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

Prepared for: Kerry County Council

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Abstract: This report presents the findings of a Tier 3 risk assessment carried out on Castleisland 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 recommendations made in an earlier 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 Castleisland historical landfill located at Castleisland, Co. Kerry. This Tier 3 makes reference to:

- Tier 1 risk assessment findings and classifications (2007 and 2011).
- Tier 2 Site investigation, testing and risk assessment (2020).

All 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 moderate (Class B) risk to the receiving environment and the site was subsequently assigned a Moderate Risk (Class B) on the EPA Section 22 register in 2009. The EPA risk assessment tool, as per the EPA CoP for Unregulated Waste Disposal Sites, yielded a highest risk score of 50% for source-pathway-receptor (SPR) linkage SPR5.

The Tier 1 risk assessment was reviewed in 2011 providing a more comprehensive assessment of the site in accordance with the EPA CoP. A number of changes in risk scores were made however the site remained classified as a Moderate risk site, with scores of 50% calculated for SPR1, SPR5, SPR7 and SPR8. All other SPR linkages were calculated to be of low risk. The 2007 and 2011 risk scores are included in Table 1.1.

Table 1-1 normalised scores for 2007 and 2013 Tier 1 assessments have been provided for reference purposes to reflect records as per the current (2020) EPA Section 22 register.

Table 1-1: Tier 1 SPR Linkages (2007 and 2011)

SPR No.	Linkage	Normalised Score	Justification[1]
Leachate migration through combined groundwater and surface water pathways			
SPR1	Leachate => surface water	13.33% (2007) 50% (2011)	Groundwater vulnerability was identified as being extreme with bedrock present at or close to the surface and the site is underlain by a regionally important karstified aquifer, there is direct connection between drainage ditches, waste body and an adjacent surface water body.
SPR2	Leachate => SWDTE	13.33% (2007) 0% (2011)	Aquifer and bedrock present a groundwater pathway however there were no direct surface water pathways from the site to sensitive surface water receptors.

SPR No.	Linkage	Normalised Score	Justification[1]
Leachate migration through groundwater pathway			
SPR3	Leachate => human presence	33.33% (2007) 33% (2011)	A housing development is located to the south-west of the site boundary and within 150m of the waste body.
SPR4	Leachate => GWDTE	16.67% (2007) 0% (2011)	There are no GWDTE located within 1km of the waste body.
SPR5	Leachate => Aquifer	50% (2007) 50% (2011)	Aquifer vulnerability extreme and is classified as being a regionally important aquifer.
SPR6	Leachate => Public Supply	21.43% (2007) 21% (2011)	Nearest public water supply is located over 1km from the site.
SPR7	Leachate => SWDTE	16.67% (2007) 50% (2011)	Aquifer vulnerability extreme and is classified as being a regionally important aquifer. There are surface water body receptors located within 50m of the waste body.
Leachate migration through surface water pathway			
SPR8	Leachate => Surface Water	0% (2007) 50% (2011)	There is direct connection between drainage ditches, the waste and a surface water body receptor within 50m of the site.
SPR9	Leachate => SWDTE	0% (2007) 0% (2011)	There are no direct surface water pathways between the site and any SWDTE.
Landfill gas migration pathway (lateral & vertical)			
SPR10	Landfill Gas => Human Presence	20% (2007) 15% (2011)	Surrounding soils are till soils and there are human receptors located between 50m - 150m from the site.
SPR11	Landfill Gas => Human Presence	0% (2007) 0% (2011)	There is no dwelling above the footprint of the waste.

Note 1: justification refers to 2011 risk scoring

1.3 Tier 2 Site investigation

Fehily Timoney and Company (FT) was appointed by Kerry County Council to:

- Carry out and prepare site investigation and testing; and
- prepare a Tier 2 environmental risk assessment report.

The Castleisland 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.

The Tier 2 site investigations confirmed that the historic landfill primarily contained mixed, inert waste deposited within a single infill area which covers an area of 2,192 m^2. The depth of waste from the seismic refraction and 2D-Resistivity surveys estimated an average thickness of 6 m. The estimate includes capping or natural fill material on top of the main waste body. An initial volume calculation estimated an interred waste volume of 13,152 m^3 (c. 18,375 tonnes) at the site.

1.4 Tier 2 Risk Classification and Tier 3 SPRs

The Tier 2 site investigation risk assessment concluded that the risk rating of the site was Moderate (Class B). The highest single risk rating for the site was calculated to be 50% for source-pathway-receptor (SPR) Linkage 5, which referred to leachate migration through a groundwater pathway to the underlying aquifer. The SPR linkages examined in this Tier 3 are discussed in further details 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	17%	Groundwater vulnerability was identified as being extreme with bedrock present at or close to the surface and the site is underlain by a regionally important karstified aquifer. Conservatively assumes there are direct surface water pathways from site to sensitive surface water receptors. The closest surface water receptor was identified as the Glenshearoon River, a tributary of the Maine River, and is located approximately 640 m from the site.
SPR2	Leachate => SWDTE	0%	Aquifer and bedrock present a groundwater pathway however there were no direct surface water pathways from the site to sensitive surface water receptors.
Leachate migration through groundwater pathway			
SPR3	Leachate => human presence	33%	A housing development is located to the south-west of the site boundary and within 150 m of the waste body. Not likely that this dwelling would be exposed to any leachate. House drinking water likely supplied via mains water supply.

SPR No.	Linkage	Normalised Score	Justification
SPR4	Leachate => GWDTE	0%	There are no GWDTE located within 1 km of the waste body.
SPR5	Leachate => Aquifer	**50%**	Aquifer vulnerability extreme and is classified as being a regionally important aquifer. Site investigation identified that waste was deposited on top of bedrock.
SPR6	Leachate => Public Supply	21%	Nearest public water supply is located over 1 km from the site.
SPR7	Leachate => SWDTE	17%	Underlying aquifer presents a pathway however the nearest sensitive surface water body, the Maine River is located within 1 km from the waste body at certain points, but no closer than 250 m from the site.
Leachate migration through surface water pathway			
SPR8	Leachate => Surface Water	17%	Conservatively assumes there are direct surface water pathways from site to sensitive surface water receptors. The closest surface water receptor was identified as the Glenshearoon River, a tributary of the Maine River, and is located approximately 640 m from the site.
SPR9	Leachate => SWDTE	0%	Conservatively assumes there are direct surface water pathways from site to sensitive surface water receptors. The closest surface water receptor was identified as the Glenshearoon River, a tributary of the Maine River, and is located approximately 64 0 m from the site.
Landfill gas migration pathway (lateral & vertical)			
SPR10	Landfill Gas => Human Presence	30%	A housing development is located to the south-west of the site boundary and within 150m of the waste body. It was also observed when conducting landfill gas monitoring in October 2019 additional houses are to be built at c.150 m west from the waste body, immediately adjacent to existing.
SPR11	Landfill Gas => Human Presence	30%	A housing development is located to the south-west of the site boundary and within 150 m of the waste body. It was also observed when conducting landfill gas monitoring in October 2019 that additional houses are to be built at c.150m west from the waste body.

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

As part of the Tier 2 site investigation and assessment, two groundwater monitoring boreholes were installed to the east and west of the waste body (upgradient and downgradient). Groundwater sampling was attempted on two occasions in July and September 2019.

However, on both occasions both wells were found to be dry and subsequently it was not possible to perform chemicals analysis on the underlying groundwater at the site. Although it was not possible to directly determine the chemical characteristics of the underlying groundwater, the presence of waste deposited directly on limestone bedrock does present an inherent risk to groundwater quality.

1.4.2 Lateral and Vertical Migration of Landfill Gas (SPR10 And SPR11)

Based on the characteristics of the site, the surrounding environment and receptors, the Tier 2 risk evaluation and rating yielded low risk scores of 30% for both lateral (SPR10) and vertical (SPR11) landfill gas migration.

Landfill gas monitoring at the site showed only trace quantities of methane (0.1% v/v) below the trigger value of 1% v/v at both boreholes (BH01 and BH02) installed outside the waste footprint. It was also observed when conducting landfill gas monitoring in October 2019 that construction was underway to the west of the site, directly north of the existing housing estate.

A review of the online Kerry County Council planning search tool confirmed that the observed construction activity refers to the development of houses as per planning reference 16739. This development will place residential units within c.150 m of the Castleisland historical landfill waste body and the access road which traverses the historical landfill may be used as a construction access road to service this housing development (see Planning Ref: 19190).

1.4.3 Leachate Migration Through Surface Water Pathway To Surface Water Receptor (SPR8)

A risk score of 17% was calculated for SPR8 linkage which refers to leachate migration through surface water pathway to a surface water receptor. Although no leachate breakout was observed at the site, as a matter of due diligence the potential risk of surface water contamination was examined.

2. TIER 3 QUANTITATIVE RISK ASSESSMENT SCOPE OF WORKS

2.1 Tier 3 Overview

A Tier 3 risk assessment includes some form of quantitative risk 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 report further examines the Tier 2 (see Table 1-2) linkages in relation to the following:

- SPR5 Leachate migration through groundwater pathway to underlying aquifer resulting in risk rating score of 50%.
- SPR8 leachate migration to surface waters 17%.
- SPR10 Lateral Landfill gas migration to human receptors resulting in a risk rating score of 30%.
- SPR11 Vertical Landfill gas migration to human receptors resulting in risk rating score of 30%.

The Tier 2 assessment concluded that the Castleisland site presents a **moderate risk** therefore a GQRA or a DQRA are required as part of this Tier 3 assessment.

This Tier 3 assessment report uses DQRAs to further assess the risks to groundwater, surface water and landfill gas receptors as follows:

- Groundwater contaminant dispersion modelling (EA Remedial Targets Worksheet) was undertaken to quantitatively assess the risks posed to the aquifer.
- An assimilative capacity assessment and mass balance calculation were carried out to predict the potential impact on surface water quality from a leachate discharge to the River Maine and Glenshearoon 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 risks:

- Leachate migration through groundwater pathway to underlying aquifer (SPR5).
- Leachate migration through surface water pathway to surface water receptor (SPR8).
- Lateral and vertical migration of landfill gas (SPR10 and SPR11).

The detailed quantitative risk assessments rely on 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 and Hydrogeological Environment

As discussed in Section 1 above, the risk to underlying groundwater quality was identified as the primary environmental risk associated with the site. The application of the EPA risk calculation and scoring methodology is reliant on understanding the geological and hydrogeological characteristics of the site and the surrounding environment. An accurate understanding and rating 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.

The historical landfill site is approximately 2.192 hectare in size and covers an area of open, agricultural land located approximately 1.1 km north-east of the centre of Castleisland town. The quaternary map provided by GSI classifies the quaternary sediments as 'Quaternary Sediments: Bedrock outcrop or subcrop'. Surrounding deposits classified as 'till derived from Namurian sandstones and shales. The site investigation identified the presence of sandy gravelly, silty clay tills.

Bedrock geology mapping shows the bedrock beneath the site is found on two different formations and geology types. The immediate infilled area is underlain by the Cloonagh Limestone Formation comprising un-bedded calcilutite limestone. The southern portion of the wider site is underlain by the Rockfield Limestone Formation, which comprises fine-grained, dark grey, argillaceous, well-bedded limestones with some cross-stratification. Limestone bedrock was encountered at depths as shallow as 0.3m below ground level at borehole BH01 while limestone bedrock was encountered at 8.8m below ground level at BH02.

