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CONSULTANTS IN ENGINEERING, ENVIRONMENTAL SCIENCE & PLANNING

NORTH KERRY LANDFILLS

TIER 3 RISK ASSESSMENT HISTORIC LANDFILL AT AHASCRA, CO. KERRY

Prepared for: Kerry County Council

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Abstract: This report represents the findings of a Tier 3 risk assessment carried out on Ahascra Historic Landfill site, Co. Kerry, and conducted in accordance with the EPA Code of Practice for unregulated landfill sites. The Tier 3 risk assessment was conducted following on from the findings on the previously conducted Tier 2 risk assessment.

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1. INTRODUCTION

1.1 Overview

Fehily Timoney and Company (FT) was appointed by Kerry County Council to carry out and prepare a Tier 3 risk assessment for Ahascra Historical landfill located at Ahascra, Co. Kerry. This Tier 3 makes reference to:

- Tier 1 risk assessment findings and classifications (2007 and 2013).
- Tier 2 Site investigation, testing and risk assessment (2020).

FT risk assessments were carried out in accordance with the Environmental Protection Agency (EPA) Code of practice (CoP) - Environmental Risk Assessment for Unregulated Waste Disposal Sites guidance document.

1.2 Tier 1 Risk Classification

Kerry County Council initially prepared a Tier 1 risk assessment in 2007. This risk assessment determined that the site was a high (Class A) risk to the receiving environment. Applying the EPA risk assessment tool as per the EPA CoP for Unregulated Waste Disposal Sites, yielded risk scores of 70% for source-pathway-receptors (SPR) linkage SPR8. A summary of the risks is presented below in Table 1.1.

The Tier 1 risk assessment was reviewed by KCC in 2013. Risk scores were assessed and recalculated, and the site was reduced from a High risk to a Moderate Risk, with the previously highest score of 70% for SPR8 being reduced to a low risk at 23%. The site was determined to present a moderate risk for SPR3 and SPR5 (41% and 61% respectively). The 2007 and 2013 risk scores are included in Table 1-1.

Table 1-1 normalised scores for 2007 and 2013. These have been provided for reference purposes and reflect current public records as per the EPA Section 22 register, which as of July 2020 present the 2007 Tier 1 assessment scores.

Table 1-1: Tier 1 SPR Linkages (2007 and 2013)

SPR No.	Linkage	Normalised Score	Justification[1]
Leachate migration through combined groundwater and surface water pathways			
SPR1	Leachate => surface water	63% (2007) 21% (2013)	Site is in an area of high groundwater vulnerability, underlain by a karstified aquifer, there is a direct surface water connection from the site to other surface water bodies.
SPR2	Leachate => SWDTE	0% (2007) 0% (2013)	Site is in an area of high groundwater vulnerability, underlain by a karstified aquifer, there is a direct surface water connection from the site however there are no receiving designated sites.

SPR No.	Linkage	Normalised Score	Justification[1]
Leachate migration through groundwater pathway			
SPR3	Leachate => human presence	40.83% (2007) 41% (2013)	Site is in an area of high groundwater vulnerability, underlain by a karstified aquifer and there are human receptors located between 50-250m from the site.
SPR4	Leachate => GWDTE	0% (2007) 0% (2013)	There are no relevant designated sites connected to the site.
SPR5	Leachate => Aquifer	61.25% (2007) 61% (2013)	Site is in an area of high groundwater vulnerability, underlain by a karstified aquifer.
SPR6	Leachate => Public Supply	26.25% (2007) 26% (2013)	Site is in an area of high groundwater vulnerability, underlain by a karstified aquifer. It is 3.6km from the edge of nearest buffer zone
SPR7	Leachate => Surface Water	61.25% (2007) 20% (2013)	Site is in an area of high groundwater vulnerability, underlain by a karstified aquifer and there are surface water bodies located between 250 m and 1km from the site.
Leachate migration through surface water pathway			
SPR8	Leachate => Surface Water	70% (2007) 23% (2013)	There are surface water pathways from the site and there are potential receiving surface water bodies between 250m - 1km from the site.
SPR9	Leachate => SWDTE	0% (2007) 0% (2013)	There are surface water pathways from the site however there are no designated surface water bodies potentially impacted.
Landfill gas migration pathway (lateral & vertical)			
SPR10	Landfill Gas => Human Presence	14 % (2007) 14% (2013)	Subsoils geology is peat and there are human receptors located between 150-250m from the site.
SPR11	Landfill Gas => Human Presence	0% (2007) 8% (2013)	Subsoils geology is peat and there are human receptors located between 150-250m from the site.

Note 1: justification refers to 2013 risk scoring

1.3 Tier 2 Site investigation

Fehily Timoney and Company (FT) was appointed by Kerry County Council (KCC) to carry out and prepare a Tier 2 site investigation, environmental risk assessment and report on the historic landfill in Ahascra, Co. Kerry.

Ahascra site investigation included the following elements:

- 1 no. Geophysical survey (2D resistivity and seismic refraction profiling.
- 5 No. Trial pit excavations.
- Installation and monitoring of 2 No groundwater boreholes.
- Topographical survey.
- Factual reporting.

Following the completion of a site investigation and Tier 2 risk assessment of the former landfill at Ahascra, Co. Kerry in 2020, it was concluded that a Tier 3 assessment should also be conducted. The findings of the Tier 2 assessment produced a firmer understanding of the characterisation of the site and facilitated the production of an updated Conceptual Site Model (CSM). The main findings of the Tier 2 assessment are discussed below.

The Tier 2 investigation confirmed the source of waste to be a mixed, primarily municipal solid waste (MSW) deposited within a single infill area which covers an area of 23,000 m^2. The depth of waste was estimated from the seismic refraction and 2D-Resistivity, an average thickness of 2.75 m has been calculated for the landfill material. The estimate includes capping or natural fill material on top of the main waste body. An initial volume calculation estimates an interred waste volume of 63,250 m^3 at the site.

1.4 Tier 2 Risk Classification and Tier 3 SPRs Considered

The Tier 2 risk assessment concluded that the risk rating of the site, as per the EPA CoP was High (Class A). The highest single risk rating for the site was calculated to be 70% for source-pathway-receptor (SPR) Linkage 8, which referred to leachate migration through a surface water pathway to a surface water receptor. The SPR linkages examined in this Tier 3 are discussed in further detail below.

Table 1-2: Tier 2 Selected SPR Linkages

SPR No.	Linkage	Normalised Score	Justification
Leachate migration through combined groundwater and surface water pathways			
SPR1	Leachate => surface water	56%	Groundwater vulnerability was identified as being moderate and the site is underlain by a regionally important karstified aquifer. A shallow drainage channel exists along the eastern perimeter of the historical landfill.
SPR2	Leachate => SWDTE	0%	The nearest groundwater protection zone is located approximately 15.8 km south-west of the site.
Leachate migration through groundwater pathway			
SPR3	Leachate => human presence	35%	One residential dwelling is located between 50m and 250m to the north-west of the site boundary and karstified aquifer presented a pathway for lateral leachate migration however low permeability peat underlies and surrounds the site limiting leachate migration to the bedrock.
SPR4	Leachate => GWDTE	0%	The nearest groundwater protection zone is located approximately 15.8 km south-west of the site.
SPR5	Leachate => Aquifer	53%	Aquifer vulnerability moderate and is classified as being a regionally important aquifer.
SPR6	Leachate => Public Supply	0%	Nearest public water supply is located over 1km from the site. Water supply identified by KCC refers to surface water abstraction on the Galey River.

SPR No.	Linkage	Normalised Score	Justification
			Historical landfill site is not located within the Galey River catchment area, based on review of EPA mapping and it not likely influence water quality of this river and supply.
SPR7	Leachate => Surface water	53%	Shallow drainage channel is present along the eastern perimeter of the site within 50m.
Leachate migration through surface water pathway			
SPR8	Leachate => Surface Water	70%	A shallow drainage channel is present along the eastern perimeter of the site and surface water results may indicate impact from the landfill.
SPR9	Leachate => SWDTE	0%	The nearest groundwater protection zone is located approximately 15.8 km south-west of the site.
Landfill gas migration pathway (lateral & vertical)			
SPR10	Landfill Gas => Human Presence	14%	A residential dwelling located within 50m to 250m north-west of the waste body.
SPR11	Landfill Gas => Human Presence	8%	A residential dwelling located within 50m to 250m north-west of the waste body.

1.4.1 Leachate Migration Through Combined Groundwater and Surface Water Pathway to Underlying Surface Water (SPR1)

Regarding the potential impact of the historical landfill on groundwater quality elevated concentrations of ammoniacal nitrogen, chloride, arsenic, manganese, iron and mineral oil above the groundwater threshold values were detected for groundwater monitoring wells BH01 and BH02, adjacent to the site boundary which indicate that the landfill may be negatively effecting groundwater quality within the locality.
A summary of these results are presented below.

Table 1-3: Summary of Groundwater Monitoring Results

Parameter	Units	EPA IGV Standards	S.I. No. 9 of 2010	BH01		BH02	
				03/09/2019	16/07/2019	03/09/2019	16/07/2019
Ammoniacal Nitrogen as N	mg/l	0.15	0.175	2.38	2.43	2.38	1.89
Chloride	mg/l	24-187.5	30	37.4	44.1	37.4	35.7
Arsenic	µg/l	7.5	10	65.6	39.2	19.2	14.4
Manganese	µg/l		50	376	341	1250	1280
Iron	mg/l		0.2	2.79	0.798	4.13	2.23
Mineral Oil >C10-C40	µg/l		10	<100	251	<100	<100

The risk of the site on groundwater quality and subsequently surface water was reflected in a calculated risk score of 56% for source-pathway-receptor (SPR1) that is; leachate migration through combined surface water and groundwater pathways.

1.4.2 Leachate Migration Through Groundwater Pathway to Underlying Aquifer (SPR5)

Groundwater monitoring conducted as part of the Tier 2 site investigation indicated that waste from the historical landfill may be having a deleterious effect on groundwater quality. The classification of the underlying aquifer is a karst aquifer means that the aquifer groundwater may provide a preferential pathway for the migration of the leachate from the site. This classification as a regionally important aquifer also demonstrates that the groundwater body has a high groundwater resource potential and as such requires some protection from contamination.

1.4.3 Leachate Migration Through Groundwater Pathway to Surface Water (SPR7)

The site is in an area of high groundwater vulnerability, underlain by a karstified aquifer and there are surface water bodies located between 250 m and 1 km from the site. The risk of the site on surface water quality was reflected in a calculated risk score of 70% for source-pathway-receptor (SPR7).

1.4.4 Leachate Migration Through Surface Water Pathway to Surface water receptor (SPR8)

Surface water monitoring was conducted at upstream and downstream locations on a small stream located to the east of the site. Monitoring demonstrated exceedances in the BOD concentrations at both upstream and downstream monitoring locations. Leachate breakouts were observed during the site walkover. Leachate may also migrate to adjacent surface water and drainage features.

The risk of the site on surface water quality was reflected in a calculated risk score of 70% for source-pathway-receptor (SPR8) that is; leachate migration through surface water pathway.

1.4.5 Landfill gas migration pathway (lateral & vertical)

Landfill gas monitoring at monitoring well locations BH01 and BH02 indicate gas concentrations detected were within the range typical of inert waste with no exceedances. A residential property is located c. 90m north-west of the site at its closest point. Although the risk scores as calculated applying the EPA Code of Practice as a matter of due diligence this potential environmental risk was examined further as part of this Tier 3 environmental risk assessment.

2. TIER 3 QUANTITATIVE RISK ASSESSMENT SCOPE OF WORKS

2.1 Tier 3 Overview

A Tier 3 quantitative risk assessment to include some form of quantitative assessment for **Moderate or High-risk sites**, either as a Generic Quantitative Risk Assessment (GQRA) or as a Detailed Quantitative Risk Assessment (DQRA).

This Tier 3 Quantitative Risk Assessment report further examines the Tier 2 (see Table 1-2) linkages in relation to the following:

- SPR1 Leachate Migration Through Combined Groundwater and Surface Water Pathway to Underlying Surface Water resulting in risk rating score of 56%.
- SPR5 Leachate Migration Through Groundwater Pathway to Underlying Aquifer resulting in risk rating score of 53%.
- SPR8 Leachate Migration Through Surface water Pathway to Surface water receptor resulting in risk rating score of 70%.
- SPR10 and SPR11 Landfill gas migration pathway (lateral & vertical) resulting risk rating scores of 14% and 8%.

Based on the outcomes of the GQRA/DQRA, suitable remediation measures and associated costs are determined, if required.

As part of the Tier 3 assessment, a review of the Tier 2 site investigation and testing assessment was conducted. As shown in Section 1 of this report the Tier 1 assessment concluded that the site presented a **moderate risk** to the environment. The Tier 2 investigations concluded that the site presented a **high risk** to the environment.

This Tier 3 assessment report uses a DQRA to further assess the risks to surface water and groundwater receptors through combined surface water and groundwater pathways.

Groundwater contaminant dispersion modelling (EA Remedial Targets Worksheet) was undertaken to quantitatively assess the risks posed to the aquifer and public water supply.

An assimilative capacity assessment and mass balance calculation were carried out to predict the potential impact on surface water quality from an assumed leachate discharge to the adjacent river.

Predictive landfill gas modelling (LandGEM) was used to assess gas migration risks.

Based on the outcomes of the DQRA, suitable remediation measures and associated costs are presented in Section 4 of this report.

3. DETAILED QUANTITATIVE RISK ASSESSMENT (DQRA)

3.1 Detailed Quantitative Risk Assessment

The detailed quantitative risk assessment addressed the following primary risks:

- Leachate Migration Through Combined Groundwater and Surface Water Pathway to Underlying Surface Water (SPR1)
- Leachate migration through groundwater pathway to underlying aquifer (SPR5).
- Leachate Migration Through Groundwater Pathway to Surface Water (SPR7)
- Lateral and vertical migration of landfill gas (SPR10 and SPR11).

The preparation of the detailed quantitative risk assessment utilises information gathered as part of the Tier 2 investigations. A summary of the relevant environmental characteristics considered in evaluating the site and carrying out this Tier 3 investigation are discussed below.

3.2 Existing Geological, Hydrogeological and Hydrological Environment

The risk to underlying groundwater quality and surface water quality were identified as two of the primary environmental risks associated with the site. The application of the EPA risk calculation and scoring methodology as outlined in the EPA CoP is reliant on understanding the geological and hydrogeological characteristics of the site and the surrounding environment. An accurate understanding and assessment of the geological and hydrogeological characteristics of the site and environment are directly linked to determining the primary source-pathway-receptor linkages and potential impacts/risks associated with the site. The Tier 2 site investigation and risk assessment provided a firmer understanding of the site and surrounding environs. A summary of the relevant environmental characteristics considered in evaluating the site and carrying out this Tier 3 investigation are discussed below.

The historical landfill site is 2.65 Ha in size and covers an area of open land located in a rural, primarily agricultural area in north Kerry. The quaternary sediments within the site are classified as 'Cut over raised peat'. Pockets of sandstone and shale tills surround the adjacent peat bog area. Further west significant alluvium deposits are shown following the Feale/Cashen River. There is no area of bedrock outcrop shown within or immediately adjacent to the site. Site investigation works identified the presence of peat and areas of sand and gravel TILL in BH01.

