DETAILED QUANTITATIVE RISK ASSESSMENT OF CARRIGEEN FORMER LANDFILL SITE, CLANE, COUNTY KILDARE

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AUTHOR	Daragh Ffrench		30/05/12
PROJECT MANAGER	Padraic Mulroy		05/02/12
CLIENT	Ciara Corrigan Environmental Officer Kildare C.C.		

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Dundalk Office
Mulroy Environmental,
30 Lisroland View, Knockbridge,
Dundalk, Co. Louth.

MOB +353 (0)86 8770380
PH +353 (0)42 9384750
FAX +353 (0)42 9384750
EMAIL ptmulroy@eircom.net

MULROY environmental

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1 INTRODUCTION

1.1 General Setting

A Tier 1 risk assessment was completed by Kildare County Council in May 2010 of a former waste disposal site (0.91 hectares in size) located at Carrigeen, Clane, Co. Kildare (to be referred forthwith as the 'Site') (see Figure 1). The site is located in a rural area approximately 700m to the south of Clane in the townland of Carrigeen approximately 110m to the west of the River Liffey which flows in an approximate north to south direction (see Figures 2 and 3). A golf course, Milicent Golf Club is located to the south of the site. There are a number of residences located within 250m of the site. The nearest residences appear to be located approximately 7.5m to the west of the site's western boundary and 29m to the southeast of the site's south-eastern boundary (see Figure 3). A further residence is located approximately 82m to the northwest and 2 residences are located 85m and 110m due west of the site's western boundary. In total there are approximately 17 residences within 250m of the site (see Figure 3).

The findings of this assessment indicated that the Site was a Moderate Risk (Class B) and so a Tier 2 risk assessment was deemed necessary (see Appendix 1).

Golder Associates Ireland Ltd (Golder) carried out a Tier 2 Environmental Risk Assessment of the former waste disposal site on behalf of Kildare County Council (KCC) in September 2010. The purpose of this assessment was to provide information that would allow an assessment to be made regarding the existence of possible significant pollutant linkages on-site, which may require remediation measures to be put in place.

Mulroy Environmental were requested by Kildare County Council to carry out a Tier 3 Quantitative Risk Assessment (QRA) on the former waste disposal site on the 22nd November, 2012. It is understood by Mulroy Environmental that in the QRA process a staged approach is generally used. This requires an initial Generic QRA to be carried out. It is understood by Mulroy Environmental that if significant exceedances of Generic Risk Assessment Criteria are identified for Carrigeen Landfill then a site specific Detailed Quantitative Risk Assessment would be carried out.

1.2 Guidance Background

Chapter 6 of EPA Code of Practice, Environmental Risk Assessment for Unregulated Waste Disposal Sites, 2007 deals with the Tier 3 process. There are two basic types of quantitative risk assessments: Generic Quantitative Risk Assessment, which 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, and Detailed Quantitative Risk Assessment which uses site-specific assessment criteria using Risk Assessment tools and models. The decision on which type of QRA that should be used is site specific and is dependent on the sensitivity of the site and also on the consultant's confidence in the available

data. In any case the quantitative risk assessment should be detailed enough to allow remedial measures to be proposed with certainty of a successful outcome. The assumptions made should always be clearly defined.

1.3 Site History

It is understood from the Tier 1 report that Kildare C.C. (KCC) were informed by locals that the site at Carrigeen, Clane Co. Kildare was a former sand and gravel pit and limestone quarry be which spanned the four land parcels under investigation i.e. the private residence and gardens, the adjoining western paddock, the eastern paddock and the southern paddock (see Figures 4 & 5). This is consistent with the subsoil mapping for the area which classes the subsoil within the area as glacio-fluvial sands and gravels derived from limestone. It is known that this material was historical dug within the area for construction purposes.

From the Tier 1 report, it is understood that the worked out quarry void was leased by KCC between August 1977 and June 1980 for the landfilling of waste, including municipal and construction waste. Once the void was filled, the land was capped with approximately 450mm soil and the site was returned to the original owner. Subsequently the western portion of the Site was developed into a private residence (i.e. to the west) and an adjoining horse paddock (i.e. to the east). In recent times, an orange leachate was noted by nearby residents collecting on the roadway immediately to the northeast of the site near the site entrance. This instigated the Tier 2 Environmental Risk Assessment.

2 OBJECTIVE

The objectives of the risk assessment are as follows:

- To evaluate potential liabilities associated with historic and/or current uses of the site, and their impact on soil and groundwater quality;
- To evaluate potential liabilities associated with historic and/or current uses of the site, and their impact on surface water quality (i.e. the adjacent River Liffey);
- To evaluate potential liabilities associated with historic and/or current uses of the site on off-site residences and their residents; and
- To make recommendations on the remediation of the site or mitigation meastures to remove the afore-mentioned risks.

It should be noted that it is not the objective of this report to assess the risk from landfill gas to off-site residences and their residents. It is the understanding of Mulroy Environmental that this is being carried out by another consultant.

3 SCOPE OF WORKS

Field and laboratory results of geological, hydrogeological and environmental information were collated and interpreted with a view to evaluating potential environmental liabilities associated with soil/groundwater quality.

Risk Assessment

A risk assessment was undertaken to provide a basis for decision making, to ensure the continued safe habitation of the 2 nearest off-site residences (i.e. to the west and southeast of the site) and for the continued safe use of the existing paddocks for horse pastureand to ensure that there will be no adverse impact to the environment particularly the River Liffey to the east of the site. 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 the intrusive site investigation programme and the soil and groundwater sampling regime.
2. *Hazard Assessment Stage* - This stage involves the development of a Conceptual Site Model. Conceptual Models are described below.
3. *Risk Estimation Stage* – A Quantitative Risk Assessment is undertaken as part of this stage to determine risks to human health and the surface water and groundwater environments. The proposed Quantitative Risk Assessment for this contract is described in more detail below.
4. *Risk Evaluation Stage* – This stage involves recommendation of remedial works.

Conceptual Model

The risk to the surrounding environment will be assessed based on the geological and hydrogeological information gathered through the site investigation programme. This information can be used to develop a conceptual 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 basic 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 will be 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 water, 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 (GQRA) of Soils

As stated previously, 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. For this purpose Mulroy Environmental propose to use 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]
- National Institute of Public Health and the Environment of The Netherlands - The Soil Protection Guidelines (Dutch Criteria) – Intervention and Target Values; [3] and
- Waste Acceptance Criteria at Murphy Environmental Waste Facility (WA 129-02|) in Hollywood, Co. Dublin – Hazardous Waste Limit.[4]

[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.

[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 (see Appendix 3). These include the 'Total Pollutant Content' limits and the 'L/S = 10 l/kg

Generic Quantitative Risk Assessment (GQRA) of Groundwater and Leachate

The results of the groundwater analysis were compared to the Maximum Allowable Concentration (MAC) values of Statutory Instrument No. 81 (Quality of Water Intended for Human Consumption) of 1998 and the Parametric Values of Statutory Instrument No. 439 (Drinking Water Regulations) of 2000. The results of the groundwater analysis were also compared to the EPA Interim Guideline Values (IGVs) from *Towards Setting Guideline Values For The Protection Of Groundwater In Ireland – Interim Report* and the Threshold Values from Statutory Instrument No. 9, European Communities Environmental Objectives (Groundwater) Regulations, 2010.

Generic Quantitative Risk Assessment (GQRA) of Surface Water

The results of the surface water analysis were compared to:

- 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.

Detailed Quantitative Risk Assessment (DQRA)

Where exceedances of the afore-mentioned Generic Assessment Criteria was found, it is proposed to use a Risk Assessment Model, *Risk Based Corrective Assessment Toolkit Model (Version 2)*.

Risk Based Corrective Assessment Toolkit Model (Version 2)

The *RBCA Tool Kit for Chemical Releases* consists of a series of linked workbooks programmed in Microsoft® Excel version 7.0 or 97 [1]. This tool can be used to calculate risk levels (i.e. 1 in a million) and/or "cleanup standards"1 for soil and groundwater (e.g. 10 mg/kg for soil or 10 mg/L for groundwater). These values are calculated based on information provided by the user. The RBCA Tool Kit is designed to be protective of human health and the environment. The Tool Kit was specifically designed to complete all calculations required for Tier 1 and Tier 2 of the RBCA planning process, as defined in the *ASTM (American Society for Testing and Material) E2081-00 Standard Guide for Risk-Based Corrective Action*. This includes the calculation of exposure concentrations and average daily intake of contaminants by humans. The Tool Kit includes analytical fate and transport models for air, groundwater and soil exposure pathways. The user can enter suitable site-specific soil, groundwater and air parameters. The user selects the level of assessment required as follows:

- Tier 1 assessment involves the generation of generic risk-based screening level (RBSL) for on-site exposure only, assuming default exposure and site parameters
- Tier 2 allows the user to evaluate risk levels and/or site-specific target levels (SSTLs) for both on-site and off-site receptor locations based on site-specific soil, groundwater and air

Limits'. The purpose of comparison with these limits is to determine if an inert landfill such as thee landfill operated by Murphy Environmental would be capable of accepting contaminated soil from the site.

parameters. In a Tier 2 assessment the user may implement the fate and transport models included in the Tool Kit to evaluate off-site receptors

An integrated toxicological and physico-chemical parameter database of 115 chemicals is provided in the Tool Kit. These include metals and organic parameters, and also, aliphatic and aromatic carbon chain lengths specified in the TPH Criteria Working Group (TPHCWG) methodology. The Tool Kit can evaluate surface soil, subsurface soil, air, groundwater and surface water. However, contaminant concentrations can only be specified for soil and groundwater.

4 ENVIRONMENTAL SETTING

4.1 Introduction

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

4.2 Site Background

As stated in the introduction, the site is located in a rural area approximately 700m to the south of Clane in the townland of Carrigeen approximately 110m to the west of the River Liffey which flows in an approximate north to south direction. A golf course, Millicent Golf Club is located to the south of the site. There are a number of residences located within 100m of the site.

The Site at Carrigeen, Clane Co. Kildare was a former quarry which spanned the four land parcels which were investigated by Golders (see Figure 5). These include:

- The private residence and gardens to the west of the site;
- The large field to the east of the residence referred to as the 'waste ground' and in this report referred to as the *'Western Paddock*';
- The *'Eastern Paddock'* to the northeast of the *'Western Paddock'*; and
- The *'Southern Paddock*' in the south-eastern corner of the site.

The 3 above-mentioned fields are currently separated from each other by fencing. The site is bounded to the north by a small country road. The site is bounded to the east by a 0.9-hectare private residence constructed in 2005. The residence on this property is located in the south-eastern corner. The River Liffey is located approximately 110m to the east of the site. As stated in Section 1.1, a golf course is located to the south of the site.

The site has an existing access/egress point on the north-eastern corner of the eastern paddock. An internal access road follows the eastern boundary of the eastern paddock as far as the southern 'paddock'.

4.3 Topography

The existing site layout and its surrounding property is illustrated in Figure 4. The existing site layout with topographical data is illustrated in Figure 6.

The land in the vicinity of the site could be described as rolling lowland type topography with small hills sloping towards the River Liffey.

The site's topography varies across the site from 73.75m AOD in the south-western corner to its highest point at approximately 75m AOD to its lowest point on the north-eastern corner of the site at 67.5m. This gradient from the south of the 'western residence' to the north-eastern corner represents a gradient of 1:25 or a 4.35% grade.

It should be noted that in order to accurately assess the relative elevation of the adjacent property to the east of the site (i.e. the eastern residence) and to subsequently assess the risk, a topographical site layout drawing which was submitted with the planning application for that residence in 2004 is incorporated into Figure 6. A review of the topography data on this drawing indicates that the eastern residence property's highest point is located on its western boundary with the Eastern Paddock at approximately 70.5m AOD and its lowest points are located on the south-eastern and north-eastern corners of the site at approximately 66.5m AOD i.e. the site slopes from the western boundary both to the northeast and south east. This represents a gradient of 1:33 or approximately 3% grade.

This overall regional topography for the area is from a west to east direction. This is to be expected given the location of the River Liffey to the east.

4.4 Stormwater and Drainage Infrastructure

A review of historical mapping indicates that the site's surrounding area consisted of a network of agricultural land drains with the catchment flowing towards the River Liffey.

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 Carrigeen area are Gleys (60%) with Brown earths (20%) with and peaty gleys (20%) mapped as secondary soils.

A National Soil Mapping Project carried out jointly by the EPA and Teagasc have identified the footprint of the site as soil type: Shallow well drained mineral soils (BminSW) which are derived from calcareous parent materials (i.e. basic or alkaline rock). The parent material for this soil are Limestone sands and gravels (GLS). This classification is based on the most up to date mapping set. The soil classifications nearest to the site are Alluvium (A) and Deep Well Drained Mineral (BminDW) soils (see Appendix 2).

Based on Golder's site-specific observations during the trialpitting exercise, the general classification for the area is considered appropriate for the site.

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 footprint of the site as subsoil type: Limestone sands and gravels (GLS) (see Figure 7). This is based on the most up to date mapping set. The soil classifications nearest to the site are Till derived chiefly from Limestone (TLs) to the north, west and south and Alluvium (A) to the east. Given the afore-mentioned, it is possible that the site was used as a sand and gravel pit and not to quarry limestone given the subsoil type and proximity to the river.

Given the findings of the trialpitting exercise carried out by Golder, the general classification for the area would appear to be correct. It should be noted that a reasonably detailed description of the overburden was given in the IGSL/Kildare C.C. borehole descriptions in Appendix 2. The presence of red brown GRAVEL with cobbles and boulders interspersed from 1.6m bgl to 7.4m would indicate alluvial sands and gravels similar to the material that was removed from the sand and gravel pit previously. The presence of 'buried' peat from 7.4m to 8.0m bgl may indicate possible 'solifluction' of gravels over the peat as a result of melting during the glacial period.

4.6 Geology

4.6.1 Regional Geology

General information concerning the bedrock geology of the region is contained in the Geological Survey of Ireland (GSI) 1:100,000 scale Sheet No. 16 "Geology of Kildare – Wicklow" (see Figure 8). The bedrock map indicates that Dinantian Pure Un-bedded Limestone (DPUL) underlies the site (i.e. Waulsortian Mudbank Limestone (WA)). This is classed as a *Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones.*

The Waulsortian limestone is a pale grey, massive reef mound complex. The Waulsortian is highly fossiliferous. It is prone to karstification, which could result in subsidence. Due to its susceptibility to karstification, secondary permeabilities are high. The Waulsortian Limestone is generally classified as a regionally important karst aquifer, however the GSI have classified the Waulsortian Limestone in the Clane area County Kildare as *Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones.*

Approximately 100m to the southeast of the site Dinantian Pure Bedded Limestone (DPBL) (i.e. Rickardstown Formation (RF) is located. This is classed as a *Locally Important Karstic aquifer.* This is classed as a cherty often dolomitised limestone. Approximately 980m to the west of the site Dinantian Upper Impure Limestone (DUIL) (i.e. Boston Hill Formation (BN) is located. This bedrock is described as Nodular & muddy limestone & shale. This is classed as a *Locally Important Karstic aquifer.*

A review of GSI geological records within 1km of the site revealed records for 4 boreholes. This data is presented in Appendix 2 along with individual GSI borehole records. A map showing the location of each of the 4 boreholes is presented in Figure 11. The closest of these boreholes is a dug well approximately 425m to the southeast of the site and to the east of the River Liffey. However, although a total depth of 3m is given this record did not provide any detail on depth to bedrock or groundwater table in the vicinity of the site. The 2nd borehole is a dug well located approximately 767m to the southeast of the site to the east of the River Liffey. However, although a total depth of 2.2m is given this record did not provide any detail on depth to bedrock or groundwater table in the vicinity of the site. The 3rd borehole is a dug well located approximately 928m to the southeast of the site to the east of the River Liffey. However, although a total depth of 10.6m is given, like the previous 2 borehole records, this record did not provide any detail on depth to bedrock or groundwater table in the vicinity of the site.

A 4th borehole record is a dug well located approximately 1038m to the southwest of the site to the west of the River Liffey. However, although a total depth of 16.5m is given, like the previous 3 borehole records, this record did not provide any detail on depth to bedrock or groundwater table in the vicinity of the site. No information is given on the yield class which of the 4 dug wells.

4.6.2 Site Geology

4.6.2.1 Subsoil/Made Ground

It is understood that 13 trial pits were dug by Golders in September, 2010. Trial pit depths varied between 1.0 and 4.5m below the ground level (i.e. depending on bedrock and maximum reach of the excavator). Natural ground was achieved in 6 of a total of 13 trial pit locations. Of the thirteen (13 No) trial pits, municipal solid waste (MSW) and/or construction and demolition waste (C&D) layers and natural ground were encountered at the following locations.

- The waste ground to the east of the Site in the 'Eastern Paddock' found up to 2.9 m, bedrock encountered as shallow as 1.0m - predominantly MSW;
- The waste in the southern half of the 'Western Paddock' found up to 4.5 m in depth (i.e. maximum reach of excavator) - predominantly MSW;
- In the eastern section of the 'Eastern Paddock' and the eastern section of the residential garden (predominantly MSW);
- The northern section of the 'Western Paddock' comprised (predominantly C&D waste); and
- The western section of the residential garden (predominantly natural ground).

The general waste profile encountered beneath the site is summarised in the above bullet list. The thickness of the MSW and C&D waste was limited in the eastern section of the site by the bedrock which was increasingly shallow to the south and eastern boundary. The bottom of the municipal/C&D waste body was not encountered to a depth of 4.5 m in the southern part of the 'Western Paddock'. Municipal/C&D waste was encountered within the southern paddock and the garden area, however these trial pits were only opened to 1.5 m in depth in order to minimise disturbance. The bottom of the waste body was not encountered at those locations.

The municipal waste layers comprised in general of plastic, rags, bottles, textiles, paper and wood. A strong waste odour was observed while excavating in the waste layers at some locations.

The C&D waste layers comprised crushed stone, brick and reworked soils.

The capping material used at the Site varied from a gravelly silty sand layer in the waste ground to a brown silty sand containing clay over the remainder of the site.

4.6.2.2 On-site Bedrock

It is understood that 3 monitoring 50mm diameter boreholes, BH01, BH02 and BH03 and 2 leachate wells, LW01 and LW02 were drilled on site by IGSL under the supervision of Kildare C.C. personnel in 2010 (see Figure 12). Basic drilling summaries were drafted up by IGSL on behalf of Kildare C.C. for each of the groundwater and leachate wells (see Appendix 2). As can be seen from this summary, the information contains depth of overlying clay cap,

plastic waste and underlying gravels and/or weathered bedrock for LW1 and LW2. As expected, drilling did not go further than bedrock for both of the leachate wells. Bedrock was identified at 3.6m bgl and 3.0 in LW1 and LW2 respectively.

In BH101 (i.e. GW1), no information was given for depth to bedrock. Weathered bedrock was identified at 5.0m in BH102 (i.e.GW2). Bedrock was not encountered at GW3. It should be noted that the technique used in the site investigation to install bedrock boreholes was an 'Air Rotary Rig'. This type of drilling technique destroys the spoil as drill cuttings and as such, it can not be relied on to give an assessment of the absence/presence of waste. For GW2, the material overlying the bedrock is described as overburden. It is therefore not possible to definitively state that waste was not encountered in BH102 (i.e. GW2). However, it would appear that the description given for borehole BH3 (i.e. GW3) was detailed enough to conclude that no waste was deposited in this area.

A borehole survey was carried out by Mulroy Environmental on the 16th February, 2012 during which standing water levels and total depth measurements were taken. This data is summarised in Table A3.1 which is located in Appendix 3. As can be seen from Table A3 .1, the total depth determined at leachate wells, LW01 and LW02 were 4.78 and 4.12m respectively. There are minor discrepancies between the depths referred to in the borehole summaries and that those identified on site. However, these are minor.

A cross-section of the site was prepared using the findings of the trialpitting exercise and this is represented on Figure 13. This cross-section extends through the site from the existing residence to the west of the site to the residence to the southeast and illustrates the approximate depth to bedrock, the depth of the waste deposited on site and the approximate groundwater table.

4.7 Hydrogeology

4.7.1 General Hydrogeological Classification

Dinantian Pure Un-bedded Limestone (DPUL) underlies the site (i.e. Waulsortian Mudbank Limestone Formation (WA)). This is classed as a *Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones.*

As stated previously, a review of GSI geological records within 1km of the site revealed records for 4 boreholes. None of these boreholes are located within the Waulsortian Mudbank Limestone Formation but they are located within the neighbouring Dinantian Pure Bedded Limestone (DPBL) (i.e. Rickardstown Formation (RF) is to the south and east of the site. This is classed as a *Locally Important Karstic aquifer.*

A map showing the location of each of the 4 boreholes is presented in Figure 11. The closest of these boreholes is a dug well approximately 425m to the southeast of the site and to the east of the River Liffey (see Appendix 2). However, although a total depth of 3m is given in this record, it did not provide any detail on depth to bedrock or groundwater table in the vicinity of the site. The 2nd borehole is a dug well located approximately 767m to the southeast of the site to the east of the River Liffey. However, although a total depth of 2.2m is given this record did not provide any detail on depth to bedrock or groundwater table in the vicinity of the site. The 3rd borehole is a dug well located approximately 928m to the southeast of the site to the east of the River Liffey. However, although a total depth of 10.6m is given, like the previous 2 borehole records, this record did not provide any detail on depth to bedrock or groundwater table in the vicinity of the site.

A 4th borehole record is a dug well located approximately 1038m to the southwest of the site to the west of the River Liffey. However, although a total depth of 16.5m is given, like the previous 3 borehole records, this record did not provide any detail on depth to bedrock or groundwater table in the vicinity of the site. No information is given on the yield class which of the 4 dug wells.

The site is located with the Dublin Groundwater Body (see Appendix 3). This GWB is located in the Greater Dublin City area and extends southwest towards Kildare. The area is generally low-lying, with areas of higher elevation surrounding to the south and to a lesser extent to the north. Elevations decrease towards the various river estuaries around Dublin city. At the boundaries of the GWB the highest elevations are to the south at the foothills of the Dublin Mountains and to the northwest where the Namurian rocks form an area of higher elevation to the southwest of Dunshaughlin.

The GSI have defined a Groundwater Protection Scheme for County Kildare which makes recommendations for restrictions to land use within Source Protection Zones based on the vulnerability of the groundwater aquifers to contamination.

4.7.2 Groundwater Flow

Groundwater flow is most likely through the underlying overburden which consists of fluvio-sands and gravels and the underlying limestone bedrock and follows the topography of the site and land to the River Liffey to the east and northeast of the site. Probable groundwater flow direction is indicated on Figure 3.

Groundwater flow within the catchments is dominantly through fissure zones within the bedrock. Minor matrix flow may occur in the defined volcanic units. Groundwater yields are poor (<40m^3/d).

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 DoE-LG, EPA and GSI have 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 DoE-LG, EPA and GSI vulnerability mapping guidelines allow for the assignment of vulnerability ratings from “extreme” to “low”, depending upon the subsoil type and thickness. With regard to sites where both low and high permeability subsoils are present, the following thicknesses of unsaturated zone are specified:

Table 1. 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

Groundwater Source Protection

The DoE-LG, EPA and GSI guidelines for Groundwater Protection Schemes allow for the combination of aquifer classification and vulnerability rating giving classifications of groundwater protection zones. The purpose of these zones is to place a control on the activities practised within a zone and thus provide protection to any underlying groundwater resources. Using DoE-LG, EPA and GSI criteria and the aquifer classification and vulnerability categories defined for the site, a Ll/E Locally Important Aquifer with Extreme vulnerability classification is assigned to the entire subject site. It should be noted that the *'Extreme'* vulnerability classification given by the GSI is based on the perceived quarrying/extractive history of the site and the perceived lack of overburden (see Figure 10). A review of the vulnerability mapping shows similar quarries to the west of the site with *'Extreme (E)'* or *'X- Rock near Surface or Karst'* vulnerability classification.

It should also be noted that the a study carried out by the Eastern River Basin Management Body under the Water Framework Directive in 2008 has classed the 'Dublin' Groundwater Body, in which the site is located as *'2a – Probably Not at Risk'*. The full water framework directive hydrogeological risk assessment report for the 'Dublin' Surface Groundwater Body is located in Appendix 3.

4.8 Hydrology

The River Liffey is located approximately 100m to the east of the site and flows in a north to south direction. A weir is located approximately 150m to the northeast of the site which serves to impede the flow of the river (see Figure 3).

The Liffey is located in the Liffey Lower 03 Catchment and is part of Hydrometric Area 09 of the Eastern River Basin District.

Two ESB owned Hydrometric Stations, Nos. 09013 and 09034 are located downstream of the site approximately 6.5km to the east-northeast. No hydrometric data is available for these stations (see Appendix 4).

A review of flooding archives indicates that 2 flood events have occurred in the vicinity of the site. One of these occurred downstream of the weir in 1954 approximately 750m from to the northeast of the site. Another occurred upstream near Millicent House approximately 1.5m to the south of the site (see Appendix 4). A review of the Kildare C.C. Local Area Engineer's report of March, 2005 does not reveal flooding in the Carrigeen area (i.e. upgradient of the afore-mentioned weir) (see Appendix 4).

In addition it should be noted that areas prone to flooding are typically noted in historical mapping. A review of all major editions of ordnance survey mapping for the Carrigeen areas indicate that no evidence of flooding exists.

A study carried out by the Eastern River Basin Management Body under the Water Framework Directive in 2008 has classed the *'Liffey Lower 03'* Surface Water Body, in which the site is located as *'1a – At Risk'* and its overall status is classed as *'Moderate'*. The full water framework directive hydrological risk assessment report for the *'Liffey Lower 03'* Surface Waterbody is located in Appendix 4.

The EPA have carried out biological monitoring approximately 310m downgradient of the site at Alexandra Bridge in Clane over a number of years. A biological quality value (Q-Rating) of 4 or 'Good' overall status has been given by the EPA (see Appendix 4 for EPA monitoring point location). No detailed historical data on the Q-status of the river at the point was obtainable from the EPA website

5 ENVIRONMENTAL SOILS RESULTS

Waste soil samples were collected at each of the 13 trial pitting locations. The three most representative locations were chosen by Golders to undergo laboratory analysis – TP1, TP4 and TP6. The samples were taken from the waste body within the excavated soil heaps. The laboratory suite was based on the Waste Acceptance Criteria specified by Council Directive 2003/33/EC.

This laboratory suite was as follows:

Total Pollutant Analyses

- Diesel Range Organic Analysis (EPH C8-C40/Total Aliphatic Hydrocarbons (Mineral Oil);
- BTEX (Benzene, Toluene, Ethylbenzene, o-, m- and p-xylenes, MTBE);
- PAH (17 speciated) to include Coronene; and
- PCBs - 7 congeners.

Analysis on CEN leachate (10:1 liquid to solid)

- Total Phenols;
- Heavy Metals - As, Ba, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Sb, Se and Zn Sulphate;
- Chloride;
- Fluoride;
- Dissolved Organic Carbon;
- Total Dissolved Solids; and
- Total Organic Carbon.

It should be noted that the above laboratory suite covers the Waste Acceptance Criteria which is in place within the Murphy Environmental waste facility (WA 129-02|) in Hollywood Great, The Nag's Head, The Naul, Co. Dublin.

The following tables, Table 2 and Table 3 represent the results of the soils and soil sample leachate analyses. These results are compared against the following Generic Assessment Criteria:

- *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);
- *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*;*
- *EIC/AGS/CL:AIRE Soil Generic Assessment Criteria for Human Health, 2010;*
- *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);
- *National Institute of Public Health and the Environment of The Netherlands - The Soil Protection Guidelines (Dutch Criteria)* – Intervention and Target Values; and
- Waste Acceptance Criteria at Murphy Environmental Waste Facility (WA 129-02|) in Hollywood, Co. Dublin.

It should be noted that where exceedances were found of the above Dutch Criteria 'Target Values' the values are underlined. Where exceedances were found for all other criteria the values are highlighted in yellow and in bold. The data in the attached tables is assessed in the following 2 sections by chemical subgrouping.

5.1 Total Pollutant Analysis

5.1.1 Diesel Range Organic Analysis (EPH C8-C40/Total Aliphatic Hydrocarbons (Mineral Oil)

Diesel Range Organics (DRO) were observed in all 4 of the samples tested, varying from 823 mg/kg (TP05) to 3,191 mg/kg (TP01). The Diesel Range Organics range of petroleum hydrocarbons analysis can be regarded as both aliphatics (i.e. saturated organics such as n-alkanes, iso-alkanes and cycloalkanes) and aromatic fraction (i.e. BTEX and Polyaromatic Hydrocarbons). The aliphatic fraction is also referred to as the Mineral Oil fraction and is usually given in conjunction with the Total DRO concentration. For all 4 samples, the Total Mineral concentration was less than the Method Detection Limit (MDL). The laboratory confirmed however that these results were as a result of naturally occurring compounds, likely to be humic acid from the biodegradation of organic products.

Table 2. Results of TPH, BTEX, Polyaromatic Hydrocarbon and PCB Laboratory Analysis on Soil Samples taken from Carrigeen Landfill, County Kildare and Comparison of Results against Generic Assessment Criteria

CHEMICAL SUBGROUPING				Aliphatics										Aromatics								
GENERIC ASSESSMENT CRITERIA		Parameter		EC C5-C6	EC>C6-C8	EC>C8-C10	EC>C10-C12	EC>C12-C16	EC>C16-C21	EC>C16-C35	EC>C21-C35	EC>C35-C44	Total Aliphatics	EC C5-C7	EC>C7-C8	EC>C8-C10	EC>C10-C12	EC>C12-C16	EC>C16-C21	EC>C21-C35	EC>C35-C44	Total Aromatics
		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
DUTCH CRITERIA CRITERIA		Dutch Intervention Levels (IV)		-	-	-	-	-	-	-	-	-	5000	-	-	-	-	-	-	-	-	-
		Dutch Target Level (TV)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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		2009 Published SGV [1]	Residential with plant	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Allotment	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-
			Industrial/ Commercial	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
MURPHY ENVIRONMENTAL WASTE LICENCE WA 129-02		WAC Values		-	-	-	-	-	-	-	-	-	500	-	-	-	-	-	-	-	-	-
		SAMPLE ID	SAMPLING DEPTH (metres BGL)																			
	TRIALPITS	TP1-01	1.5-2.0	~	~	~	~	~	~	~	~	~	<30	~	~	~	~	~	~	~	~	~
		TP4-01	0.5-2.7	~	~	~	~	~	~	~	~	~	<30	~	~	~	~	~	~	~	~	~
		TP5-01	0.8-4.5	~	~	~	~	~	~	~	~	~	<30	~	~	~	~	~	~	~	~	~
		TP6-01	1.5-2.0	~	~	~	~	~	~	~	~	~	<30	~	~	~	~	~	~	~	~	~

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 Murphy Environmental Waste Licence WAC Value is exceeded
~	'~' signifies laboratory analysis not carried out.
-	'-' signifies no Dutch Criteria or CLEA Soil Guideline Value or Murphy Environmental 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 2. Results of TPH, BTEX, Polyaromatic Hydrocarbon and PCB Laboratory Analysis on Soil Samples taken from Carrigeen Landfill, County Kildare and Comparison of Results against Generic Assessment Criteria

CHEMICAL SUBGROUPING				Total Petroleum Hydrocarbons				Gasoline Range Organics						Polyaromatic Hydrocarbons (PAHS)																	
GENERIC ASSESSMENT CRITERIA		Parameter		TPH (ORO)EPH C8-C40)	Total Aliphatics	Total Aromatics	% Aliphatics	MTBE	BTEX COMPOUNDS Benzene	Toluene	Ethylbenzene	Total Xylene	TOTAL BTEX	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b)fluoranthene	Benzo(a)pyrene	Indeno(123cd)pyrene	Dibenz(ah)anthracene	Benzo(ghi)perylene	Coronene	Total 10 EPA PAHs	Total 17 EPA PAHs
		Units		mg/kg	mg/kg	mg/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
DUTCH CRITERIA CRITERIA		Dutch Intervention Levels (IV)		-	5000	-	-	-	1000	130000	50000	25000	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	40	-
		Dutch Target Level (TV)		-	50	-	-	-	10	10	30	100	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	1	-
LQM/CIEH GENERIC ASSESSMENT CRITERIA		Residential		-	-	-	-	-	-	-	-	-	-	8.7	850	1000	780	380	9200	670	1600	5.9	9.3	7	1	4.2	0.9	47	-	-	-
		Allotment		-	-	-	-	-	-	-	-	-	-	23	160	200	160	90	2200	290	620	10	12	13	2.1	7.1	2.3	160	-	-	-
		Commercial		-	-	-	-	-	-	-	-	-	-	1100 (432)[sol]	100000	100000	71000	23000	540000	23000	54000	97	140	100	14	62	13	660	-	-	-
CLEA SOIL GUIDELINE VALUES		2009 Published SGV [1]	Residential with plant	-	-	-	-	-	330	610000	350000	720000	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-
			Allotment	-	-	-	-	-	70	120000	90000	500000	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
			Industrial/ Commercial	-	-	-	-	-	95000	4400000	2800000	9300000	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	-
MURPHY ENVIRONMENTAL WASTE LICENCE WA 129-02		WAC Values		-	500	-	-	-	-	-	-	-	6000	-	-	-	-	-	-	-	-	-	-		-	-	-	-	-	-	100
		SAMPLE ID	SAMPLING DEPTH (metres BGL)																												
	TRIALPITS	TP1-01	1.5-2.0	3191	<30	~	~	<5	<5	<5	35	154	209	<0.04	<0.03	<0.05	<0.04	<0.03	<0.04	<0.03	<0.03	<0.06	<0.02	<0.07	<0.04	<0.04	<0.04	<0.04	<0.04	<0.6	<0.64
		TP4-01	0.5-2.7	2188	<30	~	~	<5	<5	<5	160	163	323	<0.04	0.06	<0.05	<0.04	0.09	0.09	0.23	0.27	0.29	0.23	0.51	0.26	0.21	<0.04	0.21	<0.04	2.12	2.44
		TP5-01	0.8-4.5	823	<30	~	~	<5	<5	<5	<6	<5	<25	0.11	0.11	0.86	0.45	5.01	1.61	8.87	5.95	2.36	2.91	4.91	**3.1**	1.92	0.36	1.49	0.36	32.29	40.36
		TP6-01	1.5-2.0	2163	<30	~	~	<5	<5	74	172	562	813	<0.04	<0.03	<0.05	<0.04	0.1	<0.04	0.17	0.2	0.09	0.13	0.13	0.07	0.08	<0.04	0.08	<0.04	0.85	1.11

Notes:

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553 Values are shaded yellow and in **bold** wherever Dutch-TV or CLEA Soil Guideline Value or Murphy Environmental Waste Licence WAC Value is exceeded

~ '~' signifies laboratory analysis not carried out.

