Comhairle Contae Chorcaí
Cork County Council

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Administration,
Environmental Licensing Programme,
Office of Environmental Sustainability,
Environmental Protection Agency,
Headquarters,
PO Box 3000,
Johnstown Castle Estate,
County Wexford.

For the attention of Ms Caitriona Collins

21st of December 2016

Re: Kealanine Landfill - Notice in accordance with Regulation 7(4) of the Waste Management (Certification of Historic Unlicensed Waste Disposal and Recovery Activity) Regulations, 2008

Register Number H0089-01

Dear Ms Collins,

I refer to your letter of the 15th of December 2016 in relation to the above referenced and respond accordingly pertaining to the queries raised:

1. Please find attached 2 copies of a report entitled 'Kealanine Landfill Site, Review of Tier 1, Draft Tier 2 and Tier 3 Risk Assessment' and a CD-ROM containing said report which contains the Tier 3 Assessment which has been requested.
2. Please be advised that no monitoring has taken place at the site since the making of the application for a certificate of authorisation (CoA), reference no H0089-01, to the Environmental Protection Agency on the 27/8/2014.
3. In light of the fact that no monitoring has taken place at the site since the making of the application for the certificate of authorisation to the Agency item 3 of your letter is not relevant at this time in the Council's considered opinion. However I attach correspondence pertaining to same which would have been uploaded onto the Environmental Protection Agency's system when the certificate of authorisation (CoA), reference no H0089-01, was made on the 27/8/2014.

I trust the aforegoing provides you with the information you require at this time.

Yours sincerely,

Jean Sayers

Jean Sayers
Senior Executive Engineer

ENGINEERS IRELAND

RPS Group Ltd
Innishmore
Ballincollig
Co. Cork

18th July 2013

Re: Credentials in accordance with section 2.3 of Code of Practice: *Environmental Risk Assessment for Unregulated Waste Disposal Sites* (EPA, 2007)

Dear Mr O'Toole, Chartered Engineer, MIEI

Engineers Ireland is satisfied to state that you are a person who is qualified, trained and experienced to the standard set out in section 2.3 of *Code of Practice: Environmental Risk Assessment for Unregulated Waste Disposal Sites* (EPA, 2007) and has achieved chartered status or equivalent.

This notice is valid for a period of two years from today's date.

Signed:

Aidan Harney

Aidan Harney

Continuing Professional Development (CPD) Director

Engineers Ireland

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RPS

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Ms Jean Sayers
Senior Executive Engineer
Cork County Council
County Hall
Carrigrohane Road
Cork

30th July 2014

Re: Risk assessment on an historic landfill in support of an application for a certificate of authorisation in accordance with Regulation 7 of the Waste Management (Certification of Historic Unlicensed Waste Disposal and Recovery Activity) Regulation 2008.

Dear Ms Sayers,

As a person who is qualified, trained and experienced to the standard set out in section 2.3 of Code of Practice: Environmental Risk Assessment for Unregulated Waste Disposal Sites (EPA, 2007), it is my opinion that the risk assessment carried out by Cork County Council in relation to a closed landfill at Kealaline Landfill is adequate and complete. The risk assessment complies with all of the requirements of the Code of Practice. The Local Authority or its agent/contractor, in carrying out the risk assessment, has followed and competed the steps set out in the Code of Practice and associated guidance (Matrix 1 and Matrix 2 – as published).

The following items:

- the risk assessment
- the findings and conclusions of the risk assessment
- the remedial measures proposed, if any, and
- the monitoring proposed to be carried out to demonstrate the effectiveness of the remedial measures, if any,

are in my opinion, appropriate and adequate to:

- identify the instances and risks of environmental pollution arising from the closed landfill to which this application refers,
- proportionately address any and all such instances and risks of environmental pollution, and
- ensure that any future instances of environmental pollution will be detected in a timely manner

I have advised the Local Authority on the following aspects of this project or have carried out or managed the following aspects of the project on behalf of the Local Authority.

- Tier 2 risk assessment
- Tier 3 risk assessment including GQRA
- Remedial measures
- Post-remediation monitoring programme

Yours sincerely,

Larry O'Toole
Regional Director
RPS
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Kealanine Landfill Site

Review of Tier 1, Draft Tier 2 and Tier 3 Risk Assessment

June 2014

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RPS

Kealanine Landfill Site

Review of Tier 1, Tier 2 and Tier 3 Risk Assessment

DOCUMENT CONTROL SHEET

Client:	**Cork County Council**					
Project Title:	**Kealanine Landfill Site**					
Document Title:	**Review of Tier 1, Draft Tier 2 and Tier 3 Risk Assessment**					
Document No:	**RPS/MCE0761RP0001F03**					
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	1	**2**	**54**	**5**	**0**	**1**

Rev.	Status	Author(s)	Reviewed By	Approved By	Office of Origin	Issue Date
A01	Issue for Approval	C. Doyle	B. O'Leary	G. Mc Grath	Cork	January 2014
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F02	Final issue	C. Doyle	L. O'Toole	F. Maguire	Cork	June 2014
F03	Final issue	C. Doyle			Cork	June 2014

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

KEALANINE LANDFILL SITE

1. INTRODUCTION

1.1 Background

RPS was invited in October 2013 by Cork County Council to submit a tender under the Multi-Operator Framework Agreement for the provision of Environmental Consultancy and Design Services for the Kealanine Landfill Site. The tender was successful and RPS was appointed in December 2013 to undertake the works.

The brief required the review of a Draft Tier 2 and Tier 3 Risk Assessment and the development of remedial recommendations based on the results of the review. The brief also required the preparation of an Appropriate Assessment Screening for the approved remedial option.

This report provides the review of the Draft Tier 2 and Tier 3 Risk Assessment and the recommendations arising from the revised risk assessment.

An appropriate assessment screening will be completed following the approval of the recommendations and assistance is to be provided to Cork County Council to prepare the Certificate of Authorisation application on the EPA online system.

Under Section 22 of the Waste Management Act 1996 Cork County Council has an obligation to carry out an inventory and risk assessment of all closed landfill sites. To assist Local Authorities in complying with Section 22 of the Waste Management Act, the Environmental Protection Agency (the Agency) published a guidance document called 'Code of Practice-Environmental Risk Assessment for Unregulated Waste Disposal Sites' and Site Investigation Matrices (EPA, 2007).

The Code of Practice provides guidance to local authorities in relation to the investigation of old landfill sites that operated between 1977 and 1997 without the proper permitting and authorising system. The review of the Tier 1, Draft Tier 2 and Tier 3 Risk Assessments has been undertaken to confirm that the risk assessment is adequate and complete and complies with the Code of Practice.

1.2 Methodology

The review of the risk assessment has been carried out in accordance with the brief and the EPA Code of Practice for Environmental Risk Assessment for Unregulated Waste Disposal Sites (EPA, 2007).

A desk study was carried out which involved a review of the Tier 1, Draft Tier 2 and Tier 3 Risk Assessment reports which were previously completed by Cork County Council. All available data from the Environmental Protection Agency, Geological Survey of Ireland, National Parks and Wildlife Service and Ordnance Survey Ireland websites was also reviewed. The data reviewed during the desk study phase has been compiled and used in the development of the updated conceptual model.

A walkover survey of the site was carried out by RPS on the 7th of January 2014. Information on the history of the operation of the site has been obtained based on a review of the following documentation:-

- Tier 1 Study - Conceptual Site Model, Risk Screening & Prioritisation For Kealanine Landfill Site (Cork County Council, February 2008).
- Draft Tier 2 and Tier 3 Environmental Risk Assessment for Kealanine Landfill, Bantry, Co. Cork (Cork County Council commenced January 2011).
- Kealanine Landfill Report On the Geophysical Survey For Cork County Council (Apex Geoservices, October 2010).

On 25th February 2014 Cork County Council undertook additional monitoring at Kealanine Landfill site. The monitoring included the sampling and analysis of 2 no. groundwater samples (BH1 & BH2), 5 no. surface water samples (SW1, SW3, SW7, SWA & SWB) and 4 no. leachate samples (S&A1, S&A2, S&A4 & BH3). A round of gas monitoring was also undertaken at 3 no. locations (S&A1, S&A2 & S&A4).

A quantitative risk assessment (QRA) has been carried out. A site restoration plan has been prepared outlining the necessary measures for remediation and risk attenuation. A proposal for long term monitoring and assessment has also been provided.

2. DESK STUDY

A desk study review of the reports previously completed by Cork County Council on the landfill site and publically available data sources was undertaken to obtain information on the site and the surrounding area.

Information on the history of the operation of the site has been obtained based on a review of the following documentation:-

- Tier 1 Study - Conceptual Site Model, Risk Screening & Prioritisation For Kealanine Landfill Site (Cork County Council, February 2008).
- Draft Tier 2 and Tier 3 Environmental Risk Assessment for Kealanine Landfill, Bantry, Co. Cork (Cork County Council commenced January 2011).
- Kealanine Landfill Report On the Geophysical Survey For Cork County Council (Apex Geoservices, October 2010).

Information has also been obtained from the EPA website, National Parks & Wildlife website and Geological Survey of Ireland.

A site walkover survey was undertaken by RPS on the 7th of January 2014.

2.1 Location and Site Description

The landfill site is located at Kealanine (NGR 97620 55014) approximately 5km east south east of Glengarriff and 7km north northwest of Bantry. The site is located approximately 1.5km off the N71 (Bantry to Castletownbere road) via a local road. The landfill covers an area of approximately 1.6ha.

Detailed waste disposal records are unavailable for the landfilling operations as the facility operated unsupervised for a number of years. It is reported that most of the waste deposited was municipal but some wastewater sludge, end of life vehicles and oily waste was also deposited. An unknown quantity of oily waste originated from the oil spill that occurred after the Whiddy Island disaster in 1979. The oily waste was blended with municipal waste and deposited in the eastern section of the site. A small quantity of offal is also reported to have been deposited. It is estimated that the landfill contains in the region of 90,000m^3 of waste material. Based on a waste density of 1 tonne per m^3 it is likely that in the region of 90,000 tonnes of material is likely to have been deposited.

The historic maps for the area the OSI 1:10,560 sheets and the 25” maps show the stream along the southern boundary of the site predates the development of the landfill.

The landfill site is located in an area of rugged topography with bedrock outcrops forming ridges separated by areas of blanket peat. The surrounding land is used for rough grazing of sheep and horses. The historic maps for the area are available to view on the OSI website and confirm the marshy / boggy nature of the ground and outcropping bedrock prior to the commencement of landfilling operations.

The perimeter fencing is in a poor condition. There is no gate currently present at the site to prevent unauthorised entry. A member of the public or livestock can currently gain access to the site at a number of locations on the perimeter of the site.

Temporary cover material was installed on top of the waste body in 1999. The site investigation indicates 0.20m to 0.30m of topsoil was placed on the waste body, compacted and reseeded. Vegetation is well established on site and includes rushes over the top and sides of the waste mound. The historic aerial photographs show vegetation has been well established since at least 2005. The site slopes of the site are covered by scrub like vegetation in places and trees are well established on the base of the side slopes along the northern and southern boundaries of the site.

2.2 Topography

The landfill is situated on the southern slopes of Cobduff which rises to a height of approximately 380mOD. The site is located within an east northeast oriented valley. The topography of the area is strongly influenced by the geology and is dominated by ridges of outcropping bedrock separated by lower lying troughs with blanket peat deposits and marshy ground.

A topographic survey of the site was carried out in 2010 and the ground elevations range from approximately 109 mAOD at the former site entrance to 119 mAOD at the highest point in the centre of the waste mound. The gradient across the top of the mound is approximately 1:120 and the ground slopes in a south westerly direction. The side slopes range from 1: 1.9 to 1: 2 on the sides slopes around the waste mound. The steepest sections are located in the south west area of the site.

The topographical survey indicates the waste mound protrudes 7.55m to 10.5m above the surrounding natural ground level at its maximum extent.

2.3 Hydrology

The site is located within the surface water catchment of the Coomhola River. A tributary of the Coomhola River rises in the immediate vicinity of the site. The stream originates (rises) in the area of ground approximately 50m south west of the western site boundary. The stream flows in a north easterly direction at a minimum distance of 15m from the base of the waste mound. This stream is culverted under the access road to the site.

The tributary joins the Coomhola River approximately 2km downstream of the landfill site at a location approximately 300m upstream of Coomhola Bridge. The Coomhola River discharges to the sea approximately 1.5km downstream of Coomhola Bridge. There is an EPA water quality monitoring station located at Coomhola Bridge with a high status (Q4-Q5) indicated.

The stream which is located south of the landfill is indicated on the historic ordnance survey maps for the area. There is also an additional surface water flow from the higher ground to the north of the site which flows over the rock outcrop to the north of the site and skirts outside of the northern boundary of the site. The two streams join approximately 70m downstream of the landfill site.

There are a series of drains on the north western side of the site and the southern boundary of the site. These drains collect surface water runoff from the landfill site in addition to surface water runoff from the higher ground to the north west of the landfill. The drains do not directly connect to the southern stream but the water from the perimeter drains discharges to the boggy ground approximately 30m from the stream.

There is also ponding of surface water occurring in a localised low point along the eastern boundary of the site north of the former site entrance gate. This surface water drains to the eastern tributary stream.

2.4 Site Investigation Results

The site investigations undertaken at the site include the following:-

- Geophysical Survey by Apex Geoservices in October 2010.
- Site walkover survey by Cork County Council on 17th February 2011.
- Intrusive site investigation by Priority Geotechnical Ltd in May 2011.
- Site walkover by RPS on 7th January 2014.
- Additional monitoring of groundwater, surface water, leachate and landfill gas by Cork County Council on 25th February 2014.

A copy of the site investigation results are included as Appendix C.

Geophysical Investigations

A geophysical investigation was undertaken by Apex Geoservices in 2010. The surveying included EM31 conductivity measurement over the filled area and the area to the south of the landfill. Electrical resistivity profiling (3 no. profiles R1, R2 & R3), seismic refraction (along R1) and magnetometry measurements (along R1) were undertaken.

The surveying was interpreted by the geophysical contractor as indicating 10-12m of waste of which the bottom 2-4m was interpreted as being waste material which had penetrated into the in situ peat and silt. The geophysical surveying also indicated pockets of low resistivity material within the waste body which were interpreted as possible hydrocarbon zones while other zones were interpreted as commercial and domestic waste.

The geophysical surveying did not provide any evidence of leachate migration outside of the waste body in the marshy ground between the south west corner of the landfill and the road. The geophysical investigations indicated the presence of a clayey bund along the northern and western faces of the landfill.

The geophysical survey was interpreted as indicating thickly bedded competent rock at depth with a thin weathered / jointed layer of bedrock on top. This corresponds with the results of the drilling phase.

Intrusive Site Investigation

The site investigation programme undertaken in May 2011 included open hole rotary drilling, cable tool boreholes, slit trenches and hand augering.

3 no. rotary boreholes were drilled in May 2011 using the open hole drilling method these being BH1, BH2 and BH3. The borehole logs have been based on the driller's interpretation of the drill cuttings.

4 no. boreholes were installed using the cable tool drilling method these being S&A1, S&A2, S&A3 and S&A4. Samples were taken at 0.5m intervals in the cable tool boreholes and were classed in accordance with BS5930.

2 no. slit trenches ST1 and ST2 were excavated. ST1 to the south of the landfill outside of the waste body indicated a 0.84m thick peat layer. ST2 to the east of the landfill outside of the waste indicated a 0.75m thick peat layer.

Hand augering included the excavation of 3 no. probes these being HA1, HA2 and HA3.

The results of the intrusive site investigation are summarised below in Table 2.1.

BH1

BH1 was located on the south east corner of the landfill site to provide a monitoring location down gradient of the waste body. The borehole was located close to the former site entrance. The borehole was drilled to a total depth of 5.10mbgl. The borehole log indicated 2.70m of overburden overlying bedrock including a sand and gravel layer on top of the bedrock. During the drilling phase groundwater was encountered at 1.70mbgl in the sand and gravel interval. No waste material was encountered at this location. The monitoring standpipe in the borehole was screened from 3.0m to 5.10mbgl which included the overburden and bedrock intervals.

The presence of 2.70m of overburden results in an extreme vulnerability rating in this area of the site. The static water level was measured at 107.96mOD (0.68 mbgl) at the time of the site investigation which is above the top of bedrock level.

BH2

BH2 was installed on the southern side of the stream outside of the landfill site to provide information on the natural groundwater quality of the area. Due to the topography and nature of the ground it was not possible to install a groundwater monitoring borehole up gradient of the site. BH2 was drilled to a total depth of 5.10m. The borehole log indicated 3.90m of overburden including a sand and gravel layer on top of the bedrock. Groundwater was encountered at 4.00mbgl during the drilling stage in bedrock. No waste material was encountered in this location at it is located outside of the landfill site. The monitoring standpipe in the borehole was screened from 4.0m to 5.10mbgl in the bedrock interval. An estimated permeability of 10^{-6}m/sec was obtained from a falling head permeability test in the top of the bedrock.

The presence of 3.90m of overburden results in a high vulnerability rating. The static water level was measured at 107.88mOD (0.945mbgl) at the time of the site investigation which is above the top of bedrock level.

BH3

BH3 was installed in the centre of the site within the waste body. The borehole was drilled to a total depth of 14.00mbgl. The borehole indicated 9.50m of made ground / waste. Beneath the waste body 0.80m of peat was encountered over 1.20m of sandy gravel on top of the bedrock. Water was encountered at 7.50mbgl during the drilling phase within the waste body and is considered to represent the leachate level. Groundwater was encountered at 10.30mbgl in the sand and gravel layer during the drilling phase. The monitoring standpipe in the borehole was screened from 1.0m to 8.0mbgl which monitors the leachate level within the waste body. A 0.30m capping layer is present in this area of the site. The capping layer is composed of slightly silty sandy gravel with cobbles but the capping layer also contained refuse.

The presence of 2.00m of overburden above the top of rock results in an extreme vulnerability rating for this part of the site. The permeability of the sample from the capping layer in BH3 was 6.8 x 10^{-6}m/sec.

S & A1

This borehole was installed mid-way along the north western boundary of the site. The borehole was drilled to a total depth of 6.80mbgl. There was a capping layer 0.3m thick which contained occasional waste. The borehole encountered waste over the full depth of the borehole. Water was encountered at 4.50mbgl and was interpreted as the level of leachate within the waste mound. The refuse at this sampling location was composed of mixed municipal refuse. A slight sheen was seen on the waste sample during the 2011 site investigation indicating possible hydrocarbons but no hydrocarbon odour was noted between 5.00m and 6.70mbgl and no hydrocarbon sludge was encountered.

S & A2

This borehole is located in the south west corner of the landfill within the waste body. The borehole was drilled to a total depth of 10.20mbgl. There was a 0.5m thick capping layer which contained occasional waste. Waste was encountered to 8.50mbgl. A peat layer was encountered between 8.50m and 9.00mbgl which also contained mixed municipal refuse. Beneath the peat layer a layer of clayey sandy gravel was encountered between 9.00m and 9.70m. Weathered bedrock was encountered at 10.20mbgl. Water was encountered during the drilling stage at 3.50mbgl and 7.4mbgl and was interpreted as leachate. The monitoring standpipe was screened from 1.0m to 8.20mbgl in the waste body. Between 7.00m and 7.50m there was “visual and olfactory evidence of small concentrations of hydrocarbons”.

The presence of 1.2m of overburden (0.5m peat, 0.70m of clayey sandy gravel) above the bedrock results in an extreme vulnerability rating for this part of the site.

S & A3

This borehole is located in the eastern portion of the waste body. The borehole was drilled to a total depth of 7.30mbgl. There was a 0.40m capping layer composed of slightly gravelly clay but the capping layer contained occasional waste. Between 6.50m and 7.00m a layer of hydrocarbon sludge was encountered. Waste was encountered to 7.00mbgl. A layer of peat was present from 7.00m to 7.30m and had a hydrocarbon odour. Water was encountered at 6.00m during the drilling programme and is interpreted as leachate. The monitoring standpipe was screened from 1.0m to 6.30mbgl in the waste body. Natural ground beneath waste was not encountered as the borehole was terminated on an obstruction.

S &A4

This borehole is located in the north eastern portion of the site. This borehole was drilled to a total depth of 4.20mbgl. In this area of the site there was a capping layer of 0.40m composed of slightly sandy slightly gravelly clay but the capping layer contained occasional waste. Industrial sludge / hydrocarbon sludge was encountered at 4.00mbgl. Water was encountered at a depth of 2.70mbgl during the drilling programme and was interpreted as the leachate level. The monitoring standpipe was screened from 1.0m to 3.50m in the waste body. Natural ground beneath the waste body was not encountered due to an obstruction during the drilling phase.

Soil Samples

2 no. soil samples were taken from the footy base of the landfill cap. Soil sample 1 was taken from areas where iron staining was present suggesting the presence of leachate seepage. The results of the intrusive site investigations undertaken in May 2011 have been summarised in Table 2.1.

Table 2.1: Site Investigation Boreholes Summary Details

	BH1	BH2	BH3	S&A1	S&A2	S&A3	S&A4	ST1	ST2	HA1	HA2	HA3
NGR	497661E 555042N	497634E 555004N	497559E 555052N	497531E 555078N	497518E 555031N	497605E 555082N	497623E 555136N	497677E 554965N	497673E 555017N	497686E 554988N	497664E 555009N	497665E 555005N
Ground Level (mOD)	108.64mOD	108.81mOD	117.84mOD	117.69mOD	118.20mOD	119.23mOD	115.73mOD	108.50mOD	112.5mOD	110.87mOD	113.5mOD	113.5mOD
Temporary Cap Thickness (m)	Outside of waste body	Outside of waste body	0.30m but waste present in capping layer	0.30 but waste present in capping layer	0.50m but waste present in capping layer	0.40m but waste present in capping layer	0.30m but waste present in capping layer	Outside of waste body	Outside of waste body	Outside of waste body	Outside of waste body	Outside of waste body
Overburden Description	0.80m peat 0.40m sand 1.50m sand & gravel.	0.90m peat 0.30m sand 2.70m sand & gravel.	Waste to 9.50m over 0.80m peat over 1.20m sandy gravel	Waste to 6.80m	Waste to 9.00m. Peat 8.50m to 9.00m with waste over 0.70m clayey sandy gravel	Waste to 7.00m over 0.30m peat	Waste to 4.20m	0.85m topsoil 0.39m subsoil	0.10m topsoil 0.35m MG 0.75m peat	0.41m topsoil 0.48m till	0.14m topsoil 0.09m topsoil 0.28m till	0.10m topsoil 0.09 Peat 0.31m sand & gravel
Overburden Thickness (m)	2.70m	3.90m	2.00m	Unknown	1.20m	> 0.30m	Unknown	> 1.24m	> 1.20m	> 0.89m	> 0.51m	> 0.54m
Vulnerability	Extreme	High	Extreme		Extreme							
Depth of borehole	5.10m	5.10m	14.00m	6.80	10.20m	7.30m	4.20m	1.24m	1.20m	0.89m	0.51m	0.54m
Depth to top rock	2.70m	3.90m	11.50m	6.7m	9.70m	> 7.30m	> 4.20m	Unknown	Unknown	Unknown	Unknown	Unknown
Elevation top of rock (mOD)	105.94mOD	104.91mOD	106.34mOD	110.99mOD	108.50mOD	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Depth to water or leachate strike (mbgl)	1.70m water in sand & gravel	4.00m water in bedrock	7.50m leachate & 10.30m	4.50m rose to 4.40m leachate	3.50m rose to 3.2m & 7.4m rose to 7.2m leachate	6.00m leachate	2.70m leachate rose to 2.60m	Ingress at base	Ingress from topsoil	None	None	None
Water / Leachate Strike (mOD)	Water 106.94mOD	Water 104.81mOD	Leachate 110.34mOD Water 107.54mOD	Leachate 113.19mOD	Leachate 114.7mOD 110.8mOD	Leachate 113.23mOD	Leachate 113.03mOD					
Thickness of waste	None	None	9.50m	6.80m	9.00m	7.00m	4.20m	None	None	None	None	None
Waste Type	Outside of waste	Outside of waste	Mixed municipal	Mixed municipal Slight sheen at 6.7m	Mixed municipal. Slight sheen at 6m. 7.50 hydrocarbons.	Mixed municipal 6.50m hydrocarbons sludge layer & in peat	Mixed municipal 4.00m hydrocarbons	Outside of waste	Outside of waste	Outside of waste	Outside of waste	Outside of waste
Standpipe Monitoring Interval	1.0m to 5.10m	4.0m to 5.10m	1.0m to 8.0m	1.0m to 5.80m	1.0m to 8.20m	1.0m to 6.30m	1.0m to 3.50m	None	None	None	None	None

A thin covering, 0.20m to 0.50m, of temporary capping is present across the site. This cover material is composed of slightly sandy or gravelly clay. The site investigation indicates the cover material also contains refuse in places. Permeability testing was undertaken on a disturbed sample from the temporary capping layer at BH3 and indicated a permeability value of 6.8×10^{-6}m/sec.

The site investigation indicates shallow overburden depths at the site beneath the waste body ranging from 1.20m at S&A2 to 2.00m at BH3 which would indicate an extreme vulnerability rating for the groundwater body beneath the site. The shallow nature of the overburden is consistent with the outcropping bedrock in the surrounding area. The site investigation borings indicate the ground profile is composed of peat overlying sand and gravel overlying bedrock (BH1, BH2 and BH3). The cable tool borehole S&A2 confirmed the presence of clayey sandy gravel at the site.

The geophysics indicated a containment bund along the north western and south west boundary of the site. The site investigation indicated a permeability value of 1.78×10^{-8} m/sec for this bund.

The depth of waste across the site ranges from > 4.20m at S&A4 in the north eastern corner of the site to 9.50m at BH3 in the centre of the site. The elevation of the top of bedrock beneath the site ranged from 108.50mOD at S&A2, 110.99mOD at S&A1 in the west of the site, 104.91m at BH1 and 106.34m at BH3. The bedrock is deeper in the western area of the site allowing for a greater depth of waste to have been landfilled in the south and west portion of the site. The waste material has penetrated into the underlying peat layer at S&A2 and there is evidence of hydrocarbons in the peat layer in S&A3.

The presence of hydrocarbon sludge in the waste body is limited to the north eastern portion of the site at S&A3 and S & A4. A slight hydrocarbon sheen was reported in S&A1 and S&A2 but no hydrocarbon sludge was reported.

Guidance on the recommendations for a Tier 2 Main Investigation is provided in the EPA Code of Practice in Matrix 2. Matrix 2 provides guidance on the main site investigation requirements for moderate and high risk sites. The adequacy of site investigations has been assessed based on a comparison with the Code of Practice Recommendations as shown in Table 2.2.

Table 2.2: Summary of Site Investigation & Assessment of Compliance with EPA Code of Practice

Item	Site Investigation	Compliance Assessment
Shallow Probes / Hand Augers	3 shallow hand augers HA1, HA2 & HA3. Slit trenches ST1 and ST2.	Hand augering was undertaken on eastern margin of site to examine area where leachate seepage occurring. Limited depth due to shallow nature of bedrock.
Geophysics	EM31 conductivity over fill area and area to south of landfill. Electrical resistivity profiling – 3 no. profiles R1, R2 & R3. Seismic refraction along R1. Magnetometry along R1 27 readings @ 6m spacing's.	Used to target optimal locations for cable tool boreholes in relation to potential hydrocarbons. Surveying did not indicate migration of any leachate plumes in ground to south of site.
Cable Percussion Boring	S&A1, S&A2, S&A3, S&A4	Trial pits not excavated due to objections from local people. Trial pits replaced by boreholes which provided adequate information. Provided information on capping type and thickness, nature of waste, leachate levels, leachate composition, thickness and nature of overburden beneath waste body and permeability testing.
Air Rotary Open Hole Drilling	BH1, BH2, BH3	Provided information on depth to bedrock and nature of bedrock. 3 boreholes completed with one down gradient borehole meets CoP.
Gas Sampling	1 round	No potential receptors within 400m of site
Leachate sampling	Leachate sampling at 2 no. locations and eluate analysis undertaken 2 waste samples	Eluate analysis from 2 no. waste samples which meets CoP. 2 samples analysed for leachate suite meets CoP requirement for 1 – 3 samples full screen Table C.2 of landfill manual.
Soil Sampling	2 samples	Samples from foot of landfill cap in area where leachate was seeping from waste body. Soil sampling does not meet CoP for particle size, permeability & strength.
Surface Water Sampling	7 no. samples analysed	Sampling considered sufficient. Full suite at SW1, SW2, SW3, SW4 and more limited analysis at SW5, SW6 & SW7.
Groundwater sampling	2 no. locations	Not possible to install groundwater monitoring location up gradient of site due to nature of ground and access difficulties. BH2 considered representative of background quality. Full suite up gradient (BH2) and nearest down gradient (BH1).