The bedrock beneath the site is found on a single formation. The entirety of the site and surrounding area is underlain by the Waulsortian Limestone formation (CDWAUL) which is generally made up of Dinantian '*massive, unbedded lime-mudstone'.* No bedrock outcrops are shown to be present within the site area. Limestone bedrock was encountered at both borehole locations, BH01 and BH02, during site investigation works.

An examination of the national bedrock aquifer map classifies both the Glenflesk Formation as a 'Regionally Important Aquifer – Karstified (Diffuse) Bedrock (Rkd)'.

Mapping identifies the vulnerability of groundwater to contamination as 'Moderate'. This facilitates a relatively easy route for rainfall and leachate to enter the underlying groundwater aquifer.

The site is located within the catchment of the Tralee Bay-Feale, sub-catchment Glouria and river sub-basin Glouria_010. The River Feale, first order waterbody, is located approximately 1.5 km south-west of the site at its closest point.

The Glouria River (Glouria_010), second order waterbody, is located approximately 1.11 km south-east of the site and flows in a south-westerly direction before turning west eventually meeting the River Feale approximately 2km south-west of the site. Under the water framework directive (WFD), the Glouria waterbody is under review, it's not currently assigned a risk status and its ecological status or potential is unassigned.

Locally, a peatland drainage channel with very low flow rate was identified along north-eastern boundary of site during the site walkover. During periods of increased rainfall, flow direction within the drainage channel is likely south to north. Observations of the localised topography indicate that drainage channels from the surrounding peatlands and field boundaries eventually drain into the River Feale approximately 1.6 km to the west. Review of historical mapping shows a network of man-made drainage channels have been excavated north and north-west of the site, likely to assist drainage of the Kiltean Bog. Surface water flow from these land drains directs flow in a south-westerly course towards the River Feale / Cashen SAC.

3.2.1 Contaminants of Concern

With respect to groundwater quality and potentially the public groundwater supply, the Tier 2 site investigation identified the following chemicals were shown to exceed the groundwater quality overall threshold values as per the S.I. No.9 of 2010 in samples taken from both groundwater wells, BH01 and BH02. The extent of these exceedances is shown in Table 1-3 in section 1.4.

- Ammoniacal Nitrogen.
- Chloride.
- Arsenic.

The Tier 2 investigation did note however that the slightly elevated iron and manganese concentrations are typical of the local bedrock hydrochemistry and therefore may not be attributed to the presence of the landfill. Based on this conclusion, iron and manganese have not been examined further as part of the Tier 3 assessment.

The elevated concentrations of ammoniacal nitrogen, chloride, arsenic and mineral oil indicate that the landfill waste body may be impacting on groundwater quality and subsequently has the potential to negatively impact on groundwater quality.

3.2.2 Revised Conceptual Site Model (CSM)

A revised conceptual site model has been prepared as part of this Tier 3 assessment and is displayed below in Figure 3.1.

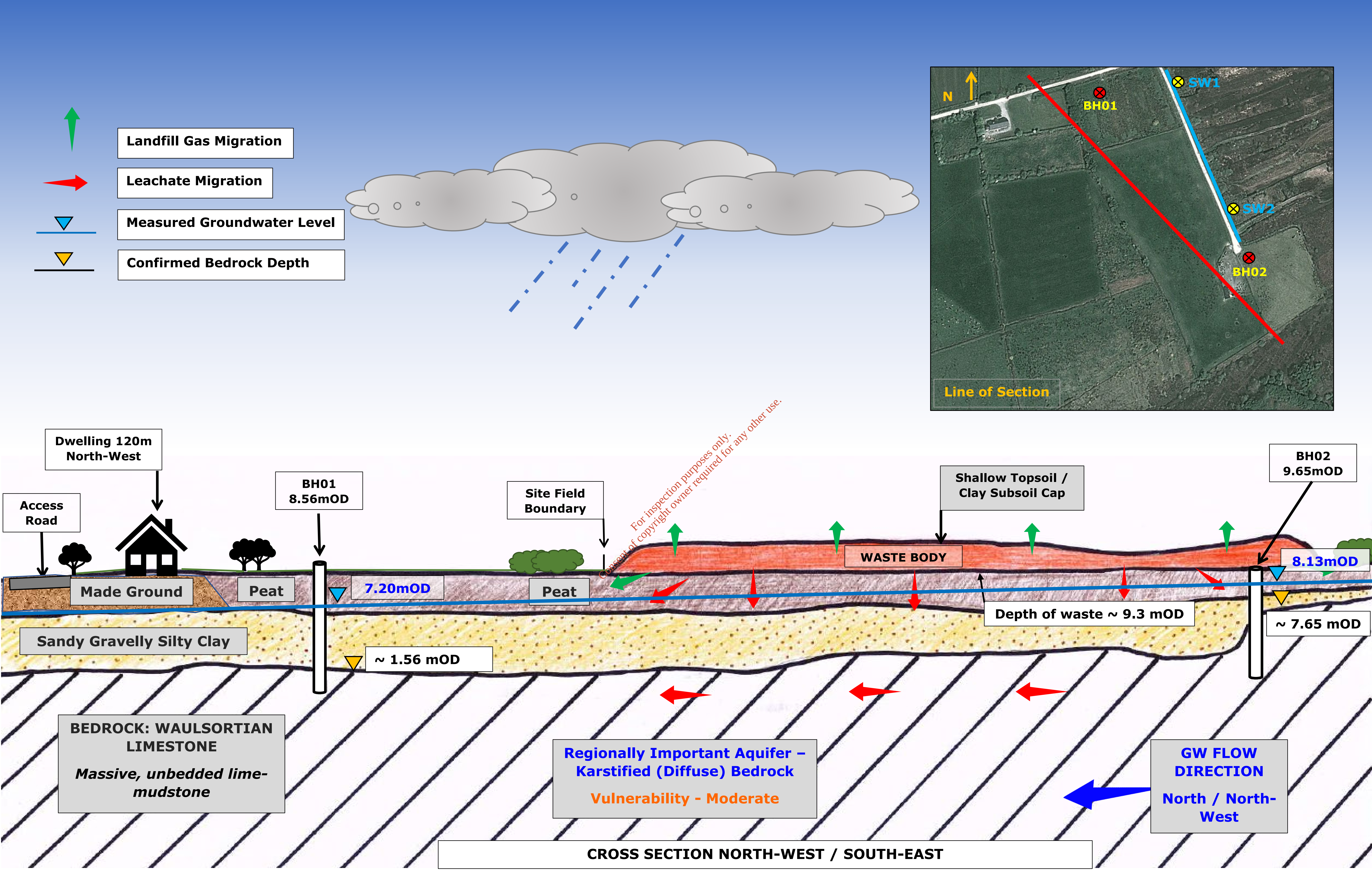

FIGURE 5.1 AHASCRA HISTORIC LANDFILL

CONCEPTUAL SITE MODEL

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3.3 Impact of Leachate on Groundwater

3.3.1 Potential Leachate Generation

In quantifying the potential impact that the leachate generated at the historical landfill may have on the underlying groundwater aquifer it is important to estimate the quantity of leachate or contaminated groundwater produced at the site. Monitoring of groundwater wells installed at the site indicated that the groundwater level is below the waste body. This indicates that the generation and subsequent vertical migration of leachate is driven primarily by rainfall percolation inputs through the waste body.

The vertical infiltration of rainfall from the site to the underlying groundwater aquifer is determined by the groundwater recharge rate at this site. Groundwater recharge is variable in the region. Groundwater recharge mapping defined the annual recharge for the site as 30 mm/yr. The effective rainfall for the area is 762 mm/yr, returning a recharge coefficient of 4% due to the presence of peat.

4% x 762 mm/year = 30 mm/year or 0.03m/year (available rainfall for recharge over the landfill area

Aquifer Recharge Volume = Recharge x area of landfill

Aquifer Recharge Volume = 0.03m/year x 23,000 m^2

Aquifer Recharge Volume over landfill area = 690 m^3/year ***[1.9 m^3/day]***

Based on this calculation and the estimated low quantity of leachate likely to be produced at the site and migrate to the underlying aquifer, it can be stated on a regional scale the site is not likely to have any noticeable direct impact on aquifer groundwater quality.

3.3.2 Leachate Dispersion Modelling and Assessment

To further determine and confirm the potential downstream concentration of leachate generated at the site and the potential risk it may pose to groundwater downstream and subsequently the public water the Hydrogeological Risk Assessment for Land Contamination - Remedial Targets Worksheet developed by the UK Environment Agency's Science Group was utilised.

This model is generally used to develop remediation targets in soil or groundwater to ensure a desired downstream concentration at a point e.g., a well or other receptor downstream. The model allows the user to predict at what point in time and distance that the desired groundwater concentration will be met.

This assessment tool was used to predict the potential groundwater concentration for select parameters downstream of the site. The model relies on the following (simplified) inputs:

- Source characteristics (i.e., leachate species concentration, retardation, half-life).
- Aquifer characteristics (permeability, porosity, hydraulic gradient).

The UK EA worksheet relies on the input of single values therefore it was necessary to make several assumptions based on available site-specific data, and typical values obtained from literature and understanding of the site.

The input parameters used in this model are outlined in Table 3-1.

Table 3-1: UK EA Remedial Targets Worksheet Model Inputs

Input Parameter	Unit	Ammoniacal Nitrogen	Chloride	Arsenic	Source
Target Concentration	*mg/l*	0.175	30	0.01	S.I No. 9 of 2010 and EPA IGV
Initial contaminant concentration in groundwater at plume core	*mg/l*	4.37 (most likely)	100	1.31	Assumed values based on typical concentrations as per UK leachate inventory (landsim manual)
Half-life for degradation of contaminant in water	*days*	$1x10^9$			Assumed high value (no degradation)
Width of plume in aquifer at source (perpendicular to flow)	*m*	90			Approximate width of site/waste extent based on site investigation
Plume thickness at source	*m*	4			Assumed thickness, waste is deposited directly on limestone bedrock
Saturated aquifer thickness	*m*	5			Assumed aquifer thickness to be upper 5m of karst limestone
Bulk density of aquifer materials	*g/cm3*	1.55			Assumed limestone bulk density
Effective porosity of aquifer	*fraction*	0.275			Median value of assumed porosity referenced in Environmental Agency Landsim manual
Hydraulic gradient	*fraction*	0.004			Calculated hydraulic gradient between BH01 and BH02 (2019 S.I)
Hydraulic conductivity of aquifer	*m/d*	8.64			Assumed single conductivity based on literature values for karst limestone
Distance to compliance point	*m*	500			Hypothetical compliance point distance
Time Since Pollutant entered groundwater	*days*	25,50, 100, 500 and 1000 years [9,125, 18,250,36,500, 182,500, 365,000 days]			Time intervals selected
Soil Water Partition Co-efficient	*l/kg*	1.25	0	137.5	Assumed - based on values referenced in Environmental Agency LandSim manual

3.3.3 Results – EA UK Remedial Targets Worksheet

This model was used to estimate the dispersion of ammoniacal nitrogen, chloride and arsenic. The groundwater concentrations at a range of distances from the source at different time intervals are presented in Table 3-2 below.

The range of distances are automatically generated by the model based on the percentages of the compliance point distance (500m) i.e., 25m [5%], 100m [20%], 250m [50%] and 500m [100%].

Table 3-2: Modelled Downstream Concentrations (UK EA Remedial Targets Worksheet)

Ammoniacal Nitrogen (mg/l)			*Groundwater threshold Value (GTV) = 0.175 mg/l*		
Years of Dispersion	**Initial Plume Concentration (mg/l)**	***Conc.at 25m (mg/l)***	***Conc. at 100 m (mg/l)***	***Conc. at 250m (mg/l)***	***Conc. at 500 m (mg/l)***
25	4.37	**2.099**	**0.734**	0.101	0.0
50	4.37	**2.352**	**0.99**	**0.321**	0.03
100	4.37	**2.479**	**1.12**	**0.502**	**0.182**
500	4.37	**2.507**	**1.15**	**0.551**	**0.295**
1000	4.37	**2.507**	**1.15**	**0.551**	**0.295**
Chloride (mg/l)			***Groundwater threshold Value (GTV) = 30 mg/l***		
25	100	**57.347**	26.2	12.568	6.560
50	100	**57.373**	26.3	12.619	6.749
100	100	**57.373**	26.3	12.619	6.749
500	100	**57.373**	26.3	12.619	6.749
1000	100	**57.373**	26.3	12.619	6.749
Arsenic (mg/l)			***Groundwater threshold Value (GTV) = 0.01 mg/l***		
25	1.31	**0.0199**	0	0	0
50	1.31	**0.075**	0	0	0
100	1.31	**0.162**	0	0	0
500	1.31	**0.4**	**0.033**	0	0
1000	1.31	**0.504**	**0.102**	0.001	0

3.3.4 Discussion of Results

The model was used to predict downgradient concentrations of the identified pollutants (ammoniacal nitrogen, chloride and arsenic at 25 m, 100m, 250m and 500 m downstream of the site after the stated number of years of dispersion (25, 50, 100, 500 and 1000) at the defined permanent source concentrations.

The model conservatively assumes a worst-case scenario of a **non-depleting** source concentration. This is very conservative and assumes that there will be no ongoing dilution and dispersion of contaminants.

Modelling following a review of concentrations in BH2 assumed source concentrations using the UK leachate inventory values as follows:

- Ammoniacal N - assumed value within lower range of typical ammoniacal N concentrations.
- Chloride - assumed value within lower range of typical chloride concentrations.
- Arsenic – assumed value within upper range of typical arsenic concentrations.

Both source concentrations exceeded observations in BH01 (removed from) and BH02 (immediately adjacent to) the waste body.

The modelling scenario adopted represented a worse-case scenario given that dilution and dispersion of leachate since the closure of the site will have significantly reduced leachate source concentrations.

Modelling estimates that Ammoniacal nitrogen concentrations exceed the groundwater quality threshold value up to 500 m from the site but only after 100 years of dispersion. Concentrations are consistently above the water quality threshold at 25m and 100m from the site at each time interval with concentrations also increasing up to 500 years. The concentrations predicted at 25m and 100m are comparable to those observed at downgradient groundwater monitoring well BH02 (2.38 mg/l and 1.89 mg/l).

With respect to chloride, exceedances are only observed up to 25m from the site. The concentrations observed at both 25m and 100m distances from the site are comparable to those observed downstream groundwater well BH02 (37.4 mg/l and 35.7 mg/l). This indicates that contamination of groundwater with chloride is likely to be localised.

The model predicts potential exceedances of the groundwater quality threshold for arsenic up to 100 m from the site with concentrations increasing over time close to the site. Concentrations predicted at 25m from the site are comparable to those observed at downgradient groundwater monitoring well BH02 (0.0192 mg/l and 0.0144 mg/l). As stated previously this model conservatively assumed a non-depleting source and therefore assumes a constant migration of arsenic from the site.

Overall, the model suggests that pollutant dispersion is more likely to be a local issue and that the historical landfill is not likely to influence groundwater quality on a regional scale.

The existing cap at the site is limited to a basic soil cap, facilitating continuous rainwater percolation through the underlying and potential generation of leachate. Given the lack of an engineered cap at the site and the potential impacts on groundwater quality locally remedial works will be required.