- '-' signifies no Dutch Criteria or CLEA Soil Guideline Value or Murphy Environmental 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. Based on a sandy loam soil with 5% soil organic matter (SOM).
3. 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 bra T

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

Table 2. Results of TPH, BTEX, Polyaromatic Hydrocarbon and PCB Laboratory Analysis on Soil Samples taken from Carrigeen Landfill, County Kildare and Comparison of Results against Generic Assessment Criteria

CHEMICAL SUBGROUPING				Polychlorinated Biphenyls								
GENERIC ASSESSMENT CRITERIA		Parameter		PCB Congener 28	PCB Congener 52	PCB Congener 101	PCB Congener 118	PCB Congener 153	PCB Congener 138	PCB Congener 180	PCB Total of 6 Congeners	PCB Total of 7 Congeners
		Units		µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg	µg/kg
DUTCH CRITERIA CRITERIA		Dutch Intervention Levels (IV)		-	-	-	-	-	-	-	1	-
		Dutch Target Level (TV)		-	-	-	-	-	-	-	0.02	-
LQM/CIEH GENERIC ASSESSMENT CRITERIA		Residential		-	-	-	-	-	-	-	-	-
		Allotment		-	-	-	-	-	-	-	-	-
		Commercial		-	-	-	-	-	-	-	-	-
CLEA SOIL GUIDELINE VALUES		2009 Published SGV [1]	Residential with plant	-	-	-	-	-	-	-	-	-
			Allotment	-	-	-	-	-	-	-	-	-
			Industrial/ Commercial	-	-	-	-	-	-	-	-	-
MURPHY ENVIRONMENTAL WASTE LICENCE WA 129-02		WAC Values		-	-	-	-	-	-	-	-	1
		SAMPLE ID	SAMPLING DEPTH (metres BGL)									
	TRIALPITS	TP1-01	1.5-2.0	<5	<5	<5	<5	<5	<5	<5	~	<35
		TP4-01	0.5-2.7	<5	<5	<5	<5	<5	<5	<5	~	<35
		TP5-01	0.8-4.5	~	~	~	~	~	~	~	~	~
		TP6-01	1.5-2.0	<5	<5	<5	<5	<5	<5	<5	~	<35

Notes:

553 Values are underlined wherever Dutch-TV is exceeded

553 Values are shaded yellow and in **bold** wherever Dutch-IV or CLEA Soil Guideline Value or Murphy Environmental Waste Licence WAC Value is exceeded

~ '~' signifies laboratory analysis not carried out.

- '-' signifies no Dutch Criteria or CLEA Soil Guideline Value or Murphy Environmental 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 3. Results of Organic Carbon, Heavy Metal, Anion, Total Dissolved Soilids and Phenol Laboratory Analysis on 10:1 Leachate Extracted from Soil Samples taken from Trialpits TP01, TP04 and TP06

CHEMICAL SUBGROUPING			Organic/ Carbon Content	Heavy Metals													Anions			TDS	Phenols
	Parameter		Dissolved Organic Carbon	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	Nickel Low Level CEN 10:1 Leachate	Molybdenum Low Level CEN 10:1 Leachate	Mercury 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
	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
MURPHY ENVIRONMENTAL WASTE LICENCE WA 129-02	WAC Values		500	0.06	0.5	20	0.04	0.5	2	0.5	0.4	0.5	0.01	0.1	4	1000	10	800	4000	1
	SAMPLE ID	SAMPLING DEPTH (metres BGL)																			
	TP1-01	1.5-2.0	390	<0.03	0.22	0.21	<0.01	<0.02	<0.12	<0.1	0.1	0.62	<0.001	<0.03	0.13	**1668**	<1	188	**4350**	<1
	TP4-01	0.5-2.7	190	<0.03	0.06	0.48	<0.01	<0.02	<0.12	<0.1	<0.06	0.23	<0.001	<0.03	<0.04	938	<1	39	3390	<1
	TP6-01	1.5-2.0	**1850**	<0.03	0.22	0.48	<0.01	<0.02	<0.12	<0.1	0.6	1.09	<0.001	<0.03	0.08	**1070**	<1	**1810**	**10550**	<1

Notes:

553 Values are shaded yellow and in Red bold wherever Murphy Environmental Waste Licence WAC Value is exceeded.

~ '~' signifies laboratory analysis not carried out.

- '-' signifies no Murphy Environmental Waste Licence WAC Value available.

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

Of the 5 compounds analysed, trace levels of Toluene, Ethylbenzene, o-, m- and p-xylenes were detected in the soil sample taken from TP06. Trace levels of Ethylbenzene, o-, m- and p-xylenes were detected in the soil samples taken from TP01 and TP04.

For the soil sample taken from TP06, the Toluene, Ethylbenzene and Total Xylenes concentrations exceeded their respective Dutch Criteria Target Values. However, it should be noted that these values were significantly lower (i.e. by 3 orders of magnitude) than their respective 2009 Soil Guideline Values (SGVs) for *'Residential with Plant Uptake'* which were 610,000µg/kg, 350,000µg/kg, and 720,000 µg/kg respectively. It should be noted that the *'Residential with Plant Uptake'* setting is the most sensitive setting and given the site's current uses (i.e. horse pasture, fallow, etc), it is likely that the *'Residential with Plant Uptake'* is a very much a worse case scenario.

5.1.3 Polyaromatic Hydrocarbons (17 speciated including Coronene)

5.1.3.1 Total PAHs

Polyaromatic Hydrocarbons were detected in 3 of the 4 soil samples, TP04, TP05 and TP06. The Total PAH-17 concentration (i.e. for 17 individual) ranged from 1.11mg/kg in TP06, to 2.44mg/kg in TP04 to 40.36mg/kg in TP05. These values were below their respective Waste Acceptance Criteria Total PAH-17 value of 100mg/kg. It should be noted that no Dutch Criteria values exist for Total PAH-17. However, Dutch Criteria Target and Intervention values exist for Total PAH-10 (i.e. for 10 individual PAHs). All three of the values were found to exceed their respective Target Value but were less than their respective Dutch Intervention Value.

5.1.3.2 Individual PAHs

Only the LQM/CIEH 2011 workshop provides Generic Assessment Criteria for individual PAH compounds (see Table 2). Of the 17 PAHs analysed only one PAH, Benzo(a)pyrene exceeds its respective LQM/CIEH GAC values for both *'Residential'* and *'Allotment'*. However, it should be noted that 3.1mg/kg would not be regarded as a gross exceedance of for *'Residential'* and *'Allotment'* GAC values which are 1mg/kg and 2.1mg/kg respectively.

5.1.4 Polychlorinated Biphenyls (PCBs - 7 congeners)

Three of the 4 samples, TP01, TP4 and TP06 were analysed for Polychlorinated Biphenyls. No Polychlorinated Biphenyls were detected within the soil samples submitted (see Table 2).

5.2 Leachate Analyses

CEN leachate extraction (i.e. 10:1 liquid to solid) was carried out on 3 of the 4 samples, TP01, TP04 and TP06 (see 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.

5.2.1 Dissolved Organic Carbon (DOC)

Dissolved Organic Carbon (DOC) analysis was carried out on the leachate extracted from all 3 samples. DOC was detected within the leachate extracted from the 3 soil samples submitted (see Table 3). One of the soil samples' (i.e. TP06) leachate showed DOC levels exceeding its respective Waste Acceptance Criteria (i.e. 800mg/kg).

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

Heavy metals analysis was carried out on the leachate extracted from all 3 samples. Of the 12 metals analysed only arsenic, barium, nickel, molybdenum and zinc were detected. No metals were detected above their respective Waste Acceptance Criteria.

5.2.3 Sulphate

Sulphate analysis was carried out on the leachate extracted from all 3 samples. Sulphates were detected within the leachate extracted from the 3 soil samples submitted (see Table 3). Two of the soil samples' (i.e. TP01 and TPO4) leachate showed sulphate levels exceeding their respective Waste Acceptance Criteria (i.e. 1,000mg/kg).

5.2.4 Fluoride

Fluoride analysis was carried out on the leachate extracted from all 3 samples. No fluorides were detected within the leachate extracted from the 3 soil samples submitted (see Table 3).

5.2.5 Chloride

Chloride analysis was carried out on the leachate extracted from all 3 samples. Chlorides were detected within the leachate extracted from the 3 soil samples submitted (see Table 3). One of the soil samples' (i.e. TP01) leachate showed chloride levels exceeding its respective Waste Acceptance Criteria (i.e. 800mg/kg).

5.2.6 Total Dissolved Solids

Total Dissolved Solids (TDS) analysis was carried out on the leachate extracted from all 3 samples. TDS were detected within the leachate extracted from the 3 soil samples submitted (see Table 3). Two of the soil samples' (i.e. TP01 and TP06) leachate showed TDS levels exceeding their respective Waste Acceptance Criteria (i.e. 4,000mg/kg).

5.2.7 Total Phenols

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

6 ENVIRONMENTAL GROUNDWATER RESULTS

Three groundwater samples and two leachate samples were collected from within the site at locations BH01 BH02 BH03, LW01 and LW02 and submitted for laboratory analysis. The laboratory suite was as follows:

Physico-chemical Parameters

- pH; and
- Electrical Conductivity.

Inorganic Analysis

- Heavy Metals - As, Ba, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Sb, Se and Zn;
- Total suspended solids;
- Total alkalinity (as $CaCO_3$); [5]
- Ammoniacal Nitrogen (as N);
- Total Oxidised Nitrogen (TON) as N;
- Chloride (Cl^-);
- Fluoride (F^-);
- Sulphate (SO_4^{2-})
- Ortho-Phosphate (PO_4);
- MR-Phosphate as P; and
- Total Cyanide.

Major Cations and Anions

- Potassium (K);
- Sodium (N);
- Calcium (Ca); and
- Magnesium (Mg).

Oxygen Demand/Organic Carbon

- Biological Oxygen Demand;
- Chemical Oxygen Demand;
- Dissolved Organic Carbon; and
- Total Organic Carbon.

The following tables, Table 4 and Table 5 represent the results of the groundwater and leachate analyses. These results are compared against the following Generic Assessment Criteria, statutory limits, Interim Guideline Values and Threshold Values. A detailed description of each of the following Generic Assessment Criteria is given in Section 3:

- *National Institute of Public Health and the Environment of The Netherlands - The Soil Protection Guidelines (Dutch Criteria)* – Intervention and Target Values;

[5] *The leachate samples were not analysed for Total Alkalinity.*

- The maximum allowable concentration (MAC) values of Statutory Instrument No. 81 (Quality of Water Intended for Human Consumption) of 1988;
- The parametric values of Statutory Instrument No. 106 (Drinking Water Regulations) of 2007;
- The Interim Guideline Values from *Towards Setting Guideline Values For The Protection Of Groundwater In Ireland – Interim Report;* and
- The Threshold Values from EC Environmental Objectives (Groundwater Regulations) Statutory Instrument No. 9, 2010.

6.1 Physicochemical Analysis

pH values vary across the site with the lowest being 7.48 in BH03 and the highest, 8.25 in BH01. The pH of the groundwater although slightly alkaline is within normal ranges.

Electrical conductivity values were as expect lowest in the groundwater samples with conductivity varying from 402µS/cm at BH02 to 725µS/cm at BH01. The conductivity of the groundwater also appears to be within normal ranges for groundwater.

Electrical conductivity values were as expected, high in the leachate samples with conductivity varying from to 1,726µS/cm at LW02 to 2,388µS/cm at LW01.

6.2 Total Alkalinity

The results obtained for Total alkalinity (as $CaCO_3$) ranged from 348mg/l in BH02 to 985mg/l in BH03. These levels would be regarded as normal for groundwater originating in a limestone bedrock area.

No alkalinity analysis was carried out on the leachate samples.

6.3 Ammoniacal Nitrogen & Total Oxidised Nitrogen (TON)

The results obtained within the groundwater samples for Ammoniacal Nitrogen ranged from 1.92mg/l in BH02 to 18.08mg/l in BH01 (i.e. both downgradient boreholes). These levels would be expected given the proximity of waste and the direction of groundwater flow towards the northeast. Very low levels of ammonia were detected in BH03 which is upgradient of the waste and would be expected to represent the background geochemistry for the area. It is possible that the low level of ammonia detected in BH03 is attributable to agricultural practices (i.e. landspreading, etc) upgradient of the site.

The results obtained within the leachate samples for Ammoniacal Nitrogen ranged from 91.65mg/l in LW02 to 100.08mg/l in LW01. These levels would be expected and are typical of leachate from domestic waste.

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

The results obtained within the groundwater samples for chloride ranged from 13.7mg/l in BH03 (i.e. the upgradient borehole) to 31.2mg/l in BH01 and 30.2mg/l in BH02 (i.e. the downgradient boreholes). These levels again would be expected given the proximity of waste

Table 4. Results of Laboratory Analyses on Groundwater and Leachate Samples taken at Carrigeen Landfill

Parameter	Units	Standards		Guidelines		Analytical Results				
						SOURCE				
						GROUNDWATER MONITORING WELLS			LEACHATE WELLS	
		SI No. 81 of 1988 - EC Regs (Quality of water intended for human consumption).	*SI No. 439 of 2000 - EC Drinking Water Regs.*	*EPA Guideline Values - From Interim Report on 'Towards Setting Guideline Values for the Protection of Groundwater in Ireland'.*	*S.I. No. 9, European Communities Environmental Objectives (Groundwater) Regulations, 2010*	BH03 (UPGRADIENT)	BH01 ((DOWN-GRADIENT))	BH02 (DOWN-GRADIENT)	LW01	LW02
		MACs	*Parametric Values*	*Interim Guideline Values*	*Threshold Values*					
Physico-Chemical Parameters										
pH	-	*6.0<pH<9.0*	*6.5<pH<9.5*	*6.5<pH<9.6*	*6.5<pH<9.6*	7.48	8.25	7.54	7.73	7.82
Electrical cond. (EC)	µS/cm	*1500*	*2500*	*1000*	*800-1875*	461	725	402	**2388**	**1726**
Dissolved oxygen (DO)	mg/l	-	-	-	-	-	-	-		-
Standard Chemistry										
Total hardness (as $CaCO_3$)	mg/l	*60 MRC (**)*	-	*200*		-	-	-	-	-
Total alkalinity (as $CaCO_3$)	mg/l	*30 MRC (**)*	-	-	-	985	430	348	-	-
Ammon. Nitrogen (as N)	mg/l	*0.23*	-	*0.12*	*0.065-0.175*	0.1	**18.08**	**1.92**	**100.08**	**91.65**
Total Oxidised Nitrogen (TON) as N	mg/l	-	-	-	-	0.7	0.8	8.4	0.6	0.6
Chloride Cl^-	mg/l	*250*	*250*	*30*	*24-187.5*	13.7	**31.2**	**30.2**	**150**	**98.5**
Fluoride F^-	mg/l	-	-		-	<0.3	<0.3	<0.3	<0.3	<0.3
Sulphate SO_4	mg/l	*250*	*250*	*200*	*187.5*	61.25	*7.09*	7.18	86.83	1.59
Sulphide S^{2-}	mg/l	-	-	-	-	-	-	-	-	-
ortho-Phosphate PO_4	mg/l	*3.35*	-	*0.03*	-	**0.11**	**1.83**	**1.67**	**11.38**	**20.98**
MR-Phosphate as P	mg/l	-	-	-	*0.035*	**0.037**	**0.596**	**0.545**	**3.711**	**6.842**
Total Cyanide	mg/l	*0*	-	*0*	-	<40	<40	<40	<40	<40
Major Cations										
Potassium K	mg/l	*12*	-	*5*	-	1.6	**20.7**	3.9	**117.6**	**76.7**
Sodium Na	mg/l	*150*	*200*	*150*	*150*	9.3	42.1	15.9	130.9	96.6
Potassium K/Sodium Na Ratio		-	-	-	-	0.17	**0.49**	0.25	**0.90**	**0.79**
Calcium Ca	mg/l	*200*	-	*200*	-	132.6	92.5	161.5	**244.7**	178.2
Magnesium Mg	mg/l	*50*	-	*50*	-	151	24	8.9	88	51.7
Oxygen Demand/Organic Carbon										
BOD	mg/l	-	-	10	-	-	-	-	**122**	2
COD	mg/l	-	-	20	-	-	-	-	**302**	**67**
TOC	mg/l	-	-	10	-	-	-	-	**376**	**74**
DOC	mg/l	-	-	-	-	-	-	-	368	61

Note:

450 Red Bold Font & Yellow Highlight indicates where SI No. 81 of 1988 MACs, SI No. 439 of 2000 Parametric Values, EPA Guideline Values or S.I. No. 9 Groundwater Reg. Threshold Levels have been exceeded

** M.R.C = Minimum Required Concentration specified in the Drinking Water Regulations (S.I. No. 81 of 1988)

< = Less than

'-' signifies analysis not carried out on sample or no SI No. 81 of 1988 MACs, SI No. 439 of 2000 Parametric Values, EPA Guideline Values or S.I. No. 9 Groundwater Reg. Threshold Levels are available.

Table 5. Results of Heavy Metals Analysis on Groundwater and Leachate Samples taken at Carrigeen Landfill

CHEMICAL SUBGROUPING		Heavy Metals										
	Parameter	Arsenic Low Level	Boron Low Level	Cadmium Low Level	Chromium Low Level	Copper Low Level	Iron Low Level	Manganese Low Level	Lead Low Level	Nickel Low Level	Mercury Low Level	Zinc Low Level
	Units	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
DUTCH CRITERIA	Dutch Intervention Levels	60	-	6	30	75	-	-	75	75	0.3	800
	Dutch Target Level	7.2	-	0.06	2.5	1.3	-	-	1.7	2.1	0.01	24
World Health Organisation Standard	Guideline Values	-	-	3	-	-	-	-	-	-	0.006	-
SI No. 81 of 1988 - EC Regs (Quality of water intended for human consumption).	MACs	50	-	5	50	500	200	50	50	50	1	1000
SI No. 439 of 2000 - EC Drinking Water Regs.	Parametric Values	10	-	5	50	-	200	50	10	-	1	-
EPA Guideline Values – From Interim Report on 'Towards Setting Guideline Values for the Protection of Groundwater in Ireland'.	Guideline Values (IGVs)	10		5	30	30	-	-	-	20	1	100
EC Environmental Objectives (Groundwater Regulations) S.I. 9, 2010	Threshold Values	7.5	750	3.75	37.5	1500	-	-	18.75	15	0.75	-
	BH01	**11.5**	175	<0.5	2.2	<7	**1124**	**1228**	<5	10	<1	12
	BH02	<2.5	39	<0.5	<1.5	<7	<20	**345**	<5	13	<1	28
	BH03	4	18	1.1	<1.5	<7	<20	**266**	<5	10	<1	9
	LW01	5	**759**	1	**32.9**	11	**33320**	**5311**	<5	**43**	<1	**176**
	LW02	**20.7**	624	0.8	24.7	8	**27010**	**1207**	<5	**18**	<1	25

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Notes:

Values are underlined wherever Dutch-TV is exceeded

Values are shaded yellow and in bold wherever Dutch-IV, WHO Standards, SI No. 439 of 2000 Parametric Values, EPA Guideline Values or Groundwater Reg. Threshold Levels are exceeded

'-' signifies analysis not carried out on sample or no Dutch-IV, WHO Standards, SI No. 439 of 2000 Parametric Values, EPA Guideline Values or Groundwater Reg. Threshold Levels are available.

and the direction of groundwater flow towards the northeast. Low levels of chloride were detected in BH03 which is upgradient of the waste and would be expected to represent the background geochemistry for the area.

The results obtained within the leachate samples for chloride ranged from 98.5mg/l in LW02 to 150mg/l in LW01. These levels would be expected and are typical of leachate from domestic waste.

No fluoride was detected within the groundwater or leachate samples taken on site.

The results obtained within the groundwater samples for sulphate ranged from 7.09mg/l in BH01 (i.e. the downgradient borehole) to 61.25mg/l in BH03 (i.e. the upgradient borehole). These results would indicate that normal sulphate levels are present in BH03 and that under anaerobic conditions sulphates are being reduced to sulphides within the groundwater downgradient of the waste body (i.e. to the northeast and east). However, it should be noted that no sulphide analysis was carried out on any of the groundwater or leachate samples by Golders.

The results obtained within the leachate samples for sulphate ranged from 1.59mg/l in LW02 to 86.83mg/l in LW01. During the groundwater monitoring round, severe sulphide staining was observed on the groundwater sampling balers contained within LW01 and LW02. This would be regarded as typical of leachate monitoring wells located within a domestic waste area.

6.5 Ortho-Phosphate (PO_4), MR-Phosphate (as P) and Total Cyanide.

The results obtained within the groundwater samples for phosphate ranged from 0.11mg/l in BH03 (i.e. the upgradient borehole) to 1.83mg/l in BH01 (i.e. the downgradient borehole). These levels again would be expected given the proximity of waste and the direction of groundwater flow towards the northeast. Low levels of ortho-phosphates were detected in BH03 which is upgradient of the waste and would be expected to represent the background geochemistry for the area. It is possible that the low level of ortho-phosphates detected in BH03 are attributable to agricultural practices (i.e. landspreading, etc) upgradient of the site.

The results obtained within the leachate samples for ortho-phosphates ranged from 11.38mg/l in LW01 to 20.98mg/l in LW02. These levels would be expected and are typical of leachate from domestic waste.

The results obtained within the groundwater samples for Molybdate-Reactive phosphate (as P) ranged from 0.037mg/l in BH03 (i.e. the upgradient borehole) to 0.596mg/l in BH01 (i.e. the downgradient borehole). These levels closely resemble those levels which were found for ortho-phosphates.

No cyanides were detected within the groundwater or leachate samples taken on site.

6.6 Major Cations

The results obtained within the groundwater samples for potassium ranged from 1.6mg/l in BH03 (i.e. the upgradient borehole) to 20.7mg/l in BH01 (i.e. the downgradient borehole). The value obtained for the sample from BH101 exceeded the EPA Interim Guideline Value (IGV). This level was also reflected in the Potassium/Sodium ratio which was 0.49. A ratio greater than 0.4 generally would indicate an impact by domestic leachate.

The results obtained for sodium, calcium and magnesium were all less than their respective MAC Values quoted in the E.C. Regulations (Quality of water intended for human consumption) of 1988, Parametric Values quoted in the Drinking Water Regulations of 2007, their corresponding EPA Interim Guideline Values (IGVs) and their corresponding Threshold Values quoted in the E.C. Environmental Objectives (Groundwater Regulations), 2010.

The results obtained within the leachate samples for potassium ranged from 76.7mg/l in LW02 to 117.6mg/l in LW01. Both of these values grossly exceeded the EPA Interim Guideline Value (IGV) of 5mg/l. These levels were also reflected in the Potassium/Sodium ratios of 0.79 and 0.90. These ratios would indicate an impact by domestic leachate.

With the exception of the calcium levels identified in LW01, the results obtained for sodium, calcium and magnesium were all less than their respective MAC Values quoted in the E.C. Regulations (Quality of water intended for human consumption) of 1988, Parametric Values quoted in the Drinking Water Regulations of 2007, their corresponding EPA Interim Guideline Values (IGVs) and their corresponding Threshold Values quoted in the E.C. Environmental Objectives (Groundwater Regulations), 2010.

6.7 Oxygen Demand/Organic Carbon

Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Organic Carbon (DOC) and Total Organic Carbon (TOC) analyses were only carried out on the leachate samples taken from LW01 and LW02.

Biological Oxygen Demand (BOD)

Values of 122µg/l was obtained in LW01. This value exceeds the corresponding EPA IGV.

Chemical Oxygen Demand (COD)

Values of 302µg/l and 67µg/l were obtained in LW01 and LW02 respectively. These values exceed the corresponding EPA IGV.

Total Organic Carbon (TOC)

Values of 376µg/l and 74µg/l were obtained in LW01 and LW02 respectively. These values exceed the corresponding EPA IGV.

6.8 Heavy Metals

Of the 11 heavy metals analysed, the reported concentrations for all parameters are within their corresponding Dutch Criteria Intervention and Target Levels, World Health Organisation

Guideline Values 2008, MAC Values quoted in the E.C. Regulations (Quality of water intended for human consumption) of 1988, Parametric Values quoted in the Drinking Water Regulations of 2007, their corresponding EPA Interim Guideline Values (IGVs) and their corresponding Threshold Values quoted in the E.C. Environmental Objectives (Groundwater Regulations) 2010 with the exception of:

- *Arsenic*

Values of 11.5µg/l and 20.7µg/l were obtained in BH01 and LW02 respectively. These values exceed the corresponding EPA IGVs and Threshold Values.

- *Barium*

A value of 759µg/l was obtained in LW01. This value exceeds its corresponding Threshold Value.

- *Cadmium*

Values of 1.1, 1 and 0.08µg/l were obtained in BH03, LW01 and LW02 respectively. These exceed the corresponding Dutch Criteria Target level which is 0.06µg/l.

- *Chromium*

A value of 32.9µg/l was obtained in LW01. This value exceeds its corresponding Threshold Value. A value of 24.7µg/l was obtained in LW02. This exceeded the corresponding Dutch Criteria Target level which is 2.5µg/l.

- *Copper*

Values of 11 and 8µg/l were obtained in BH03, LW01 and LW02 respectively. These exceed the corresponding Dutch Criteria Target level which is 1.3µg/l.

- *Iron*

Values of 1,124µg/l, 33,320µg/l and 27,010µg/l were obtained in BH01, LW01 and LW02 respectively. These values exceed the corresponding Drinking Water MACs and Parametric Values which are 200µg/l. These values would be expected as iron, which is sensitive to oxygen levels, is typically reduced to its more mobile Fe^{2+} species and released or leached from soil and bedrock into groundwater during anaerobic (i.e. reducing) conditions.

- *Manganese*

Values of 1,228µg/l, 345µg/l, 266µg/l, 5,311µg/l and 1,207µg/l were obtained in BH01, BH02, BH03, LW01 and LW02 respectively. These values exceed the corresponding Drinking Water MACs and Parametric Values which are 50µg/l. Like iron, these values would be expected as manganese is typically reduced to its more mobile Mn^{2+} species and released or leached from soil and bedrock into groundwater during anaerobic (i.e. reducing) conditions.

- *Nickel*

Values of 43µg/l and 18µg/l were obtained in LW01 and LW02 respectively. These values exceed the corresponding EPA IGVs and Threshold Values which are 20µg/l and 15µg/l respectively.

Values of 10, 13 and 10µg/l were obtained in BH01, BH02 and BH03 respectively. These exceed the corresponding Dutch Criteria Target level which is 2.1µg/l.

- *Zinc*

A value of 176µg/l was obtained in LW01. This value exceeds the corresponding EPA IGV which is 176µg/l.

Values of 28 and 25µg/l were obtained in BH02 and LW02 respectively. These marginally exceed the corresponding Dutch Criteria Target level which is 24µg/l.

6.9 Polyaromatic Hydrocarbons

Groundwater samples from BH02 and LW01 were analysed for Polyaromatic Hydrocarbons. As can be seen from Table 6, low levels of 4 Polyaromatic Hydrocarbons (i.e. Naphthalene, Acenaphthene, Fluorene and Phenanthrene) were detected in the leachate sample taken from LW01. Of these 4 compounds, Naphthalene and Phenanthrene were detected at levels marginally exceeding the Dutch Target Level. [6]

6.10 Diesel Range Organic Analysis (EPH C8-C40/Total Aliphatic Hydrocarbons (Mineral Oil)

Groundwater samples from BH02 and LW01 were analysed for Diesel Range Organic Analysis. As can be seen from Table 6, Diesel Range Organics were detected in the groundwater sample taken from BH02. It should be noted however, that no concentration of Total Aliphatics (i.e. Mineral Oil Fraction) was given in the raw laboratory data. In addition, no 'Product Identification' was provided by the laboratory. As such, no conclusion can be drawn on the contamination identified in BH03, as the laboratory technique has an affinity to detect humic acids and other non-petroleum compounds and report them as Diesel Range Organics.

6.11 Summary of Groundwater Quality

An ion balance was carried on the results of the inorganic anion and cation analysis of the groundwater. As can be seen from Table A3.2 (see Appendix 3), the largest ion balance was obtained for BH03 i.e. 12.09%. For groundwater, an ion balance error of up to 15 per cent is generally acceptable. The potassium/sodium ratio, the levels of trace organics and ammonia and the distribution of heavy metals within the groundwater in the downgradient boreholes on site indicate that the groundwater has been moderately to severely impacted by leachate emanating from the domestic wastes identified during the trial pitting exercise carried out by Golders.

[6] *This is indicated on Table 1 by those numbers underlined.*

Table 6. Results of TPH and PAH Analysis on Groundwater and Leachate Samples taken at Carrigeen Landfill

CHEMICAL SUBGROUPING		Diesel Range Organics		Polyaromatic Hydrocarbons (PAHS)															
	Parameter	EPH	Product Identification	Naphthalene	Acenaphthylene	Acenaphthene	Fluorene	Phenanthrene	Anthracene	Fluoranthene	Pyrene	Benzo(a)anthracene	Chrysene	Benzo(b)+ Benzo(k)fluoranthene	Benzo(a)pyrene	Indeno(123cd)pyrene	Dibenzo(ah)anthracene	Benzo(ghi)perylene	Total 16 EPA PAHs
	Units	µg/l		µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
DUTCH CRITERIA	Dutch Intervention Levels	-		70	-	-	-	5	5	1	-	0.5	0.2	0.05	0.05	0.05	-	0.05	-
	Dutch Target Level	-		0.01	-	-	-	0.003	0.0007	0.003	-	0.0001	0.003	0.0004	0.0005	0.0004	-	0.0003	-
World Health Organisation Standard	Guideline Values	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SI No. 81 of 1988 - EC Regs (Quality of water intended for human consumption).	MACs	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SI No. 439 of 2000 - EC Drinking Water Regs.	Parametric Values	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EPA Guideline Values – From Interim Report on 'Towards Setting Guideline Values for the Protection of Groundwater in Ireland'.	Guideline Values (IGVs)	10		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EC Environmental Objectives (Groundwater Regulations) S.I. 9, 2010	Threshold Values	-	-	-	-	-	-	-	-	-	-	-	-	-	0.0075	-	-	-	-
	WA-BH02-01	**881**	-	<0.014	<0.013	<0.013	<0.014	<0.011	<0.013	<0.012	<0.13	<0.015	<0.011	<0.018	<0.016	<0.011	<0.01	<0.011	<0.195
	WA-LW01-01	<10	-	2.96	<0.013	0.10	0.06	0.06	<0.013	<0.012	<0.13	<0.015	<0.011	<0.018	<0.016	<0.011	<0.01	<0.011	3.18

Notes:

553	Values are underlined wherever Dutch-TV is exceeded
553	Values are shaded yellow and in bold wherever Dutch-IV, WHO Standards, SI No. 439 of 2000 Parametric Values, EPA Guideline Values or Groundwater Reg. Threshold Levels are exceeded
-	'-' signifies analysis not carried out on sample or no Dutch-IV, WHO Standards, SI No. 439 of 2000 Parametric Values, EPA Guideline Values or Groundwater Reg. Threshold Levels are available.

7 ENVIRONMENTAL SURFACE WATER RESULTS

A single surface water sample was collected at a stream located to the north of the site (see Figure 12) and was submitted for laboratory analysis. The laboratory suite was as follows:

Physico-chemical Parameters

- pH;
- Electrical Conductivity; and
- Dissolved Oxygen.

Inorganic Analysis

- Total Suspended Solids;
- Heavy Metals - As, Ba, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Sb, Se and Zn;
- Total suspended solids;
- Total alkalinity (as $CaCO_3$);
- Ammoniacal Nitrogen (as N);
- Total Oxidised Nitrogen (TON) as N;
- Chloride (Cl^-);
- Sulphate (SO_4^{2-});
- Ortho-Phosphate (PO_4);
- MR-Phosphate as P; and
- Total Cyanide.

Major Cations and Anions

- Potassium (K);
- Sodium (N);
- Calcium (Ca); and
- Magnesium (Mg).

Oxygen Demand/Organic Carbon

- Biological Oxygen Demand; and
- Chemical Oxygen Demand.

The following tables, Table 7 represent the results of the surface water analyses. These results are compared against the following Generic Assessment Criteria, statutory limits, Interim Guideline Values and Threshold Values. A detailed description of each of the following Generic Assessment Criteria is given in Section 3:

- 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.

7.1 Physicochemical Analysis

The pH of the surface water although slightly alkaline is within normal ranges (see Table 7). The electrical conductivity of the groundwater also appears to be within normal ranges for groundwater. The dissolved oxygen was 80% of maximum oxygen saturation. This is equivalent to its respective S.I. No. 272 Surface Water Threshold Value.

7.2 Total Alkalinity

The result obtained for Total alkalinity (as $CaCO_3$) was 271mg/l (see Table 7). This level would be regarded as normal for surface water originating in a limestone bedrock area.

7.3 Ammoniacal Nitrogen & Total Oxidised Nitrogen (TON)

The result obtained for the surface water sample for Ammoniacal Nitrogen was 3.05mg/l which exceeded respective S.I. No. 272 Surface Water Threshold Value (see Table 7). It is possible that the low level of ammonia detected within the groundwater is attributable to agricultural practices (i.e. landspreading, etc) upgradient of the site. However, it should be noted that groundwater discharging towards the northeast may be impacting on surface water quality.

7.4 Anions (Chloride (Cl^-), Sulphate (SO_4^{2-}) and Sulphide (S^{2-})

The results obtained for the surface water sample for chloride, Sulphate (SO_4^{2-}) and Sulphide (S^{2-}) were all lower than their respective Drinking Water MACs, Parametric or Threshold Values (see Table 7).

7.5 Ortho-Phosphate (PO_4), MR-Phosphate (as P) and Total Cyanide.

The result obtained for the surface water sample for Molybdate Reactive-phosphate was 0.173mg/l which exceeds its respective S.I. No. 272 Surface Water Threshold Value (see Table 7). It is possible that the low level of phosphates detected in the surface water are attributable to agricultural practices (i.e. landspreading, etc) upgradient of the site. However, it should also be noted that groundwater discharging towards the northeast may be impacting on surface water quality.

No cyanides were detected within the surface water sample taken on site.

7.6 Major Cations

The results obtained within the surface water sample for potassium ranged was 3.2mg/l which would be regarded as normal. This level was also reflected in the Potassium/Sodium ratio which was 0.33. A ratio greater than 0.4 generally would indicate an impact by domestic leachate (see Table 7).