An examination of the national bedrock aquifer mapping classifies the underlying bedrock aquifer as 'Regionally Important Aquifer – Karstified (diffuse)' below the site and 'Locally Important Aquifer – Bedrock which is Moderately Productive only in Local Zones' to the south of the site.

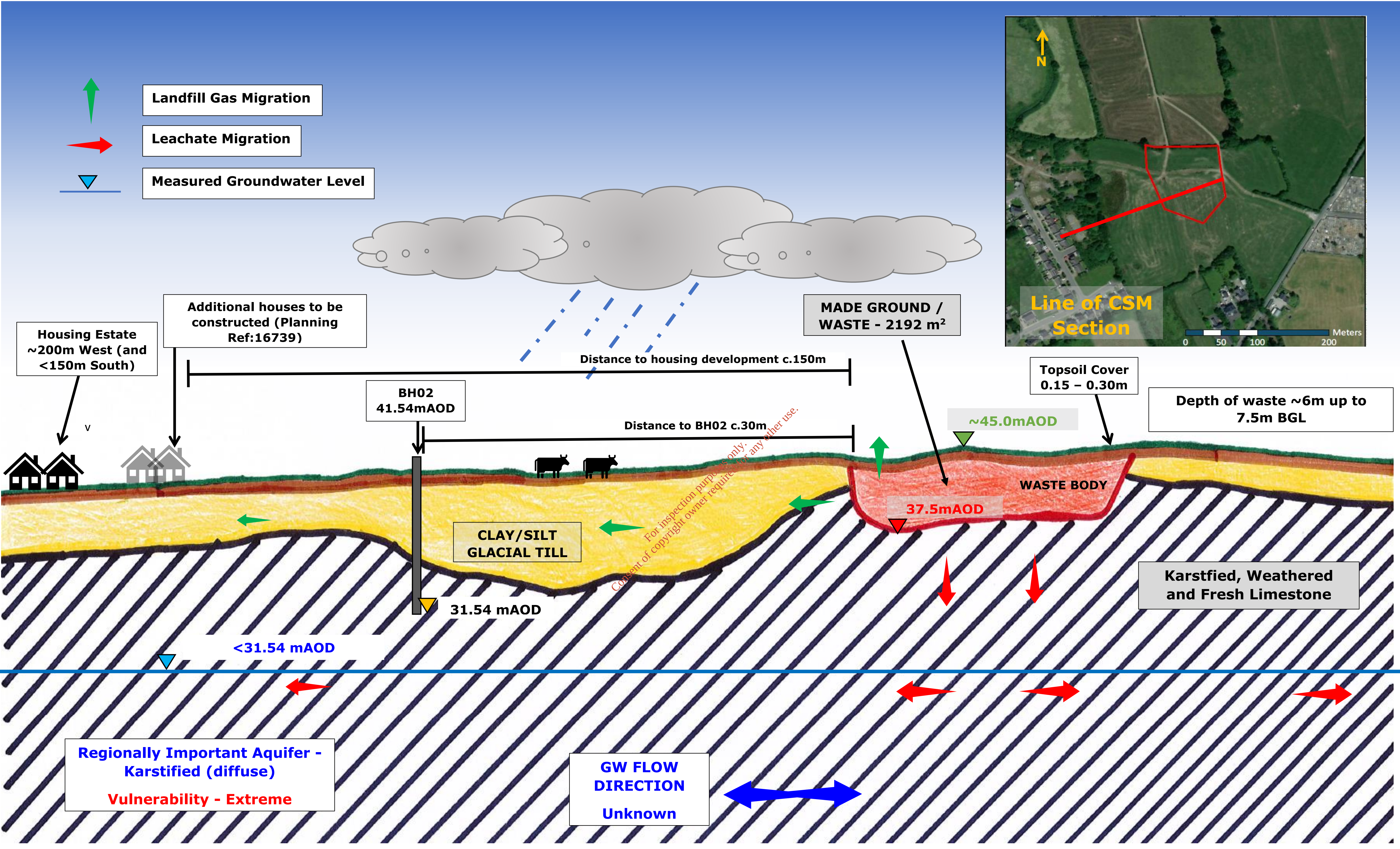
There are no Groundwater Drinking Water Protection Areas within the site boundaries according to GSI. The closest one, Ardfert PWS, is located approximately 23.8 km North-West from the site.

The vulnerability of groundwater to contamination is characterised as 'X (Rock at or near surface)' and is surrounded by an area of E (Extreme) Vulnerability.

This vulnerability is consistent with site investigation results indicating that the depth to bedrock in the locality and at the site can be shallow. This facilitates a relatively easy route for rainfall and hence leachate to enter the underlying groundwater aquifer.

3.2.1 Conceptual Site Model (CSM)

A revised conceptual site model has been prepared as part of this Tier 3 assessment. The revised CSM illustrates the identified potential groundwater and landfill gas pathway from the site to nearby residential areas.



CROSS SECTION WEST-EAST

FIGURE 3.1 CASTLEISLAND HISTORIC LANDFILL

CONCEPTUAL SITE MODEL

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3.3 Impact of Leachate on Groundwater

The site location is underlain by a 'Regionally Important Aquifer - Karstified (diffuse)'. The aquifer vulnerability is classified as being extreme at the site, indicating that the aquifer at the is location is extremely vulnerable to and can directly influenced by rainwater infiltration at the site, and as subsequently by any pollutants migrating vertically to the bedrock aquifer.

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. During the Tier 2 site investigation both wells (BH01 and BH02) were found to be dry therefore it was not possible to confirm groundwater levels. It is known however that the waste material has been deposited directly on top of the underlying bedrock, there it is possible that groundwater may transect the waste body or that waste material is in direct contact with the bedrock aquifer with the majority of groundwater flow occurring within the upper, epikarstic layer of this bedrock formation.

The vertical infiltration of rainfall above the site to the underlying groundwater aquifer is determined by the groundwater recharge rate at this site. The recharge coefficient applied by GSI to the areas where the groundwater vulnerability is classified as being an area where rock is at or close to the surface is 85%. Applying an effective rainfall rate 1,162 mm/year this equates to a recharge rate of 988 mm/year.

85% x 1,162 mm/year = 988 mm/year or 0.988 m/year (available rainfall for recharge over the landfill area

Aquifer Recharge Volume = Recharge x area of landfill

Aquifer Recharge Volume = 0.988 m/year x 2,192 m²

Aquifer Recharge Volume over landfill area = 2,165 m³/year ***[5.93 m³/day]***

GSI has characterised the underlying aquifer, the Castlemaine groundwater body (GWB) as being 146 km² in area. The Castleisland historical landfill waste footprint was determined to be 2,165 m² in area based on the findings of the site investigation. This accounts for 0.0015% of the Castlemaine GWB area.

This indicates that at a regional level and with respect to the groundwater quality of the overall groundwater body the site is not likely to have a negative impact.

3.3.2 Leachate Dispersion Modelling and Assessment

To further determine the potential downstream concentration of leachate/contaminated groundwater generated at the site and the potential risk it may pose to contaminating groundwater downstream the Hydrogeological Risk Assessment for Land Contamination - Remedial Targets Worksheet developed by the UK Environment Agency's Science Group was utilised, See Appendix 1.

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 the desired groundwater concentration will be met.

This assessment tool was utilised to predict the potential groundwater concentration for select parameters/contaminants 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).

As groundwater monitoring wells at the site were found to be dry when sampling it was necessary to make assumptions with respect to the potential characteristics of leachate present at the site. Ammonia is a commonly occurring pollutants associated with landfills and arises primarily through the degradation of organic matter. As such, ammonia was selected as a representative pollutant to assess the potential impact of groundwater contamination downstream of the site.

The UK EA worksheet relies on the input of single values; therefore, it was necessary to make several assumptions using available site-specific data and typical values obtained from literature studies representing prevailing site conditions.

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

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

Input Parameter	Unit	Ammoniacal Nitrogen	Source
Target Concentration	*mg/l*	0.175	S.I No. 9 of 2010[1] and EPA IGV[2]
Initial contaminant concentration in groundwater at plume core	*mg/l*	0.5	Assumed based on characteristics of leachate and groundwater at similar historical landfill sites
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*	50	Approximate width of site/waste extent based on site investigation
Plume thickness at source	*m*	1	Assumed thickness, waste is deposited directly on limestone bedrock
Saturated aquifer thickness	*m*	3	Assumed - GSI state that majority of groundwater flow in this groundwater body occur in upper few metres of bedrock

[1] S.I. No. 9/2010 - European Communities Environmental Objectives (Groundwater) Regulations 2010

[2] Towards Setting Guideline Values For the Protection of Groundwater in Ireland-Interim Report (EPA, 2003)

Input Parameter	Unit	Ammoniacal Nitrogen	Source
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*	0.003	Assumed - GSI state hydraulic gradient for Castlemaine groundwater body to generally be low c. 0.001 - 0.005
Hydraulic conductivity of aquifer	*m/d*	0.008	Assumed single conductivity based on range for limestone applied in LandSim manual
Distance to compliance point	*m*	300	Hypothetical compliance point
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	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. The groundwater concentrations at a range of distances from the source at different time intervals are presented in Table 3-2 over.

The range of distances are automatically generated by the model based on the percentages of the compliance point distance (270 m) i.e. 15 m [5%], 75 m [25%], 150 m [50%] and 300 m [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 15m (mg/l)***	***Conc. at 75 m (mg/l)***	***Conc. at 150m (mg/l)***	***Conc. at 300 m (mg/l)***
25	0.5	0	0	0	0
50	0.5	$1.13x10^{-6}$	0	0	0
100	0.5	$1.77x10^{-4}$	0	0	0
500	0.5	0.015	0	0	0
1000	0.5	0.031	$9.12x10^{-8}$	0	0

3.3.4 Discussion of Results

The model was used to predict downgradient concentrations of ammoniacal nitrogen at 15 m, 75 m, 150 m and 300 m downstream of the site after the stated number of years of dispersion (25, 50, 100, 500 and 1000 years) at the defined permanent source concentrations.

The model conservatively assumes a worst-case scenario of a non-depleting source concentration. The source concentrations applied in the model were based on the groundwater concentrations observed in other comparable historical landfills in the wider region.

With respect to ammoniacal nitrogen no exceedances of the groundwater threshold value were observed to take place at any distance and at any time interval. Pollutant dispersion is limited to within 75 m of the site, with concentrations only detected at 75 m after 1000 years. This indicates that groundwater pollution, if occurring, is likely to be localised and will not impact on groundwater quality regionally.

3.4 Impact of Leachate on Receiving Surface Waters

The Tier 2 site investigation and assessment did not identify any major surface water bodies likely to be impacted on by any potential leachate breakout or discharge from the site, however as precautionary approach, in preparing this Tier 3 DQRA an assessment on the potential impact of any discharge from the site on the potential receiving surface water catchment has been conducted. The Maine River located directly south of Castleisland was identified a potential receiving water body for any surface water run-off or leachate breakout from the site.

Groundwater sampling conducted at the site showed installed groundwater wells to be dry on two occasions and at the time of sampling adjacent surface drains were also shown to be dry. Accordingly, the potential impact of the site on the surface water catchments and receiving surface water features was assessed by conducting an assimilative capacity assessment and a mass balance calculation, See Appendix 2, using a theoretical concentration of ammonia as the representative potential pollutant.

