strategy will have no significant impact on the groundwater or surface water receptors downgradient of the site.

To conclude, following the installation of the engineered landfill cap, the site is not expected to have a significant impact on groundwater quality at a regional scale and as such, any potential impact that may also be associated with the presence of waste below the water table at the site is mitigated. In order to ensure that this is the case, a one-year programme of quarterly groundwater monitoring is recommended at select boreholes. The proposed groundwater quality monitoring targets for remedial validation are as follows:

- Chloride concentrations between 78 and 300mg/l at borehole BH11 and between 4.7 and 103mg/l at BH17;
- Ammonia concentrations between 8.8 and 15mg/l at borehole BH11 and between 0.76 and 1.2mg/l at BH17; and
- Concentrations of the remaining Substances of Concern to be compared to assess their conformance with DQRA predictions.

13 HUMAN RISK DETAILED QUANTITATIVE RISK ASSESSMENT (DQRA)

Despite the fact that VOCs were absent in the groundwater monitored onsite to date, it was determined that the possibility of VOCs and mercury present within the soil body should be assessed to determine whether these compounds might volatilise into outdoor or indoor air. To assess these pathways the Risk Based Corrective Action (RBCA) Model was used. A Tier 2 analysis was used to evaluate baseline risks for both on-site and off-site receptor locations based on site-specific soil data. A copy of the RBCA Model outputs are included in Appendix 15.

The following plate (see Plate 27) outlines the various exposure pathways identified and assessed in the model. It should be noted that soil exposure via dermal contact was not selected as it is proposed that an engineered landfill cap is installed onsite and therefore this would break the potential source to receptor pathway. The groundwater ingestion exposure pathway was not assessed as there are no known potable water abstraction sources in the area. In addition, the Hydrogeological DQRA developed for the site has determined that the groundwater beneath the waste body discharges into either one of two streams depending on the water table elevation.

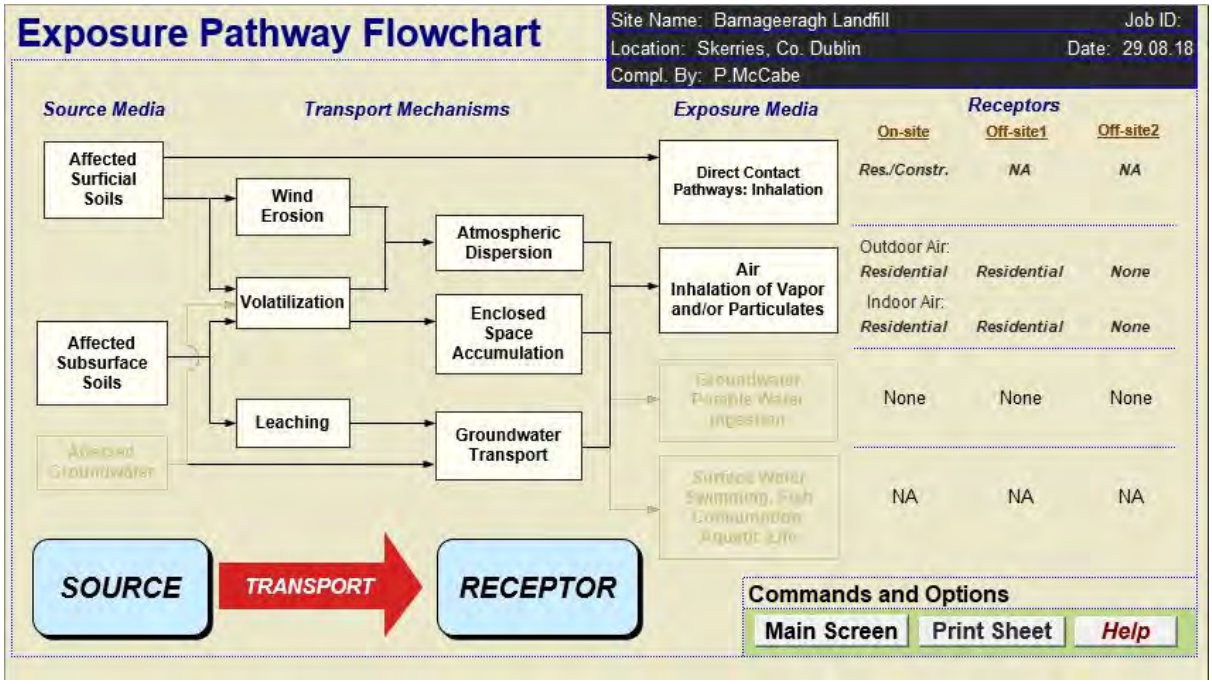

Plate 27. RBCA exposure pathway flowchart produced for the Barnageeragh Landfill, Skerries Co. Dublin.

