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TUAM HISTORICAL LANDFILL SITE

TIER 3 ENVIRONMENTAL RISK ASSESSMENT HISTORICAL LANDFILL AT TUAM, CO. GALWAY

Prepared for: Galway County Council

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HISTORICAL LANDFILL AT TUAM, CO. GALWAY

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Abstract: This report represents the findings of a Tier 3 assessment carried out at Tuam Historical Landfill, Co. Galway, conducted in accordance with the EPA Code of Practice for unregulated landfill sites.

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1. INTRODUCTION

1.1 Overview

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

- GCC Tier 1 risk assessment findings and classifications;
- GCC Closure and Remediation Plan (1999);
- Tier 2 risk assessment (FT, 2020).

The Tier 3 risk assessment is 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

The Tier 1 risk assessment determined that the overall risk score for Tuam historical landfill was 70%, resulting in a risk classification of High (Class A), with a score of 70% being applied to SPR linkages SPR 10 and SPR11, referring to potential of landfill gas to human receptors via vertical and lateral migration.

1.3 Tier 2 Site Investigation

FT was appointed by Galway County Council to:

- Carry out site investigations and environmental monitoring;
- Prepare a Tier 2 environmental risk assessment report on the Tuam historical landfill, located at Tuam, Co. Galway.

Tuam site investigation included the following elements:

- 1 no. Topographical Survey;
- 1 No. Geophysical survey (2D resistivity, EM31 Ground Conductivity and seismic refraction profiling);
- Installation of 2 no. groundwater monitoring wells;
- Excavation of 5 No. trial pits;
- Groundwater and surface water sampling and landfill gas monitoring;
- Waste/made ground sampling and analysis;
- Factual reporting.

The findings of the site investigation suggested the waste material comprised mixed municipal waste material that was deposited in a single infill area with an estimated footprint of 23,300 m^2. Trial pits TP01, TP02 and TP03 were excavated within the previously capped portion of the landfill area. In each of these trial pits a Geosynthetic Clay Liner (GCL) cap was encountered at depths of 0.4m, 0.2m and 0.2m b.g.l at each trial pits respectively. The presence of waste however was also confirmed from previous site investigations (pre-remediation) conducted at the site which are detailed in site closure and remediation plan prepared in 1999. Three boreholes BH1, BH2 and BH3 were excavated within the landfill and recorded the presence of made ground and landfill material.

Waste material was recorded at the following depths:

- BH1 - 0.2m - 5.0m bgl (0.2m of topsoil cover);
- BH2 - 0.2m - 5.0m bgl (0.2m of topsoil cover);
- BH3 - 0.0m - 9.0m bgl (0.0m of topsoil cover).

The Tier 2 assessment estimated a waste volume of 145,407.7 m^3 based on a combination of the geophysical survey profiles and borehole logs for previously installed in waste boreholes (BH1 - BH3) was determined. Applying an assumed waste density of 1.6 tn/m^3 this equates to 232,652 tonnes of waste.

The current landfill cap does not appear to match the proposed capping design as specified within the Closure and Remediation Plan.

1.3.1 Closure and Remediation Plan for Tuam Landfill

Preparation of the Tier 2 assessment and this Tier 3 assessment included the review of a Closure and Remediation Plan (CMP) report for the Tuam historical landfill, prepared in 1999, following closure of the site.

The report detailed the outcome of a programme of site investigation and environmental monitoring, a proposed remediation plan for the site and associated cost estimates to the complete the work. The aims of the CMP were:

- *"To reduce leachate generation;*
- *To separate leachate from surface water as much as practicably possible (by preventing leachate from seeping out through the sides of the landfill;*
- *To control landfill gas migration;*
- *To improve overall appearance of the landfill;*
- *To provide suitable conditions for plant and other vegetation growth."*

Although at the time of preparing the CMP no landfill specific BATNEEC ('best available technology not entailing excessive costs') EPA guidance document on the use of BATNEEC was established, it is stated that the concept and principles of BATNEEC were considered in developing the plan and the measures proposed in the remediation plan 'are considered to fully comply with the principles of BATNEEC'.

The proposed remediation plan was approved by the EPA and comprised the following elements:

Control of Leachate

- Installation of surface water drains along west and east side of the site;
- Capping of regraded landfill. Capping will extend down sides of the landfill and into sides of the drain until underlying peat layer is encountered. Surface drains will divert surface run off away from landfill to reduce leachate generation;
- A shallow barrier will be constructed along base of waste material if deemed necessary to completely isolate leachate from surface water drain.

Control of Surface Water

- Construction of open channel diversion ditches in line with existing drains along northern and southern sides of the site. Ditches will be wide and shallow with side slopes no greater than 1:2.5;
- Improvement/clearance of pre-existing drains.