3.4.1 Assimilative Capacity Assessment

Table 3-3 shows the assimilative capacity of receiving waters in relation to Ammonia to be **0.838 kg/day**:

Table 3-3: Assimilative Capacity

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)	0.114	Assumed background concentration as per 2014 baseline concentration from EPA monitoring Station RS22M010300 on River Maine
F95 = the 95%ile flow in the river (m^3/s)	0.373	Obtained from online EPA Hydrotool for section of River Maine
Assimilative Capacity kg/day	**0.838**	AC (kg/day) = (0.14 - 0.035) x 0.08 x 86 .4

3.4.2 Potential Impacts of Leachate Breakouts on Receiving Surface Waters

To determine the potential impact 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 was calculated by 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:* *0.08 - 5 l/s*
- *Concentration of ammonia in leachate:* *0.5 mg/l NH_4 assumed based on monitoring at comparable historical landfill sites*
- *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 (0.08 - 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 0.5 mg/l was assumed for this calculation, based on a review of groundwater/leachate monitoring results obtained at comparable historical landfill sites. 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.

3.4.3 Mass Balance Assessment

A mass balance calculation was used to determine the potential change in ammonia concentration within the receiving water downstream of the discharge. The following calculation as shown in Table 3-4 was applied:

Table 3-4: Mass Balance Calculation

$T = (FC + fc)/(F_{Note\ 4} + f)$		
Where:		*Source*
F_1 is the river flow upstream of the discharge (95%ile flow m^3/sec);	0.373	Obtained from online EPA Hydrotool for Maine River
F_2 is the river flow upstream of the discharge (95%ile flow m^3/sec);	0.0343	Obtained from online EPA Hydrotool Glenshearoon River (tributary of River Maine)
C is the concentration of pollutant in the river upstream of the discharge (mean concentration in mg/l);	0.114	Assumed background concentration as per 2014 baseline concentration from EPA monitoring Station RS22M010300
f is the flow of the discharge (m^3/sec);	0.00008[1] to 0.005	Assumed discharge rate based on total estimated rainfall on site and notional leachate breakout rates
c is the maximum concentration of pollutant in the discharge (mg/l);	0.5	Assumed based on review of groundwater/leachate monitoring at comparable historical landfill sites
T is the concentration of pollutant downstream of the discharge.	Varies 0.08 -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

Note 1: estimated total rainfall volume on waste footprint area based on effective rainfall rate of 1,162 mm/year.

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

Assumed Leachate Breakout Flow (l/s)	Assumed Leachate Breakout Flow (m^3/day)	Daily Mass Emission (kg/day) assuming NH_4 concentration 0.891 mg/l	F_1 % Impact Breakout has on of Assimilative Capacity (see Note 3)	F_1 Estimated Downstream Concentration NH_4 (mg/l)	F_2 Estimated Downstream Concentration NH_4 (mg/l)
0.08	6.98	0.003	0.4%	0.114	0.115
1	86.4	0.043	5%	0.115	0.125
2	172.8	0.086	10%	0.116	0.135
3	259.2	0.130	15%	0.117	0.145
4	345.6	0.173	21%	0.118	0.154
5	432	0.216	26%	0.119	0.163

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 0.838 kg/day ammonia (Table 3-3).

Note 4: 2 No locations considered F_1 (River Maine 450 m d/s) and F_2 (Glenshearoon River).

Table 3-5 F_1 results show that in the event of a leachate breakout:

- Leachate discharge flow rates of greater than 5 litres/s (346 m^3/day) will be compliant with S.I. No. 77 of 2019 ('Good' status 95%-ile 0.140 mg/l).
- Leachate discharge flow rates greater than 0.08 litre/s (6.97 m^3/day) will not be compliant with S.I. No. 77 of 2019 ('Good' status mean 0.065 mg/l).

Table 3-5 mass balance calculation predicts that (F_1) leachate breakouts containing of 0.5 mg/l NH_4 will cause downstream concentrations of ammonia 0.114 mg/l to 0.119 mg/l for flow rates between 0.08 and 5 l/s.

Table 3-5 F_2 ammonia concentrations in the Glenshearoon River discharging into the River Maine for leachate breakout discharge rates (0.08 to 5 litres/sec) will not be compliant with:

- S.I. No. 77 of 2019 ('Good' status 95%-ile 0.140 mg/l), at leachate breakout/discharge rates of 3 l/s and 5 l/s
- S.I. No. 77 of 2019 ('Good' status mean 0.065 mg/l).

The leachate breakout estimates of >2 l/s from the site is considered to be very conservative given that the total rainfall at the site is estimated to be 0.08 l/s (6.98 m^3/day).

3.4.4 Discussion of Results

Overall the assimilative capacity assessment to determine potential impacts of leachate breakouts on receiving surface waters shows:

- For a leachate breakout flow rate of <0.08 l/s, and assuming that all potential leachate is discharged to the receiving water, there will be no change in ammonia concentration immediately downstream of the site.
- The River Maine waterbody has an assimilative capacity able to accommodate leachate breakout flows up to 5 l/s for 'Good' status 95%-ile (0.140 mg/l) flows. Background concentrations currently exceed the 'Good' status mean water quality threshold value of 0.065 mg/l based on review of EPA monitoring data.
- The potential impact on a small water body such as the Glenshearoon River is greater for leachate breakout rates of 3 - 5 l/s with predicted downstream ammonia concentrations exceeding the 95%-ile water quality threshold of 0.140 mg/l.

There are no records of leachate breakout occurring on site and the estimate of surface rainfall of 0.08 l/s assumes in this assessment there will be no percolation inputs to groundwater as a worst-case scenario and that such leachate as may be produced will move laterally into adjacent surface waters. However, in the absence of detailed leachate breakout flow rate information being available, the CoP requires a conservative approach to be adopted. Accordingly, the DQRA was carried out and it concluded that no remedial measures will be required to mitigate the risk of leachate breakout contaminating receiving surface waters.

3.5 Landfill Gas Assessment - LandGEM

Monitoring for landfill gases emitted from offsite wells BH01 and BH02 was conducted in October 2019 as part of the Tier 2 site investigation. Both wells yielded methane concentrations of 0.1% v/v and carbon dioxide concentrations of 0.2% v/v and 0.1%v/v 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. Therefore, the risk of gas migration is low. Because the site has a shallow cap gas migration is likely to be via vertical diffuse surface emissions.

Following a site visit it was observed that infrastructure (roads and foundations) had been started for a small housing development to the west and within 100 m landfill footprint. Site investigations also showed the cap thickness to be very shallow and that remedial works may be required to increase cap thickness. Even though the Tier 1 and 2 risk assessments considered the risk of gas migration to be low, the CoP requires a conservative approach to be adopted. Accordingly this Tier 3 risk assessment determined the need for a DQRA to examine potential gas flow rates to facilitate an assessment of risk in the event that diffuse surface flows are prevented, by capping works or other, and gas is required to move laterally.

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 3-6 below.

The results of this model aid in informing what, if any, remedial measures or control measures should be put in place to mitigate or monitor that risk.

Table 3-6: Landfill Gas Monitoring Results October 2019

Date: 24/10/2019						
Sample Station	CH_4	CO_2	O_2	Atmospheric Pressure	Staff Member	Weather
	(% v/v)	(% v/v)	(% v/v)	(mbar)		
BH01	0.1	0.2	21.4	1009	Emily Archer	Scattered cloud with light showers, 8-12°C
BH02	0.1	0.1	21.6			

Although the concentrations are shown to be below the EPA trigger levels for offsite locations, the relative proximity of existing and proposed houses to the site presents a potential landfill gas risk.

Table 3-7: LandGEM Model Inputs

Landfill Characteristics	Input	Source
Landfill Open Year	1970	Exact timeframe of landfill operation is unknown. Assumed site to be operational through the 1970s. Start of filling operations assumed.
Landfill Closure Year	1985	Anecdotal evidence suggests landfilling activities ceased c.1980s
Have Model Closure Calculate Closure Year	Yes	
Waste Design Capacity (megagrams/tonnes)	18,375	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	

Landfill Characteristics	Input	Source
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	1225	Exact waste acceptance quantities per year are unknown. Worst case assumed waste design capacity was filled equally over 1970 to 1985 (15 year) period

3.5.1 Results - LandGEM

LandGEM produces a report based on the model inputs. 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 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 4.594 m^3/hr of methane across the entire site area. This will reduce to 2.787 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	50	30,480	40,247	24,411	0.006	0.003	4.594	2.787
Methane	13	8.143	20,123	12,205	0.002	0.001	2.297	1.393
Carbon dioxide	37	22.340	20,123	12,205	0.004	0.003	2.297	1.393
NMOC	1	0.350	161	98	0.000	0.000	0.018	0.011

The approximate maximum waste deposition footprint was estimated to be approximately 2,192 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 over.

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	0.023	18.361	0.000	0.002
Methane	0.006	9.180	0.000	0.001
Carbon dioxide	0.017	9.180	0.000	0.001
NMOC	0.000	0.073	0.000	0.000

3.5.2 Discussion of Results

The outcome of the LandGEM model predicts a low rate of landfill gas generation in the current year (2019) (4.594 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 40-2,500+ 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 moderate quantity, of 40,247 m^3/year or 4.594 m^3/hour of landfill gas across the whole site is generated and assuming 50% percent of that volume being methane (2.297 m^3). Landfill gas monitoring of groundwater wells conducted in 2019 yielded only trace amounts of methane present, at 0.1% v/v. 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.1970 to 1985) and predicted generation rates from 1985 onwards following closure of the site. The model assumes equal production rates for both methane and carbon dioxide and the pink line for carbon dioxide overlies the blue line for methane.