Following the input of all parameters required to run the model, the calculated risk from all exposure pathways in the RBCA model was assessed in comparison with a Hazard Index (HI). Anything over a HI of 1 requires further assessment or mitigation. The results of the RBCA model for the site, adding up all of the exposure pathways indicate the HI is over two orders of magnitude lower i.e., 100 times less, than a HI of 1 (see Plate 28). Therefore, it can be concluded that no carcinogenic risk limits or toxicity limits have been exceeded and as a consequence

the VOCs, mercury or organic contaminants detected within the soil is not predicted to have a detrimental health effect on outdoor or indoor quality at the site.

Return | Print Sheet | RBCA SITE ASSESSMENT | Baseline Risk Summary-All Pathways

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BASELINE RISK SUMMARY TABLE

	BASELINE CARCINOGENIC RISK					BASELINE TOXIC EFFECTS				
	Individual COC Risk		Cumulative COC Risk		Risk	Hazard Quotient		Hazard Index		Toxicity
EXPOSURE PATHWAY	Maximum Value	Target Risk	Total Value	Target Risk	Limit(s) Exceeded?	Maximum Value	Applicable Limit	Total Value	Applicable Limit	Limit(s) Exceeded?
OUTDOOR AIR EXPOSURE PATHWAYS										
Complete? ■	6.3E-10	1.0E-5	6.3E-10	1.0E-5	□	9.4E-4	1.0E+0	9.4E-4	1.0E+0	□
INDOOR AIR EXPOSURE PATHWAYS										
Complete? ■	2.4E-8	1.0E-5	2.4E-8	1.0E-5	□	3.3E-3	1.0E+0	3.4E-3	1.0E+0	□
SOIL EXPOSURE PATHWAYS										
Complete? ■	6.5E-7	1.0E-5	6.5E-7	1.0E-5	□	NC	1.0E+0	NC	1.0E+0	□
GROUNDWATER EXPOSURE PATHWAYS										
Complete? □	NA	NA	NA	NA	□	NA	NA	NA	NA	□
SURFACE WATER EXPOSURE PATHWAYS										
Complete? □	NA	NA	NA	NA	□	NA	NA	NA	NA	□
CRITICAL EXPOSURE PATHWAY (Maximum Values From Complete Pathways)										
	6.5E-7	*1.0E-5*	*6.5E-7*	*1.0E-5*	□	*3.3E-3*	*1.0E+0*	*3.4E-3*	*1.0E+0*	□
	Soil		*Soil*			*Indoor Air*		*Indoor Air*		

Plate 28. RBCA baseline risk summary of all pathways produced for the Barnageeragh Landfill, Skerries Co. Dublin.

14 CONCEPTUAL SITE MODEL (CSM) (WITH & WITHOUT MITIGATION MEASURES)

The following Conceptual Site Models, represents the current risks (i.e. given the findings of both the trialpit investigation, borehole investigation and landfill gas assessment) posed by the site without any mitigation measures being put in place (i.e. do nothing scenario) and with mitigation measures put in place.

Figure 22 illustrates the *Conceptual Site Model* (i.e. given the findings of both trialpit and borehole investigations and landfill gas assessment) for the residential and proposed public park development with no mitigation works carried out.

Figure 23 illustrates the *Conceptual Site Model* (i.e. given the findings of both trialpit and borehole investigations and landfill gas assessment) for the residential and proposed public park development with mitigation works (i.e. engineered capping layer, biocover/venting area near BH4 and passive gas venting wells) carried out.

The key component of the Conceptual Site Model is the identification of landfill gas migrating in a northerly direction from the historic landfill as found in BH1, BH4, BH8, BH9, BH10 and BH12 and in a north-easterly direction as found by BH17. It should be noted that no complaints by residents to the north have been made with regard to the any odours. In addition, no evidence of landfill gases has been found within the stormwater drainage manholes (i.e. ST1 & ST2) in the vicinity of the newly built residences to the north or in the stormwater/surface water drainage manholes (i.e. SW1 & SW2) to the northeast (i.e. adjacent to the road). Likewise, no evidence of landfill gases were observed within internal services in the newly constructed residences or following completion, within radon sumps or water mains chambers.

Of the 40 soil samples analysed, there was an exceedance in the Residential CLEA Soil Guideline Value, LQM/CIEH Generic Assessment Criteria or Dutch Intervention Value in 18 samples. This included an exceedance in one or more metals in 17 samples and 1 exceedance in Benzo(a)pyrene (SO-TP8-01).

No exceedances in the relevant GACs were observed for the 2 topsoils sampled from the landscaped area on site.