The results obtained for potassium, sodium, calcium and magnesium were all less than their respective MAC Values quoted in S.I. No. 294, Parametric Values quoted in the S.I. No. 278

Table 7. Results of Laboratory Analyses on a Surface Water Sample (SW01) taken at Carrigeen Landfill

Parameter	Units	Statutory Limits			SURFACE WATER
		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*	
		MACs	*Parametric Values*	*Threshold Values*	SW01
Physico-Chemical Parameters					
pH	-	-	-	*6..0<pH<9..0*	8.39
Electrical cond. (EC)	µS/cm	-	*2500*	-	507
Dissolved oxygen (DO)	%	-	-	*80*	80
Standard Chemistry					
Total suspended solids	mg/l	*50*	-	-	47
Total alkalinity (as $CaCO_3$)	mg/l	-	-	-	271
Ammon. Nitrogen (as N)	mg/l	-	-	*0.09*	**3.05**
Ammonium	mg/l	-	*0.3*	-	**3.93**
Total Oxidised Nitrogen (TON) as N	mg/l	-	-	-	3.7
Chloride Cl^-	mg/l	-	*250*	-	15
Sulphate SO_4	mg/l	-	*250*	-	20.25
Sulphide S^{2-}	mg/l		-	-	<0.3
ortho-Phosphate PO_4	mg/l		-	-	**0.53**
MR-Phosphate as P	mg/l	-	-	*0.025*	**0.173**
Total Cyanide	mg/l	-	-	*10*	<40
Major Cations					
Potassium K	mg/l	-	-	-	3.2
Sodium Na	mg/l	-	-	-	9.6
Potassium K/Sodium Na Ratio		-	-	-	0.33
Calcium Ca	mg/l	-	-	-	122.3
Magnesium Mg	mg/l	-	-	-	5.8
Heavy Metals					
Arsenic	µg/l	-	-	*25*	<2.5
Boron	µg/l	-	*1000*	-	42
Cadmium Cd	µg/l	-	*5*	-	<0.5
Chromium Cr	µg/l	-	-	-	<1.5
Copper	µg/l	-	-	*30*	<7
Iron Fe	µg/l	-	*200*	-	160
Lead Pb	µg/l	-	-	*7.2*	<5
Nickel Ni	µg/l	-	-	*20*	2
Manganese Mn	µg/l	-	*50*	-	**146**
Mercury Hg	µg/l	-	-	-	<1
Zinc Zn	µg/l	-	-	-	6
Oxygen Demand/Organic Carbon					
BOD	mg/l	-	-	*1.3*	<1
COD	mg/l	-	-	*40*	20

Note:

450 Red Bold Font & Border indicates where SI No. 294 of 1989 MACs, SI No. 278 of 2007 Parametric Values, or S.I. No. 272 Surface Water Reg. Threshold Levels have been exceeded

** M.R.C = Minimum Required Concentration specified in the Drinking Water Regulations (S.I. No. 81 of 1988)

< = Less than

'-' signifies analysis not carried out on sample or no SI No. 81 of 1988 MACs, SI No. 439 of 2000 Parametric Values, EPA Guideline Values or S.I. No. 9 Groundwater Reg. Threshold Levels are available.

Drinking Water Regulations of 2007 and S.I. No. 272, European Communities Environmental Objectives (Surface Water) Regulations 2009 Threshold Values (see Table 7).

7.7 Oxygen Demand

Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) analyses were carried out on the surface water sample. For Biological Oxygen Demand (BOD) analysis, a value below the detection limit was obtained in SW01. For Chemical Oxygen Demand (COD) analysis, a value of 20µg/l was obtained in SW01 (see Table 7).

7.8 Heavy Metals

Of the 11 heavy metals analysed, the reported concentrations for all parameters are within their respective MAC Values quoted in S.I. No. 294, Parametric Values quoted in the S.I. No. 278 Drinking Water Regulations of 2007 and S.I. No. 272, European Communities Environmental Objectives (Surface Water) Regulations 2009 Threshold Values (see Table 7) with the exception of:

- *Manganese*

A value of 146µg/l was obtained for the surface water exceeding the corresponding Parametric Value quoted in the S.I. No. 278 Drinking Water Regulations of 2007 which is 50µg/l.

Like iron, these values would be expected as manganese is typically reduced to its more mobile Mn^{2+} species and released or leached from soil and bedrock into groundwater during anaerobic (i.e. reducing) conditions.

7.9 Summary of Surface Water Quality

An ion balance was carried on the results of the inorganic anion and cation analysis of the surface water. As can be seen from Table A3.2 (see Appendix 3), the ion balance for SW01 was 0.99%. For surface water, an ion balance error of up to 10 per cent is generally acceptable. The levels of ammonia, phosphates and manganese within the surface water in the stream to the northeast suggest that the stream may be receiving impacted contaminated groundwater rising into the stream through baseflow. However, it should be noted that this stream may also be impacted by surface water run-off from agriculture upgradient of the site.

8 GENERIC QUANTITATIVE RISK ASSESSMENT

In line with the scope of works provided by Kildare County Council, the soil, groundwater leachate and surface water results have been compared to Generic Acceptance Criteria (GAC) in Sections 5, 6 and 7. In assessing what poses the most risk to potential receptors only exceedances of soil and groundwater GACs are used.

For soils, although the assessment of contaminants in CEN 10:1 leachate is useful, as an indicator of potential long-term leachability, 'Total Pollutant' content provides the most relevant data for risk assessment to potential receptors.

For groundwater risk assessment, although the assessment of contaminants in leachate is useful, actual groundwater contaminant concentrations provide the most relevant data for risk assessment to potential receptors.

The exceedances of the above-mentioned GACs can be summarised as follows:

8.1 Soil

Of the 17 PAHs analysed only one PAH, Benzo(a)pyrene exceeds its respective LQM/CIEH GAC values for both *'Residential'* and *'Allotment'*. However, it should be noted that 3.1mg/kg would not be regarded as a gross exceedance of for *'Residential'* and *'Allotment'* GAC values which are 1mg/kg and 2.1mg/kg respectively.

8.2 Groundwater

Ammoniacal Nitrogen ranged from 1.92mg/l in BH02 to 18.08mg/l in BH01 (i.e. both downgradient boreholes).

The results obtained within the groundwater samples for chloride ranged from 31.2mg/l in BH01 to 30.2mg/l in BH02 (i.e. the downgradient boreholes).

The results obtained within the groundwater samples for Molybdate-Reactive phosphate (as P) ranged from 0.037mg/l in BH03 (i.e. the upgradient borehole) to 0.596mg/l in BH01 (i.e. the downgradient borehole).

The results obtained within the groundwater samples for potassium was 20.7mg/l in BH01 (i.e. the downgradient borehole).

Of the heavy metals analysed, for arsenic a values of 11.5µg/l was obtained in BH01. For manganese, values of 1,228µg/l, 345µg/l and 266µg/l were obtained in BH01, BH02 and BH03, respectively. For iron, a value of 1,124µg/l was obtained in BH01.

Diesel Range Organics were detected at 881mg/l in the groundwater sample taken from BH02. It should be noted however, that no concentration of Total Aliphatics (i.e. Mineral Oil Fraction) was given in the raw laboratory data. In addition, no 'Product Identification' was provided by the laboratory. As such, no conclusion can be drawn on the contamination identified in BH03, as the laboratory technique has an affinity to detect humic acids and other non-petroleum compounds and report them as Diesel Range Organics.

Although, most of the afore-mentioned exceedances of GACs would not be classed as gross exceedances, given the proximity of residences to the site and the existence of a controlled water body approximately 110m to the east of the site, it was concluded that a DQRA would be carried out on those contaminants that were found to exceed their respective GACs.

9 DETAILED QUANTITATIVE RISK ASSESSMENT

9.1 Refined Conceptual Model

Due to the exceedance of the generic assessment criteria for groundwater, a refined conceptual model for the site has been collated in line with BS10175 (5) and CLR11 (6). The site conceptual model (SCM) identifies sources of contamination, receptors that could be impacted together with pathways, termed potentially complete pollutant linkages that connect the two. When a potentially complete pollutant linkage is identified, an estimation of the risk should be made which may involve further investigation or risk assessment.

The scope of the site specific risk assessment has been extended to include the adjacent surface water body, the River Liffey which is located 110m to the east of the site. Therefore, the complete pollutant linkages and site data for both sites have been considered.

9.1.1 DQRA of Soil

The data presented in Section 8 indicates that the concentrations of Benzo(a)pyrene in soil may indicate potentially unacceptable risks to human health from dermal contact or ingestion routes. This soil sample was taken from a composite sample from 0.8m below ground level to 4.5m bgl. Potential pathways that could result in exposure of the receptor to the potential sources are direct contact, ingestion, dermal contact and inhalation of contaminated dust and soil. It should be noted that that although this pathway is unlikely given the presence of the overlying capping material, it is a useful exercise to confirm that no risk is posed to the existing residents in the residence to the west of the site.

9.1.2 DQRA of Groundwater

The data presented in Section 8 indicates that the concentrations of ammonia, potassium, Molybdate-Reactive phosphate, chloride and the heavy metals, arsenic, manganese and iron in groundwater may indicate potentially unacceptable risks to the controlled water (i.e. the River Liffey) via baseflow from the underlying groundwater aquifer.

The data presented in Section 8 indicates that the concentrations of Diesel Range Organics which were detected at 881mg/l in the groundwater sample taken from BH02 may indicate potentially unacceptable risks to the controlled water (i.e. the River Liffey). However as stated previously, it should be noted however, that no concentration of Total Aliphatics (i.e. Mineral Oil Fraction) was given in the raw laboratory data. In addition, no 'Product Identification' was provided by the laboratory. As such, no conclusion can be drawn on the contamination identified in BH03, as the laboratory technique has an affinity to detect humic acids and other non-petroleum compounds and report them as Diesel Range Organics.

However, given the importance of insuring the continued quality of the River Liffey

Although the house to the southeast of the site is technically hydraulically downgradient the absence of volatile organic compounds within the groundwater would indicate that contaminated groundwater would not pose a vapour intrusion risk to that property. There are

no other viable receptors such as water abstraction boreholes identified in the immediate vicinity of the site and more importantly downgradient of the site.

Table 8 records the potential pollutant linkages that have been identified at the site. Justifications for the identification of a potential pollutant linkage together with the likelihood are also discussed in Table 8-1.

Table 8. Identification of Potentially Complete Pollutant Linkages

Source	Pathway	Receptor	Linkage?
PAH (Benzo(a) pyrene impacted soil)	Direct contact; ingestion, dermal contact and inhalation of dust and soils.	Residents of house to west of site	**Complete/Incomplete.** Site covered in 400mm capping, plausible pathway absent. Residents not expected to come into contact with underlying soil during routine activities. However, may encounter if vegetable gardening is initiated on east of site.
		Livestock (i.e. horses in western paddock)	**Incomplete.** Site covered in 400mm capping, plausible pathway absent. Residents not expected to come into contact with underlying soil during routine activities.
		Future construction workers	**Incomplete.** Construction workers may come into contact with site soil. However the use of suitable PPE and good hygiene measures should mitigate risks posed through this pathway.
	Leaching and subsequent migration	Groundwater in locally important aquifer	**Complete:** Pathway due to presence of permeable alluvial sands, silts & gravels underlying impacted materials in the vicinity of the site.
		Groundwater (shallow) body within superficial sand & gravel deposits	**Complete:** Pathway due to presence of permeable alluvial sands, silts & gravels underlying impacted materials in the vicinity of the site.
		River Liffey 110m to east of site	
		Boreholes within 1km site; closest 425m to the southeast of the site and to the east of the River Liffey	**Incomplete**. Plausible pathway absent due to distance and direction of groundwater flow.

Table 8. Identification of Potentially Complete Pollutant Linkages (continued)

Source	Pathway	Receptor	Linkage?
Ammonia, potassium, MRP, chloride arsenic, manganese & iron impacted groundwater	Direct contact; ingestion and dermal contact	Residents of house to southeast of site	**Incomplete.** Groundwater recorded at between 1.07m and 4.1m bgl, therefore plausible pathway absent.
		Livestock (i.e. horses in western paddock)	
		Future construction workers	**Incomplete.** Construction workers may come into contact with groundwater (i.e. during pipe laying). However the use of suitable PPE and good hygiene measures should mitigate risks posed through this pathway.
	Migration	Groundwater in locally important aquifer	**Complete:** Pathway present due to presence of permeable alluvial sands, silts & gravels underlying impacted materials
		Groundwater (shallow) body within superficial deposits	**Complete.** Contamination in site groundwater may migrate vertically and horizontally.
		River Liffey 110m to east of site	**Complete:** Pathway due to presence of permeable alluvial sands, silts & gravels underlying impacted materials in the vicinity of the site. Also short distance to stream.
		Boreholes within 1km of site; closest 425m to the southeast of the site and to the east of the River Liffey	**Incomplete**. Plausible pathway absent due to distance and direction of groundwater flow.
Potential vapours associated with TPH impacted groundwater	Vertical migration and inhalation of vapours	Residents of house to southeast of site	**Complete/Incomplete.** Level of VOCs/BTEX/MTBE not determined by laboratory analysis
		Livestock (i.e. horses in western paddock)	**Incomplete.** Livestock are unlikely to be impacted due to short duration on site.
		Future construction workers	**Incomplete**. Vapours likely to migrate vertically and then dilute with air at the surface hence plausible pathway considered absent.

Potentially complete pollutant linkages have been identified at the site with respect to:

- Ingestion of contaminated vegetables by PAH (Benzo(a) pyrene impacted soil) by residents of western residence;
- Leaching and subsequent migration of PAH (Benzo(a) pyrene) impacted soil) to underlying groundwater and subsequent baseflow to the River Liffey; and
- Migration of Ammonia, potassium, MRP, chloride arsenic, manganese & iron impacted groundwater to the River Liffey.

The receptors with which a potentially complete pollutant linkage were identified include residents and groundwater (shallow) in the superficial deposits and underlying aquifer and adjacent River Liffey.

A Schematic Site Conceptual Model illustrating the potentially complete pollutant linkages is included in Figure 13. Future risks to construction workers will be task specific and can be managed with appropriate health and safety protocols thus are not considered further in this report.

9.2 Detailed Quantitative Risk Assessment

As a result of the previous GQRA, a Detailed Quantitative Risk Assessment (DQRA) has been carried out using the Risk-Based Corrective Action(7) (RBCA) model to assess risks to human health and to assess risks to Controlled Waters.

9.2.1 Human Health

The following complete pollutant linkages required additional detailed assessment using the RBCA model:

- Ingestion of contaminated vegetables by PAH (Benzo(a) pyrene impacted soil) by residents of western residence.

Risk Based Corrective Action (7) (RBCA) was used to confirm the risks to human health (residents) via ingestion of contaminated vegetables. It should be noted that the current residence does not carry out vegetable gardening on site and that a 400mm capping layer is present on the eastern side of the residence property. However, given the confirmed presence of Benzo(a) pyrene from soil taken from 0.8m to 4.5m at TP5, it was concluded that it would be prudent to apply the 'precautionary principle' when assessing its risk to the adjacent residents.

The input parameters used in RBCA(7) were altered to reflect those at the site, data given in CLR10(9) and Environment Agency Briefing Notes 2 and 3(10,11). The determinant parameters such as solubility, Henry's Law and diffusion co-efficients were altered to reflect those of P5-079/TR1(12). The Henry's Law Constants were altered to reflect 10 degrees Celsius in line with Environment Agency Briefing Note 2(10).

The input parameters for the residents are recorded and justified in Table A5.1 and A5.2 of Appendix 5. The outputs sheets from the RBCA model are also presented in Appendix 5 with Site Specific Target Levels (SSTLs) presented in Tables A5.6 and A5.7 and summarised in Table 9 below.

9.2.2 Controlled Waters

The potential for contaminants within site groundwater to migrate off-site has been assessed in this section. Risks to Controlled Waters have also been assessed using Risk Based Corrective Action (7) (RBCA).

The following complete pollutant linkages required additional detailed assessment:

- Migration of arsenic, manganese and ammonia impacted groundwater to the River Liffey 110m to the east of the site.

The site investigations indicate that the site is underlain by waste which lies either directly on bedrock or is underlain by layers of alluvial sands, gravels and silts. There is an absence of information on the depth to bedrock and the depth of the overburden underlying the site. The geological records for the area indicate that the underlying geology is Dinantian Pure Un-bedded Limestone (DPUL) (i.e. Waulsortian Mudbank Limestone Formation (WA)). This is classed as a *Locally Important Aquifer - Bedrock which is Moderately Productive only in Local Zones.*

The input parameters used in the modelling are included in Table A5.4 in Appendix 5. The determinants modelled were arsenic, manganese and ammonia. These determinands were selected on the basis of their exceedances of their respective GACs for the groundwater sample collected from the BH01 and/or BH02. The outputs sheets from the RBCA model are also presented in Appendix 5 with Site Specific Target Levels (SSTLs) presented in Table A5.8 and summarised in Table 9 below.

Table 9. Summary of Site Specific Target Levels (SSTLs) for Soil, Subsoil and Groundwater

DETERMINAND	CONC. (mg/kg)	CONC. (mg/l)	SOIL SSTL (0.4-0.5)	SUBSOIL SSTL (0.5-1.1)	GROUNDWATER SSTL	EXCEEDANCE
Benzo(a)pyrene	3.1	<0.016	$4.5 * 10^{1}$	9.9	$1.6 * 10^{-3}$	No
Ammonia	ND	18.1	$1.0 * 10^{6}$	$1.5 * 10^{4}$	$3.0 * 10^{2}$	No
Manganese	ND	1.12	$1.0 * 10^{6}$	$1.0 * 10^{6}$	$1.0 * 10^{6}$	No
Arsenic	ND	0.0115	$1.9 * 10^{1}$	$4.8 * 10^{5}$	$1.0 * 10^{6}$	No

Note: ND signifies 'Not Determined' by laboratory analysis

10 CONCLUSIONS

10.1 Soil & Groundwater Contamination

The results of the laboratory analysis on the soil, groundwater and leachate indicate that the soil and groundwater in the vicinity of the site and downgradient have been historically contaminated by the waste infilling.

Low to moderate levels of a Polyaromatic Hydrocarbon, Benzo(a)pyrene were indentified at various depths in the soil on site.

Elevated levels of ammonia, arsenic, manganese, potassium and chloride were indentified in the groundwater monitoring wells. These levels were identified at greater levels in the on-site leachate wells as expected. The highest level of contamination was identified in BH01, the downgradient borehole in the northeast.

It is the opinion of Mulroy Environmental that the petroleum analysis carried out on the soil and groundwater was inconclusive and that the method used was incorrect. As such, little information can be drawn from the petroleum analysis carried out on the soil and groundwater and data could not be used to determine Site Specific Target Levels (SSTLs).

The evidence suggests strongly that a contaminant plume exists on site which is emanating in a southwest to northeast direction towards the River Liffey.

10.2 Impact on Human Receptors

The soil contamination identified on site is unlikely to impact on the residences to the west and east. However, given the proximity of the 'Western Residence' on the edge of the waste body, it is possible that residents could be impacted if vegetable gardening or substantial ground movement works were carried out on the eastern boundary of the residence. This impact would be through dermal contact and/or ingestion of contaminated vegetables by residents or dermal contact by construction workers during earth moving or handling exercises.

10.3 Impact on Controlled Waters (i.e. River Liffey)

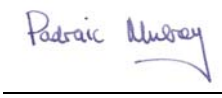
The results of the DQRA suggest that contaminated groundwater originating from the site may be discharging to the River Liffey by baseflow. However, the results of the DQRA indicated that no exceedances were identified of Site Specific Target Levels for the Controlled Water (i.e. the River Liffey). It is likely that this contamination is being considerably diluted within the aquifer prior to it reaching the edge of the river and then subsequently by the flow within the river which is substantial.

11 RECOMMENDATIONS

The following works are recommended:

- On-going on-site groundwater and leachate monitoring is continued;
- Groundwater and leachate samples are analysed for Total Petroleum Hydrocarbons – Core Working Group (CWG) laboratory suite. The purpose of this is assess any risk posed by volatile organic compounds (i.e. BTEX/MTBE, GRO, etc) via vapour intrusion to the residence located to the southeast of the site;
- Improvement of capping in the 'Eastern Paddock' to reduce further leachate generation from the site; and
- Monitoring of the River Liffey at upgradient and downgradient points of the site during periods of low flow (i.e. July-August). The purpose of this is to determine if groundwater contaminants are reaching and discharging to the river at levels which would be a risk to downgradient receptors. This sampling would entail surface water samples being taken adjacent to the western bank of the river and surface water samples being taken mid-stream (i.e. by motor launch). A comprehensive laboratory suite based on that already used for groundwater on site. However, it is recommended that trace organic analysis (e.g. Volatile Organic Compound, Semi-volatile Organic Compound, TPH-CWG, etc) is also carried out on the groundwater.

If you have any questions or require clarification with regard to any item of this report, please contact me at 086-8770380.



Padraic Mulroy, BSc., MSc., IRCA, MIEI, MIPSS, C.Sci., SiLC
Managing Director
Mulroy Environmental

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MULROY ENVIRONMENTAL
SERVICE CONSTRAINTS

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 Kildare County Council (the "client") in accordance with the terms of a contract between Mulroy Environmental and the "client" dated 22nd November 2011. 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.

3. Unless otherwise agreed the Services were performed by Mulroy Environmental exclusively for the purposes of the client. Mulroy Environmental is not aware of any interest of or reliance by any party other than the client in or on the Services. Unless expressly provided in writing, Mulroy Environmental does not authorise, consent or condone any party other than the client relying upon the Services. Should this report or any part of this report, or otherwise details of the Services or any part of the Services be made known to any such party, and such party relies thereon that party does so wholly at its own and sole risk and Mulroy Environmental disclaims any liability to such parties. Any such party would be well advised to seek independent advice from a competent environmental consultant and/or lawyer.

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.

5. The passage of time may result in changes in site conditions, regulatory or other legal provisions, technology or economic conditions which could render the report inaccurate or unreliable. The information and conclusions contained in this report should not be relied upon in the future without the written advice of Mulroy Environmental. In the absence of such written advice of Mulroy Environmental, reliance on the report in the future shall be at the client's own and sole risk. Should Mulroy Environmental be requested to review the report in the future, Mulroy Environmental shall be entitled to additional payment at the then existing rate or such other terms as may be agreed between Mulroy Environmental and the client.

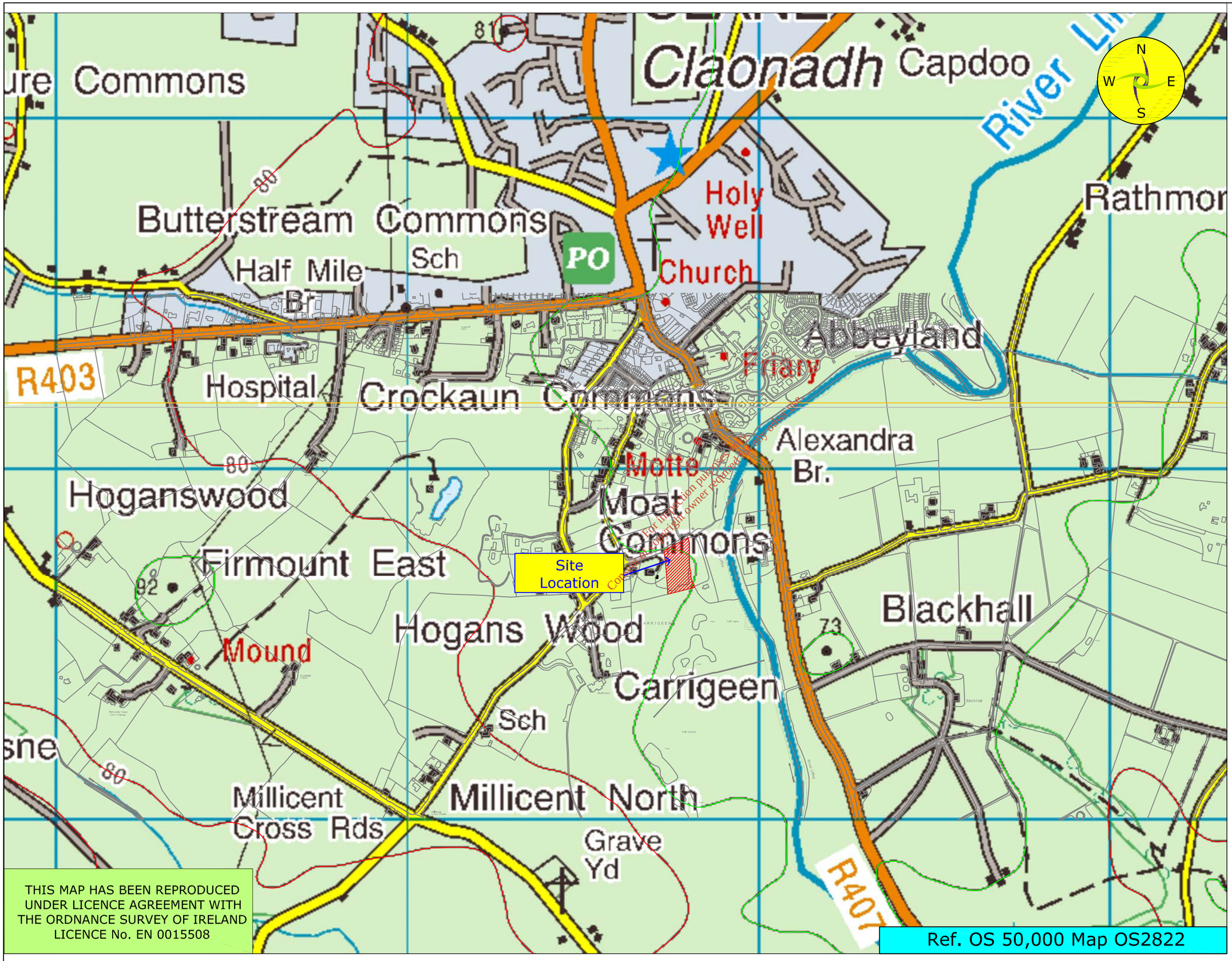
6. The observations and conclusions described in this report are based solely upon the Services which were provided pursuant to the agreement between the client and Mulroy Environmental. Mulroy

Environmental has not performed any observations, investigations, studies or testing not specifically set out or required by the contract between the client and Mulroy Environmental. Mulroy Environmental is not liable for the existence of any condition, the discovery of which would require performance of services not otherwise contained in the Services. For the avoidance of doubt, unless otherwise expressly referred to in the introduction to this report, Mulroy Environmental did not seek to evaluate the presence on or off the site of asbestos, electromagnetic fields, lead paint, heavy metals, radon gas or other radioactive or hazardous materials.

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.



THIS MAP HAS BEEN REPRODUCED UNDER LICENCE AGREEMENT WITH THE ORDNANCE SURVEY OF IRELAND LICENCE No. EN 0015508

Ref. OS 50,000 Map OS2822

LEGEND

SITE BOUNDARY

NOTES

1. FIGURED DIMENSIONS ONLY TO BE TAKEN FROM THIS DRAWING

2. ALL LEVELS SHOWN RELATE TO ORDNANCE SURVEY DATUM AT MALIN HEAD

Issue	Date	Description	By	Chkd.

Client: Kildare C.C

Project: Tier 3 Detailed Quantitative Risk Assessment (DQRA) of Former Landfill Site at Carrigeen, Clane, Co. Kildare

Title: Site Location

Scale: 1:10,000@A3

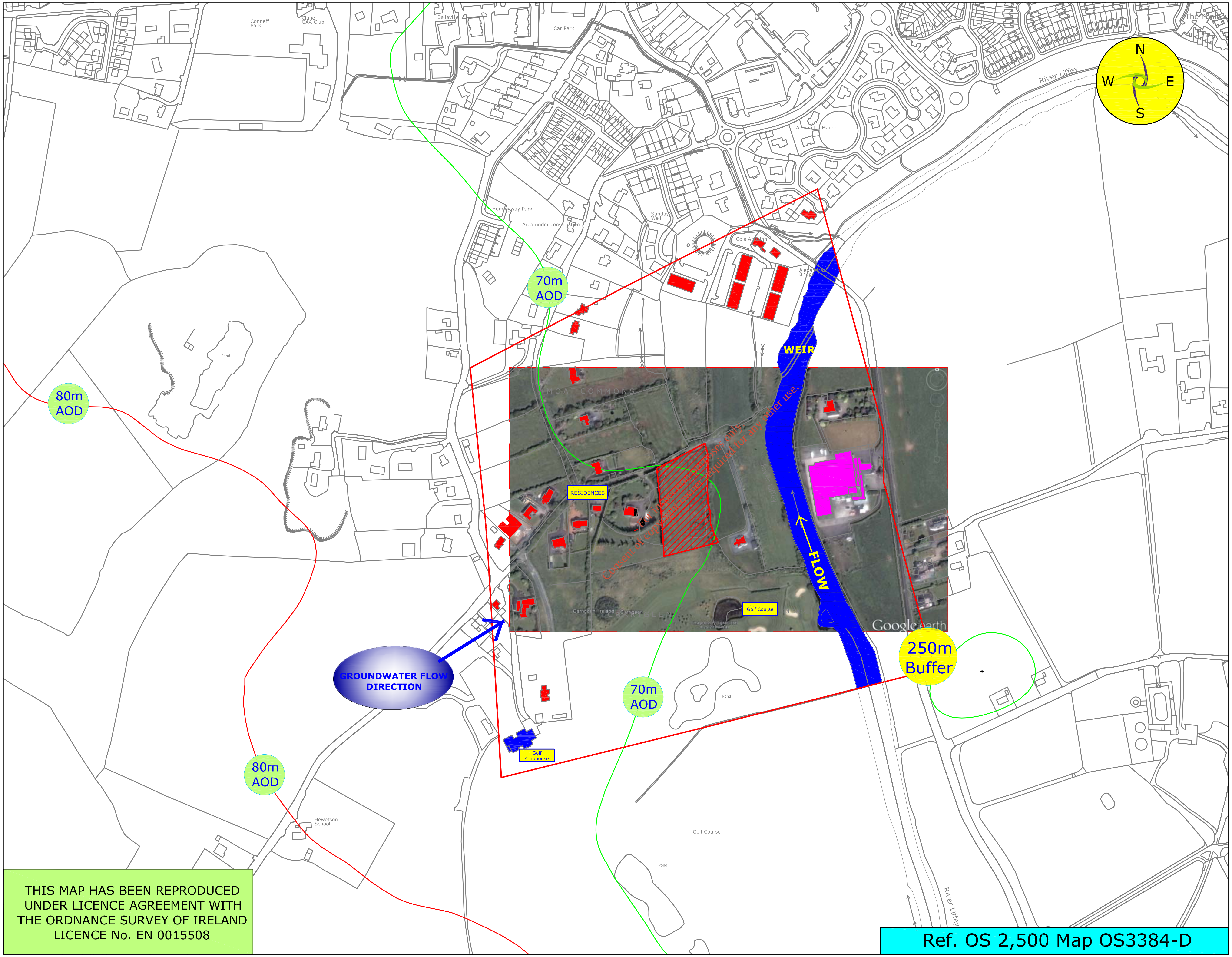
Prepared by:	Checked:	Date:
D.F	P.M.	26-03-12

Project Director: P.MULROY

MULROY environmental

Drawing No.: Figure 1

Issue: 0



LEGEND

- SITE BOUNDARY
- RESIDENCE
- INDUSTRIAL
- AGRICULTURAL
- SURFACE WATER FEATURE
- 250M BUFFER
- COMMERCIAL
- CONTOUR

NOTES

1. FIGURED DIMENSIONS ONLY TO BE TAKEN FROM THIS DRAWING
2. ALL LEVELS SHOWN RELATE TO ORDNANCE SURVEY DATUM AT MALIN HEAD

Issue	Date	Description	By	Chkd.

Client: Kildare C.C

Project: Tier 3 Detailed Quantitative Risk Assessment (DQRA) of Former Landfill Site at Carrigeen, Clane, Co Kildare

Title: Site Location

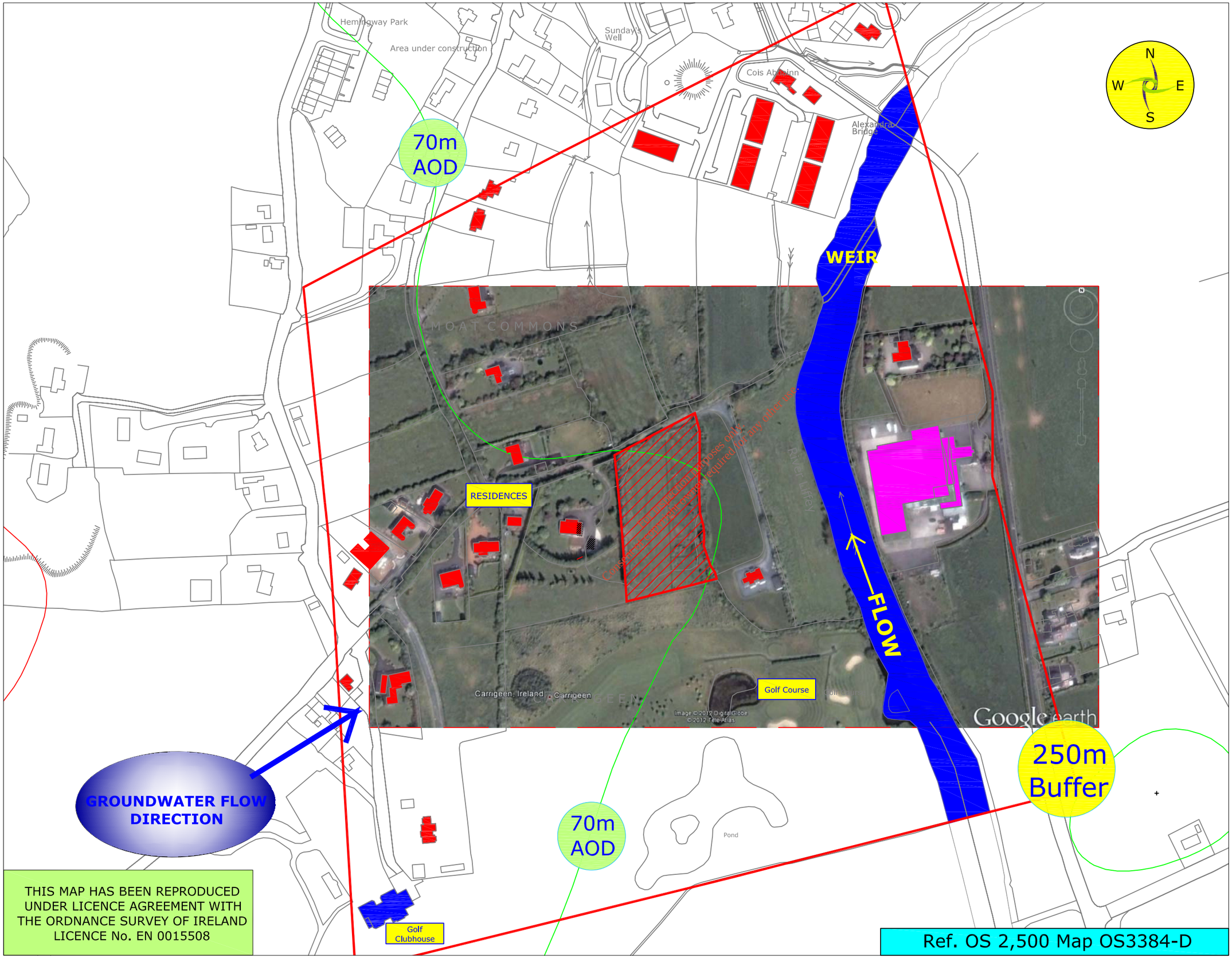
Scale: 1:5,000@A3

Prepared by: D.F | Checked: P.M. | Date: 02-02-12

Project Director: P.MULROY

MULROY environmental

Drawing No.: Figure 2 | Issue: 0



LEGEND

- SITE BOUNDARY
- RESIDENCES
- COMMERCIAL
- INDUSTRIAL
- AGRICULTURAL
- 250M BUFFER
- OS CONTOUR (70m AOD)
- SURFACE WATER FEATURE

NOTES

1. FIGURED DIMENSIONS ONLY TO BE TAKEN FROM THIS DRAWING
2. ALL LEVELS SHOWN RELATE TO ORDNANCE SURVEY DATUM AT MALIN HEAD

Issue	Date	Description	By	Chkd.