3.4 Impact of Leachate on Receiving Surface Waters

Although surface water monitoring did not indicate contamination of adjacent surface water the potential impact of leachate emissions to the adjacent river along the western boundary of the site was identified as being a primary risk associated with the site. Ammonia concentrations detected in groundwater monitoring boreholes installed at the site were shown to exceed the relevant groundwater quality threshold values.

Ammonia is a commonly occurring pollutant associated with landfills which may pose a risk to surface waters, where a pathway exists.

Therefore, in the absence of laboratory evidence of surface water contamination, a conservative assessment determined the impact of ammonia, as the representative potential pollutant, being discharged into the receiving water courses:

- Over a range of theoretical leachate breakout flow rates between 1 and 5 l/s, and
- at an assumed ammonia concentration of 2.2 mg/l based on groundwater sample ammonia concentrations

The potential impact of the site on this receiving surface waterbody was assessed by conducting an assimilative capacity assessment and mass balance calculations with ammonia chosen as a representative potential pollutant.

3.4.1 Assimilative Capacity Assessment

Table 3-3 shows the inputs assumed to assess assimilative capacity of the receiving waterbody:

Table 3-3: Assimilative Capacity Calculation Inputs

Assimilative capacity = (C_{max} – C_{back}) x F95 x 86.4 kg/day		
Where:	Value	Source
C_{max} = maximum permissible concentration (EQS – 95%ile value) (mg/l)	0.14	95%-ile 'good' status threshold as per S.I No. 77 of 2019 - European Union Environmental Objectives (Surface Waters) (Amendment) Regulations 2019
C_{back} = background upstream concentration (mg/l mean value)	0.065	Assumed background concentration as 'good' status mean threshold value for ammonia as per S.I No. 77 of 2019 - European Union Environmental Objectives (Surface Waters) (Amendment) Regulations 2019
F95 = the 95%ile flow in the river (m^3/s)	0.045	Assumed 95%-ile flow for a receiving water body based on similar catchments
Assimilative Capacity kg/day	0.29	AC (kg/day) = (0.14 - 0.065) x 0.045 x 86 .4

3.4.2 Potential Impacts of Leachate Breakouts on Receiving Surface Waters

To determine potential impacts that leachate surface breakouts from the landfill may have on the assimilative capacity of the receiving water body, the mass of ammonia discharging from the site is calculated applying the equation below.

Mass Emission (kg/day) = Discharge Flow (m^3/day) x Concentration (mg/l) /1000

Assumed criteria:

- *Flow range of assumed leachate breakouts:* *1-5 l/s*
- *Concentration of ammonia in leachate:* *2.2 mg/l NH_4 based on borehole observations*
- *Significant pollution threshold if:* *> S.I. No. 77 of 2019 ('Good' status mean 0.065 mg/l) or*
  > S.I. No. 77 of 2019 ('Good' status 95%-ile 0.140 mg/l)

A range of assumed discharge flows (1 - 5 litres/second) was applied and the percentage of the assimilative capacity removed following discharge to the receiving water was also calculated (Daily Mass Emission ÷ Assimilative Capacity). A discharge ammonia concentration of 2.2 mg/l (highest ammonia observation from groundwater BH02) was assumed for this calculation. The calculated mass emissions and the impacts on the assimilative capacity, for a range of assumed discharge rates, of the receiving water are shown in Table 3-5.
To determine the impact that discharge from the site may have on the assimilative capacity of the receiving water body the mass of ammonia discharging from the site is calculated applying the equation below.

Mass Emission (kg/day) = Discharge Flow (m^3/day) x Concentration (mg/l) /1000

A range of assumed discharge flows (1 - 5 litres/second) were applied and the percentage of the assimilative capacity removed following discharge to the receiving water was also calculated (Daily Mass Emission/Assimilative Capacity). An ammonia concentration of 2.2 mg/l was assumed for this calculation. This assumption was based on the maximum recorded ammonia concentration detected in groundwater monitoring wells installed at the site.

3.4.3 Mass Balance Assessment

Table 3-4 shows the mass balance calculation to determines the potential change in ammonia concentration within the receiving water downstream of the discharge.

Table 3-4: Mass Balance Calculation

T = (FC + fc)/(F + f)		
Where:		*Source*
F is the river flow upstream of the discharge (95%ile flow m^3/sec);	0.045	Assumed 95%-ile flow for a receiving water body based on similar catchments
C is the concentration of pollutant in the river upstream of the discharge (mean concentration in mg/l);	0.065	Assumed background concentration as 'good' status mean threshold value for ammonia as per S.I No. 77 of 2019 - European Union Environmental Objectives (Surface Waters) (Amendment) Regulations 2019
f is the flow of the discharge (m^3/sec);	0.001 to 0.005	Assumed discharge rate
c is the maximum concentration of pollutant in the discharge (mg/l);	2.2	Maximum concentration detected in groundwater monitoring wells
T is the concentration of pollutant downstream of the discharge.	Varies 1-5 l/s	Predicted ammonia concentration in receiving water downstream of discharge
Water Quality Standard (mg/l)	0.140	'Good' Status 95%-ile as per S.I No. 77 of 2019
	0.065	'Good' Status Mean as per S.I No. 77 of 2019

Table 3-5: Potential Impacts of Leachate Breakouts on Assimilative Capacity of Receiving Downstream Waters

Assumed Leachate Breakout Flow (l/s) Flow (litre/sec)	Assumed Leachate Breakout Flow (m^3/day)	Daily Mass Emission (kg/day) assuming NH_4 concentration 2.2 mg/l	% Impact Breakout has on of Assimilative Capacity (see Note 3)%-age of AC	Estimated Downstream Concentration NH_4 (mg/l)
1	86	0.19	65%	0.111
2	173	0.38	130%	0.156
3	259	0.57	196%	0.198
4	346	0.76	261%	0.239
5	432	0.95	326%	0.279

Note 1: Water quality standard as per S.I. No. 77 of 2019 ('Good' status 95%-ile 0.140 mg/l).

Note 2: Water quality standard as per S.I. No. 77 of 2019 ('Good' status mean 0.065 mg/l).

Note 3: Assimilative capacity assumed to be 0.29 mg/l ammonia (Table 3-3).

Table 3-5 results show that leachate discharge flow rates of:

- 2, 3, 4 and 5 litres/s (173, 259, 346 and 432 m^3/day) will be non-compliant with S.I. No. 77 of 2019 ('Good' status 95%-ile 0.140 mg/l)
- 1, 2, 3, 4 and 5 litres/s (86, 173, 259, 346 and 432 m^3/day) will be non-compliant with both S.I. No. 77 of 2019 ('Good' status 95%-ile 0.140 mg/l) and S.I. No. 77 of 2019 'Good' status mean concentration of 0.065.

At discharge rates of 2, 3, 4 and 4 litres/s (173, 289, 346, and 432 m^3/day) the discharges to surface waters will exceed the assimilative capacity of the river, with respect to ammonia.

Tables 3-4 and 3-5 mass balance calculations predicts that leachate breakouts containing of 2.20 mg/l NH_4 will cause downstream concentrations of ammonia from 0.111 mg/l to 0.279 mg/l for flow rates between 1 and 5 l/s.

3.4.4 Discussion of Results

Overall the assimilative capacity assessment shows that:

- For leachate breakout flows (2 to 5 l/s) the downstream surface water assimilative capacity will be unable to accommodate leachate breakouts containing up to 2.2 mg/l NH_4 for 'Good' status mean flows and 'Good; status 95%-ile flows.
- For a low leachate breakout flow rates (1 l/s) the downstream surface water assimilative capacity will be able to accommodate leachate breakouts containing up to 2.2 mg/l NH_4 for only the 'Good' status 95%-ile flows.

On the basis of visual site observations, the leachate breakout flow rates were estimated to exceed 1 l/s.

Accordingly, remedial measures will be required to mitigate the risk of leachate breakout contaminating receiving surface waters.

3.5 Landfill Gas Assessment – LandGEM

LandGEM is an excel based screening model developed by the US EPA for estimating the quantity of landfill gases generated during both the operational phase of a landfill and post-closure of the landfill. The model applies a first-order decomposition rate equation to estimate the quantity of landfill gases being produced from decomposing waste present in a landfill.

The model relies on a limited number of inputs, some of which are supplied within the model as a variety of default values and site-specific information provided by the user. A summary of the model inputs used for this Tier 3 assessment are presented in Table 3-7.

The results of this model are provided to assist future remedial measures or control measures as may be required to facilitate management of landfill gas.

Monitoring for landfill gas emitted from offsite wells BH01 and BH02 was conducted in October 2019 as part of the Tier 2 site investigation. Methane concentrations of 0.2% v/v and 0.5% v/v, and carbon dioxide concentrations of 0.1% v/v and 0.3%v/v were detected at BH01 and BH02 respectively. In accordance with the EPA CoP the trigger level for methane outside the waste body is 1.0% v/v for methane and 1.5% v/v for carbon dioxide.

Table 3-6: Well Gas Monitoring Results October 2019

Date: 23-10-2019						
Sample Station	CH_4	CO_2	O_2	Atmospheric Pressure	Staff Member	Weather
	(% v/v)	(% v/v)	(% v/v)	(mbar)		
BH01	0.2	0.1	21.3	1005	Emily Archer	Overcast, heavy rain, showers, 12°C
BH02	0.5	0.3	21.6			

Table 3-7: LandGEM Model Inputs

Landfill Characteristics	Input	Source
Landfill Open Year	1975	Exact timeframe of landfill operation is unknown. Assumed site to be operational through the 1970s. Start of filling operations assumed.
Landfill Closure Year	1990	Anecdotal evidence suggests landfilling activities ceased c.1980
Have Model Closure Calculate Closure Year	Yes	
Waste Design Capacity (megagrams/tonnes)	88,550	Mass based on estimated waste volume determined as part of Tier 2 assessment and site investigation.
Determining Model Parameters		
Methane Generation Rate, k (year^{-1})	CAA Conventional – 0.05	Default value – maximum values applied as a conservative worst-case scenario approach
Potential Methane Generation Capacity, L_0 (m^3/Mg)	CAA Conventional – 1070	
NMOC Concentration (ppmv as hexane)	CAA – 4,000	
Methane Content (% by volume)	CAA – 50% by volume	

Select Gases/pollutants		
Gas/Pollutant #1	Total Landfill Gas	Standard – No other specific gases of concern
Gas/Pollutant #2	Methane	
Gas/Pollutant #3	Carbon Dioxide	
Gas/Pollutant #4	NMOC	
Enter Waste Acceptance Rates (Mg/year)		
1970 - 1980	5,903	Exact waste acceptance quantities per year are unknown. Worst case assumed waste design capacity was filled equally over 1975 to 1990 (15 year) period

3.5.1 Results - LandGEM

As an output, LandGEM produces a report on the model inputs and outputs. This report is included in Appendix 3 of this report. LandGEM estimates the mass and volume of landfill gases generated both during the operational/filling phase of the landfill and beyond. The estimated quantity of gas generated for the current year (2019) and after 10 years of further +degradation (2029) are presented in Table 3-8.

The model predicted that the site is currently generating 14.215 m^3/hr of methane across the entire site area. This will reduce to 8.622 m^3/hr by 2029.

Table 3-8: Estimated landfill Gases Generated (2019 and 2029)

Gas/Pollutant	Tonnes/year		m^3/year		tonnes/hour		m^3/hour	
	2019	2029	2019	2029	2019	2029	2019	2029
Total Landfill Gas	311	188.639	249,045	151,054	0.036	0.022	28.430	17.244
Methane	83	50.388	124,523	75,527	0.009	0.006	14.215	8.622
Carbon dioxide	228	138.252	124,523	75,527	0.026	0.016	14.215	8.622
NMOC	4	2.166	996	604	0.000	0.000	0.114	0.069

The approximate maximum waste deposition footprint was estimated to be approximately 23,000 m^2. The estimated volume and mass of landfill gas generated and potentially released per m^2 of the total landfill area are presented in Table 3-9.

Table 3-9: Estimated gases generated/released per m^2 (2019)

Gas/Pollutant	Tonnes/year/m^2	m^3/year/m^2	tonnes/hour/m^2	m^3/hour/m^2
Total Landfill Gas	0.014	6.568	10.828	6.568
Methane	0.004	3.284	5.414	3.284
Carbon dioxide	0.010	3.284	5.414	3.284
NMOC	0.000	0.026	0.043	0.026

3.5.2 Discussion of Results

The outcome of the LandGEM model predicts a low rate of landfill gas generation in 2019 of 249,045 m^3/year (28.43 m^3/hr).

The EPA guidance document, 'Management of Low Levels of Landfill Gas' prepared by Golder Associates Ireland Ltd outlines readily available flaring technologies that meet EPA requirements on temperature and retention specifications. These technologies generally require gas flow rates ranging from 40 m^3/hr to greater than 2,500 m^3/hr with methane contents ranging from 10 to 50+ percent. The lowest methane content referring to Low-CV (Calorific value) flare technology.

As shown in Table 3-8 LandGEM estimated that in the current year (2019) a relatively low quantity, of 28.43 m^3/hour of landfill gas across the whole site is generated and assuming 50% percent of that volume being methane (14.215m^3). Landfill gas monitoring of groundwater wells conducted in 2019 yielded only trace amounts of methane present. The LandGEM model suggests that at the estimated quantity of waste deposited at the site that methane production is still occurring in low quantities and will continue for a number of years.

Figure 3-2 below shows the estimated landfill gas generation rates per year during the assumed operational phase (c.1975 to 1990) and predicted generation rates from 1990 onwards following closure of the site. Note that the model assumes equal production rates for both methane and carbon dioxide and are represented by the pink trendline because the blue line is below the pink line.

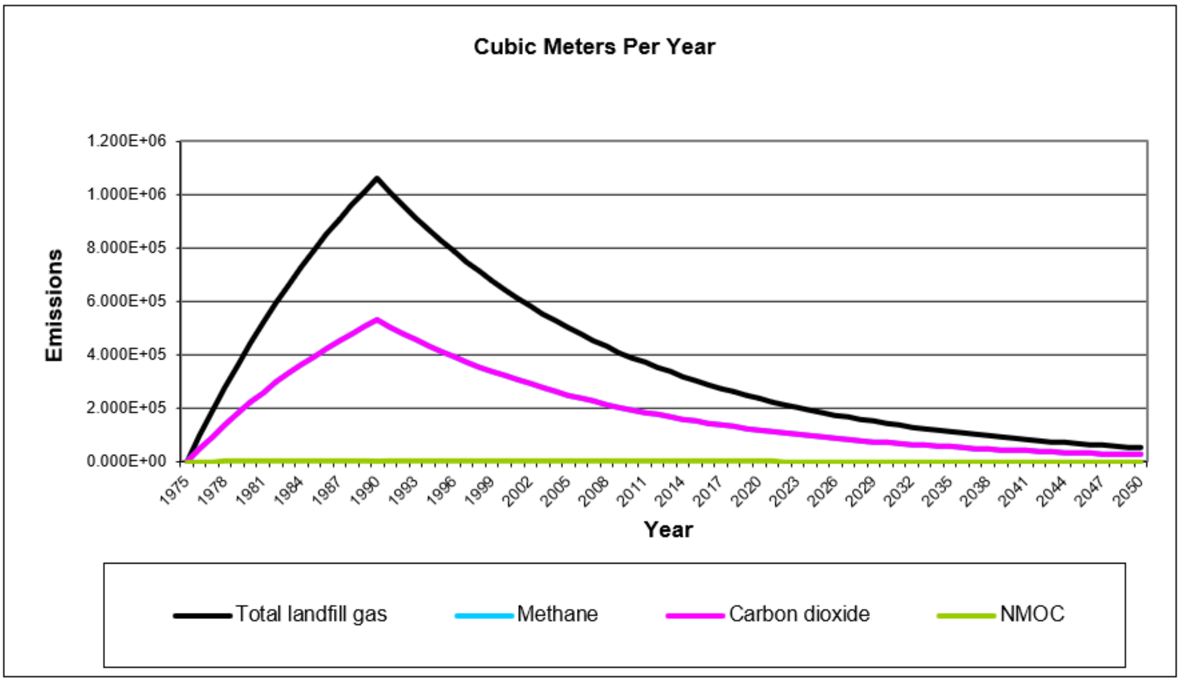


Figure 3-2: LandGEM Landfill Gas Volume Generation Rate

The complete summary report on model inputs and outputs/results generated by LandGEM is included in Appendix 3 of this report.