Item	Site Investigation	Compliance Assessment
Pumping Test	Not undertaken	Not considered necessary as low permeability bedrock.
Ecological Survey	Not undertaken	No sites of ecological significance in the vicinity of the site.
Surface Water Surveys	3 no. small stream risk surveys were completed	Results indicated at least Q4
Odour /Dust or Asbestos Survey	Not undertaken	There is no dust being generated at the site as site temporary capped and re-vegetated. Odour only in one area of site from ponded water resulting from leachate seepage.
Topographic Survey	Completed	Contoured topographic survey completed and borehole locations surveyed.

The site investigation matrix also looks at specialist surveys including ecological surveys and surface water surveys. A stream score survey was undertaken by Cork County Council. There are no designated sites of potential ecological significance in the vicinity of the site therefore no further ecological surveys are considered necessary. An appropriate assessment screening will be undertaken on the proposed remedial works plan once approval has been obtained from Cork County Council.

Based on a comparison of the requirements of Matrix 2 and the actual site investigations undertaken (see Table 2.2), taking account of the additional boreholes that were undertaken in lieu of trial pits, the site investigation undertaken is considered adequate to meet the recommendations of the EPA Code of Practice.

2.5 Bedrock Geology

The National Draft Generalised Bedrock Map for the area indicates the landfill site is located close to the boundary between the Devonian Old Red Sandstones (DORS) to the north and Dinantian Mudstones and Sandstones (DMSC) to south.

The study area is covered by the 1:100,000 Scale Geological Survey of Ireland Sheet 24 Geology of West Cork (GSI, 2002) which provided greater detail on the bedrock formations in the area (Figure 2.1). The northern portion of site is underlain by the Toe Head Formation (TH) which is composed of cross bedded green and purple sandstones, fine grained grey sandstones and interbedded sandstone and mudstone sequences.

The southern portion of the site is composed of the Old Head Sandstone Formation (OH). This formation is composed of fine grained sandstones and minor mudstones.

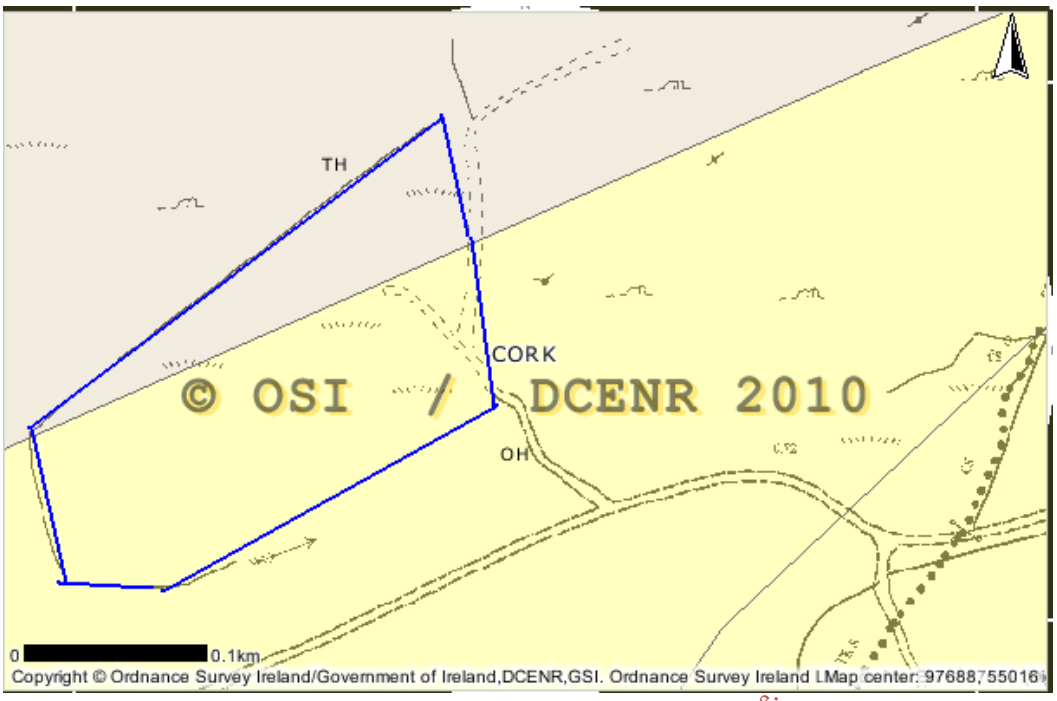


Figure 2.1: Bedrock Geology Map

There is a north west to south east trending fault mapped in the area approximately 150m east of the site entrance. More detailed information on the rock outcrop in the area is available from the GSI historic field sheet 105/1 (scale 1:10,650) which have been obtained from the GSI website. The historic field sheet provides description of the rock outcrops. The outcrop at the site indicates "dark bluish grey slate and grit" dipping at 65 degrees to the SSE. All of the bedrock in the area dips to the SSE varying from 65 degrees to 80 degrees. There is a band of outcropping rock to the north east of the site including purple, grey and green sandstone and mudstone (grits and slates).

Bedrock outcrops are visible within the landfill site and in the adjacent lands. The site investigation has confirmed the bedrock profile beneath the waste body. A falling head test in BH2 in the top of bedrock indicated a permeability value of 10^{-6} m/s. This was in a zone of more fractured and weathered bedrock and permeabilities at greater depth in the bedrock would be expected to be lower.

2.6 Overburden Geology

Information on the subsoil of the area is available from the Teagasc subsoil map (Figure 2.2). The subsoil map indicates the site is underlain by shallow bedrock (Rck) with bedrock either being present at the surface or at a shallow depth (area shaded in grey). There is an area of peat deposits (PKtPt) between the site and the road to the south of the site (area shaded in brown). There is an area of till to the east of the site (area shaded in red). Localised sand and gravel deposits were also encountered in a number of the boreholes.

Information on the soil in the area is available from the EPA website and an extract is provided as Figure 2.3. The soil is (AminSRPT) acid shallow, lithosolic or podzolic type soils potentially with peaty topsoil (area shaded in grey). The area to the south of the landfill is composed of blanket peat (BktPt).

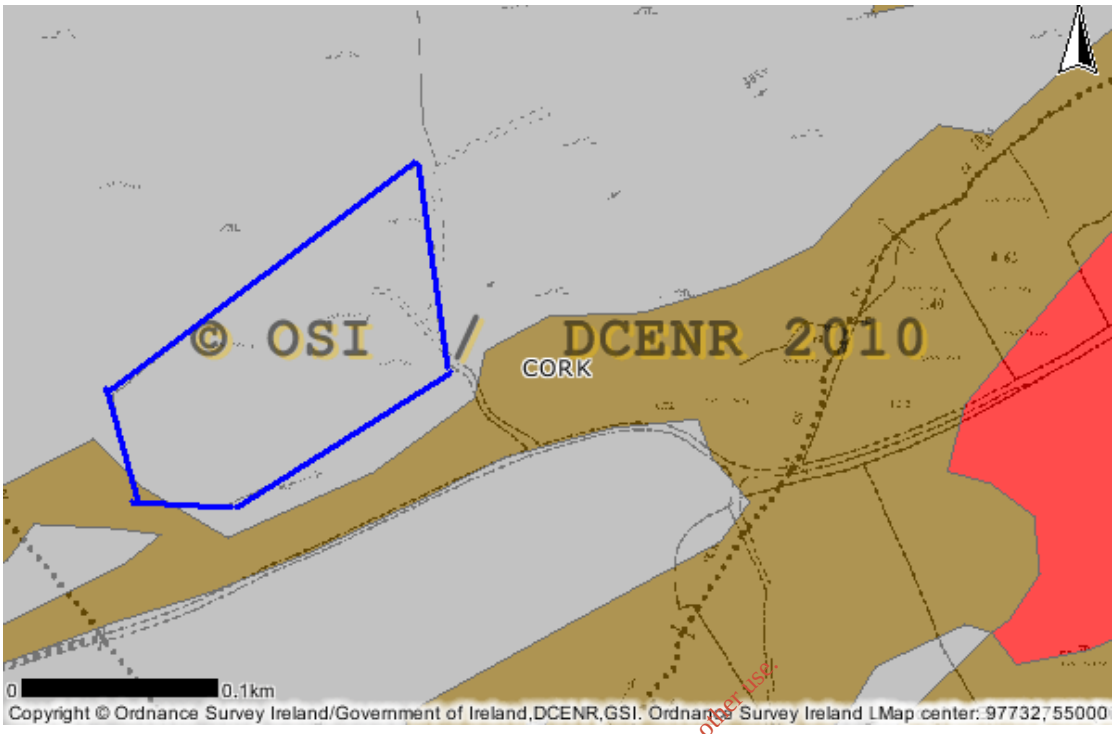


Figure 2.2: Teagasc Subsoil Map

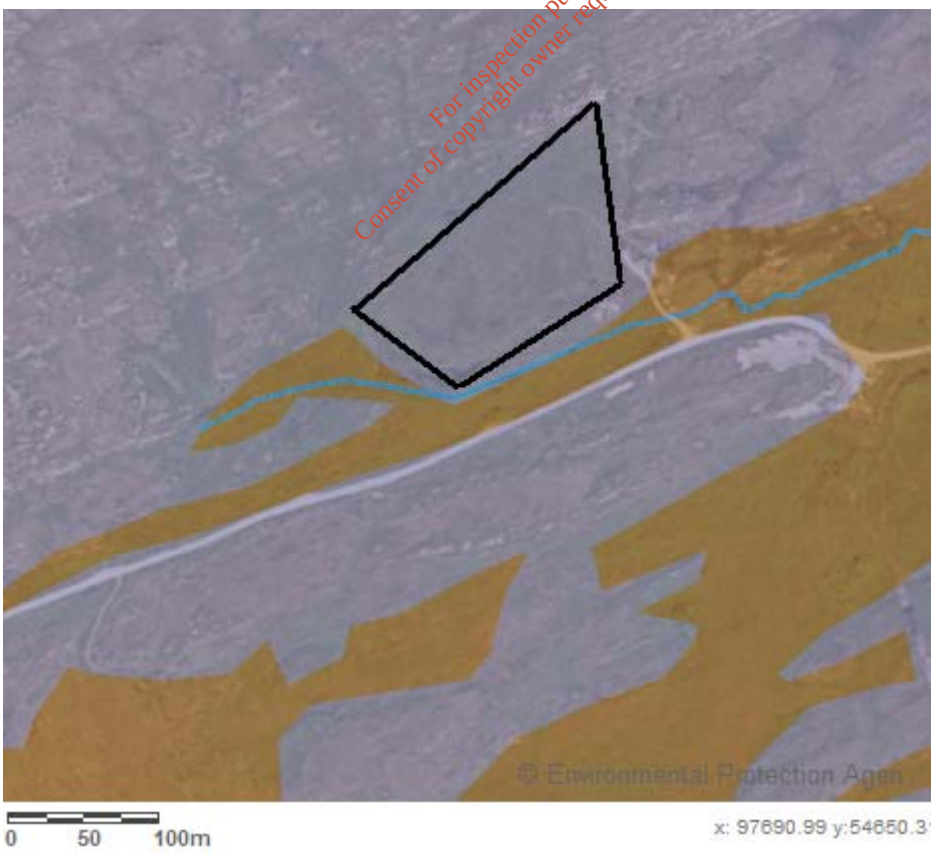


Figure 2.3: EPA Soil Map

2.7 Hydrogeology

The bedrock beneath the landfill site is classed as Locally Important Aquifer bedrock (Ll) which is moderately productive only in local zones as shown on Figure 2.4.

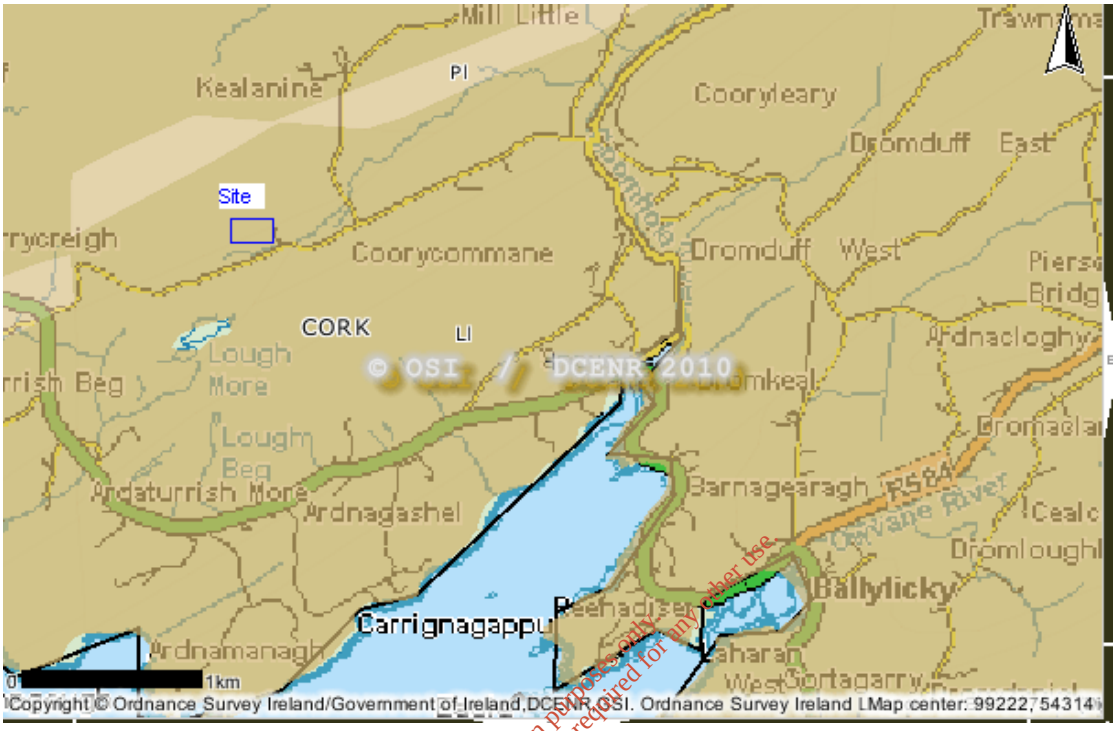


Figure 2.4: Bedrock Aquifer Map

The regional groundwater flow is expected to be in an easterly direction, similar to the surface water flow direction.

The site is located in the Beara Sneem Groundwater Body. The GSI have compiled a description for this groundwater body which summarises the main hydrogeological properties. Most groundwater flow is expected to occur in top 15m to 20m of the bedrock within a weathered zone a few metres in thickness and permeability decreases rapidly with depth. In some areas the weathered zone is connected to a deeper fractured zone but these zones of enhanced permeability tend to be in proximity to faults and fold axes. The GSI report low storage and low transmissivites values (2 – 20m^2/d) for this groundwater body.

Due to the low permeability of the rock and the topography of the area a high proportion of runoff is expected to discharge rapidly to surface watercourses via upper layers of aquifer. Short groundwater flow paths are typical, 30m to 300m, with groundwater discharging rapidly to surface water.

The Beara Sneem Groundwater Body has a WFD Risk Score of 1a i.e. at risk of not achieving good status. The WFD risk score is unrelated to the landfilling activities and relates to the risk associated with the water quality exceeding specific standards for the whole of the groundwater body.

Iron and manganese are often naturally elevated within this groundwater body due to the naturally low pH and the presence of peaty soils and iron rich sandstones.

The GSI vulnerability map indicates the site is located in an area of extreme vulnerability X where rock is at or near the surface (Figure 2.5 - red area). The areas shaded in pink adjacent to the road have an extreme vulnerability rating E- extreme vulnerability. The site specific data from the site investigation phase confirms the extreme vulnerability across the site.

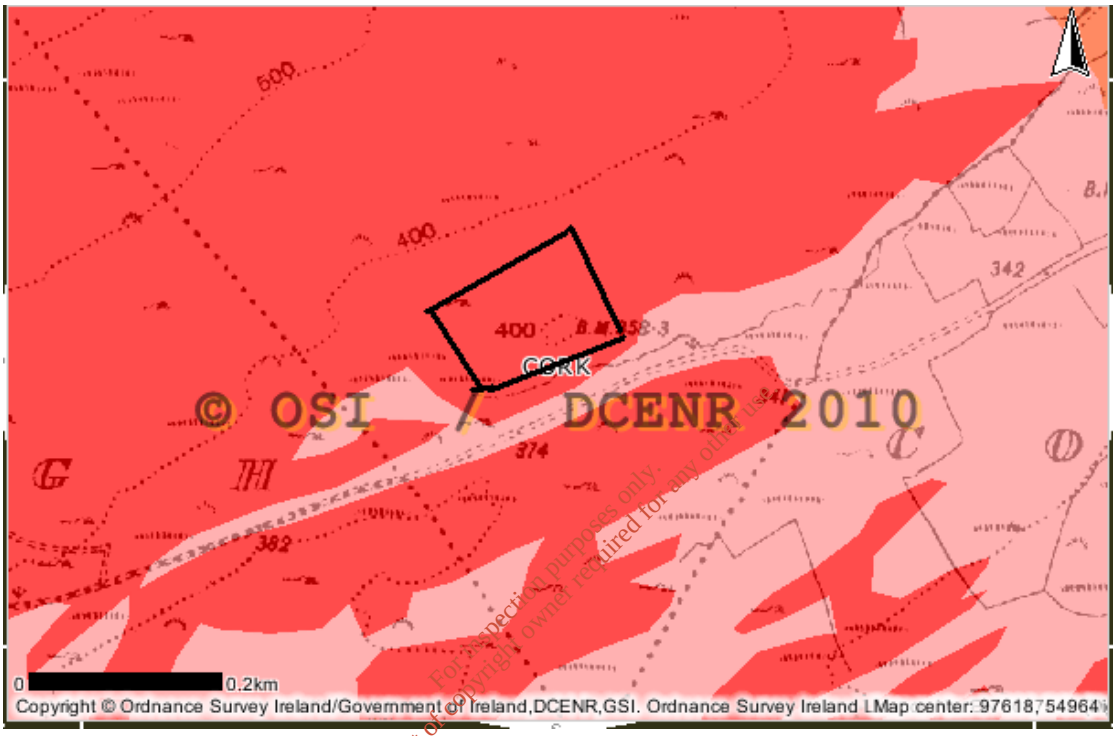


Figure 2.5: GSI Groundwater Vulnerability Map

The site investigation confirmed the presence of an upper weathered layer in the bedrock. Sand and gravel material was also encountered on top of the gravel beneath the peat deposits. Groundwater was encountered in the sand and gravel and in the top of bedrock. A permeability value of 10^{-6}m/sec was estimated for the upper weathered bedrock profile in BH2 (0.08m/d). The sand and gravel deposits on the top of bedrock are not considered to be extensive at the site and do not have significant groundwater potential.

2.8 Private Wells

Information on the extent of the public water supply network was obtained from Cork County Council which confirms that the area surrounding the landfill site is not served by the mains water supply and all houses are likely to be served by private wells.

Based on a review of the available OSI mapping and a drive through survey in the area on the 7th of January 2014 the closest house is located approximately 550m from the landfill site. It is estimated that there may be 3 no. properties potentially served by private wells within a 1km radius of the site of which 2 no. properties are likely to be down gradient of the landfill site. As a result of the short groundwater flow paths (< 300m) which are typical of this aquifer type no impact is expected on these private wells.

2.9 Waste Body

A topographic survey of the site was undertaken in October 2010. There are two portions to the landfill, the main waste body and a smaller mound in the northern corner of the site.

No detailed records are available on the waste deposited at the site. The site investigations and topographic survey indicate the waste thickness is up to 10m in places. The waste deposition ceased completely in November 1997. The site is considered to contain mostly municipal waste from the surrounding areas. The shell and auger boreholes indicated the presence of plastic bags, refuse sacks, packaging, glass, ceramic, metal and timber. Some wastewater sludge and end of life vehicles are also reported to have been deposited. An unknown quantity of crude oil waste from the Whiddy Island Disaster in 1979 was also landfilled at the site.

The borehole logs indicate a waste thickness of 4.20m (S&A4) to 9.50m (BH3). Due to the bedrock profile the thickness of waste is shallower in the north and east of the site. The site investigation confirmed the presence of hydrocarbons in the east (S&A3) and north east (S&A4) of the site in the waste samples. A hydrocarbon slight sheen and odour was detected in S&A1 and S&A2 but there was no hydrocarbon sludge recorded at these locations.

The site walkover on 7th January 2014 indicates shallow cover material in places where exposed waste is visible along sheep tracks. Waste material was also reported within the top soil interval during the intrusive site investigations.

2.10 Leachate

Leachate was encountered in all of the boreholes within the waste body. The Draft Tier 2 and Tier 3 Report by Cork County Council (commenced January 2011) indicated the leachate level varied from 111.1mOD to 113.7mOD which corresponded to a leachate head of between 1.2m and 4.3m.

Based on site walkover (January 2014) and the earlier investigations undertaken by Cork County Council it is evident that leachate migration is occurring to the surface water drains in the vicinity of the site. The presence of iron staining and a visible sheen on the ponded surface water close to the former site entrance confirms that leachate seeps are present along the eastern edge of the landfill site. The discharge of leachate is also occurring to the drain along the north-west and western boundary of the site as evidenced by the presence of iron staining.

The discharge of leachate to the surface water drains in the area is expected based on the hydrogeology of the site. The low permeability bedrock results in leachate preferentially moving along the top of bedrock and in the upper weathered layer of rock. This results in leachate seeps being present at the rock and overburden interface. Groundwater in the area discharges to the surface water drains and streams in the area.

Leachate samples were originally analysed from boreoles S&A2 and BH3 in May 2011. The samples were tested for the full suite of parameters as outlined in the Landfill Monitoring Manual (Table C.2, EPA Landfill Monitoring Manual). When compared to the drinking water limits and IGV values for groundwater the results indicate elevated ammonia and manganese and PAH.

In addition two waste samples from the drilling phase underwent NRA leachate testing. The analysis of the eluate samples also indicated elevated ammonia, manganese and hydrocarbons in S&A3. There is no information in the site investigation documentation on the depth of the waste samples that underwent NRA leachate testing.

The results of the leachate analysis have also been compared to the typical levels for landfill leachate (from Table 3 Typical Leachate composition of 30 samples from UK / Irish Landfills accepting mainly domestic waste, (Landfill Operational Practices Manual, EPA, 1997)). The results indicate the leachate is of low strength when compared to the typical concentrations.

An additional round of sampling and analysis was undertaken by Cork County Council on the 25th of February 2014. The results of the leachate analysis are discussed in Section 4.2.1 Generic Quantitative Risk Assessment.

2.11 Gas Monitoring

During the site investigation phase in 2011 gas concentrations were measured at 4 no. locations within the landfill (S&A1, S&A2, S&A3 & S&A4). An elevated concentration of methane (20% v/v) was measured at S&A3 which was greater than the upper explosive limit of 5% v/v. The borehole was sealed at the time after the gas reading was recorded. During the 2011 round of gas monitoring the methane concentrations in all of the other boreholes ranged from 0 to 2.1% v/v.

An additional round of gas monitoring was undertaken by Cork County Council on the 25th of February 2014 to determine what current gas levels at the site are. It was not possible to undertake monitoring at S&A3 as this borehole was previously sealed. The results of both rounds of gas monitoring are presented in Table 2.3 below. No gas flow rate monitoring was undertaken at the site. It is reported that the standpipes were not sealed and on this basis the samples are taken from vented boreholes.

Table 2.3: Results of Landfill Gas Monitoring

Location	Date	CH_4 % v/v	CO_2 % v/v	O_2 % v/v	Atmospheric Pressure (Mb)	Temp 0^c
S&A1	20/07/11	0.2	0.3	19.7		
S&A1	25/02/14	27.9	19.6	0	976	8.3
S&A2	20/07/11	2.1	3.2	17.7		
S&A2	25/02/14	10.0	5.7	16.0	976	6.3
BH3	20/07/11	0	0	20.1		
BH3	25/02/14	43	8.0	1.0	976	8.0
S&A4	20/07/11	0.4	4.5	11.7		
S&A4	25/02/14	0	0	20.1	976	7.2
BH1	20/07/11	0	1.9	17.8		
BH1	25/02/14	0	0.2	19.6	978	7.7
S&A3	20/07/11	20	19	28		
BH2	25/02/14	0	0.1	20.5	978	7.9

The gas monitoring at the landfill site indicates that methane generation is still occurring within the waste body in significant concentrations in the case of boreholes S&A1, S&A2, S&A3 (2011 reading only) and BH3. On this basis it is recommended that a gas collection layer is included as part of the final capping design.

2.12 Surface Water Monitoring

The results of the analysis of 7 no. surface water samples are available from the vicinity of the landfill site:-

- SW1 – Stream to the south of the landfill upstream of the bedrock outcrop.
- SW2 – Drainage ditch running along the northern perimeter of the landfill.
- SW3 – Upstream side of the bridge at the entrance.
- SW4 – Background quality. Sample taken from small stream to north of landfill.
- SW5 – Surface water ponding to east of landfill.
- SW6 – Surface water ponding to west of landfill.
- SW7 – Upstream side of the bridge 0.4 km downstream of the landfill.
- SWA – Northern stream up gradient of landfill.
- SWB - Northern stream down gradient of landfill.

SW1, SW2 and SW3 were sampled in September 2010 while SW4, SW5, SW6 and SW7 were sampled in May 2011. An additional round of sampling was undertaken by Cork County Council on the 25th February 2014 which included sampling at SW1, SW3, SW7, SWA and SWB. SWA is located up gradient of the landfill site on the stream to the north of the site. SWB is also located on the northern stream but at a location down gradient of the landfill site.

The results of the monitoring indicate the main parameters of concern are ammonia, iron, manganese and hydrocarbons. The results of the monitoring are discussed in detail in Section 4.2.2 as part of the Quantitative Risk Assessment. The monitoring indicates that the landfill is impacting on the surface water quality in the immediate vicinity of the site but the levels reduce to within natural background levels at the monitoring location 400m down gradient of the site.

In addition to the chemical analysis of the surface water samples at the site Cork County Council have also carried out a small stream risk survey in 2011. The survey indicated that the water quality was at least Q4 status.

2.13 Groundwater Monitoring

The monitoring of groundwater quality was undertaken at 2 no. groundwater monitoring boreholes. BH1 is located down gradient of the site while BH2 is located on the opposite side of the surface water stream and is considered to be representative of the background groundwater quality in the area.

The results of the groundwater monitoring are discussed in detail in Section 4.2.3 as part of the Quantitative Risk Assessment. The main parameters of concern were iron, manganese, hydrocarbons and ammonia. Elevated iron and manganese may be a natural feature of the area based on the information in the Beara Sneem Groundwater Body description. Typically this occurs due to low pH, peaty soils and the presence of iron rich bedrock.

Based on the available groundwater monitoring results the landfill site is not significantly impacting on the groundwater quality.

2.14 Protected Areas / Designated Area

Based on a review of the mapping on the National Parks and Wildlife Services Website there are no designated sites indicated down gradient of the landfill sites. The closest designated site is located at Glengarriff Harbour and Woodland which is located at a distance of 2km from the landfill site. This designated site is not located down gradient of the landfill and is not hydraulically connected to the designated site.

3. CONCEPTUAL SITE MODEL

The discussion of the conceptual site model (CSM) has been subdivided into the following elements:-

- Source
- Pathway
- Receptor

In order for a risk to be present a complete source – pathway – receptor linkage must be present.

3.1 Source

The site covers an area of 1.6ha approximately. No detailed waste disposal records are available but it is reported that mostly municipal waste was deposited at the site. Some wastewater sludge, end of life vehicles and oily waste has also been deposited at the site. This has been confirmed by the intrusive site investigations which have included the drilling of 5 no. boreholes within the waste body. The presence of hydrocarbons is concentrated in the eastern portion of the site. It is estimated that in the region of 90,000m^3 of waste has been deposited at the site.

The site investigations indicate the thickness of the waste body ranges from 4.20m to 9.50m. Waste has penetrated into the peat layer beneath the site and waste is also present within the layer of cover material.

The site investigations confirm the presence of leachate within the wastebody. The analysis of the leachate indicates a low strength leachate when compared to the typical leachate composition quoted by the EPA for UK / Irish Landfills accepting mainly domestic waste (Landfill Operational Practices Manual, EPA 1997). Based on the results of the site investigation the main parameters of concern are ammonia, iron, manganese and hydrocarbons. The Draft Tier 2 and Tier 3 report indicated a leachate head of between 1.2m and 4.3m within the waste body.