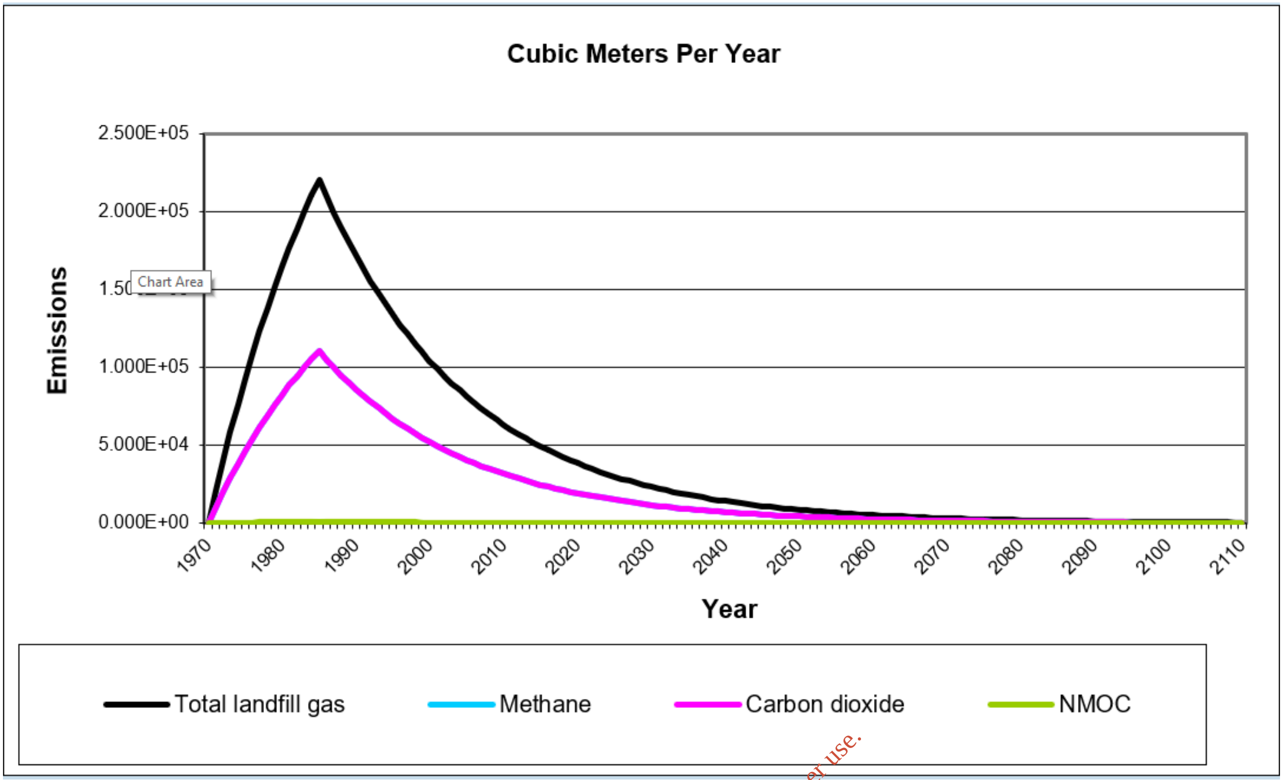


Figure 3-2: LandGEM Landfill Gas Volume Generation Rate

The complete summary report on model inputs and outputs/results generated by LandGEM is included in Appendix 3 of this report. In the vent that capping works are required remedial works to address lateral gas migration will need to be considered.

4. SUMMARY RISK ASSESSMENT FINDINGS

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

This Tier 3 assessment:

- Reviewed the findings of the Tier 1 risk assessment (determined the site to be of moderate risk (Class B).
- Reviewed the findings of the Tier 2 site investigation and risk assessment (determined the site to be of moderate risk (Class B).
- 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.

Subsequent reviews in this Tier 3 assessment determined:

- The site to be a Moderate Risk (Class B), with the main risk being the direct connection between the waste body and the underlying aquifer with the potential to impact on groundwater quality.

The Tier 3 risk assessment confirmed earlier Tier 1 and Tier 2 assessments that leachate does not pose a risk to adjacent surface waters.

During site walkovers it was observed that the site has a local housing development being constructed within 100 m of the site boundary.

4.1.1 Groundwater

The examination of the potential leachate generation from the site determined that on a regional scale the site does not pose a risk to the groundwater quality of the underlying groundwater body with the site only occupying 0.0015% of the groundwater body area. However, the presence of waste which is potentially in direct contact with underlying groundwater does mean that there is an inherent risk. The identification of the underlying aquifer as being a regionally important, karstified aquifer also signifies that there is a direct pathway for groundwater and leachate migration downgradient from the site. Additionally, the presence waste may still pose a risk to groundwater quality at a local level.

The UK EA Remedial Targets Worksheet model was used to examine the potential impacts on aquifer/groundwater and surface water quality. The model did not show any potential exceedances on the groundwater quality threshold for ammoniacal nitrogen. The model does not calculate concentrations based on a depleting source; hence the results are conservative.

Intrusive site investigation showed that the site only comprises a shallow soil cap (maximum 400 mm), therefore it is recommended that a more suitable cap be installed to reduce the infiltration of rainfall to the underlying waste (and to mitigate the risk of poaching by cattle exposing waste in wet weather) and subsequently reduce or eliminate any leachate generation. Further details regarding the proposed landfill cap are discussed in Section 4 below.

4.1.2 Surface Water

An assimilative capacity assessment and mass balance calculations indicate that potential breakout of leachate and discharge to the River Maine is not likely to have an adverse impact on water quality. The receiving river is likely to have sufficient capacity to accommodate any potential leachate emission at the site assuming conservative breakout flow rates of between 0.08 - 5l/s. A mass balance calculation was carried out to predict the potential concentration of ammonia within the river downstream of the site, assuming discharge rates of 0.08 ls to 5l/s of leachate to the river. The calculation predicted the background concentration of 0.114 mg/l would increase by 0 to 0.005 mg/l at each discharge rate accordingly and predict downstream concentrations of 0.114 mg/l to 0.119 mg/l. Calculations showed that leachate breakout at higher rates had the potential to adversely impact on water quality on a smaller receiving waterbody such as the Glenshearoon River, located within the adjacent catchment.

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 elevated gas during surveys and the calculated risk from landfill gas is relatively low.

The primary environmental risks were deemed to be:

- Leachate contaminating groundwater.

Remedial works requiring a cap may increase the risk of lateral gas migration from the site.

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. It is expected that the site will remain as agricultural type land post remediation. Site walkovers and Tier 2 and 3 risk assessment showed:

- Evidence of in-situ MSW waste.
- Evidence of low-level landfill gas emissions.
- Assessment that leachate has potential to contaminate receiving groundwaters.
- 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.

The Tier 3 assessment also determined that in the event that remedial works interfered with the current gas migration pathway which facilitates diffuse vertical migration of landfill gas from the surface of the existing cap, that the proposed works would need to consider the risk of lateral gas migration and possible impacts on adjacent residential units.

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.

5.2 Remediation Plan

5.2.1 Proposed Engineering Solution

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.
- Make provision for passive venting and oxidation if required, of landfill gas to prevent lateral gas migration.
- Make provision for perimeter gas monitoring.

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

- P1767-0201-0001

Engineering solutions will need to consider:

- Maintenance of access following construction of cap along existing site road alignments.
- Outlet for above liner sub surface drainage.
- Appropriate grassed waterway and subsurface drainage measures to manage surface and subsurface drainage flows.
- Management of below liner leachate that may be released in the short term following secondary consolidation.
- Oxidation (using biological filter or similar) or venting of landfill gas as may be required.

5.2.2 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.

5.2.3 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.

5.2.4 Subsoil

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

5.2.5 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.

5.2.6 Surface drainage

Surface runoff from the cap shall runoff onto the adjacent cap.

Surface drainage layouts using grassed waterways shall also accommodate subsurface drainage outfalls from the cap.

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.

5.2.7 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.

5.2.8 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:

- Carry out a gas management risk assessment.
- Mitigate risks of asphyxiation and explosion in any below ground chambers (subsurface drainage or similar).
- Mitigate environmental pollution in accordance with best practice.
- Make provision for perimeter gas monitoring on lands bounding residential properties.

Gas management design proposals shall make reference to and update gas prediction model estimates to facilitate future landfill gas management proposals.

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

Gas oxidation and /or venting technologies shall be fenced and isolated from pedestrian, vehicular or animal activities.

Shallow perimeter wells < 3.0 m deep shall be installed at a spacing no greater than 25 m on the boundary of between the landfill and adjacent residential properties.

5.2.9 Site Access road

The proposed cap shall be placed over existing farm access tracks. These tracks shall be reinstated using a 300 uniformly graded granular fill D_{50} 50 mm formation placed over a separation membrane and geogrid with top surface coincident with cap.

5.2.10 Proposed Groundwater and Surface Water Monitoring Regime

Existing groundwater wells were found to be dry at both monitoring events.

Adjacent lands are free draining and existing watercourses were also dry during the site walkovers.

In the event that groundwater is encountered samples shall be taken every 12 months from groundwater monitoring boreholes BH01 and BH02.

In the event that surface water discharges are evident surface water monitoring shall be carried out at the subsurface drainage outfall location.

The EPA Landfill Monitoring landfill manual outlines recommended, minimum monitoring requirements for groundwater. 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).*

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

Monitoring Parameter[3]	Frequency	Surface Water	Groundwater/Leachate
Fluid Level	Annual	-	-
Flow Rate		-	-
Temperature		✓	✓
Dissolved Oxygen		✓	-
pH		✓	✓

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

Monitoring Parameter[3]	Frequency	Surface Water	Groundwater/Leachate
Electrical Conductivity[4]		✓	✓
Total suspended solids		✓	-
Total dissolved solids		-	✓
Ammonia (as N)		✓	✓
Total oxidized nitrogen (as N)		✓	✓
Total organic carbon		-	✓
Biochemical Oxygen Demand		✓	-
Chemical Oxygen Demand		✓	-
Metals[5]		✓	✓
Total Alkalinity (as $CaCO_3$)		✓	✓
Sulphate		✓	✓
Chloride		✓	✓
Molybdate Reactive Phosphorous[6]		✓	✓
Cyanide (Total)		✓	✓
Fluoride		✓	✓

5.2.11 Proposed Gas Monitoring Regime

Gas monitoring shall be carried out at boreholes BH01 and BH02 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.

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

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

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

- Carbon monoxide.
- Temperature.

5.3 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:

Table 5-2: Castleisland Historic Landfill Renedialtion Cost Estimate

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	***0.5725***	***ha***		
General Site Clearance	0.5725	ha	€20,000.00	€11,450.00
Excavation Works	5725	m^2		
Excavation of Existing Cover/Capping for Reuse/Filling	2863	m^3	€15.00	€42,937.50
Landfill Capping Works	5725			
Preparation of Excavated Surfaces	5725	m^2	€0.75	€4,293.75
Supply and Installation of 50mm Protection Layer	5725	m^2	€1.75	€10,018.75
Supply and Installation of Landfill Gas Collection Layer	5725	m^2	€5.50	€31,490.00
Installation of 1mm LLDPE Cap	5725	m^2	€6.50	€37,212.50
Installation of Sub Surface drainage collection Layer	5725	m^2	€5.50	€31,487.50
Surface drainage	5725	m^2	€1.00	€5,725.00
Importation of 800mm Subsoil Capping Layer	5725	m^2	€8.50	€48,662.50
Importation of 200mm Topsoil Capping Layer	5725	m^2	€3.00	€17,175.00
Seeding	5725	m^2	€2.00	€11,450.00
Fencing	303	m2	€100.00	€30,265.49
Allowance Landfill Gas Migration Network Infrastructure	5000	m^2	€3.00	€15,000.00

Item	Quantity	Unit	Rate, €	Cost
Allowance surface Water Drainage Infrastructure	5725	m^2	€4.00	€22,900.00
Allowance road	360	m^3	€15.00	€5,400.00
Allowance geogrid	360	m^2	€5.00	€1,800.00
Allowance separation membrane	360	m^2	€2.00	€720.00
Biological filter /vent	1	Item	€10,000.00	€10,000.00
Independent CQA	1	Sum	€5,000.00	€5,000.00
Sub-Total 1				**€412,987.99**
Add 10% Contractor Prelims	10.0%			€41,298.80
Sub-Total 2				**€454,286.79**
Add 7.5% Contingency	7.5%			€34,071.51
Grand Total (excl VAT)				**€488,358.30**

Notes

This preliminary cost estimate will be subject to tendered submissions which will reflect prevailing market conditions.

Management of hazardous materials has not been allowed for.

Pricing is based primarily on concept design provided for the site, no detailed designs have been completed.