4. SUMMARY FINDINGS AND RECOMMENDATIONS

In summary, the Tier 3 environmental risk assessment has determined the need for remedial works.

The Tier 3 assessment:

- Reviewed the findings of the Tier 1 risk assessment (determined the site to be of moderate risk (Class B 2013) and a high risk (Class A 2007)).
- Reviewed the findings of the Tier 2 site investigation and risk assessment (determined the site to be of high risk (Class A)).
- Assessed and determined the overall risk the site may pose to the receiving environment.
- Determine appropriate measures, if required, to mitigate or eliminate that risk.

4.1.1 Groundwater

The UK EA Remedial Targets Worksheet model was used to examine the potential impacts on aquifer/groundwater quality. The model did show potential exceedances on the groundwater quality threshold for select parameters. The model does not calculate concentrations based on a depleting source and results are conservative. However, it is clear that unless remedial works are carried out there may be contamination local (within 500 m of the site) for in excess of 100 years.

The potential contribution of groundwater and leachate to the aquifer was also estimated. Based on the estimated recharge values for the site it is expected that the site following rainfall, which after infiltrating into the waste body will result in low volumes of leachate discharging to the underlying aquifer unless remedial works are carried out.

4.1.2 Surface Water

Assimilative capacity assessment and mass balance calculations indicate that potential breakouts of leachate and discharge to the adjacent river may have an impact on water quality downstream of the site. Analysis shows the receiving waterbody is likely to have an assimilative capacity able to accommodate potential leachate emissions at the site at a discharge rate of 1 litre/sec, with respect to ammonia. A mass balance calculation predicted that 1 l/s of ammonia would increase background concentration of 0.065 mg/l by 0.046 mg/l ammonia from a to 0.111 mg/l downstream. At an ammonia concentration of 0.111 mg/l, river quality remains below the ‘good’ status 95%-ile threshold value of 0.140 mg/l for ammonia, as per the *European Union Environmental Objectives (Surface Waters) (Amendment) Regulations 2019 - S.I No. 77/2019.*

Although, the DQRA demonstrates that the potential risk to the underlying groundwater and subsequently surface water from leachate and groundwater migration from the site is very low to negligible, mitigation is still recommended. Mitigation measures are proposed to reduce or eliminate any risk to the regionally important aquifer underlying the site and potential sensitive surface water receptors from the historical site.

4.1.3 Landfill Gas

The output from LandGEM showed that landfill gas will continue to be generated for several years although in minimal quantities.

Although gas monitoring did not indicate the presence of gas at that time and the calculated the risk from landfill gas is relatively low, taking into the account the relative proximity of the site to an existing residential unit, it is recommended that landfill gas control measures should be installed at the site to further minimise the risk of landfill gas migration. Appropriate control measures shall be selected in accordance with the EPA Guidance document: *Management of Low Levels of Landfill Gas. Appropriate measures are* discussed in Section 5.

5. REMEDIAL ACTION PLAN

5.1 Overview of the Risks

5.1.1 Tier 3 Summary Findings

The existing site has a basic soil cap with an established grass cover used by cattle for grazing, this activity is expected to continue post-remediation. Site walkovers and Tier 2 and 3 risk assessment showed:

- Evidence of in-situ mixed and primarily municipal solid wastes.
- Evidence of leachate breakouts.
- Evidence of low-level landfill gas emissions.
- Assessment that leachate has potential to contaminate receiving surface and ground waters.
- An in-situ landfill cap that is not compliant with either the Landfill Directive or Environmental Protection Agency (EPA) publication landfill manual - Landfill Site Design.
- Proximity to buildings.

The proposed engineering solution to address these issues shall:

- Require an engineered cap over the in-situ cap using guidance presented in the EPA Landfill Design Manual Guidance for Non-hazardous Landfills.
- Be cognisant of the future site use and proposed adjacent developments.

The preliminary remediation design footprint with a typical indicative cross section is presented in Appendix 4 on drawing:

- P1766-0101-0003

5.1.2 Objectives of the Proposed Remediation Plan

Based on the findings of the modelling exercises and quantitative risk assessment the following measures are proposed to mitigate the identified risks to receiving ground and surface waters.

- Isolate the waste body from:
  - Rainfall inputs, and
  - groundwater flows.
- Facilitate passive venting of landfill gas through the proposed cap via a controlled outlet.

Engineering solutions will need to consider:

- Outlet for surface drainage runoff.
- Outlet for above liner sub surface drainage outfall.
- Appropriate grassed water way subsurface drainage measures to manage surface water runoff.
- Management of below liner leachate that may be released in the short-term following secondary consolidation.
- Oxidation using biological filter or similar approved if required and or safe passive venting of potentially explosive landfill gas emissions.

5.1.3 Engineered Cap

The engineered cap shall comprise:

- 200 mm topsoil, on
- 800 mm subsoil, on
- Subsurface drainage geocomposite and collection pipework or similar, on
- 1mm LLDPE, on
- Gas collection geocomposite and collection pipework or similar, on
- Waste.

Key design criteria recommendations for respective elements are listed below under respective section headings.

5.1.4 Topsoil

Topsoil 200 mm shall be placed on top of the subsoil. Topsoil shall be seeded with a robust pasture or similar durable grassland mix.

Topsoil shall be compliant to BS3882:2015 or equal approved and graded to ensure no localized surface depressions are present.

5.1.5 Subsoil

Infill subsoil materials will be required to re-profile the landfill to fill in localised depressions.

Subsoil 800 mm thick shall be provided using a uniformly graded material with stone sizes not greater that 50 mm or equal approved.

5.1.6 Subsurface drainage on cap

A subsurface drainage layer on the cap barrier (hydraulic conductivity should be equal to or greater than $1x10^{-4}$ m/s for a thickness of 500 mm) or equal approved geocomposite shall be placed between the subsoil and barrier layer.

The drainage layer shall discharge to a subsurface pipe work collection system and thence to the surface drainage system.

5.1.7 Surface drainage

Surface drainage layouts using grassed waterways shall collect and direct surface water runoff including subsurface drainage outfall flows to one or more dedicated surface drainage outfalls into existing surface water perimeter drain(s).

Surface drainage shall be designed to mitigate the risk of rill or gully erosion giving rise to suspended solids loading exceeding of 25 mg/l on the cap and within receiving waters.

5.1.8 Barrier System

The barrier system shall use 1.0 mm LLDPE or similar approved.

This barrier will require vertical cut-offs on all boundaries to mitigate the risk of landfill gas migration and leachate egress following secondary consolidation.

5.1.9 Landfill gas management

The landfill gas collection system shall comprise an under-liner gas collection geocomposite or similar approved stone drainage later. The Landfill Directive does not define a thickness or permeability. The EPA Landfill Site Design manual advises equivalence should not be less than a 150 mm stone layer with a hydraulic permeability of $1x10^{-4}$m/s.

The gas collection layer shall make provision for:

- Passive venting of landfill above the liner with methane oxidation if required.
- Management of below liner leachate breakouts or condensate using gravel soakaways or similar approved.

Gas management proposals shall:

- Mitigate environmental pollution in accordance with best practice.
- Mitigate risks of asphyxiation and explosion.
- Carry out a gas management risk assessment.
- Review and update as required the gas prediction model estimates in this report to inform the most appropriate landfill gas oxidation solution or venting as may be required.

Gas wells/vent stacks if required shall terminate at least 3.0 m above adjacent ground surfaces and be capped to prevent rainfall ingress and insertion of ignition sources (cigarettes or other).

Biological filters if used shall be fenced and isolated from pedestrian, vehicular or animal activities.

Existing wells on site shall be capped and retained for future monitoring as may be required.

5.1.10 Proposed Groundwater and Surface Water Monitoring Regime

The EPA Landfill Monitoring landfill manual outlines recommended, minimum monitoring requirements for ground and surface waters. These parameters are shown in Table 5-1 below and are as presented in Table C.2 of the EPA's *Landfill Manuals - Landfill Monitoring, 2nd Edition (2003).*

Groundwater monitoring shall be carried out at existing perimeter wells BH1 and BH2 and surface water monitoring shall be carried out at the proposed surface water discharge outfall in the north west corner of the site annually in accordance parameters listed in Table 5-1.

Table 5-1: Parameters for Monitoring of Groundwater and Surface Water

Monitoring Parameter[1]	Frequency	Surface Water	Groundwater
Fluid Level	Annual	-	-
Flow Rate		-	-
Temperature		✓	✓
Dissolved Oxygen		✓	-
pH		✓	✓
Electrical Conductivity[2]		✓	✓
Total suspended solids		✓	-
Total dissolved solids		-	✓
Ammonia (as N)		✓	✓
Total oxidized nitrogen (as N)		✓	✓
Total organic carbon		-	✓
Biochemical Oxygen Demand		✓	-
Chemical Oxygen Demand		✓	-
Metals[3]		✓	✓
Total Alkalinity (as $CaCO_3$)		✓	✓

[1] Tables D.1 and D.2 of the EPA Landfill Monitoring manual recommend guideline minimum reporting values for parameters

[2] Where saline influences are suspected, a salinity measurement should also be taken

[3] Metals for analysis should include: calcium, magnesium, sodium, potassium, iron, manganese, cadmium, chromium (total), copper, nickel, lead, zinc, arsenic, boron and mercury.

Monitoring Parameter[1]	Frequency	Surface Water	Groundwater
Sulphate		✓	✓
Chloride		✓	✓
Molybdate Reactive Phosphorous[4]		✓	✓
Cyanide (Total)		✓	✓
Fluoride		✓	✓

5.1.11 Proposed Gas Monitoring Regime

Gas monitoring shall be carried out at existing site boreholes (6 No.) and at any future oxidation or venting outlet.

It is recommended that:

- Gas monitoring be carried out annually.
- Vertical gas monitoring wells be allowed to vent passively throughout the year.
- Prior to annual monitoring, well vents should be closed for a period of 24 hours to allow representative sampling.

Gas sampling should be carried out using a calibrated gas analyser for the following parameters:

- Methane
- Carbon dioxide
- Oxygen
- Carbon monoxide
- Temperature

5.2 Remediation Cost Estimates

The following section outlines the potential costs associated with the remediation of the site. The costs estimate is limited to "once-off" civil and mechanical and electrical works.

Long term costs associated with maintenance, license compliance and environmental liabilities are not considered.

Table 5.2 outlines the costs associated with capping the site:

[4] Total Phosphorus should be measured in leachate samples where colorimetric interference is likely.

Table 5-2: Engineers Estimate for Ahascra Historic Remediation

Item	Quantity	Unit	Rate, €	Cost
Design				
Allowance for Additional Site Investigation works	1	Rate	€25,000.00	€25,000.00
Detailed Design and Supervision	1	Rate	€40,000.00	€40,000.00
Land Rental Costs	1	Rate	€5,000.00	€5,000.00
General Site Clearance and Demolition Works	***2.3***	***ha***		
General Site Clearance	2.3	ha	€20,000.00	€46,000.00
Excavation Works	23000	m^2		
Excavation of Existing Cover/Capping for Reuse/Filling	11500	m^3	€15.00	€172,500.00
Landfill Capping Works	23000			
Preparation of Excavated Surfaces	23000	m^2	€0.75	€17,250.00
Supply and Installation of 50mm Protection Layer	23000	m^2	€1.75	€40,250.00
Supply and Installation of Landfill Gas Collection Layer	23000	m^2	€5.50	€126,502.50
Installation of 1mm LLDPE Cap	23000	m^2	€6.50	€149,500.00
Installation of Sub Surface drainage collection Layer	23000	m^2	€5.50	€126,500.00
Surface drainage	23000	m^2	€1.00	€23,000.00
Geogrid in soft spots	5750	m^2	€5.00	€28,750.00
Importation of infill grading material	15000	m^2	€0.50	€7,500.00
Importation of 800mm Subsoil Capping Layer	23000	m^2	€8.50	€195,500.00
Importation of 200mm Topsoil Capping Layer	23000	m^2	€3.00	€69,000.00
Seeding	23000	m^2	€2.00	€46,000.00
Fencing	607	m2	€100.00	€60,663.00
Allowance Landfill Gas Migration Network Infrastructure	5000	m^2	€3.00	€15,000.00
Allowance surface Water Drainage Infrastructure	23000	m^2	€4.00	€92,000.00
Biological filter	1	Item	€10,000.00	€10,000.00
Independent CQA	1	Sum	€5,000.00	€5,000.00
Landfill Gas Pumping Trial				
Mobilisation	1	Sum	€3,500.00	€3,500.00

Item	Quantity	Unit	Rate, €	Cost
Landfill Gas Well ex. M&E, inc. piping and backfill	2	No.	€4,000.00	€8,000.00
Landfill Gas Well Heads	3	No.	€500.00	€1,500.00
Supporting Infrastructure	1	Sum	€5,000.00	€5,000.00
Design, Supervision and Interpretation	1	Sum	€10,000.00	€10,000.00
Sub-Total 1				**€1,328,915.50**
Add 10% Contractor Prelims	10.0%			€132,891.55
Sub-Total 2				**€1,461,807.05**
Add 7.5% Contingency	7.5%			€109,635.53
Grand Total (excl VAT)				**€1,571,442.58**

FT in making this Engineers Estimate advises the following:

- FT used rates over the period 2018 to 2019 for similar tendered works items where possible and has used engineering judgement to estimate rates & sums where similar rates were not available.
- Management of hazardous materials was not allowed for.
- Pricing was based on a concept design, no detailed designs were prepared.
- The cost estimate assumes that materials to be imported are readily available from local sources.
- The cost estimate excludes VAT.
- The cost estimate excludes in/deflation.
- The estimate includes for a level of contingency as indicated.
- Prices may change subject to prevailing market conditions.