Rainfall on the site will percolate through the existing cover material and percolate through the waste body. The waste mound has a relatively flat top surface area which will encourage percolation through the waste body due to the permeable nature of the existing cover material. There is currently in the region of 0.2m to 0.50 of cover material present which was classed as slightly sandy clay. Permeability testing on the existing cover material (BH3) yielded a value of 6.8 x 10 $^{-6}$m/sec. Ponding of water on the waste mound was not evident at the time of the walkover survey despite the growth of rushes taking place across the site and the permeability of the cover material has been assessed as moderate.

As outlined in Section 2.11 two rounds of gas monitoring have been undertaken at the site. The 2011 monitoring was undertaken during the site investigation phase. Monitoring was undertaken in the 5 no. boreholes within the waste body (S&A1, S&A2, S&A3, S&A4 and BH3). Low levels of methane (0 to 2.1% v/v) were encountered generally at that time which

was considered to be consistent with the age of the waste. 20% methane was however measured at S&A3 which was considered to be related to localised hydrocarbons in this area. The higher methane concentration at S&A3 was not considered to be representative of the conditions across the site at that time. The landfilling of waste ceased 16 years ago and on this basis the site would be expected to be past peak gas generation. In general the rate of decomposition reaches a peak within the first two or three years of placement then slowly tapers off for periods up to 25 years or more.

Notwithstanding this, the February 2014 gas monitoring results indicate methane at levels ranging from 10% v/v to 43% v/v across the centre and south western portion of the site. It was not possible to monitor S&A3 as this borehole has been sealed. The February 2014 gas monitoring results indicate that methane generation is still occurring within the waste body.

3.2 Pathway

The landfill is not lined therefore pathways exist for leachate migration through the base of the waste body. The site investigations indicate the presence of in the region of 0.8m of peat deposits beneath the waste body. No peat was encountered beneath the waste body at S&A1 along the north western boundary of the site. The peat is underlain by sand and gravel in places which overlies weathered bedrock. A permeability value of 10^{-6} m/s was obtained for the bedrock (BH2). Both the geophysical surveying and site investigation confirm the presence of a weathered interval at the top of bedrock.

The sand and gravel deposits and the weathered bedrock interval are considered to be the main zones for preferential leachate movement.

The intrusive site investigations and water quality monitoring indicate that based on the hydrogeological regime at the site the discharge of leachate to surface water is expected to be dominant. This is based on the low permeability of the bedrock and the short groundwater flow paths. The results of the surface water and groundwater confirm that the leachate is having a more significant impact on the surface water quality with significantly higher ammonia concentrations being measured in the surface water than in the groundwater.

Bedrock is present at the surface in the south eastern corner of the site. The low permeability is likely to be acting as a barrier to leachate movement in this area of the site. Leachate seeps are seen to occur at the surface in the vicinity of the former site entrance which is immediately north of this area of outcropping bedrock. The presence of the low permeability bedrock in the south eastern corner of the site is also resulting in the preferential discharge of leachate to the drainage ditches along the north western and south west site boundaries.

No impermeable capping is present on the waste body therefore vapour migration and gas migration through the existing cover material is possible. There is potential for gas migration in the sand and gravel deposits beneath the waste material. There is potential for gas migration in the weathered and fractured bedrock beneath the site. The migration pathways can be summarised as follows:-

Leachate Migration Pathways

- Leachate migration through the sand and gravel deposits on the top of bedrock and discharging to surface water.

- Leachate migration along upper weathered rock and discharging to surface water.
- Leachate migration along the layer of weathered bedrock and fractures in bedrock impacting on groundwater.

Landfill Gas Migration Pathways

- No impermeable capping present allowing for vapour migration and gas migration to the surface.
- Sand and gravel deposits present in places on the top of bedrock.
- Layer of weathered bedrock and fractures in the bedrock.

3.3 Receptors

The area is not currently served by a public water supply scheme. Information on the public water supply schemes in the area was obtained from Cork County Council. All houses in the vicinity of the site are served by private supply which is expected to be domestic wells. There are no houses located within 500m of the site. The closest house is located approximately 550m from the landfill site. There are 3 no. residential properties located within 1km of the landfill site boundary.

There are no designated sites located in the vicinity of the site. The closest designated site is located at Glengarriff Harbour and Woodland which is located at a distance of 2km from the landfill site. This designated site is not located down gradient of the landfill and is not hydraulically connected to the designated site.

The bedrock aquifer in the vicinity of the site has only a low potential for groundwater resources development.

There is no public water supply located down gradient of the site. The source at Snave Bridge (2.3km) down gradient of the site has not been in use since 2009.

A tributary of the Coomhola River rises in the area of marshy ground located south west of the landfill site. The stream passes within 15m of the southern boundary of the site. The surface water drains on the perimeter of the landfill site do not discharge directly to the stream but discharge to the marshy ground which the stream flows through.

The potential receptors can be summarised as follows:-

Leachate Migration Receptors

The following potential receptors have been assessed in terms of leachate migration:-

Human Presence:-

- The closest private wells are located 550m down gradient of the site.

Protected Areas:-

- There are no designated sites located down gradient of the site.

Aquifer Category:-

- Locally important aquifer which is moderately productive only in local zones.

Public Water Supplies:-

- There is no public water supply abstraction points located down gradient of the landfill site. Snave Bridge on the Coomhola River (2.3km down gradient) previously served 100 people but is no longer in use by Cork County Council. The supply has not been in use since 2009 due to water quality issues unrelated to the former landfill site. The issues with the Snave Water Supply related to the disinfection contact tank being subject to occasional flooding, the contact time for disinfection did not meet the required levels for effective chlorination and there was no barrier present against potential for cryptosporidium and cryptosporidium had been detected.

Surface Water Bodies:-

- An un-named tributary of the Coomhola River is located within 15m of the landfill site.

Landfill Gas Migration Receptors

Human Presence:-

- There are no houses located within 500m of the site. The site has been closed since November 1997. The gas monitoring during the site investigation phases indicated limited gas generation in 2011 although higher levels were recorded in some of the boreholes in the 2014 round of monitoring.

4. RISK ASSESSMENT

4.1 Revised Risk Evaluation

The conceptual site model has been reviewed and a revised risk assessment has been undertaken following a review of the Tier 1 Report (Cork County Council, February 2008) and Draft Tier 2 and Tier 3 Environmental Risk Assessment (Cork County Council, commenced January 2011). The network diagrams for the S-P-R linkage scenarios for the site are contained in Appendix A and are summarised below.

Table 4.1: Revised Risk Assessment

Table	Element	Score
1a	Leachate site area > 1 < 5 ha municipal with potentially small hazardous waste fraction	7/10
1b	Landfill Gas > 1 < 5 ha municipal with potentially small hazardous waste fraction	7/10
2a	Leachate Migration: Pathways Groundwater Vulnerability extreme	3 / 3
2b	Leachate Migration: Pathways Groundwater Flow Regime poorly productive groundwater body (Ll aquifer)	1 / 5
2c	Leachate Migration: Pathways Surface Water Drainage – while the drainage ditches from the perimeter of the landfill site drain to the marshy ground in the south west corner of the site this is considered to be a direct connection.	2 / 2
2d	Landfill Gas Lateral Migration Potential – this applies where buildings, structures or other enclosed spaces are presented adjacent to or within 250m of the waste body. There are no structures or buildings within 250m of the landfill site.	Not applicable
2e	Landfill Gas Vertical Migration Potential – this applies where buildings, structured or other enclosed spaces are present above the waste body. There are no structures, buildings or enclosed spaces within present above the waste body.	Not applicable
3a	Leachate Migration: Receptor Human Presence greater than 250m but less than 1km.	1 / 3
3b	Leachate Migration: Receptor Protected Areas > 1km of waste body	0 / 3
3c	Leachate Migration: Locally important aquifer (Ll)	3 / 5
3d	Leachate Migration: Receptor Public Water Supplies public supply (> 1km no karst aquifer). It should be noted that the source at Snave Bridge 2.3km from site is no longer in use.	0 / 7
3e	Leachate Migration: Receptor Surface Water Bodies within 50m of site boundary.	3 / 3
3f	Landfill Gas: Receptor Human Presence >250m	0.5 / 5

Leachate Migration through Combined Groundwater and Surface Water Pathways

The network diagrams are presented as Figure 1 in Appendix A.

SPR 1 – present

SPR1 = 1a X (2a + 2b + 2c) X 3e
SPR1 = 7 x (3 + 1 + 2) X 3
SPR1 = 126
Normalised Score SPR1 = 126 / 300
Normalised Score SPR1 = 42%

There is potential for leachate to migrate through the peat into the sand and gravel deposits and the top of bedrock. Most of the groundwater movement is expected to take place in the top 15m of bedrock. The low permeability of the locally important bedrock aquifer likely to result in short flow paths with groundwater re emerging in the surface water drains rather than flowing long distances in the bedrock. There is potential for the leachate to impact on down gradient surface water.

Potential for migration horizontally through the high permeability overburden deposits to discharge to the surface water drains on the perimeter of the site.

SPR 2 – Not applicable as there is no Surface Water Dependant Terrestrial Ecosystems (SWDTE) present.

Leachate Migration through Groundwater Pathway

The network diagrams are presented as Figure 2 in Appendix A.

Human presence private well – area served by private wells therefore this is relevant.
SPR3 = 1a X (2a + 2b) X 3a
SPR3 = 7 X (3 + 1) X 1
SPR3 = 28
Normalised Score SPR3 = 28/240
Normalised Score SPR3 = 12%

Impact of leachate on groundwater / terrestrial dependant terrestrial ecosystem
SPR4 = 1a X (2a + 2b) X 3b
SPR4 = 7 X (3 + 1) X 0
SPR4 = 0
No groundwater / terrestrial dependent terrestrial ecosystem present.

Impact of leachate on aquifer
SPR5 = 1a X (2a + 2b) X 3c
SPR5 = 7 X (3 + 1) X 3
SPR5 = 84
Normalised Score SPR5 = 84/400
Normalised Score SPR5 = 21%

Impact of leachate on public supply – area served by mains supply
SPR6 = 1a X (2a + 2b) X 3d
SPR6 = 7 X (3 + 1) X 0
SPR6 = 0%
No potential impact as Snave Bridge supply not in use.

Impact of leachate on surface water body
SPR7 = 1a X (2a + 2b) X 3e
SPR7 = 7 X (3 + 1) X 3
SPR7 = 84
Normalised Score SPR7 = 84/240
Normalised Score = 35%

Leachate Migration through Surface Water Pathway

The network diagrams are presented as Figure 3 in Appendix A.

Impact on Surface Water Body
SPR8 = 1a X 2c X 3e
SPR8 = 7 X 2 X 3
SPR8 = 42
Normalised Score SPR8 = 42/60
Normalised Score = 70%

Impact on SWDTE
SPR9 = 1a X 2c X 3b
SPR9 = 7 X 2 X 0
SPR9 = 0%
No Surface Water Dependant Terrestrial Ecosystem present

Landfill Gas (Lateral and Vertical)

The network diagrams are presented as Figure 4 in Appendix A.

SPR10 = 1b X 2d X 3f
SPR10 = 7 X N/A X 0.5/5
SPR10 = Not Applicable
There are no buildings, structures or other enclosed spaces adjacent or within 250m of the landfill site.

SPR 11 = 1b X 2e X 3f
SPR11 = 7/10 X N/A X 0.5/5
SPR11 = Not Applicable

There are no buildings, structures or other enclosed spaces adjacent or within 250m of the landfill site.

The closest buildings, structures or enclosed spaces are located at a distance of > 500m.

Risk Classification

SPR1 42%
SPR2 Not applicable
SPR3 12%
SPR4 Not applicable
SPR5 21%
SPR6 Not applicable
SPR7 35%
SPR8 70%
SPR9 Not applicable
SPR10 Not applicable
SPR11 Not applicable

On the basis of the risk score for SPR8 (70%) the site would be classed as being a high risk site. On this basis it was decided to proceed with the undertaking of a generic quantitative risk assessment (QRA).

Table 4.2: Summary of Overall Risk Rating

Groundwater & Surface Water	Groundwater only	Surface water only	Lateral & Vertical	
Calculator	SPR Values	Maximum Score	Linkages	Normalised Score
SPR 1 =	12	30	Leachate => surface water	42
SPR 2 =	0	30	Leachate => SWDTE	0
SPR 3 =	2	24	Leachate => human presence	12
SPR 4 =	0	24	Leachate => GWDTE	0
SPR 5 =	8	40	Leachate => Aquifer	21
SPR 6 =	0	56	Leachate => Surface Water	0
SPR 7 =	8	24	Leachate => SWDTE	35
SPR 8 =	4	6	Leachate => Surface Water	70
SPR 9 =	0	6	Leachate => SWDTE	0
SPR 10 =	0	15	Landfill Gas => Human Presence	0
SPR 11 =	0	25	Landfill Gas => Human Presence	0

Risk Classification	Range of Risk Scores
Highest Risk (Class A)	Greater than or equal to 70% for any individual SPR lingage
Moderate Risk (Class B)	Between 40-70% for any individual SPR linkage
Lowest Risk (Class C)	Less than or equal to 40% for any individual SPR linkage

4.2 Generic Quantitative Risk Assessment

A generic quantitative risk assessment was carried out to evaluate the pollutant linkage at the site taking into account the source, the pathway and receptor following the refinement of the conceptual site model. A decision was made to undertake a generic quantitative risk assessment using generic assessment criteria (GAC) as the site had been assessed as posing a potential high risk to the environment based on the Risk Assessment Methodology and scoring system outlined in the EPA Code of Practice (Chapter 4 of Code of Practice).

In accordance with the Code of Practice the risk has been assessed for each pollutant linkage by comparing representative site concentrations with screening levels. In order for a risk to be present the source, pathway and target have to be linked.

As there is only a limited amount (2 rounds) of surface water and groundwater quality monitoring results available it is not considered that a detailed quantitative risk assessment would provide any greater level of certainty.

The screening levels which have been used include the drinking water regulations, the surface water regulations and UK soil guideline values. The site specific information from the site investigation has been examined. It should be noted that the data from BH3 is leachate data from within the waste body rather than groundwater monitoring data from beneath the waste body.

4.2.1 Leachate Assessment

The results of the analysis of leachate are provided in Table 4.3. The results have been compared to the values typically quoted for leachate, groundwater and drinking water limits based on the following publications:

- Typical Leachate Composition (Source Table 3 Landfill Operational Practices Manual, EPA 1997);
- SI No. 9 of 2010 European Communities Environmental Objectives (Groundwater) Regulations, 2010 – Schedule 5 outlines groundwater threshold values which are the levels below which a groundwater body is classed as having good chemical status;
- Groundwater Interim Guideline Values (Interim Guideline Values, Towards Setting Guideline Values For The Protection of Groundwater In Ireland EPA, 2000);
- SI No. 122 of 2014 Drinking Water Regulations.

Comparing the results of the analysis of the eluate to the IGV values and drinking water limits is considered to be a very conservative methodology as the analysis results relate to leachate samples and eluate analysis from within the waste body.

The results indicate the leachate is of a low strength when compared to the ranges quoted for typical leachate concentrations. The results indicate that the majority of the parameters measured are within the level set for the drinking water limits.

The 2011 results for mineral oil concentration and EPH concentration indicate that the total hydrocarbon concentration in the eluate is above the 10 ug/l assessment criteria in terms of the limits set for drinking water. The hydrocarbon concentrations are considered to represent hot spot concentrations as the samples for testing were targeted in the areas where there was visible hydrocarbon contamination.

The concentration of iron, manganese and ammonia are also above the assessment criteria in terms of the limits set for drinking water. The use of drinking water limits is a very conservative comparison. The leachate is of low strength when compared to the typical concentration seen for UK / Irish landfills accepting mainly domestic waste as outlined previously in Section 2.10.

An additional round of sampling was undertaken in February 2014. Monitoring was undertaken at S&A1, S&A2, S&A4 and BH3. It was not possible to sample at S&A3 as this borehole was sealed in 2011 following the completion of the site investigation phase.

The 2014 results indicate a significant reduction in the ammonia concentration at S&A2, S&A4 and BH3. The concentration of iron remains elevated at S&A2 and BH3 and has increased from the levels seen in 2011. The manganese concentration also remains elevated at S&A2, S&A4 and BH3. The sulphate concentration has increased at all monitoring locations since 2011.

The 2014 round of analysis indicates that the concentration of Total Petroleum Hydrocarbons was less than 0.01 mg/l limit of detection at all of the sampling locations. The BTEX concentrations were also less than the limit of detection of 1 ug/l at all sampling locations. PAH levels in boreholes S&A2, S&A4 and BH3 from sampling in 2011 were above drinking water limits.

The concentration of the majority of metals analysed (cadmium, chromium, copper, mercury, nickel and aluminium) were within the limits set by the Drinking Water Regulations. The arsenic concentration in S&A4 and BH3 has reduced below the MAC in the 2014 round of monitoring.

There is no 2014 monitoring data for S&A3 which historically had the highest concentrations measured on site. The concentration of zinc at S&A4 has increased above the IGV in the 2014 sample.

Table 4.3: Leachate Testing

Parameter	Units	S&A1 2014	S&A2 Eluate 2011	S&A2 2011	S&A2 2014	S&A3 Eluate 2011	S&A3 2011	S&A4 2011	S&A4 2014	BH3 2011	BH3 2014	Typical Leachate Overall Range	GW Regulations 2010 Schedule 5 Threshold Values	GW IGV	Drinking Water Regulations SI 122 of 2014
Total Coliforms	Cfu/100 ml	0	0		> 10,000	0			0		350			0	0
Faecal Coliforms	Cfu/100 mls	0	0		3,400	0			0		1			0	0
Colour	Pt-Co		190			88								No abnormal change	No abnormal change
pH	pH units	7.4	8.25		7.4	8.57			7.4		7.3	6.4 to 8.0		6.5 – 9.5	6.5 – 9.5
Electrical Conductivity	uS/cm	1,200	437		820	722			1,000		1,000	503 to 19,200	800 -1875	1,000	2,500
DOC	mg/l		33			42									
Total Alkalinity	mg/l	440	162		400	253			400		490	176 to 8840		No abnormal change	
Total Ammonia	mg/l	0.74	13.27	33.21	0.32	13.26	45.63	121.90	0.32	121.90	0.34	< 0.2 to 1,700	0.065 -0.175	0.15	0.30
Calcium	mg/l	99	33.1	129.2	160	13.3		117.7	200	117.7	130	43 to 1,440		200	
Magnesium	mg/l	16	7.2	21.8	24	3.8		54.1	12	54.1	15	18 to 470		50	
Chloride	mg/l	42	5.8	21.5	32	5.5	210	67.9	43	67.9	41	27 to 3,410	24 – 187.5	30	250
Dissolved Oxygen	mg/l		8			9								No abnormal change	
Total Hardness	mg/l		113			49								200	
Potassium	mg/l	17	6.8	12.6	13	30.5	163.9	71.1	10	71.1	10	2.7 to 1,480		5 mg/l	
Sodium	mg/l	25	5.9	19.1	30	38.8	196.8	79.6	23	79.6	24	12 to 3,000	150	150 mg/l	200
Arsenic	µg/l	2.0	1.8	4.8	1.4	9.0	20.2	10.7	1.2	10.7	1.2	1 to 49	7.5	10 ug/l	10 ug/l
Cadmium	µg/l	< 0.08	0.05	< 0.5	< 0.08	0.03		< 0.5	< 0.08	< 0.5	< 0.08	< 10 to 30	3.75	5 ug/l	5 ug/l
Chromium	µg/l	< 1.0	1.1	< 1.5	< 1.0	2.0		1.8	< 1.0	1.8	< 1.0	< 0.04 to 0.56	37.5	30 ug/l	50 ug/l
Copper	µg/l	6.3	6.5	< 7	2.9	39.7		< 7	1.7	< 7	1.3	< 20 to 160	1,500	30 ug/l	2,000 ug/l
Mercury	µg/l	< 0.5	< 0.5	< 1	< 0.5	< 0.5		< 1	< 0.5	< 1	< 0.5	< 0.1 to 1.0	0.75	1 ug/l	1 ug/l
Nickel	µg/l	< 1.0	2.9	4	< 1.0	10.2		4	19	4	< 1.0	< 30 to 330	15	20 ug/l	20 ug/l
Zinc	µg/l	6.4	47.2	33	5.1	20.3	81	48	270	48	12	10 to 6,700		100 ug/l	
Aluminium	µg/l		114.4			180.5						< 100	150	200 ug/l	200 ug/l
Iron	µg/l	4.4	45.7	< 20	1,300	110.4	477	26	< 20	26	5,400	400 to 664,000		200 ug/l	200 ug/l
Manganese	µg/l	1.3	85.4	1,581	1,500	62.7	68	851	650	851	1,400	100 to 23,200		50 ug/l	50 ug/l
Boron	µg/l	0	142.1	280	0	163.2	1,138	770	0	770	0	< 0.02 to 116	750	1,000 ug/l	1,000 ug/l
Nitrate	mg/l		3.5			2.8							37.5	25 mg/l	50 mg/l
Nitrite	mg/l		< 0.02			< 0.02							0.375	0.1 mg/l	0.5 mg/l
Total Nitrogen (mg/l)	mg/l		16			220								No abnormal change	
Ortho-phosphate	mg/l		0.35			0.35						< 0.1 to 15.8		0.03 mg/l	
Sulphate	mg/l	1,100	6.57	35.19	750	6.45	1.74	7.77	810	7.77	510	< 5 to 739	187.5	200 mg/l	250 mg/l
PAH (16 total)	µg/l			1.43				1.59		1.59			0.075		0.10 ug/l

Parameter	Units	S&A1 2014	S&A2 Eluate 2011	S&A2 2011	S&A2 2014	S&A3 Eluate 2011	S&A3 2011	S&A4 2011	S&A4 2014	BH3 2011	BH3 2014	Typical Leachate Note[1] Overall Range	GW Regulations 2010 Schedule 5 Threshold Values	GW IGV	Drinking Water Regulations SI 122 of 2014
GRO (C4-C8)	µg/l					< 100	< 100								
GRO (C8-C12) (µg/l)	µg/l		< 100			1,200	1,050								
GRO (C4-C12) (µg/l)	µg/l		< 100			1,211	1,050								
MTBE	µg/l		< 5			< 5								30 ug/l	
BTEX	µg/l	< 1.0			< 1.0				< 1.0		< 1.0				
Benzene	µg/l		< 5			< 5								1.0 ug/l	
Toluene	µg/l		< 5			< 5								10 ug/l	
Ethylbenzene	µg/l		< 5			8								10 ug/l	
m/p-xylene	µg/l		< 5			26								10 ug/l	
0-xylene	µg/l		< 5			12								10 ug/l	
EPH (C8 – C40) (µg/l)	µg/l		4,719			13,821	19,035								
Mineral Oil	µg/l		< 10			4,146									
Total Petroleum Hydrocarbons	mg/l	< 0.01			< 0.01				< 0.01		< 0.01			0.01 mg/l 10 ug/l	
Fluoride	mg/l	10		< 0.3	3.7			< 0.3	0.29	< 0.3	8.8				
TON	mg/l	< 0.20		< 0.05	< 0.20			< 0.05	< 0.20	< 0.05	0				
Lead	µg/l	< 1.0		< 5.0	< 1.0			< 5.0	< 1.0	< 5.0	< 1.0	40 to 280			
Phosphorous - total	mg/l			1.906				1.284		1.284					
COD	mg/l	34		18	24			59	13	59	24	< 10 to 33,700			
BOD	mg/l	8.5		< 1	6.3		39	4	< 4	4	25	< 0.5 to > 4,800			
TOC	mg/l	17			9				12		15				
Total cyanide	mg/l	< 0.05		< 0.01	< 0.05			< 0.01	< 0.05	< 0.01	< 0.05	< 0.05 to 0.16	0.0375		
Acid herbicides	µg/l			< 0.01				< 0.01		< 0.01					
Total Pesticides	µg/l			< 0.01				< 0.01		< 0.01			0.375		
VOC	µg/l			p/m xylene 7 ug/l				p/m xylene 3 ug/l		p/m xylene 3 ug/l					

4.2.2 Surface Water Assessment

The surface water quality monitoring results have been compared to the limits set in the following regulations and guidance documents as part of the generic quantitative risk assessment:-

- European Communities Environmental Objectives (Surface Waters) Regulations, 2009 (S.I. No. 272 of 2009).
- European Communities Environmental Objectives (Surface Waters) (Amendment) Regulations 2012.
- EQS for Surface Water EPA Publication "Towards Setting Guideline Values for the Protection of Groundwater In Ireland" (Interim Report, EPA, 2003).
- European Communities (Drinking Water) Regulations, 2014 (S.I. No. 122 of 2014).

The results are presented in Table 4.4. The majority of the parameters measured at the site are compliant with the assessment criteria these being the limits set by the surface water regulations or the drinking water regulations.

Based on the available monitoring data there are only a few concentrations which are above the surface water regulations and the drinking water limits which have been taken as the GAC criteria. The results of the analysis of the surface water samples indicate the main parameters of concern are ammonia, iron and manganese.

In general the highest concentrations were seen at SW2 in the surface water sample from 2010. This monitoring location was located in the drainage ditch running along the northern perimeter of the landfill.

While the iron and manganese concentrations are expected to be naturally elevated in the area as a results of the nature of the bedrock there is evidence that the landfill is leading to higher concentrations in the vicinity of the site in particular at monitoring locations SW1 and SW2. The iron concentration at SW2 in 2010 significantly exceeded the GAC levels. On this basis the landfill site is seen to have resulted in elevated iron concentrations in 2010. Following a review of the 2010 and 2011 monitoring data it was recommended that additional sampling be undertaken to confirm in particular the background water quality up gradient of the site.

On 25th February 2014 an additional round of surface water monitoring was undertaken. Samples were taken from two additional monitoring locations on the stream which drains the higher ground to the north of the site. Monitoring location SWA is located on the northern stream upstream of the landfill site and was selected to provide information on the background surface water quality within the catchment. Monitoring location SWB is also located on the northern stream at a point downstream of the landfill site but upstream of the confluence of the northern and southern streams. The February 2014 round of monitoring also included sampling of the previously monitored locations SW1 stream to south of landfill upstream of the bedrock outcrop, SW3 upstream side of bridge at site entrance and SW7 upstream side of bridge 0.4km downstream of landfill.

Down gradient of the site (SW3, SW7 & SWB), the iron concentration in 2010 and 2014 was less than the drinking water limit of 200 ug/l and less than the 1,000 ug/l EQS recommended by the EPA. There is no limit specified for iron in the 2009 surface water regulations. The iron concentration at SWA which is located up gradient of the site and considered likely to represent background concentrations was < 20 mg/l (25/02/14). The 2014 results indicate low iron concentrations both up gradient and down gradient of the site with a concentration ≤ 20 mg/l reported at SWA, SW1, SW3, SW7 and SWB.

In 2010, monitoring round the manganese concentration at SW1 and SW2 were elevated and significantly higher than the 300 ug/l EQS recommended by the EPA (2003, EQS). No limit has been set for manganese in the 2009 surface water regulations. The 2014 data indicates a level of 46 mg/l at SWA up gradient of the site, 4.6 mg/l at SW1, 30 mg/l at SW3, 19 mg/l at SW7 and 34 mg/l at SWB. The 2014 results indicate a low manganese concentration both up gradient and down gradient of the site.

The zinc concentration at SW1 in 2010 (252.4 ug/l) was higher than the concentration specified in 2009 Surface Water Regulations but the concentration of zinc was not elevated at any other location on any other sampling date and is not elevated down gradient of the site.

The 2010 and 2011 results indicated elevated ammonia in the drains and stream in the vicinity of the site (11 to 66 mg/l). On all sampling dates the ammonia concentration at SW7, located downstream of the site, had considerably reduced. For example in 2011 the ammonia concentration was 0.13 mg/l and in 2014 was 0.28 mg/l. These ammonia levels still slightly exceed the concentrations specified in the Surface Water Regulations for high status (≤ 0.04 mg/l mean) and good status (≤ 0.065 mg/l mean) waters. The 2014 monitoring data indicates an ammonia concentration of 0.21 mg/l up gradient of the landfill site which is similar to the levels seen down gradient of the landfill site at SW7. The highest ammonia concentration in 2014 was seen at SW3 where a concentration of 0.6 mg/l was measured. This indicated that the landfill site is impacting on the ammonia concentration in the surface water in the immediate vicinity of the site but that the level returns to within background levels 400m down gradient of the site.