This cost estimate assumes that materials to be imported are available from local sources.

This cost estimate excludes VAT.

This cost estimate excludes in/deflation.

Costs are largely based on previously tendered rates for similar work or cited reference sources, Prices may have changed in the intervening period.

It is assumed that the new site is serviced assuming public road access.

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	5.00E-01	mg/l	*Assumed concentration based on groundwater monitoring at comparable historical landfill sites.*
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	5.00E+01	m	*Approximate width of site/waste extent based on site investigation*
Plume thickness at source	Sy	1.00E+00	m	*Assumed thickness - waste is placed directly on bedrock*
Saturated aquifer thickness	da	3.00E+00	m	*Assumed - GSI state that majority of groun*
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	3.00E-03	fraction	*Assumed - GSI state tha tgenerally hydraulic gradient of Castlemaine GWB is low (0.001-0.005)*
Hydraulic conductivity of aquifer	K	8.00E-03	m/d	*Assumed single conductivity based on ran*
Distance to compliance point	x	3.00E+02	m	*Hypothetical compliance point at 300m*
Distance (lateral) to compliance point perpendicular to flow direction	z		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	3.00E+01	m	*see options*
Transverse dispersivity	az	3.00E+00	m	*see options*
Vertical dispersivity	ay	3.00E-01	m	*see options*

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		fraction
Organic carbon partition coefficient	Koc		l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc.n}$		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	3.00E+01	7.41E+00	m
Transverse dispersivity	**az**	0.00E+00	3.00E+00	7.41E-01	m
Vertical dispersivity	**ay**	0.00E+00	3.00E-01	7.41E-0[illegible]	

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

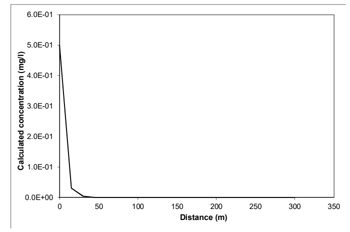
Calculated Parameters

	Variable	Value	Unit
Groundwater flow velocity	v	8.73E-05	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	1.08E-05	m/d
Contaminant concentration at distance x, assuming one-way vertical dispersion	C_{ED}	0.00E+00	mg/l
Attenuation factor (one way vertical dispersion, CO/CED)	**AF**	breakthrough at compliance point	

Remedial Targets

Remedial Target	No impact	**mg/l**	For comparison with measured groundwater concentration.
Domenico - Time Variant			
Distance to compliance point	**300**	**m**	
Concentration of contaminant at compliance point C_{ED}/C_0	**0.00E+00**	**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.



Calculated concentrations for distance-concentration graph

Domenico - Time Variant
From calculation sheet

Distance	Concentration
	mg/l
0	5.0E-01
15.0	3.07E-02
30.0	3.98E-03
45.0	2.58E-04
60.0	7.45E-06
75.0	9.12E-08
90.0	4.61E-10
105.0	0.00E+00
120.0	0.00E+00
135.0	0.00E+00
150.0	0.00E+00
165.0	0.00E+00
180.0	0.00E+00
195.0	0.00E+00
210.0	0.00E+00
225.0	0.00E+00
240.0	0.00E+00
255.0	0.00E+00
270.0	0.00E+00
285.0	0.00E+00
300.0	0.00E+00

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:	Castleisland
Completed by:	EOC
Date:	########
Version:	1.01

FEHILY TIMONEY

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APPENDIX 2

Surface Water 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)	0.114
F95 = the 95%ile flow in the river (m^3/s)	0.373

Note: (60x60x24)/1000 = 86.4

AC kg/d	=	(Cmax	-	Cbak)	x	F95	x	86.4
	=	0.14	-	0.114	x	0.373	x	86.4
	=		0.026		x	0.373	x	86.4
AC kg/d	=	0.838 kg/day						

Emission Concentration (mg/l) 0.5 Assumed based on groundwater monitoring at comparable historical landfill sites

l/s	Flow (m3/day)	Daily Mass Emission (kg/day)	%-age of AC		GSI Effective Rainfall	1162	mm/year
1	86.4	0.043	5%		Rainfall	1.162	m/year
2	172.8	0.086	10%		Waste Footprin	2,192	m2
3	259.2	0.130	15%		Volume of Rain	2547	m3/year
4	345.6	0.173	21%			6.98	m3/day
5	432	0.216	26%			0.00008	m3/s
0.08	6.98	0.003	0.4%			0.08	l/s

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 =	0.373	m^3/sec
C =	0.114	mg/l
f =	86.4	m^3/day
	0.0000800	m^3/sec
c =	0.500	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 = (F x C + *f* x c) / (F + *f*)

1. (0.373 x 0.114 + 0.000 x 0.500) / (0.373 + 0.000)
2. (0.042522 + 0.000) / 0.3731
3. 0.043 / 0.373
4. **T = 0.114 mg/l**

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

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APPENDIX 3

LandGem Model Summary Report

Summary Report

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

Date: Wednesday 12 February 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	**1970**	
Landfill Closure Year (with 80-year limit)	**1984**	
Actual Closure Year (without limit)	***1984***	
Have Model Calculate Closure Year?	**Yes**	
Waste Design Capacity	**18,375**	*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)*
1970	1,225	1,348	0	0
1971	1,225	1,348	1,225	1,348
1972	1,225	1,348	2,450	2,695
1973	1,225	1,348	3,675	4,043
1974	1,225	1,348	4,900	5,390
1975	1,225	1,348	6,125	6,738
1976	1,225	1,348	7,350	8,085
1977	1,225	1,348	8,575	9,433
1978	1,225	1,348	9,800	10,780
1979	1,225	1,348	11,025	12,128
1980	1,225	1,348	12,250	13,475
1981	1,225	1,348	13,475	14,823
1982	1,225	1,348	14,700	16,170
1983	1,225	1,348	15,925	17,518
1984	1,225	1,348	17,150	18,865
1985	0	0	18,375	20,213
1986	0	0	18,375	20,213
1987	0	0	18,375	20,213
1988	0	0	18,375	20,213
1989	0	0	18,375	20,213
1990	0	0	18,375	20,213
1991	0	0	18,375	20,213
1992	0	0	18,375	20,213
1993	0	0	18,375	20,213
1994	0	0	18,375	20,213
1995	0	0	18,375	20,213
1996	0	0	18,375	20,213
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2001	0	0	18,375	20,213
2002	0	0	18,375	20,213
2003	0	0	18,375	20,213
2004	0	0	18,375	20,213
2005	0	0	18,375	20,213
2006	0	0	18,375	20,213
2007	0	0	18,375	20,213
2008	0	0	18,375	20,213
2009	0	0	18,375	20,213

WASTE ACCEPTANCE RATES (Continued)

Year	Waste Accepted		Waste-In-Place	
	(Mg/year)	(short tons/year)	(Mg)	(short tons)
2010	0	0	18,375	20,213
2011	0	0	18,375	20,213
2012	0	0	18,375	20,213
2013	0	0	18,375	20,213
2014	0	0	18,375	20,213
2015	0	0	18,375	20,213
2016	0	0	18,375	20,213
2017	0	0	18,375	20,213
2018	0	0	18,375	20,213
2019	0	0	18,375	20,213
2020	0	0	18,375	20,213
2021	0	0	18,375	20,213
2022	0	0	18,375	20,213
2023	0	0	18,375	20,213
2024	0	0	18,375	20,213
2025	0	0	18,375	20,213
2026	0	0	18,375	20,213
2027	0	0	18,375	20,213
2028	0	0	18,375	20,213
2029	0	0	18,375	20,213
2030	0	0	18,375	20,213
2031	0	0	18,375	20,213
2032	0	0	18,375	20,213
2033	0	0	18,375	20,213
2034	0	0	18,375	20,213
2035	0	0	18,375	20,213
2036	0	0	18,375	20,213
2037	0	0	18,375	20,213
2038	0	0	18,375	20,213
2039	0	0	18,375	20,213
2040	0	0	18,375	20,213
2041	0	0	18,375	20,213
2042	0	0	18,375	20,213
2043	0	0	18,375	20,213
2044	0	0	18,375	20,213
2045	0	0	18,375	20,213
2046	0	0	18,375	20,213
2047	0	0	18,375	20,213
2048	0	0	18,375	20,213
2049	0	0	18,375	20,213

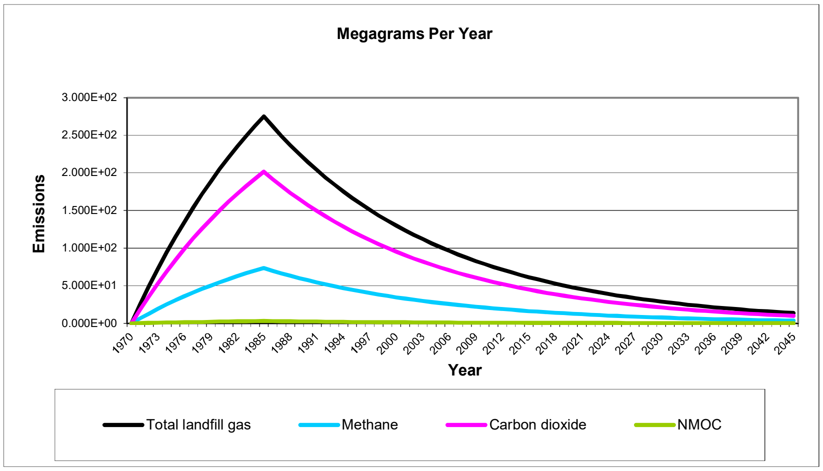
Pollutant Parameters

	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)

	Gas / Pollutant Default Parameters:			User-specified Pollutant Parameters:	
	Compound	Concentration (*ppmv*)	Molecular Weight	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
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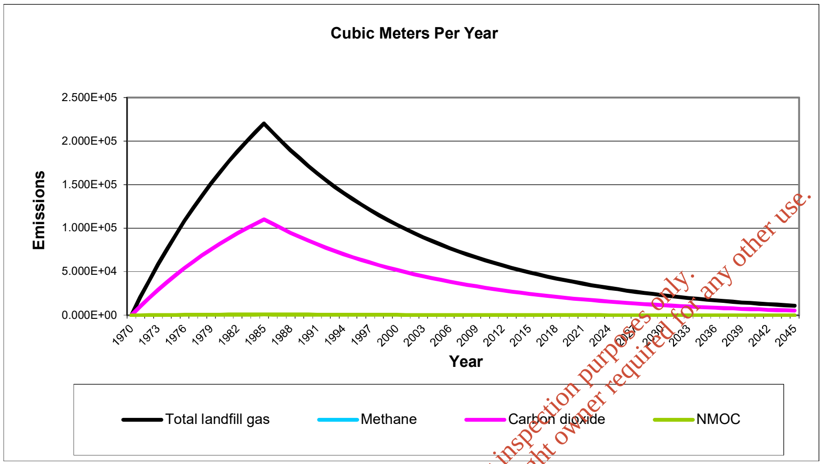
2.500E+02
2.000E+02
1.500E+02
1.000E+02
5.000E+01
0.000E+00
Year
Total landfill gas
Methane
Carbon dioxide
NMOC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Emissions
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2.000E+05
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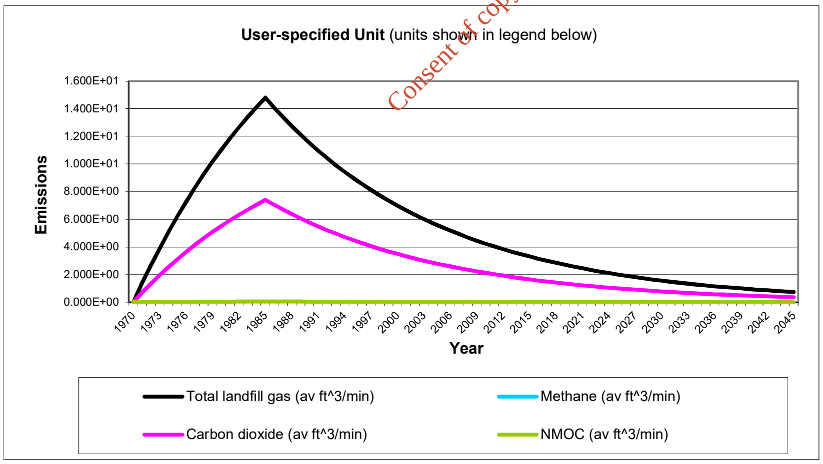
1.000E+05
5.000E+04
0.000E+00
Year
Total landfill gas
Methane
Carbon dioxide
NMOC