FEHILY TIMONEY

CONSULTANTS IN ENGINEERING, ENVIRONMENTAL SCIENCE & PLANNING

APPENDIX 1

EA UK Remedial Targets Worksheet

R&D Publication 20 Remedial Targets Worksheet, Release 3.2

Level 3 - Groundwater

See Note

Input Parameters (using pull down menu)

	Variable	Value	Unit	Source
Contaminant		Ammoniacal Nitrogen		from Level 1
Target Concentration	C_T	1.75E-01	mg/l	from Level 1

Select analytical solution (click on brown cell below, then on pull-down menu)

Domenico - Time Variant — Equations in HRA publication

Approach for simulating vertical dispersion: Simulate vertical dispersion in 1 direction

Select nature of decay rate (click on brown cell below, then on pull-down menu)

Approach for simulating degradation of pollutants: Apply degradation rate to pollutants in all phases (e.g. field derived valu

	Variable	Value	Unit	Source of parameter value
Initial contaminant concentration in groundwater at plume core	C_0	4.37E+00	mg/l	*Minimum ammoniacal N concentration as per UK leachate inventory (old landfill)*
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+09	days	*Assumed high value (no degradation)*
Calculated decay rate	λ	6.93E-10	$days^{-1}$	
Width of plume in aquifer at source (perpendicular to flow)	Sz	9.00E+01	m	*Approximate width of site/waste extent based on site investigation*
Plume thickness at source	Sy	4.00E+00	m	*Assumed thickness - assuming plume migration occuring in upper limestone*
Saturated aquifer thickness	da	5.00E+00	m	*Assumed thickness of upper karst limestoı*
Bulk density of aquifer materials	ρ	1.55E+00	g/cm^3	*Assumed limestone bulk density*
Effective porosity of aquifer	n	2.75E-01	fraction	*median of assumed assumed porosity applied in LandSim (0.05-0.5)*
Hydraulic gradient	i	4.00E-03	fraction	*Calculated hydraulic gradient between BH01 and BH02*
Hydraulic conductivity of aquifer	K	8.64E+00	m/d	*Assumed single conductivity based on on*
Distance to compliance point	x	5.00E+02	m	*Hypothetical compliance point at 500m*
Distance (lateral) to compliance point perpendicular to flow direction	z	[redacted]	m	
Distance (depth) to compliance point perpendicular to flow direction	y		m	
Time since pollutant entered groundwater	t	3.65E+05	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	1.25E+00	l/kg	*see options*
Longitudinal dispersivity	ax	5.00E+01	m	*see options*
Transverse dispersivity	az	5.00E+00	m	*see options*
Vertical dispersivity	ay	5.00E-01	m	*see options*

Calculated Parameters

	Variable		
Groundwater flow velocity	v	1.26E-01	m/d
Retardation factor	Rf	8.05E+00	fraction
Decay rate used	λ	6.93E-10	d^{-1}
Rate of contaminant flow due to retardation	u	1.56E-02	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	2.95E-01	mg/l
Attenuation factor (one way vertical dispersion, C0/CED)	**AF**	**1.48E+01**	

Remedial Targets

Remedial Target	**2.59E+00**	**mg/l**	For comparison with measured groundwater concentration.
Domenico - Time Variant			
Distance to compliance point	**500**	**m**	
Concentration of contaminant at compliance point (C_{ED}/C_0)	**2.95E-01**	**mg/l**	Domenico - Time Variant
after	**3.7E+05**	**days**	

Care should be used when calculating remedial targets using the time variant options as this may result in an overestimate of the remedial target.
The recommended value for time when calculating the remedial target is 9.9E+99.

Select Method for deriving Partition Co-efficient (using pull down menu)

User specified value for partition coefficient

Entry if specify partition coefficient (option)

Soil water partition coefficient	Kd	1.25E+00	l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	[redacted]	fraction
Organic carbon partition coefficient	Koc		l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$	[redacted]	l/kg
Sorption coefficient for ionised species	$K_{oc,i}$		l/kg
pH value	pH		
acid dissociation constant	pKa		
Fraction of organic carbon in aquifer	foc		fraction
Soil water partition coefficient	Kd	1.25E+00	l/kg

Define dispersivity (click brown cell and use pull down list)

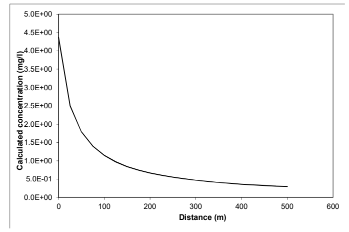
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	m
Longitudinal dispersivity	**ax**	0.00E+00	5.00E+01	9.12E+00	m
Transverse dispersivity	**az**	0.00E+00	5.00E+00	9.12E-01	m
Vertical dispersivity	**ay**	0.00E+00	5.00E-01	9.12E-02	

Note values of dispersivity must be > 0

For calculated value, assumes ax = 0.1 *x, az = 0.01 * x, ay = 0.001 * x

Xu & Eckstein (1995) report $ax = 0.83(\log_{10}x)^{2.414}$; az = ax/10, ay = ax/100 are assumed



Note graph assumes plume disperses vertically in one direction only. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

Note

This sheet calculates the Level 3 remedial target for groundwater, based on the distance to the receptor or compliance located down hydraulic gradient of the source. Three solution methods are included, the preferred option is Ogata Banks.

By setting a long travel time it will give the steady state solution, which should be used to calculate remedial targets.

The measured groundwater concentration should be compared with the Level 3 remedial target to determine the need for further action.

Note if contaminant is not subject to first order degradation, then set half life as 9.0E+99.

This worksheet should be used if pollutant transport and degradation is best described by a first order reaction. If degradation is best desribed by an electron limited degradation such as oxidation by O2, NO3, SO4 etc than an alternative solution should be used

Site being assessed:	Ahascra
Completed by:	EOC
Date:	########
Version:	1.01

Calculated concentrations for distance-concentration graph

Domenico - Time Variant
From calculation sheet

Distance	Concentration (mg/l)
0	4.4E+00
25.0	2.51E+00
50.0	1.79E+00
75.0	1.40E+00
100.0	1.15E+00
125.0	9.73E-01
150.0	8.44E-01
175.0	7.46E-01
200.0	6.67E-01
225.0	6.04E-01
250.0	5.51E-01
275.0	5.07E-01
300.0	4.70E-01
325.0	4.37E-01
350.0	4.09E-01
375.0	3.84E-01
400.0	3.62E-01
425.0	3.43E-01
450.0	3.25E-01
475.0	3.09E-01
500.0	2.95E-01

FEHILY TIMONEY

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APPENDIX 2

Assimilative Capacity Assessment

Assimilative capacity = (Cmax – Cback) x F95 x 86.4 kg/day								**Ammonia**
Where:								
C_{max} = maximum permissible concentration (EQS – 95%ile value) (mg/l)								0.14
C_{back} = background upstream concentration (mg/l mean value)								0.065
F95 = the 95%ile flow in the river (m^3/s)								0.045
Note: (60x60x24)/1000 = 86.4								
AC kg/d	=	**(Cmax**	-	**Cbak)**	x	**F95**	x	**86.4**
	=	0.14	-	0.065	x	0.045	x	86.4
	=		0.075		x	0.045	x	86.4
AC kg/d	=	**0.29 kg/day**						

Emission Concentration (mg/l) 2.2

Flow (m3/day)	Daily Mass Emission (kg/day)	%-age of AC
86.4	0.190	65%
172.8	0.380	130%
259.2	0.570	196%
345.6	0.760	261%
432	0.950	326%

Mass balance Equation:

$$T = \frac{FC + fc}{F + f}$$

$$f(m^3/sec) = \frac{f\left(\frac{m^3}{day}\right) \div 24hours}{3600\ seconds}$$

F =	0.045	m^3/sec
C =	0.065	mg/l
f =	86.4	m^3/day
	0.005	m^3/sec
c =	2.200	mg/l

where:

- F is the river flow upstream of the discharge (95%ile flow m^3/sec);
- C is the concentration of pollutant in the river upstream of the discharge (mean concentration in mg/l);
- f is the flow of the discharge (m^3/sec);
- c is the maximum concentration of pollutant in the discharge (mg/l);
- T is the concentration of pollutant downstream of the discharge.

$$T = \frac{F \times C + f \times c}{F + f}$$

1 $$\frac{0.045 \times 0.065 + 0.005 \times 2.200}{0.045 + 0.005}$$

2 $$\frac{0.002925 + 0.011}{0.0500}$$

3 $$\frac{0.014}{0.050}$$

4 **T = 0.279 mg/l**

EQS (mg/l)	
0.14	*Good' Status 95%-ile EQS*
0.065	*Good' Status mean EQS*

FEHILY TIMONEY

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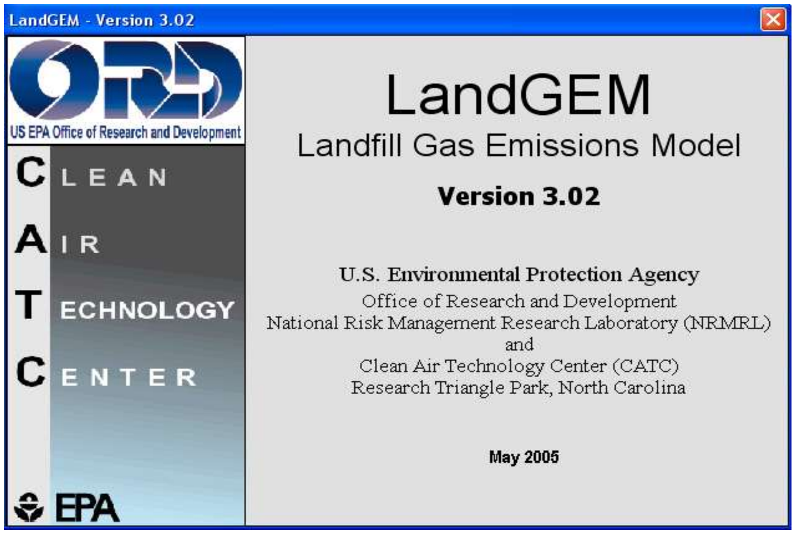
APPENDIX 3

LandGEM Summary Report



Summary Report

Landfill Name or Identifier: Ahascra Historical Landfill - Co.Kerry

Date: Monday 2 March 2020

Description/Comments:

About LandGEM:

First-Order Decomposition Rate Equation:

$$Q_{CH_4} = \sum_{i=1}^{n} \sum_{j=0.1}^{1} kL_o \left(\frac{M_i}{10} \right) e^{-kt_{ij}}$$

Where,

Q_{CH4} = annual methane generation in the year of the calculation *(m^3/year)*
i = 1-year time increment
n = (year of the calculation) - (initial year of waste acceptance)
j = 0.1-year time increment
k = methane generation rate *($year^{-1}$)*
L_o = potential methane generation capacity (*m^3/Mg*)

M_i = mass of waste accepted in the i^{th} year (*Mg*)
t_{ij} = age of the j^{th} section of waste mass M_i accepted in the i^{th} year (*decimal years*, e.g., 3.2 years)

LandGEM is based on a first-order decomposition rate equation for quantifying emissions from the decomposition of landfilled waste in municipal solid waste (MSW) landfills. The software provides a relatively simple approach to estimating landfill gas emissions. Model defaults are based on empirical data from U.S. landfills. Field test data can also be used in place of model defaults when available. Further guidance on EPA test methods, Clean Air Act (CAA) regulations, and other guidance regarding landfill gas emissions and control technology requirements can be found at http://www.epa.gov/ttnatw01/landfill/landflpg.html.

LandGEM is considered a screening tool — the better the input data, the better the estimates. Often, there are limitations with the available data regarding waste quantity and composition, variation in design and operating practices over time, and changes occurring over time that impact the emissions potential. Changes to landfill operation, such as operating under wet conditions through leachate recirculation or other liquid additions, will result in generating more gas at a faster rate. Defaults for estimating emissions for this type of operation are being developed to include in LandGEM along with defaults for convential landfills (no leachate or liquid additions) for developing emission inventories and determining CAA applicability. Refer to the Web site identified above for future updates.

Input Review

LANDFILL CHARACTERISTICS

Landfill Open Year	**1975**	
Landfill Closure Year (with 80-year limit)	**1990**	
Actual Closure Year (without limit)	***1990***	
Have Model Calculate Closure Year?	**Yes**	
Waste Design Capacity	**88,550**	*megagrams*

MODEL PARAMETERS

Methane Generation Rate, k	**0.050**	*$year^{-1}$*
Potential Methane Generation Capacity, L_o	**170**	*m^3/Mg*
NMOC Concentration	**4,000**	*ppmv as hexane*
Methane Content	**50**	*% by volume*

GASES / POLLUTANTS SELECTED

Gas / Pollutant #1:	**Total landfill gas**
Gas / Pollutant #2:	**Methane**
Gas / Pollutant #3:	**Carbon dioxide**
Gas / Pollutant #4:	**NMOC**

WASTE ACCEPTANCE RATES

Year	Waste Accepted		Waste-In-Place	
	(Mg/year)	*(short tons/year)*	*(Mg)*	*(short tons)*
1975	5,903	6,493	0	0
1976	5,903	6,493	5,903	6,493
1977	5,903	6,493	11,806	12,987
1978	5,903	6,493	17,709	19,480
1979	5,903	6,493	23,612	25,973
1980	5,903	6,493	29,515	32,467
1981	5,903	6,493	35,418	38,960
1982	5,903	6,493	41,321	45,453
1983	5,903	6,493	47,224	51,946
1984	5,903	6,493	53,127	58,440
1985	5,903	6,493	59,030	64,933
1986	5,903	6,493	64,933	71,426
1987	5,903	6,493	70,836	77,920
1988	5,903	6,493	76,739	84,413
1989	5,903	6,493	82,642	90,906
1990	5	6	88,545	97,400
1991	0	0	88,550	97,405
1992	0	0	88,550	97,405
1993	0	0	88,550	97,405
1994	0	0	88,550	97,405
1995	0	0	88,550	97,405
1996	0	0	88,550	97,405
1997	0	0	88,550	97,405
1998	0	0	88,550	97,405
1999	0	0	88,550	97,405
2000	0	0	88,550	97,405
2001	0	0	88,550	97,405
2002	0	0	88,550	97,405
2003	0	0	88,550	97,405
2004	0	0	88,550	97,405
2005	0	0	88,550	97,405
2006	0	0	88,550	97,405
2007	0	0	88,550	97,405
2008	0	0	88,550	97,405
2009	0	0	88,550	97,405
2010	0	0	88,550	97,405
2011	0	0	88,550	97,405
2012	0	0	88,550	97,405
2013	0	0	88,550	97,405
2014	0	0	88,550	97,405

WASTE ACCEPTANCE RATES (Continued)

Year	Waste Accepted		Waste-In-Place	
	(Mg/year)	(short tons/year)	(Mg)	(short tons)
2015	0	0	88,550	97,405
2016	0	0	88,550	97,405
2017	0	0	88,550	97,405
2018	0	0	88,550	97,405
2019	0	0	88,550	97,405
2020	0	0	88,550	97,405
2021	0	0	88,550	97,405
2022	0	0	88,550	97,405
2023	0	0	88,550	97,405
2024	0	0	88,550	97,405
2025	0	0	88,550	97,405
2026	0	0	88,550	97,405
2027	0	0	88,550	97,405
2028	0	0	88,550	97,405
2029	0	0	88,550	97,405
2030	0	0	88,550	97,405
2031	0	0	88,550	97,405
2032	0	0	88,550	97,405
2033	0	0	88,550	97,405
2034	0	0	88,550	97,405
2035	0	0	88,550	97,405
2036	0	0	88,550	97,405
2037	0	0	88,550	97,405
2038	0	0	88,550	97,405
2039	0	0	88,550	97,405
2040	0	0	88,550	97,405
2041	0	0	88,550	97,405
2042	0	0	88,550	97,405
2043	0	0	88,550	97,405
2044	0	0	88,550	97,405
2045	0	0	88,550	97,405
2046	0	0	88,550	97,405
2047	0	0	88,550	97,405
2048	0	0	88,550	97,405
2049	0	0	88,550	97,405
2050	0	0	88,550	97,405
2051	0	0	88,550	97,405
2052	0	0	88,550	97,405
2053	0	0	88,550	97,405
2054	0	0	88,550	97,405