Re-grading of Landform

- Re-grading of land to achieve side slopes of 1:2.5 to 1:3 where possible;
- Pull back waste along sides of site to the centre of the site to form a dome in keeping with surrounding topography.
- Toe of slopes will be within site boundary.
- Development of contour plan and cut and fill exercise.

Final Cover Material

- Top cover with a maximum slope of 1:2.5 (where possible) to consist of:
    - 300mm thick low permeable clayey soil layer;
    - 200mm topsoil layer and other vegetation;
    - regulation layer varying between 100-1000mm in depth;
- Low permeability layer: Should consist of a compacted low hydraulic conductivity clayey soil with hydraulic conductivity of $1x10^{-9}$ m/s to control leachate generation by minimising infiltration;
- Topsoil Layer: Foundation for grass and vegetation growth;
- Regulation Layer: 100 to 1000mm layer applied to surface of the waste to create an even surface for application of layers above.

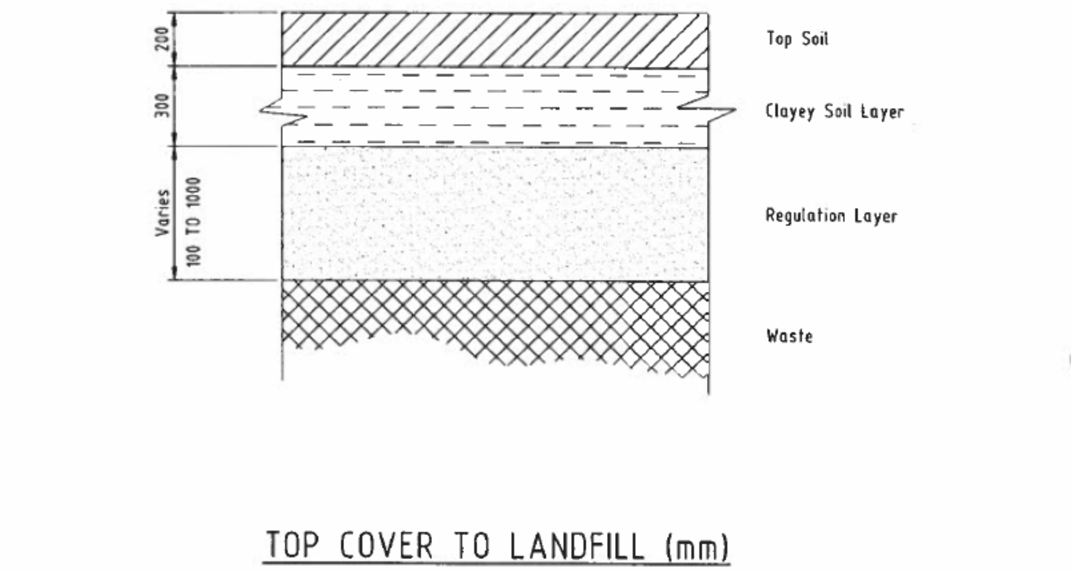

Figure 1-1: Proposed Top Cover Material (Closure and Remediation Plan (1999))

The CMP states that a sample of soil material obtained from a construction site, intended for use as a low permeability layer was tested (Classification Testing and Compaction/Permeability Testing). It was found that the material tested had no significant clay content required to the achieve the necessary low permeability and was therefore not suitable.

Landfill Gas Migration

- Gas collection/drainage layer not necessary in final capping as understood majority of gas has vented over lifetime of landfill and the waste had been covered by a final capping material.
- Combined gas/leachate monitoring boreholes (BH1, BH2 and BH3) installed within the waste body in 1999 to facilitate ongoing monitoring. Monitoring results would inform necessity for further measures.

Final Landscaping

- Historic landfill to be planted with grass and trees to aid integration into the surrounding landscape.

Fencing

- Erection of new fence (of suitable material) around perimeter of historic landfill to connect existing concrete fence to road.

Monitoring

- Monitoring programme (leachate, groundwater and surface water) to be developed and established to monitor efficacy of remediation;
- Monitoring of landfill gas within and outside the waste body.

1.4 Tier 2 Risk Classification and Tier 3 Source Pathway Receptors

The Tier 2 site investigation risk assessment concluded that the risk rating of the site was High (Class A). Applying the EPA scoring matrix, the highest single risk rating for the site was calculated to be 70% for source-pathway-receptor (SPR) Linkages 10 and 11, which refers to landfill migration to human receptors. Moderate scores of 42%, 61%, 41%and 47% were also calculated for SPR1, SPR5, SPR7 and SPR8. All other SPR risks were calculated to be low (see Table 1-1):