Exceedances in the GACs for ammonia, sulphate, phosphate, iron and manganese results were observed for groundwater

The potential ‘Sources’ of Contamination are:

- Contaminated soil within the waste matrix in 18 samples;
- Contaminated groundwater underlying the waste body and migrating north-eastwards to the adjacent stream and eastwards towards Barnageeragh Stream; and
- Landfill gas underlying the waste body and present within the overburden in the vicinity of BH1, BH4, BH8, BH9, BH10, BH12 and BH17.

The 'Pathways' are:

- Downward (i.e. vertical) migration of inorganic and organic contaminants into the underlying aquifer either in the overburden and or underlying bedrock followed by migration off-site (i.e. to the northeast and east);
- Groundwater migration towards the culverted surface water bodies to the north and east of the site and the discharge of contaminants into these surface water bodies via baseflow during high groundwater table;
- Groundwater migration towards Barnageeragh Stream to the east of the site and the discharge of contaminants into these surface water bodies via baseflow during low groundwater table;
- Surface water migration in the un-named stream via the existing stormwater infrastructure and discharge of contaminants into the sea to the north of the site;
- Surface water migration in the Barnageeragh Stream via the existing stream network and discharge of contaminants into the sea to the east of Skerries;
- Lateral migration of landfill gases from the unsaturated zone within the waste body through the overburden (i.e. made ground and/or indigenous soil);
- Lateral migration of VOCs from the unsaturated zone within the waste body through the overburden (i.e. made ground and/or indigenous soil);
- During the construction phase, construction workers coming into contact with contaminated soil during the laying of services or transfer of contaminated soil within the site; and
- Following construction, maintenance workers coming into contact (i.e. through dermal route) with contaminated soil with the waste body under the imported topsoil/capping layer.

The 'Targets' are:

- The principle targets are the occupiers of the newly built residences to the north, northwest and to the north/northeast of the roadway;
- The residents of Barnageeragh Cove and visitors to the proposed public park development immediately to the north of the waste body;
- Underlying groundwater aquifer;
- Surface water bodies to the north and east of the site; and
- On-site construction workers.

The 2 following Conceptual Site Models for the site have been collated in line with BS10175 and CLR11 (see Figures 22 and 23). The CSM identifies potential sources of contamination, receptors that could be impacted and pathways which can potentially link the source and receptors.

14.1 Conceptual Site Model without Mitigation Measures

Table 12 records the potential pollutant linkages that were identified at the site. Justifications for the identification of a potential pollutant linkage together with the likelihood are also discussed in Table 12 (see Figure 22).

Table 12. Identification of Potentially Complete Pollutant Linkages without Mitigation Measures

SOURCE	PATHWAY	RECEPTOR	LINKAGE?
Contaminated soil exceeding GACs within waste landfill body	Direct contact with off-site residents dermal contact and inhalation of dust and soils.	Residents of newly built residences to north, northwest and across road to north	**Incomplete.** Residents not expected to come into contact with underlying soil during routine activities.
		Users of the proposed public park area combining historic landfill and greenfield area to the north	**Incomplete.** Residents and visitors to public park will not come into contact with underlying soil.
		Operatives on WWTP to southeast of the site	**Incomplete.** Site operatives not expected to come into contact with underlying soil during routine activities.
	Leaching and subsequent migration	Groundwater in Poor bedrock aquifer	**Complete.** Given the findings of the groundwater analysis, the groundwater under the site has been impacted by the overlying waste body
		Diverted surface water bodies to north and east of waste body	**Incomplete.** Given the age of the waste and the introduction of an impermeable cap, the impact on the stream is expected to be low and contact between landfill body and surface water body is not proven
		No downgradient potable water abstraction borehole	**Incomplete**. No potential groundwater well receptors and groundwater discovered to be discharging to adjacent streams.

Table 12. Identification of Potentially Complete Pollutant Linkages without Mitigation Measures (continued)

SOURCE	PATHWAY	RECEPTOR	LINKAGE?
Ammonia contaminated groundwater underlying waste body	Direct contact with off-site (i.e. downgradient) residents, residents or visitors to public park via dermal contact or ingestion	Residents of newly built residences to northwest, north and north of road	**Incomplete.** Residents not expected to come into contact with groundwater as potable water supply provided by Fingal C.C.
		Users of the proposed public park area combining historic landfill and greenfield area to the north	**Incomplete.** Residents and visitors using proposed public park unlikely to come into contact with contaminated groundwater as potable water supply provided by Fingal C.C.
		Off-site residences to the north and downgradient of site	**Incomplete.** No abstraction wells downgradient of site and potable water supply provided by Fingal C.C.
		Operatives on WWTP to southeast of the site	**Incomplete.** Site operatives not expected to come into contact with underlying groundwater during routine activities.
	Migration via underlying Poor Aquifer	Re-routed surface water bodies to north and east of site	**Complete:** Contamination proven in groundwater and elevated ammonia predicated in adjacent streams as a consequence.
		Irish Sea	**Incomplete.** Significant dilution available on outfall