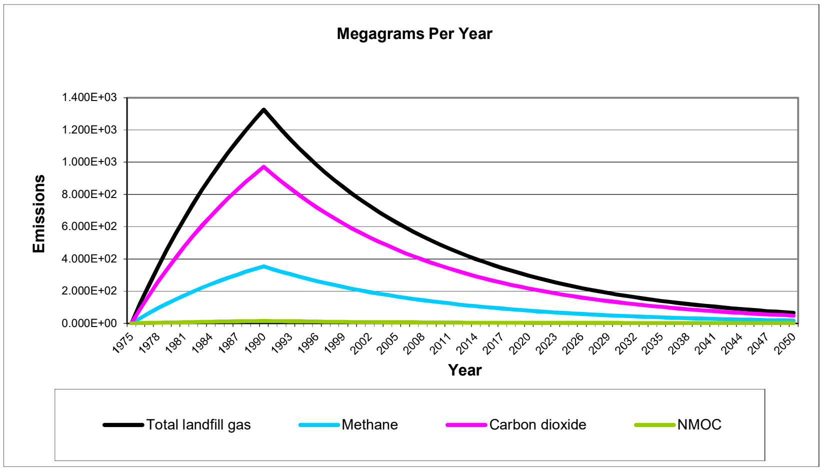
Pollutant Parameters

	Compound	Gas / Pollutant Default Parameters: Concentration (*ppmv*)	Molecular Weight	User-specified Pollutant Parameters: Concentration (*ppmv*)	Molecular Weight
Gases	Total landfill gas		0.00		
	Methane		16.04		
	Carbon dioxide		44.01		
	NMOC	4,000	86.18		
Pollutants	1,1,1-Trichloroethane (methyl chloroform) - HAP	0.48	133.41		
	1,1,2,2-Tetrachloroethane - HAP/VOC	1.1	167.85		
	1,1-Dichloroethane (ethylidene dichloride) - HAP/VOC	2.4	98.97		
	1,1-Dichloroethene (vinylidene chloride) - HAP/VOC	0.20	96.94		
	1,2-Dichloroethane (ethylene dichloride) - HAP/VOC	0.41	98.96		
	1,2-Dichloropropane (propylene dichloride) - HAP/VOC	0.18	112.99		
	2-Propanol (isopropyl alcohol) - VOC	50	60.11		
	Acetone	7.0	58.08		
	Acrylonitrile - HAP/VOC	6.3	53.06		
	Benzene - No or Unknown Co-disposal - HAP/VOC	1.9	78.11		
	Benzene - Co-disposal - HAP/VOC	11	78.11		
	Bromodichloromethane - VOC	3.1	163.83		
	Butane - VOC	5.0	58.12		
	Carbon disulfide - HAP/VOC	0.58	76.13		
	Carbon monoxide	140	28.01		
	Carbon tetrachloride - HAP/VOC	4.0E-03	153.84		
	Carbonyl sulfide - HAP/VOC	0.49	60.07		
	Chlorobenzene - HAP/VOC	0.25	112.56		
	Chlorodifluoromethane	1.3	86.47		
	Chloroethane (ethyl chloride) - HAP/VOC	1.3	64.52		
	Chloroform - HAP/VOC	0.03	119.39		
	Chloromethane - VOC	1.2	50.49		
	Dichlorobenzene - (HAP for para isomer/VOC)	0.21	147		
	Dichlorodifluoromethane	16	120.91		
	Dichlorofluoromethane - VOC	2.6	102.92		
	Dichloromethane (methylene chloride) - HAP	14	84.94		
	Dimethyl sulfide (methyl sulfide) - VOC	7.8	62.13		
	Ethane	890	30.07		
	Ethanol - VOC	27	46.08		

Pollutant Parameters (Continued)

	Compound	Gas / Pollutant Default Parameters: Concentration (*ppmv*)	Molecular Weight	User-specified Pollutant Parameters: Concentration (*ppmv*)	Molecular Weight
Pollutants	Ethyl mercaptan (ethanethiol) - VOC	2.3	62.13		
	Ethylbenzene - HAP/VOC	4.6	106.16		
	Ethylene dibromide - HAP/VOC	1.0E-03	187.88		
	Fluorotrichloromethane - VOC	0.76	137.38		
	Hexane - HAP/VOC	6.6	86.18		
	Hydrogen sulfide	36	34.08		
	Mercury (total) - HAP	2.9E-04	200.61		
	Methyl ethyl ketone - HAP/VOC	7.1	72.11		
	Methyl isobutyl ketone - HAP/VOC	1.9	100.16		
	Methyl mercaptan - VOC	2.5	48.11		
	Pentane - VOC	3.3	72.15		
	Perchloroethylene (tetrachloroethylene) - HAP	3.7	165.83		
	Propane - VOC	11	44.09		
	t-1,2-Dichloroethene - VOC	2.8	96.94		
	Toluene - No or Unknown Co-disposal - HAP/VOC	39	92.13		
	Toluene - Co-disposal - HAP/VOC	170	92.13		
	Trichloroethylene (trichloroethene) - HAP/VOC	2.8	131.40		
	Vinyl chloride - HAP/VOC	7.3	62.50		
	Xylenes - HAP/VOC	12	106.16		

Graphs


Megagrams Per Year
Emissions
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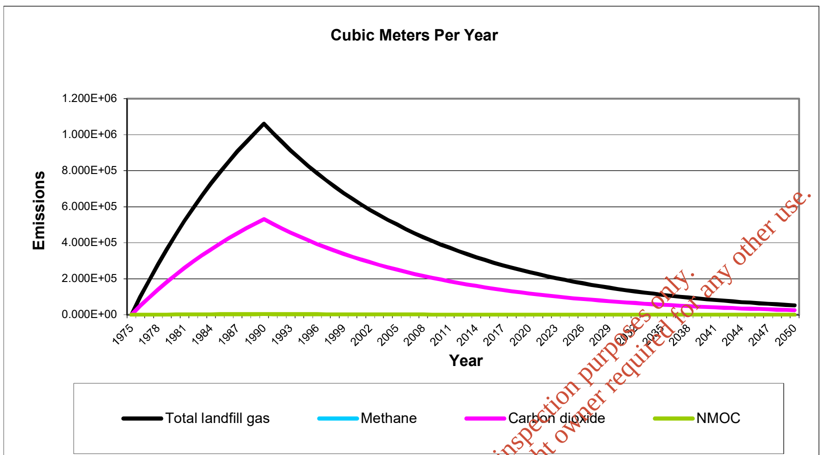
1.200E+03
1.000E+03
8.000E+02
6.000E+02
4.000E+02
2.000E+02
0.000E+00
1975 1978 1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020 2023 2026 2029 2032 2035 2038 2041 2044 2047 2050
Year
Total landfill gas
Methane
Carbon dioxide
NMOC


Cubic Meters Per Year
Emissions
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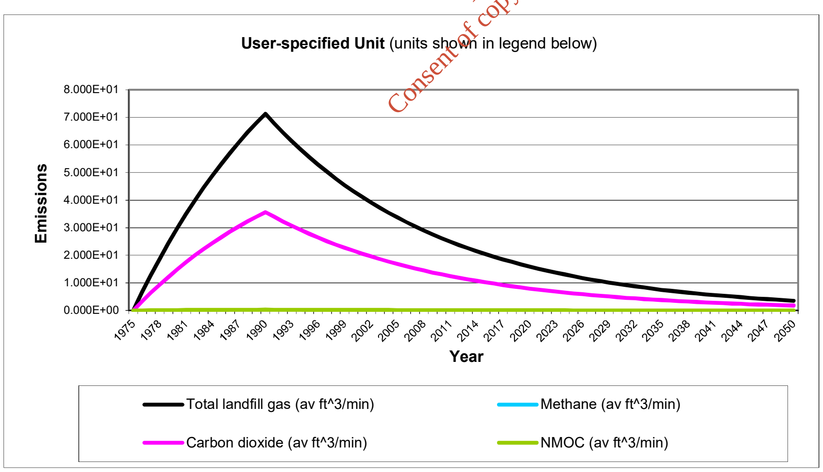
6.000E+05
4.000E+05
2.000E+05
0.000E+00
1975 1978 1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020 2023 2026 2029 2032 2035 2038 2041 2044 2047 2050
Year
Total landfill gas
Methane
Carbon dioxide
NMOC


User-specified Unit (units shown in legend below)
Emissions
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7.000E+01
6.000E+01
5.000E+01
4.000E+01
3.000E+01
2.000E+01
1.000E+01
0.000E+00
1975 1978 1981 1984 1987 1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020 2023 2026 2029 2032 2035 2038 2041 2044 2047 2050
Year
Total landfill gas (av ft^3/min)
Methane (av ft^3/min)
Carbon dioxide (av ft^3/min)
NMOC (av ft^3/min)

Results

Year	Total landfill gas			Methane		
	(Mg/year)	(m^3/year)	(av ft^3/min)	(Mg/year)	(m^3/year)	(av ft^3/min)
1975	0	0	0	0	0	0
1976	1.225E+02	9.813E+04	6.593E+00	3.273E+01	4.906E+04	3.297E+00
1977	2.391E+02	1.915E+05	1.286E+01	6.387E+01	9.574E+04	6.432E+00
1978	3.500E+02	2.803E+05	1.883E+01	9.349E+01	1.401E+05	9.415E+00
1979	4.555E+02	3.647E+05	2.451E+01	1.217E+02	1.824E+05	1.225E+01
1980	5.558E+02	4.451E+05	2.990E+01	1.485E+02	2.225E+05	1.495E+01
1981	6.512E+02	5.215E+05	3.504E+01	1.740E+02	2.607E+05	1.752E+01
1982	7.420E+02	5.942E+05	3.992E+01	1.982E+02	2.971E+05	1.996E+01
1983	8.284E+02	6.633E+05	4.457E+01	2.213E+02	3.317E+05	2.228E+01
1984	9.105E+02	7.291E+05	4.899E+01	2.432E+02	3.646E+05	2.449E+01
1985	9.887E+02	7.917E+05	5.319E+01	2.641E+02	3.958E+05	2.660E+01
1986	1.063E+03	8.512E+05	5.719E+01	2.839E+02	4.256E+05	2.860E+01
1987	1.134E+03	9.078E+05	6.100E+01	3.028E+02	4.539E+05	3.050E+01
1988	1.201E+03	9.617E+05	6.461E+01	3.208E+02	4.808E+05	3.231E+01
1989	1.265E+03	1.013E+06	6.806E+01	3.379E+02	5.064E+05	3.403E+01
1990	1.326E+03	1.062E+06	7.133E+01	3.541E+02	5.308E+05	3.567E+01
1991	1.261E+03	1.010E+06	6.786E+01	3.369E+02	5.050E+05	3.393E+01
1992	1.200E+03	9.607E+05	6.455E+01	3.205E+02	4.803E+05	3.227E+01
1993	1.141E+03	9.138E+05	6.140E+01	3.048E+02	4.569E+05	3.070E+01
1994	1.086E+03	8.693E+05	5.840E+01	2.900E+02	4.346E+05	2.920E+01
1995	1.033E+03	8.269E+05	5.556E+01	2.758E+02	4.134E+05	2.778E+01
1996	9.822E+02	7.865E+05	5.285E+01	2.624E+02	3.933E+05	2.642E+01
1997	9.343E+02	7.482E+05	5.027E+01	2.496E+02	3.741E+05	2.513E+01
1998	8.888E+02	7.117E+05	4.782E+01	2.374E+02	3.558E+05	2.391E+01
1999	8.454E+02	6.770E+05	4.549E+01	2.258E+02	3.385E+05	2.274E+01
2000	8.042E+02	6.440E+05	4.327E+01	2.148E+02	3.220E+05	2.163E+01
2001	7.650E+02	6.126E+05	4.116E+01	2.043E+02	3.063E+05	2.058E+01
2002	7.277E+02	5.827E+05	3.915E+01	1.944E+02	2.913E+05	1.958E+01
2003	6.922E+02	5.543E+05	3.724E+01	1.849E+02	2.771E+05	1.862E+01
2004	6.584E+02	5.272E+05	3.542E+01	1.759E+02	2.636E+05	1.771E+01
2005	6.263E+02	5.015E+05	3.370E+01	1.673E+02	2.508E+05	1.685E+01
2006	5.958E+02	4.771E+05	3.205E+01	1.591E+02	2.385E+05	1.603E+01
2007	5.667E+02	4.538E+05	3.049E+01	1.514E+02	2.269E+05	1.525E+01
2008	5.391E+02	4.317E+05	2.900E+01	1.440E+02	2.158E+05	1.450E+01
2009	5.128E+02	4.106E+05	2.759E+01	1.370E+02	2.053E+05	1.379E+01
2010	4.878E+02	3.906E+05	2.624E+01	1.303E+02	1.953E+05	1.312E+01
2011	4.640E+02	3.715E+05	2.496E+01	1.239E+02	1.858E+05	1.248E+01
2012	4.413E+02	3.534E+05	2.375E+01	1.179E+02	1.767E+05	1.187E+01
2013	4.198E+02	3.362E+05	2.259E+01	1.121E+02	1.681E+05	1.129E+01
2014	3.993E+02	3.198E+05	2.149E+01	1.067E+02	1.599E+05	1.074E+01
2015	3.799E+02	3.042E+05	2.044E+01	1.015E+02	1.521E+05	1.022E+01
2016	3.613E+02	2.893E+05	1.944E+01	9.652E+01	1.447E+05	9.721E+00
2017	3.437E+02	2.752E+05	1.849E+01	9.181E+01	1.376E+05	9.247E+00
2018	3.270E+02	2.618E+05	1.759E+01	8.733E+01	1.309E+05	8.796E+00
2019	3.110E+02	2.490E+05	1.673E+01	8.308E+01	1.245E+05	8.367E+00
2020	2.958E+02	2.369E+05	1.592E+01	7.902E+01	1.184E+05	7.959E+00
2021	2.814E+02	2.253E+05	1.514E+01	7.517E+01	1.127E+05	7.570E+00
2022	2.677E+02	2.144E+05	1.440E+01	7.150E+01	1.072E+05	7.201E+00
2023	2.546E+02	2.039E+05	1.370E+01	6.802E+01	1.020E+05	6.850E+00
2024	2.422E+02	1.940E+05	1.303E+01	6.470E+01	9.698E+04	6.516E+00

Results (Continued)