Client: Kildare C.C

Project: Tier 3 Detailed Quantitative Risk Assesment (DORA) of Former Landfill Site at Carrigeen, Clane, Co. Kildare

Title: Site Location

Scale: 1:3,000@A3

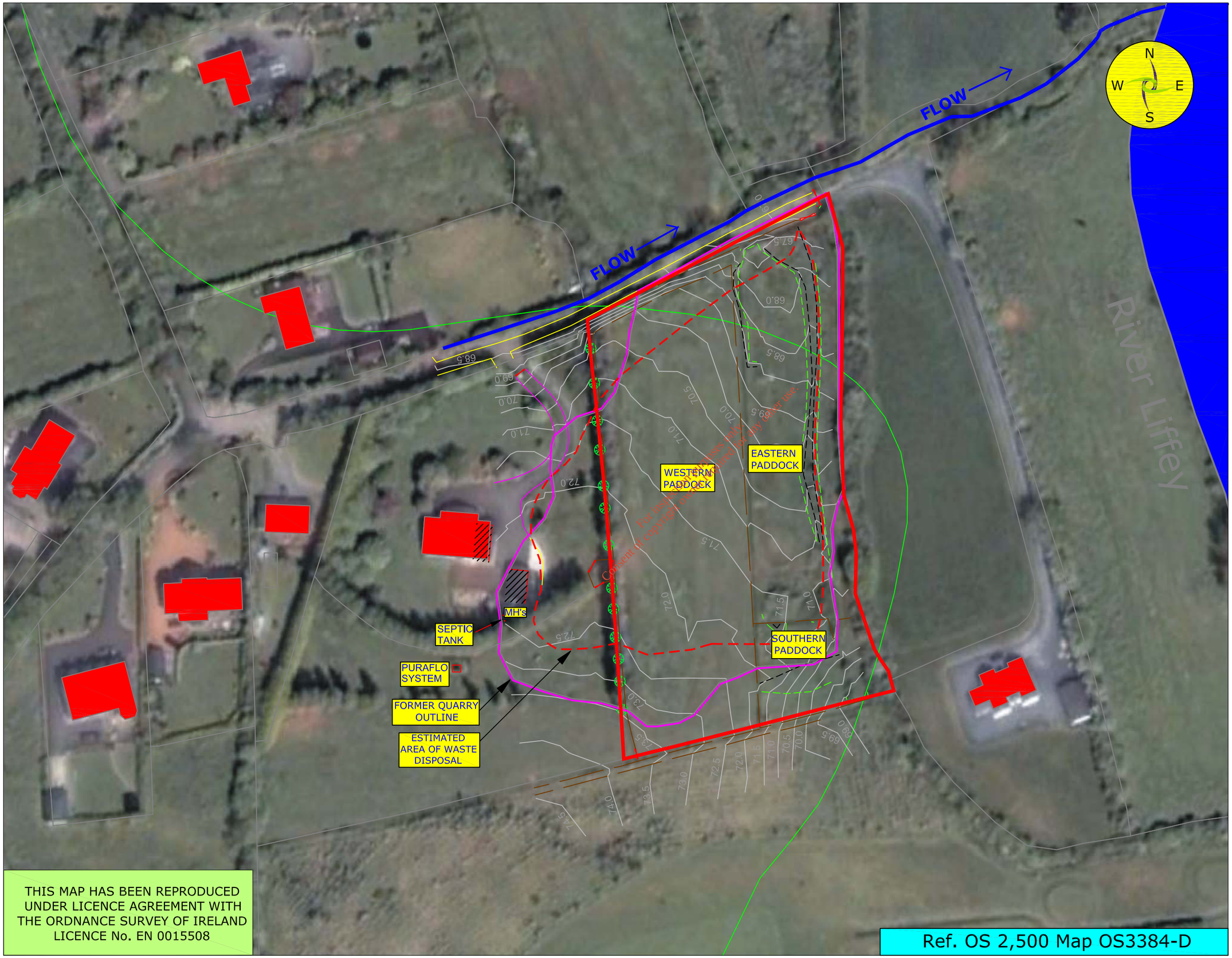
Prepared by:	Checked:	Date:
D.F	P.M.	02-02-12

Project Director: P.MULROY

MULROY environmental

Drawing No.: Figure 3

Issue: 0



LEGEND

- SITE BOUNDARY
- RESIDENCES
- COMMERCIAL
- FORMER QUARRY OUTLINE
- ESTIMATED AREA OF WASTE DISPOSAL
- SITE FENCING
- SURFACE WATER FEATURE

NOTES

1. FIGURED DIMENSIONS ONLY TO BE TAKEN FROM THIS DRAWING
2. ALL LEVELS SHOWN RELATE TO ORDNANCE SURVEY DATUM AT MALIN HEAD

Issue	Date	Description	By	Chkd.

Client: Kildare C.C

Project: Tier 3 Detailed Quantitative Risk Assesment (DORA) of Former Landfill Site at Carrigeen, Clane, Co. Kildare

Title: Existing Site Layout

Scale: 1:1,000@A3

Prepared by:	Checked:	Date:
D.F	P.M.	02-02-12

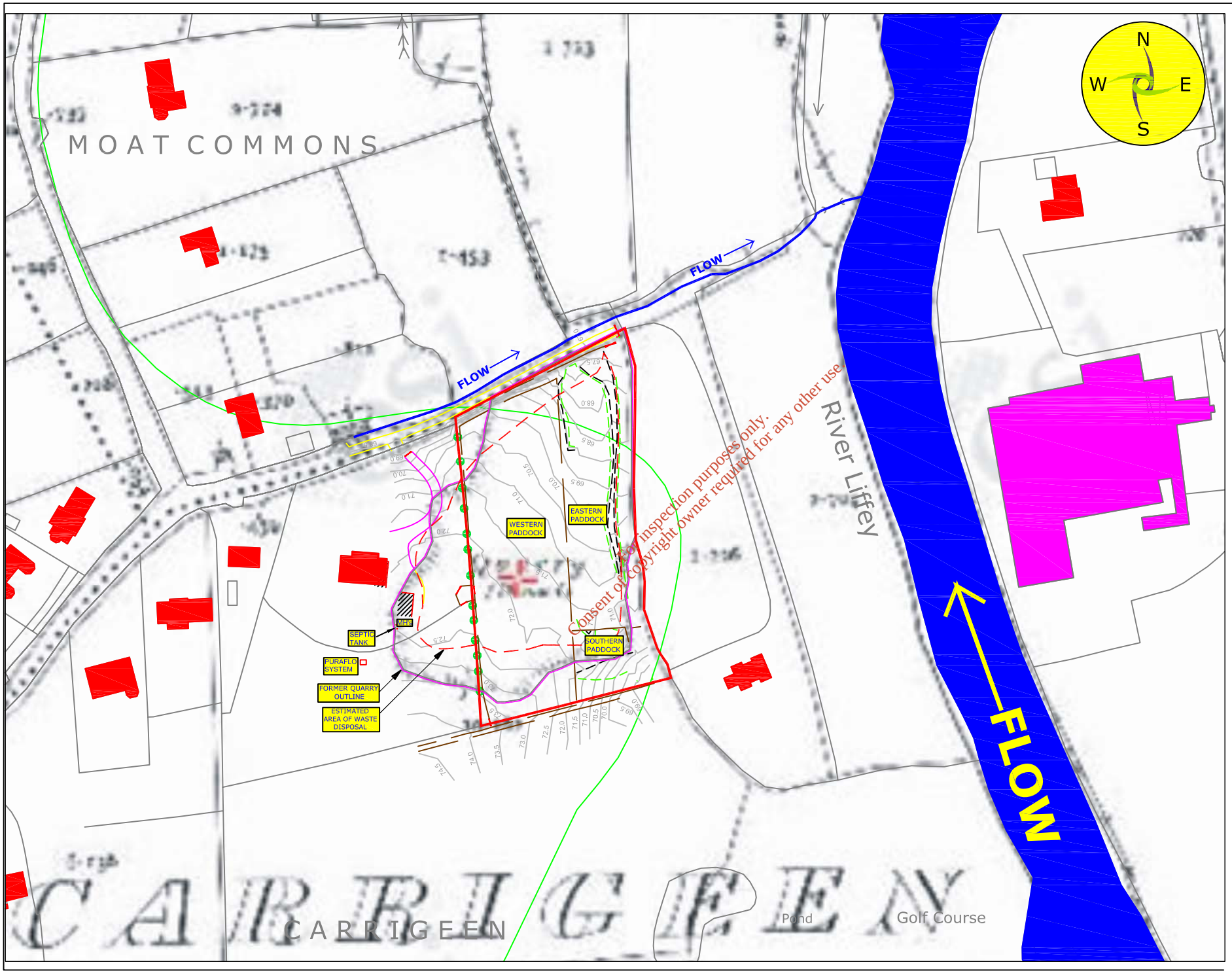
Project Director: P.MULROY

MULROY environmental

Drawing No.: Figure 4

Issue: 0

Ref. OS 2,500 Map OS3384-D



LEGEND

- SITE BOUNDARY
- RESIDENCE
- INDUSTRIAL
- FORMER QUARRY OUTLINE
- ESTIMATED AREA OF WASTE DISPOSAL

NOTES

1. FIGURED DIMENSIONS ONLY TO BE TAKEN FROM THIS DRAWING
2. ALL LEVELS SHOWN RELATE TO ORDNANCE SURVEY DATUM AT MALIN HEAD

Issue	Date	Description	By	Chkd.

Client: Kildare C.C.

Project: Tier 3 Detailed Quantitative Risk Assessment (DORA) of Former Landfill Site at Carrigeen, Clane, Co.Kildare,

Title: Historical 25" map Quarry Boundary line.

Scale: 1:2000@A4

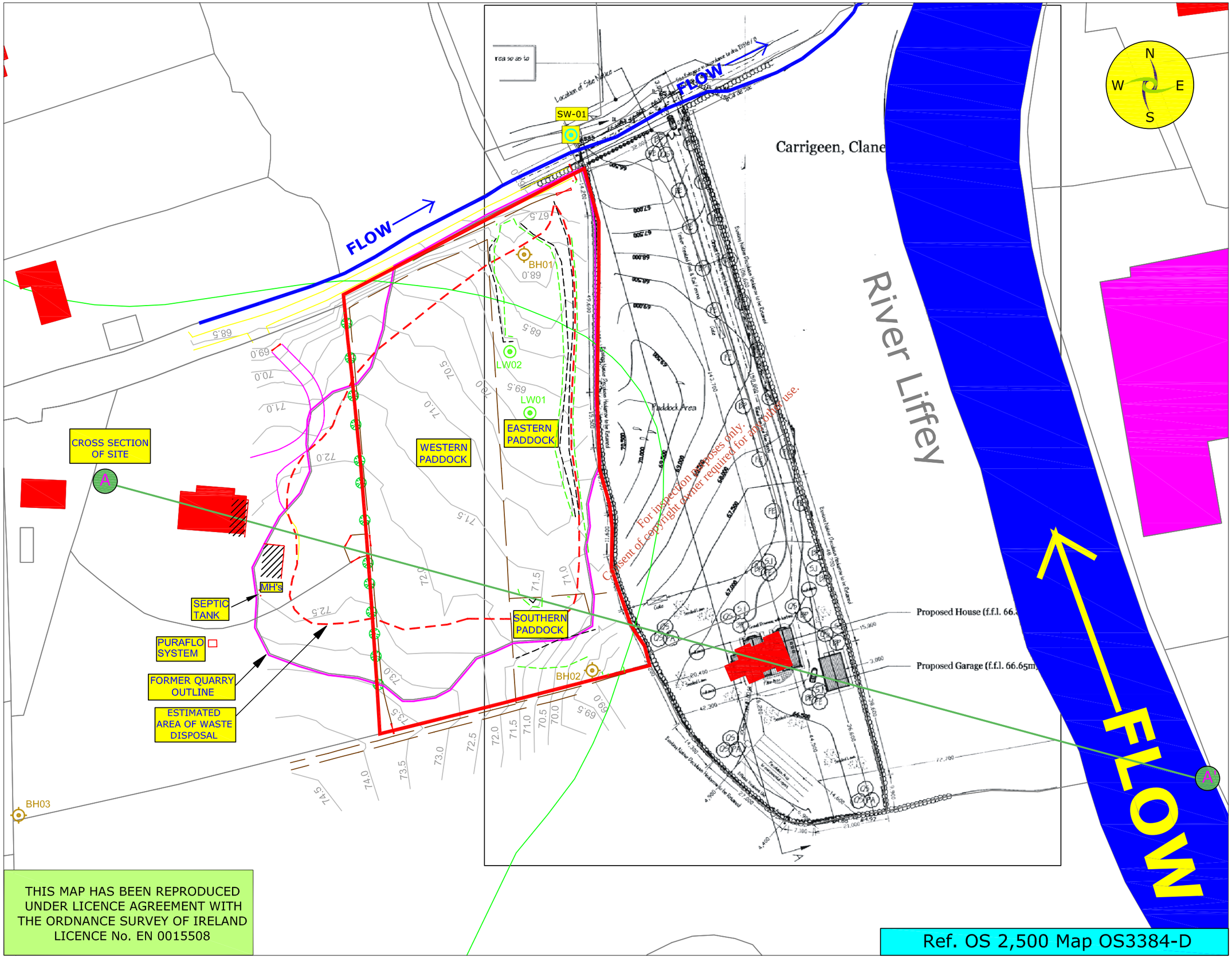
Prepared by:	Checked:	Date:
D.F.	P.M.	08-03-12

Project Director: P.MULROY

MULROY environmental

Drawing No.: Figure 5

Issue: 0



LEGEND

- SITE BOUNDARY
- RESIDENCES
- SURFACE WATER FEATURE
- CROSS SECTION LOCATION
- LEACHATE MONITORING LOCATION (LW02)
- SURFACE WATER MONITOING LOCATION
- GROUNDWATER MONITORING LOCATION (BH03)

NOTES

1. FIGURED DIMENSIONS ONLY TO BE TAKEN FROM THIS DRAWING
2. ALL LEVELS SHOWN RELATE TO ORDNANCE SURVEY DATUM AT MALIN HEAD

Issue	Date	Description	By	Chkd.

Client: Kildare C.C

Project: Tier 3 Detailed Quantitative Risk Assesment (DQRA) of Former Landfill Site at Carrigeen, Clane, Co.Kildare

Title: Topography of Site

Scale: 1:1,100@A3

Prepared by:	Checked:	Date:
D.F	P.M.	02-02-12

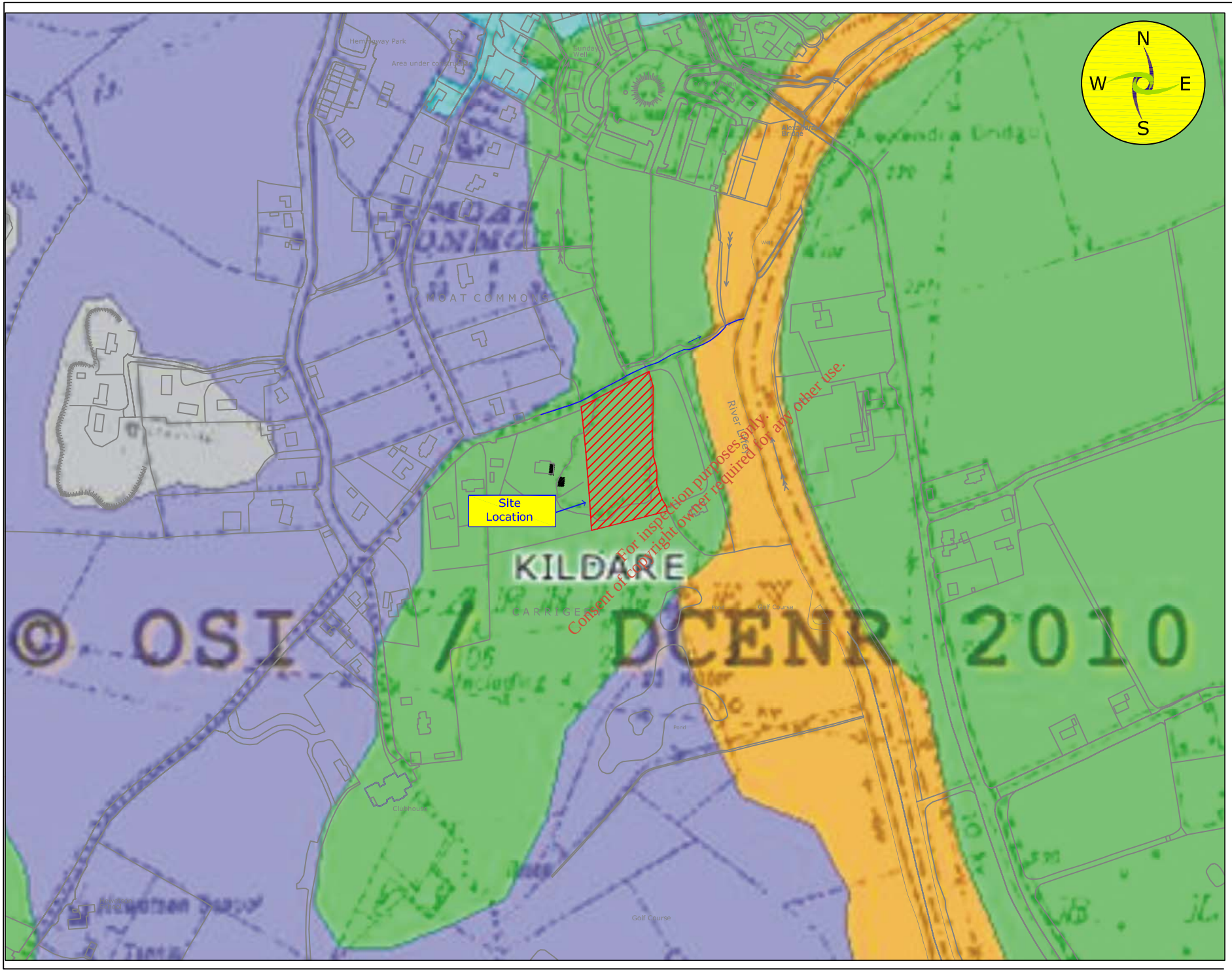
Project Director: P.MULROY

MULROY environmental

Drawing No.: Figure 6

Issue: 0

Ref. OS 2,500 Map OS3384-D



LEGEND

- SITE BOUNDARY
- GLS-GLACIOFLUVIAL SANDS AND GRAVELS
- TLS-TILL DERIVED CHIEFLY FROM LIMESTONE
- A-ALLUVIUM
- RCK-BEDROCK OUTCROP AND SUBCROP
- MADE- MADE GROUND

NOTES

1. FIGURED DIMENSIONS ONLY TO BE TAKEN FROM THIS DRAWING

2. ALL LEVELS SHOWN RELATE TO ORDNANCE SURVEY DATUM AT MALIN HEAD

Issue	Date	Description	By	Chkd.

Client: Kildare C.C.

Project: Tier 3 Detailed Quantitative Risk Assessment (DORA) of Former Landfill Site at, Carrigeen, Clane, Co. Kildare

Title: Subsoil Map

Scale: 1:5,000@A4

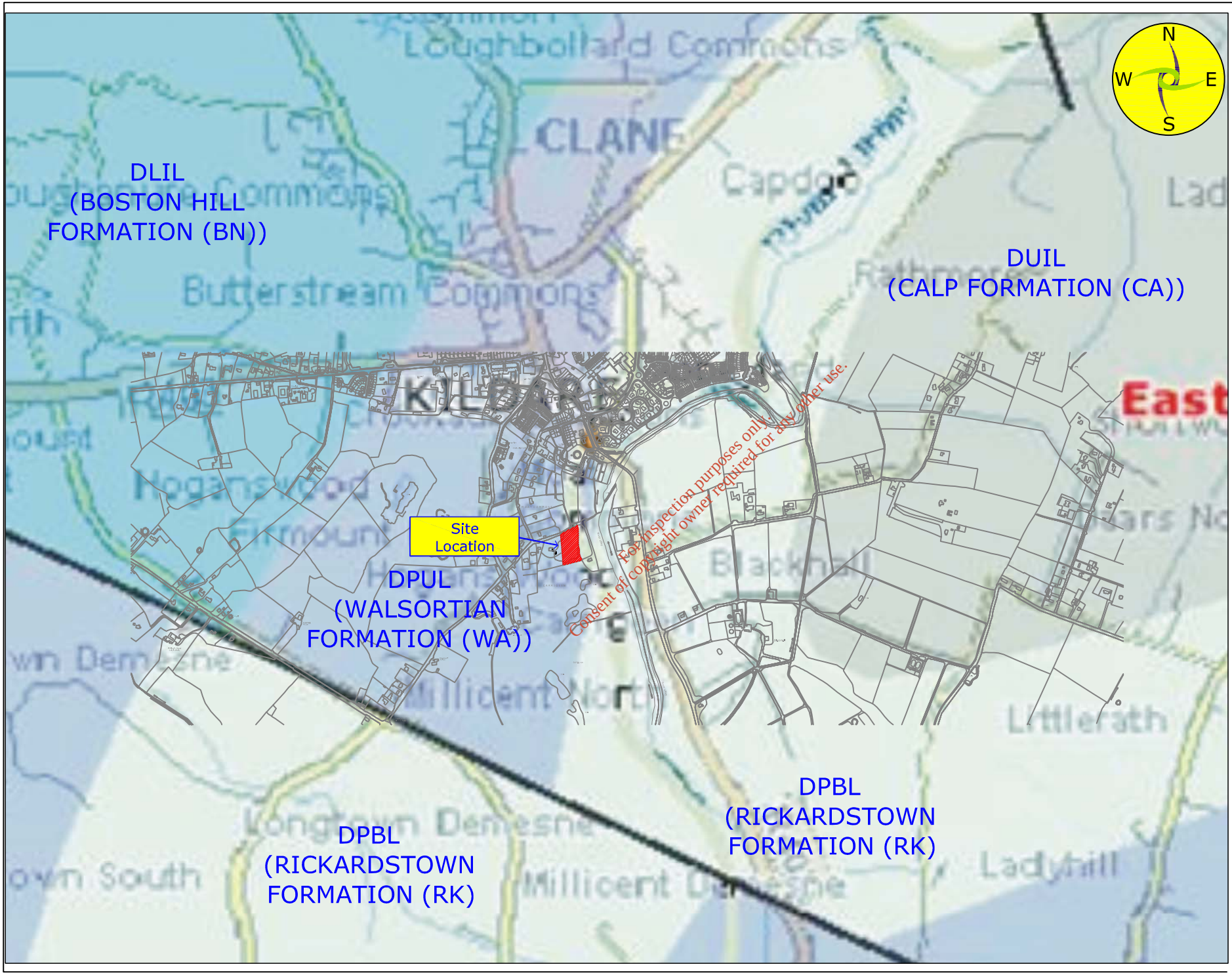
Prepared by:	Checked:	Date:
D.F.	P.M.	31-01-12

Project Director: P.MULROY

MULROY environmental

Drawing No.: Figure 7

Issue: 0



LEGEND

- SITE BOUNDARY
- DPUL-DINANTIAN PURE UNBEDDED LIMESTONES (WALSORTIAN FORMATION)
- DPBL-DINANTIAN PURE BEDDED LIMESTONES (RICKARDSTOWN FORMATION)
- DLIL-DINANTIAN LOWER IMPURE LIMESTONES (BOSTON HILL FORMATION)
- DUIL-DINANTIAN UPPER IMPURE LIMESTONES (CALP FORMATION)

NOTES

1. FIGURED DIMENSIONS ONLY TO BE TAKEN FROM THIS DRAWING

2. ALL LEVELS SHOWN RELATE TO ORDNANCE SURVEY DATUM AT MALIN HEAD

Issue	Date	Description	By	Chkd.

Client: Kildare C.C.

Project: Tier 3 Detailed Quantitative Risk Assessment (DORA) of Former Landfill Site at Carrigeen, Clane, Co.Kildare

Title: Bedrock Map

Scale: 1:20,000@A4

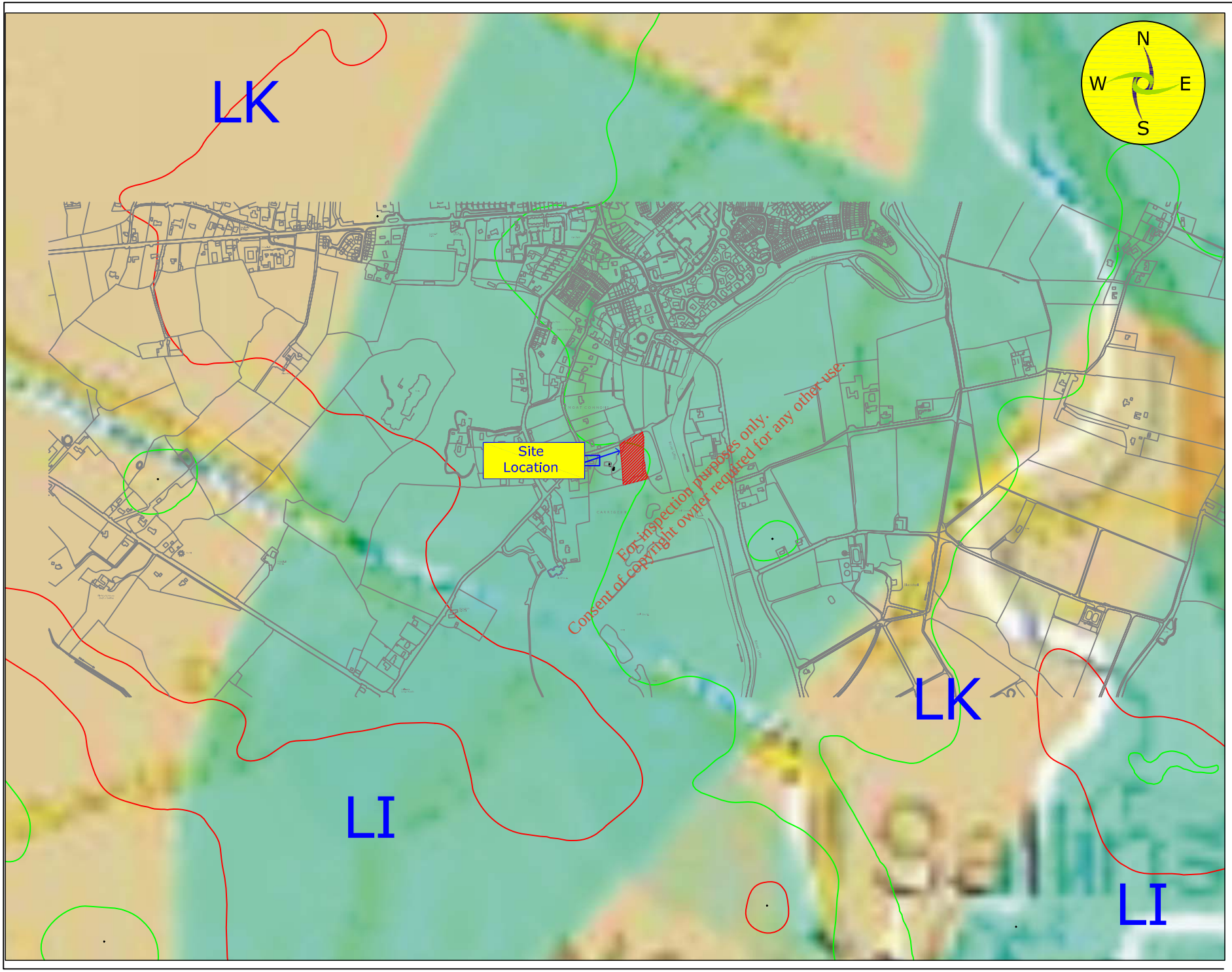
Prepared by:	Checked:	Date:
D.F.	P.M.	31-01-12

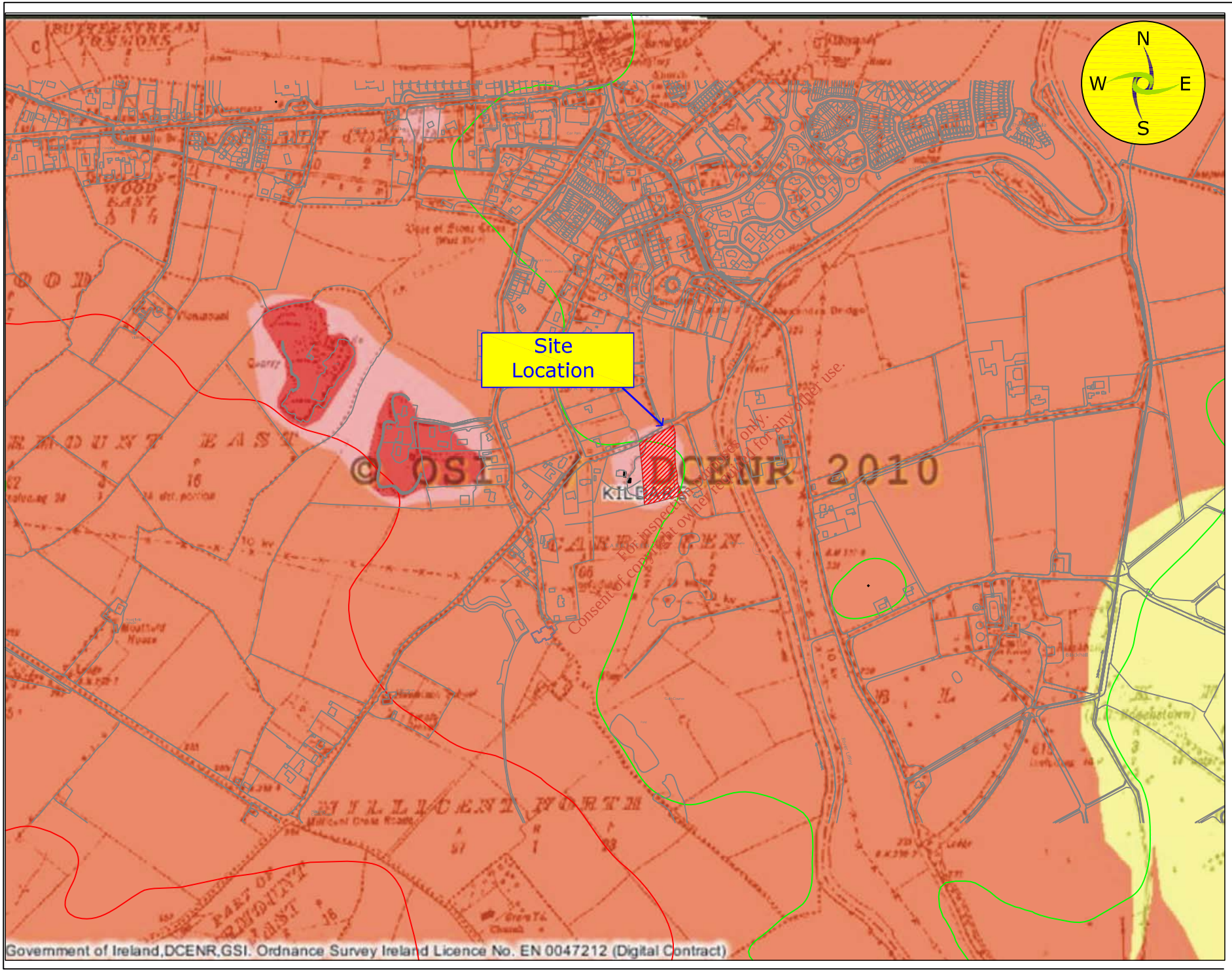
Project Director: P.MULROY

MULROY environmental

Drawing No.: Figure 8

Issue: 0





LEGEND

- SITE BOUNDARY
- X-(Rock near Surface or Karst)
- E-Extream
- H-High
- M-Moderate
- L-Low

NOTES

1. FIGURED DIMENSIONS ONLY TO BE TAKEN FROM THIS DRAWING

2. ALL LEVELS SHOWN RELATE TO ORDNANCE SURVEY DATUM AT MALIN HEAD

Issue	Date	Description	By	Chkd.

Client: Kildare C.C.

Project: Tier 3 Detailed Quantitative Risk Assessment (DQRA) of Former Landfill Site at Carrigeen, Clane, Co.Kildare

Title: Vulnerability Map

Scale: 1:10,000@A4

Prepared by:	Checked:	Date:
D.F.	P.M.	31-01-12

Project Director: P.MULROY

MULROY environmental

Drawing No.: Figure 10

Issue: 0

LEGEND

- SITE BOUNDARY
- Well accuracy within 10m to 50m
- Well accuracy within 1Km

NOTES

1. FIGURED DIMENSIONS ONLY TO BE TAKEN FROM THIS DRAWING
2. ALL LEVELS SHOWN RELATE TO ORDNANCE SURVEY DATUM AT MALIN HEAD

Issue	Date	Description	By	Chkd.

Client: Kildare C.C.