User-specified Unit (units shown in legend below)
Emissions
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1.400E+01
1.200E+01
1.000E+01
8.000E+00
6.000E+00
4.000E+00
2.000E+00
0.000E+00
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)
1970	0	0	0	0	0	0
1971	2.543E+01	2.036E+04	1.368E+00	6.793E+00	1.018E+04	6.841E-01
1972	4.962E+01	3.973E+04	2.670E+00	1.325E+01	1.987E+04	1.335E+00
1973	7.263E+01	5.816E+04	3.908E+00	1.940E+01	2.908E+04	1.954E+00
1974	9.452E+01	7.569E+04	5.085E+00	2.525E+01	3.784E+04	2.543E+00
1975	1.153E+02	9.236E+04	6.206E+00	3.081E+01	4.618E+04	3.103E+00
1976	1.351E+02	1.082E+05	7.271E+00	3.610E+01	5.411E+04	3.636E+00
1977	1.540E+02	1.233E+05	8.285E+00	4.113E+01	6.165E+04	4.142E+00
1978	1.719E+02	1.377E+05	9.249E+00	4.592E+01	6.883E+04	4.625E+00
1979	1.890E+02	1.513E+05	1.017E+01	5.047E+01	7.565E+04	5.083E+00
1980	2.052E+02	1.643E+05	1.104E+01	5.480E+01	8.215E+04	5.519E+00
1981	2.206E+02	1.766E+05	1.187E+01	5.892E+01	8.832E+04	5.934E+00
1982	2.353E+02	1.884E+05	1.266E+01	6.284E+01	9.420E+04	6.329E+00
1983	2.492E+02	1.996E+05	1.341E+01	6.657E+01	9.978E+04	6.704E+00
1984	2.625E+02	2.102E+05	1.412E+01	7.012E+01	1.051E+05	7.062E+00
1985	2.751E+02	2.203E+05	1.480E+01	7.349E+01	1.102E+05	7.401E+00
1986	2.617E+02	2.096E+05	1.408E+01	6.991E+01	1.048E+05	7.040E+00
1987	2.489E+02	1.993E+05	1.339E+01	6.650E+01	9.967E+04	6.697E+00
1988	2.368E+02	1.896E+05	1.274E+01	6.325E+01	9.481E+04	6.370E+00
1989	2.253E+02	1.804E+05	1.212E+01	6.017E+01	9.019E+04	6.060E+00
1990	2.143E+02	1.716E+05	1.153E+01	5.723E+01	8.579E+04	5.764E+00
1991	2.038E+02	1.632E+05	1.097E+01	5.444E+01	8.160E+04	5.483E+00
1992	1.939E+02	1.552E+05	1.043E+01	5.179E+01	7.762E+04	5.216E+00
1993	1.844E+02	1.477E+05	9.922E+00	4.926E+01	7.384E+04	4.961E+00
1994	1.754E+02	1.405E+05	9.439E+00	4.686E+01	7.024E+04	4.719E+00
1995	1.669E+02	1.336E+05	8.978E+00	4.457E+01	6.681E+04	4.489E+00
1996	1.587E+02	1.271E+05	8.540E+00	4.240E+01	6.355E+04	4.270E+00
1997	1.510E+02	1.209E+05	8.124E+00	4.033E+01	6.045E+04	4.062E+00
1998	1.436E+02	1.150E+05	7.728E+00	3.836E+01	5.751E+04	3.864E+00
1999	1.366E+02	1.094E+05	7.351E+00	3.649E+01	5.470E+04	3.675E+00
2000	1.300E+02	1.041E+05	6.992E+00	3.471E+01	5.203E+04	3.496E+00
2001	1.236E+02	9.899E+04	6.651E+00	3.302E+01	4.950E+04	3.326E+00
2002	1.176E+02	9.416E+04	6.327E+00	3.141E+01	4.708E+04	3.163E+00
2003	1.119E+02	8.957E+04	6.018E+00	2.988E+01	4.479E+04	3.009E+00
2004	1.064E+02	8.520E+04	5.725E+00	2.842E+01	4.260E+04	2.862E+00
2005	1.012E+02	8.105E+04	5.446E+00	2.704E+01	4.052E+04	2.723E+00
2006	9.628E+01	7.709E+04	5.180E+00	2.572E+01	3.855E+04	2.590E+00
2007	9.158E+01	7.333E+04	4.927E+00	2.446E+01	3.667E+04	2.464E+00
2008	8.712E+01	6.976E+04	4.687E+00	2.327E+01	3.488E+04	2.344E+00
2009	8.287E+01	6.636E+04	4.458E+00	2.213E+01	3.318E+04	2.229E+00
2010	7.883E+01	6.312E+04	4.241E+00	2.106E+01	3.156E+04	2.121E+00
2011	7.498E+01	6.004E+04	4.034E+00	2.003E+01	3.002E+04	2.017E+00
2012	7.132E+01	5.711E+04	3.837E+00	1.905E+01	2.856E+04	1.919E+00
2013	6.785E+01	5.433E+04	3.650E+00	1.812E+01	2.716E+04	1.825E+00
2014	6.454E+01	5.168E+04	3.472E+00	1.724E+01	2.584E+04	1.736E+00
2015	6.139E+01	4.916E+04	3.303E+00	1.640E+01	2.458E+04	1.651E+00
2016	5.840E+01	4.676E+04	3.142E+00	1.560E+01	2.338E+04	1.571E+00
2017	5.555E+01	4.448E+04	2.989E+00	1.484E+01	2.224E+04	1.494E+00
2018	5.284E+01	4.231E+04	2.843E+00	1.411E+01	2.116E+04	1.421E+00
2019	5.026E+01	4.025E+04	2.704E+00	1.343E+01	2.012E+04	1.352E+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)*
2020	4.781E+01	3.828E+04	2.572E+00	1.277E+01	1.914E+04	1.286E+00
2021	4.548E+01	3.642E+04	2.447E+00	1.215E+01	1.821E+04	1.223E+00
2022	4.326E+01	3.464E+04	2.328E+00	1.156E+01	1.732E+04	1.164E+00
2023	4.115E+01	3.295E+04	2.214E+00	1.099E+01	1.648E+04	1.107E+00
2024	3.914E+01	3.134E+04	2.106E+00	1.046E+01	1.567E+04	1.053E+00
2025	3.723E+01	2.982E+04	2.003E+00	9.946E+00	1.491E+04	1.002E+00
2026	3.542E+01	2.836E+04	1.906E+00	9.461E+00	1.418E+04	9.528E-01
2027	3.369E+01	2.698E+04	1.813E+00	8.999E+00	1.349E+04	9.063E-01
2028	3.205E+01	2.566E+04	1.724E+00	8.560E+00	1.283E+04	8.621E-01
2029	3.048E+01	2.441E+04	1.640E+00	8.143E+00	1.221E+04	8.201E-01
2030	2.900E+01	2.322E+04	1.560E+00	7.746E+00	1.161E+04	7.801E-01
2031	2.758E+01	2.209E+04	1.484E+00	7.368E+00	1.104E+04	7.420E-01
2032	2.624E+01	2.101E+04	1.412E+00	7.009E+00	1.051E+04	7.059E-01
2033	2.496E+01	1.999E+04	1.343E+00	6.667E+00	9.993E+03	6.714E-01
2034	2.374E+01	1.901E+04	1.277E+00	6.342E+00	9.506E+03	6.387E-01
2035	2.258E+01	1.808E+04	1.215E+00	6.032E+00	9.042E+03	6.075E-01
2036	2.148E+01	1.720E+04	1.156E+00	5.738E+00	8.601E+03	5.779E-01
2037	2.043E+01	1.636E+04	1.099E+00	5.458E+00	8.182E+03	5.497E-01
2038	1.944E+01	1.557E+04	1.046E+00	5.192E+00	7.783E+03	5.229E-01
2039	1.849E+01	1.481E+04	9.948E-01	4.939E+00	7.403E+03	4.974E-01
2040	1.759E+01	1.408E+04	9.463E-01	4.698E+00	7.042E+03	4.731E-01
2041	1.673E+01	1.340E+04	9.001E-01	4.469E+00	6.699E+03	4.501E-01
2042	1.591E+01	1.274E+04	8.562E-01	4.251E+00	6.372E+03	4.281E-01
2043	1.514E+01	1.212E+04	8.145E-01	4.044E+00	6.061E+03	4.072E-01
2044	1.440E+01	1.153E+04	7.748E-01	3.846E+00	5.765E+03	3.874E-01
2045	1.370E+01	1.097E+04	7.370E-01	3.659E+00	5.484E+03	3.685E-01
2046	1.303E+01	1.043E+04	7.010E-01	3.480E+00	5.217E+03	3.505E-01
2047	1.239E+01	9.925E+03	6.668E-01	3.311E+00	4.962E+03	3.334E-01
2048	1.179E+01	9.441E+03	6.343E-01	3.149E+00	4.720E+03	3.172E-01
2049	1.121E+01	8.980E+03	6.034E-01	2.996E+00	4.490E+03	3.017E-01
2050	1.067E+01	8.542E+03	5.740E-01	2.849E+00	4.271E+03	2.870E-01
2051	1.015E+01	8.126E+03	5.460E-01	2.711E+00	4.063E+03	2.730E-01
2052	9.653E+00	7.729E+03	5.193E-01	2.578E+00	3.865E+03	2.597E-01
2053	9.182E+00	7.352E+03	4.940E-01	2.453E+00	3.676E+03	2.470E-01
2054	8.734E+00	6.994E+03	4.699E-01	2.333E+00	3.497E+03	2.350E-01
2055	8.308E+00	6.653E+03	4.470E-01	2.219E+00	3.326E+03	2.235E-01
2056	7.903E+00	6.328E+03	4.252E-01	2.111E+00	3.164E+03	2.126E-01
2057	7.518E+00	6.020E+03	4.045E-01	2.008E+00	3.010E+03	2.022E-01
2058	7.151E+00	5.726E+03	3.847E-01	1.910E+00	2.863E+03	1.924E-01
2059	6.802E+00	5.447E+03	3.660E-01	1.817E+00	2.723E+03	1.830E-01
2060	6.470E+00	5.181E+03	3.481E-01	1.728E+00	2.591E+03	1.741E-01
2061	6.155E+00	4.928E+03	3.311E-01	1.644E+00	2.464E+03	1.656E-01
2062	5.855E+00	4.688E+03	3.150E-01	1.564E+00	2.344E+03	1.575E-01
2063	5.569E+00	4.459E+03	2.996E-01	1.488E+00	2.230E+03	1.498E-01
2064	5.297E+00	4.242E+03	2.850E-01	1.415E+00	2.121E+03	1.425E-01
2065	5.039E+00	4.035E+03	2.711E-01	1.346E+00	2.018E+03	1.356E-01
2066	4.793E+00	3.838E+03	2.579E-01	1.280E+00	1.919E+03	1.289E-01
2067	4.560E+00	3.651E+03	2.453E-01	1.218E+00	1.826E+03	1.227E-01
2068	4.337E+00	3.473E+03	2.334E-01	1.159E+00	1.737E+03	1.167E-01
2069	4.126E+00	3.304E+03	2.220E-01	1.102E+00	1.652E+03	1.110E-01
2070	3.924E+00	3.143E+03	2.111E-01	1.048E+00	1.571E+03	1.056E-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)*
2071	3.733E+00	2.989E+03	2.008E-01	9.971E-01	1.495E+03	1.004E-01
2072	3.551E+00	2.843E+03	1.911E-01	9.485E-01	1.422E+03	9.553E-02
2073	3.378E+00	2.705E+03	1.817E-01	9.023E-01	1.352E+03	9.087E-02
2074	3.213E+00	2.573E+03	1.729E-01	8.583E-01	1.286E+03	8.644E-02
2075	3.056E+00	2.447E+03	1.644E-01	8.164E-01	1.224E+03	8.222E-02
2076	2.907E+00	2.328E+03	1.564E-01	7.766E-01	1.164E+03	7.821E-02
2077	2.766E+00	2.215E+03	1.488E-01	7.387E-01	1.107E+03	7.440E-02
2078	2.631E+00	2.107E+03	1.415E-01	7.027E-01	1.053E+03	7.077E-02
2079	2.502E+00	2.004E+03	1.346E-01	6.684E-01	1.002E+03	6.732E-02
2080	2.380E+00	1.906E+03	1.281E-01	6.358E-01	9.530E+02	6.403E-02
2081	2.264E+00	1.813E+03	1.218E-01	6.048E-01	9.065E+02	6.091E-02
2082	2.154E+00	1.725E+03	1.159E-01	5.753E-01	8.623E+02	5.794E-02
2083	2.049E+00	1.641E+03	1.102E-01	5.472E-01	8.203E+02	5.511E-02
2084	1.949E+00	1.561E+03	1.049E-01	5.206E-01	7.803E+02	5.243E-02
2085	1.854E+00	1.484E+03	9.974E-02	4.952E-01	7.422E+02	4.987E-02
2086	1.763E+00	1.412E+03	9.487E-02	4.710E-01	7.060E+02	4.744E-02
2087	1.677E+00	1.343E+03	9.025E-02	4.480E-01	6.716E+02	4.512E-02
2088	1.596E+00	1.278E+03	8.585E-02	4.262E-01	6.388E+02	4.292E-02