Year	Total landfill gas			Methane		
	(Mg/year)	(m^3/year)	(av ft^3/min)	(Mg/year)	(m^3/year)	(av ft^3/min)
2025	2.304E+02	1.845E+05	1.240E+01	6.154E+01	9.225E+04	6.198E+00
2026	2.192E+02	1.755E+05	1.179E+01	5.854E+01	8.775E+04	5.896E+00
2027	2.085E+02	1.669E+05	1.122E+01	5.569E+01	8.347E+04	5.608E+00
2028	1.983E+02	1.588E+05	1.067E+01	5.297E+01	7.940E+04	5.335E+00
2029	1.886E+02	1.511E+05	1.015E+01	5.039E+01	7.553E+04	5.075E+00
2030	1.794E+02	1.437E+05	9.654E+00	4.793E+01	7.184E+04	4.827E+00
2031	1.707E+02	1.367E+05	9.183E+00	4.559E+01	6.834E+04	4.592E+00
2032	1.624E+02	1.300E+05	8.736E+00	4.337E+01	6.501E+04	4.368E+00
2033	1.544E+02	1.237E+05	8.310E+00	4.125E+01	6.184E+04	4.155E+00
2034	1.469E+02	1.176E+05	7.904E+00	3.924E+01	5.882E+04	3.952E+00
2035	1.397E+02	1.119E+05	7.519E+00	3.733E+01	5.595E+04	3.759E+00
2036	1.329E+02	1.064E+05	7.152E+00	3.551E+01	5.322E+04	3.576E+00
2037	1.264E+02	1.013E+05	6.803E+00	3.378E+01	5.063E+04	3.402E+00
2038	1.203E+02	9.632E+04	6.471E+00	3.213E+01	4.816E+04	3.236E+00
2039	1.144E+02	9.162E+04	6.156E+00	3.056E+01	4.581E+04	3.078E+00
2040	1.088E+02	8.715E+04	5.856E+00	2.907E+01	4.358E+04	2.928E+00
2041	1.035E+02	8.290E+04	5.570E+00	2.765E+01	4.145E+04	2.785E+00
2042	9.848E+01	7.886E+04	5.298E+00	2.630E+01	3.943E+04	2.649E+00
2043	9.368E+01	7.501E+04	5.040E+00	2.502E+01	3.751E+04	2.520E+00
2044	8.911E+01	7.135E+04	4.794E+00	2.380E+01	3.568E+04	2.397E+00
2045	8.476E+01	6.787E+04	4.560E+00	2.264E+01	3.394E+04	2.280E+00
2046	8.063E+01	6.456E+04	4.338E+00	2.154E+01	3.228E+04	2.169E+00
2047	7.669E+01	6.141E+04	4.126E+00	2.049E+01	3.071E+04	2.063E+00
2048	7.295E+01	5.842E+04	3.925E+00	1.949E+01	2.921E+04	1.963E+00
2049	6.940E+01	5.557E+04	3.734E+00	1.854E+01	2.778E+04	1.867E+00
2050	6.601E+01	5.286E+04	3.552E+00	1.763E+01	2.643E+04	1.776E+00
2051	6.279E+01	5.028E+04	3.378E+00	1.677E+01	2.514E+04	1.689E+00
2052	5.973E+01	4.783E+04	3.214E+00	1.595E+01	2.391E+04	1.607E+00
2053	5.682E+01	4.550E+04	3.057E+00	1.518E+01	2.275E+04	1.528E+00
2054	5.405E+01	4.328E+04	2.908E+00	1.444E+01	2.164E+04	1.454E+00
2055	5.141E+01	4.117E+04	2.766E+00	1.373E+01	2.058E+04	1.383E+00
2056	4.890E+01	3.916E+04	2.631E+00	1.306E+01	1.958E+04	1.316E+00
2057	4.652E+01	3.725E+04	2.503E+00	1.243E+01	1.862E+04	1.251E+00
2058	4.425E+01	3.543E+04	2.381E+00	1.182E+01	1.772E+04	1.190E+00
2059	4.209E+01	3.370E+04	2.265E+00	1.124E+01	1.685E+04	1.132E+00
2060	4.004E+01	3.206E+04	2.154E+00	1.069E+01	1.603E+04	1.077E+00
2061	3.809E+01	3.050E+04	2.049E+00	1.017E+01	1.525E+04	1.025E+00
2062	3.623E+01	2.901E+04	1.949E+00	9.677E+00	1.450E+04	9.746E-01
2063	3.446E+01	2.759E+04	1.854E+00	9.205E+00	1.380E+04	9.271E-01
2064	3.278E+01	2.625E+04	1.764E+00	8.756E+00	1.312E+04	8.818E-01
2065	3.118E+01	2.497E+04	1.678E+00	8.329E+00	1.248E+04	8.388E-01
2066	2.966E+01	2.375E+04	1.596E+00	7.923E+00	1.188E+04	7.979E-01
2067	2.821E+01	2.259E+04	1.518E+00	7.536E+00	1.130E+04	7.590E-01
2068	2.684E+01	2.149E+04	1.444E+00	7.169E+00	1.075E+04	7.220E-01
2069	2.553E+01	2.044E+04	1.374E+00	6.819E+00	1.022E+04	6.868E-01
2070	2.428E+01	1.945E+04	1.307E+00	6.487E+00	9.723E+03	6.533E-01
2071	2.310E+01	1.850E+04	1.243E+00	6.170E+00	9.249E+03	6.214E-01
2072	2.197E+01	1.760E+04	1.182E+00	5.869E+00	8.798E+03	5.911E-01
2073	2.090E+01	1.674E+04	1.125E+00	5.583E+00	8.369E+03	5.623E-01
2074	1.988E+01	1.592E+04	1.070E+00	5.311E+00	7.960E+03	5.349E-01
2075	1.891E+01	1.514E+04	1.018E+00	5.052E+00	7.572E+03	5.088E-01

Results (Continued)

Year	Total landfill gas			Methane		
	(Mg/year)	(m^3/year)	(av ft^3/min)	(Mg/year)	(m^3/year)	(av ft^3/min)
2076	1.799E+01	1.441E+04	9.679E-01	4.805E+00	7.203E+03	4.840E-01
2077	1.711E+01	1.370E+04	9.207E-01	4.571E+00	6.852E+03	4.604E-01
2078	1.628E+01	1.303E+04	8.758E-01	4.348E+00	6.517E+03	4.379E-01
2079	1.548E+01	1.240E+04	8.331E-01	4.136E+00	6.200E+03	4.166E-01
2080	1.473E+01	1.179E+04	7.925E-01	3.934E+00	5.897E+03	3.962E-01
2081	1.401E+01	1.122E+04	7.538E-01	3.742E+00	5.610E+03	3.769E-01
2082	1.333E+01	1.067E+04	7.171E-01	3.560E+00	5.336E+03	3.585E-01
2083	1.268E+01	1.015E+04	6.821E-01	3.386E+00	5.076E+03	3.410E-01
2084	1.206E+01	9.657E+03	6.488E-01	3.221E+00	4.828E+03	3.244E-01
2085	1.147E+01	9.186E+03	6.172E-01	3.064E+00	4.593E+03	3.086E-01
2086	1.091E+01	8.738E+03	5.871E-01	2.915E+00	4.369E+03	2.935E-01
2087	1.038E+01	8.311E+03	5.584E-01	2.772E+00	4.156E+03	2.792E-01
2088	9.873E+00	7.906E+03	5.312E-01	2.637E+00	3.953E+03	2.656E-01
2089	9.392E+00	7.521E+03	5.053E-01	2.509E+00	3.760E+03	2.527E-01
2090	8.934E+00	7.154E+03	4.807E-01	2.386E+00	3.577E+03	2.403E-01
2091	8.498E+00	6.805E+03	4.572E-01	2.270E+00	3.402E+03	2.286E-01
2092	8.084E+00	6.473E+03	4.349E-01	2.159E+00	3.236E+03	2.175E-01
2093	7.689E+00	6.157E+03	4.137E-01	2.054E+00	3.079E+03	2.069E-01
2094	7.314E+00	5.857E+03	3.935E-01	1.954E+00	2.928E+03	1.968E-01
2095	6.958E+00	5.571E+03	3.743E-01	1.858E+00	2.786E+03	1.872E-01
2096	6.618E+00	5.300E+03	3.561E-01	1.768E+00	2.650E+03	1.780E-01
2097	6.296E+00	5.041E+03	3.387E-01	1.682E+00	2.521E+03	1.694E-01
2098	5.988E+00	4.795E+03	3.222E-01	1.600E+00	2.398E+03	1.611E-01
2099	5.696E+00	4.561E+03	3.065E-01	1.522E+00	2.281E+03	1.532E-01
2100	5.419E+00	4.339E+03	2.915E-01	1.447E+00	2.169E+03	1.458E-01
2101	5.154E+00	4.127E+03	2.773E-01	1.377E+00	2.064E+03	1.387E-01
2102	4.903E+00	3.926E+03	2.638E-01	1.310E+00	1.963E+03	1.319E-01
2103	4.664E+00	3.735E+03	2.509E-01	1.246E+00	1.867E+03	1.255E-01
2104	4.436E+00	3.552E+03	2.387E-01	1.185E+00	1.776E+03	1.193E-01
2105	4.220E+00	3.379E+03	2.270E-01	1.127E+00	1.690E+03	1.135E-01
2106	4.014E+00	3.214E+03	2.160E-01	1.072E+00	1.607E+03	1.080E-01
2107	3.818E+00	3.058E+03	2.054E-01	1.020E+00	1.529E+03	1.027E-01
2108	3.632E+00	2.908E+03	1.954E-01	9.702E-01	1.454E+03	9.771E-02
2109	3.455E+00	2.767E+03	1.859E-01	9.229E-01	1.383E+03	9.295E-02
2110	3.287E+00	2.632E+03	1.768E-01	8.779E-01	1.316E+03	8.841E-02
2111	3.126E+00	2.503E+03	1.682E-01	8.351E-01	1.252E+03	8.410E-02
2112	2.974E+00	2.381E+03	1.600E-01	7.943E-01	1.191E+03	8.000E-02
2113	2.829E+00	2.265E+03	1.522E-01	7.556E-01	1.133E+03	7.610E-02
2114	2.691E+00	2.155E+03	1.448E-01	7.187E-01	1.077E+03	7.239E-02
2115	2.560E+00	2.050E+03	1.377E-01	6.837E-01	1.025E+03	6.886E-02

Results (Continued)

Year	Carbon dioxide			NMOC		
	(Mg/year)	*(m^3/year)*	*(av ft^3/min)*	*(Mg/year)*	*(m^3/year)*	*(av ft^3/min)*
1975	0	0	0	0	0	0
1976	8.981E+01	4.906E+04	3.297E+00	1.407E+00	3.925E+02	2.637E-02
1977	1.752E+02	9.574E+04	6.432E+00	2.745E+00	7.659E+02	5.146E-02
1978	2.565E+02	1.401E+05	9.415E+00	4.018E+00	1.121E+03	7.532E-02
1979	3.338E+02	1.824E+05	1.225E+01	5.229E+00	1.459E+03	9.802E-02
1980	4.073E+02	2.225E+05	1.495E+01	6.381E+00	1.780E+03	1.196E-01
1981	4.773E+02	2.607E+05	1.752E+01	7.477E+00	2.086E+03	1.402E-01
1982	5.438E+02	2.971E+05	1.996E+01	8.519E+00	2.377E+03	1.597E-01
1983	6.071E+02	3.317E+05	2.228E+01	9.511E+00	2.653E+03	1.783E-01
1984	6.673E+02	3.646E+05	2.449E+01	1.045E+01	2.916E+03	1.960E-01
1985	7.246E+02	3.958E+05	2.660E+01	1.135E+01	3.167E+03	2.128E-01
1986	7.791E+02	4.256E+05	2.860E+01	1.220E+01	3.405E+03	2.288E-01
1987	8.309E+02	4.539E+05	3.050E+01	1.302E+01	3.631E+03	2.440E-01
1988	8.802E+02	4.808E+05	3.231E+01	1.379E+01	3.847E+03	2.585E-01
1989	9.270E+02	5.064E+05	3.403E+01	1.452E+01	4.052E+03	2.722E-01
1990	9.716E+02	5.308E+05	3.567E+01	1.522E+01	4.246E+03	2.853E-01
1991	9.243E+02	5.050E+05	3.393E+01	1.448E+01	4.040E+03	2.714E-01
1992	8.793E+02	4.803E+05	3.227E+01	1.377E+01	3.843E+03	2.582E-01
1993	8.364E+02	4.569E+05	3.070E+01	1.310E+01	3.655E+03	2.456E-01
1994	7.956E+02	4.346E+05	2.920E+01	1.246E+01	3.477E+03	2.336E-01
1995	7.568E+02	4.134E+05	2.778E+01	1.186E+01	3.307E+03	2.222E-01
1996	7.199E+02	3.933E+05	2.642E+01	1.128E+01	3.146E+03	2.114E-01
1997	6.848E+02	3.741E+05	2.513E+01	1.073E+01	2.993E+03	2.011E-01
1998	6.514E+02	3.558E+05	2.391E+01	1.020E+01	2.847E+03	1.913E-01
1999	6.196E+02	3.385E+05	2.274E+01	9.706E+00	2.708E+03	1.819E-01
2000	5.894E+02	3.220E+05	2.163E+01	9.233E+00	2.576E+03	1.731E-01
2001	5.606E+02	3.063E+05	2.058E+01	8.783E+00	2.450E+03	1.646E-01
2002	5.333E+02	2.913E+05	1.958E+01	8.354E+00	2.331E+03	1.566E-01
2003	5.073E+02	2.771E+05	1.862E+01	7.947E+00	2.217E+03	1.490E-01
2004	4.825E+02	2.636E+05	1.771E+01	7.559E+00	2.109E+03	1.417E-01
2005	4.590E+02	2.508E+05	1.685E+01	7.191E+00	2.006E+03	1.348E-01
2006	4.366E+02	2.385E+05	1.603E+01	6.840E+00	1.908E+03	1.282E-01
2007	4.153E+02	2.269E+05	1.525E+01	6.506E+00	1.815E+03	1.220E-01
2008	3.951E+02	2.158E+05	1.450E+01	6.189E+00	1.727E+03	1.160E-01
2009	3.758E+02	2.053E+05	1.379E+01	5.887E+00	1.642E+03	1.104E-01
2010	3.575E+02	1.953E+05	1.312E+01	5.600E+00	1.562E+03	1.050E-01
2011	3.400E+02	1.858E+05	1.248E+01	5.327E+00	1.486E+03	9.985E-02
2012	3.235E+02	1.767E+05	1.187E+01	5.067E+00	1.414E+03	9.498E-02
2013	3.077E+02	1.681E+05	1.129E+01	4.820E+00	1.345E+03	9.035E-02
2014	2.927E+02	1.599E+05	1.074E+01	4.585E+00	1.279E+03	8.594E-02
2015	2.784E+02	1.521E+05	1.022E+01	4.361E+00	1.217E+03	8.175E-02
2016	2.648E+02	1.447E+05	9.721E+00	4.149E+00	1.157E+03	7.777E-02
2017	2.519E+02	1.376E+05	9.247E+00	3.946E+00	1.101E+03	7.397E-02
2018	2.396E+02	1.309E+05	8.796E+00	3.754E+00	1.047E+03	7.036E-02
2019	2.279E+02	1.245E+05	8.367E+00	3.571E+00	9.962E+02	6.693E-02
2020	2.168E+02	1.184E+05	7.959E+00	3.397E+00	9.476E+02	6.367E-02
2021	2.062E+02	1.127E+05	7.570E+00	3.231E+00	9.014E+02	6.056E-02
2022	1.962E+02	1.072E+05	7.201E+00	3.073E+00	8.574E+02	5.761E-02
2023	1.866E+02	1.020E+05	6.850E+00	2.924E+00	8.156E+02	5.480E-02
2024	1.775E+02	9.698E+04	6.516E+00	2.781E+00	7.758E+02	5.213E-02