Project: Tier 3 Detailed Quantitative Risk Assessment (DQRA) of Former Landfill Site at Carrideen, Clane, Co.Kildare

Title: Adjacent Borewell Map

Scale: 1:20,000@A3

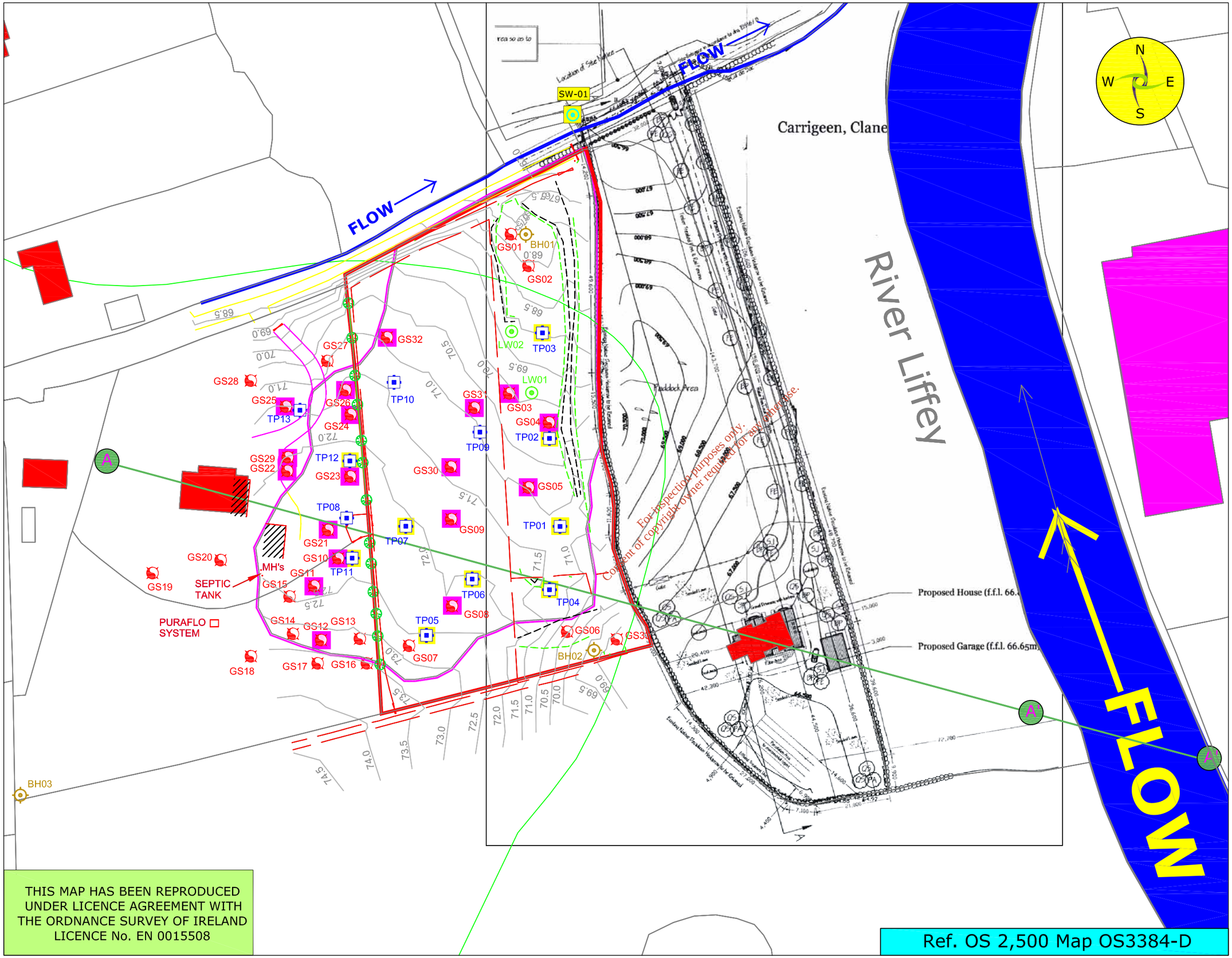
Prepared by:	Checked:	Date:
D.F.	P.M.	31-01-12

Project Director: P.MULROY

MULROY environmental

Drawing No.: Figure 11

Issue: 0



LEGEND

- SITE BOUNDARY
- GAS SPIKE MONITORING LOCATIONS
- TRIAL PIT LOCATIONS
- GAS MONITORING LOCATIONS WITH >5% CH4
- DOMESTIC WASTE CONFIRMED IN TRIAL PIT
- SECTION LOCATION (SEE FIGURE 13)
- SURFACE WATER MONITORING POINT
- GROUNDWATER MONITORING BOREHOLE LOCATIONS
- LEACHATE MONITORING WELL LOCATIONS

NOTES

1. FIGURED DIMENSIONS ONLY TO BE TAKEN FROM THIS DRAWING
2. ALL LEVELS SHOWN RELATE TO ORDNANCE SURVEY DATUM AT MALIN HEAD

Issue	Date	Description	By	Chkd.

Client: Kildare C.C

Project: Tier 3 Detailed Quantitative Risk Assessment(DQRA) of Former Landfill Site at Carrigeen, Clane, Co.Kildare

Title: Site Investigation Monitoring Point & Section Location Map

Scale: 1:1,000@A3

Prepared by:	Checked:	Date:
D.F	P.M.	10-04-12

Project Director: P.MULROY

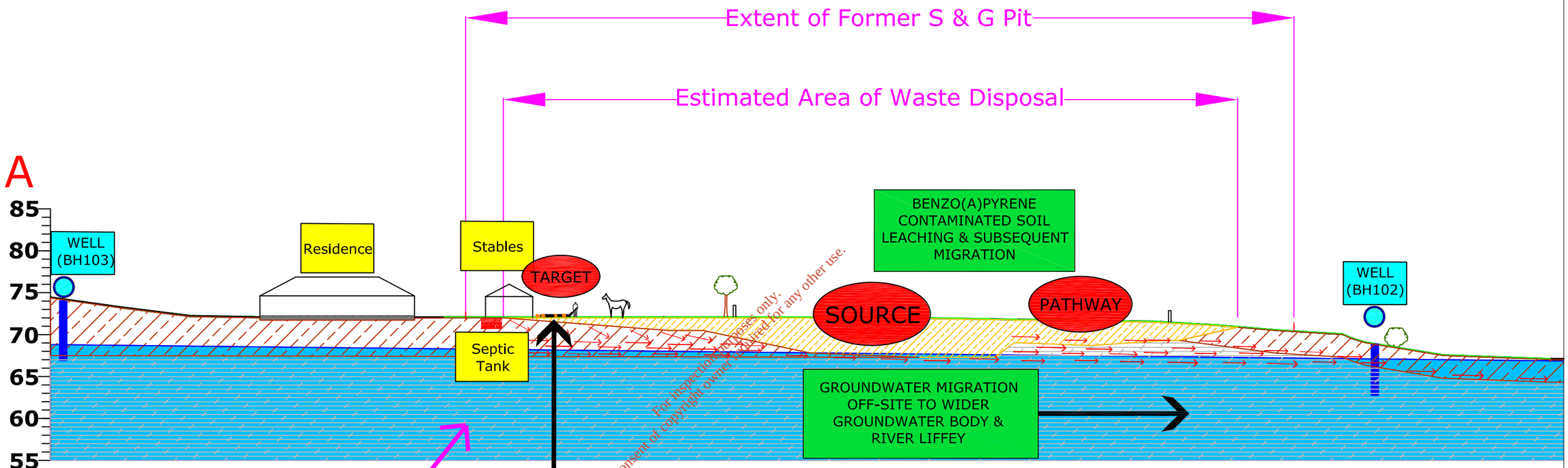
MULROY environmental

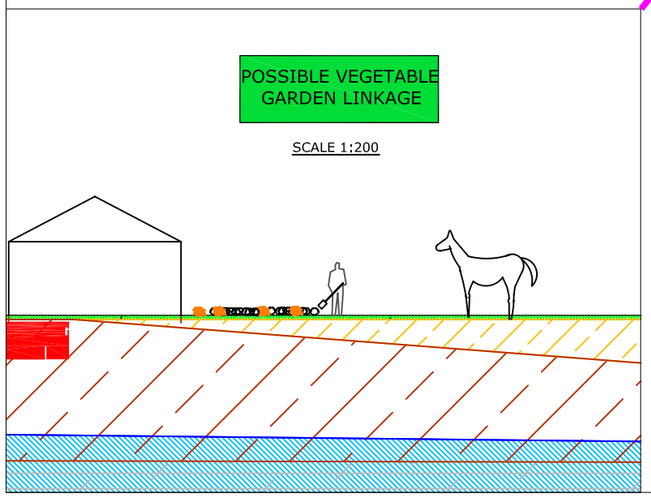
Drawing No.: Figure 12

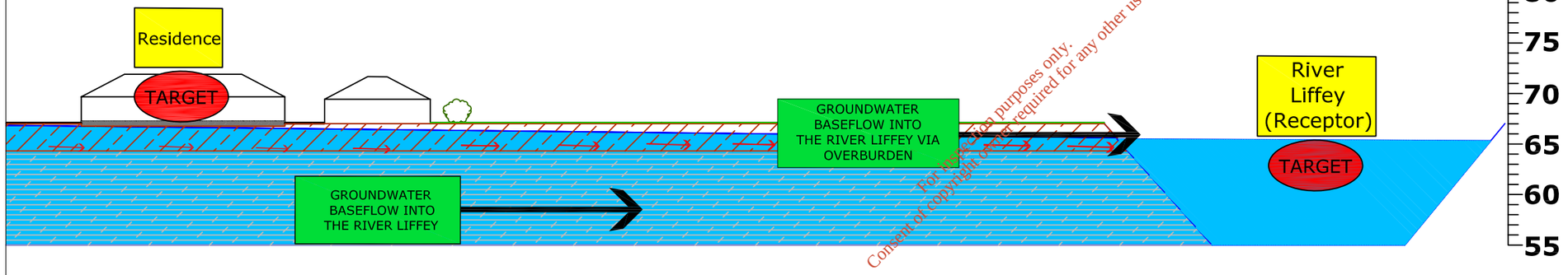
Issue: 0

Ref. OS 2,500 Map OS3384-D

CONCEPTUAL SITE MODEL







LEGEND

Groundwater table during Winter season (in overburden)

Bedrock aquifer (approximated at 4.5bgl)

Area of waste disposal

NOTES

1. FIGURED DIMENSIONS ONLY TO BE TAKEN FROM THIS DRAWING

2. ALL LEVELS SHOWN RELATE TO ORDNANCE SURVEY DATUM AT MALIN HEAD

Issue	Date	Descrlption	By	Chkd.

Client:

Kildare C.C

Project:

Carrigeen Tier 1
Environmental Risk Assessment of
Former Landfill Site.

Title:

Conceptual Site Model

Scale:

1:500@A3

Prepared by:	Checked:	Date:
D.F	P.M.	30-05-12

Project Director: P.MULROY

MULROY environmental

Drawing No.: Figure 13

Issue: 0

APPENDIX 1

EPA'S CODE OF PRACTICE: ENVIRONMENTAL RISK ASSESSMENT FOR UNREGULATED WASTE DISPOSAL SITES TIER 1. RISK SCREENING & PRIORITISATION

Site : Carrigeen, Clane

Table	Score	Rationale
1a: Leachate Hazard	5	Municipal waste landfilled between 1977 and 1980 of <1ha.
1b: Landfill Gas Hazard	5	Municipal waste landfilled between 1977 and 1980 of <1ha.
2a: Leachate Migration - GW Vulnerability	3	Extreme vulnerability due to bedrock.
2b: Leachate Migration - GW Flow Regime	1	Poorly productive bedrock groundwater body. (Ll)
2c: Leachate Migration - SW Drainage	2	Leachate runoff to stream which in turn discharges to the Liffey.
2d: Landfill Gas - Laterial Migration	2	Bedrock. Nearest dwelling 7.5m from waste body.
2e: Landfill Gas - Vertical Migration	0	Receptor not located above waste body.
3a: Leachate Migration - Human Presence	3	Nearest dwelling 7.5m from waste body.
3b: Leachate Migration - Protected Area	0	There are no protected areas within 1km of the waste body.
3c: Leachate Migration - Aquifier Category	3	Ll, Locally important aquifer.
3d: Leachate Migration - Public Water Supply	0	No public water supply within 1km and not a karst aquifer.
3e: Leachate Migration - Surface Water Bodies	3	Leachate runoff to stream 6.5m from waste body,which in turn discharges to the Liffey.
3f: Landfill Gas - Human Presence	5	Nearest dwelling 7.5m from waste body.

SPR (Source Pathway Receptor) Linkage

SPR 1= 1a X (2a + 2b + 2c) X 3e
SPR 2= 1a X (2a + 2b + 2c) X 3b (SWDTE)
SPR 3= 1a X (2a + 2b) X 3a
SPR 4= 1a X (2a + 2b) X 3b
SPR 5= 1a X (2a + 2b) X 3c
SPR 6= 1a X (2a + 2b) X 3d
SPR 7= 1a X (2a + 2b) X 3e
SPR 8= 1a X 2c X 3e
SPR 9= 1a X 2c X 3b (SWDTE)
SPR 10= 1b X 2d X 3f
SPR 11= 1b X 2e X 3f

	Site score	Max score	%
SPR 1:	90	300	30.00%
SPR 2:	0	300	0.00%
SPR 3:	60	240	25.00%
SPR 4:	0	240	0.00%
SPR 5:	60	400	15.00%
SPR 6:	0	560	0.00%
SPR 7:	60	240	25.00%
SPR 8:	30	60	50.00%
SPR 9:	0	60	0.00%
SPR 10:	50	150	33.33%
SPR 11:	0	250	0.00%

Moderate Risk (Class B)

Site: Carrigeen, Clane

Table 1a: LEACHARE: SOURCE/HAZARD SCORING MATRIX

	WASTE FOOTPRINT (ha)		
WASTE TYPE	≤ 1 ha	>1≤ 5 ha	> 5 ha
C&D[20]	0.5	1	1.5
Municipal[21]	5	7	10
Industrial[22]	5	7	10
Pre 1977 sites[23]	1	2	3
		Max	10

1a	5

Table 1b: LANDFILL GAS: SOURCE/HAZARD SCORING MATRIX

	WASTE FOOTPRINT (ha)		
WASTE TYPE	≤ 1 ha	>1≤ 5 ha	> 5 ha
C&D[20]	0.5	1	1.5
Municipal[21]	5	7	10
Industrial[22]	5	7	10
Pre 1977 sites[23]	1	2	3
		Max	10

1b	5

Table 2a: LEACHATE MIGRATION: PATHWAYS

Parameter	Points available
GROUNDWATER FLOW REGIME (Vertical Pathway)	
Extreme Vulnerability	3
High Vulnerability	2
Moderate Vulnerability	1
Low Vulnerability	0.5
High - Low Vulnerability	2

2a	3

Table 2b: LEACHATE MIGRATION: PATHWAYS

Parameter	Points available
GROUNDWATER FLOW REGIME (Horizontal Pathway)	
Karstified Groundwater bodies (Rk)	5
Productive Fissured Bedrock Groundwater Bodies (Rf and Lm)	3
Gravel Groundwater bodies (RG and Lg)	2
Poorly Productive Bedrock Ground Water Bodies (Ll, Pl, PU)	1

2b	1

Table 2c: LEACHATE MIGRATION: PATHWAYS

Parameter	Points available
SURFACE WATER DRAINAGE (surface water pathway)	
Is there a direct connection between drainage ditches associated with the waste body and adjacent surface water body? Yes	2
If no direct connection	0

2c	2

Table 2d: LANDFILL GAS: PATHWAY assuming receptor within 250m of source

Parameter	Points available
LANDFILL GAS LATERIAL MIGRATION POTENTIAL	
Sand and gravel, Made ground, urban, Karst	3
Bedrock	2
All other Tills (including limestone, sandstone etc - moderate Permeability	1.5
All Namurian or Irish Sea Tills (low permeability)	1
Clay, Alluvium, Peat	1

2d	2

Table 2e: LANDFILL GAS: PATHWAY assuming receptor located above source

Parameter	Points available
LANDFILL GAS LATERIAL MIGRATION POTENTIAL	
Sand and gravel, Made ground, urban, Karst	5
Bedrock	3
All other Tills (including limestone, sandstone etc - moderate Permeability	2
All Namurian or Irish Sea Tills (low permeability)	1
Clay, Alluvium, Peat	1

2e	0

Table 3a: LEACHATE MIGRATION: RECEPTORS

Parameter	Points available
HUMAN PRESENCE (presence of a house indicates potential private well)	
On or within 50m of waste body	3
Greater than 50m but less than 250m of the waste body	2
Greater than 250m but less than 1km of the waste body	1
Greater than 1km of the waste body	0

3a	3

Table 3b: LEACHATE MIGRATION: RECEPTORS

Parameter	Points available
PROTECTED AREAS (SWDTE or GWDTE)	
On or within 50m of waste body	3
Greater than 50m but less than 250m of the waste body	2
Greater than 250m but less than 1km of the waste body	1
Greater than 1km of the waste body	0
Undesignated sites within 50m of waste body	1
Undesignated sites greater than 50m but less than 250m of the waste body	0.5
Undesignated sites greater than 250m of the waste body	0

3b	0

Table 3c: LEACHATE MIGRATION: RECEPTORS

Parameter	Points available
AQUIFIER CATEGORY (resource potential)	
Regionally Important Aquifier (Rk, Rf, Rg)	5
Locally Important Aquifier (Ll, Lm, Lg)	3
Poor Aquifier (Pl, Pu)	1

3c	3

Table 3d: LEACHATE MIGRATION: RECEPTORS

Parameter	Points available
PUBLIC WATER SUPPLY (other than private wells)	
Within 100m of site boundary	7
Greater than 100m but less than 300m or within Inner SPA (SI) for GW supplies	5
Greater than 300m but less than 1km or within Outer SPA (SO) for GW supplies	3
Greater than 1km (karst aquifier)	3
Greater than 1km (no karst aquifier)	0

3d	0

Table 3e: LEACHATE MIGRATION: RECEPTORS

Parameter	Points available
SURFACE WATER BODIES	
Within 50m of site boundary	3
Greater than 50m but less than 250m	2
Greater than 250m but less than 1km	1
Greater than 1km	0

3e	3

Table 3f: LANDFILL GAS: RECEPTORS

Parameter	Points available
HUMAN PRESENCE	
On site or within 50m of site boundary	5
Greater than 50m but less than 150m	3
Greater than 150m but less than 250m	1
Greater than 250m	0.5

3f	5

APPENDIX 2

- KILDARE C.C. BOREHOLE DESCRIPTIONS
- EPA/TEAGASC SOIL DATA
- EPA/TEAGASC SUBSOIL DATA
- DETAILED GSI RECORDS ON BOREHOLES WITHIN 1KM OF SITE

LW1

0.0	1.1	Clay Soil Till
1.1	3.4	Black Bag Waste Layer
3.4	3.6	Boulder Clay
3.6	3.7	Weathered Rock
3.7	4.5	Rock Water
0.0	1.0	Plain Pipe
1.0	4.5	Slotted Pipe

LW2

0.0	0.9	Brown overburden
0.9	1.6	Sandy gravelly Clay
1.6	2.4	Fill plastic etc
2.4	2.8	Black damp gravel Clay
2.8	3.0	Brown sandy Gravel
3.0	3.2	Weathered Rock
3.2	3.8	Solid Rock (water Present)
0.0	1.0	Plain Pipe
1.0	3.8	Slotted Pipe

GW 1

0.0	1.7	Plain Pipe
1.5	1.7	Bentonite
1.7	8.0	Gravel
1.7	8.0	Slotted Pipe

GW 2

0.0	5.0	Overburden
5.0	5.7	Rock
5.7	8.0	Fractured Rock
0.0	5.3	Plain Pipe
5.3	8.0	Slotted Pipe
5.0	5.2	Bentonite
5.2	8.0	Gravel

GW 3

0.0	1.2	Brown gravelly Clay/Silt
1.2	1.6	Brown gravelly Clay/Silt
1.6		Large cobbles (gravel)
1.6	4.4	Layer of red brown Sand
4.4	4.7	Brown sandy Gravel
4.7	4.8	Boulder
4.8	5.4	Brown sandy gravel
5.4	6.5	Dark brown sandy gravel
6.5	7.4	Dark brown silty gravelly Clay
7.4	8.0	Black peaty Clay
0.0	3.4	Plain Pipe
3.4	8.0	Slotted Pipe

Environmental Protection Agency

Soil Details

Print Close

Code	22
Name	BminSW
Location	KILDARE
Parent Material	GLs
Type Group	Shallow well drained mineral
Description	Derived from mainly calcareous parent materials
Included Great Soil Group	Renzinas, Lithosols

The soils and subsoils maps were created by the Spatial Analysis Unit, Teagasc. The project was completed in May 2006 and was a collaboration between Teagasc, Geological Survey of Ireland, Forest Service and the EPA. The project was funded by the DEHLG under the National Development Plan

If you have a query about this mapping tool, contact the Environmental Protection Agency, GIS Unit, Office of Environmental Assessment, PO Box 3000, Johnstown Castle Estate, Co. Wexford.
Tel: Locall 1890 33 55 99 or 053 91 60600; Fax 053 91 60699.
Email queries should be directed to info@epa.ie for the attention of the GIS Unit.

Soil Details

Print Close

Code	51
Name	AlluvMIN
Location	KILDARE
Parent Material	A
Type Group	Alluviums
Description	Mineral alluvium
Included Great Soil Group	Variable

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Subsoil Details

Print Close

Code	705
Name	Rck
Location	KILDARE
Type Name	Rck
Type	Bedrock at surface
Type Group	Other categories

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Subsoil Details

Print Close

Code	118
Name	TLs
Location	KILDARE
Type Name	TLs
Type	Limestone till (Carboniferous)
Type Group	Tills

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Subsoil Details

Print Close

Code	212
Name	GLs
Location	KILDARE
Type Name	GLs
Type	Limestone sands and gravels (Carboniferous)
Type Group	Glaciofluvial sands and gravels

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Subsoil Details

Print Close

Code	702
Name	Made
Location	KILDARE
Type Name	Made
Type	Made ground
Type Group	Other categories

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Subsoil Details

Print Close

Code	400
Name	A
Location	KILDARE
Type Name	A
Type	Alluvium undifferentiated
Type Group	Alluvium

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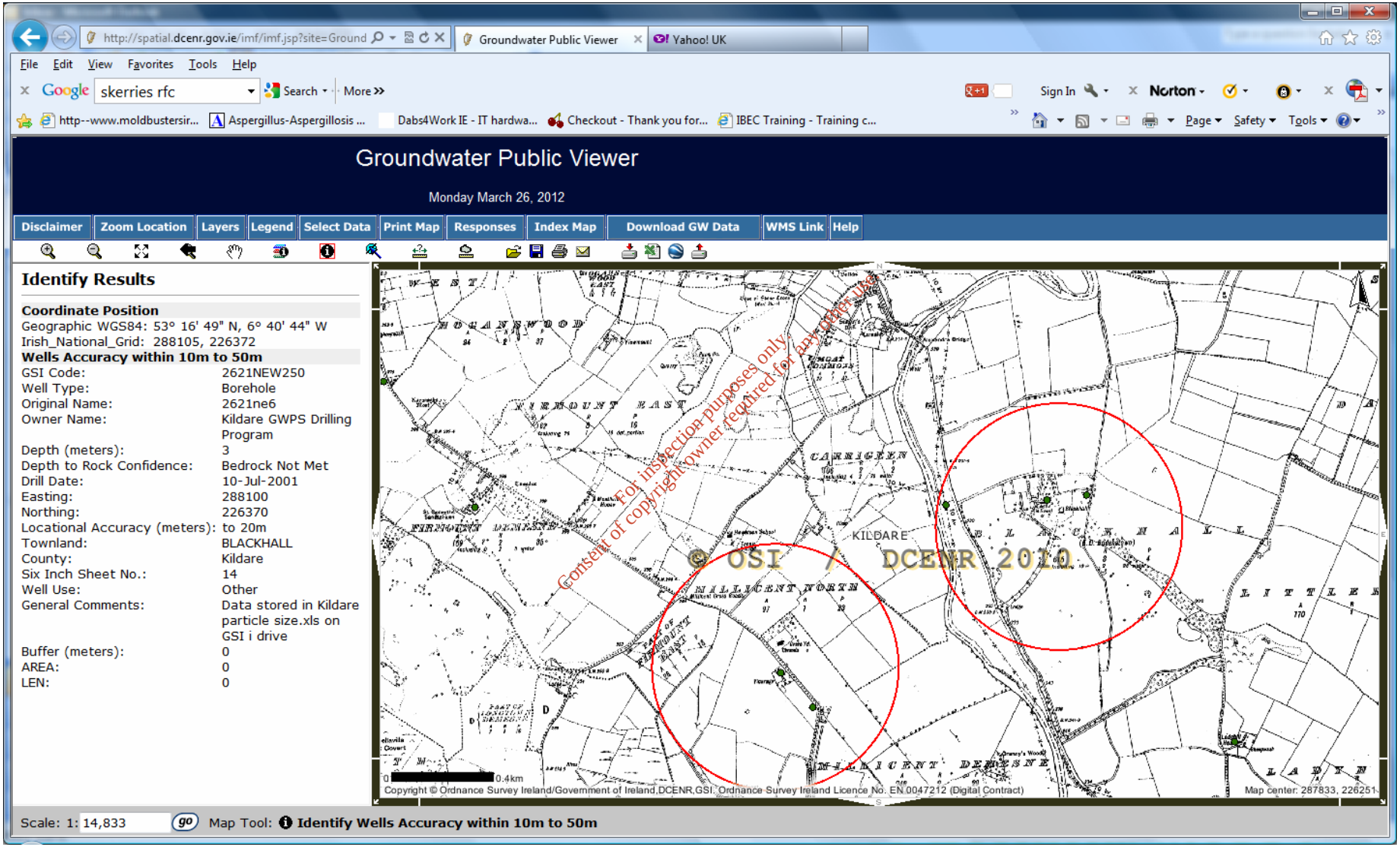
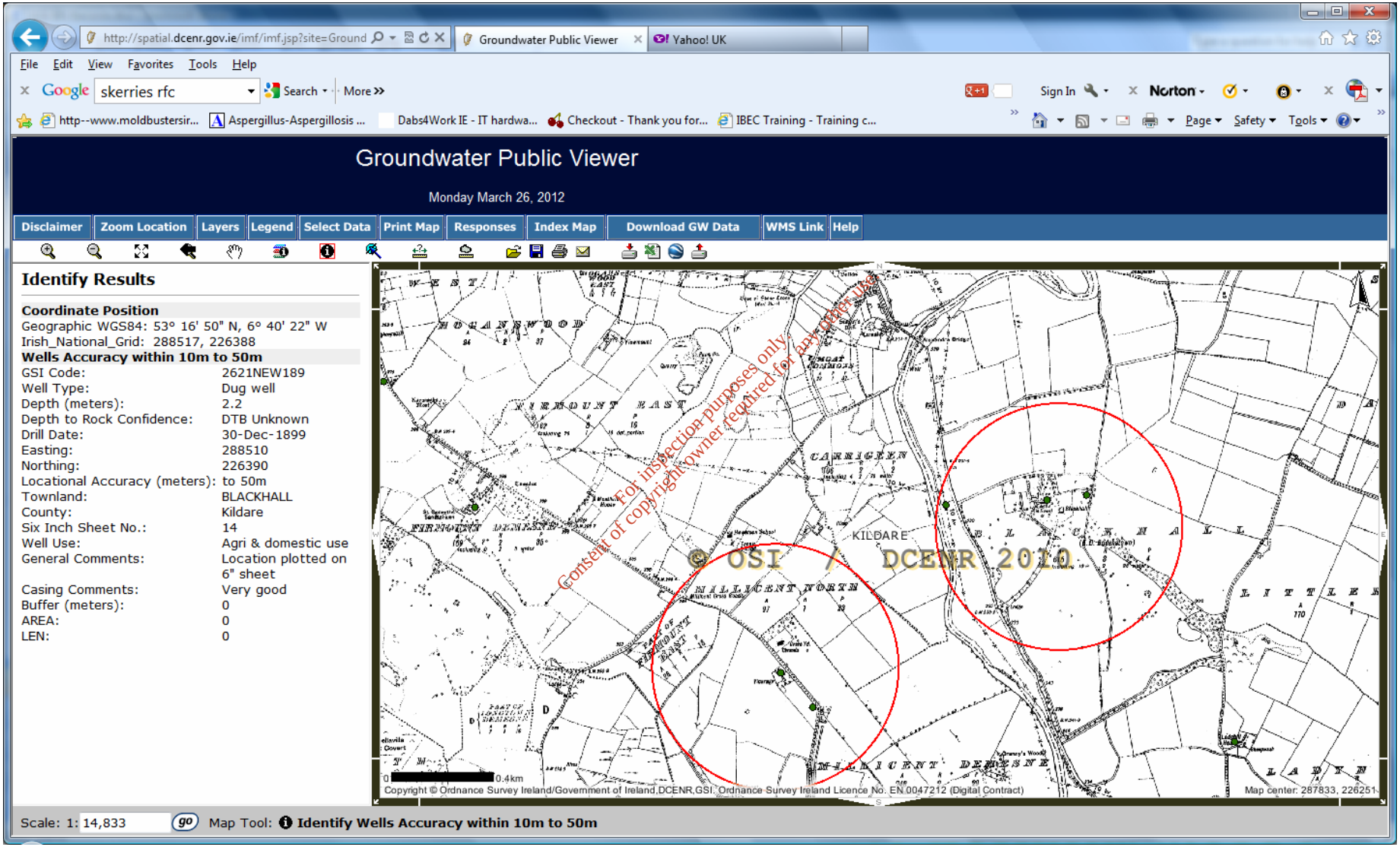
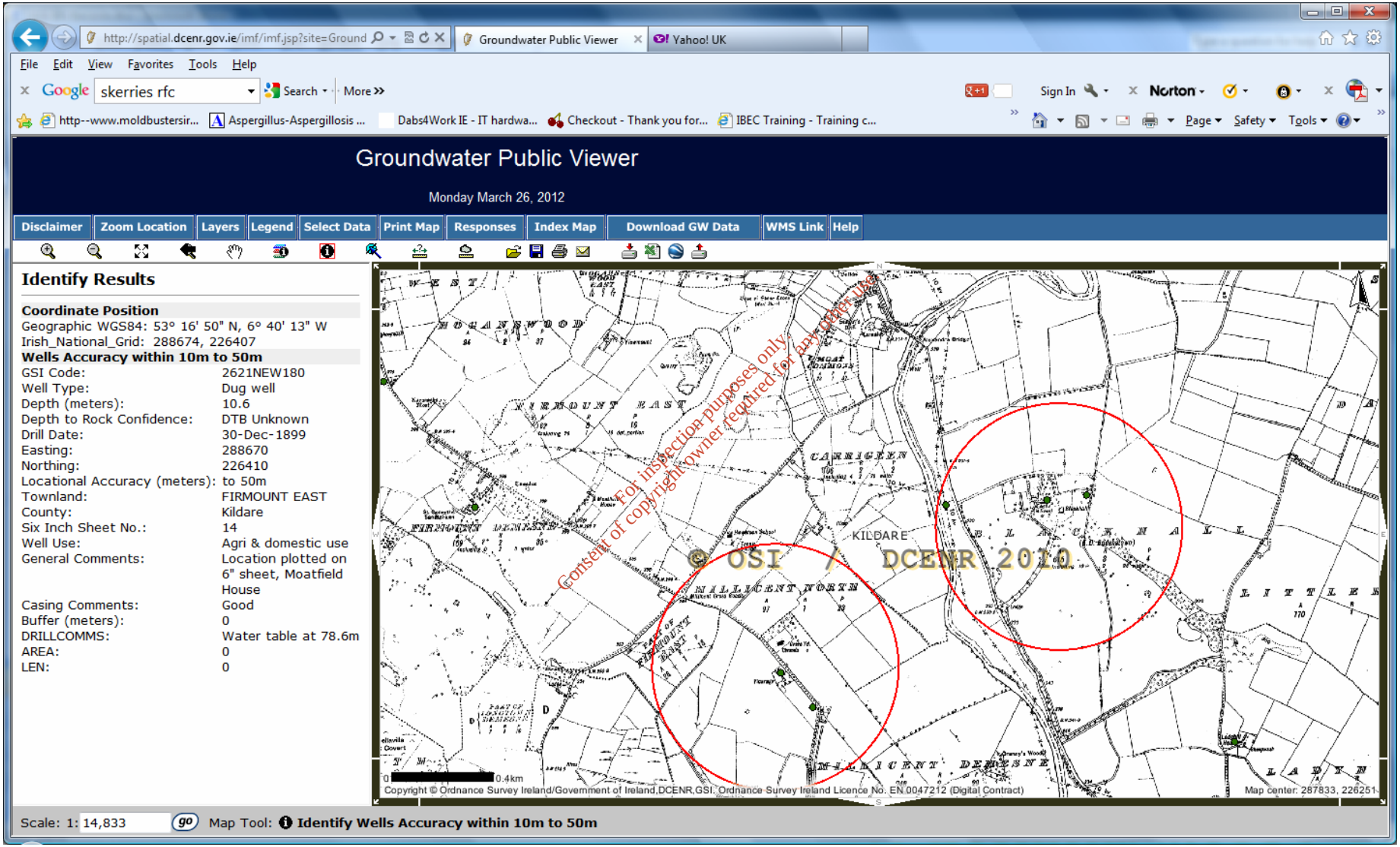
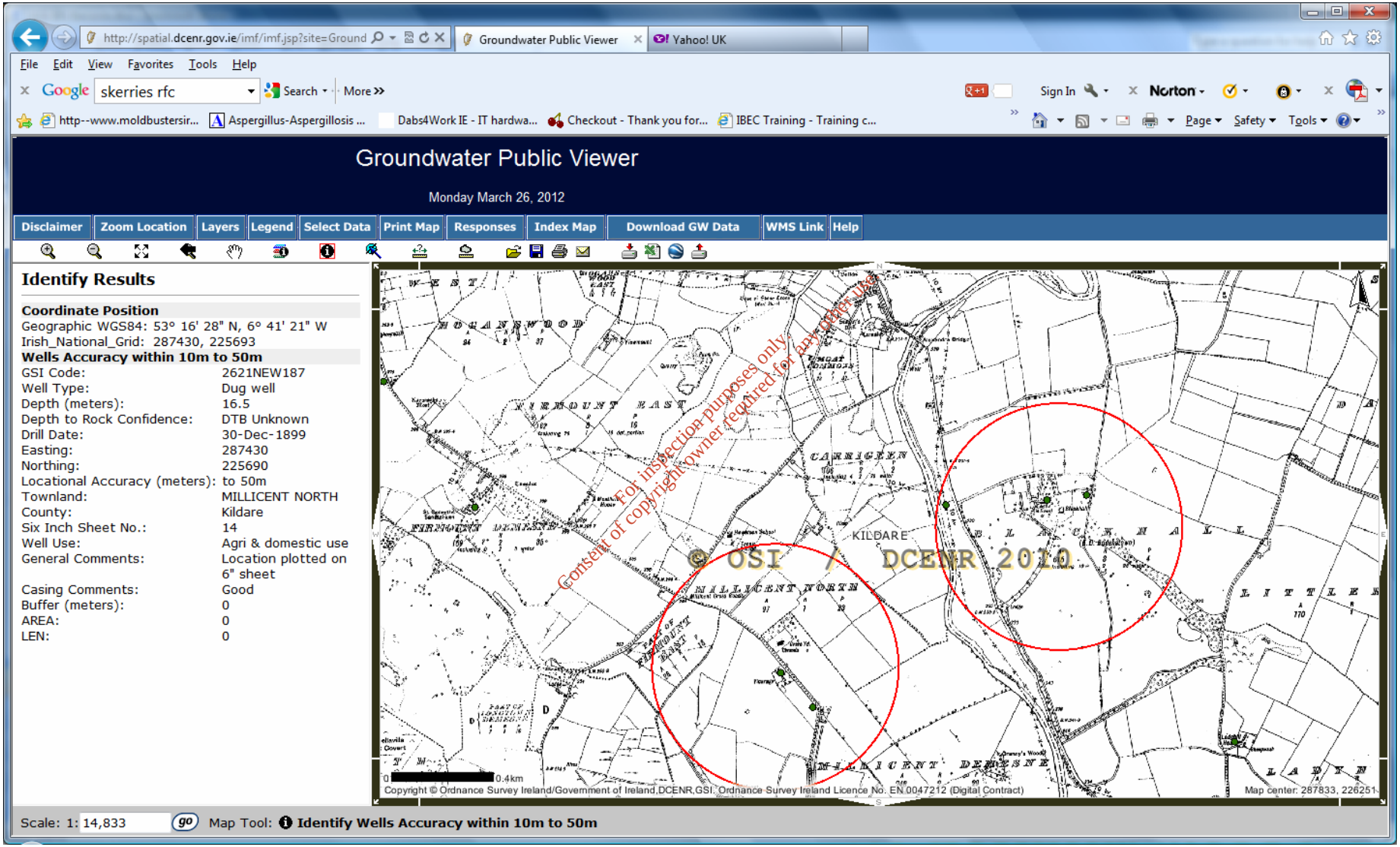
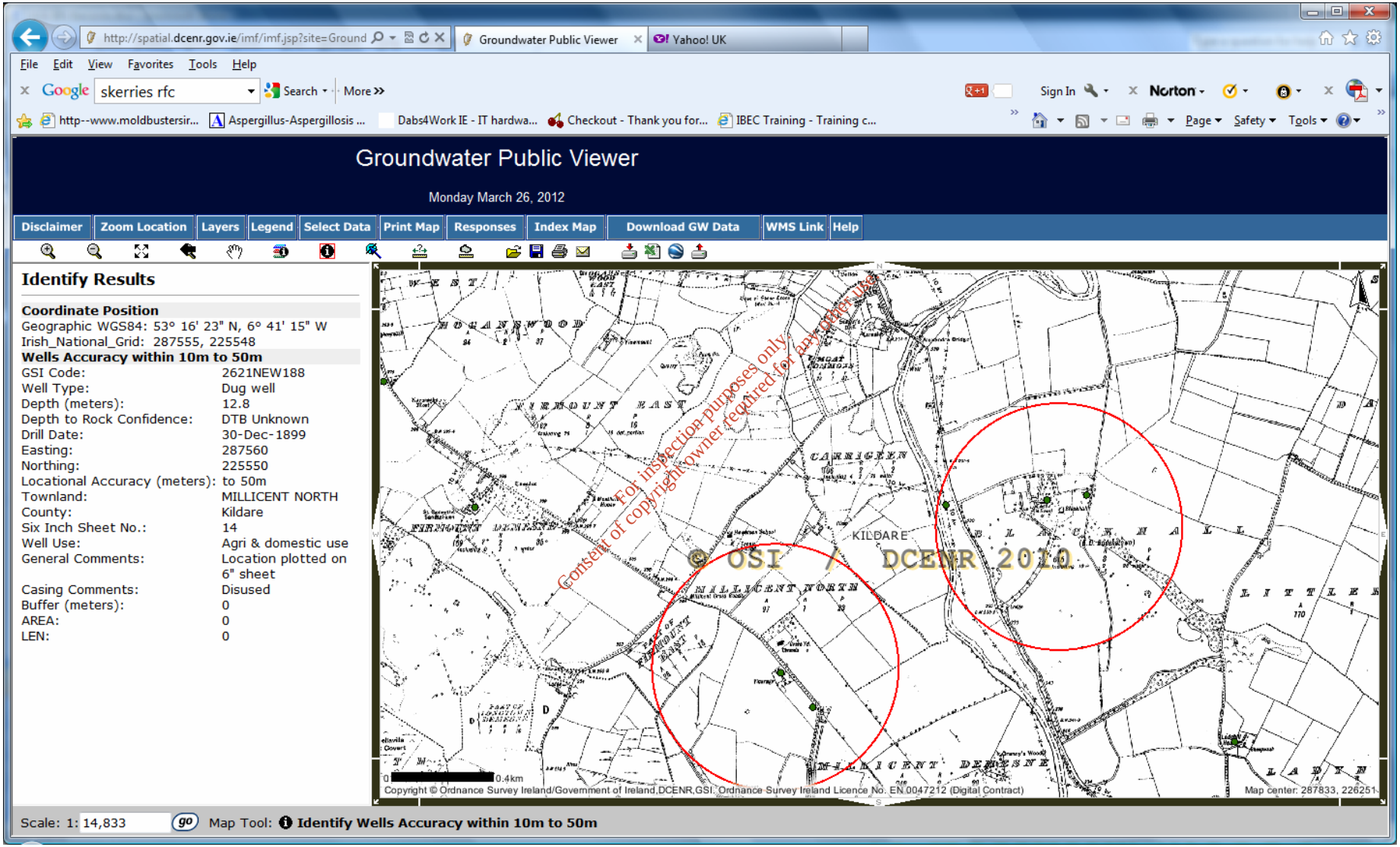
Email queries should be directed to info@epa.ie for the attention of the GIS Unit.