Table 12. Identification of Potentially Complete Pollutant Linkages without Mitigation Measures (continued)

SOURCE	PATHWAY	RECEPTOR	LINKAGE?
Landfill gases in proximity of BH1, BH4, BH12 and BH17	Migration by preferential pathways via underground man-made services in proximity to the waste body	Residents of newly built residences to northwest, north and north of road	**Incomplete.** No underground services in proximity of waste body with exception of foul rising main running to the south and north. Gas probe survey indicated absence of landfill gases in proximity of rising main.
		Users of the proposed public park area combining historic landfill and greenfield area to the north	**Incomplete.** No known services running in a northerly direction from the waste body towards the Proposed public park area
		Off-site residences to the north and downgradient of site	**Incomplete.** Given distance and absence of services running in a northerly direction.
		Operatives on WWTP to southeast of the site	**Incomplete.** Landfill gas probe survey at WWTP/route of rising main did not indicate presence/migration of landfill gas
	Lateral migration from waste body via overburden (i.e. made ground & subsoil)	Residents of newly built residences to northwest, north and north of road	**Incomplete:** Given the distance and concentrations of landfill gas in BH1 & BH4 area, migration to residences is feasible (i.e. however in recent house gas surveys and data from GS01-GS04 have shown that this is not happening at the time of writing).
		Proposed public park area immediately to north of waste body	**Incomplete:** Given the distance and concentrations of landfill gas in BH1 & BH4 area, migration to Proposed public park area to the north is unlikely – balance gases have not been displaced by CO_2 & CH_4
		Off-site residences to the north and downgradient of site	**Incomplete:** Given the distance to residences to the north of the road, it is unlikely that this is occurring if no landfill gas was identified in BH13, BH14 & BH16
		Operatives on WWTP to southeast of the site	**Incomplete.** Potential for migration of landfill gas to WWTP via overburden. However, landfill gas probe survey at WWTP/route of rising main did not indicate presence/migration of landfill gas. Also a shallow cut-off trench is located along the western boundary of the WWTP with the site.

As can be seen from Table 12, a complete pollutant linkage only exists where groundwater contamination has been confirmed.

14.2 Conceptual Site Model with Mitigation Measures

Table 13 records the potential pollutant linkages that have been identified at the site with mitigation measures in place (see Figure 23). These mitigation measures include the capping of the historic landfill, biocover/bioventing zone near BH4 and the installation/continued use of passive gas venting wells. Justifications for the identification of a potential pollutant linkage together with the likelihood are also discussed in Table 13.

Table 13. Identification of Potentially Complete Pollutant Linkages with Mitigation Measures

SOURCE	PATHWAY	RECEPTOR	LINKAGE?
Contaminated soil exceeding GACs within waste landfill body	Direct contact with off-site residents dermal contact and inhalation of dust and soils.	Residents of newly built residences to north, northwest and across road to north	**Incomplete.** Residents not expected to come into contact with underlying soil during routine activities. Capping will decrease chances of this occurrence.
		Users of the proposed public park area combining historic landfill and greenfield area to the north	**Incomplete.** Residents and visitors using proposed public park unlikely to come into contact with contaminated groundwater as potable water supply provided by Fingal C.C.
		Operatives on WWTP to southeast of the site	**Incomplete.** Site operatives not expected to come into contact with underlying soil during routine activities.
	Leaching and subsequent migration	Groundwater in Poor bedrock aquifer	**Complete:** Given the findings of the groundwater analysis, the groundwater under the site has been impacted by the overlying waste body. Capping will decrease the quantity of leachate generated.
		Diverted surface water bodies to north and east of waste body	**Incomplete:** The Hydrogeological DQRA has predicted that following the installation of the engineered landfill cap, the adjacent surface water receptors will not be impacted.
		Downgradient potable water abstraction borehole	**Incomplete**. No potable water abstraction wells downgradient of site.