2089	1.518E+00	1.215E+03	8.166E-02	4.054E-01	6.077E+02	4.083E-02
2090	1.444E+00	1.156E+03	7.768E-02	3.856E-01	5.780E+02	3.884E-02
2091	1.373E+00	1.100E+03	7.389E-02	3.668E-01	5.498E+02	3.694E-02
2092	1.306E+00	1.046E+03	7.028E-02	3.489E-01	5.230E+02	3.514E-02
2093	1.243E+00	9.950E+02	6.686E-02	3.319E-01	4.975E+02	3.343E-02
2094	1.182E+00	9.465E+02	6.360E-02	3.157E-01	4.733E+02	3.180E-02
2095	1.124E+00	9.004E+02	6.049E-02	3.003E-01	4.502E+02	3.025E-02
2096	1.070E+00	8.564E+02	5.754E-02	2.857E-01	4.282E+02	2.877E-02
2097	1.017E+00	8.147E+02	5.474E-02	2.718E-01	4.073E+02	2.737E-02
2098	9.678E-01	7.749E+02	5.207E-02	2.585E-01	3.875E+02	2.603E-02
2099	9.206E-01	7.371E+02	4.953E-02	2.459E-01	3.686E+02	2.476E-02
2100	8.757E-01	7.012E+02	4.711E-02	2.339E-01	3.506E+02	2.356E-02
2101	8.330E-01	6.670E+02	4.482E-02	2.225E-01	3.335E+02	2.241E-02
2102	7.923E-01	6.345E+02	4.263E-02	2.116E-01	3.172E+02	2.131E-02
2103	7.537E-01	6.035E+02	4.055E-02	2.013E-01	3.018E+02	2.028E-02
2104	7.169E-01	5.741E+02	3.857E-02	1.915E-01	2.870E+02	1.929E-02
2105	6.820E-01	5.461E+02	3.669E-02	1.822E-01	2.730E+02	1.835E-02
2106	6.487E-01	5.195E+02	3.490E-02	1.733E-01	2.597E+02	1.745E-02
2107	6.171E-01	4.941E+02	3.320E-02	1.648E-01	2.471E+02	1.660E-02
2108	5.870E-01	4.700E+02	3.158E-02	1.568E-01	2.350E+02	1.579E-02
2109	5.584E-01	4.471E+02	3.004E-02	1.491E-01	2.236E+02	1.502E-02
2110	5.311E-01	4.253E+02	2.858E-02	1.419E-01	2.126E+02	1.429E-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)*
1970	0	0	0	0	0	0
1971	1.864E+01	1.018E+04	6.841E-01	2.920E-01	8.146E+01	5.473E-03
1972	3.637E+01	1.987E+04	1.335E+00	5.697E-01	1.589E+02	1.068E-02
1973	5.323E+01	2.908E+04	1.954E+00	8.339E-01	2.326E+02	1.563E-02
1974	6.927E+01	3.784E+04	2.543E+00	1.085E+00	3.028E+02	2.034E-02
1975	8.453E+01	4.618E+04	3.103E+00	1.324E+00	3.694E+02	2.482E-02
1976	9.905E+01	5.411E+04	3.636E+00	1.552E+00	4.329E+02	2.908E-02
1977	1.129E+02	6.165E+04	4.142E+00	1.768E+00	4.932E+02	3.314E-02
1978	1.260E+02	6.883E+04	4.625E+00	1.974E+00	5.506E+02	3.700E-02
1979	1.385E+02	7.565E+04	5.083E+00	2.169E+00	6.052E+02	4.066E-02
1980	1.504E+02	8.215E+04	5.519E+00	2.356E+00	6.572E+02	4.415E-02
1981	1.617E+02	8.832E+04	5.934E+00	2.533E+00	7.066E+02	4.747E-02
1982	1.724E+02	9.420E+04	6.329E+00	2.701E+00	7.536E+02	5.063E-02
1983	1.827E+02	9.978E+04	6.704E+00	2.861E+00	7.983E+02	5.364E-02
1984	1.924E+02	1.051E+05	7.062E+00	3.014E+00	8.408E+02	5.649E-02
1985	2.016E+02	1.102E+05	7.401E+00	3.159E+00	8.812E+02	5.921E-02
1986	1.918E+02	1.048E+05	7.040E+00	3.005E+00	8.383E+02	5.632E-02
1987	1.824E+02	9.967E+04	6.697E+00	2.858E+00	7.974E+02	5.358E-02
1988	1.736E+02	9.481E+04	6.370E+00	2.719E+00	7.585E+02	5.096E-02
1989	1.651E+02	9.019E+04	6.060E+00	2.586E+00	7.215E+02	4.848E-02
1990	1.570E+02	8.579E+04	5.764E+00	2.460E+00	6.863E+02	4.611E-02
1991	1.494E+02	8.160E+04	5.483E+00	2.340E+00	6.528E+02	4.386E-02
1992	1.421E+02	7.762E+04	5.216E+00	2.226E+00	6.210E+02	4.172E-02
1993	1.352E+02	7.384E+04	4.961E+00	2.117E+00	5.907E+02	3.969E-02
1994	1.286E+02	7.024E+04	4.719E+00	2.014E+00	5.619E+02	3.775E-02
1995	1.223E+02	6.681E+04	4.489E+00	1.916E+00	5.345E+02	3.591E-02
1996	1.163E+02	6.355E+04	4.270E+00	1.822E+00	5.084E+02	3.416E-02
1997	1.107E+02	6.045E+04	4.062E+00	1.734E+00	4.836E+02	3.250E-02
1998	1.053E+02	5.751E+04	3.864E+00	1.649E+00	4.600E+02	3.091E-02
1999	1.001E+02	5.470E+04	3.675E+00	1.569E+00	4.376E+02	2.940E-02
2000	9.525E+01	5.203E+04	3.496E+00	1.492E+00	4.163E+02	2.797E-02
2001	9.060E+01	4.950E+04	3.326E+00	1.419E+00	3.960E+02	2.660E-02
2002	8.618E+01	4.708E+04	3.163E+00	1.350E+00	3.767E+02	2.531E-02
2003	8.198E+01	4.479E+04	3.009E+00	1.284E+00	3.583E+02	2.407E-02
2004	7.798E+01	4.260E+04	2.862E+00	1.222E+00	3.408E+02	2.290E-02
2005	7.418E+01	4.052E+04	2.723E+00	1.162E+00	3.242E+02	2.178E-02
2006	7.056E+01	3.855E+04	2.590E+00	1.105E+00	3.084E+02	2.072E-02
2007	6.712E+01	3.667E+04	2.464E+00	1.051E+00	2.933E+02	1.971E-02
2008	6.385E+01	3.488E+04	2.344E+00	1.000E+00	2.790E+02	1.875E-02
2009	6.073E+01	3.318E+04	2.229E+00	9.514E-01	2.654E+02	1.783E-02
2010	5.777E+01	3.156E+04	2.121E+00	9.050E-01	2.525E+02	1.696E-02
2011	5.495E+01	3.002E+04	2.017E+00	8.609E-01	2.402E+02	1.614E-02
2012	5.227E+01	2.856E+04	1.919E+00	8.189E-01	2.285E+02	1.535E-02
2013	4.972E+01	2.716E+04	1.825E+00	7.789E-01	2.173E+02	1.460E-02
2014	4.730E+01	2.584E+04	1.736E+00	7.410E-01	2.067E+02	1.389E-02
2015	4.499E+01	2.458E+04	1.651E+00	7.048E-01	1.966E+02	1.321E-02
2016	4.280E+01	2.338E+04	1.571E+00	6.704E-01	1.870E+02	1.257E-02
2017	4.071E+01	2.224E+04	1.494E+00	6.377E-01	1.779E+02	1.195E-02
2018	3.872E+01	2.116E+04	1.421E+00	6.066E-01	1.692E+02	1.137E-02
2019	3.684E+01	2.012E+04	1.352E+00	5.771E-01	1.610E+02	1.082E-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)
2020	3.504E+01	1.914E+04	1.286E+00	5.489E-01	1.531E+02	1.029E-02
2021	3.333E+01	1.821E+04	1.223E+00	5.221E-01	1.457E+02	9.787E-03
2022	3.170E+01	1.732E+04	1.164E+00	4.967E-01	1.386E+02	9.310E-03
2023	3.016E+01	1.648E+04	1.107E+00	4.725E-01	1.318E+02	8.856E-03
2024	2.869E+01	1.567E+04	1.053E+00	4.494E-01	1.254E+02	8.424E-03
2025	2.729E+01	1.491E+04	1.002E+00	4.275E-01	1.193E+02	8.013E-03
2026	2.596E+01	1.418E+04	9.528E-01	4.066E-01	1.134E+02	7.622E-03
2027	2.469E+01	1.349E+04	9.063E-01	3.868E-01	1.079E+02	7.251E-03
2028	2.349E+01	1.283E+04	8.621E-01	3.679E-01	1.027E+02	6.897E-03
2029	2.234E+01	1.221E+04	8.201E-01	3.500E-01	9.764E+01	6.561E-03
2030	2.125E+01	1.161E+04	7.801E-01	3.329E-01	9.288E+01	6.241E-03
2031	2.022E+01	1.104E+04	7.420E-01	3.167E-01	8.835E+01	5.936E-03
2032	1.923E+01	1.051E+04	7.059E-01	3.012E-01	8.404E+01	5.647E-03
2033	1.829E+01	9.993E+03	6.714E-01	2.866E-01	7.994E+01	5.371E-03
2034	1.740E+01	9.506E+03	6.387E-01	2.726E-01	7.605E+01	5.109E-03
2035	1.655E+01	9.042E+03	6.075E-01	2.593E-01	7.234E+01	4.860E-03
2036	1.574E+01	8.601E+03	5.779E-01	2.466E-01	6.881E+01	4.623E-03
2037	1.498E+01	8.182E+03	5.497E-01	2.346E-01	6.545E+01	4.398E-03
2038	1.425E+01	7.783E+03	5.229E-01	2.232E-01	6.226E+01	4.183E-03
2039	1.355E+01	7.403E+03	4.974E-01	2.123E-01	5.922E+01	3.979E-03
2040	1.289E+01	7.042E+03	4.731E-01	2.019E-01	5.634E+01	3.785E-03
2041	1.226E+01	6.699E+03	4.501E-01	1.921E-01	5.359E+01	3.601E-03
2042	1.166E+01	6.372E+03	4.281E-01	1.827E-01	5.097E+01	3.425E-03
2043	1.109E+01	6.061E+03	4.072E-01	1.738E-01	4.849E+01	3.258E-03
2044	1.055E+01	5.765E+03	3.874E-01	1.653E-01	4.612E+01	3.099E-03
2045	1.004E+01	5.484E+03	3.685E-01	1.573E-01	4.387E+01	2.948E-03
2046	9.549E+00	5.217E+03	3.505E-01	1.496E-01	4.173E+01	2.804E-03
2047	9.084E+00	4.962E+03	3.334E-01	1.423E-01	3.970E+01	2.667E-03
2048	8.641E+00	4.720E+03	3.172E-01	1.354E-01	3.776E+01	2.537E-03
2049	8.219E+00	4.490E+03	3.017E-01	1.288E-01	3.592E+01	2.414E-03
2050	7.818E+00	4.271E+03	2.870E-01	1.225E-01	3.417E+01	2.296E-03
2051	7.437E+00	4.063E+03	2.730E-01	1.165E-01	3.250E+01	2.184E-03
2052	7.074E+00	3.865E+03	2.597E-01	1.108E-01	3.092E+01	2.077E-03
2053	6.729E+00	3.676E+03	2.470E-01	1.054E-01	2.941E+01	1.976E-03
2054	6.401E+00	3.497E+03	2.350E-01	1.003E-01	2.798E+01	1.880E-03
2055	6.089E+00	3.326E+03	2.235E-01	9.539E-02	2.661E+01	1.788E-03
2056	5.792E+00	3.164E+03	2.126E-01	9.073E-02	2.531E+01	1.701E-03
2057	5.509E+00	3.010E+03	2.022E-01	8.631E-02	2.408E+01	1.618E-03
2058	5.241E+00	2.863E+03	1.924E-01	8.210E-02	2.290E+01	1.539E-03
2059	4.985E+00	2.723E+03	1.830E-01	7.810E-02	2.179E+01	1.464E-03
2060	4.742E+00	2.591E+03	1.741E-01	7.429E-02	2.072E+01	1.392E-03
2061	4.511E+00	2.464E+03	1.656E-01	7.066E-02	1.971E+01	1.325E-03
2062	4.291E+00	2.344E+03	1.575E-01	6.722E-02	1.875E+01	1.260E-03
2063	4.082E+00	2.230E+03	1.498E-01	6.394E-02	1.784E+01	1.199E-03
2064	3.882E+00	2.121E+03	1.425E-01	6.082E-02	1.697E+01	1.140E-03
2065	3.693E+00	2.018E+03	1.356E-01	5.785E-02	1.614E+01	1.084E-03
2066	3.513E+00	1.919E+03	1.289E-01	5.503E-02	1.535E+01	1.032E-03
2067	3.342E+00	1.826E+03	1.227E-01	5.235E-02	1.460E+01	9.813E-04
2068	3.179E+00	1.737E+03	1.167E-01	4.980E-02	1.389E+01	9.334E-04
2069	3.024E+00	1.652E+03	1.110E-01	4.737E-02	1.321E+01	8.879E-04
2070	2.876E+00	1.571E+03	1.056E-01	4.506E-02	1.257E+01	8.446E-04