The 2010 and 2011 monitoring data indicated hydrocarbon contamination at SW5 where an EPH (C4-C12) concentration of 112 ug/l was measured. PAH were not detected at SW1, SW2, SW3 or SW4 at this time. The sample at SW5 was from ponded surface water from a direct leachate seep. No hydrocarbons were detected downstream of the site at SW7 at this time.

The 2014 data included the analysis of Total Petroleum Hydrocarbons (TPH) and BTEX. The results for SW1, SW3 and SWB were less than the detection limits. TPH was detected in the sample from SW7 and SWA. The highest concentration was measured at SWA (0.46mg/l) which represents the surface water quality up gradient of the site. A concentration of 0.14 mg/l was reported at SW7.

There was no evidence of any issue in relation to herbicides, pesticides, VOC's or SVOC's in the surface water in the vicinity of the site during the 2010 or 2011 sampling rounds.

In relation to the February 2014 monitoring data the only parameter to exceed the generic assessment criteria down gradient of the site was the ammonia concentration. The elevated TPH at SW7 in February 2014 cannot be confirmed as being related to the former landfill site as a higher concentration was measured up gradient of the landfill site on the sampling date.

The surface water monitoring also indicates high pH values. The 2014 monitoring indicates a pH of 9.2 pH units both up gradient of the site (SWA) and down gradient of the site (SW7).

The results of the assessment indicate that the landfill is impacting on the surface water quality in the immediate vicinity of the site but the levels reduce to within natural background levels at the monitoring location 400m down gradient of the site.

Table 4.4: Surface Water Monitoring

Date		SW1 01/09/10	SW1 25/02/14	SW2 01/09/10	SW3 01/09/10	SW3 25/02/14	SW4 11/05/11	SW5 13/05/11	SW6 13/05/11	SW7 11/05/11	SW7 25/02/14	SWA 25/02/14	SWB 25/02/14	2009 SW Regs MAC / EQS Inland Surface Waters	Drinking Water Regs SI 122 of 2014	EQS EPA 2003
pH		8.42	9.6	7.55	8.25	9.3					9.2	9.2	9.2		6.5 – 9.5	
E.C.	(µS/cm)	557	150	1548	571	180					160	130	130		2,500	1,000
D.O.	(mg/l)		10			10					10	10	10			
TSS	(mg/l)	44		2258	96		< 10									
Sulphate	(mg/l)	0.34	5.8	< 0.05	0.43	4.8	0.58	6.35	< 0.05	1.73	5.0	4.5	4.7		250	200
Arsenic	(µg/l)	25.9	< 1	1.5	<0.9	< 10	< 2.5	3.0	4.3	< 2.5	< 1	< 1	< 1	20-25	10	25
Boron	(µg/l)	170.1	< 20	358.8	172.5	< 20	< 12	486	484	12	< 20	< 20	< 20		1,000	2,000
Calcium	(mg/l)	46	5.2	126.4	42.5	< 5	0.6				< 5	< 5	< 5			
Chloride	(mg/l)	29.3	41	42.3	32.8	39	10.6	58.5	38.9	11.8	40	39	38		250	250
Fluoride	(mg/l)	< 0.3	0.078	< 0.3	< 0.3	0.075	< 0.3				0.076	0.076	0.078	0.5 – 1.5	0.8	5
Cadmium	(µg/l)	0.08	< 0.08	0.35	< 0.03	< 0.08	< 0.5			< 0.5	< 0.08	< 0.08	< 0.08	≤ 0.45 – 1.5 depending on hardness	5	5
Chromium	(µg/l)	1.2	< 1	4.7	0.5	< 1	< 1.5			< 1.5	< 1	< 1	< 1	0.6-3.4	50	30
Copper	(µg/l)	< 3.0	< 1	< 3.0	< 3.0	< 1	< 7			< 7	< 1	< 1	< 1	5 - 30	2,000	30
Mercury	(µg/l)	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 1			< 1	< 0.5	< 0.5	< 0.5	0.05 - 0.07	1	1
Nickel	(µg/l)	0.7	< 1	3.6	1.8	< 1	< 2			< 2	< 1	< 1	< 1		20	50
Lead	(µg/l)	2.5	< 1	1.6	< 0.4	< 1	< 5			< 5	< 1	< 1	< 1		10	10
Zinc	(µg/l)	252.4	2.8	2.1	6.3	2.3	29	28	25	23	6.3	8.5	6.9	Mean 8 / 50 /100		100
Iron	(µg/l)	135.8	20	4589.0	21.3	< 20	< 20	23	31	114	< 20	< 20	< 20		200	1,000
Manganese	(µg/l)	2602	4.6	2562	178.6	30	29	360	233	19	31	46	34		50	300
Magnesium	(mg/l)	18	1.9	35.1	17.3	2.5	0.8				2.1	1.7	1.8			
Potassium	(mg/l)	19	< 0.5	41.2	19.8	1.4	< 0.1	46.2	47.5	0.7	< 0.5	< 0.5	< 0.5			
Sodium	(mg/l)	31.8	18	47.1	33.5	18	7.1	64.1	47.2	8.3	17	17	17		200	
Phosphorous		26		12	18		< 5			< 5						
Ammonia	(mg/l)	11.33	< 0.2	52.82	12.69	0.6	< 0.03	66.63	46.44	0.13	0.28	0.21	< 0.2	≤ 0.04 high status ≤ 0.065 good status	0.30	0.02 NH3
TON	(mg/l)	0.87	< 0.2	< 0.05	0.46	1	< 0.05				0	< 0.2	< 0.2			
COD	(mg/l)	26		33	33		< 7									
T. Alkalinity	(mg/l)	253		729	238		8									
BOD	(mg/l)	9		1	6		< 1	11	11	< 1						
TOC	(mg/l)		22			25					26	25	24			
PAH 16 Total	(µg/l)	< 0.1		< 0.1	< 0.1		< 0.195								0.10	0.2
TPH	(mg/l)		< 0.01			< 0.01					0.14	0.46	< 0.01			
BTEX	(mg/l)		< 0.001			< 0.001					< 0.001	< 0.001	< 0.001			
Total Cyanide	(µg/l)	< 40	< 50	< 40	< 40	< 50	< 10			< 10	< 50	< 50	< 50		50	10
Acid Herbicides	(µg/l)						< 0.01									
Pesticides	(µg/l)						< 0.01								0.10	
VOCs	(µg/l)						ND									
SVOC	(µg/l)	ND			ND											
EPH (C4-12)	(µg/l)							112	< 10	< 10						

4.2.3 Groundwater Quality Assessment

The groundwater quality monitoring results have been compared to the limits set in the following regulations and guidance documents as part of the generic quantitative risk assessment:-

- European Communities Environmental Objectives (Groundwater) Regulations, 2010 (S.I. No. 9 of 2010);
- European Communities (Drinking Water) Regulations, 2014 (S.I. No. 122 of 2014);
- IGV for Groundwater EPA Publication "Towards Setting Guideline Values for the Protection of Groundwater In Ireland" (Interim Report, EPA, 2003).

The generic assessment criteria have been based on the limits set in the drinking water regulations and the interim guideline values set by the EPA for groundwater (Table 4.5).

An additional round of monitoring was undertaken in February 2014 and included the sampling of BH1 and BH2. BH2 is located on the south side of the southern stream and is considered to represent the background or up gradient groundwater quality. The main parameters of concern are iron, manganese, ammonia and hydrocarbons.

BH1 is located down gradient of the landfill site and elevated iron and manganese were detected at this location when compared to the IGV and drinking water limits.

The manganese concentration in BH1 in 2011 was 2,508 ug/l while a concentration of 110 ug/l was measured in 2014. Both results are above the IGV of 50 ug/l for groundwater. It should be noted that a higher manganese concentration was measured in BH2 in 2011. BH2 is the up gradient monitoring point and is considered to represent the background concentration. In February 2014 the manganese level in BH2 at 11 ug/l was less than the IGV.

The iron concentration in BH1 in 2011 was 324 ug/l. This concentration was above the 200 ug/l IGV for groundwater. In the February 2014 sample the concentration was less than the IGV with a concentration of 30 ug/l measured. On both of these sampling dates the concentration in BH2 was < 20 ug/l which is considered to represent the background concentration.

Naturally elevated iron and manganese would be expected in the area due to the nature of the bedrock and the presence of peaty soils in the area. It is expected that an acidic pH would be a characteristic of the area. However the 2014 samples indicated a pH of 8.5 which is alkaline.

All of the other metals concentrations, arsenic, cadmium, chromium, copper, mercury, nickel, zinc and lead are within the generic assessment criteria i.e. the IGV and MAC concentrations.

The ammonia concentration in BH1 in 2011 was measured at 0.99 mg/l which exceeded the IGV of 0.15 mg/l but was significantly lower than both the concentrations being measured within the waste body and the levels measured in the surface water drains on the perimeter of the landfill site at this time. The ammonia concentration at BH1 in 2011 was above the GAC

of 0.15 mg/l however the 2014 concentration was < 0.20 mg/l.

The concentration of PAH at both groundwater sampling locations in 2011 was less than the limit of detection of 0.195 ug/l. The results of monitoring in 2014 indicated a higher concentration of Total Petroleum Hydrocarbons (TPH) in BH2 (0.24 mg/l) which is the up gradient monitoring location. This may be due to the proximity of this sampling point to the road. In 2014 the concentration of BTEX and TPH at BH1 were less than the limit of detection.

No acid herbicides, pesticides, total phenols or VOCs were detected at either groundwater monitoring location. There is no evidence of hydrocarbon contamination in the groundwater at the site.

Based on the available groundwater monitoring data particularly the monitoring data from 2014 and taking account of the background concentrations measured in BH2, there is no evidence of significant groundwater contamination at BH1 arising from the landfill.

Table 4.5: Results of Groundwater Quality Monitoring

Parameter	Units	BH1 2011	BH1 2014	BH2 2011	BH2 2014	Groundwater Regulations SI No. 9 of 2010	Groundwater IGV	Drinking Water Regulations SI No. 122 of 2014
Total Coliforms	Cfu/100ml	1	28	6	52		0	0
Faecal Coliforms	Cfu/100mls	1	1	6	0		0	0
pH			8.5		8.5		6.5 – 9.5	6.5 – 9.5
EC	Us/cm		370		200	800 – 1,875	1,000	2,500
Total Dissolved Solids	mg/l	203		160				
Total Alkalinity	mg/l	149	61	74	12		No abnormal change	
Total Ammonia	mg/l	0.99	< 0.2	0.06	< 0.2	0.065 -0.175	0.15	0.30
Calcium	mg/l	41.2	40	15.7	14		200	
Magnesium	mg/l	8.8	7.6	4.9	4		50	
Chloride	mg/l	24.6	47	13.9	49	24 – 187.5	30	250
Potassium	mg/l	4.9	8.6	0.7	< 0.5		5 mg/l	
Sodium	mg/l	21.1	26	13.6	18	150	150 mg/l	200
Arsenic	µg/l	5.8	< 1	< 2.5	< 1	7.5	10 ug/l	10 ug/l
Cadmium	µg/l	< 0.5	< 0.08	< 0.5	< 0.08	3.75	5 ug/l	5 ug/l
Chromium	µg/l	< 1.5	< 1	< 1.5	< 1	37.5	30 ug/l	50 ug/l
Copper	µg/l	< 7	1.9	< 7	2.4	1,500	30 ug/l	2,000 ug/l
Mercury	µg/l	< 1	< 0.5	< 1	< 0.5	0.75	1 ug/l	1 ug/l
Nickel	µg/l	< 2	< 1	< 2	< 1	15	20 ug/l	20 ug/l
Zinc	µg/l	23	1.2	23	< 1		100 ug/l	
Lead	µg/l	< 5	< 1	< 5	< 1	18.75	10 ug/l	10 ug/l
Iron	µg/l	324	30	< 20	< 20		200 ug/l	200 ug/l
Manganese	µg/l	2508	110	3594	11		50 ug/l	50 ug/l
Boron	µg/l	94	0	< 12	< 20	750	1,000 ug/l	1,000 ug/l
Sulphate	mg/l	6.73	7.4	4.47	12	187.5	200 mg/l	250 mg/l
PAH total	µg/l	< 0.195		< 0.195		0.075		0.10 ug/l
Total Petroleum Hydrocarbons	mg/l		< 0.01		0.24		0.01 mg/l	
BTEX	mg/l		< 0.001		< 0.001			
Fluoride	mg/l	< 0.3	0.1	< 0.3	0.097		1.0 mg/l	0.8
TON	mg/l	3.1	3	1.6	1			
Phosphorous - total	µg/l	70		2313				
TOC	mg/l	2	28	292	26			
Total cyanide	mg/l	< 0.01	< 0.05	< 0.01	< 0.05	37.5 ug/l		
Acid herbicides	µg/l	< 0.01		< 0.01				
Pesticides	µg/l	< 0.01		< 0.01		0.1 individual / 0.5 total schedule 4. Schedule 5 0.375		
Total phenols	µg/l	ND		ND			0.5 ug/l	
VOC	µg/l	ND		ND				

Table 4.6: Soil / Waste Analysis

Parameter	Unit	Soil 1	Soil 2	S&A4	EPA Note [1]	EPA Note [2]	SGV's Commercial Land Use	SGV's Allotment Land Use	SGV's Residential Land Use
Total sulphate	mg/kg	1,443	1,195	782		200 – 1,500			
Chloride	mg/kg	345	118	165		30 - 300			
Fluoride	mg/kg	0.40	0.04						
Total Oxidised Nitrogen	mg/kg	187.2	76.7						
Ammoniacal nitrogen	mg/kg	< 0.4	< 0.4	57.4		1,00 – 4,000			
Calcium	mg/kg	107,400	39,200			5,000 – 30,000			
Magnesium	mg/kg	1,668	1,385			1,000 – 15,000			
Sodium	mg/kg	306	277	469		500 – 15,000			
Potassium	mg/kg	905	495	621		1,000 – 30,000			
Boron	mg/kg	6.5	13.5	1.8		20 - 1000	192,000	45	291
Arsenic	mg/kg	2.4	88.9	14.1		1 - 50	640	43	32
Cadmium	mg/kg	< 0.1	< 0.1		1	0.1 - 1	230	1.8	10
Chromium	mg/kg	3.6	3.2			5 - 250	8840 (iv) 35 (vi)	15,300(iii) 2.1 (vi)	1 (iii) 4.3 (vi)
Copper	mg/kg	11	8		50	2 - 100	71,700	524	2,230
Mercury	mg/kg	< 0.1	< 0.1		1	0.03 – 0.8	26	26	1
Nickel	mg/kg	5.2	3.8		30	0.5 - 100	1,800	230	130
Lead	mg/kg	8	9		50	2 - 80			
Zinc	mg/kg	131	55	179	150	10 - 200	665,000	618	3,750

Parameter	Unit	Soil 1	Soil 2	S&A4	EPA Note [1]	EPA Note [2]	SGV's Commercial Land Use	SGV's Allotment Land Use	SGV's Residential Land Use
Manganese	mg/kg	1,398	1,034	506		20 – 3,000			
Iron	mg/kg	157,400	289,100	27,370		10,000 – 50,000			
Phosphorous	mg/kg	474	472			200 – 2,000			
Orthophosphate	mg/kg	0.21	0.45						
TOC	%	6.4	7.9						
Total cyanide	mg/kg	1.23	0.98						
EPH (C8-C40)	ug/kg	880	461	14,902					
GRO (C4-C8)	ug/kg	989	< 200	6,555					
GRO (C8-C12)	ug/kg	801	< 200	21,873					
GRO (C4-C12)	ug/kg	1,790	< 200	28,428					

Note [1] Table A.1 Maximum Concentration of Heavy Metals In Soil based on Sewage Sludge Directive. Publication towards Setting Environmental Quality Objectives for Soil (EPA, 2002).
Note [2] typical range of major and trace elements in non polluted agricultural soils.

4.2.4 Soil & Waste Assessment

The soil and waste analysis results have been compared to the generic assessment criteria for soils which have been developed to be protective of human health based on different final end uses.

A copy of the Soil Guideline Values (SGV's) and Generic Assessment Criteria (GAC) used in the assessment are contained in Appendix D. The results of the analysis of the soil and waste sample have been compared to the soil guideline values specified in the following documents:-

- The LQM / CIEH Generic Assessment Criteria for Human Health Risk Assessment (2nd Edition), July, 2009.
- SGV reports by the Environment Agency.
- Environment Agency Science Report SC050021/SR3 – Updated technical background to the CLEA model, January 2009.

The proposed final end use of the site has not been decided to date therefore Appendix D contains a copy of the SGV's / GAC's for commercial end use, allotment end use and residential end use. It is likely that the final end use will involve the grazing of animals on the restored site.

It should be noted that there are not values specified for all parameters that were analysed in the soil / waste samples. Screening values are not derived for parameters that are unlikely to pose a risk to human health.

The soil and waste analysis results have also been compared to the background data for soil based on the EPA publication Towards Setting Environmental Quality Objectives For Soil (EPA, 2002). The results have been compared to the typical range of major and trace elements in non polluted agricultural soils (Table 4.6 Note 2) and the maximum permitted concentration of heavy metals in soil based on the sewage sludge directive (Table 4.6 Note 1).

It is not possible to compare the results of the soil or waste analysis to the assessment criteria for TPH and BTEX compounds as the SGV's are specified for target fraction concentrations based on the TPH- CWG analysis. Based on the analysis undertaken to date it is not possible to confirm whether the TPH concentrations within the soils relate to aliphatic or aromatic compounds and therefore it is not possible to comment on whether the GAC in relation to hydrocarbons have been exceeded.

Due to the location of the site it is not likely to be utilised for residential development, commercial / industrial end use or allotment. Based on the surrounding land use the likely end use would be restoration to agricultural end use for grazing of livestock. On this basis the allotment end use criteria are not directly applicable as human health receptors are unlikely to actually be exposed to the identified contamination due to the depth of the identified contamination which is unlikely to impact on grass production. The soil analysis (Sample 1 and Sample 2) indicates substantially lower EPH and GRO levels than within the waste body (Table 4.6).

It should also be noted that there can be interferences in TPH levels from naturally occurring materials such as peat, dried grass or humic material in top soil. It should be noted that peat deposits are present beneath the waste body and in the surrounding area.

The only GACs protective of human health which was confirmed as being exceeded was the arsenic concentration in Sample 2 which was above the GAC for residential and allotment end use but was less than the limit specified for commercial end use.

The installation of the final capping will involve the installation of a 0.5m interval of topsoil and subsoil above the low permeability barrier layer. The grass sward will be established on clean imported topsoil and subsoil. In the event of animals grazing on the site in the future there will be no connection between the waste body and the vegetation growing on the site.

4.3 Summary

A generic quantitative risk assessment (QRA) has been completed on the landfill site based on the site investigation and environmental monitoring carried out in 2010, 2011 and 2014.

The results of the assessment indicate the leachate is of low strength when compared to ranges quoted for typical leachate concentrations. The hydrocarbon concentrations in the east of the site are considered to be hotspot concentrations. The main contaminants of concern identified in the leachate were iron, manganese, ammonia and hydrocarbons. The 2014 data indicates that hydrocarbons in the leachate monitoring locations S&A1, S&A2, S&A4 and BH3 were less than the limit of detection.

The main parameters of concern in relation to the potential impact on the surface water in the vicinity of the site are ammonia, iron and manganese. There is no evidence of metals or hydrocarbons presenting a risk to the surface water down gradient of the site. The February 2014 results indicate no issue in relation to the concentration of iron and manganese down gradient of the site. The landfill is having an impact on the ammonia concentration in the immediate vicinity of the site (SW3) but the level returns to within background concentrations 400m down gradient of the site. The 2010 and 2011 data indicated hydrocarbon contamination at SW5 which was ponded water from a direct leachate seep. The 2014 data indicates a higher concentration of hydrocarbons in the up gradient monitoring location (SWA) than down gradient of the landfill site (SW7).

In relation to the groundwater quality the main parameters of concern are iron, manganese, ammonia and hydrocarbons. Based on the available monitoring data there is no evidence of significant groundwater contamination in the vicinity of the site.

The site investigation results indicate that there is a limited amount of material which could be classed as hazardous under the European Waste Catalogue and Hazardous Waste List. The environmental monitoring data indicates that the landfill is not having a significant effect on the groundwater or surface water down gradient of the site.

The risk to human health based on the measured concentrations of contaminants in the soil / waste are considered to be low while the site remains in its current use and form. The seepage of leachate is occurring along the central area of the eastern boundary of the landfill

site. The installation of a permanent capping system is recommended to reduce the leachate generation and leachate seepage.

In relation to gas due to the distance of neighbouring properties from the landfill the gas levels are not considered to pose a risk to neighbouring properties and were not included in the QRA. Methane is still being generated at the site and this would need to be taken into account in the design of any capping layer.

The quantitative risk assessment indicates that the waste material does not pose a significant risk to the groundwater down gradient of the site. The main risk relates to the surface water quality in the immediate vicinity of the site. Based on the dilute nature of the leachate present at the site and the results of the surface water and groundwater quality monitoring a risk classification of moderate is deemed as being more appropriate to the site.

To date only two rounds of monitoring data are available. As some of the measured site concentrations have been higher than the generic assessment criteria remedial measures are recommended and these are discussed in Section 5.

5. REMEDIAL OPTIONS

5.1 Remediation Plan

A number of remedial options have been considered as part of the risk assessment. The options which can break the links identified by the source pathway receptor model include:-

- Removal of waste to a licensed landfill
- Installation of an infiltration barrier.

Source Removal

The excavation and removal of waste off site to a licensed landfill facility would have the main advantage of completely removing the source of contamination. The disadvantages of this option include the associated costs, considerable environmental nuisance during the excavation and removal process and the high number of vehicle movements that would be required to remove the material off site.

There would be considerable environmental issues associated with the excavation of the waste including:-

- Odour nuisance caused by waste excavation.
- Dust nuisance as a result of excavation of waste and soil material and vehicle movements required to transport the material offsite.
- Bird nuisance from scavenging gulls and crows during the excavation operation.
- Fly and rodent nuisance as a result of excavation of waste.
- Increase in noise levels as a result of excavation, sorting operations and transport of material offsite.
- Potential for contamination of surface water and leachate generation as a result of runoff from working areas during periods of wet weather requiring temporary leachate control measures.
- Potential contamination of watercourses through mobilisation of contaminants within the waste excavated.
- Excavation of previous stabilised waste along the north western and south western side of the site may create issues in relation to slope stability.
- Significant increase in traffic movements on road network in surrounding areas as a result of material being transported offsite.

It is estimated that in the region of 90,000 tonnes of waste may have been deposited at the site. The removal of this material would involve approximately 4,500 truckloads of material off site based on 20 tonnes per truck.

The estimated cost of this option is 10.8M excluding VAT for the landfilling of 90,000 tonnes on a licenced facility based on a rate of € 120 per tonne. This estimate excludes the costs associated with transportation of the material to a suitably licensed facility and the restoration of the site following the removal of the waste.

Installation of Low Permeability Barrier

A water balance has been prepared for the site to demonstrate the reduction in the volume of leachate being generated as a result of the installation of a low permeability capping layer (such as compacted clay, LLDPE or GCL) at the site. The installation of a low permeability barrier would significantly reduce the volume of leachate being generated at the site and significantly reduce the volume of leachate being discharged to the surface water and groundwater in the vicinity of the site. The purpose of the water balance is to determine if there is any significant pollutant linkage remaining after the installation of a final cap.

The average monthly rainfall figures from Valentia, Co. Kerry have been used to predict the potential leachate that would have been generated had a low permeability engineered cap been installed at the site. The calculated PE Penman evapotranspiration data was also obtained from the Met Eireann Weather Bulletin for Valentia, Co. Kerry.

Based on the recommended final capping design it is estimated that an infiltration of the order of 6% would be achieved for a worst case scenario. The infiltration range for restored areas outlined in the EPA Landfill Site Design Manual (EPA, 2000) is 2 to 10% of effective rainfall in a worst case scenario for a geosynthetic clay liner cap. On this basis a 6% infiltration figure has been used in the Water Balance Calculations.

The landfill site is currently covered by a layer of slightly sandy or gravelly clay across the site with a permeability of 6.8 x 10^{-6}m/sec measured at BH3. The GSI recharge co efficients for different hydrogeological settings have been consulted. Based on the relatively flat nature of the waste body and the nature of the temporary cover, is considered to be equivalent to GSI category of 'moderate permeability subsoil overlain by well drained soil'. Based on this a minimum recharge co efficient of 80% with an inner range of 50 – 70% would apply. In order to provide a conservative estimate on the potential improvement the recharge co efficient of 60% has been used for the current uncapped situation.

The full area of the site has been used for the water balance calculation (16,000m^2). The water balance calculation has been based on the methodology outlined in the Landfill Site Design Manual (EPA, 2000).

Lo = [ER (A) + LW + IRCA + ER (1)] – [aW]

Where:

Lo = leachate produced (m^3)
ER = effective rainfall (m)
A = area (m^2)
LW = liquid waste
IRCA = infiltration through restored and capped areas (m)

1 = surface area of lagoons (m^2)
A = absorptive capacity of waste (m^3/t)
W = weight of waste deposited (t/a)

The rainfall and evapotranspiration figures from 2012 have been used for illustrative purposes as this is the most recent full year for which data is available from the Met Eireann Weather Bulletin. During 2012 no liquid waste was deposited and there is no leachate lagoon present at the site. The site has not been permanently capped therefore these items can be omitted from the above formula and the leachate volume can be calculated from:

L0 = ER(A)

The effective rainfall has been calculated based on the GSI recharge co efficient and the effective rainfall. The following volumes have been calculated:-

- 60% infiltration 10,063m3
- 6% infiltration 1,006m3

Table 5.1: Leachate Generation Current Status Temporary Capping 60% Infiltration

Period	2012 Rainfall (mm)	2012 Evapotranspiration	Effective Rainfall (mm)	Effective Rainfall (m)	Volume of Leachate (m^3)
Jan	156.7	21	81.42	0.08142	1303
Feb	67.6	21	27.96	0.02796	447
March	42.3	48	0	0	0
April	119.1	51	40.86	0.04086	654
May	53.5	51	1.5	0.0015	24
June	128.3	64	38.58	0.03858	617
July	172.9	51	73.14	0.07314	1170
August	163.9	49	68.94	0.06894	1103
September	74.6	39	21.36	0.02136	342
October	136.2	28	64.92	0.06492	1039
November	212.9	18	116.94	0.11694	1871
December	173.5	18	93.3	0.0933	1493
Total					10,063

Table 5.2: Leachate Generation Proposed Final Engineered Cap 6% Infiltration

Period	2012 Rainfall (mm)	2012 Evapotranspiration	Effective Rainfall (mm)	Effective Rainfall (m)	Volume of Leachate (m3)
Jan	156.7	21	8.142	0.008142	130
Feb	67.6	21	2.796	0.002796	45
March	42.3	48	0	0	0
April	119.1	51	4.086	0.004086	65
May	53.5	51	0.15	0.00015	2
June	128.3	64	3.858	0.003858	62
July	172.9	51	7.314	0.007314	117
August	163.9	49	6.894	0.006894	110
September	74.6	39	2.136	0.002136	34
October	136.2	28	6.492	0.006492	104
November	212.9	18	11.694	0.011694	187
December	173.5	18	9.33	0.00933	149
Total					1,006

The estimated volume of leachate produced during 2012 is 10,063 m^3 in the event of the final capping having been in place this would have been reduced to 1,006m^3. The water balance has demonstrated that the installation of a properly designed cap will significantly reduce the volume of rainfall infiltrating the waste body and therefore the volume of leachate being generated at the site.

5.2 Recommended Solution

As demonstrated in Section 5.1 above, the installation of a low permeability barrier would limit the amount of water that could enter the landfill and therefore restrict the decay of the waste and the generation of contaminated leachate. It is considered that this is a more appropriate, cost-effective and sustainable solution for the remediation of the site compared to the full excavation and removal of the waste.

The main advantage of this option is that it would prevent the excavation of large volumes of waste or the requirement to remove material from site. This option is the most economic solution, can easily be installed and would provide an immediate solution.

It is therefore recommended that the remedial option is based on the final capping of the site.

The EPA recommendations for non hazardous biodegradable landfill capping systems as set out in the EPA Landfill Site Design Manual are as follows:-

- Topsoil 150 – 300mm and subsoil of at least 1m.
- Drainage layer of 0.5m thick having a minimum hydraulic conductivity of 1 x 10–4m/s.
- Compacted mineral layer of minimum 0.6m thickness having a hydraulic conductivity of less than or equal to 1 x 10-9m/s or a geosynthetic material (GCL) or similar that provides equivalent protection.