Table 13. Identification of Potentially Complete Pollutant Linkages with Mitigation Measures (continued)

SOURCE	PATHWAY	RECEPTOR	LINKAGE?
Ammonia contaminated groundwater underlying waste body	Direct contact with off-site (i.e. downgradient) residents, WWTP operatives or users/visitors to public park via dermal contact or ingestion	Residents of newly built residences to northwest, north and north of road	**Incomplete.** Residents not expected to come into contact with groundwater as potable water supply provided by Fingal C.C. Capping layer will serve to impede leachate production from the waste body.
		Users of the proposed public park area combining historic landfill and greenfield area to the north	**Incomplete.** Residents and visitors using proposed public park unlikely to come into contact with contaminated groundwater as potable water supply provided by Fingal C.C.
		Off-site residences to the north and downgradient of site	**Incomplete.** No potable abstraction wells downgradient of site and potable water supply provided by Fingal C.C.
		Operatives on WWTP to southeast of the site	**Incomplete.** Site operatives not expected to come into contact with underlying groundwater during routine activities.
	Migration via underlying Poor Aquifer	Re-routed surface water bodies to north and east of site	**Incomplete:** The Hydrogeological DQRA has predicted that following the installation of the engineered landfill cap, the adjacent surface water receptors will not be impacted.
		Irish Sea	**Incomplete.** Significant dilution available on outfall

Table 13. Identification of Potentially Complete Pollutant Linkages with Mitigation Measures (continued)

SOURCE	PATHWAY	RECEPTOR	LINKAGE?
Landfill gases in proximity of BH1, BH4, BH12 and BH17	Migration by preferential pathways /underground man-made services in proximity to the waste body	Residents of newly built residences to northwest, north and north of road	**Incomplete.** No underground services in proximity of waste body with exception of foul rising main running to the south and north. Gas probe survey indicated absence of landfill gases in proximity of rising main at northern edge of landfill
		Users of the proposed public park area combining historic landfill and greenfield area to the north	**Incomplete.** No proposed services running in a northerly direction from the waste body towards the proposed public park area
		Off-site residences to the north and downgradient of site	**Incomplete.** Given distance and absence of services running in a northerly direction.
		Operatives on WWTP to southeast of the site	**Incomplete.** Landfill gas probe survey at WWTP/route of rising main did not indicate presence/migration of landfill gas
	Lateral migration from waste body via overburden (i.e. made ground & subsoil)	Residents of newly built residences to northwest, north and north of road	**Incomplete:** With construction of biocover/venting area near BH4 & maintenance of existing passive gas venting wells, migration to residences will be unlikely.
		Users of the proposed public park area combining historic landfill and greenfield area to the north	**Incomplete:** With construction of biocover/venting area near BH4 & maintenance of existing passive gas venting wells, migration to residences will be unlikely.
		Off-site residences to the north and downgradient of site	**Incomplete:** With construction of biocover/venting area near BH4 & maintenance of existing passive gas venting wells, migration to residences will be unlikely.
		Operatives on WWTP to southeast of the site	**Incomplete:** With construction of biocover/venting area near BH4 & maintenance of existing passive gas venting wells, migration to WWTP via overburden. Landfill gas probe survey at WWTP/route of rising main did not indicate presence/migration of landfill gas. Also a shallow cut-off trench is located along the western boundary of the WWTP with the site.

<u>As can be seen from Table 13, a complete pollutant linkage only exists where groundwater contamination has been confirmed directly beneath the site.</u>

15 CONCLUSIONS

The conclusions of this report are based on the findings of our conceptual model, which is discussed in Section 13, and has been developed over the course of the last year. The CSM has identified 4 key potential source-pathway-receptor linkages:

1) Landfill gas potentially migrating from the former waste deposit through Made Ground or silt clay indigenous soil to the housing to the north of the waste mass;
2) Groundwater contaminated by the waste deposit flowing north from the waste mass with possible volatilization into the unsaturated zone beneath the houses;
3) Contaminated groundwater flow north, northeast, and south from the waste deposit; and
4) Surface water impacted by contaminated groundwater discharging to Irish Sea.

Contaminant linkages 'direct contact' and 'ingestion' associated with the deposited waste were assessed as incomplete since the waste deposit will be buried beneath a clean clay cap and landscaping.

15.1 Potential Linkage 1 – Landfill Gas

As can be seen from Table 11 in Section 10, following the introduction of the gas venting wells, using the ***Wilson & Card Methodology (i.e. Situation A)***, based on a worst-case scenario, the ***CIRIA R149 Characteristic Situation '1' (very low risk)*** was applied to 7 of the 21 boreholes on site. The modified Wilson and Card Classification system detailed in CIRIA665 indicates for a ***'very low risk classification'*** to apply, CO_2 values should be typically <5.0%, while CH_4 values should be typically <1.0% while the GSV should not exceed 0.07. This applied to the four boreholes (GAS1 – GAS4) installed directly to the south of the newly developed houses, BH2 which is located towards the western boundary of the landfill, BH3 which is located within the waste body and BH5 which is located on the north western end of the landfill (see Table 11). An exceedance of 5.0% for CO_2 and/or 1.0% for CH_4 was observed in 14 of the 21 boreholes and those boreholes were therefore automatically classified as the next risk level higher i.e., ***'low risk'*** (i.e. even though 13 of the 14 GSVs did not exceed 0.07). For BH4, the maximum (worst case) methane and CO_2 concentrations were 73.6% and 20.9% respectively, which combined with worst case flow measurement, results in GSVs of 0.29 for methane and 0.08 for CO_2. Because the methane GSV was less than 0.7 this borehole is classed as ***'low risk'*** using this methodology.