Results (Continued)

Year	Carbon dioxide			NMOC		
	(Mg/year)	*(m^3/year)*	*(av ft^3/min)*	*(Mg/year)*	*(m^3/year)*	*(av ft^3/min)*
2071	2.736E+00	1.495E+03	1.004E-01	4.286E-02	1.196E+01	8.034E-04
2072	2.603E+00	1.422E+03	9.553E-02	4.077E-02	1.137E+01	7.642E-04
2073	2.476E+00	1.352E+03	9.087E-02	3.878E-02	1.082E+01	7.269E-04
2074	2.355E+00	1.286E+03	8.644E-02	3.689E-02	1.029E+01	6.915E-04
2075	2.240E+00	1.224E+03	8.222E-02	3.509E-02	9.790E+00	6.578E-04
2076	2.131E+00	1.164E+03	7.821E-02	3.338E-02	9.312E+00	6.257E-04
2077	2.027E+00	1.107E+03	7.440E-02	3.175E-02	8.858E+00	5.952E-04
2078	1.928E+00	1.053E+03	7.077E-02	3.020E-02	8.426E+00	5.661E-04
2079	1.834E+00	1.002E+03	6.732E-02	2.873E-02	8.015E+00	5.385E-04
2080	1.745E+00	9.530E+02	6.403E-02	2.733E-02	7.624E+00	5.123E-04
2081	1.659E+00	9.065E+02	6.091E-02	2.600E-02	7.252E+00	4.873E-04
2082	1.578E+00	8.623E+02	5.794E-02	2.473E-02	6.899E+00	4.635E-04
2083	1.502E+00	8.203E+02	5.511E-02	2.352E-02	6.562E+00	4.409E-04
2084	1.428E+00	7.803E+02	5.243E-02	2.237E-02	6.242E+00	4.194E-04
2085	1.359E+00	7.422E+02	4.987E-02	2.128E-02	5.938E+00	3.990E-04
2086	1.292E+00	7.060E+02	4.744E-02	2.025E-02	5.648E+00	3.795E-04
2087	1.229E+00	6.716E+02	4.512E-02	1.926E-02	5.373E+00	3.610E-04
2088	1.169E+00	6.388E+02	4.292E-02	1.832E-02	5.111E+00	3.434E-04
2089	1.112E+00	6.077E+02	4.083E-02	1.743E-02	4.861E+00	3.266E-04
2090	1.058E+00	5.780E+02	3.884E-02	1.658E-02	4.624E+00	3.107E-04
2091	1.006E+00	5.498E+02	3.694E-02	1.577E-02	4.399E+00	2.956E-04
2092	9.574E-01	5.230E+02	3.514E-02	1.500E-02	4.184E+00	2.811E-04
2093	9.107E-01	4.975E+02	3.343E-02	1.427E-02	3.980E+00	2.674E-04
2094	8.663E-01	4.733E+02	3.180E-02	1.357E-02	3.786E+00	2.544E-04
2095	8.240E-01	4.502E+02	3.025E-02	1.291E-02	3.601E+00	2.420E-04
2096	7.839E-01	4.282E+02	2.877E-02	1.228E-02	3.426E+00	2.302E-04
2097	7.456E-01	4.073E+02	2.737E-02	1.168E-02	3.259E+00	2.190E-04
2098	7.093E-01	3.875E+02	2.603E-02	1.111E-02	3.100E+00	2.083E-04
2099	6.747E-01	3.686E+02	2.476E-02	1.057E-02	2.949E+00	1.981E-04
2100	6.418E-01	3.506E+02	2.356E-02	1.005E-02	2.805E+00	1.885E-04
2101	6.105E-01	3.335E+02	2.241E-02	9.563E-03	2.668E+00	1.793E-04
2102	5.807E-01	3.172E+02	2.131E-02	9.097E-03	2.538E+00	1.705E-04
2103	5.524E-01	3.018E+02	2.028E-02	8.653E-03	2.414E+00	1.622E-04
2104	5.254E-01	2.870E+02	1.929E-02	8.231E-03	2.296E+00	1.543E-04
2105	4.998E-01	2.730E+02	1.835E-02	7.830E-03	2.184E+00	1.468E-04
2106	4.754E-01	2.597E+02	1.745E-02	7.448E-03	2.078E+00	1.396E-04
2107	4.522E-01	2.471E+02	1.660E-02	7.085E-03	1.976E+00	1.328E-04
2108	4.302E-01	2.350E+02	1.579E-02	6.739E-03	1.880E+00	1.263E-04
2109	4.092E-01	2.236E+02	1.502E-02	6.410E-03	1.788E+00	1.202E-04
2110	3.893E-01	2.126E+02	1.429E-02	6.098E-03	1.701E+00	1.143E-04

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APPENDIX 4

Remediation Plan Drawings

Chainage	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000
Finished Cap		46.284	45.987	45.744	45.726	45.596	45.386	45.185	
Ex. Ground	45.308	45.287	44.917	44.625	44.331	43.960	44.077	44.297	43.492
Lvl Difference		-0.998	-1.070	-1.118	-1.395	-1.635	-1.309	-0.889	

SECTION X1

Scale 1:100

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Rev.	Description	App By	Date
A	ISSUE FOR APPROVAL	CJC	03.03.20

PROJECT	MID KERRY LANDFILL ASSESSMENTS
CLIENT	KERRY COUNTY COUNCIL
SHEET	CASTLEISLAND LANDFILL PLAN & SECTION OF PROPOSED CAP
Date	03.03.20
Project number	P1767
Scale (@ A1-)	As Shown
Drawn by	SK
Checked by	CJC
Drawing Number	P1767-0201-0001
Rev	A

O:\ACAD\2019\P1767\P1767-0201-0001

03 March 2020

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