- Gas collection layer of natural material (minimum 0.3m) or a geosynthetic layer.

The purpose of the soil (topsoil and subsoil) layer is to protect the drainage layer and barrier layer and provide a substrate for the establishment of the grass sward. Based on the remediation of the site to low intensity grassland it is proposed to install a 0.50m layer of soil (100mm topsoil and 400mm subsoil). The 0.50m combined soil thickness is considered sufficient to protect the low permeability barrier layer on the basis that no trees are proposed to be grown on the site and the site is not being developed as a public amenity area. This is in accordance with the 0.50m total combined soil depth specified by the EPA in the Landfill Restoration Manual (EPA Manual Table 4.3) for inert landfills with no capping layer or gas control layer. The proposed future end use of the site to include animal grazing is considered compatible with the installation of the low permeability capping layer and the 0.5m soil layer.

The use of engineered clay may be cost prohibitive, however, a product such as an LLDPE or GCLwould be a cost effective alternative as part of the final capping. While the installation of the final capping would slightly increase site levels, it would prevent the excavation of large volumes of waste or the requirement to remove material from site. The purpose of the barrier layer is to reduce the volume of rainfall infiltrating into the waste body. This will reduce the volume of leachate being generated and consequently reduce the volume of leachate being discharged to the surface water and groundwater in the vicinity of the site.

The results of the 2014 round of gas monitoring indicate that methane is still being generated at the site and a gas collection layer will also need to be incorporated into the final capping system. The purpose of the gas collection layer is to prevent excessive build up of landfill gas beneath the geomembrane barrier layer and to prevent strain of the geomembrane layer which could lead to it being damaged. The gas collection layer and passive vents will also minimise the risk of migration of landfill gas beyond the site.

Based on the above therefore the recommended final capping solution should be composed of the following elements:-

- 0.50m of soil (100mm topsoil and 400mm subsoil).
- Drainage layer 0.5m thick with permeability of 1 x 10-4m/s or equivalent geosynthetic material.
- Compacted mineral layer 0.6m thick with permeability < 1 x 10-9 m/s or geosynthetic material (LLDPE or GCL) or similar that provides equivalent protection.
- Gas collection layer 0.3m minimum of natural material or geosynthetic layer.

The final capping would be installed after an initial vegetation scrape and site reprofiling to facilitate surface water runoff from the site. A 0.50m layer of topsoil (100mm) and subsoil (400mm) is proposed as part of the final capping detail. The installation of the final capping will slightly increase site levels but this would not be out of character with the surrounding hummocky topography of the area. A cross section detail of the proposed capping layer is provided as Figure 5.1.

Some regrading of the side slopes will be required particularly along the northern, western and eastern boundaries to provide more appropriate side slopes on which to place the

capping system. The stability of the lining system should be considered in any final design solution.

The lining system should be anchored appropriately and some backfilling of the adjoining ditches (preferably with low permeability material) may be required to provide a toe or key within which the capping layers can be tied in or anchored into and to limit direct discharge of seepage into the streams.

A low permeability clay (or other) plug should also be formed or constructed where the capping encounters the edge of the rock outcrop to seal off any localised seepages. It is not considered necessary or practicable at this stage to line the outer face of the rock outcrop as the volumes of leachate should reduce after capping however the sides and base of the outcrop should be monitored over time to check whether seepages are occurring.

The results of the February 2014 round of monitoring indicate that methane is still being generated at the site. On this basis it is recommended that a perimeter gas collection trench will be constructed around the full perimeter of the site with passive gas vents. The gas collection system from the capping should preferably tie in to this trench or be vented separately.

It is recommended that stock proof fencing be installed on the full perimeter of the site to prevent livestock gaining access to the site to prevent damage (poaching) to the cover material. This stock proof fencing would need to be installed prior to the commencement of the capping works to prevent livestock from the surrounding area accessing the site. Following the establishment of the grass sward it may be possible for livestock grazing to take place at a later date.

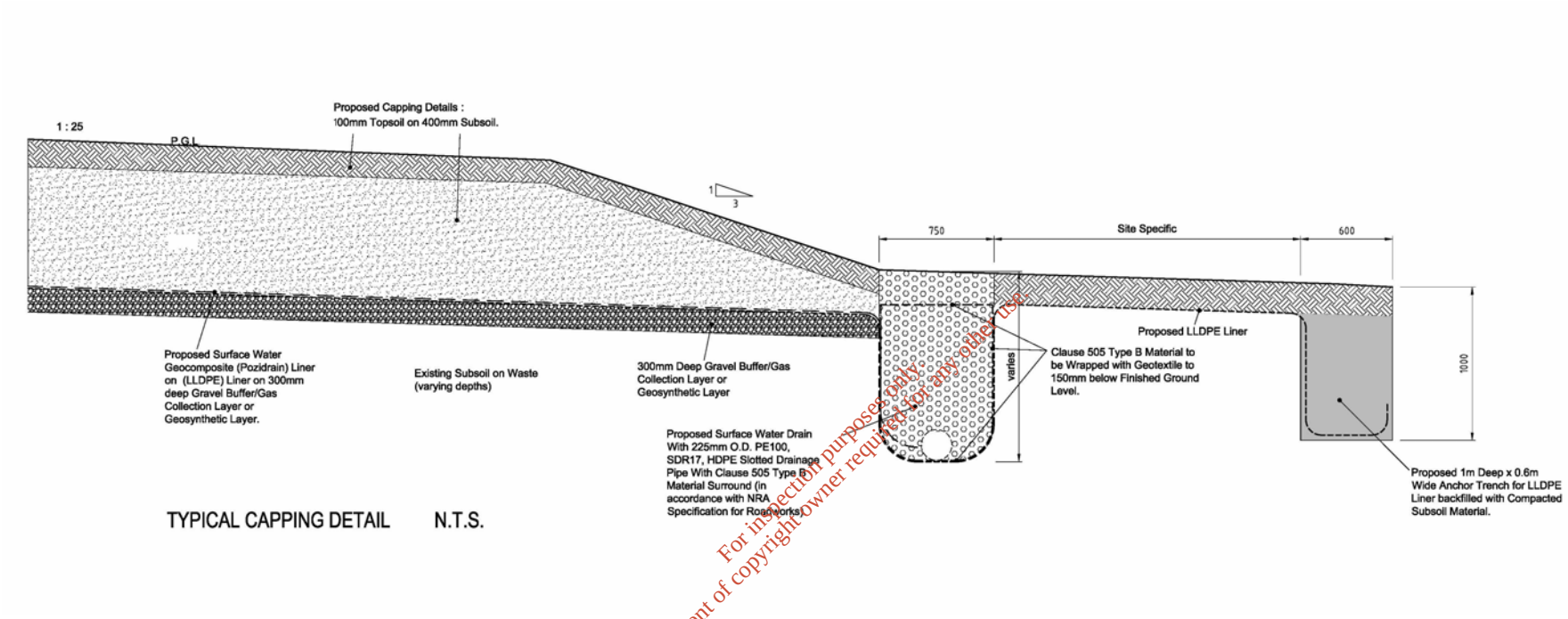


Figure 5.1: Typical Capping Detail

6. CONCLUSTIONS AND RECOMMENDATIONS

6.1 Remediation Option

The revised risk assessment concludes that a moderate risk classification is more appropriate for the site based on the results of the monitoring data.

There are two remedial options which break the source pathway receptor model linkage. These are (a) removal of the waste to a licensed landfill (b) installation of low permeability barrier.

The risk of environmental pollution arising from the excavation, removal and transportation of waste to a suitably licensed facility is considered to be greater than the option of leaving the waste in situ and installing a low permeability capping layer.

The main environmental risk associated with the waste body is the discharge of leachate to the surface water drains and streams in the vicinity of the site. The installation of a low permeability capping layer will significantly reduce the volume of leachate being generated. This will significantly reduce the volume of leachate being discharged to the surface water in the vicinity of the site as outlined in Section 5.1.

From a cost perspective the excavation and removal of the waste to a suitably licensed facility would cost in excess of € 10.8M compared to an estimate of € 350,000 to €400,000 for the installation of a low permeability capping layer.

The recommended remedial option therefore is to leave the waste in situ and undertake the installation of a low permeability barrier layer within the final capping across the entire surface of the site. The proposed remedial option has been designed to ensure that there is no significant pollutant linkage remaining after the installation of the final cap has taken place.

This solution has been developed to take into account the findings of the risk assessment, recommended best practice in terms of the EPA Landfill Restoration and Aftercare Manual in combination with development of the most cost effective solution.

It is considered that the installation of the final capping will reduce the generation of leachate sufficiently to ensure that no significant pollutant linkage remains present. The construction of the low permeability barrier layer and its impact on the source – pathway – receptor linkage has been assessed in terms of the following:-

- The water balance demonstrates the potential reduction in the volume of leachate being generated.
- The reduction in the leachate generation will lead to a reduction in the volume of leachate being discharged to the surface water and groundwater in the immediate vicinity of the site. This will lead to a reduction in the concentration of contaminants in groundwater and surface water.

6.2 Remediation Monitoring Programme

It is recommended that a monitoring programme be put in place to monitor any changes in groundwater and surface water composition or gas levels following on from the implementation of the remedial works. The installation of additional monitoring boreholes is not required. It is recommended that the existing boreholes installed on site are retained for monitoring purposes during the aftercare monitoring period. Table 6.1 outlines the recommended monitoring frequencies and sampling locations for monitoring during the aftercare period.

Table 6.1: Environmental Monitoring Requirements Aftercare Phase

Item	Frequency	Proposed Monitoring Locations
Leachate Levels	Bi annual	S&A1, S&A2, S&A4
Leachate composition	Bi annual	S&A1, S&A2, S&A4
Gas Levels	Bi annual	S&A1, S&A2, S&A4
Surface Water Composition	Bi annual	SW1, SW3, SW4, SW6, SW7, SWA & SWB
Groundwater Composition	Bi annual	BH1, BH2
Groundwater Levels	Bi annual	BH1, BH2

The recommended parameters for the aftercare monitoring period are outlined in Table 6.2. It is recommended that the monitoring programme be reviewed after 2 years. As part of the review an assessment shall be made on the possibility of reducing the number of monitoring locations based on the first two years of monitoring data.

It is recommended that gas monitoring be undertaken during and following the installation of the final capping. Landfill gas will be monitored using a portable landfill gas analyser for the following parameters: volumetric flow rate, atmospheric pressure, and temperature and landfill gas composition.

Table 6.2: Recommended Monitoring Parameters for Aftercare Monitoring

Aftercare Monitoring	Parameters
Landfill Gas	Methane, carbon dioxide, oxygen, atmospheric pressure, temperature.
Groundwater	Groundwater level, temperature, pH, electrical conductivity, ammonia, total oxidised nitrogen, total organic carbon, calcium, magnesium, sodium, potassium, iron, manganese, cadmium, chromium, copper, nickel, lead, zinc, arsenic, boron, mercury, total alkalinity, sulphate, chloride, cyanide, fluoride, F. Coliforms, T. Coliforms, total petroleum hydrocarbons & BTEX.
Surface Water	Temperature, pH, electrical conductivity, total organic carbon, dissolved oxygen, ammonia, total oxidised nitrogen, total alkalinity, sulphate, chloride, cyanide, fluoride, calcium, magnesium, sodium, potassium, iron, manganese, cadmium, chromium, copper, nickel, lead, zinc, arsenic, boron mercury and total petroleum hydrocarbons & BTEX.

APPENDIX A

NETWORK DIAGRAMS

Figure No. 1: Network Diagram For Leachate Migration Through Combined Groundwater & Surface Water Pathways

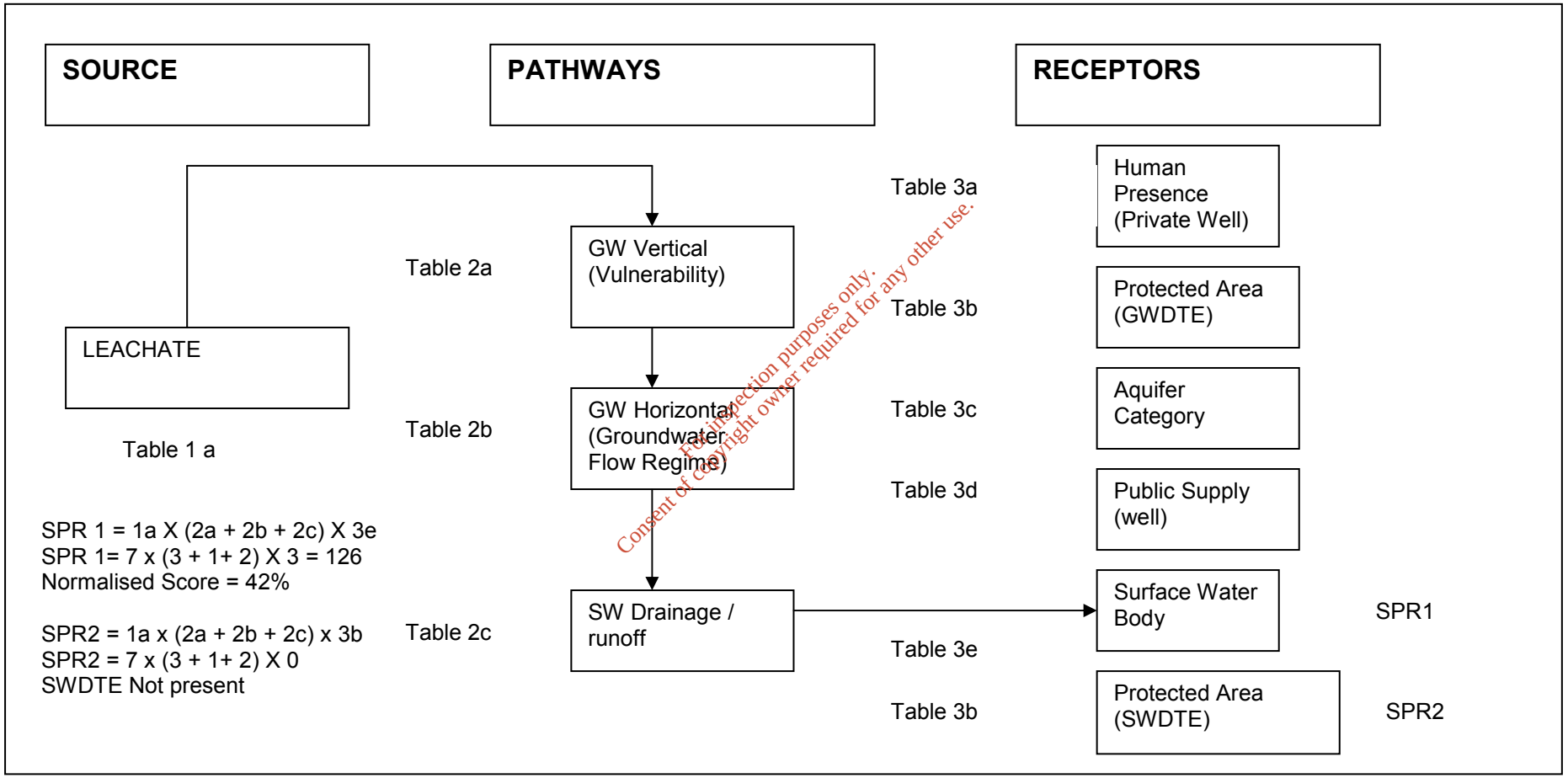


Figure No. 2: Network Diagram For Leachate Migration Through Groundwater Pathways

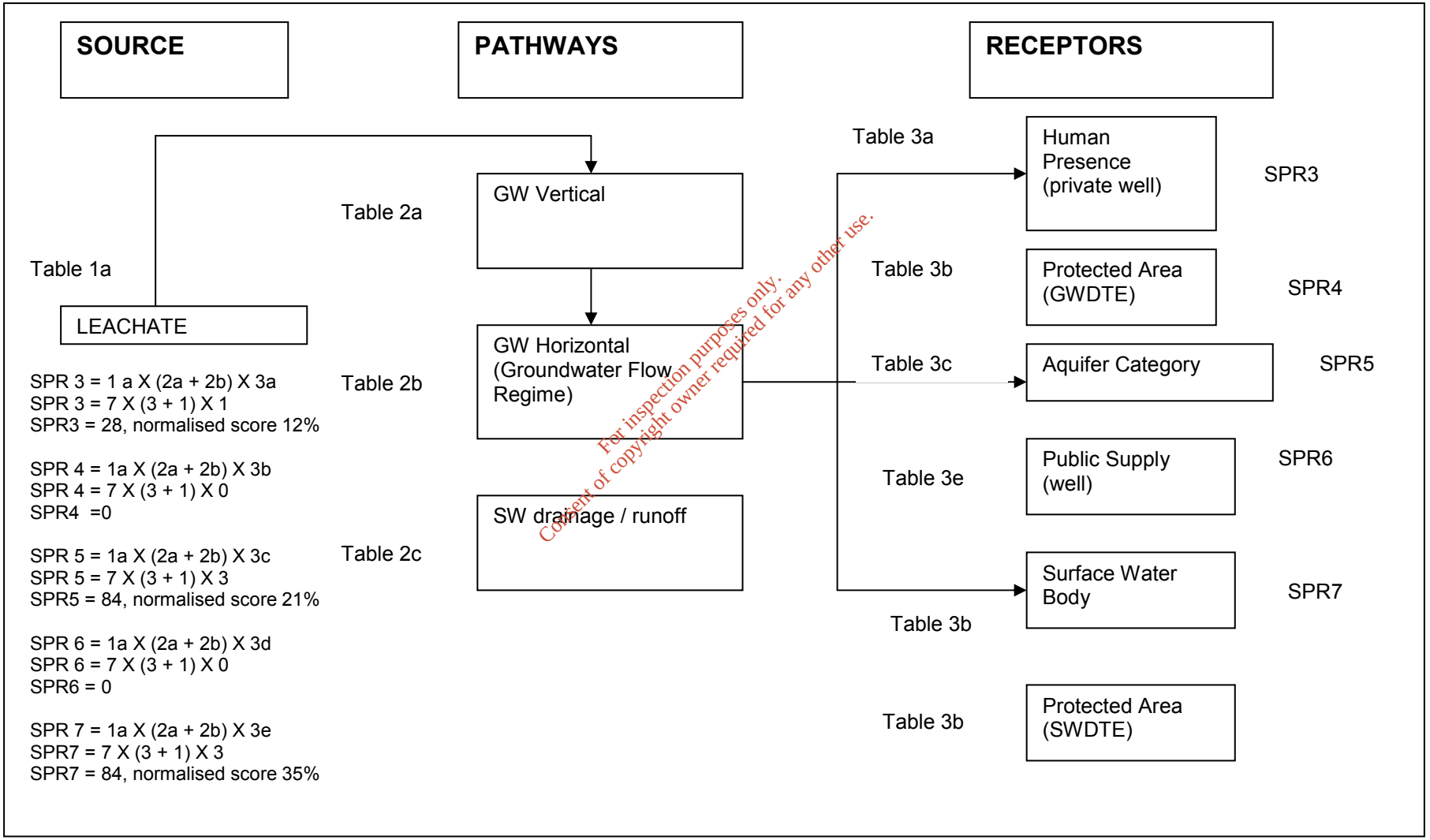


Figure No. 3: Network Diagram For Leachate Migration Through Surface Water Pathway

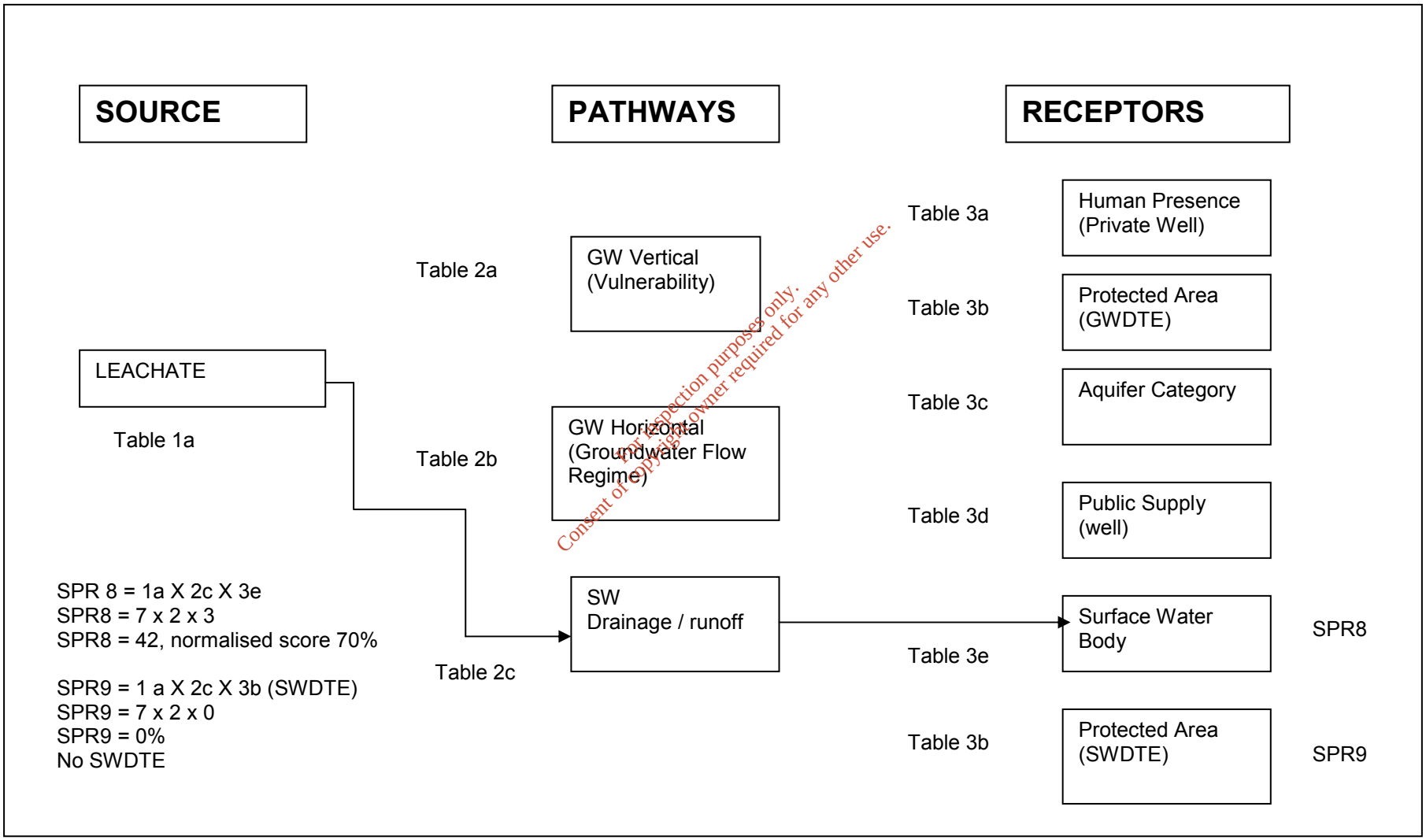
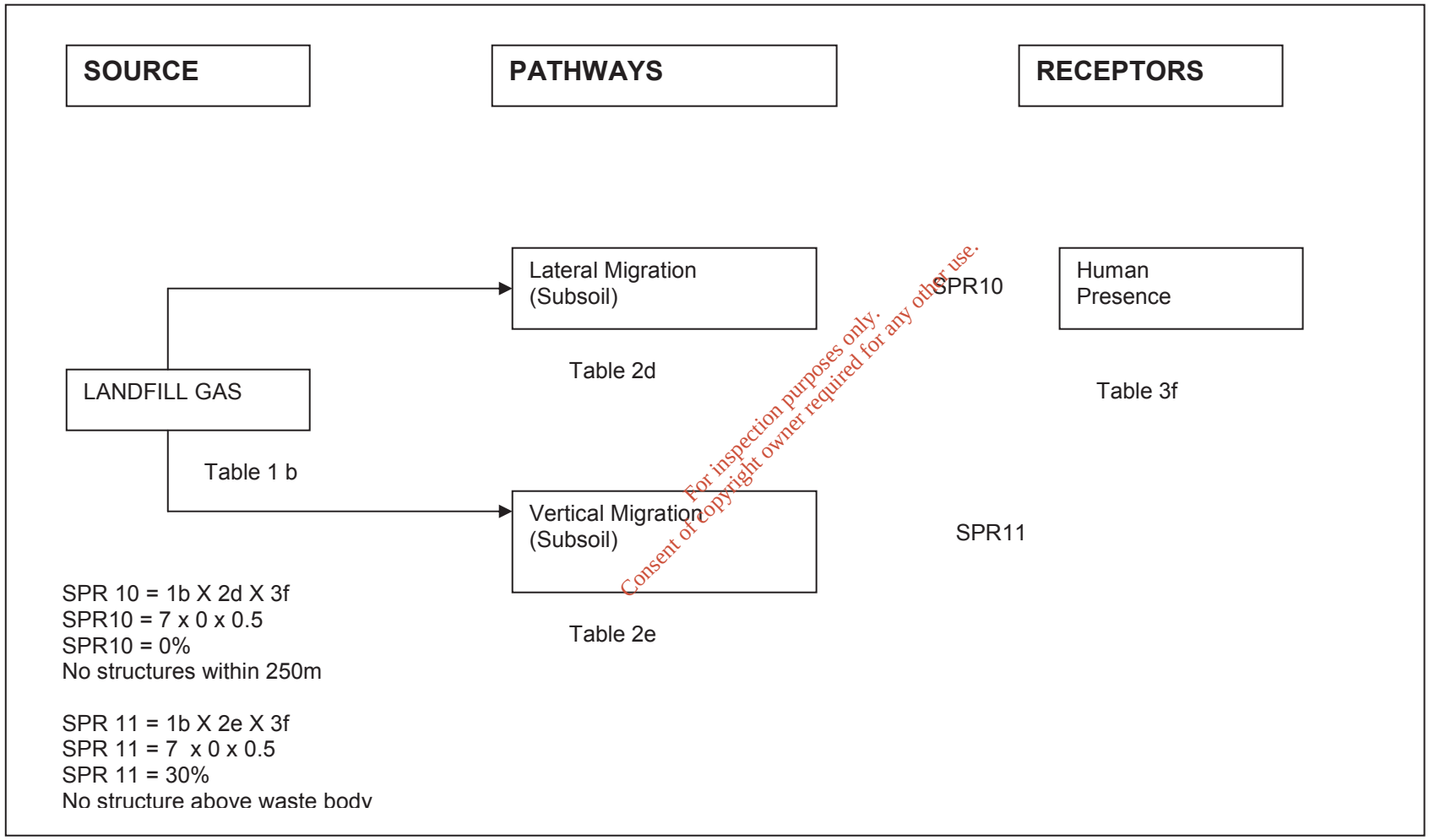


Figure No. 4: Network Diagram For Landfill Gas Migration Pathways (Lateral & Vertical)



APPENDIX B

FIGURES

Figure 1. Site Location Map

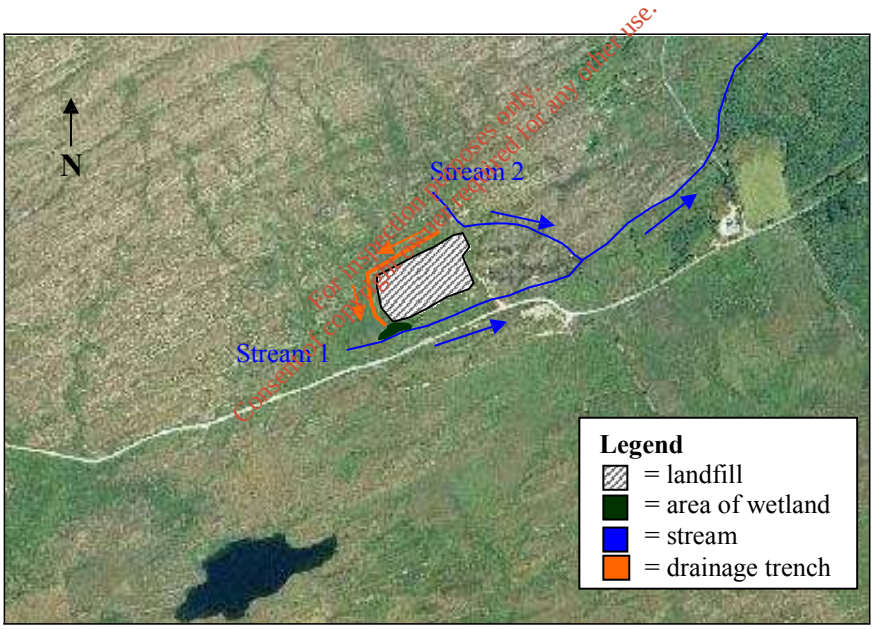


Figure 2. Schematic representation of hydraulic regime (Not to scale).