Based on a worst-case scenario the alternative NHBC risk classification methodology was also applied, with 7 of the 21 boreholes on site achieving a ***'Green Light'*** status (see Table 11). This applied to the same 7 boreholes assigned a ***'very low risk'*** using the Wilson & Card Methodology. Four boreholes were assigned an ***'Amber 1'*** classification because of an exceedance of either the 1% CH_4 limit and/or the 5% CO_2 limit for this category. Eight boreholes were assigned an ***'Amber 2'*** classification given an exceedance of either the 5% CH_4 limit and/or the 10% CO_2 limit for this category. Borehole BH4 was given a ***'Red'*** classification under this methodology due to the CH_4 concentration in excess of 20%. It should be noted that BH9 which was previously classified as ***'Red'***, was classified as 'Amber 1' following the installation of the passive gas venting wells.

The Conceptual Site Model has proven that there is 'low' gas generation (i.e. insufficient to remove balance gas from the subsurface). This process of risk reduction is in line with BS8485:2015 6.3.7.1 that suggests the

designation of GSV should be made by inspection of all the data based on the conceptual site model for the situation with the development's sub-structure and foundations in place.

The potential gas migration pathways from the waste body to residences to the west has been assessed as 'very low risk' (i.e. through GS1-GS4, BH2, BH3 and BH5) while the potential gas migration pathways from the waste body to the WWTP to the east has been assessed as 'low risk'. Even though the risk has been assessed as very low risk in pathway boreholes BH2, BH3 and BH5 (see Table 11), further gas monitoring has been undertaken within the houses and services next to the houses where gas may flow along preferential pathways such as the gravel surrounding the services. This receptor point monitoring is a further precautionary measure. The monitoring determined that methane was absent or present at trace concentrations within the radon sumps and where the water supply entered the base of the house. Carbon dioxide, which occurs naturally as a result of respiration in soils, was detected at trace concentrations. This data supports the findings of the risk assessment and indicates that risks posed by gas from the waste body are low.

The indoor air monitoring of the residences identified a number of volatile compounds in air within the houses. However, these compounds were associated with decorating paints, glues and background vehicle emissions. There was a noticeable odour of paints, varnishes and glues in the houses, and evidence of rubber cement tubes on the ground external to the houses during their construction.

15.2 Potential Linkage 2 – Contaminant Volatilisation from Soil or Groundwater

A total of 35 groundwater samples have been taken across three monitoring rounds to date from 14 groundwater monitoring wells. No VOCs were detected within the groundwater above the method detection limit in any of these samples. The potential pathway of volatilisation from tested groundwater into the houses is therefore incomplete.

Only two VOCs, namely vinyl chloride and cis 1,2-dichloroethene (DCE) were detected in one soil sample (SO-TP21-01). It should be noted that this sample was taken from a trial pit located 51m from the nearest residence. To asses this pathway, the Risk Based Corrective Action model (RBCA) was used to assess whether the soil detections pose any risk to receptors indoors or outdoors. The calculated risk from all exposure pathways in the RBCA model was assessed in comparison with a Hazard Index (HI). Anything over a HI of 1 requires further assessment or mitigation. The results of the RBCA model adding up all of the exposure pathways indicated that the HI is over two orders of magnitude lower (i.e., 100 times less, than a HI of 1) (see Section 13).

15.3 Potential Linkage 3 – Contaminated groundwater flow north, northeast, and south from the waste deposit

The Hydrogeological Conceptual Model development relates to the identification of two possible groundwater discharge pathways at the site (see DQRA HCM in Appendix 12). The main pathway is active during periods of maximum groundwater elevation from October to May. Under this maximum groundwater elevation scenario (i.e. Scenario 1) groundwater flows east beneath the site and discharges to the stream/drain that runs along eastern site boundary. During periods of minimum groundwater elevation, the water table drops below the invert level of the eastern boundary stream/drain and discharge to this surface water feature is no longer possible. Under this

minimum groundwater elevation scenario (i.e. Scenario 2) groundwater flows east beneath the site and continues flowing east beneath the boundary stream to eventually discharge to the Barnageeragh Stream to the east of the Irish Water WWTP site.