APPENDIX 3

- TABLE A3.1. CARRIGEEN LANDFILL GROUNDWATER MONITORING DATA TAKEN ON THE 16.02.12

- TABLE A3.2. MAJOR ION BALANCE ON GROUNDWATER, LEACHATE AND SURFACE WATER SAMPLES TAKEN AT CARRIGEEN LANDFILL

- GEOLOGICAL SURVEY OF IRELAND-DUBLIN GROUNDWATER BODY (GWB) DESCRIPTION

- GROUNDWATER PROTECTION RESPONSE FOR ON-SITE WASTEWATER SYSTEMS FOR SINGLE HOUSES-SUMMARY SHEET

- EASTERN RIVER BASIN MANAGEMENT BODY HYDROGEOLOGICAL RISK ASSESSMENT REPORT FOR THE 'DUBLIN' SURFACE GROUNDWATER BODY

Table A3.1. Carrigeen Landfill Groundwater Monitoring Data taken on the 16.02.12

Borehole Name	Easting	Northing	Elevation (m AOD)	Standing Water Level (mbgl from TOC)	Standing Water Level (m AOD)	Total Depth (mbgl from TOC)	Total Depth (m AOD)
BH101	287782	226779	67.2	1.07	66.13	8.63	58.57
BH102	287802	226665	71.2	4.1	67.1	8.49	62.71
BH103	287645	226623	73.7	4.89	68.81	6.85	66.85
LW01	287783	226708	72.2	3.56	68.64	4.78	67.42
LW02	287780	226728	70.2	3.46	66.74	4.12	66.08
HYDRAULIC GRADIENT BH103 TO BH101							
DISTANCE BETWEEN ON SITE BOREHOLES (m)	429			**DIFFERENCE IN SWL (m)**	2.68		
GRADIENT BETWEEN ON SITE BOREHOLES	1 to 160						
HYDRAULIC GRADIENT BH102 TO BH101							
DISTANCE BETWEEN ON SITE BOREHOLES (m)	240			**DIFFERENCE IN SWL (m)**	0.97		
GRADIENT BETWEEN ON SITE BOREHOLES	1 to 247						

Table A3.2. Major Ion Balance on Groundwater, Leachate and Surface Water Samples taken at Carrigeen Landfill

		Cations				Anions			Balance			
Sample	Elec. Cond. (μScm^{-1})	Ca^{2+} (meq L^{-1})	Mg^{2+} (meq L^{-1})	Na^{+} (meq L^{-1})	K^{+} (meq L^{-1})	Cl^{-} (meq L^{-1})	SO_4^{2-} (meq L^{-1})	HCO_3^{-} (meq L^{-1})	$\sum^{+}$ (meq L^{-1})	$\sum^{-}$ (meq L^{-1})	% Ion Balance Error	pH
BH01	725	4.6157685	1.973684	1.830673566	0.52946593	0.87993908	0.147616073	10.117647	8.949592	11.1452	-10.92626	8.25
BH02	402	8.0588822	0.731908	0.69139453	0.09975445	0.85173591	0.149489902	8.1882353	9.581939	9.189461	2.09083	7.54
BH03	461	6.6167665	12.41776	0.404400574	0.0409249	0.38638351	1.275244639	23.176471	19.47986	24.8381	-12.09046	7.48
SW01	507	6.1027944	0.476974	0.417445754	0.08184981	0.42304764	0.421611493	6.3764706	7.079064	7.22113	-0.993456	8.39

Dublin GWB: Summary of Initial Characterisation.

Hydrometric Area Local Authority	Associated surface water bodies	Associated terrestrial ecosystems	Area (km^2)
Dublin Co. Co. Kildare Co. Co. Meath Co. Co. Hydrometric Area 9	**Rivers** - Ballough Stream, Broadmeadow, Clonshanbo, Dodder, Fairyhouse Stream, Liffey, Lyreen, Mayne, Rye Water, Santry, Tolka, Ward	Dodder Valley (991), Sluice River Marsh (1763), Santry Demesne (178), Liffey Valley (128), Booterstown Marsh (1205) Donadea Wood (1391), Hodgestown Bog (1393), Liffey Bank Above Athgarvan (1396), Mouds Bog (SAC 395), Rye Water Valley (1398)	837

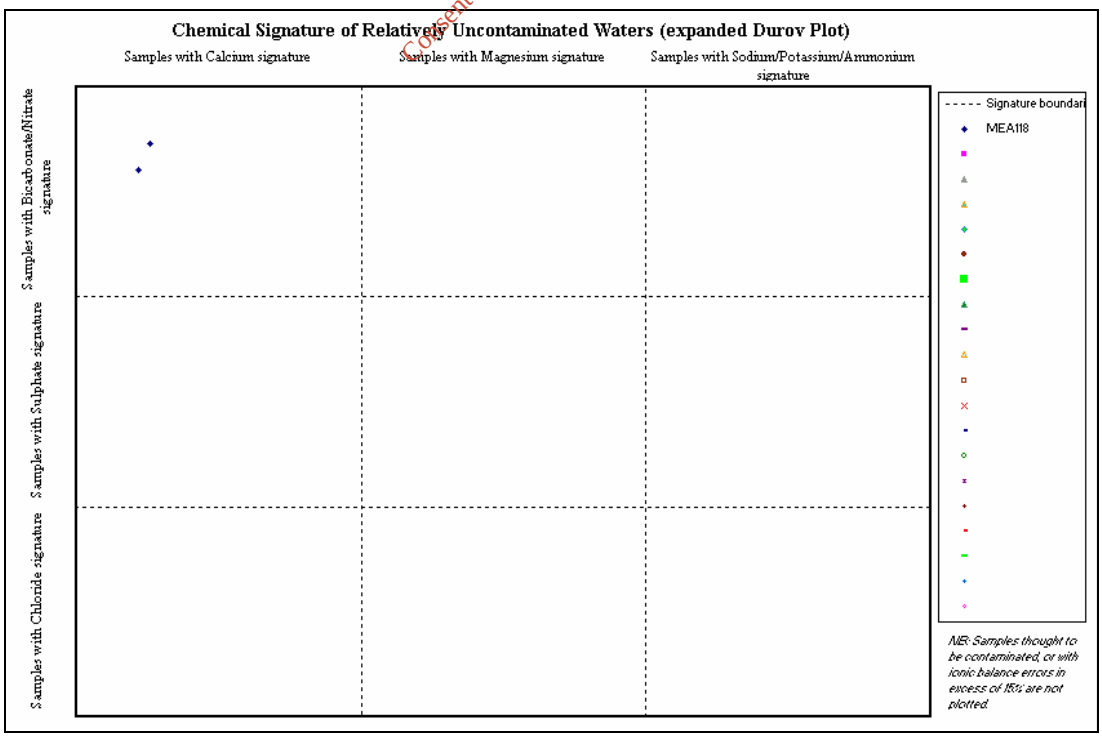
Topography		This GWB is located in the Greater Dublin City area and extends southwest towards Kildare. The area is generally low-lying, with areas of higher elevation surrounding to the south and to a lesser extent to the north. Elevations decrease towards the various river estuaries around Dublin city. At the boundaries of the GWB the highest elevations are to the south at the foothills of the Dublin Mountains and to the northwest where the Namurian rocks form an area of higher elevation to the southwest of Dunshaughlin.
Geology and Aquifers	Aquifer type(s)	**Ll:** Locally important aquifer, moderately productive only in local zones **Pl:** Poor aquifer, generally unproductive except for local zones
	Main aquifer lithologies	Dinantian Upper Impure Limestones Dinantian Lower Impure Limestones Dinantian Pure Unbedded Limestones Dinantian Mixed Sandstones, Shales and Limestones. Namurian Undifferentiated rock.
	Key structures.	In the Dublin Basin minor open NE/SW folds cause strike swings in otherwise predominantly E-W striking moderate to shallow dipping strata. A parallel anticline is present to the south in the core of which the Portraine and Lambay inliers are exposed and which continues SW towards Hermitage, exposing the Boston Hill formation along its axis. At the southern margin of the basin the Donnybrook-Tallaght syncline is present. The structure of the area south of Portmarnock is uncertain owing to the drift cover, but a further pair of major folds may occur, with the reef limestone plunging and or being faulted out west of the Balgriffin-Raheny area (Crieghton *et al* 1979).
	Key properties	In general permeability in these rock units are likely to be low (1-10m^2/d) (Creighton *et al*). Secondary dolomitisation along faults in the Dublin area suggests that they have been, and may still be, open to allow fluid migration. (ERA 1991). Pumping test analysis at the public supply boreholes at Dunboyne, Co. Meath provided transmissivity values between 10 and 150 m^2/d. (Woods 1996) A series of hydrogeological tests were carried out in the Barrockstown area around 4.5km north of Maynooth. Double Packer tests carried out on two boreholes in the area gave permeabilities ranging from 1.4 x 10^{-6} to 6.1 x 10^{-7} m/s. In situ Rising/Falling Head tests in eight of the bedrock wells gave similar results but more diverse than the packer test results, varying from 5.04 x 10^{-5} to 7.39 x 10^{-9} m/s (Cullen 1998).
	Thickness	There is a distinct reduction in the permeabilities of these rocks with depth. Packer tests show permeabilities reduce an order of magnitude for each five metres of depth in the limestone (Aspinwall & Company, 1979). Most groundwater flow will take place close to the surface with additional isolated flow along fractures and fissures located at depths up to 50 m.b.g.l.
Overlying Strata	Lithologies	There are a number of subsoil types. Their distribution is related to ice flow directions during the last ice age. To the south we find till derived from Granite and Lower Paleozoic rocks in the Dublin Mountains. Along the coast and some distance inshore there are deposits of Irish Sea Till, which is the least permeable of the subsoils. The majority of the aquifer is overlain by limestone-derived till which came from the limestone expanses around Dublin. There are smaller gravel deposits in the area, which will be the most permeable of the subsoils, including glacial deposits and alluvial gravels. To the very southwest of the GWB, in Kildare, there are major gravel deposits, including the Mid-Kildare Gravel Aquifer (The Curragh).
	Thickness	The thickness of the subsoil, as in all Ireland, is highly variable. There are thick deposits of till along the coast, over 10m thick in places. The thickness reduces further inland. West of Lucan the till deposits are mostly quite thin (<3m), with some exceptions e.g. along the river channels of the Liffey and other streams. The thickness of the overlying till increases west of a line connecting Dunboyne, Co. Meath to Maynooth to Newcastle, Co Kildare.
	% Area aquifer near surface	The area of aquifer close to surface may be quite significant. Thin subsoil areas are located towards the center of the GWB where.
	Vulnerability	The vulnerability of the groundwater is generally Extreme between Maynooth and Phoenix Park in Dublin, to the east and west of this area the general vulnerability is Moderate. It must be remembered that the vulnerability, as with subsoil thickness, is highly variable at all scales.

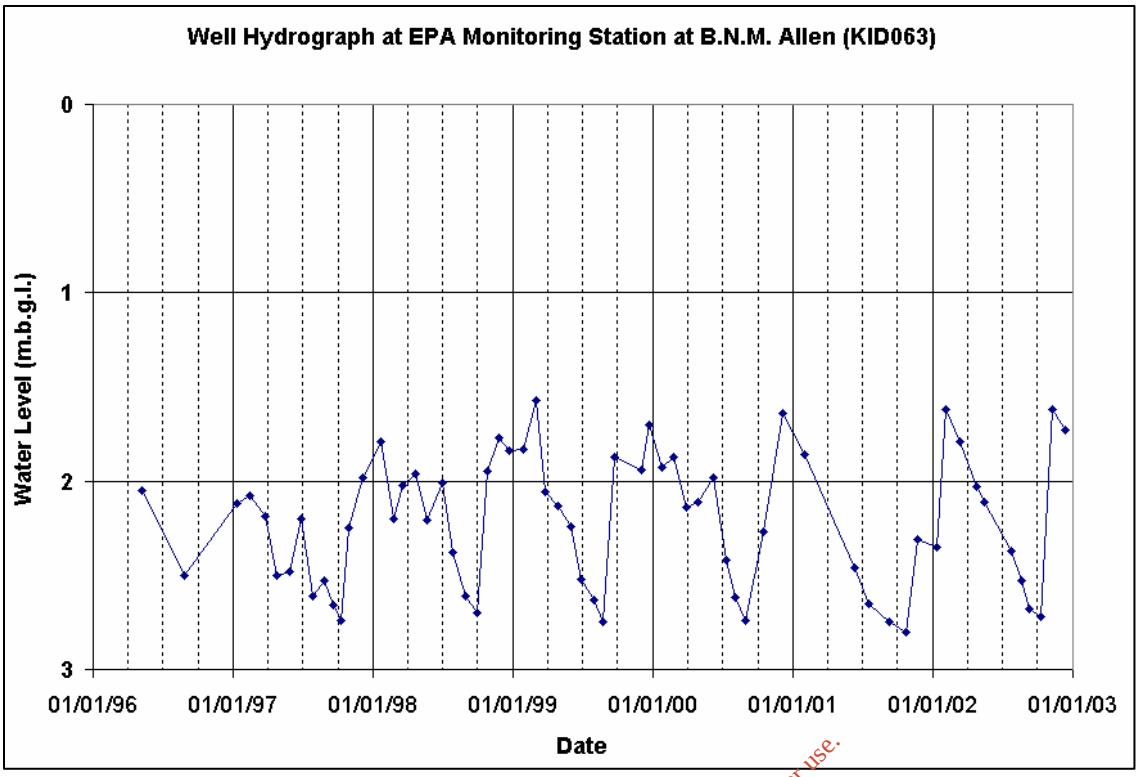
Recharge	Main recharge mechanisms	The area of the GWB beneath Dublin City will have completely different recharge processes than the rest of the GWB in rural areas. Dublin City is essentially a cement cap on the limestone, which prevents the area from receiving recharge. The only open areas where recharge may occur are at parks, squares and gardens. Conservatively it is estimated that 10% of the city area is available for recharge. Some recharge occurs from leaking sewers, mains and storm drains. To optimize recharge calculations an estimate of the leakage from mains and other water works would be of use. Elsewhere diffuse recharge will occur via rainfall percolating through the subsoil. The proportion of the effective rainfall that recharges the aquifer is largely determined by the thickness and permeability of the soil and subsoil, and by the slope. Due to the generally low permeability of the aquifers within this GWB, a high proportion of the recharge will then discharge rapidly to surface watercourses via the upper layers of the aquifer, effectively reducing further the available groundwater resource in the aquifer.
	Est. recharge rates	*[Information to be added at a later date]*
Discharge	Springs and large known abstractions	GSI Source Reports – Dunboyne (Abstraction is 1160m^3/d from four wells). A number of warm springs are situated in the Lucan and Celbridge areas. Typical spring temperatures range from 12.5-25°C, which is significantly above temperatures normally expected for Irish groundwater. It is thought that the groundwater issuing from these springs comes from a much deeper source than most groundwater in Ireland (Burdon, 1983). The presence of warm springs has been associated with deep faults, which would allow deeper, warmer waters to the surface rapidly, and it may be that they are more noticeable in poorer aquifers where the dilution effect of colder, shallower, younger waters is reduced.
	Main discharge mechanisms	The GWB will discharge directly to the Irish Sea along the coast. There will be discharge to the overlying gravel aquifers in places (ERA 1991) and there will also be discharge to the overlying rivers, if they are in hydraulic continuity with the aquifer. Dry Weather Flows vary (0.01 to 3 l/s/km^2) but typical values are quite low (<1 l/s/km^2). This implies the aquifer does not support large baseflows to the rivers during summer time.
	Hydrochemical Signature	The hydrochemical analyses of groundwater from the area indicate a very hard water (350-480 mg/l ($CaCO_3$)), with a high alkalinity (300 - 350 mg/l ($CaCO_3$)). Conductivities are also very high, ranging 550-900 µS/cm. This groundwater is a calcium bicarbonate water, as can be seen from the accompanying Durov Diagram.
Groundwater Flow Paths		The general groundwater flow direction in this aquifer is towards the coast and also towards the River Liffey and Dublin City. This aquifer is not expected to maintain regional groundwater flow paths. Groundwater circulation from recharge to discharge points will more commonly take place over a distance of less than a kilometre. The majority of groundwater flow will be a rapid flow in to upper weathered zone but flow in conduits is commonly recorded at depths of 30 to 50 m b.g.l. . The aquifer is not considered to have any primary porosity and flow will be through fractures, some of which will have been enlarged by karstification and dolomitisation. The fissured nature and the moderate permeability of the bedrock close to the surface imply that water will move at high velocities.
Groundwater & surface water interactions		The will by highly varied groundwater and surface water interaction processes occurring within the large area of this groundwater body. The nature of these interactions will be determined by local factors and it is therefore impossible to generalize over such a large area. Such local influences could include the depths and permeability of subsoil, slope, local permeability of the rock, overlying surface water bodies and human alterations to the environment. Such interactions should be considered on a local scale where the importance of them is most critical e.g. at protected areas.
Conceptual model	This GWB occupies a large area extending across the County Dublin from Malahide to Blackrock west across the whole county and extending into Kildare and Meath as far as Kilcock. The area is mostly low-lying with very little surface topography. The GWB is composed of moderate permeability karstified limestone. Very small areas of low permeability impure limestones are incorporated with this GWB, since they are isolated and do not alter significantly the flow system. The boundaries of this GWB are defined to the south by the contact with the Granites and Lower Paleozoic rocks, to the west and north by the extent of the Liffey catchment to the east by the coast. Groundwater flow occurs along fractures, joints and major faults. There are a number of warm springs located within this GWB, which suggest deep groundwater circulation is possible. Recharge occurs diffusely through the subsoils and via outcrops. Special attention must be paid to recharge assessments for the urban areas, which account for almost a quarter of the area of this GWB. The aquifers within the GWB are generally unconfined, but may become locally confined where the subsoil is thicker and/or lower permeability. Most flow in this aquifer will occur near the surface. In general, the effective thickness of this aquifer is likely to be about 10 m, comprising a weathered zone of a few metres and a connected fractured zone below this. However, deep-water strikes are commonly found in more isolated faults/ fractures at depths of 30 – 50 m.b.g.l. Flow path lengths are not considered to be on a regional scale, and are typically less than 1km in length. Groundwater discharges to the numerous streams and rivers crossing the aquifer, and to the springs and seeps towards the coast.	
Attachments		
Instrumentation	Stream gauge: 08001, 08003, 08004, 08005, 08006, 08007, 08008, 08009, 08012, 08013, 09002, 09003, 09004, 09005, 09006, 09009, 09011, 09012, 09015, 09018, 09019, 09022, 09024, 09030, 09035, 09036, 09037, 09041, 09043, 09044, 09048, 09049, 09055, 09101, 09102, 10038 Borehole Hydrograph: Dundrum CMH (DLR 030), B.N.M. Allen (KID063), EPA Representative Monitoring boreholes: Batterstown (MEA118)	

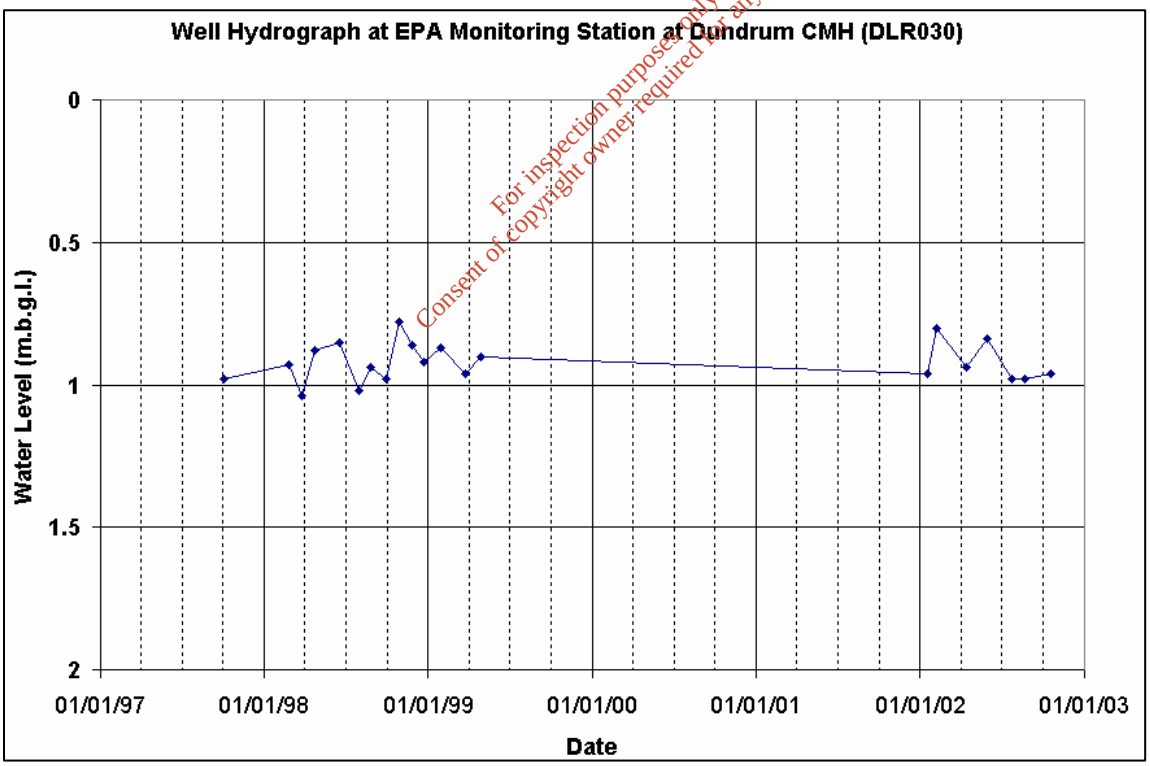
Information Sources	Aspinwall and Company (1979) *Hydrogeological survey of proposed waste disposal site at Gollierstown, Co. Dublin.* Report prepared for Dublin Co. Co. Burdon D J (1983) *Irish Groundwater Resources in Relation to Geothermal Energy Investigations*. Unpublished Report to GSI. 275pp. Creighton J R, Daly D & Reilly T A (1979) *The Geology and Hydrogeology of County Dublin with Particular Reference to the location of Waste Disposal Sites.* Unpublished GSI Report. pp 48 Cullen K T (1998) *Proposed Barrockstown Waste Management Facility*. Kelly C & Fitzsimons V. (2002) *County Kildare Groundwater Protection Scheme*. Main Report. Final report to Kildare County Council. Geological Survey of Ireland 55pp. McConnell B, Philcox M & Geraghty M, 2001. *Geology of Meath: A geological description to accompany the bedrock geology 1:100,000 scale map series, Sheet 13, Meath.* Geological Survey of Ireland. 77 p. McConnell B, Philcox M, Sleeman A G, Stanley G, Flegg A M, Daly E P & Warren W P 1994. *A Geological description to accompany the Bedrock Geology 1:100,000 Scale Map Series, Sheet 16, Kildare-Wicklow*. Geological Survey of Ireland, 70 pp. Woods L (1998) *Dunboyne Public Supply, Groundwater Source protection Zones.* Report to Meath County Council. Geological Survey of Ireland. 54 p. Woods L, Meehan R & Wright G R, 1998. *County Meath Groundwater Protection Scheme*. Report to Meath County Council. Geological Survey of Ireland. 54 p Wright G R & Woods L (2003) *County Wicklow Groundwater Protection Scheme* Report to Wicklow County Council. Geological Survey of Ireland
Disclaimer	Note that all calculation and interpretations presented in this report represent estimations based on the information sources described above and established hydrogeological formulae

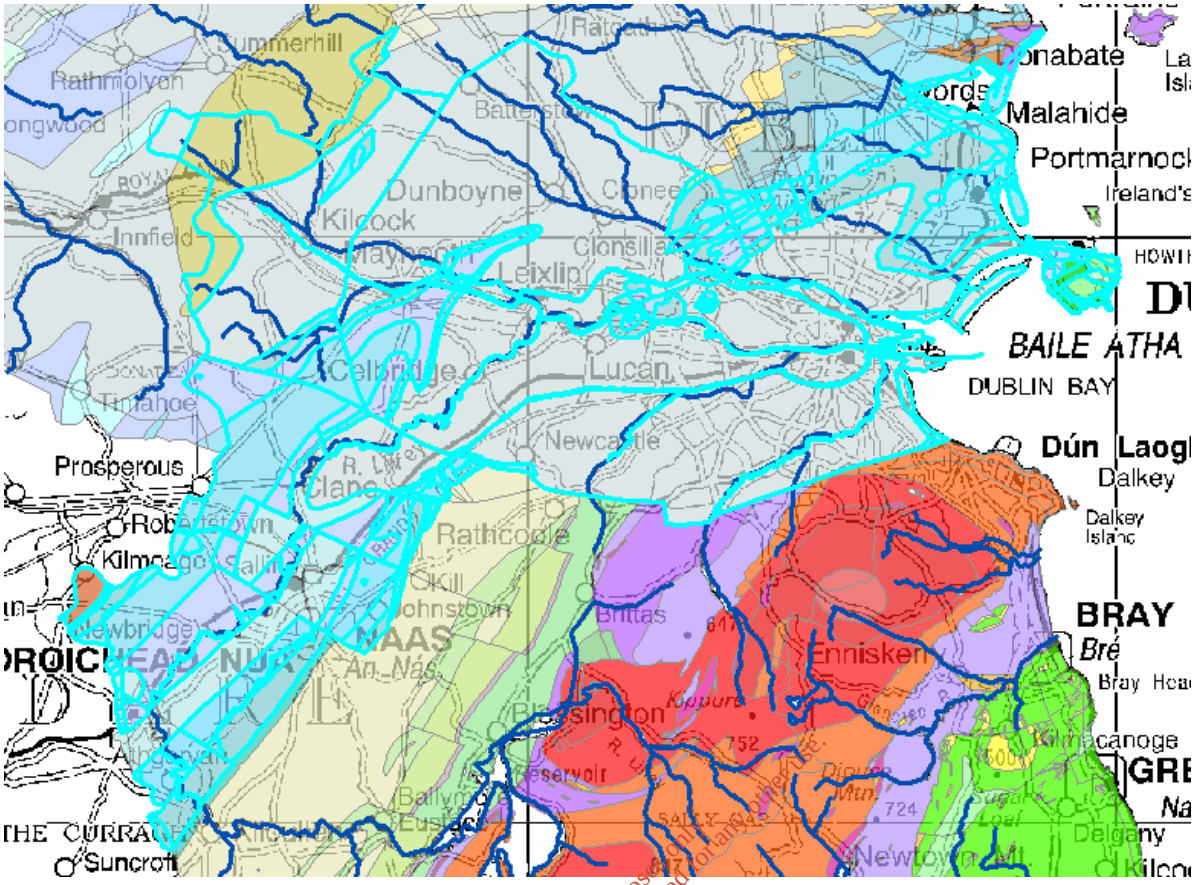
Table 1 Bedrock formations contained within the Dublin GWB

Unit Name	Code	Description
Ballysteen Formation	BA	Fossiliferous dark gray muddy limestone
Boston Hill Formation	BN	Nodular & muddy limestone & shale
Feighcullen Formation	FE	Skeletal, oolitic & micritic limestone
Lucan Formation	LU	Dark limestone & shale (`Calp)
Namurian (undifferentiated)	NAM	Shale & sandstone
Old Red Sandstone (undifferentiated)	ORS	Red conglomerate, sandstone & mudstone
Rush Conglomerate Formation	RU	Conglomerate, shale, limestone
Tober Colleen Formation	TC	Calcareous shale, limestone conglomerate
Waulsortian Limestones	WA	Massive unbedded fine-grained limestone









water matters
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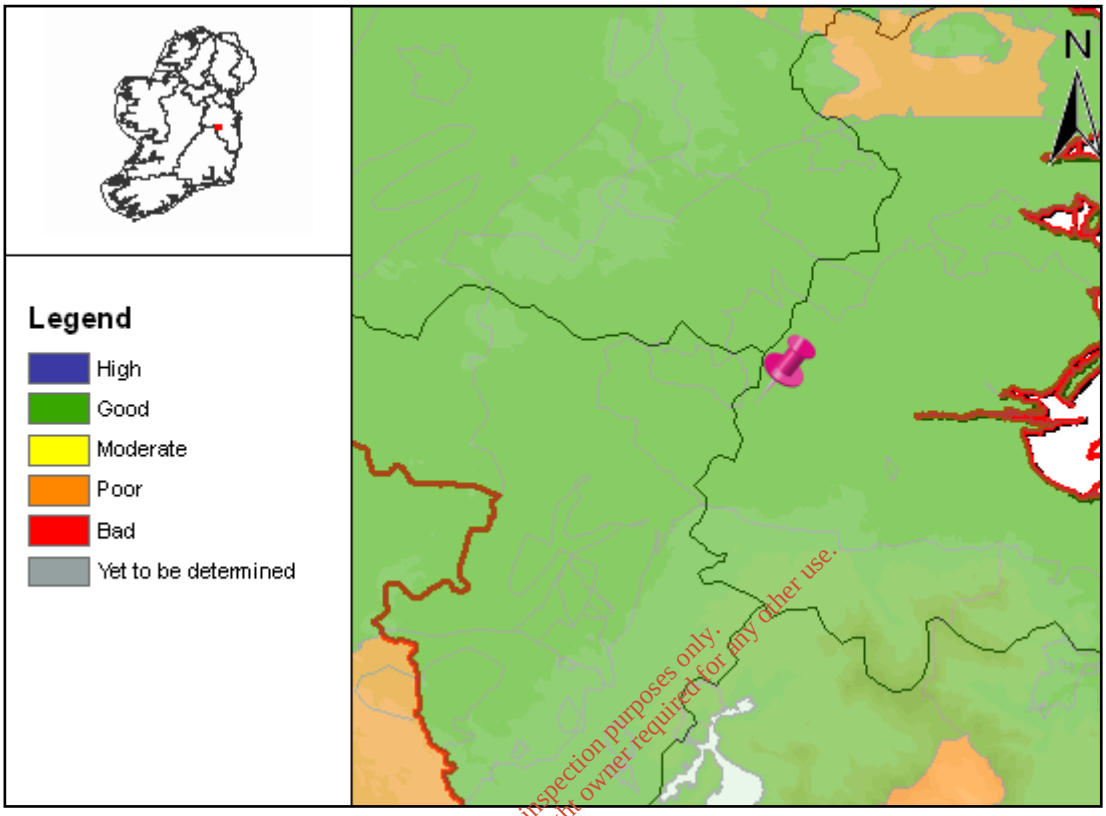
Full Report for Waterbody Dublin



River Basin Management Plans (RBMPs) have been published for all River Basin Districts in Ireland in accordance with the requirements of the Water Framework Directive. The WaterMaps viewer is an integral part of the River Basin Management Plan and provides access to information at individual waterbody level and at Water Management Unit level for all the River Basin Districts in Ireland.