.

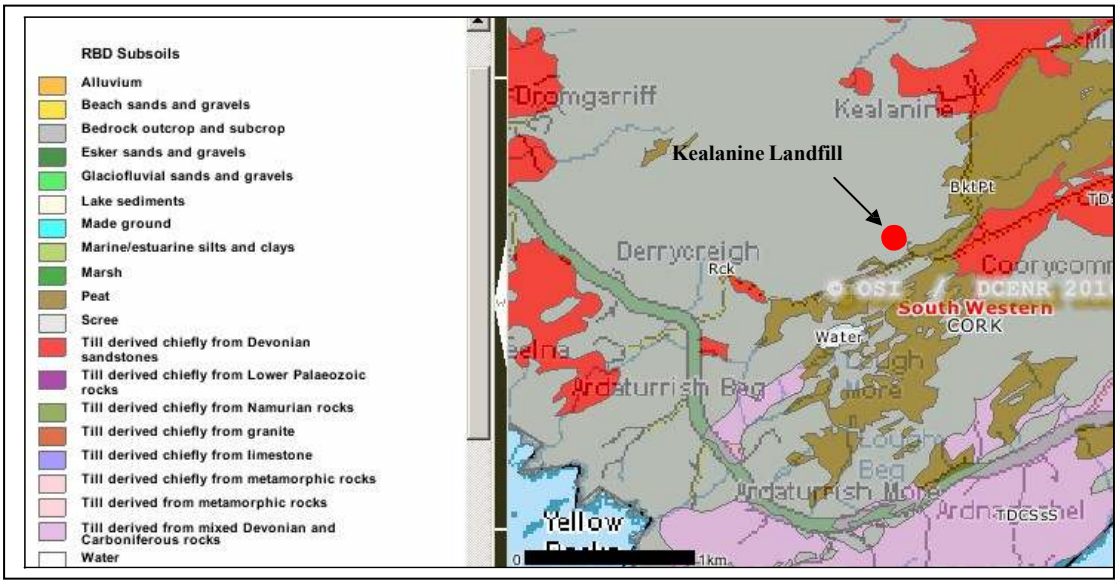


Figure 3. Subsoil map for Kealanine Landfill (reproduced from Teagasc/EPA 1:50,000 digital subsoils map, GSI website)

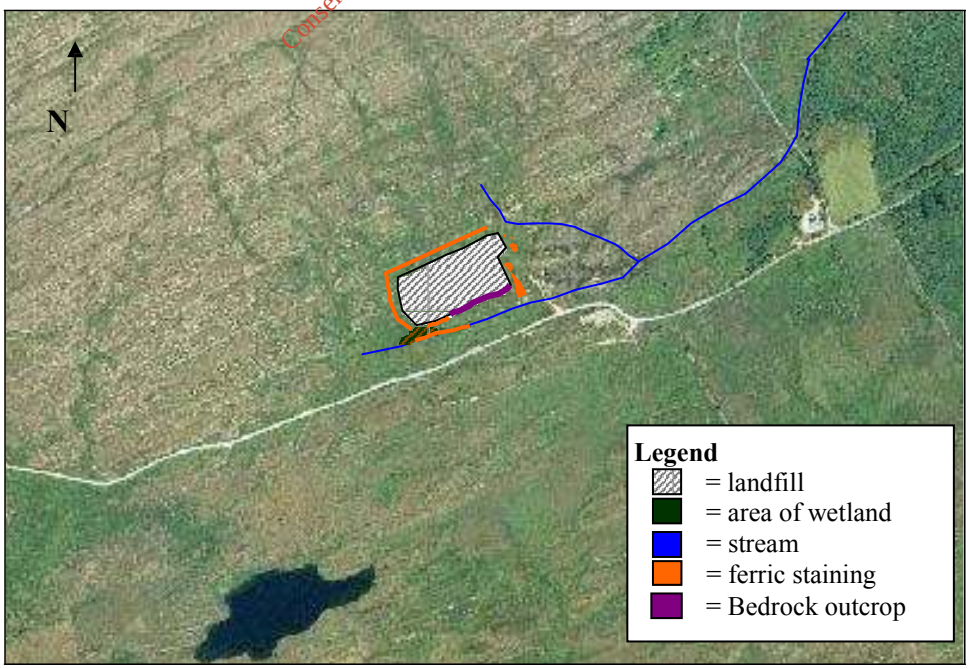


Figure 4 Extent of ferric staining.

Figure 5 Location of boreholes and hand auger holes

Figure 6 Position of Slit Trenches and Soil Sampling L ocations.

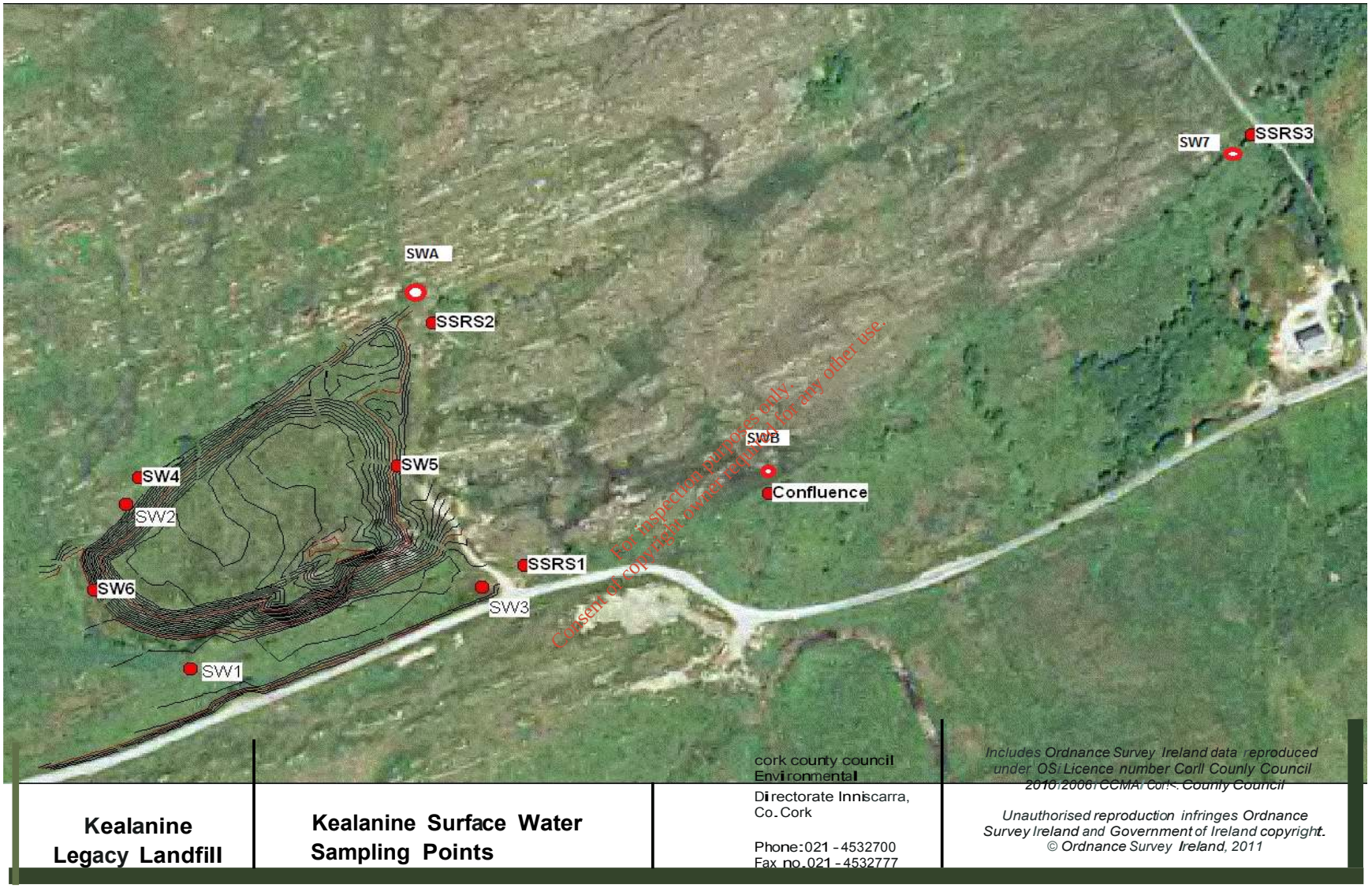


Figure 7 Surface Water Sampling Locations & Location of Confluence of 2 no. Streams (Amended by RPS to include SWA, SWB & SW7).

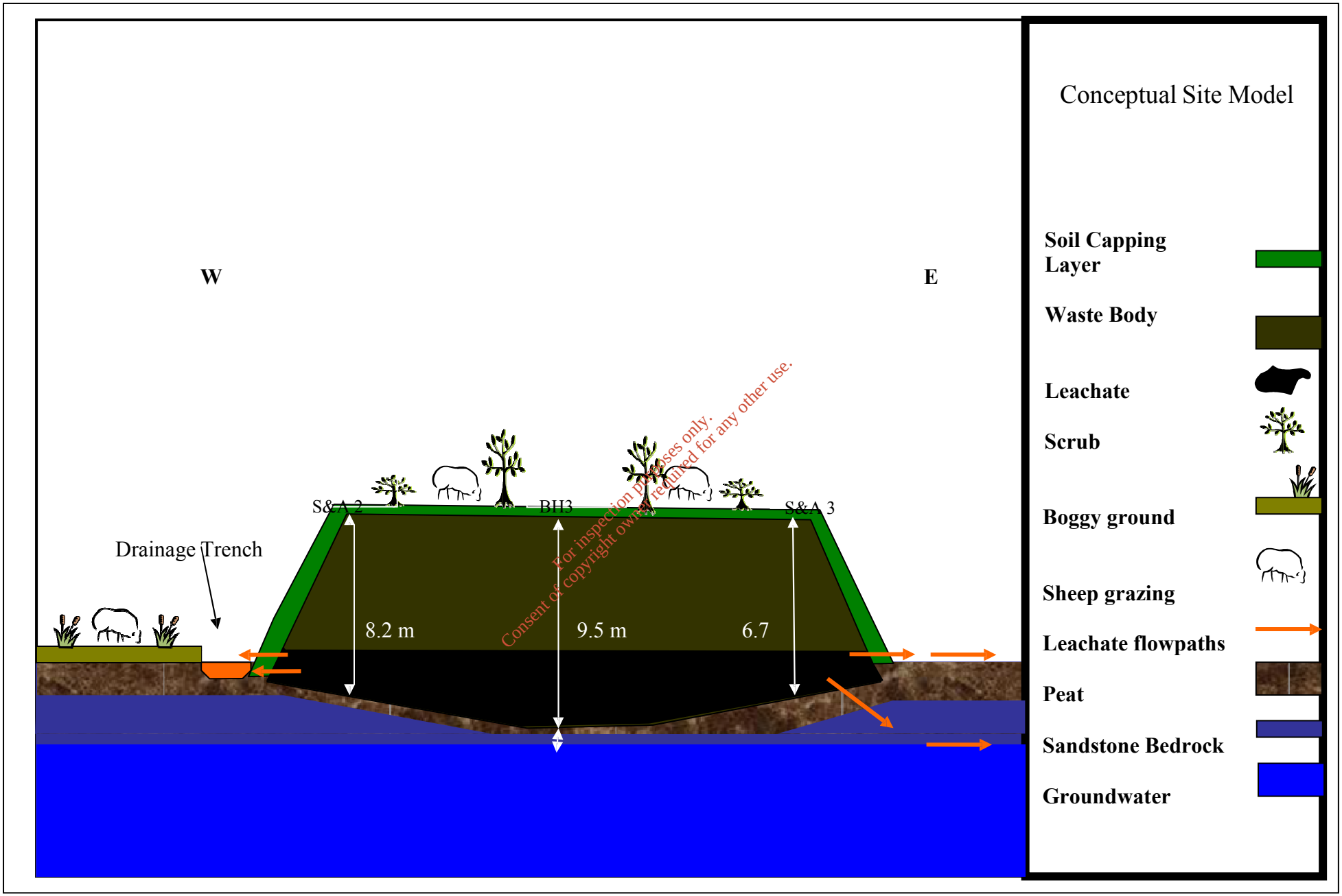


Figure 8 Refined Conceptual Site Model: Longitudinal section

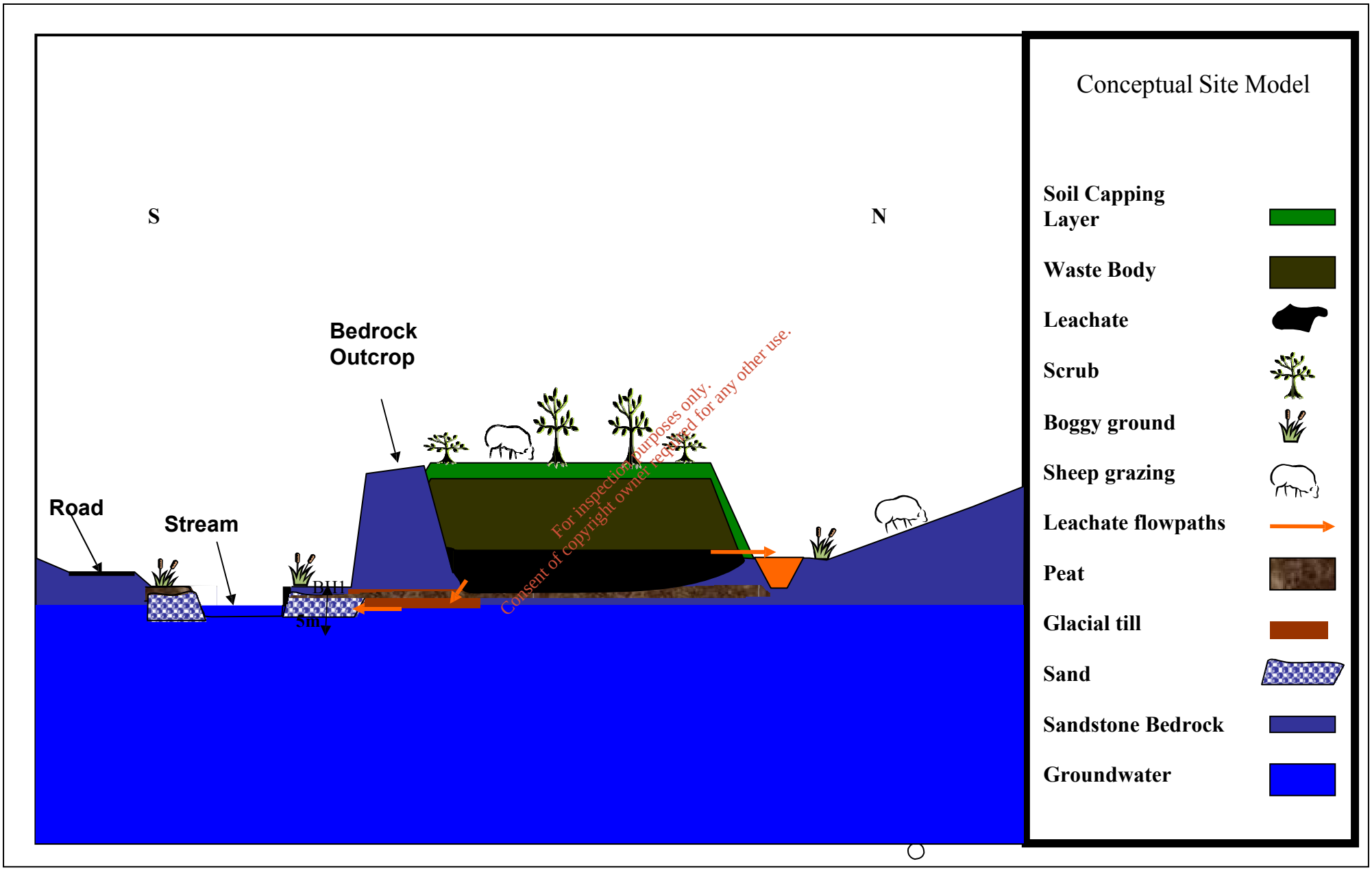


Figure 9 Refined Conceptual Site Model: Cross Section

APPENDIX C

SITE INVESTIGATION RESULTS

Comhairle Contae Chorcaí

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An Rannóg Comhshaoil,
Inis Cara, Co. Chorcaí.

Fón: (021) 4532700
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SLIT TRENCH LOG ST1

Project: Kealanine Landfill

Excavator: 13t CAT 312B

Logged by: Cormac Ó Súilleabháin Date: 04/05/2011

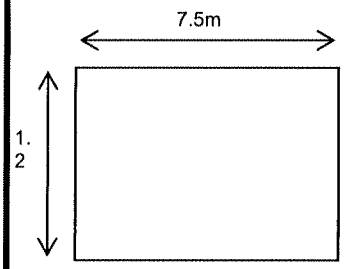
Location: IG 97677 54965

All dimensions on this sheet are in metres unless otherwise stated

Elevation: 108.5 mOD

Samples & in-situ tests			Result		Strata details			
Depth (mbgl)	Type	Peak Residual			O.D. Level	Legend	Depth	Description
								TOPSOIL 'A' horizon: Dark brown, very soft, saturated, Peat with abundant grass roots and rootlets to 0.34 mbgl.
0.5								TOPSOIL: Brown, very fibrous, very soft, saturated, Peat.
0.85								Subsoil: Grey & purple/ping, loose, occasional large gravel and cobble sized clasts of weathered sandstone coarse SAND.
1.24								Refusal at 1.24 mbgl. Slit trench ends.

Plan



Bearing : 290°

Stability :

Trial pit walls very stable

General remarks :

Excavated between landfill and adjacent downgradient stream

Groundwater :

Ingress from base of hole. Slow

See Plate 4, Appendix III

Sequence summary:

Peat over SAND

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Inis Cara, Co. Chorcaí.

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Comhairle Contae Chorcaí

SLIT TRENCH LOG ST2

Project: Kealanine Landfill

Excavator: 13t CAT 312B

Logged by: Cormac Ó Súilleabháin Date: 04/05/2011

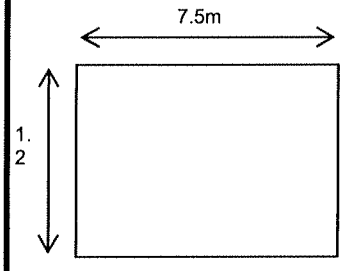
Location: IG 97673 55017

All dimensions on this sheet are in metres unless otherwise stated

Elevation: 112.5 mOD

Samples & in-situ tests				Result		Strata details			
Depth (mbgl)	Type	Peak Result	Notes			O.D. Level	Legend	Depth	Description
0.1								0.1	TOPSOIL: Brown, very soft, saturated, gravely CLAY loam with abundant rootlets
0.45								0.45	MADEGROUND: C&D waste, gravelly SAND with occasional subangular mixed cobblers, bricks and plastic, firm and dry.
1.2								1.2	Dark brown, moist, Peat, varies from very soft to firm
									Refusal at 1.2 mbgl. Slit trench ends.

Plan



Bearing : 280°

Stability :

Trial pit walls very stable

General remarks :

Excavated to east of landfill. Water ingress from topsoil

Groundwater :

Dry

Sequence summary:

Madeground over peat over bedrock

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HAND AUGER LOG HA1

Project: Kealanine Landfill

Excavator: Hand Auger

Logged by: Cormac Ó Súilleabháin Date: 31/05/2011

Location: IG 97686 54986

All dimensions on this sheet are in metres unless otherwise stated

Elevation: 110.87 mOD

Samples & in-situ tests			Result		Strata details			
Depth (mbgl)	Type	Peak Residual			O.D. Level	Legend	Depth	Description
0.41								TOPSOIL 'A' horizon: Dark brown, very soft, saturated, Peat with abundant grass roots and rootlets to 0.34 mbgl.
0.89								Glacial till. Grass roots, moist. No odour
								Refusal at 0.89 mbgl.

Plan

Stability :

General remarks :

Drilled upgradient of BH1

Groundwater :

Sequence summary:

Peat over till

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HAND AUGER LOG HA2

Project: Kealanine Landfill

Excavator: Hand Auger

Logged by: Cormac Ó Súilleabháin Date: 31/05/2011

Location: IG 97664 55009

Elevation: 113.5 mOD

All dimensions on this sheet are in metres unless otherwise stated

Samples & in-situ tests			Result		Strata details			
Depth (mbgl)	Type	Peak Residual			O.D. Level	Legend	Depth	Description
0.14								TOPSOIL 'A' horizon: Orange/red ferric staining, abundant grass roots and rootlets.
0.23								Topsoil. Grass roots, moist
0.51								Till with occasional small gravel. Black/grey, saturated, odour.
								Refusal at 0.51 mbgl.

Plan

Stability :

General remarks :

Drilled upgradient of BH1

Groundwater :

Sequence summary:

Topsoil over till

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Comhairle Contae Chorcaí

HAND AUGER LOG HA3

Project: Kealanine Landfill

Excavator: Hand Auger

Logged by: Cormac Ó Súilleabháin Date: 31/05/2011

Location: IG 97665 55005

Elevation: 113.5 mOD

All dimensions on this sheet are in metres unless otherwise stated

Samples & in-situ tests			Result		Strata details			
Depth (mbgl)	Type	Peak Residual			O.D. Level	Legend	Depth	Description
0.10							0.10	TOPSOIL 'A' horizon: Orange/red ferric staining, abundant grass roots and rootlets.
0.23							0.23	Peat. Black, saturated, odour
0.54							0.54	Sand/Gravel. No returns
								Refusal at 0.54 mbgl.

Plan

Stability :

General remarks :

Drilled upgradient of BH1

Groundwater :

Sequence summary:

Topsoil over peat

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Drilled By AK

Logged By

Borehole No **BH 1**

Sheet 1 of 1

Project Name:	**Project No.**	**Co-ords:**	**Hole Type**
Kealanine Landfill	P11030	497661E - 555042N	RO
Client: Cork County Council	**Dates:** 04/05/2011	**Level:** 108.64 m AOD	**Scale** 1:50

Well / Backfill	Water Strikes	Samples & In Situ Testing: Depth (m)	Type	Results	Casing / Flush	Level (m AOD)	Depth (m)	Stratum Description	Legend
								Open hole boring. Driller described: PEAT.	
						107.84	0.80		
								Grey, slightly clayey very gravelly SAND. Sand is coarse. Gravel is fine to coarse, subangular, siltstone.	
						107.44	1.20		
	▽							Open hole boring. Driller described: Weathered rock. Recovered as: SAND AND GRAVEL.	
						105.94	2.70	Open hole boring. Driller described: Rock.	
					5.10	103.54	5.10	End of Borehole at 5.10 m	

1 2 3 4 5 6 7 8

Water	Depth (m)	Type	Results	Casing	Level	Depth

Groundwater:

Struck	Rose to	After	Sealed	Comment
1.70m	-	-	-	

Hole Information:

Hole Depth	Hole Diameter	Casing Diameter
5.10m	131	131mm

Chiselling:

Depths (m)	Time (hhmm)	Tool
to		

Remarks: Borehole terminated at required depth. 50mm dia standpipe installed, response zone from 5.1m to 1.0m.

Shift Data:

Groundwater	Shift (dd/mm/yyyy)	Casing depth	Remarks
-	04/05/2011	0.00m	Start of Borehole
-	04/05/2011	5.10m	End of Borehole

Equipment & Methods: DeltaBase 520

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Drilled By AK

Logged By

Borehole No **BH 2**

Sheet 1 of 1

Project Name:	**Project No.**	**Co-ords:**	**Hole Type**
Kealanine Landfill	P11030	497634E - 555004N	RO
Client: Cork County Council	**Dates:** 04/05/2011	**Level:** 108.81 m AOD	**Scale** 1:50

Well / Backfill	Water Strikes	Samples & In Situ Testing: Depth (m)	Type	Results	Casing / Flush	Level (m AOD)	Depth (m)	Stratum Description	Legend
								Open hole boring. PEAT.	
						107.91	0.90		
						107.61	1.20	Grey, slightly clayey very gravelly SAND. Sand is coarse. Gravel is fine to coarse, subangular, siltstone.	
								Open hole boring. Driller described: SAND AND GRAVEL.	
	▽					104.91	3.90	Open hole boring. Driller described: Rock.	
					5.10	103.71	5.10	End of Borehole at 5.10 m	

Water	Depth (m)	Type	Results	Casing	Level	Depth

Groundwater:

Struck	Rose to	After	Sealed	Comment
4.00m	-	-	-	

Hole Information:

Hole Depth	Hole Diameter	Casing Diameter
5.10m	200	200mm

Chiselling:

Depths (m)	Time (hhmm)	Tool
to		

Remarks: Borehole terminated at required depth. 50mm dia standpipe installed, response zone from 5.1m to 4.0m.

Shift Data:

Groundwater	Shift (dd/mm/yyyy)	Casing depth	Remarks
-	04/05/2011	0.00m	Start of Borehole
-	04/05/2011	5.10m	End of Borehole

Equipment & Methods: DeltaBase 520

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Drilled By	Borehole No
AK	**BH 3**
Logged By	Sheet 1 of 2

Project Name:	**Project No.**	**Co-ords:** 497559E - 555052N	**Hole Type**
Kealanine Landfill	P11030		RO
Client: Cork County Council	**Dates:** 05/05/2011	**Level:** 117.84 m AOD	**Scale** 1:50

Well / Backfill	Water Strikes	Samples & In Situ Testing: Depth (m)	Type	Results	Casing / Flush	Level (m AOD)	Depth (m)	Stratum Description	Legend
		0.00-0.30	B			117.54	0.30	Open hole boring. MADEGROUND described as: Slightly silty sandy GRAVEL with some cobbles (capping layer) with occasional mixed municipal waste. Dry to damp. No odour.	
								Open hole boring. MADEGROUND described as: Mixed municipal waste.	
						114.34	3.50	Open hole boring. MADEGROUND described as: GRAVEL.	
						113.54	4.30	Open hole boring. MADEGROUND described as: Mixed municipal waste.	
						112.94	4.90	Open hole boring. MADEGROUND described as: sandy GRAVEL.	
						112.44	5.40	Open hole boring. MADEGROUND described as: Mixed municipal waste. Saturated from 7.50 mbgl.	

Continued next sheet

Water	Depth (m)	Type	Results	Casing	Level	Depth

Groundwater:

Struck	Rose to	After	Sealed	Comment
7.50m 10.30m	- -	- -	- -	

Hole Information:

Hole Depth	Hole Diameter	Casing Diameter
14.00m	131	131mm

Chiselling:

Depths (m)	Time (hhmm)	Tool
to		

Remarks: Borehole terminated at required depth. 50mm dia standpipe installed, response zone from 8.0m to 1.0m.

Shift Data:

Groundwater	Shift (dd/mm/yyyy)	Casing depth	Remarks
-	05/05/2011	0.00m	Start of Borehole
-	05/05/2011	14.00m	End of Borehole

Equipment & Methods: DeltaBase 520

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Drilled By AK
Logged By

Borehole No **BH 3**
Sheet 2 of 2

Project Name:	**Project No.**	**Co-ords:**	**Hole Type**
Kealanine Landfill	P11030	497559E - 555052N	RO
Client: Cork County Council	**Dates:** 05/05/2011	**Level:** 117.84 m AOD	**Scale** 1:50

Well / Backfill	Water Strikes	Samples & In Situ Testing: Depth (m)	Type	Results	Casing / Flush	Level (m AOD)	Depth (m)	Stratum Description	Legend
						108.34	9.50	Open hole boring. MADEGROUND described as: Mixed municipal waste. Saturated from 7.50 mbgl.	
	▽							Open hole boring. Peat.	
						107.54	10.30	Open hole drilling: Driller described: Weathered rock recovered as Sandy GRAVEL.	
						106.34	11.50	Open hole drilling. Driller described: Rock.	
					14.00	103.84	14.00	End of Borehole at 14.00 m	

Water	Depth (m)	Type	Results	Casing	Level	Depth

Groundwater:

Struck	Rose to	After	Sealed	Comment
7.50m 10.30m	- -	- -	- -	

Hole Information:

Hole Depth	Hole Diameter	Casing Diameter
14.00m	131	131mm

Chiselling:

Depths (m)	Time (hhmm)	Tool
to		

Remarks: Borehole terminated at required depth. 50mm dia standpipe installed, response zone from 8.0m to 1.0m.