Results (Continued)

Year	Carbon dioxide			NMOC		
	(Mg/year)	(m^3/year)	(av ft^3/min)	(Mg/year)	(m^3/year)	(av ft^3/min)
2025	1.689E+02	9.225E+04	6.198E+00	2.645E+00	7.380E+02	4.959E-02
2026	1.606E+02	8.775E+04	5.896E+00	2.516E+00	7.020E+02	4.717E-02
2027	1.528E+02	8.347E+04	5.608E+00	2.394E+00	6.678E+02	4.487E-02
2028	1.453E+02	7.940E+04	5.335E+00	2.277E+00	6.352E+02	4.268E-02
2029	1.383E+02	7.553E+04	5.075E+00	2.166E+00	6.042E+02	4.060E-02
2030	1.315E+02	7.184E+04	4.827E+00	2.060E+00	5.747E+02	3.862E-02
2031	1.251E+02	6.834E+04	4.592E+00	1.960E+00	5.467E+02	3.673E-02
2032	1.190E+02	6.501E+04	4.368E+00	1.864E+00	5.201E+02	3.494E-02
2033	1.132E+02	6.184E+04	4.155E+00	1.773E+00	4.947E+02	3.324E-02
2034	1.077E+02	5.882E+04	3.952E+00	1.687E+00	4.706E+02	3.162E-02
2035	1.024E+02	5.595E+04	3.759E+00	1.604E+00	4.476E+02	3.008E-02
2036	9.742E+01	5.322E+04	3.576E+00	1.526E+00	4.258E+02	2.861E-02
2037	9.267E+01	5.063E+04	3.402E+00	1.452E+00	4.050E+02	2.721E-02
2038	8.815E+01	4.816E+04	3.236E+00	1.381E+00	3.853E+02	2.589E-02
2039	8.385E+01	4.581E+04	3.078E+00	1.314E+00	3.665E+02	2.462E-02
2040	7.976E+01	4.358E+04	2.928E+00	1.250E+00	3.486E+02	2.342E-02
2041	7.587E+01	4.145E+04	2.785E+00	1.189E+00	3.316E+02	2.228E-02
2042	7.217E+01	3.943E+04	2.649E+00	1.131E+00	3.154E+02	2.119E-02
2043	6.865E+01	3.751E+04	2.520E+00	1.075E+00	3.000E+02	2.016E-02
2044	6.531E+01	3.568E+04	2.397E+00	1.023E+00	2.854E+02	1.918E-02
2045	6.212E+01	3.394E+04	2.280E+00	9.731E-01	2.715E+02	1.824E-02
2046	5.909E+01	3.228E+04	2.169E+00	9.257E-01	2.583E+02	1.735E-02
2047	5.621E+01	3.071E+04	2.063E+00	8.805E-01	2.457E+02	1.651E-02
2048	5.347E+01	2.921E+04	1.963E+00	8.376E-01	2.337E+02	1.570E-02
2049	5.086E+01	2.778E+04	1.867E+00	7.967E-01	2.223E+02	1.493E-02
2050	4.838E+01	2.643E+04	1.776E+00	7.579E-01	2.114E+02	1.421E-02
2051	4.602E+01	2.514E+04	1.689E+00	7.209E-01	2.011E+02	1.351E-02
2052	4.378E+01	2.391E+04	1.607E+00	6.858E-01	1.913E+02	1.285E-02
2053	4.164E+01	2.275E+04	1.528E+00	6.523E-01	1.820E+02	1.223E-02
2054	3.961E+01	2.164E+04	1.454E+00	6.205E-01	1.731E+02	1.163E-02
2055	3.768E+01	2.058E+04	1.383E+00	5.902E-01	1.647E+02	1.106E-02
2056	3.584E+01	1.958E+04	1.316E+00	5.615E-01	1.566E+02	1.052E-02
2057	3.409E+01	1.862E+04	1.251E+00	5.341E-01	1.490E+02	1.001E-02
2058	3.243E+01	1.772E+04	1.190E+00	5.080E-01	1.417E+02	9.523E-03
2059	3.085E+01	1.685E+04	1.132E+00	4.833E-01	1.348E+02	9.058E-03
2060	2.934E+01	1.603E+04	1.077E+00	4.597E-01	1.282E+02	8.617E-03
2061	2.791E+01	1.525E+04	1.025E+00	4.373E-01	1.220E+02	8.196E-03
2062	2.655E+01	1.450E+04	9.746E-01	4.159E-01	1.160E+02	7.797E-03
2063	2.526E+01	1.380E+04	9.271E-01	3.957E-01	1.104E+02	7.416E-03
2064	2.402E+01	1.312E+04	8.818E-01	3.764E-01	1.050E+02	7.055E-03
2065	2.285E+01	1.248E+04	8.388E-01	3.580E-01	9.988E+01	6.711E-03
2066	2.174E+01	1.188E+04	7.979E-01	3.405E-01	9.500E+01	6.383E-03
2067	2.068E+01	1.130E+04	7.590E-01	3.239E-01	9.037E+01	6.072E-03
2068	1.967E+01	1.075E+04	7.220E-01	3.081E-01	8.596E+01	5.776E-03
2069	1.871E+01	1.022E+04	6.868E-01	2.931E-01	8.177E+01	5.494E-03
2070	1.780E+01	9.723E+03	6.533E-01	2.788E-01	7.778E+01	5.226E-03
2071	1.693E+01	9.249E+03	6.214E-01	2.652E-01	7.399E+01	4.971E-03
2072	1.610E+01	8.798E+03	5.911E-01	2.523E-01	7.038E+01	4.729E-03
2073	1.532E+01	8.369E+03	5.623E-01	2.400E-01	6.695E+01	4.498E-03
2074	1.457E+01	7.960E+03	5.349E-01	2.283E-01	6.368E+01	4.279E-03
2075	1.386E+01	7.572E+03	5.088E-01	2.171E-01	6.058E+01	4.070E-03

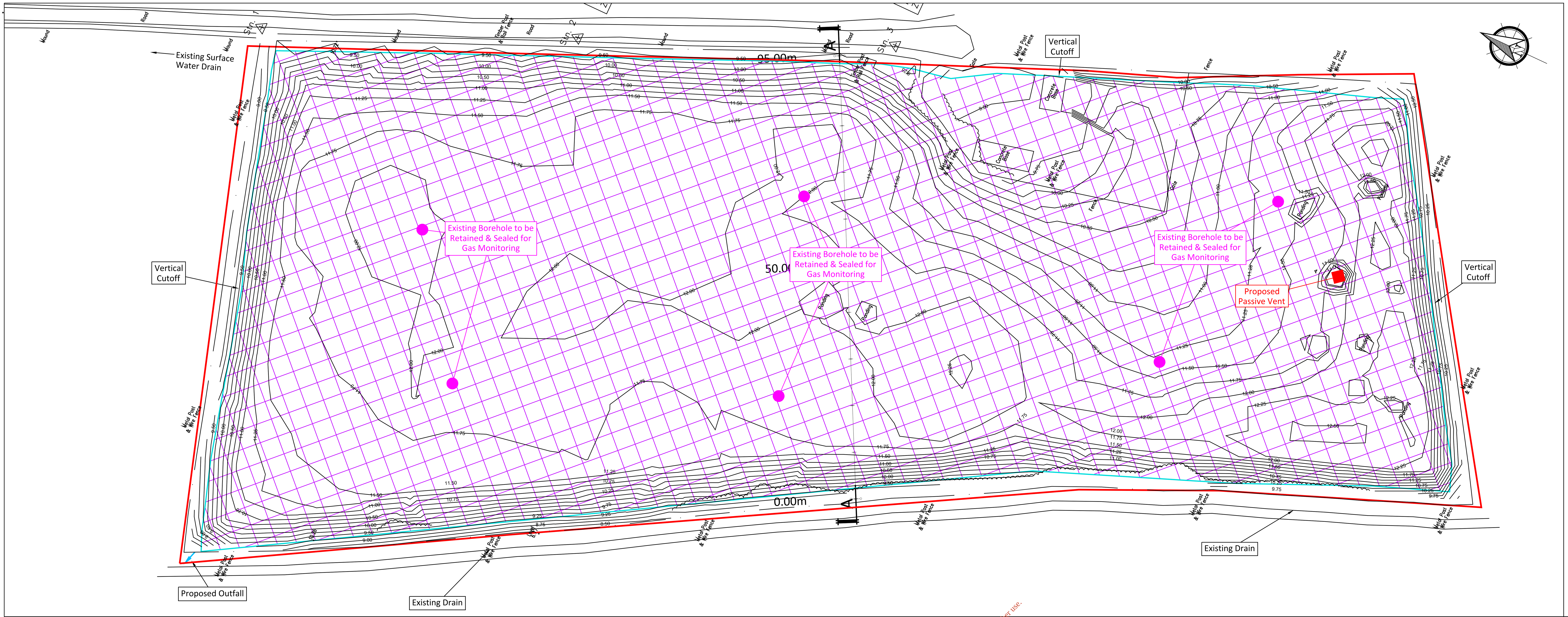
Results (Continued)

Year	Carbon dioxide			NMOC		
	(Mg/year)	(m^3/year)	(av ft^3/min)	(Mg/year)	(m^3/year)	(av ft^3/min)
2076	1.318E+01	7.203E+03	4.840E-01	2.065E-01	5.762E+01	3.872E-03
2077	1.254E+01	6.852E+03	4.604E-01	1.965E-01	5.481E+01	3.683E-03
2078	1.193E+01	6.517E+03	4.379E-01	1.869E-01	5.214E+01	3.503E-03
2079	1.135E+01	6.200E+03	4.166E-01	1.778E-01	4.960E+01	3.332E-03
2080	1.079E+01	5.897E+03	3.962E-01	1.691E-01	4.718E+01	3.170E-03
2081	1.027E+01	5.610E+03	3.769E-01	1.609E-01	4.488E+01	3.015E-03
2082	9.768E+00	5.336E+03	3.585E-01	1.530E-01	4.269E+01	2.868E-03
2083	9.291E+00	5.076E+03	3.410E-01	1.456E-01	4.061E+01	2.728E-03
2084	8.838E+00	4.828E+03	3.244E-01	1.385E-01	3.863E+01	2.595E-03
2085	8.407E+00	4.593E+03	3.086E-01	1.317E-01	3.674E+01	2.469E-03
2086	7.997E+00	4.369E+03	2.935E-01	1.253E-01	3.495E+01	2.348E-03
2087	7.607E+00	4.156E+03	2.792E-01	1.192E-01	3.325E+01	2.234E-03
2088	7.236E+00	3.953E+03	2.656E-01	1.134E-01	3.162E+01	2.125E-03
2089	6.883E+00	3.760E+03	2.527E-01	1.078E-01	3.008E+01	2.021E-03
2090	6.547E+00	3.577E+03	2.403E-01	1.026E-01	2.861E+01	1.923E-03
2091	6.228E+00	3.402E+03	2.286E-01	9.757E-02	2.722E+01	1.829E-03
2092	5.924E+00	3.236E+03	2.175E-01	9.281E-02	2.589E+01	1.740E-03
2093	5.635E+00	3.079E+03	2.069E-01	8.828E-02	2.463E+01	1.655E-03
2094	5.361E+00	2.928E+03	1.968E-01	8.398E-02	2.343E+01	1.574E-03
2095	5.099E+00	2.786E+03	1.872E-01	7.988E-02	2.229E+01	1.497E-03
2096	4.850E+00	2.650E+03	1.780E-01	7.599E-02	2.120E+01	1.424E-03
2097	4.614E+00	2.521E+03	1.694E-01	7.228E-02	2.016E+01	1.355E-03
2098	4.389E+00	2.398E+03	1.611E-01	6.875E-02	1.918E+01	1.289E-03
2099	4.175E+00	2.281E+03	1.532E-01	6.540E-02	1.825E+01	1.226E-03
2100	3.971E+00	2.169E+03	1.458E-01	6.221E-02	1.736E+01	1.166E-03
2101	3.778E+00	2.064E+03	1.387E-01	5.918E-02	1.651E+01	1.109E-03
2102	3.593E+00	1.963E+03	1.319E-01	5.629E-02	1.570E+01	1.055E-03
2103	3.418E+00	1.867E+03	1.255E-01	5.355E-02	1.494E+01	1.004E-03
2104	3.251E+00	1.776E+03	1.193E-01	5.093E-02	1.421E+01	9.548E-04
2105	3.093E+00	1.690E+03	1.135E-01	4.845E-02	1.352E+01	9.082E-04
2106	2.942E+00	1.607E+03	1.080E-01	4.609E-02	1.286E+01	8.639E-04
2107	2.798E+00	1.529E+03	1.027E-01	4.384E-02	1.223E+01	8.218E-04
2108	2.662E+00	1.454E+03	9.771E-02	4.170E-02	1.163E+01	7.817E-04
2109	2.532E+00	1.383E+03	9.295E-02	3.967E-02	1.107E+01	7.436E-04
2110	2.409E+00	1.316E+03	8.841E-02	3.773E-02	1.053E+01	7.073E-04
2111	2.291E+00	1.252E+03	8.410E-02	3.589E-02	1.001E+01	6.728E-04
2112	2.179E+00	1.191E+03	8.000E-02	3.414E-02	9.525E+00	6.400E-04
2113	2.073E+00	1.133E+03	7.610E-02	3.248E-02	9.061E+00	6.088E-04
2114	1.972E+00	1.077E+03	7.239E-02	3.089E-02	8.619E+00	5.791E-04
2115	1.876E+00	1.025E+03	6.886E-02	2.939E-02	8.198E+00	5.508E-04

CONSULTANTS IN ENGINEERING,
ENVIRONMENTAL SCIENCE & PLANNING

APPENDIX 4

Remediation Plan Drawings



Legend

- Site Boundary
- Subsurface Drainage Layer & Overliner Pipework Collection System
- 1. LLDPE Footprint 2. Underliner Gas Collection System

PLAN

Scale 1:500

Legend

- Existing Ground Level
- Subsurface Drainage Layer & Overliner Pipework Collection System
- LLDPE
- Gas Collection Layer & Pipe Collection System

Chainage	0.000	10.000	20.000	40.000	50.000	60.000	70.000	80.000	90.000	95.000
Extg Ground Level		11.579	11.939	12.000	12.008	11.801	11.952	11.987	10.556	9.585
Capping Level		12.629	12.989	13.050	13.058	12.851	13.002	13.037	11.606	
LLDPE		11.529	11.889	11.950	11.958	11.751	11.902	11.937	10.506	
Gas Collection		11.479	11.839	11.900	11.908	11.701	11.852	11.887	10.456	

SECTION A-A

Scale 1:100

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Rev.	Description	App By	Date
A	ISSUE FOR APPROVAL	CJC	25.02.20

PROJECT
SOUTH AND WEST KERRY LANDFILLS

CLIENT
KERRY COUNTY COUNCIL

SHEET
AHASCRA HISTORIC LANDFILL TYPICAL CROSS SECTION OF PROPOSED CAP

Date: 25.02.20	Project number: P1766	Scale (@ A1-): As Shown	
Drawn by: SOC	Drawing Number: P1766-0101-0003		Rev: A
Checked by: EA			

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03 March 2020

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