Detailed Quantitative Risk Assessment (DQRA) modelling was carried out to assess the potential impact on groundwater and surface water of Substances of Concern (SOCs) that were detected in the landfill waste at the site. The SOCs modelled were representative of the contaminant groups present in the waste and comprised of DCE, ammonia, arsenic, benzo(a)pyrene, chloride, lead, mercury, naphthalene, phenol, decane and hexadecane.

The DQRA model predicts that ammonia, chloride, arsenic, DCE, and naphthalene occur at slightly elevated above background concentrations in the groundwater at the downgradient site boundary and at the surface water receptors over varying timescales.

The DQRA predicts that following the installation of an engineered cap at the site, there will be exceedances of EQS criteria for chloride, ammonia, arsenic, mercury, c1,2-Dichloroethene and naphthalene. There is no significant environmental impact associated with the predicted exceedances. The contaminant concentrations of groundwater at the downgradient receptors are predicted to be mitigated such that the contaminant concentrations do not result in breaches of the Groundwater and Surface Water Regulations.

Based on the interpretation of all the available site data and on the outcome of the detailed groundwater quantitative risk assessment, the installation of the engineered cap is considered the best remedial option for the site and it is considered that this strategy will have no significant impact on the groundwater or surface water receptors downgradient of the site.

15.4 Potential Linkage 4 – Surface water impacted by contaminated groundwater discharging to Irish Sea

Under the maximum groundwater elevation scenario (i.e. Scenario 1) groundwater flows east beneath the site and discharges to the stream/drain that runs along eastern site boundary. During periods of minimum groundwater elevation, the water table drops below the invert level of the eastern boundary stream/drain and discharge to this surface water feature is no longer possible. Under this minimum groundwater elevation scenario (i.e. Scenario 2) groundwater flows east beneath the site and continues flowing east beneath the boundary stream to eventually discharge to the Barnageeragh Stream to the east of the Irish Water WWTP site.

It should be noted that the water quality in the surface water on-site indicates that ammonia in groundwater baseflow to the site boundary stream may rapidly oxidise to nitrate. Considering this and the significant dilution available within the Irish Sea, the impact to the 2 surface water bodies and the Irish Sea is considered to be negligible.

16 RECOMMENDATIONS

Following on from the conclusion in the previous section, the following recommendations are given for the site:

1. It is recommended that the landfill is capped to the following specifications. A '*Preliminary Technical Proposal for the Proposed Capping Layer Report'* has been prepared by capping specialists, AGL Consulting Geotechnical Engineers (see Appendix 23 and Figures 24-26). The purpose of the cap is to reduce the penetration of precipitation through the existing waste body thus reducing the quantity of leachate produced. The primary components of the landfill capping system are as follows:
    a) A min. 300 mm thick cover layer of Class 2 cohesive subsoil with low stone content to regulate the surface of the non-hazardous waste. To protect the liner from puncture a maximum particle size of 28 mm will be specified for this material;
    b) A 1.0 mm thick LLDPE (Linear Low-Density Polyethylene) geomembrane with a permeability of k < 1 x 10-9m/s (e.g. GSE Ultra-Flex or equivalent). The smooth liner will be used across the crest of the landfill, whereas the textured liner with higher interface frictional resistance will be used on the perimeter side slopes;
    c) A geo-composite drainage layer with a permeability, k < 1 x 10^{-9}m/s (e.g. Pozidrain 4S250 or equivalent – 4mm thickness) to intercept groundwater infiltration through the overlying topsoil and subsoil layers, and to prevent a build-up of groundwater over the LLDPE liner, which can contribute to shallow slope instability;
    d) An 850mm thick layer of Class 2 cohesive subsoil as a protective and anchoring layer for the LLDPE liner. To protect the liner and drainage layer from puncture or damage, a maximum particle size of 28 mm will be specified for the material within 300 mm of the base of this layer;
    e) A 150mm thick layer of Class 5A/5B Topsoil to create a vegetated surface to the landfill. The topsoil shall be seeded with a typical wild grass seed (e.g. Table 6/5 of the TII Specification for Roadworks), or as otherwise specified in the landscape design; and
    f) The principle function of the engineered landfill cap is to mitigate the potential for Substances of Concern (SOCs) to occur at downgradient receptors due to contaminant migration from the waste. The design is consistent with the *EPA Landfill Design Guidance (2000)* and should provide for an infiltration rate of 31mm/year.
2. An uncapped biocover/venting zone is created in the vicinity of borehole BH4, where passive gas venting wells, GV1-GV3 are located. This soil in this area will be mixed with oversized wood fragments or similar and suitable trees may be planted to enhance the porosity of the soil and increase 'venting off' of landfill gases and oxidizing of methane (see Figures 24-26);
3. Further passive gas venting wells are installed in the vicinity of borehole BH17 to help removed landfill gases being generated and trapped in this area;
4. All works carried out during the *'Landfill Restoration and Aftercare'* phase should be carried out in accordance with current health and safety regulations;
5. The proposed landscaping planting regime for the historic landfill part of the public park should be carefully selected on the basis that the roots do not affect the underlying LLDPE liner;