Equipment & Methods: DeltaBase 520

Shift Data:

Groundwater	Shift (dd/mm/yyyy)	Casing depth	Remarks
-	05/05/2011	0.00m	Start of Borehole
-	05/05/2011	14.00m	End of Borehole

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Drilled By JF

Logged By SC

Borehole No **S&A 1**

Sheet 1 of 1

Project Name:	**Project No.**	**Co-ords:**	**Hole Type**
Kealanine Landfill	P11030	497531E - 555078N	Cable
Client: Cork County Council	**Dates:** 05/05/2011	**Level:** 117.69 m AOD	**Scale** 1:50

Well / Backfill	Water Strikes	Samples & In Situ Testing: Depth (m)	Type	Results	Casing / Flush	Level (m AOD)	Depth (m)	Stratum Description	Legend
		0.00-0.30	B			117.39	0.30	MADEGROUND described as: Capping layer with occasional mixed municipal waste including commercial and domestic refuse. Dry to damp. No odour. Soft brown slightly sandy, CLAY with occasional subangular mixed cobbles and abundant roots and rootlets (80%). Plastic: Bags, refuse sacks, packaging, bottle tops (15%). Misc, incl. glass, ceramics and metal (5%).	
		0.30-1.00	B						
		1.00-1.50	B			116.19	1.50	MADEGROUND described as: Mixed municipal waste. Damp. No odour. Plastic: Bags, refuse sacks, lids, milk cartons, containers, sweet wrappers (55%). Organic detritus incl. capping layer (35%). Timber (5%). Misc. incl. glass, metal, textile (5%).	
		1.50-2.00	B						
		2.00-2.50	B			115.19	2.50	MADEGROUND described as: Mixed municipal waste. Damp. Odour. Plastic: Bags, refuse sacks, bottles, containers, packaging (45%). Textiles: Clothing, sponge, sacking (40%). Cardboard (5%). Gravely organic detritus (5%). Misc. incl. metal, glass (5%).	
		2.50-3.00	B			114.69	3.00	MADEGROUND described as: Mixed municipal waste. Moist. Odour. Gravely organic detritus (50%). Plastic: Bottles, bottle tops, packaging, bags. Misc. incl. glass, metal, textile (5%).	
		3.00-3.50	B			114.19	3.50	MADEGROUND described as: Mixed municipal waste. Moist. Slight odour. Plastic: Bottles, bottle tops, packaging, bags, packaging foam, thread spool, cable (60%). Textile: clothing (20%). Misc. incl. organic detritus, glass, metal, gravel (20%).	
		3.50-4.00	B			113.69	4.00	MADEGROUND described as: Mixed municipal waste. Moist. Slight odour. Plastic: Refuse sacks, bags, bottles, packaging, containers (60%). Textile: clothing (30%). Misc. incl. organic detritus, timber, metal, gravel (10%).	
▼		4.00-4.50	B			113.19	4.50	MADEGROUND described as: Mixed municipal waste. Moist. Slight odour. Organic detritus (60%). Plastic: Refuse sacks, bags, bottles, packaging, containers (30%). Misc. incl. timber, glass, metal (10%).	
		4.50-5.00	B			112.69	5.00	MADEGROUND described as: Mixed municipal waste. Moist. Slight odour. Plastic: Refuse sacks, bags, bottles, packaging, containers (85%). Misc. incl. organic detritus, timber, glass, metal (15%).	
		5.00-5.50	B						
		5.50-6.00	B						
		6.00-6.70	B						
					6.80	110.99 110.89	6.70 6.80	MADEGROUND described as: Mixed municipal waste. Moist. Slight odour. Slight sheen suggestive of hydrocarbon contamination but no associated odour. Plastic: Refuse sacks, bags, bottles, packaging, containers (70%). Misc. incl. organic detritus, timber, glass, metal, mixed subangular gravel (30%). .	
								Chiselled from 6.7m to 6.8m for 30 minutes.	
								End of Borehole at 6.80 m	

Water	Depth (m)	Type	Results	Casing	Level	Depth

Groundwater:

Struck	Rose to	After	Sealed	Comment
4.50m	4.40m	20min	-	

Hole Information:

Hole Depth	Hole Diameter	Casing Diameter
6.80m	200	200mm

Chiselling:

Depths (m)	Time (hhmm)	Tool
6.70 to 6.80	0030	Chisel

Remarks: Borehole terminated due to assumed rock. 50mm dia standpipe installed, response zone from 5.8m to 1.0m.

Equipment & Methods: Dando 2000

Shift Data:

Groundwater	Shift (dd/mm/yyyy)	Casing depth	Remarks
-	05/05/2011	0.00m	Start of Borehole
-	05/05/2011	6.80m	End of Borehole

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Drilled By JF

Logged By SC

Borehole No **S&A 2**

Sheet 1 of 2

Project Name:	**Project No.**	**Co-ords:**	**Hole Type**
Kealanine Landfill	P11030	497518E - 555031N	Cable
Client: Cork County Council	**Dates:** 06/05/2011-09/05/2011	**Level:** 118.20 m AOD	**Scale** 1:50

Well / Backfill	Water Strikes	Samples & In Situ Testing: Depth (m)	Type	Results	Casing / Flush	Level (m AOD)	Depth (m)	Stratum Description	Legend
		0.00-0.50	B					MADEGROUND described as: Capping layer with occasional mixed municipal. Dry to damp. No odour. Soft brown slightly sandy CLAY with occasional subangular mixed cobbles and abundant roots and rootlets (90%). Plastic: Bags, packaging (10%).	
		0.20-1.00	B			117.70	0.50		
		1.00-1.50	B					MADEGROUND described as: Mixed municipal waste. Damp. No odour. Plastic: Bags, refuse sacks, sacking, lids, hose (80%). Organic detritus incl. capping layer (15%). Misc. incl. glass, metal (5%).	1
		1.50-2.00	B			116.70	1.50		
		2.00-2.50	B			116.20	2.00	MADEGROUND described as: Mixed municipal waste. Damp. Slight odour. Organic detritus (45%). Plastic: Bags, refuse sacks, bottles, tops, packaging, vials (40%). Timber (10%). Misc. incl. metal, glass, textile (5%).	2
		2.50-3.00	B					MADEGROUND described as: Mixed municipal waste. Wet. Odour. Plastic: Bottles, bottle tops, packaging, bags (70%). Misc. incl. organic detritus, glass, metal, textile (25%). Newspaper - no date legible (5%).	
	▽	3.00-3.50	B			115.20	3.00		3
		3.50-4.00	B			114.70	3.50	MADEGROUND described as: Mixed municipal waste. Wet. Pungent odour. Plastic: Bottles, bottle tops, packaging, bags (60%). Misc. incl. organic detritus, glass, metal (25%). Textile (10%). Newspaper - no date legible (5%).	
		4.00-4.50	B					MADEGROUND described as: Mixed municipal waste. Saturated. Slight odour. Gravely organic detritus (80%). Misc. incl. mixed plastic, timber, metal, glass, ceramic (20%).	4
		4.50-5.00	B			113.70	4.50		
		5.00-5.50	B			113.20	5.00	MADEGROUND described as: Mixed municipal waste. Saturated. Odour. Plastic: Refuse sacks, bags, bottles, packaging, containers (60%). Misc. incl. organic detritus, timber, textile, cardboard, glass, metal (10%).	5
		5.50-6.00	B					MADEGROUND described as: Mixed municipal waste. Saturated. Odour. Slight sheen suggestive of hydrocarbon contamination but no associated odour. Organic detritus (70%). Plastic: Refuse sacks, bags, bottles, packaging, containers (20%). Misc. incl. cardboard, glass, metal (10%).	
		6.00-6.50	B			112.20	6.00		6
		6.50-7.00	B					MADEGROUND described as: Mixed municipal waste. Saturated. Odour. Organic detritus (55%). Plastic: Refuse sacks, bags, bottles, packaging, containers (25%). Metal (10%). Misc. incl. cardboard, textile, timber, glass (10%).	
	▽	7.00-7.50	B			111.20	7.00		7
		7.50-8.00	B			110.70	7.50	MADEGROUND described as: Mixed municipal waste. Saturated. Visual and olfactory indicators of presence of small concentrations of hydrocarbons. Rope (50%). Misc. incl. organic detritus, timber, textile, cardboard, glass, metal (45%). Plastic: Refuse sacks, bags, packaging, (10%).	
		8.00-8.50	B					MADEGROUND described as: Mixed municipal waste. Saturated. Slight odour. Rope, organic detritus, batteries, timber, textile, cardboard, glass, metal, refuse sacks, bags, packaging, gravel copper wire.	8
		8.50-9.00	B			109.70	8.50		
			B			109.20	9.00		
								Continued next sheet	
	Water	Depth (m)	Type	Results	Casing	Level	Depth		

Groundwater:

Struck	Rose to	After	Sealed	Comment
3.50m	3.20m	20min	-	
7.40m	7.20m	20min	-	

Hole Information:

Hole Depth	Hole Diameter	Casing Diameter
10.20m	200	200mm

Chiselling:

Depths (m)	Time (hhmm)	Tool
to		

Remarks: Borehole terminated at required depth. 50mm dia standpipe installed, response zone from 8.2m to 1.0m.

Equipment & Methods: Dando 2000

Shift Data:

Groundwater	Shift (dd/mm/yyyy)	Casing depth	Remarks
-	06/05/2011	0.00m	Start of Borehole
-	06/05/2011	9.00m	End of shift
-	09/05/2011	9.00m	Start of shift
-	09/05/2011	10.20m	End of Borehole

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Drilled By JF

Logged By SC

Borehole No **S&A 2**

Sheet 2 of 2

Project Name:	**Project No.**	**Co-ords:**	**Hole Type**
Kealanine Landfill	P11030	497518E - 555031N	Cable
Client: Cork County Council	**Dates:** 06/05/2011-09/05/2011	**Level:** 118.20 m AOD	**Scale** 1:50

Well / Backfill	Water Strikes	Samples & In Situ Testing: Depth (m)	Type	Results	Casing / Flush	Level (m AOD)	Depth (m)	Stratum Description	Legend
		9.00-9.50						8.50m - 9.00m : Peat (70%). . Only partially penetrated by leachate Mixed municipal waste, saturated, slight odour (30%).	
						108.50	9.70		
		9.50-10.20	B					9.00m - 9.70m : Dark grey/brown, clayey, very sandy GRAVEL. Clean - no leachate contamination	
					10.20	108.00	10.20	Weathered bedrock.	
								End of Borehole at 10.20 m	

Water	Depth (m)	Type	Results	Casing	Level	Depth

Groundwater:

Struck	Rose to	After	Sealed	Comment
3.50m	3.20m	20min	-	
7.40m	7.20m	20min	-	

Hole Information:

Hole Depth	Hole Diameter	Casing Diameter
10.20m	200	200mm

Chiselling:

Depths (m)	Time (hhmm)	Tool
to		

Remarks: Borehole terminated at required depth. 50mm dia standpipe installed, response zone from 8.2m to 1.0m.

Equipment & Methods: Dando 2000

Shift Data:

Groundwater	Shift (dd/mm/yyyy)	Casing depth	Remarks
-	06/05/2011	0.00m	Start of Borehole
-	06/05/2011	9.00m	End of shift
-	09/05/2011	9.00m	Start of shift
-	09/05/2011	10.20m	End of Borehole

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Drilled By	Borehole No
JF	**S&A 3**
Logged By SC	Sheet 1 of 1

Project Name:	**Project No.**	**Co-ords:** 497605E - 555082N	**Hole Type**
Kealanine Landfill	P11030		Cable
Client: Cork County Council	**Dates:** 09/05/2011-11/05/2011	**Level:** 119.23 m AOD	**Scale** 1:50

Well / Backfill	Water Strikes	Samples & In Situ Testing: Depth (m)	Type	Results	Casing / Flush	Level (m AOD)	Depth (m)	Stratum Description	Legend
		0.00-0.40	B			118.83	0.40	MADEGROUND described as: Capping layer with occasional mixed municipal. Dry to damp. No odour. Soft brown slightly sandy slightly gravelly CLAY with occasional subangular mixed cobbles and abundant roots and rootlets (80%). Plastic: Bags, packaging for mussels, bottle tops, containers (20%).	
		0.40-1.00	B			118.23	1.00	MADEGROUND described as: Mixed municipal waste. Damp. No odour. Subangular mixed cobbles (30%). Plastic: Bags, refuse sacks, packaging (30%). Organic detritus incl. capping layer (20%). Timber (20%).	1
		1.00-1.50	B			117.73	1.50	MADEGROUND described as: Mixed municipal waste. Damp. Slight odour. Carpet.	
		1.50-2.00	B			117.23	2.00	MADEGROUND described as: Mixed municipal waste. Saturated. Odour. Organic detritus (60%). Plastic: Refuse sacks, bags, bottles, bottle tops, packaging, foam (20%). Glass (10%). Textile (10%).	2
		2.00-2.50	B			116.73	2.50	MADEGROUND described as: Mixed municipal waste. Damp. No odour. Metal engine part. No visual of olfactory evidence of associated hydrocarbon contamination.	
		2.50-3.00	B			116.23	3.00	MADEGROUND described as: Mixed municipal waste. Moist. Slight odour. Plastic: Refuse sacks, bags, bottles, packaging, containers (60%). Textile: footwear (20%). Metal (10%). Timber (10%).	3
		3.00-3.50	B			115.23	4.00	MADEGROUND described as: Mixed municipal waste. Moist. Odour. Plastic: Refuse sacks, bags, bottles, packaging, containers, (45%). Organic detritus (30%). Textiles incl. nappies (15%). Misc. incl. , paper, glass, metal (10%).	4
		3.50-4.00	B			114.23	5.00	MADEGROUND described as: Mixed municipal waste. Wet. Odour. Organic detritus (30%). Plastic: Refuse sacks, coal bags, bottle tops, containers (30%). Metal (20%). Textile (15%). Misc. incl. paper, timber, wood, glass, (5%).	5
		4.00-4.50	B			113.73	5.50	MADEGROUND described as: Mixed municipal waste. Damp. Odour. Plastic: Refuse sacks, bags, bottles, bottle tops, packaging, containers (50%). Metal (20%). Textiles incl. nappies (20%). Misc. incl. organic detritus, timber, glass (10%).	6
		4.50-5.00	B			113.23	6.00	MADEGROUND described as: Mixed municipal waste. Moist. Slight odour. Plastic: Refuse sacks, bags, packaging, containers (30%). Fishing net and rope (30%). Organic detritus (30%) . Misc: timber, textile, cardboard, glass, metal (10%).	7
		5.00-5.50	B			112.73	6.50	MADEGROUND described as: Mixed municipal waste. Saturated. Visual and olfactory indicators confirm presence of hydrocarbons. Plastic: Refuse sacks, bags, bottles, bottle tops, packaging, containers, (40%). Sludge (40%). Fishing net (10%). Misc. incl. nappies, newspaper - no date, glass, metal (10%).	8
		5.50-6.00	B			112.23	7.00	MADEGROUND described as: Industrial waste. Saturated. Visual and olfactory indicators	
		6.00-6.50	B						
		6.50-7.00	B						
		7.00-7.30	B		7.30	111.93	7.30		

Continued next sheet

Water	Depth (m)	Type	Results	Casing	Level	Depth

Groundwater:

Struck	Rose to	After	Sealed	Comment
6.00m	6.90m	20min	-	

Hole Information:

Hole Depth	Hole Diameter	Casing Diameter
7.30m	200	200mm

Chiselling:

Depths (m)	Time (hhmm)	Tool
7.30 to 7.30	0020	Chisel

Remarks: Borehole terminated due to assumed rock. 50mm dia standpipe installed, response zone from 6.3m to 1.0m.

Equipment & Methods: Dando 2000

Shift Data:

Groundwater	Shift (dd/mm/yyyy)	Casing depth	Remarks
-	09/05/2011	0.00m	Start of Borehole
-	09/05/2011	1.00m	End of shift
-	10/05/2011	1.00m	Start of shift
-	10/05/2011	4.50m	End of shift
-	11/05/2011	4.50m	Start of shift
-	11/05/2011	7.30m	End of Borehole

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Borehole No **S&A 3**

Sheet 1+ of 1

Project Name:	**Project No.**	**Co-ords:**	**Hole Type**
Kealanine Landfill	P11030	497605E - 555082N	Cable
Client: Cork County Council	**Dates:** 09/05/2011-11/05/2011	**Level:** 119.23 m AOD	**Scale** 1:50

Well / Backfill	Water Strikes	Samples & In Situ Testing: Depth (m)	Type	Results	Casing / Flush	Level (m AOD)	Depth (m)	Stratum Description	Legend
								6.50m - 7.00m : confirm presence of hydrocarbons. Hydrocarbon sludge (85%). Fishing net and plastic (15%).	
								7.00m - 7.30m : Dark grey Peat with subangular gravel and occasional subangular cobbles, with hydrocarbon odour, saturated.	
								End of Borehole at 7.30 m	

10 11 12 13 14 15 16 17

	Water	Depth (m)	Type	Results	Casing	Level	Depth

Groundwater:

Struck	Rose to	After	Sealed	Comment
6.00m	6.90m	20min	-	

Hole Information:

Hole Depth	Hole Diameter	Casing Diameter
7.30m	200	200mm

Chiselling:

Depths (m)			Time (hhmm)	Tool
7.30	to	7.30	0020	Chisel

Remarks: Borehole terminated due to assumed rock. 50mm dia standpipe installed, response zone from 6.3m to 1.0m.

Equipment & Methods: Dando 2000

Shift Data:

Groundwater	Shift (dd/mm/yyyy)	Casing depth	Remarks
-	09/05/2011	0.00m	Start of Borehole
-	09/05/2011	1.00m	End of shift
-	10/05/2011	1.00m	Start of shift
-	10/05/2011	4.50m	End of shift
-	11/05/2011	4.50m	Start of shift
-	11/05/2011	7.30m	End of Borehole

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Drilled By	Borehole No
JF	**S&A 4**
Logged By SC	Sheet 1 of 1

Project Name:	**Project No.**	**Co-ords:**	**Hole Type**
Kealanine Landfill	P11030	497623E - 555136N	Cable
Client: Cork County Council	**Dates:** 12/05/2011	**Level:** 115.73 m AOD	**Scale** 1:50

Well / Backfill	Water Strikes	Depth (m)	Type	Results	Casing / Flush	Level (m AOD)	Depth (m)	Stratum Description	Legend
		0.00-0.30	B			115.43	0.30	MADEGROUND described as: Capping layer with occasional mixed municipal waste. Dry to damp. No odour. Soft brown slightly sandy, slightly gravely CLAY with occasional subangular mixed cobbles and abundant roots and rootlets (95%). Plastic bags (5%).	
		0.30-1.00	B			114.73	1.00	MADEGROUND described as: Mixed municipal waste. Damp. No odour. Organic detritus incl. capping layer (35%). Plastic: Bags, refuse sacks, packaging, bottles (30%). Textile (20%). Rubber car tube (10%). Misc. incl. glass, metal (5%).	
		1.00-1.50	B			114.23	1.50	MADEGROUND described as: Mixed municipal waste. Moist. No odour. Organic detritus incl. soil/subsoil (65%). Plastic: Packaging, bags, bottle tops (20%). Textile (10%). Misc. incl. glass, metal, ceramic (5%).	
		1.50-2.00	B			113.73	2.00	MADEGROUND described as: Mixed municipal waste. Moist. Slight odour. Organic detritus (50%). Textile incl. nappy (30%). Plastic: Refuse sacks, bags, containers, tubs, bottle tops, packaging (15%). Misc. incl. glass, metal (5%).	
		2.00-2.70	B			113.03	2.70	MADEGROUND described as: Mixed municipal waste. Wet. Odour. Organic detritus (40%). Plastic: Refuse sacks, bags, containers, tubs, bottle tops, packaging (40%). Textile (10%). Misc. incl. glass, metal, (10%).	
		2.70-3.00	B			112.23	3.50	MADEGROUND described as: Industrial waste. Saturated. Visual and olfactory indicators confirm presence of hydrocarbons. . Hydrocarbon sludge (60%). Plastic (30%). Misc. incl. glass, metal, textile (10%).	
		3.00-3.50	B			111.73	4.00	Peat with gravel. Wet. Hydrocarbon odour.	
		3.50-4.00	B					End of Borehole at 4.20 m	
		4.00-4.20	B		4.20				

Water	Depth (m)	Type	Results	Casing	Level	Depth

Groundwater:

Struck	Rose to	After	Sealed	Comment
2.70m	2.60m	20min	-	

Hole Information:

Hole Depth	Hole Diameter	Casing Diameter
4.20m	200	200mm

Chiselling:

Depths (m)			Time (hhmm)	Tool
4.20	to	4.20	0010	Chisel

Remarks: Borehole terminated due assumed rock. 50mm dia standpipe installed, response zone from 3.5m to 1.0m.

Equipment & Methods: Dando 2000

Shift Data:

Groundwater	Shift (dd/mm/yyyy)	Casing depth	Remarks
-	12/05/2011	0.00m	Start of Borehole
-	12/05/2011	4.20m	End of Borehole

Permeability testign on recompacted bulk disturbed samples

RESULTS							
Location	**Depth, m**	**Strata**	**Bulk density**		**Permeability, k**		**Method**
					1.0 x10^{-8}	ms^{-1}	
					2.6 x10^{-8}	ms^{-1}	
					2.09 x10^{-8}	ms^{-1}	
					4.06 x10^{-8}	ms^{-1}	Falling head
ST1	0.48	PEAT	999	kg/m^3	2.44 x10-8	ms^{-1}	
					2.06 x10^{-8}	ms^{-1}	
					1.51 x10^{-8}	ms^{-1}	Falling head
CB1	0.3	CLAY	1817	kg/m^3	1.78 x10^{-8}	ms^{-1}	
					1.18x10^{-4}	ms^{-1}	
					1.2x10^{-4}	ms^{-1}	Constant head
ST1	1.24	GRAVEL	1782	kg/m^3	1.2x10^{-4}	ms^{-1}	
					4.1 x10^{-6}	ms^{-1}	
					9.1 x10^{-6}	ms^{-1}	
					7.1 x10^{-6}	ms^{-1}	
BH03	0.3	CLAY	-		6.8 x10^{-6}	ms^{-1}	Falling head

Notes:
Falling head test caried out in modified proctor mould.
Samples compacted under light effort, 2.5kg drop hammed into mould.
Saturation under back-pressure, test conducted at steady state flow conditions.

Constant head test carried out in 80mmdiameter hydraulic cell.
Samples compacted under light effort, tamping rod to fill cell.

Falling head sampes saturated under vacumn fincluding a period up 24hours soaking.
Samples assumed saturated.

KEY TO SYMBOLS ON EXPLORATORY HOLE RECORDS

All linear dimensions are in metres or millimetres

DESCRIPTIONS

**	Drillers Description
Friable	Easily crumbled

SAMPLES

U( )	Undisturbed 102mm diameter sample, ( ) denotes number of blows to drive sampler
U( )F, U( )P	F- not recovered, P-partially recovered
U38	Undisturbed 38mm diameter sample
P(F), (P)	Piston sample - disturbed
B	Bulk sample - disturbed
D	Jar Sample - disturbed
W	Water Sample
CBR	California Bearing Ratio mould sample
ES	Chemical Sample for Contamination Analysis
SPTLS	Standard Penetration Test S lump sample from split sampler

CORE RECOVERY AND ROCK QUALITY

TCR	Total Core Recovery (% of Core Run)
SCR	Solid Core Recovery (length of core having at least one full diameter as % of core run)
RQD	Rock Quality Designation (length of solid core greater than 100mm as % of core run)

Where there is insufficient space for the TCR, SCR and RQD, the results may be found in the remarks column

If	Fracture Spacing in mm (Minimum/Average/Maximum) NI - non intact, NR - no recovery
AZCL	Assumed Zone of Core Loss
NI	Non intact

GROUNDWATER

▽	Groundwater strike
▼	Groundwater level after standing period
Date/Water	Date of shift (day/month)/Depth to water at end of previous shift shown above the date and depth to water at beginning of shift given below the date

INSITU TESTING

S	Standard Penetration Test - split barrel sampler
C	Standard Penetration Test - solid 60° cone
SW	Self Weight Penetration
Ivp, HVp (R)	In Situ Vane Test, Hand Vane Test (R) demonstrates remoulded strength
K(F), (C), (R), (P)	Permeability Test
HP	Hand Penetrometer Test

MEASURED PROPERTIES

N	Standard Penetration Test - blows required to drive 300mm after seating drive
x/y	Denotes x blows for y mm within the Standard Penetration Test
x*/y	Denotes x blows for y mm within the seating drive
c_u	Undrained Shear Strength (kN/m^2)
CBR	California Bearing Ratio

ROTARY DRILLING SIZES

Index Letter	Nominal Diameter (mm)	
	Borehole	Core
N	75	54
H	99	76
P	120	92
S	146	113

KEY TO SYMBOLS - LABORATORY TEST RESULT

U	Undisturbed Sample	
P	Piston Sample	
TWS	Thin Wall Sample	
B	Bulk Sample - Disturbed	
D	Jar Sample - Disturbed	
W	Water Sample	
pH	Acidity/Alkalinity Index	
SO_3	% - Total Sulphate Content (acid soluble)	
SO_3	g/ltr - Water Soluble Sulphate (Water or 2:1 Aqueous Soil Extract)	
+	Calcareous Reaction	
Cl	Chloride Content	
PI	Plasticity Index	
<425	% of material in sample passing 425 micron sieve	
LL	Liquid Limit	
PL	Plastic Limit	
MC	Water Content	
NP	Non Plastic	
Yb	Bulk Density	
Yd	Dry Density	
Ps	Particle Density	
U/D	Undrained/Drained Triaxial	
U/C	Unconsolidated/Consolidated Triaxial	
T/M	Single Stage/Multistage Triaxial	
100/38	Sample Diameter (mm)	
REM	Remoulded Triaxial Test Specimen	
TST	Triaxial Suction Test	
V	Vane Test	
DSB	Drained Shear Box	
RSB	Residual Shear Box	
RS	Ring Shear	
σ_3	Cell Pressure	
σ_1-σ_3	Deviator Stress	
c	Cohesion	
c_	Effective Cohesion Intercept	
ϕ	Angle of Shearing Resistance - Degrees	
ϕ_	Effective Angle of Shearing Resistance	
εf	Strain at Failure	
*	Failed under 1st Load	
**	Failed under 2nd Load	
#	Untestable	
##	Excessive Strain	
p_o	Effective Overburden Pressure	
m_v	Coefficient of Volume Decrease	
c_v	Coefficient of Consolidation	
Opt	Optimum	
Nat	Natural	
Std	Standard Compaction - 2.5kg Rammer	(¶ CBR)
Hvy	Heavy Compaction - 4.5kg Rammer	(§ CBR)
Vib	Vibratory Compaction	
CBR	California Bearing Ratio	
Sat m.c.	Saturation Moisture Content	
MCV	Moisture Condition Value	

Key sheet		pgl priority geotechnical

APPENDIX D

GENERIC QUANTATIVE RISKASSESSMENT SGV'S / GAC'S

SGVs / GACs for Tier 2 Generic Quantitative Risk Assessment - Commercial Land Use

METALS

	Value (mg/kg)	SGV or GAC?	Ref	Notes
Arsenic	640	SGV	2	a,b,c
Beryllium	420	GAC	1	a,b,c
Boron	192,000	GAC	1	a,b,c
Cadmium	230	SGV	2	a,b,c
Chromium III	8,840	GAC	1	a,b,c
Chromium VI	35	GAC	1	a,b,c
Copper	71,700	GAC	1	a,b,c
Mercury - Elemental	26	SGV	2	a,b,c,e
Mercury - Inorganic	3,600	SGV	2	a,b,c,e
Mercury - Methyl	410	SGV	2	a,b,c,e
Nickel	1,800	SGV	2	a,b,c
Selenium	13,000	SGV	2	a,b,c
Vanadium	3160	GAC	1	a,b,c
Zinc	665,000	GAC	1	a,b,c

TOTAL PETROLEUM HYDROCARBONS (TPH)