The following report provides summary plan information about the selected waterbody (indicated by the pin in the map above) relating to its status, risks, objectives, and measures proposed to retain status where this is adequate, or improve it where necessary. Waterbodies can relate to surface waters (these include rivers, lakes, estuaries [transitional waters], and coastal waters), or to groundwaters. Other relevant information not included in this report can be viewed using the WaterMaps viewer, including areas listed in the Register of Protected Areas.

You will find brief notes at the bottom of some of the individual report sheets that will help you in interpreting the information presented. More detailed information can be obtained in relation to all aspects of the RBMPs at www.wfdireland.ie.

Date Reported to Europe:July 2010

Date Report Created 01/06/2012

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Summary Information:

Water Management Unit:	N/A
WaterBody Category:	Groundwater Waterbody
WaterBody Name:	Dublin
WaterBody Code:	IE_EA_G_008
Overall Status:	Good
Overall Objective:	Protect
Overall Risk:	2a Probably Not At Risk
Heavily Modified:	No

Report data based upon final RBMP, 2009-2015.

The information provided above is a summary of the principal findings related to the selected waterbody. Further details and explanation of individual elements of the report are outlined in the following pages.

Date Reported to Europe:July 2010

Date Report Created 01/06/2012

water matters
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Chemical and Quantitative Status Report

Water Management Unit:	N/A
WaterBody Category:	Groundwater Waterbody
WaterBody Name:	Dublin
WaterBody Code:	IE_EA_G_008
Overall Status Result:	Good
Heavily Modified:	No

	Status Element Description	Result
	Status information	
INS	Status associated with saline intrusion into groundwater	N/A
DWS	Status associated with exceedances of water quality above specific standards	N/A
DS	Chemical status of groundwater due to pressure from diffuse sources of pollution	N/A
CLS	Chemical status of groundwater due to pressure from contaminated soil or land.	N/A
MS	Chemical status of groundwater due to pressure from mine sites (active or closed).	N/A
UAS	Chemical status of groundwater due to pressures from urban areas	N/A
GWS	General groundwater quality status	N/A
RPS	Status associated with MRP loading to rivers	N/A
TNS	Status associated with nitrate loading to transitional and coastal waters	N/A
SWS	Overall status associated with nutrient loadings to rivers and transitional and coastal waters	N/A
SQS	Status associated with dependant surface water quantitative status	N/A
GDS	Groundwater dependant terrestrial ecosystems status	N/A
QSO	Quantitative status overall	Good
CSO	Chemical status overall	Good
OS	Overall status	Good

GS -HC : Good status High Confidence
GS- LC : Good status Low Confidence
n/a - not assessed

Status
By 'Status' we mean the condition of the water in the waterbody. It is defined by its chemical status and quantitative status, whichever is worse. Groundwaters are ranked in one of 2 status classes: Good or Poor.

You can read more about status and how it is measured in our RBMP Document Library at www.wfdireland.ie (Directory 15 Status).

Date Reported to Europe:July 2010

Date Report Created 01/06/2012

water matters
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Risk Report

Water Management Unit: N/A

WaterBody Category: Groundwater Waterbody

WaterBody Name: Dublin

WaterBody Code: IE_EA_G_008

Overall Risk Result: 2a Probably Not At Risk

Heavily Modified: No

	Risk Test Description	Risk
	Groundwater Dependent Terrestrial Ecosystems	
TE	GWDTE Risk	N/A
	Groundwater Quality	
DIF	Diffuse Elements (General) Risk	N/A
DW	Drinking Waters Risk	N/A
INT	Intrusions Risk	N/A
WB	Water Balance Risk	N/A
	Groundwater Quality (General)	
GQ	General Groundwater Quality Risk	N/A
	Groundwater Quality (Point Risk)	
CL	Contaminated Land Risk	N/A
LF	Landfill Risk	N/A
MI	Mine Risk	N/A
QY	Quarry Risk	N/A
UR	Urban Risk	N/A
UW	UWWT Risk	N/A
	GW Diffuse Risk Sources	
WB3	Mobile Nutrients (NO3)	N/A
WB4	Mobile Chemicals	N/A
WB5	Clustered OSWTSs and leaking urban sewerage systems	N/A
	GW Hydrology	
WB1	Water balance - Abstraction	N/A
WB2	Abstraction - Intrusion	N/A

Date Reported to Europe:July 2010

Date Report Created 01/06/2012

	GW Point Risk Sources		
WB10	Risk from Point sources of pollution - Contaminated Land		N/A
WB11	Risk from Point sources of pollution - Trade Effluent Discharges		N/A
WB12	Risk from Point sources of pollution - Urban Wastewater Discharges		N/A
WB6	Risk from Point sources of pollution - Mines		N/A
WB7	Risk from Point sources of pollution - Quarries		N/A
WB8	Risk from Point sources of pollution - Landfills		N/A
WB9	Risk from Point sources of pollution - Oil Industry Infrastructure		N/A
	Overall Risk		
RA	Groundwater Overall - Worst Case		N/A
	Risk information		
CLR	Contaminated land risk	2b	Not At Risk
DR	Risk of groundwater due to pressure from diffuse sources of pollution	2a	Probably Not At Risk
DWR	Risk associated with exceedances of water quality above specific standards	2b	Not At Risk
GDR	Groundwater dependant terrestrial ecosystems risk	2b	Not At Risk
GWR	General groundwater quality risk	2a	Probably Not At Risk
INR	Risk associated with saline intrusion into groundwater	2b	Not At Risk
LR	Risk due to landfills sites/old closed dump sites	2b	Not At Risk
MR	Mines risk	2b	Not At Risk
NULL	Diffuse nitrates from agriculture risk		N/A
QR	Risk due to quarries	2b	Not At Risk
RA	Revised risk assessment	2a	Probably Not At Risk
RPR	Risk associated with MRP loading to rivers	2b	Not At Risk
SQR	Risk associated with dependant surface water quantitative status	2b	Not At Risk
SWR	Overall risk associated with nutrient loadings to rivers and transitional and coastal waters	2b	Not At Risk
TNR	Risk associated with nitrate loading to transitional and coastal waters	2b	Not At Risk
UAR	Risk of groundwater due to pressures from urban areas	2b	Not At Risk
UWR	Risk due to direct discharges of urban wastewater	2b	Not At Risk

Risk
By 'risk' we mean the risk that a waterbody will not achieve good ecological or good chemical status/potential at least by 2015. To examine risk the various pressures acting on the waterbody were identified along with any evidence of impact on water status. Depending on the extent of the pressure and its potential for impact, and the amount of information available, the risk to the water body was placed in one of four categories: 1a at risk; 1b probably at risk; 2a probably not at risk; 2b not at risk. Note that '2008' after the risk category means that the risk assessment was revised in 2008. All other risks were determined as part of an earlier risk assessment in 2005.

You can read more about risk assessment in our 'WFD Risk Assessment Update' document in the RBMP document library, and other documents at www.wfdireland.ie (Directory 31 Risk Assessments).

Date Reported to Europe:July 2010

Date Report Created 01/06/2012

water matters
'our Plan'

Objectives Report

Water Management Unit: N/A

WaterBody Category: Groundwater Waterbody

WaterBody Name: Dublin

WaterBody Code: IE_EA_G_008

Overall Objective: Protect

Heavily Modified: No

	Objectives Description	Result
	Objectives information	
OB1	Prevent deterioration objective	Protect
OB2	Restore at least good status objective	No Status
OB3	Reduce chemical pollution objective	No Status
OB4	Protected areas objective	No Status
OBO	Overall objectives - objective	Protect

Extended timescales
Extended timescales have been set for certain waters due to technical, economic, environmental or recovery constraints. Extended timescales are usually of one planning cycle (6 years, to 2021) but in some cases are two planning cycles (to 2027).

Objectives
In general, we are required to ensure that our waters achieve at least good status/potential by 2015, and that their status does not deteriorate. Having identified the status of waters (this is given earlier in this report), the next stage is to set objectives for waters. Objectives consider waters that require protection from deterioration as well as waters that require restoration and the timescales needed for recovery. Four default objectives have been set initially:-

Prevent Deterioration
Restore Good Status
Reduce Chemical Pollution
Achieve Protected Areas Objectives

These objectives have been refined based on the measures available to achieve them, the latter's likely effectiveness, and consideration of cost-effective combinations of measures. Where it is considered necessary extended deadlines have been set for achieving objectives in 2021 or 2027.

Date Reported to Europe:July 2010

Date Report Created 01/06/2012

APPENDIX 4

- KILDARE C.C. LOCAL AREA ENGINEER'S REPORT OF MARCH, 2005 REGARDING FLOODING IN THE CLANE AREA

- WATER CATCHMENT & HYDROMETRIC STATION MAP

- EPA BIOLOGICAL MONITORING LOCATION MAP – Q-RATING

- EASTERN RIVER BASIN MANAGEMENT BODY HYDROLOIGAL RISK ASSESSMENT REPORT FOR THE WATERBODY LIFFEY_LOWER3

MINUTES OF MEETING

Reference:	**P4D403A – F310 – 017 – 004-001**	**Page 1 of 3**
Project No.:	**P4D403A**	
Project Title:	**OPW Flood Hazard Mapping – Phase 1**	
Purpose of Meeting:	**Kildare County Council – Oral Report – Area Engineer – Clane**	
Participating:	**Area Engineer** **Supervisor** **Search Manager**	**Kildare County Council** **Kildare County Council** **ESBI**
Venue:	**Clane**	
Date of Meeting:	**22/03/05**	
Copies to: **Compiled by:**	**Search Manager ESBI**	
Status	**Draft**	
Approved for ESBI:		
Approved for Kildare County Council		
Date:		

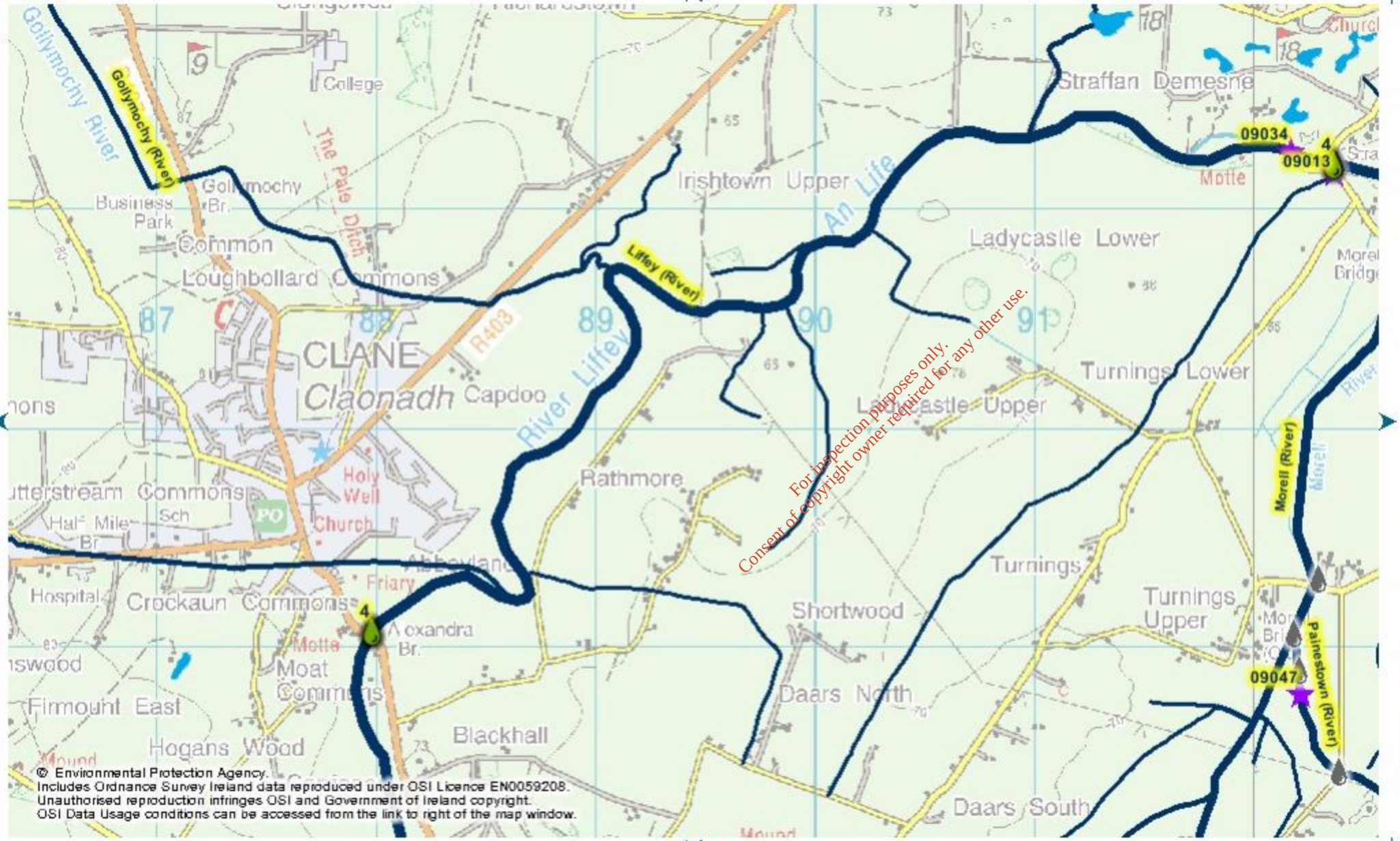
Meeting with Area Engineer for Clane 22/03/05

The Area Engineer and his supervisor outlined 29 areas that are or were prone to flooding. These are: -

1. Newtown – River Blackwater overflows its banks after heavy rain. This occurs every year.
   Flood Id = 1272
2. Timoltan/Fanagh – Drain overflows after heavy rain every year. A property is affected. Road is liable to flooding.
   Flood Id = 1274
3. Clonshanbo – The Clonshanbo river overflows its banks after heavy rain every year. The main Clane – Kilcock road is liable to flooding and was flooded in January 2005. Road has been raised by the council.
   Flood Id = 1276
4. Staplestown at mill pond – Mill pond over flows after heavy rain a couple of times per year. County road is liable to flooding.
   Flood Id = 1277
5. Allenwood – Low lying area floods after heavy rain. Road is liable to flooding. No property is affected
   Flood Id = 1278
6. Prosperous – A property is flooded after heavy rain every year
   Flood Id = 1279
7. Killinagh – Area floods after heavy rain every year. The culvert of a stream under the Grand Canal can't take volume of water.
   Flood Id = 1280
8. Bluetown– Flooding occurs after heavy rain every year. This is due to inadequate drainage and drains being filled in by property owners
   Flood Id = 1281
9. Staplestown Bog– Road is liable to flooding after heavy rain every year.
   Flood Id = 1282
10. Killeenmore - Flood plain of Morell river and tributaries. A number of properties were flooded in November 2000 and November 2002. OPW have undertaken remedial work
    Flood Id = 1283
11. Ladyhill– River overflows its banks onto flood plain after heavy rain. Road is liable to flood.
    Flood Id = 1284
12. Commons, Clane- The Butterstream overflows its banks after heavy rain every year. A property is affected. Road is liable to flooding
    Flood Id = 1285
13. Ballycaghan – Low lying land floods every year. Road is liable to flooding
    Flood Id = 1287
14. School Street, Kilcock – Low lying land floods after heavy rain every year due to inadequate drainage
    Flood Id = 1288
15. Kilcock – Low lying land floods after heavy rain every year due to inadequate drainage
    Flood Id = 1289
16. Ryewater, Kilcock – Ryewater overflows its banks after heavy rain every year onto flood plain.
    Flood Id = 1290
17. Millicent Road, Clane – Low lying area floods after heavy rain every year due to inadequate and blocked drainage. Road is liable to flood . There has been significant development.

Flood Id = 1291

18. Laragh– Stream overflows its banks after heavy rain every year. Road is liable to flood. This area flooded in 2005
    Flood Id = 1292
19. Loughballard, Clane – Low lying area floods every year after heavy rain due to inadequate drainage
    Flood Id = 1293
20. Clonfert – Property is flooded after heavy rain. Water flows off high land and stream overflows
    Flood id = 1294
21. Carrick Hill – Low point in upland area floods after heavy rain. The council may have resolved the issue.
    Flood id = 1295
22. Boyne Bridge, Edenderry – Flood plain of the River Boyne
    Flood Id = 1296
23. Ballycowan – Flood plain of the River Boyne
    Flood Id = 1297
24. Thomastown – Stream overflow its banks after significant rainfall. Last flooded November 2000
    Flood Id = 1298
25. Calfstown – Low lying area floods after heavy rain. The garden of a Property has been flooded
    Flood Id = 1299
26. Oldcourt Road – Water flows across road after heavy rain
    Flood Id = 1300
27. Moyvally – Water flows off the main road into the side road after heavy rain every year
    Flood Id = 1301
28. Carbury – Standing water in bog every winter
    Flood Id = 1302
29. Knockanally/Dysart – Flood plain of tributaries of River Blackwater.
    Flood Id = 1303



Legend

Bathing Water Quality

- Good Water Quality 2010
- Sufficient Water Quality 2010
- Poor Water Quality 2010
- No 2010 results - New for 2011

Current River Quality

- Q4-5, Q5 - High Status
- Q4 - Good Status
- Q3-4 - Moderate Status
- Q2-3, Q3 - Poor Status
- Q1, Q1-2, Q2 - Bad Status

Historical River Qualit

Lake Quality 2007 - 2009

- Oligotrophic/Mesotrophic
- Moderately Eutrophic
- Highly/Strongly Eutrophic
- Hypertrophic

Coastal and Estuarine

Links

Information about data changes and up

More information on EPA spatial data service

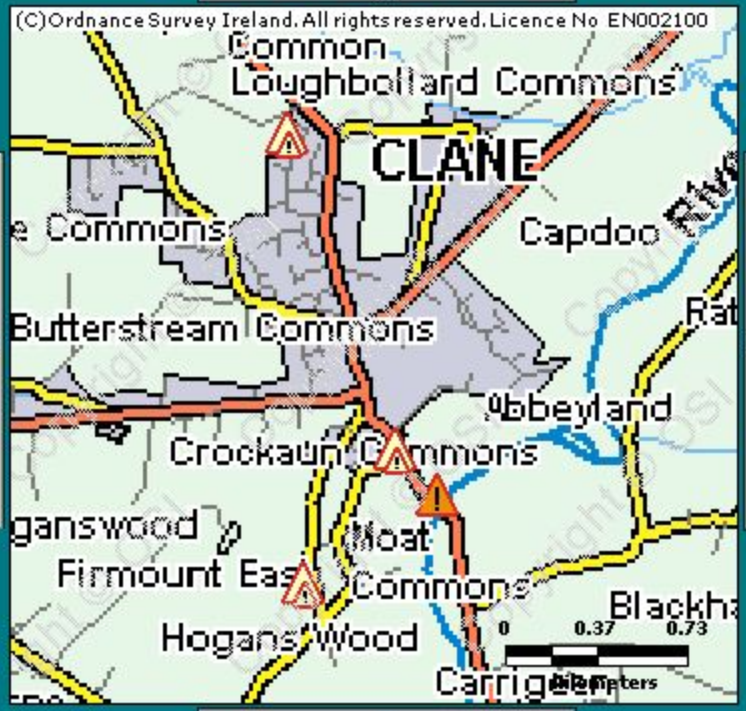
Usage of this viewer implies acceptance of th

EPA Export 26-05-2018:04:34:43

OPW

National Flood Hazard Mapping

Navigation Tools | Selection Tools



Use the Search options below to find Flood Events by Location

County: Kildare

Town: Clane

or Townland:

Catchment: Select

National Grid Reference: -

Open Advanced Search

Search Results: Location Search

(1-2) of 4 Results Listed.

1. Flood Event: Liffey Clane Dec 1954
Start Date: 08/Dec/1954
County: Kildare
Flood Quality Code: 2

Additional Information

Reports (2) Press Archive (1) More Mapped Information

2. Flood Event: Loughbollard, Clane Recurring
Start Date: -
County: Kildare
Flood Quality Code: 4

Additional Information

Reports (1) More Mapped Information

(1-2) of 4 Results Listed.

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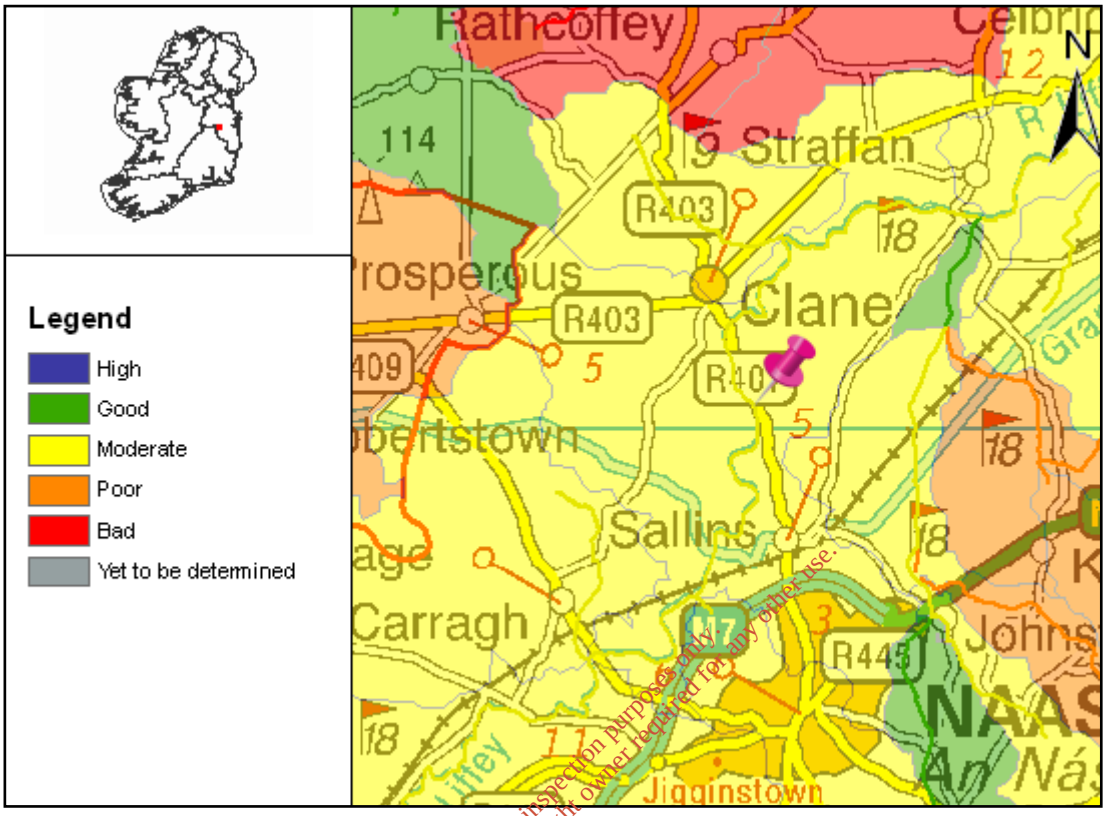
Full Report for Waterbody Liffey Lower 3



River Basin Management Plans (RBMPs) have been published for all River Basin Districts in Ireland in accordance with the requirements of the Water Framework Directive. The WaterMaps viewer is an integral part of the River Basin Management Plan and provides access to information at individual waterbody level and at Water Management Unit level for all the River Basin Districts in Ireland.

The following report provides summary plan information about the selected waterbody (indicated by the pin in the map above) relating to its status, risks, objectives, and measures proposed to retain status where this is adequate, or improve it where necessary. Waterbodies can relate to surface waters (these include rivers, lakes, estuaries [transitional waters], and coastal waters), or to groundwaters. Other relevant information not included in this report can be viewed using the WaterMaps viewer, including areas listed in the Register of Protected Areas.

You will find brief notes at the bottom of some of the individual report sheets that will help you in interpreting the information presented. More detailed information can be obtained in relation to all aspects of the RBMPs at www.wfdireland.ie.

Date Reported to Europe:July 2010

Date Report Created 27/03/2012

water matters
'our Plan'

Summary Information:

Water Management Unit:	IE_EA_Liffey
WaterBody Category:	River Waterbody
WaterBody Name:	Liffey Lower 3
WaterBody Code:	IE_EA_09_1870_3
Overall Status:	Moderate
Overall Objective:	Restore_2027
Overall Risk:	1a At Risk
Heavily Modified:	No

Report data based upon final RBMP, 2009-2015.

The information provided above is a summary of the principal findings related to the selected waterbody. Further details and explanation of individual elements of the report are outlined in the following pages.

Date Reported to Europe:July 2010

Date Report Created 27/03/2012

water matters
'our Plan'

Status Report

Water Management Unit:	IE_EA_Liffey
WaterBody Category:	River Waterbody
WaterBody Name:	Liffey Lower 3
WaterBody Code:	IE_EA_09_1870_3
Overall Status Result:	Moderate
Heavily Modified:	No

	Status Element Description	Result
	Status information	
Q	Macroinvertebrate status	Moderate
PC	General physico-chemical status	Moderate
FPQ	Freshwater Pearl Mussel / Macroinvertebrate status	N/A
DIA	Diatoms status	N/A
HYM	Hydromorphology status	Good
FIS	Fish status	N/A
SP	Specific Pollutants status (SP)	N/A
ES	Overall ecological status	Moderate
CS	Overall chemical status (PAS)	N/A
EXT	Extrapolated status	N/A
MON	Monitored water body	YES
DON	Donor water bodies	N/A

n/a - not assessed

Status
By 'Status' we mean the condition of the water in the waterbody. It is defined by its chemical status and its ecological status, whichever is worse. Waters are ranked in one of 5 status classes: High, Good, Moderate, Poor, Bad. However, not all waterbodies have been monitored, and in such cases the status of a similar nearby waterbody has been used (extrapolated) to assign status. If this has been done the first line of the status report shows the code of the waterbody used to extrapolate.

You can read more about status and how it is measured in our RBMP Document Library at www.wfdireland.ie (Directory 15 Status).

Date Reported to Europe:July 2010

Date Report Created 27/03/2012

water matters
'our Plan'

Risk Report

Water Management Unit: IE_EA_Liffey

WaterBody Category: River Waterbody

WaterBody Name: Liffey Lower 3

WaterBody Code: IE_EA_09_1870_3

Overall Risk Result: 1a At Risk

Heavily Modified: No

	Risk Test Description		Risk
	Diffuse Risk Sources		
RD1	EPA diffuse model (2008)	1a	At Risk
RD2a	Road Wash - Soluble Copper	2a	Probably Not At Risk
RD2b	Road Wash - Total Zinc	2a	Probably Not At Risk
RD2c	Road Wash - Total Hydrocarbons	2a	Probably Not At Risk
RD3	Railways	2b	Not At Risk
RD4a	Forestry - Acidification (2008)	2b	Not At Risk
RD4b	Forestry - Suspended Solids (2008)	2b	Not At Risk
RD4c	Forestry - Eutrophication (2008)	2a	Probably Not At Risk
RD5	Overall Unsewered (2008)	1a	At Risk
RD5a	Unsewered Areas - Pathogens (2008)	1a	At Risk
RD5b	Unsewered Phosphorus (2008)	2b	Not At Risk
RD6a	Arable	2b	Not At Risk
RD6b	Sheep Dip	2b	Not At Risk
RD6c	Forestry - Dangerous Substances	2b	Not At Risk
RDO	Diffuse Overall -Worst Case (2008)	1a	At Risk
	Hydrology		
RHY1	Water balance - Abstraction		N/A
	Morphological Risk Sources		
RM1	Channelisation (2008)	2b	Not At Risk
RM2	Embankments (2008)	2b	Not At Risk
RM3	Impoundments	1a	At Risk
RM4	Water Regulation	2b	Not At Risk
RM5	Intensive Landuse		N/A
RMO	Morphology Overall - Worst Case (2008)	1a	At Risk
	Overall Risk		
RA	Rivers Overall - Worst Case (2008)	1a	At Risk

Date Reported to Europe:July 2010

Date Report Created 27/03/2012

	Point Risk Sources		
RP1	WWTPs (2008)	1a	At Risk
RP2	CSOs	1a	At Risk
RP3	IPPCs (2008)	2b	Not At Risk
RP4	Section 4s (2008)	2b	Not At Risk
RP5	WTPs/Mines/Quarries/Landfills		N/A
RPO	Overall Risk from Point Sources - Worst Case (2008)	1a	At Risk
	Q Value		
Q	EPA Q rating and Margaritifera Assessment		N/A
	Q/RDI or Point/Diffuse		
QPD	Q class/EPA Diffuse Model or worst case of Point and Diffuse (2008)	1a	At Risk
	Rivers Direct Impacts		
RDI1	Rivers Direct Impacts - Dangerous Substances		N/A

Risk
By 'risk' we mean the risk that a waterbody will not achieve good ecological or good chemical status/potential at least by 2015. To examine risk the various pressures acting on the waterbody were identified along with any evidence of impact on water status. Depending on the extent of the pressure and its potential for impact, and the amount of information available, the risk to the water body was placed in one of four categories: 1a at risk; 1b probably at risk; 2a probably not at risk; 2b not at risk. Note that '2008' after the risk category means that the risk assessment was revised in 2008. All other risks were determined as part of an earlier risk assessment in 2005.

You can read more about risk assessment in our 'WFD Risk Assessment Update' document in the RBMP document library, and other documents at www.wfdireland.ie (Directory 31 Risk Assessments).

Date Reported to Europe:July 2010

Date Report Created 27/03/2012

water matters
'our Plan'

Objectives Report

Water Management Unit: IE_EA_Liffey

WaterBody Category: River Waterbody

WaterBody Name: Liffey Lower 3

WaterBody Code: IE_EA_09_1870_3

Overall Objective: Restore_2027

Heavily Modified: No

	Objectives Description	Result
	Objectives information	
OB1	Prevent deterioration objective	No Status
OB2	Restore at least good status objective	No Status
OB3	Reduce chemical pollution objective	No Status
OB4	Protected areas objective	Restore_2027
OB5	Northern Ireland Environment Agency objective	No Status
OBO	Overall objectives	Restore_2027

Extended timescales
Extended timescales have been set for certain waters due to technical, economic, environmental or recovery constraints. Extended timescales are usually of one planning cycle (6 years, to 2021) but in some cases are two planning cycles (to 2027).

Objectives
In general, we are required to ensure that our waters achieve at least good status/potential by 2015, and that their status does not deteriorate. Having identified the status of waters (this is given earlier in this report), the next stage is to set objectives for waters. Objectives consider waters that require protection from deterioration as well as waters that require restoration and the timescales needed for recovery. Four default objectives have been set initially:-

Prevent Deterioration
Restore Good Status
Reduce Chemical Pollution
Achieve Protected Areas Objectives

These objectives have been refined based on the measures available to achieve them, the latter's likely effectiveness, and consideration of cost-effective combinations of measures. Where it is considered necessary extended deadlines have been set for achieving objectives in 2021 or 2027.

Date Reported to Europe:July 2010

Date Report Created 27/03/2012

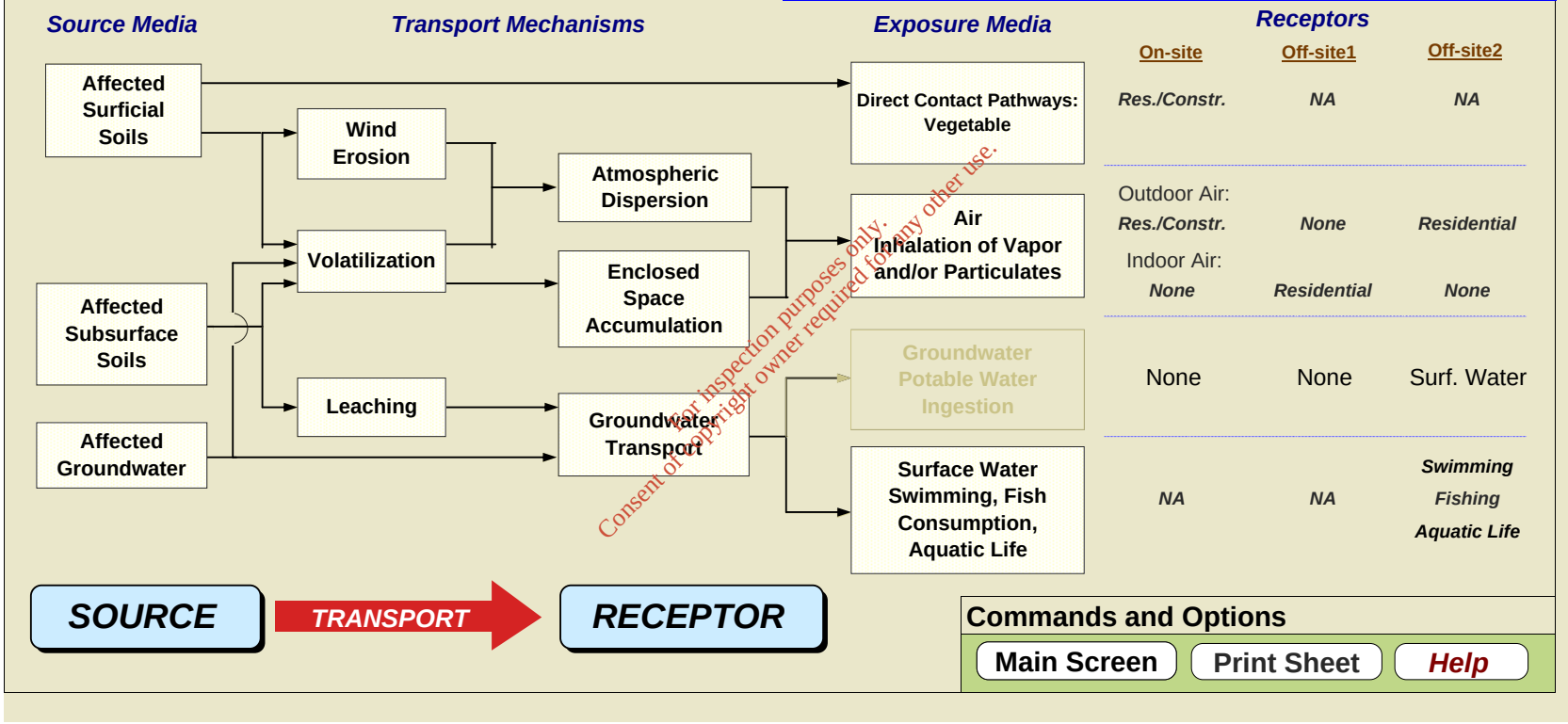
APPENDIX 5

EXPOSURE PATHWAY FLOWCHART

- TABLE A5.1 EXPOSURE ASSESSMENT PARAMETERS FOR RESIDENTIAL USE – INPUTS FOR RBCA MODEL
- TABLE A5.2 ADDITIONAL PARAMETERS FOR CONTINUED RESIDENTIAL USE - INPUTS FOR RBCA MODEL
- TABLE A5.3. CHEMICAL PROPERTIES OF CHEMICALS OF CONCERN
- TABLE A5.4. INPUT PARAMETER SUMMARY SHEET
- TABLE A5.5. CONCENTRATIONS OF CONTAMINANTS OF CONCERN
- TABLE A5.6. CALCULATED SITE SPECIFIC TARGET LEVELS FOR SOIL (0.4-0.5M BGL)
- TABLE A5.7. CALCULATED SITE SPECIFIC TARGET LEVELS FOR SUBSOIL (0.5-1.1M BGL)
- TABLE A5.8. CALCULATED SITE SPECIFIC TARGET LEVELS FOR GROUNDWATER
- TABLE A5.9. CUMULATIVE RISK WORKSHEET

Exposure Pathway Flowchart

Site Name: Carrigeen Landfill | Job ID: Historic LF
Location: Clane, County Kildare | Date: 31.05.2012
Compl. By: Padraic Mulroy, Mulroy Environmental



Commands and Options

Main Screen | Print Sheet | Help

Table A5.1 Exposure Assessment Parameters for Residential Use - Inputs for RBCA Model

PARAMETER	VALUE	JUSTIFICATION
Averaging time	43 years	Equal to exposure duration - CLR 10 for residential end use.
Body weight	68.5kg	Adult female in line with CLR10 for residential end use.
Exposure frequency	365 days	In line with CLR10 for a residential end use, Table 6.1.
Exposure duration	43 years	Equal to exposure duration - CLR 10 for residential end use.