6. The existing on-site groundwater monitoring well and gas monitoring network (i.e. 21 wells) should be protected through the introduction where necessary of concrete plinths with all well tophats padlocked to prevent vandalism;
7. The existing passive gas venting wells should receive occasional maintenance to ensure that the cowls rotate with minimal wind speed. This is to ensure that the decrease in methane levels observed in boreholes BH4 and BH1 in landfill gases continues;
8. In order to confirm that groundwater quality is improving over time, groundwater monitoring is carried out on selected wells on a quarterly basis;
9. In order to confirm that landfill gas generation is continuing to decrease over time following the introduction of the biocover/venting zone near BH4 and the passive gas venting wells, landfill gas monitoring of the existing wells, residences and services should be carried out on a monthly basis; and
10. Further surface water monitoring is carried out on both streams during high and low groundwater conditions to determine the effect of the groundwater on surface water quality.

If you have any questions or require clarification with regard to any item of this report, Mulroy Environmental can be contacted at 042-9384750.

Yours sincerely,

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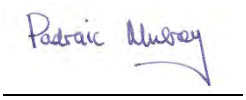

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MULROY ENVIRONMENTAL
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1. This report and the Environmental Site Assessment carried out in connection with the report (together the "Services") were compiled and carried out by Mulroy Environmental for Winsac Ltd. (the "client") in accordance with the terms of a contract, PRP413.31.5.2017 between Mulroy Environmental and the "client" dated 31st May, 2017. The Services were performed by Mulroy Environmental with the skill and care ordinarily exercised by a reasonable Environmental consultant at the time the Services were performed. Further, and in particular, the Services were performed by Mulroy Environmental taking into account the limits of the scope of works required by the client, the time scale involved and the resources, including financial and manpower resources, agreed between Mulroy Environmental and the client.

2. Other than that expressly contained in paragraph 1 above, Mulroy Environmental provides no other representation or warranty whether express or implied, in relation to the Services.

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4. It is Mulroy Environmental understanding that this report is to be used for the purpose described in the introduction to the report. That purpose was a significant factor in determining the scope and level of the Services. Should the purpose for which the report is used, or the proposed use of the site change, this report may no longer be valid and any further use of or reliance upon the report in those circumstances by the client without Mulroy Environmental be requested to review the report after the date hereof, Mulroy Environmental shall be entitled to additional payment at the then existing rates or such other terms as agreed between Mulroy Environmental and the client.

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7. The Services are based upon Mulroy Environmental's observations of existing physical conditions at the Site gained from a walk-over survey of the site together with Mulroy Environmental's interpretation of information including documentation, obtained from third parties and from the client on the history and usage of the site. The Services are also based on information and/or analysis provided by independent testing and information services or laboratories upon which Mulroy Environmental was reasonably entitled to rely. The Services clearly are limited by the accuracy of the information, including documentation, reviewed by Mulroy Environmental and the observations possible at the time of the walk-over survey. Further Mulroy Environmental was not authorised and did not attempt to independently verify the accuracy or completeness of information, documentation or materials received from the client or third parties, including laboratories and information services, during the performance of the Services. Mulroy Environmental is not liable for any inaccurate information or conclusions, the discovery of which inaccuracies required the doing of any act including the gathering of any information which was not reasonably available to Mulroy Environmental and including the doing of any independent investigation of the information provided to Mulroy Environmental save as otherwise provided in the terms of the contract between the client and Mulroy Environmental.

8. The Phase II or intrusive environmental site investigation aspects of the Services is a limited sampling of the site at pre-determined borehole and soil vapour locations based on the operational configuration of the site. The conclusions given in this report are based on information gathered at the specific test locations and can only be extrapolated to an undefined limited area around those locations. The extent of the limited area depends on the soil and groundwater conditions, together with the position of any current structures and underground facilities and natural and other activities on site. In addition chemical analysis was carried out for a limited number of parameters [as stipulated in the contract between the client and Mulroy Environmental] [based on an understanding of the available operational and historical information,] and it should not be inferred that other chemical species are not present.

9. Any site drawing(s) provided in this report is (are) not meant to be an accurate base plan, but is (are) used to present the general relative locations of features on, and surrounding, the site.