	1% SOM (mg/kg)	2.5% SOM (mg/kg)	6% SOM (mg/kg)	SGV or GAC?	Ref	Notes
Aliphatic EC 5-6	3400	6200	13,000	GAC	1	a,c,d
Aliphatic EC >6-8	8300	18,000	42,000	GAC	1	a,c,d
Aliphatic EC >8-10	2100	5100	12,000	GAC	1	a,c,d
Aliphatic EC >10-12	10,000	24,000	49,000	GAC	1	a,c,d
Aliphatic EC >12-16	61,000	83,000	91,000	GAC	1	a,c,d
Aliphatic EC >16-35	1,600,000	1,800,000	1,800,000	GAC	1	a,c,d
Aliphatic EC >35-44	1,600,000	1,800,000	1,800,000	GAC	1	a,c,d
Aromatic EC 5-7 (benzene)	28,000	49,000	90,000	GAC	1	a,c,d
Aromatic EC >7-8 (toluene)	59,000	110,000	190,000	GAC	1	a,c,d
Aromatic EC >8-10	3700	8,600	18,000	GAC	1	a,c,d
Aromatic EC >10-12	17,000	29,000	34,500	GAC	1	a,c,d
Aromatic EC >12-16	36,000	37,000	37,800	GAC	1	a,c,d
Aromatic EC >16-21	28,000	28,000	28,000	GAC	1	a,c,d
Aromatic EC >21-35	28,000	28,000	28,000	GAC	1	a,c,d
Aromatic EC >35-44	28,000	28,000	28,000	GAC	1	a,c,d
Aliphatic + Aromatic EC >44-70	28,000	28,000	28,000	GAC	1	a,c,d

BTEX COMPOUNDS

	Value (mg/kg)	SGV or GAC?	Ref	Notes
Benzene	95	SGV	2	a,b,c,d,g
Toluene	4400	SGV	2	a,b,c,d,g
Ethylbenzene	2800	SGV	2	a,b,c,d,g
o-Xylene	2600	SGV	2	a,b,c,d,g,h
m-Xylene	3500	SGV	2	a,b,c,d,g,h
p-Xylene	3200	SGV	2	a,b,c,d,g,h

POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

	1% SOM (mg/kg)	2.5% SOM (mg/kg)	6% SOM (mg/kg)	SGV or GAC?	Ref	Notes
Acenaphthene	85,000	98,000	100,000	GAC	1	a,c,d
Acenaphthylene	84,000	97,000	100,000	GAC	1	a,c,d
Anthracene	530,000	540,000	540,000	GAC	1	a,c,d
Benzo(a)anthracene	90	95	97	GAC	1	a,c,d
Benzo(a)pyrene	14	14	14	GAC	1	a,c,d
Benzo(b)fluoranthene	100	100	100	GAC	1	a,c,d
Benzo(ghi)perylene	650	660	660	GAC	1	a,c,d
Benzo(k)fluoranthene	140	140	140	GAC	1	a,c,d
Chrysene	140	140	140	GAC	1	a,c,d
Dibenzo(ah)anthracene	13	13	13	GAC	1	a,c,d
Fluoranthene	23,000	23,000	23,000	GAC	1	a,c,d
Fluorene	64,000	69,000	71,000	GAC	1	a,c,d
Indeno(123-cd)pyrene	60	61	62	GAC	1	a,c,d
Naphthalene	200	480	1,100	GAC	1	a,c,d
Phenanthrene	22,000	22,000	23,000	GAC	1	a,c,d
Pyrene	54,000	54,000	54,000	GAC	1	a,c,d

CHLORINATED HYDROCARBONS

	1% SOM (mg/kg)	2.5% SOM (mg/kg)	6% SOM (mg/kg)	SGV or GAC?	Ref	Notes
1,2-Dichloroethane	0.71	1	1.8	GAC	1	a,c,d
1,1,1-Trichloroethane	700	1400	3100	GAC	1	a,c,d
1,1,2,2-Tetrachloroethane	290	580	1200	GAC	1	a,c,d
1,1,1,2-Tetrachloroethane	120	260	590	GAC	1	a,c,d
Tetrachloroethene	130	290	660	GAC	1	a,c,d
Carbon Tetrachloride	3	6.6	15	GAC	1	a,c,d
Trichloroethene	12	25	55	GAC	1	a,c,d
Chloroform (Trichloromethane)	110	190	370	GAC	1	a,c,d
Vinyl Chloride	0.063	0.081	0.12	GAC	1	a,c,d
Chlorobenzene	59	130	310	GAC	1	a,c,d
1,2-Dichlorobenzene	2100	5100	12,000	GAC	1	a,c,d
1,3-Dichlorobenzene	32	77	180	GAC	1	a,c,d
1,4-Dichlorobenzene	4500	10,000	22,000	GAC	1	a,c,d
1,2,3-Trichlorobenzene	110	270	620	GAC	1	a,c,d

1,2,4-Trichlorobenzene	230	560	1,300	GAC	1	a,c,d
1,3,5-Trichlorobenzene	24	57.8	140	GAC	1	a,c,d
1,2,3,4-Tetrachlorobenzene	1800	3200	4,500	GAC	1	a,c,d
1,2,3,5-Tetrachlorobenzene	52	120	250	GAC	1	a,c,d
1,2,4,5-Tetrachlorobenzene	44	73	97	GAC	1	a,c,d
Pentachlorobenzene	650	770	830	GAC	1	a,c,d
Hexachlorobenzene	48	53	55	GAC	1	a,c,d

EXPLOSIVES

	1% SOM (mg/kg)	2.5% SOM (mg/kg)	6% SOM (mg/kg)	SGV or GAC?	Ref	Notes
2,4,6 Trinitrotoluene (TNT)	1000	1000	1100	GAC	1	a,c,d
RDX	6400	6400	6400	GAC	1	a,c,d
HMX	110,000	110,000	110,000	GAC	1	a,c,d

PESTICIDES

	1% SOM (mg/kg)	2.5% SOM (mg/kg)	6% SOM (mg/kg)	SGV or GAC?	Ref	Notes
Aldrin	54	54	54	GAC	1	a,c,d
Dieldrin	90	91	92	GAC	1	a,c,d
Atrazine	870	880	880	GAC	1	a,c,d
Dichlorvos	842	872	893	GAC	1	a,c,d
Alpha-Endosulfan	2310	2990	3390	GAC	1	a,c,d
Beta-Endosulfan	2580	3160	3480	GAC	1	a,c,d
Alpha-Hexachlorocyclohexanes	14,000	14,600	14,900	GAC	1	a,c,d
Beta-Hexachlorocyclohexanes	1120	1130	1130	GAC	1	a,c,d
Gamma-Hexachlorocyclohexanes	532	546	552	GAC	1	a,c,d

PHENOLS

	1% SOM (mg/kg)	2.5% SOM (mg/kg)	6% SOM (mg/kg)	SGV or GAC?	Ref	Notes
Phenol		3200		SGV	2	a,b,c,f
Chlorophenols (2-Chlorophenol or 2,4-Dichlorophenol)	3500	4000	4200	GAC	1	a,c,d
Pentachlorophenol	1200	1300	1400	GAC	1	a,c,d

OTHER CONTAMINANTS

	1% SOM (mg/kg)	2.5% SOM (mg/kg)	6% SOM (mg/kg)	SGV or GAC?	Ref	Notes
Carbon Disulphide	12	23	50	GAC	1	a,c,d
Hexachloro-1,3,-butadiene	32	69	120	GAC	1	a,c,d
Dioxins, Furans and Dioxin-like PCB		240 ug/kg		SGV	2	a,b,c,i

Notes

(a) Based on a sandy loam soil as defined in Ref. 3
(b) Based on 6% SOM
(c) Based on a pH of 7
(d) Assumes free phase contamination is not present
(e) The SGV for inorganic mercury can normally be used for comparison with results of laboratory analysis, but due consideration must be given at the Desk Study (Phase 1) stage as to whether elemental or methyl mercury may be present
(f) Based on a threshold protective of direct skin contact with phenol
(g) At a lower SOM, the SGV may not be sufficiently protective
(h) When assessing a fresh xylene spill, the m-Xylene SGV should be compared with the Total Xylene soil concentration. If the xylene source is unknown or is weathered, the Total Xylene soil concentration (total of 3 isomers) should be compared against the lowest SGV for the particular land use
(i) SGV to be compared with the sum of the soil concentrations of all Dioxin, Furan and Dioxin-like PCB (77, 81, 126, 169, 105, 114, 118, 123, 156, 157, 167 ,189) congeners

Refs

(1) The LQM/CIEH Generic Assessment Criteria for Human Health Risk Assessment (2nd Edition), July 2009
(2) Individual SGV reports released by the Environment Agency
(3) Environment Agency Science Report SC050021/SR3 - Updated technical background to the CLEA model, January 2009

SGVs / GACs for Tier 2 Generic Quantitative Risk Assessment - Residential Land Use

METALS

	Value (mg/kg)	SGV or GAC?	Ref	Notes
Arsenic	32	SGV	2	a,b,c
Beryllium	51	GAC	1	a,b,c
Boron	291	GAC	1	a,b,c
Cadmium	10	SGV	2	a,b,c
Chromium III	627	GAC	1	a,b,c
Chromium VI	4.3	GAC	1	a,b,c
Copper	2330	GAC	1	a,b,c
Mercury - Elemental	1	SGV	2	a,b,c,e
Mercury - Inorganic	170	SGV	2	a,b,c,e
Mercury - Methyl	11	SGV	2	a,b,c,e
Nickel	130	SGV	2	a,b,c
Selenium	350	SGV	2	a,b,c
Vanadium	75	GAC	1	a,b,c
Zinc	3750	GAC	1	a,b,c

TOTAL PETROLEUM HYDROCARBONS (TPH)

	1% SOM (mg/kg)	2.5% SOM (mg/kg)	6% SOM (mg/kg)	SGV or GAC?	Ref	Notes
Aliphatic EC 5-6	30	55	110	GAC	1	a,c,d
Aliphatic EC >6-8	73	160	370	GAC	1	a,c,d
Aliphatic EC >8-10	19	46	110	GAC	1	a,c,d
Aliphatic EC >10-12	93	230	540	GAC	1	a,c,d
Aliphatic EC >12-16	740	1700	3000	GAC	1	a,c,d
Aliphatic EC >16-35	45,000	64,000	76,000	GAC	1	a,c,d
Aliphatic EC >35-44	45,000	64,000	76,000	GAC	1	a,c,d
Aromatic EC 5-7 (benzene)	65	130	280	GAC	1	a,c,d
Aromatic EC >7-8 (toluene)	120	270	611	GAC	1	a,c,d
Aromatic EC >8-10	27	65	151	GAC	1	a,c,d
Aromatic EC >10-12	69	160	346	GAC	1	a,c,d
Aromatic EC >12-16	140	310	593	GAC	1	a,c,d
Aromatic EC >16-21	250	480	770	GAC	1	a,c,d
Aromatic EC >21-35	890	1100	1,230	GAC	1	a,c,d
Aromatic EC >35-44	890	1100	1,230	GAC	1	a,c,d
Aliphatic + Aromatic EC >44-70	1,200	1300	1,300	GAC	1	a,c,d

BTEX COMPOUNDS

	Value (mg/kg)	SGV or GAC?	Ref	Notes
Benzene	0.33	SGV	2	a,b,c,d,g
Toluene	610	SGV	2	a,b,c,d,g
Ethylbenzene	350	SGV	2	a,b,c,d,g
o-Xylene	250	SGV	2	a,b,c,d,g,h
m-Xylene	240	SGV	2	a,b,c,d,g,h
p-Xylene	230	SGV	2	a,b,c,d,g,h

POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

	1% SOM (mg/kg)	2.5% SOM (mg/kg)	6% SOM (mg/kg)	SGV or GAC?	Ref	Notes
Acenaphthene	210	480	1000	GAC	1	a,c,d
Acenaphthylene	170	400	850	GAC	1	a,c,d
Anthracene	2300	4900	9200	GAC	1	a,c,d
Benzo(a)anthracene	3.1	4.7	5.9	GAC	1	a,c,d
Benzo(a)pyrene	0.83	0.94	1	GAC	1	a,c,d
Benzo(b)fluoranthene	5.6	6.5	7	GAC	1	a,c,d
Benzo(ghi)perylene	44	46	47	GAC	1	a,c,d
Benzo(k)fluoranthene	8.5	9.6	10	GAC	1	a,c,d
Chrysene	6	8	9.3	GAC	1	a,c,d
Dibenzo(ah)anthracene	0.76	0.86	0.9	GAC	1	a,c,d
Fluoranthene	260	460	670	GAC	1	a,c,d
Fluorene	160	380	780	GAC	1	a,c,d
Indeno(123-cd)pyrene	3.2	3.9	4.2	GAC	1	a,c,d
Naphthalene	1.5	3.7	8.7	GAC	1	a,c,d
Phenanthrene	92	200	380	GAC	1	a,c,d
Pyrene	560	1000	1600	GAC	1	a,c,d

CHLORINATED HYDROCARBONS

	1% SOM (mg/kg)	2.5% SOM (mg/kg)	6% SOM (mg/kg)	SGV or GAC?	Ref	Notes
1,2-Dichloroethane	0.0054	0.008	0.014	GAC	1	a,c,d
1,1,1-Trichloroethane	6.2	13	28	GAC	1	a,c,d
1,1,2,2-Tetrachloroethane	1.4	2.9	6.3	GAC	1	a,c,d
1,1,1,2-Tetrachloroethane	0.9	2.1	4.8	GAC	1	a,c,d
Tetrachloroethene	0.94	2.1	4.8	GAC	1	a,c,d
Carbon Tetrachloride	0.018	0.039	0.089	GAC	1	a,c,d
Trichloroethene	0.11	0.22	0.49	GAC	1	a,c,d
Chloroform (Trichloromethane)	0.75	1.3	2.7	GAC	1	a,c,d
Vinyl Chloride	0.00047	0.00064	0.00099	GAC	1	a,c,d
Chlorobenzene	0.33	0.73	1.7	GAC	1	a,c,d
1,2-Dichlorobenzene	16	39	91	GAC	1	a,c,d
1,3-Dichlorobenzene	0.29	0.7	1.7	GAC	1	a,c,d
1,4-Dichlorobenzene	30	72	167	GAC	1	a,c,d
1,2,3-Trichlorobenzene	1	2.6	6.1	GAC	1	a,c,d

1,2,4-Trichlorobenzene	1.8	4.5	11	GAC	1	a,c,d
1,3,5-Trichlorobenzene	0.23	0.57	1.3	GAC	1	a,c,d
1,2,3,4-Tetrachlorobenzene	12	29	62	GAC	1	a,c,d
1,2,3,5-Tetrachlorobenzene	0.49	1.2	2.8	GAC	1	a,c,d
1,2,4,5-Tetrachlorobenzene	0.3	0.68	1.4	GAC	1	a,c,d
Pentachlorobenzene	5.2	10	17	GAC	1	a,c,d
Hexachlorobenzene	0.59	1	1.4	GAC	1	a,c,d

EXPLOSIVES

	1% SOM (mg/kg)	2.5% SOM (mg/kg)	6% SOM (mg/kg)	SGV or GAC?	Ref	Notes
2,4,6 Trinitrotoluene (TNT)	1.6	3.7	8	GAC	1	a,c,d
RDX	3.5	7.4	16	GAC	1	a,c,d
HMX	5.7	13	26	GAC	1	a,c,d

PESTICIDES

	1% SOM (mg/kg)	2.5% SOM (mg/kg)	6% SOM (mg/kg)	SGV or GAC?	Ref	Notes
Aldrin	1.7	2	2.1	GAC	1	a,c,d
Dieldrin	0.69	1.4	2.2	GAC	1	a,c,d
Atrazine	0.24	0.56	1.3	GAC	1	a,c,d
Dichlorvos	0.29	0.6	1.3	GAC	1	a,c,d
Alpha-Endosulfan	2.9	7	16	GAC	1	a,c,d
Beta-Endosulfan	2.8	6.6	15	GAC	1	a,c,d
Alpha-Hexachlorocyclohexanes	19	46	100	GAC	1	a,c,d
Beta-Hexachlorocyclohexanes	1.7	3.9	8.5	GAC	1	a,c,d
Gamma-Hexachlorocyclohexanes	0.58	1.4	3	GAC	1	a,c,d

PHENOLS

	1% SOM (mg/kg)	2.5% SOM (mg/kg)	6% SOM (mg/kg)	SGV or GAC?	Ref	Notes
Phenol		420		SGV	2	a,b,c
Chlorophenols (2,4-Dichlorophenol or 2,3,4,6-Tetrachlorophenol)	0.87	2	4.4	GAC	1	a,c,d
Pentachlorophenol	0.55	1.3	2.96	GAC	1	a,c,d

OTHER CONTAMINANTS

	1% SOM (mg/kg)	2.5% SOM (mg/kg)	6% SOM (mg/kg)	SGV or GAC?	Ref	Notes
Carbon Disulphide	0.1	0.2	0.44	GAC	1	a,c,d
Hexachloro-1,3,-butadiene	0.21	0.51	1.2	GAC	1	a,c,d
Dioxins, Furans and Dioxin-like PCBs		8 ug/kg		SGV	2	a,b,c,i

Notes

(a) Based on a sandy loam soil as defined in Ref. 3
(b) Based on 6% SOM
(c) Based on a pH of 7
(d) Assumes free phase contamination is not present
(e) The SGV for inorganic mercury can normally be used for comparison with results of laboratory analysis, but due consideration must be given at the Desk Study (Phase 1) stage as to whether elemental or methyl mercury may be present
(f) Based on a threshold protective of direct skin contact with phenol
(g) At a lower SOM, the SGV may not be sufficiently protective
(h) When assessing a fresh xylene spill, the m-Xylene SGV should be compared with the Total Xylene soil concentration. If the xylene source is unknown or is weathered, the Total Xylene soil concentration (total of 3 isomers) should be compared against the lowest SGV for the particular land use
(i) SGV to be compared with the sum of the soil concentrations of all Dioxin, Furan and Dioxin-like PCB (77, 81, 126, 169, 105, 114, 118, 123, 156, 157, 167 ,189) congeners

Refs

(1) The LQM/CIEH Generic Assessment Criteria for Human Health Risk Assessment (2nd Edition), July 2009
(2) Individual SGV reports released by the Environment Agency
(3) Environment Agency Science Report SC050021/SR3 - Updated technical background to the CLEA model, January 2009

SGVs / GACs for Tier 2 Generic Quantitative Risk Assessment - Allotment Land Use

METALS

	Value (mg/kg)	SGV or GAC?	Ref	Notes
Arsenic	43	SGV	2	a,b,c
Beryllium	55	GAC	1	a,b,c
Boron	45	GAC	1	a,b,c
Cadmium	1.8	SGV	2	a,b,c
Chromium III	15,300	GAC	1	a,b,c
Chromium VI	2.1	GAC	1	a,b,c
Copper	524	GAC	1	a,b,c
Mercury - Elemental	26	SGV	2	a,b,c,e
Mercury - Inorganic	80	SGV	2	a,b,c,e
Mercury - Methyl	8	SGV	2	a,b,c,e
Nickel	230	SGV	2	a,b,c
Selenium	120	SGV	2	a,b,c
Vanadium	18	GAC	1	a,b,c
Zinc	618	GAC	1	a,b,c

TOTAL PETROLEUM HYDROCARBONS (TPH)

	1% SOM (mg/kg)	2.5% SOM (mg/kg)	6% SOM (mg/kg)	SGV or GAC?	Ref	Notes
Aliphatic EC 5-6	740	1700	3900	GAC	1	a,c,d
Aliphatic EC >6-8	2300	5600	13,000	GAC	1	a,c,d
Aliphatic EC >8-10	320	770	1700	GAC	1	a,c,d
Aliphatic EC >10-12	2200	4400	7300	GAC	1	a,c,d
Aliphatic EC >12-16	11,000	13,000	13,000	GAC	1	a,c,d
Aliphatic EC >16-35	260,000	270,000	270,000	GAC	1	a,c,d
Aliphatic EC >35-44	260,000	270,000	270,000	GAC	1	a,c,d
Aromatic EC 5-7 (benzene)	13	27	57	GAC	1	a,c,d
Aromatic EC >7-8 (toluene)	22	51	120	GAC	1	a,c,d
Aromatic EC >8-10	8.6	21	51	GAC	1	a,c,d
Aromatic EC >10-12	13	31	74	GAC	1	a,c,d
Aromatic EC >12-16	23	57	130	GAC	1	a,c,d
Aromatic EC >16-21	46	110	260	GAC	1	a,c,d
Aromatic EC >21-35	370	820	1600	GAC	1	a,c,d
Aromatic EC >35-44	370	820	1600	GAC	1	a,c,d
Aliphatic + Aromatic EC >44-70	1200	2100	3000	GAC	1	a,c,d

BTEX COMPOUNDS

	Value (mg/kg)	SGV or GAC?	Ref	Notes
Benzene	0.07	SGV	2	a,b,c,d,g
Toluene	120	SGV	2	a,b,c,d,g
Ethylbenzene	90	SGV	2	a,b,c,d,g
o-Xylene	160	SGV	2	a,b,c,d,g,h
m-Xylene	180	SGV	2	a,b,c,d,g,h
p-Xylene	160	SGV	2	a,b,c,d,g,h

POLYCYCLIC AROMATIC HYDROCARBONS (PAHs)

	1% SOM (mg/kg)	2.5% SOM (mg/kg)	6% SOM (mg/kg)	SGV or GAC?	Ref	Notes
Acenaphthene	34	85	200	GAC	1	a,c,d
Acenaphthylene	28	69	160	GAC	1	a,c,d
Anthracene	380	950	2200	GAC	1	a,c,d
Benzo(a)anthracene	2.5	5.5	10	GAC	1	a,c,d
Benzo(a)pyrene	0.6	1.2	2.1	GAC	1	a,c,d
Benzo(b)fluoranthene	3.5	7.4	13	GAC	1	a,c,d
Benzo(ghi)perylene	70	120	160	GAC	1	a,c,d
Benzo(k)fluoranthene	6.8	14	23	GAC	1	a,c,d
Chrysene	2.6	5.8	12	GAC	1	a,c,d
Dibenzo(ah)anthracene	0.76	1.5	2.3	GAC	1	a,c,d
Fluoranthene	52	130	290	GAC	1	a,c,d
Fluorene	27	67	160	GAC	1	a,c,d
Indeno(123-cd)pyrene	1.8	3.8	7.1	GAC	1	a,c,d
Naphthalene	4.1	9.9	23	GAC	1	a,c,d
Phenanthrene	16	38	90	GAC	1	a,c,d
Pyrene	110	270	620	GAC	1	a,c,d

CHLORINATED HYDROCARBONS

	1% SOM (mg/kg)	2.5% SOM (mg/kg)	6% SOM (mg/kg)	SGV or GAC?	Ref	Notes
1,2-Dichloroethane	0.0046	0.0083	0.016	GAC	1	a,c,d
1,1,1-Trichloroethane	48	110	240	GAC	1	a,c,d
1,1,2,2-Tetrachloroethane	0.41	0.89	2	GAC	1	a,c,d
1,1,1,2-Tetrachloroethane	0.79	1.9	4.4	GAC	1	a,c,d
Tetrachloroethene	1.6	3.7	8.7	GAC	1	a,c,d
Carbon Tetrachloride	0.16	0.37	0.85	GAC	1	a,c,d
Trichloroethene	0.43	0.95	2.2	GAC	1	a,c,d
Chloroform (Trichloromethane)	0.36	0.7	1.5	GAC	1	a,c,d
Vinyl Chloride	0.00055	0.001	0.0018	GAC	1	a,c,d

Chlorobenzene	5.9	14	32	GAC	1	a,c,d
1,2-Dichlorobenzene	94	230	540	GAC	1	a,c,d
1,3-Dichlorobenzene	0.25	0.61	1.5	GAC	1	a,c,d
1,4-Dichlorobenzene	15	37	88	GAC	1	a,c,d
1,2,3-Trichlorobenzene	4.7	12	28	GAC	1	a,c,d
1,2,4-Trichlorobenzene	31	75	180	GAC	1	a,c,d
1,3,5-Trichlorobenzene	4.7	12	28	GAC	1	a,c,d
1,2,3,4-Tetrachlorobenzene	4.4	11	26	GAC	1	a,c,d
1,2,3,5-Tetrachlorobenzene	0.38	0.94	2.2	GAC	1	a,c,d
1,2,4,5-Tetrachlorobenzene	0.064	0.16	0.37	GAC	1	a,c,d
Pentachlorobenzene	1.2	3.1	7.1	GAC	1	a,c,d
Hexachlorobenzene	0.18	0.42	0.92	GAC	1	a,c,d

EXPLOSIVES

	1% SOM (mg/kg)	2.5% SOM (mg/kg)	6% SOM (mg/kg)	SGV or GAC?	Ref	Notes
2,4,6 Trinitrotoluene (TNT)	0.24	0.58	1.4	GAC	1	a,c,d
RDX	0.52	1.1	2.5	GAC	1	a,c,d
HMX	0.86	1.9	3.9	GAC	1	a,c,d

PESTICIDES

	1% SOM (mg/kg)	2.5% SOM (mg/kg)	6% SOM (mg/kg)	SGV or GAC?	Ref	Notes
Aldrin	1.3	2.6	4	GAC	1	a,c,d
Dieldrin	0.13	0.32	0.73	GAC	1	a,c,d
Atrazine	0.037	0.085	0.2	GAC	1	a,c,d
Dichlorvos	0.044	0.091	0.2	GAC	1	a,c,d
Alpha-Endosulfan	0.47	1.2	2.7	GAC	1	a,c,d
Beta-Endosulfan	0.44	1.1	2.6	GAC	1	a,c,d
Alpha-Hexachlorocyclohexanes	3	7.4	18	GAC	1	a,c,d
Beta-Hexachlorocyclohexanes	0.26	0.64	1.5	GAC	1	a,c,d
Gamma-Hexachlorocyclohexanes	0.089	0.22	0.52	GAC	1	a,c,d

PHENOLS

	1% SOM (mg/kg)	2.5% SOM (mg/kg)	6% SOM (mg/kg)	SGV or GAC?	Ref	Notes
Phenol	280			SGV	2	a,b,c
Chlorophenols (2,4-Dichlorophenol or 2,3,4,6-Tetrachlorophenol)	0.13	0.3	0.7	GAC	1	a,c,d
Pentachlorophenol	0.084	0.21	0.49	GAC	1	a,c,d

OTHER CONTAMINANTS

	1% SOM (mg/kg)	2.5% SOM (mg/kg)	6% SOM (mg/kg)	SGV or GAC?	Ref	Notes
Carbon Disulphide	4.8	10	23	GAC	1	a,c,d
Hexachloro-1,3,-butadiene	0.25	0.61	1.4	GAC	1	a,c,d
Dioxins, Furans and Dioxin-like PCBs	8 ug/kg			SGV	2	a,b,c,i

Notes

(a) Based on a sandy loam soil as defined in Ref. 3
(b) Based on 6% SOM
(c) Based on a pH of 7
(d) Assumes free phase contamination is not present
(e) The SGV for inorganic mercury can normally be used for comparison with results of laboratory analysis, but due consideration must be given at the Desk Study (Phase 1) stage as to whether elemental or methyl mercury may be present
(f) Based on a threshold protective of direct skin contact with phenol
(g) At a lower SOM, the SGV may not be sufficiently protective
(h) When assessing a fresh xylene spill, the m-Xylene SGV should be compared with the Total Xylene soil concentration. If the xylene source is unknown or is weathered, the Total Xylene soil concentration (total of 3 isomers) should be compared against the lowest SGV for the particular land use
(i) SGV to be compared with the sum of the soil concentrations of all Dioxin, Furan and Dioxin-like PCB (77, 81, 126, 169, 105, 114, 118, 123, 156, 157, 167 ,189) congeners

Refs

(1) The LQM/CIEH Generic Assessment Criteria for Human Health Risk Assessment (2nd Edition), July 2009
(2) Individual SGV reports released by the Environment Agency
(3) Environment Agency Science Report SC050021/SR3 - Updated technical background to the CLEA model, January 2009

APPENDIX E

COST ESTIMATE

Table E1: Cost Estimate for Installation of Final Capping

Item	Unit	Quantity	Rate	Cost Estimate
Preliminaries				€ 20,000
Site Scrape	m^2	16,000	€ 0.50	€ 8,000.00
Geocomposite Gas Collection Layer	m^2	16,000	€ 4.50	€ 72,000.00
Perimeter Gas Venting Trench	m	350	€ 32	€ 11,200.00
Geosynthetic Clay Liner (LLDPE)	m^2	16,000	€ 5.00	€ 80,000.00
Geosynthetic Surface Water Drainage Layer	m^2	16, 000	€ 4.50	€ 72,000.00
Subsoil Layer 400mm	m^3	6,400	€ 10.00	€ 64,000.00
Topsoil 100mm	m^3	1,600	€ 2.25	€ 3,600.00
Surface Water Drains	m	350	€ 40	€ 14,000.00
Perimeter Fencing	m	350	€ 10	€ 3,500.00
Sub Total excl. VAT				€ 348,300.00