Table A5.2 Additional Parameters for Residential Use - Inputs for RBCA Model

PARAMETER	VALUE	JUSTIFICATION
Depth to water bearing unit	1.07m	This is the standing water level identified in the nearest monitoring borehole, BH01 which is approximately 107m from the River Liffey
Soil type – Taken as sand as most permeable underlying geology encountered during intrusive site investigation		
Total porosity	0.46 [-]	CLEA sand from Briefing Note 2 as this is the most permeable CLEA soil and underlying site geology comprises sands and gravels.
Volumetric water content	0.15 [-]	
Dry bulk density	1.6	
Vertical hydraulic conductivity	5.6m/d	
Vapour permeability	7.20E-12m^2	Calculated for a CLEA sand using equations in Briefing Note 2.
Capillary zone thickness	0.05m	Default value for sand from RBCA as RBCA sand is similar to CLEA sand and value is not included in Briefing Note 2.
Fraction of organic carbon	0.0058	Modelling used 1% SOM (0.58% TOC) in line with the published CLEA SGVs using CLEA sand.
Soil/water pH	8.25	Field pH at BH01 during site investigation was 8.25
Groundwater plume width at source	124m	Measured distance perpendicular to groundwater flow direction between BH01 and BH02 with an extra 4m (i.e. 2m to edge of plume)
Foundation area	221m^2	Based on site data for nearest residence to the west.
Foundation perimeter	63m	
Building volume/area ratio	5m	Considered reasonable for residence.
Building air exchange rate	24 No./day	CLEA Briefing Note 3 for a commercial property, considered reasonable for a residence.
Depth to slab base	0.15m	Briefing Note 3 for a residentail property, considered reasonable for a for an residence.
Foundation crack fraction	0.00028 [-]	Calculated using building perimeter and foundation area in line with Briefing Note 3 (0.002m x perimeter/area).
Volumetric air content of cracks	0.31 [-]	Assumed equal to underlying soil type in assumption that cracks become filled with soil over time. Discussion for Equation 6 -Briefing Note 2. Underlying soil is assumed to be CLEA sand.
Volumetric water content of cracks	0.15 [-]	
Indoor/outdoor differential pressure	25g/cm/s^2	There is no specific information available for an industrial building, reasonable value used.

Table A5.3. Chemical Properties of Chemicals of Concern

CHEMICAL DATA FOR SELECTED COCs

Physical Property Data

Constituent	CAS Number	Type	Molecular Weight (g/mole)		Aqueous Solubility (@ 20 - 25 C) (mg/L)		Soil Saturation Limit Calculated	Vapor Pressure (@ 20 - 25 C) (mm Hg)		Henry's Constant (@ 20 - 25 C) (unitless)		log (Koc) or log (Kd) (@ 20 - 25 C) log(L/kg)		
Benzo-a-pyrene	50-32-8	O	252.31528	TX07	0.00162	TX07	9.937623825	4.89E-09	TX07	4.70E-05	TX07	5.98E+00	Koc	TX07
Ammonia	7664-41-7	I	17.03052	TX07	531000	TX07	error Ksw	7.47E+03	TX07	1.36E-02	TX07	4.90E-01	Koc	TX07
Manganese	7439-96-5	M	54.938	TX07	0	TX07	1000000	0.00E+00	TX07	0.00E+00	TX07	1.70E+00	Kd	TX07
Arsenic	7440-38-2	M	74.9216	TX07	0	TX07	1000000	0.00E+00	TX07	0.00E+00	TX07	1.40E+00	Kd	TX07

Site Name: Carrigeen Landfill
Site Location: Clane, County Kildare
Job ID: Historic LF
Date Completed: 31.05.2012
Completed By: Padraic Mulroy, Mulroy Environmental

Table A5.3. Chemical Properties of Chemicals of Concern

CHEMICAL DATA FOR SELECTED COCs

Physical Property Data

Constituent	pH specific Kd for non-organics: Surface Soil Column Slope	Surface Soil Column y-Intercept	Surface Soil Column logKd_pH (L/kg)	Water Bearing Unit Slope	Water Bearing Unit y-Intercept	Water Bearing Unit logKd_pH (L/kg)		log(Kow) (@ 20 - 25 C) log(L/kg)		Diffusion Coefficients: Air (cm^2/s)		Water (cm^2/s)	
Benzo-a-pyrene	-	-	-	-	-	-	-	6.11E+00	TX07	4.30E-02	TX07	9.00E-06	TX07
Ammonia	-	-	-	-	-	-	-	2.29E-01	TX07	2.59E-01	TX07	6.93E-05	TX07
Manganese	-	-	-	-	-	-	-	0.00E+00	TX07	0.00E+00	TX07	0.00E+00	TX07
Arsenic	3.05E-02	1.25E+00	1.50E+00	3.05E-02	1.25E+00	1.50E+00	E2	6.79E-01	TX07	0.00E+00	TX07	0.00E+00	TX07

Site Name: Carrigeen Landfill
Site Location: Clane, County Kildare
Job ID: Historic LF
Date Completed: 31.05.2012
Completed By: Padraic Mulroy, Mulroy Environmental

Table A5.3. Chemical Properties of Chemicals of Concern

CHEMICAL DATA FOR SELECTED COCs

Miscellaneous Parameters

Constituent	Analytical Detection Limits: Groundwater (mg/L)		Analytical Detection Limits: Soil (mg/kg)		Half Life (First-Order Decay): Saturated (days)	Half Life (First-Order Decay): Unsaturated (days)		Soil-to-Plant Biotransfer Factors: Above-grd (unitless)	Soil-to-Plant Biotransfer Factors: Below-grd (unitless)		Relative Bioavailability Factor		Leaf Concen. Factor Calculated (mg/kg)/(mg/L)	Root Concen. Factor Calculated (mg/kg)/(mg/L)	Bioconcentration Factor	
Benzo-a-pyrene	1.00E-02	S2	6.60E-01	S2	1.06E+03	1.06E+03	H	-	-	-	1.00E+00	TX07	2.0636	1528.1399	26000	LY
Ammonia	-	-	-	-	-	-	-	-	-	-	1.00E+00	TX07	-	-	-	-
Manganese	-	-	2.00E-03	S	7.00E+00	7.00E+00	H	1.00E-01	5.00E-02	TX07	1.00E+00	TX07	-	-	-	-
Arsenic	1.00E-02	S	5.30E-02	S	-	-	-	1.00E-02	8.00E-03	TX07	7.80E-01	TX07	-	-	-	-

Site Name: Carrigeen Landfill
Site Location: Clane, County Kildare
Job ID: Historic LF
Date Completed: 31.05.2012
Completed By: Padraic Mulroy, Mulroy Environmental

Table A5.3. Chemical Properties of Chemicals of Concern

CHEMICAL DATA FOR SELECTED COCs

Dermal Exposure

Constituent	Water Dermal Permeability Data					
	Dermal Permeability Coeff. (cm/hr)	Lag time for Dermal Exposure (hr)	Critical Exposure Time (hr)	Relative Contr of Derm Perm Coeff	Water/Skin Derm Ads. Fact Calculated	
Benzo-a-pyrene	1.2	2.9	14	130	9.782988812	D
Ammonia	0.001	-	-	-	-	D
Manganese	0.001	-	-	-	-	D
Arsenic	0.001	-	-	-	-	D

Site Name: Carrigeen Landfill
Site Location: Clane, County Kildare
Job ID: Historic LF
Date Completed: 31.05.2012
Completed By: Padraic Mulroy, Mulroy Environmental

Table A5.3. Chemical Properties of Chemicals of Concern

CHEMICAL DATA FOR SELECTED COCs

Constituent	Dermal Relative Abs. Factor Calculated	Absorbtion Fraction		
		Dermal (unitless)	Gastrointestinal (unitless)	
Benzo-a-pyrene	0.146067416	0.13	0.89	TX07
Ammonia	0.05	0.01	0.2	TX07
Manganese	0.166666667	0.01	0.06	TX07
Arsenic	0.031578947	0.03	0.95	TX07

Site Name: Carrigeen Landfill
Site Location: Clane, County Kildare
Job ID: Historic LF
Date Completed: 31.05.2012
Completed By: Padraic Mulroy, Mulroy Environmental

Table A5.3. Chemical Properties of Chemicals of Concern

CHEMICAL DATA FOR SELECTED COCs

Regulatory Standards

Constituent	Maximum Contaminant Level		Time-Weighted Average Workplace Criteria		UK Soil Guideline Values				
					Residential/Plant mg/kg	Residential/No Plant mg/kg	Allotments mg/kg	Commercial/Ind. mg/kg	
Benzo-a-pyrene	0.0002	MC	0.2	OS	-	-	-	-	-
Ammonia	-	-	35	OS	-	-	-	-	-
Manganese	-	-	1	OS	-	-	-	-	-
Arsenic	0.01	MC	0.5	OS	-	-	-	-	-

Site Name: Carrigeen Landfill
Site Location: Clane, County Kildare
Job ID: Historic LF
Date Completed: 31.05.2012
Completed By: Padraic Mulroy, Mulroy Environmental

Table A5.3. Chemical Properties of Chemicals of Concern

CHEMICAL DATA FOR SELECTED COCs

Regulatory Standards

	Surface Water Quality Criteria									
	Aquatic Life Protection				Human Health Protection					
Constituent	Freshwater (mg/L)		Marine (mg/L)		Drink & Freshwater Fish (mg/L)		Freshwater Fish (mg/L)		Saltwater Fish (mg/L)	
Benzo-a-pyrene	-	-	-	-	0.000099	T3	0.00081	T3	0.00054	T3
Ammonia	-	-	-	-	-	-	-	-	-	-
Manganese	-	-	-	-	-	-	-	-	-	-
Arsenic	0.19	T1	0.078	T1	0.05	T3	0.00014	E	0.00014	E

Site Name: Carrigeen Landfill
Site Location: Clane, County Kildare
Job ID: Historic LF
Date Completed: 31.05.2012
Completed By: Padraic Mulroy, Mulroy Environmental

Table A5.3. Chemical Properties of Chemicals of Concern

CHEMICAL DATA FOR SELECTED COCs

Toxicity Parameters

Constituent	Oral RfD or TDSI (mg/kg/day)		Dermal RfD or TDSI (mg/kg/day)		Inhalation Equivalent RfC or TCA (mg/m^3)		Oral Equivalent Slope Factor 1/(mg/kg/day)		Dermal Equivalent Slope Factor 1/(mg/kg/day)		Inhalation Equivalent Unit Risk Factor 1/($\mu g/m^3$)	
Benzo-a-pyrene	-	-	-	-	-	-	7.3	EPA-I	7.3	D2	0.00088	EPA-N
Ammonia	-	-	-	-	0.1	EPA-I	-	-	-	-	-	-
Manganese	-	-	-	-	0.00005	EPA-I	-	-	-	-	-	-
Arsenic	0.0003	EPA-I	0.0003	D2	-	-	1.5	EPA-I	1.5	D2	0.0043	EPA-I

Site Name: Carrigeen Landfill
Site Location: Clane, County Kildare
Job ID: Historic LF
Date Completed: 31.05.2012
Completed By: Padraic Mulroy, Mulroy Environmental

Table A5.4 Input Parameter Summary Sheet

RBCA SITE ASSESSMENT — Input Parameter Summary

Site Name: Carrigeen Landfill
Site Location: Clane, County Kildare

Completed By: Padraic Mulroy, Mulroy Environmental
Date Completed: 31.05.2012

Exposure Parameters		Residential				Commercial/Industrial		User Defined
		Child*	Adolescent	Adult	Age Adjusted**	Adult	Construction	
ATc	Averaging time for carcinogens (yr)	43	43	43				-
ATn	Averaging time for non-carcinogens (yr)	6	12	43		25	1	-
BW	Body weight (kg)	15	35	68.5		70	70	-
ED	Exposure duration (yr)	6	12	30		25	1	-
τ	Averaging time for vapor flux (yr)	30	30	30		25	1	-
EF	Exposure frequency (days/yr)	365	365	365		250	180	-
EFD	Exposure frequency for dermal exposure	365	365	365		250	180	-
IRw	Ingestion rate of water (L/day)	1	1	2	2.5	1		-
IRs	Ingestion rate of soil (mg/day)	200	200	100	379	50	100	-
SA	Skin surface area (dermal) (cm^2)	2023	2023	3160	4695	3160	3160	-
M	Soil to skin adherence factor	0.5	0.5	0.5				-
ETswim	Swimming exposure time (hr/event)	1	3	3				
EVswim	Swimming event frequency (events/yr)	12	12	12				
IRswim	Water ingestion while swimming (L/hr)	0.5	0.5	0.05	0.6			
SAswim	Skin surface area for swimming (cm^2)	3500	8100	23000	18738			
IRfish	Ingestion rate of fish (kg/yr)	0.025	0.025	0.025	0.052			
FIfish	Contaminated fish fraction (unitless)	1	1	1				
IRbg	Below-ground vegetable ingestion	0.002	0.002	0.006	0.006			
IRabg	Above-ground vegetable ingestion	0.001	0.001	0.002	0.002			
VGbg	Above-ground Veg. Ingest. Correction Factor	0.01	0.01	0.01				
VGabg	Below-ground Veg. Ingest. Correction Factor	0.01	0.01	0.01				

* = Child Receptor used for Non-Carcinogens
** = Age-adjusted rate is effective value corresponding to adult exposure factors.

Complete Exposure Pathways and Receptors	On-site	Off-site 1	Off-site 2
Groundwater:			
Groundwater Ingestion	None	None	Surf. Water
Soil Leaching to Groundwater Ingestion	None	None	Surf. Water
Apply Secondary MCLs	No	No	No
Applicable Surface Water Exposure Routes:			
Swimming	*NA*	*NA*	None
Fish Consumption	*NA*	*NA*	None
Aquatic Life Protection	*NA*	*NA*	None
Soil:			
Direct Contact: Vegetable	Res./Constr.	*NA*	*NA*
Apply CLEA- UK SGV levels		No	
Outdoor Air:			
Particulates from Surface Soils	Res./Constr.	None	Residential
Volatilization from Soils	Res./Constr.	None	Residential
Volatilization from Groundwater	Residential	None	Residential
Indoor Air:			
Volatilization from Soils	None	*NA*	*NA*
Volatilization from Groundwater	None	Residential	None
Soil Leaching to Groundwater Volatilization	None	None	None

Receptor Distance from Source Media	On-site	Off-site 1	Off-site 2	(Units)
Groundwater receptor	NA	NA	110	(m)
Outdoor air inhalation receptor	0	NA	40	(m)
Indoor air inhalation receptor	0	40	NA	(m)

Target Health Risk Values		Individual	Cumulative
TR	Target Risk (carcinogens)	1.0E-5	1.0E-5
THQ	Target Hazard Quotient (non-carcinogenic risk)	1.0E+0	1.0E+0

Modeling Options	
RBCA tier	Tier 2
Outdoor air volatilization model	Surface & Subsurface Models: ASTM Model
Indoor air volatilization model	Johnson & Ettinger model
Soil leaching model	ASTM leaching model
Use soil attenuation model (SAM) for leachate?	Yes
Use dual equilibrium desorption model?	Yes
Apply Mass Balance Limit for Soil Volatilization?	No
Apply UK (CLEA) SGV as soil concentration limit	No
Vegetable calculation options	Below ground only for organics
Air dilution factor	3-D Gaussian dispersion
Groundwater dilution-attenuation factor	Domenico model

NOTE: NA = Not applicable

Table A5.4 Input Parameter Summary Sheet

RBCA SITE ASSESSMENT — Input Parameter Summary

Site Name: Carrigeen Landfill
Site Location: Clane, County Kildare

Completed By: Padraic Mulroy, Mulroy Environmental
Date Completed: 31.05.2012

Surface Soil Column Parameters		Value			(Units)
h_{cap}	Capillary zone thickness	5.0E-2			(m)
h_v	Vadose zone thickness	1.0E+0			(m)
ρ_s	Soil bulk density	1.6E+0			(g/cm^3)
f_{oc}	Fraction organic carbon	5.8E-3			(-)
θ_T	Soil total porosity	4.6E-1			(-)
		capillary	vadose	foundation	
θ_w	Volumetric water content	0.414	0.15	0.12	(-)
θ_a	Volumetric air content	0.046	0.31	0.26	(-)
K_{vs}	Vertical hydraulic conductivity	5.6E+2			(cm/d)
k_v	Vapor permeability	7.2E-12			(m^2)
L_{gw}	Depth to groundwater	1.1E+0			(m)
pH	Soil/groundwater pH	8.3E+0			(-)
			Construction		
W	Length of source-zone area parallel to wind	4.5E+1	4.5E+1		(m)
W_{gw}	Length of source-zone area parallel to GW flow	1.2E+2			(m)
L_{ss}	Thickness of affected surface soils	4.0E-1			(m)
A	Source zone area	1.0E+4			(m^2)
L_s	Depth to top of affected soils	5.0E-1			(m)
L_{base}	Depth to base of affected soils	1.1E+0			(m)
L_{subs}	Thickness of affected soils	5.7E-1			(m)

Outdoor Air Parameters		Value	(Units)
U_{air}	Ambient air velocity in mixing zone	2.3E+0	(m/s)
δ_{air}	Air mixing zone height	2.0E+0	(m)
Q/C	Inverse mean concentration at the center of source	NA	
P_a	Areal particulate emission rate	6.9E-14	(g/cm^2/s)
V	Fraction of vegetative cover	NA	
U_m	Mean annual airvelocity at 7m	NA	
U_t	Equivalent 7m air velocity threshold value	NA	
F(x)	Windspeed function dependant on Um/Ut	NA	
PEF	Partculate Emission Factor	6.9E-12	

Building Parameters		Residential	Commercial	(Units)
L_b	Building volume/area ratio	NA	NA	(m)
A_b	Foundation area	NA	NA	(m^2)
X_{crk}	Foundation perimeter	NA	NA	(m)
ER	Building air exchange rate	NA	NA	(1/s)
L_{crk}	Foundation thickness	NA	NA	(m)
Z_{crk}	Depth to bottom of foundation slab	NA	NA	(m)
η	Foundation crack fraction	NA	NA	(-)
dP	Indoor/outdoor differential pressure	NA	NA	(g/cm/s^2)
Q_s	Convective air flow through slab	NA	NA	(m^3/s)
θ_{wcrack}	Volumetric water content of cracks	NA	NA	(-)
θ_{acrack}	Volumetric air content of cracks	NA	NA	(-)
BV	Building Volume	NA	NA	(m^3)
w	Building Width Perpendicular to GW flow	NA	NA	(m)
L	Building Length Parallel to GW flow	NA	NA	(m)
ν	Saturated Soil Zone Porosity	NA	NA	(-)

Groundwater Parameters		Value	(Units)
δ_{gw}	Groundwater mixing zone depth	4.0E+0	(m)
I_f	Net groundwater infiltration rate	3.0E+1	(cm/yr)
U_{gw}	Groundwater Darcy velocity	3.5E+0	(cm/d)
V_{gw}	Groundwater seepage velocity	7.6E+0	(cm/d)
K_s	Saturated hydraulic conductivity	5.6E+2	(cm/d)
i	Groundwater gradient	6.3E-3	(-)
S_w	Width of groundwater source zone	1.2E+2	(m)
S_d	Depth of groundwater source zone	4.0E+0	(m)
θ_{eff}	Effective porosity in water-bearing unit	4.6E-1	(-)
$f_{oc\text{-}sat}$	Fraction organic carbon in water-bearing unit	1.0E-3	(-)
pH_{sat}	Groundwater pH	8.3E+0	(-)
	Biodegradation considered?	No	

Transport Parameters		Off-site 1	Off-site 2	Off-site 1	Off-site 2	(Units)
Lateral Groundwater Transport		Groundwater Ingestion		Groundwater to Indoor Air		
α_x	Longitudinal dispersivity	NA	1.1E+1	4.0E+0	NA	(m)
α_y	Transverse dispersivity	NA	3.6E+0	1.3E+0	NA	(m)
α_z	Vertical dispersivity	NA	5.5E-1	2.0E-1	NA	(m)
Lateral Outdoor Air Transport		Soil to Outdoor Air Inhal.		GW to Outdoor Air Inhal.		
σ_y	Transverse dispersion coefficient	NA	4.4E+0	NA	4.4E+0	(m)
σ_z	Vertical dispersion coefficient	NA	3.0E+0	NA	3.0E+0	(m)
ADF	Air dispersion factor	NA	1.0E+0	NA	1.0E+0	(-)

Surface Water Parameters		Off-site 2	(Units)
Q_{sw}	Surface water flowrate	NA	(m^3/s)
W_{pi}	Width of GW plume at SW discharge	NA	(m)
δ_{pi}	Thickness of GW plume at SW discharge	NA	(m)
DF_{sw}	Groundwater-to-surface water dilution factor	NA	(-)

NOTE: NA = Not applicable

Table A5.5 Concentration of Contaminants of Concern

RBCA SITE ASSESSMENT	User-Specified COC Data

REPRESENTATIVE COC CONCENTRATIONS IN SOURCE MEDIA

CONSTITUENT	Representative COC Concentration			
	Groundwater		Soils (0.5 - 1.1 m)	
	value (mg/L)	note	value (mg/kg)	note
Benzo-a-pyrene	0.0E+0	BH02 (DOWNGRAIENT)	3.1E+0	TP05-01 08-4.5m bgl
Ammonia	1.8E+1	BH01 (DOWNGRADIENT)	0.0E+0	No data
Manganese	1.2E+0	BH01 (DOWNGRADIENT)	0.0E+0	No data
Arsenic	1.2E+1	BH01 (DOWNGRADIENT)	0.0E+0	No data

*** = Chemical with user-specified data**

Site Name: Carrigeen Landfill
Date Completed: 31.05.2012
Site Location: Clane, County Kildare
Job ID: Historic LF
Completed By: Padraic Mulroy, Mulroy Environmental

Table A5.6 Calculated Site Specific Target Levels for Soil 0.4-0.5m bgl

RBCA SITE ASSESSMENT

Site Name: Carrigeen Landfill
Site Location: Clane, County Kildare

Completed By: Padraic Mulroy, Mulroy Environmental
Date Completed: 31.05.2012

Job ID: Historic LF

SURFACE SOIL (0.5 - 0.4 m)
SSTL VALUES

Target Risk (Class A & B) 1.0E-5
Target Hazard Quotient 1.0E+0

Groundwater DAF Option: Domenico - No Decay
(One-directional vert. dispersion)

SSTL Results For Complete Exposure Pathways (Checked if Pathway is Complete)

CONSTITUENTS OF CONCERN		Representative Concentration	■ Soil Leaching to Groundwater			□ Soil Leaching to Groundwater/ Groundwater Volatilization to Indoor Air			□ Soil Vol. to Indoor Air	■ Soil Volatilization and Surface Soil Particulates to Outdoor Air				■ Direct Contact Pathways: Vegetable Consumption		Applicable SSTL	SSTL Exceeded ?	Required CRF
			On-site (0 m)	Off-site 1 (40 m)	Off-site 2 (110 m)	On-site (0 m)	Off-site 1 (40 m)	Off-site 2 (40 m)	On-site (0 m)	On-site (0 m)		Off-site 1 (10 m)	Off-site 2 (40 m)	On-site (0 m)				Only if "yes" left
CAS No.	**Name**	(mg/kg)	None	None	Surf. Water	None	None	None	None	Residential	Construction Worker	None	Residential	Residential	Construction Worker	(mg/kg)	"■" if yes	
50-32-8	Benzo-a-pyrene	3.1E+0			>9.9E+0					>9.9E+0	>9.9E+0		>9.9E+0	4.5E+1	1.0E+6	4.5E+1	□	<1
7664-41-7	Ammonia	0.0E+0			NC					Csat?	Csat?		Csat?	(V)Tox?	1.0E+6	1.0E+6	□	<1
7439-96-5	Manganese	0.0E+0			NC					>1.0E+6	>1.0E+6		>1.0E+6	(V)Tox?	1.0E+6	1.0E+6	□	<1
7440-38-2	Arsenic	0.0E+0			NC					4.8E+5	>1.0E+6		4.8E+5	1.9E+1	1.0E+6	1.9E+1	□	<1

* = Chemical with user-specified data

">" indicates risk-based target concentration greater than constituent residual saturation value. NA = Not applicable. NC = Not calculated.

Table A5.7 Calculated Site Specific Target Levels for Subsoil (0.5-1.1m bgl)

RBCA SITE ASSESSMENT

Site Name: Carrigeen Landfill
Site Location: Clane, County Kildare

Completed By: Padraic Mulroy, Mulroy Environmental
Date Completed: 31.05.2012

Job ID: Historic LF

SUBSURFACE SOIL (0.5 - 1.1 m) SSTL VALUES

Target Risk (Class A & B) 1.0E-5
Target Hazard Quotient 1.0E+0

Groundwater DAF Option: Domenico - No Decay
(One-directional vert. dispersion)

SSTL Results For Complete Exposure Pathways (Checked if Pathway is Complete)

			■ Soil Leaching to Groundwater			☐ Soil Leaching to Groundwater/ Groundwater Volatilization to Indoor Air			☐ Soil Vol. to Indoor Air	■ Soil Volatilization to Outdoor Air			Applicable SSTL	SSTL Exceeded ?	Required CRF
CONSTITUENTS OF CONCERN		**Representative Concentration**	On-site (0 m)	Off-site 1 (40 m)	Off-site 2 (110 m)	On-site (0 m)	Off-site 1 (40 m)	Off-site 2 (40 m)	On-site (0 m)	On-site (0 m)	Off-site 1 (10 m)	Off-site 2 (40 m)			Only if "yes"
CAS No.	**Name**	(mg/kg)	None	None	Surf. Water	None	None	None	None	Residential	None	Residential	(mg/kg)	"■" if yes	left
50-32-8	Benzo-a-pyrene	3.1E+0			>9.9E+0					>9.9E+0		>9.9E+0	>9.9E+0	☐	
7664-41-7	Ammonia	0.0E+0			NC					1.5E+4		1.5E+4	1.5E+4	☐	<1
7439-96-5	Manganese	0.0E+0			NC					>1.0E+6		>1.0E+6	>1.0E+6	☐	
7440-38-2	Arsenic	0.0E+0			NC					4.8E+5		4.8E+5	4.8E+5	☐	<1

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* = Chemical with user-specified data

">" indicates risk-based target concentration greater than constituent residual saturation value. NA = Not applicable. NC = Not calculated.

Table A5.8 Calculated Site Specific Target Levels for Groundwater

RBCA SITE ASSESSMENT

Site Name: Carrigeen Landfill | Completed By: Padraic Mulroy, Mulroy Environmental | Job ID: Historic LF

Site Location: Clane, County Kildare | Date Completed: 31.05.2012

GROUNDWATER SSTL VALUES

Target Risk (Class A & B) 1.0E-5

Target Hazard Quotient 1.0E+0

Groundwater DAF Option: Domenico - No Decay (One-directional vert. dispersion)

SSTL Results For Complete Exposure Pathways (Checked if Pathway is Complete)

CONSTITUENTS OF CONCERN		Representative Concentration	■ Groundwater			■ Groundwater Volatilization to Indoor Air			■ Groundwater Volatilization to Outdoor Air			Applicable SSTL	SSTL Exceeded ?	Required CRF
			On-site (0 m)	Off-site 1 (40 m)	Off-site 2 (110 m)	On-site (0 m)	Off-site 1 (40 m)	Off-site 2 (40 m)	On-site (0 m)	Off-site 1 (10 m)	Off-site 2 (40 m)			Only if "yes"
CAS No.	**Name**	(mg/L)	None	None	Surf. Water	None	Residential	None	Residential	None	Residential	(mg/L)	"■" if yes	left
50-32-8	Benzo-a-pyrene	0.0E+0			NA		>1.6E-3		>1.6E-3		>1.6E-3	>1.6E-3	☐	NA
7664-41-7	Ammonia	1.8E+1			NA		>5.3E+5		3.0E+2		3.0E+2	3.0E+2	☐	<1
7439-96-5	Manganese	1.2E+0			NA		>1.0E+6		>1.0E+6		>1.0E+6	>1.0E+6	☐	NA
7440-38-2	Arsenic	1.2E+1			NA		>1.0E+6		>1.0E+6		>1.0E+6	>1.0E+6	☐	NA

* = Chemical with user-specified data

">" indicates risk-based target concentration greater than constituent solubility value. NA = Not applicable. NC = Not calculated.

Table A5.9 Cumulative Risk Worksheet

RBCA SITE ASSESSMENT	Cumulative Risk Worksheet

Site Name: Carrigeen Landfill | Completed By: Padraic Mulroy, Mulroy Environmer | Job ID: Historic LF

Site Location: Clane, County Kildare | Date Completed: 31.05.2012 | *1 OF 3*

CUMULATIVE RISK WORKSHEET

CONSTITUENTS OF CONCERN		Representative Concentration		Proposed CRF		Resultant Target Concentration	
CAS No.	Name	Soil (mg/kg)	Groundwater (mg/L)	Soil	GW	Soil (mg/kg)	Groundwater (mg/L)
50-32-8	Benzo-a-pyrene	3.1E+0	0.0E+0	NA	NA	3.1E+0	0.0E+0
7664-41-7	Ammonia	0.0E+0	1.8E+1	NA	NA	0.0E+0	1.8E+1
7439-96-5	Manganese	0.0E+0	1.2E+0	NA	NA	0.0E+0	1.2E+0
7440-38-2	Arsenic	0.0E+0	1.2E+1	NA	NA	0.0E+0	1.2E+1

Cumulative Values:

Table A5.9 Cumulative Risk Worksheet

RBCA SITE ASSESSMENT | **Cumulative Risk Worksheet**

Site Name: Carrigeen Landfill | Site Name: Carrigeen Landfill | Completed By: Padraic Mulroy, Mulroy Environmental Job ID: Historic LF

Site Location: Clane, County Kildare | Site Location: Clane, County Kildare | Date Completed: 31.05.2012 | *2 OF 3*

CUMULATIVE RISK WORKSHEET

Cumulative Target Risk: 1.0E-5 Target Hazard Index: 1.0E+0

ON-SITE RECEPTORS

CONSTITUENTS OF CONCERN		Outdoor Air Exposure: Residential		Indoor Air Exposure: None		Soil Exposure: Residential		Groundwater Exposure: None	
		Target Risk: 1.0E-5	Target HQ: 1.0E+0	Target Risk: 1.0E-5	Target HQ: 1.0E+0	Target Risk: 1.0E-5	Target HQ: 1.0E+0	Target Risk: 1.0E-5	Target HQ: 1.0E+0
CAS No.	**Name**	Carcinogenic Risk	Hazard Quotient	Carcinogenic Risk	Hazard Quotient	Carcinogenic Risk	Hazard Quotient	Carcinogenic Risk	Hazard Quotient
50-32-8	Benzo-a-pyrene	5.9E-8	Tox?			7.0E-7	Tox?		
7664-41-7	Ammonia		error				Tox?		
7439-96-5	Manganese		0.0E+0				Tox?		
7440-38-2	Arsenic	0.0E+0	Tox?			0.0E+0	0.0E+0		
Cumulative Values:		**5.9E-8**	**0.0E+0**	**0.0E+0**	**0.0E+0**	**7.0E-7**	**0.0E+0**	**0.0E+0**	**0.0E+0**

* indicates risk level exceeding target risk

Table A5.9 Cumulative Risk Worksheet

RBCA SITE ASSESSMENT	Cumulative Risk Worksheet		Cumulative Risk Worksheet
Site Name: Carrigeen Landfill	Site Name: Carrigeen Landfill	Completed By: Padraic Mulroy, Mulroy Environmental	Job ID: Historic LF
Site Location: Clane, County Kildare	Site Location: Clane, County Kildare	Date Completed: 31.05.2012	Job ID: Historic LF
		3 OF 3	*3 OF 3*

CUMULATIVE RISK WORKSHEET

Cumulative Target Risk: 1.0E-5 Target Hazard Index: 1.0E+0

Groundwater DAF Option: Domenico - No Decay | Groundwater DAF Option: Domenico - No Decay

OFF-SITE RECEPTORS

CONSTITUENTS OF CONCERN		Outdoor Air Exposure: None		Outdoor Air Exposure: Residential (40 m)		Indoor Air Exposure: Residential (40 m)		Indoor Air Exposure: None		Groundwater Exposure: None		Groundwater Exposure: Surface Water (110 m)	
		Target Risk: 1.0E-5	Target HQ: 1.0E+0	Target Risk: 1.0E-5	Target HQ: 1.0E+0	Target Risk: 1.0E-5	Target HQ: 1.0E+0	Target Risk: 1.0E-5	Target HQ: 1.0E+0	Target Risk: 1.0E-5	Target HQ: 1.0E+0	Target Risk: 1.0E-5	Target HQ: 1.0E+0
CAS No.	**Name**	Carcinogenic Risk	Hazard Quotient	Carcinogenic Risk	Hazard Quotient	Carcinogenic Risk	Hazard Quotient	Carcinogenic Risk	Hazard Quotient	Carcinogenic Risk	Hazard Quotient	Carcinogenic Risk	Hazard Quotient
50-32-8	Benzo-a-pyrene	5.9E-8	Tox?	5.9E-8	Tox?	0.0E+0	Tox?					5.6E-10	Tox?
7664-41-7	Ammonia		error		error		2.8E-5					Tox?	Tox?
7439-96-5	Manganese		0.0E+0		0.0E+0		0.0E+0					Tox?	Tox?
7440-38-2	Arsenic	0.0E+0	Tox?	0.0E+0	Tox?	0.0E+0	Tox?					error Ksw	error Ksw
Cumulative Values:		**5.9E-8**	**0.0E+0**	**5.9E-8**	**0.0E+0**	**0.0E+0**	**2.8E-5**	**0.0E+0**	**0.0E+0**	**0.0E+0**	**0.0E+0**	**5.6E-10**	**0.0E+0**

■ indicates risk level exceeding target risk

indicates risk level exceeding target risk