Table 1-1: Tier 2 SPR and Selected Tier 3 SPRs

SPR No.	Linkage	Normalised Score	Justification
Leachate migration through combined groundwater and surface water pathways			
SPR1	Leachate => surface water	**42%**	GSI describes the groundwater vulnerability as High. Geophysical survey suggests that there is 5-10m of overburden underlying the waste material and atop competent limestone bedrock. The underlying bedrock groundwater aquifer is classified by the GSI as a Regionally Important Aquifer - Karstified - conduit (Rkd). Surface water drains have been constructed along the boundary of the landfill flowing into the River Killeelaun and Clare River. Clare River is located c.90m of the site boundary.
SPR2	Leachate => SWDTE	0%	The River Clare is part of the Lough Corrib SAC (Site Code: 000297) and is located approximately 2km south-west of the site.
Leachate migration through groundwater pathway			
SPR3	Leachate => human presence (private well)	20%	GSI describes the groundwater vulnerability as High. Geophysical survey suggests that there is 5-10m of overburden underlying the waste material and atop competent limestone bedrock. The underlying bedrock groundwater aquifer is classified by the GSI as a Regionally Important Aquifer - Karstified - conduit (Rkd). The Civic Amenity (CA) Site is located adjacent to capped landfill however no groundwater drinking water supply is present. Other closest receptor (agricultural buildings) is greater than 250m from the site.
SPR4	Leachate => GWDTE	0%	The River Clare is part of the Lough Corrib SAC (Site Code: 000297) and is located approximately 2km south-west of the site.
SPR5	Leachate => Aquifer	**61%**	Site is underlain by a Regionally Important Aquifer - Karstified - conduit (Rkd).
SPR6	Leachate => Public Supply (well)	26%	The Claretuam Belclare Group Water Scheme is located c.4.6km west of the site.

SPR No.	Linkage	Normalised Score	Justification
SPR7	Leachate => Surface Water	**41%**	GSI describes the groundwater vulnerability as High and Site is underlain by a Regionally Important Aquifer - Karstified - conduit (Rkd). Clare River is located c.90m of the site boundary.
Leachate migration through surface water pathway			
SPR8	Leachate => Surface Water	**47%**	Surface water drains have been constructed along the boundary of the landfill flowing into the River Killeelaun and Clare River. Clare River is located c.90m of the site boundary.
SPR9	Leachate => SWDTE	0%	Nearest protected site is the River Clare which is part of the Lough Corrib SAC (Site Code: 000297) and is located approximately 2km south-west of the site.
Landfill gas migration pathway (lateral & vertical)			

1.4.1 Leachate migration to surface water via groundwater and surface water pathways (SPR1, 7, 8)

Historical landfills were often constructed adopting the approach of dilution and dispersion. The Tuam historic landfill does not include an engineered basal liner however the naturally occurring underlying peat and clay provide a natural form of containment due to their low permeability, limiting vertical migration of leachate from the base of the landfill. Presence of leachate at the landfill presents potential for the migration of pollutants from the site to the adjacent land drains, and further downstream to receiving streams and rivers.

Although upstream surface water monitoring indicated that elevated concentrations of some monitoring parameters and pollutants may be naturally occurring, the presence of some metals at elevated concentrations downstream of the site indicate the potential that the landfill may be causing pollution of surface water downstream.

The potential risk the site may pose to the water quality of the Clare River, downstream of the site has been further assessed as part of this Tier 3 assessment.

1.4.2 Leachate migration to aquifer via groundwater pathways (SPR 5)

Applying the EPA risk screening tool a moderate score of 61% was calculated for SPR5 based on the classification of the receiving groundwater aquifer as a regionally important aquifer and high groundwater aquifer vulnerability. The classification of the underlying bedrock aquifer as a regionally important karstified bedrock aquifer pertains to the aquifer having some resource value thereby warranting some form of protection.

Previous site investigation and groundwater monitoring indicated that leachate migration was occurring from the site downgradient, however results also indicated that this effect is more likely to be localized. Due to the sensitivity of the underlying aquifer to pollution and the outcome of groundwater monitoring, the potential risk to the underling aquifer is further assessed in this Tier 3 quantitative risk assessment.

1.4.3 Lateral and vertical landfill gas migration to human receptors (SPR10 and SPR11)

The civic amenity (CA) site located immediately adjacent to the historical landfill waste body presents an inherent risk with respect to landfill gas. The presence of a GCL over the waste body limits the vertical migration of landfill gas and consequently landfill gas may be forced to move laterally. The presence of made ground underlying the CA site also presents a potential preferential pathway for lateral migration of landfill gas.

The excavation of trial pits immediately adjacent to the CA site in conjunction with the geophysical survey indicated a potential for waste material to be present beneath the CA site therefore the potential for direct vertical migration of landfill gas to the CA has also been considered in this Tier 3 assessment.

2. TIER 3 QUANTITATIVE RISK ASSESSMENT

2.1 Tier 3 Overview

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

The 2020 Tier 2 assessment and site investigation findings conclude that the Tuam site presents a **high risk** therefore a GQRA or a DQRA are required as part of this Tier 3 assessment.

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

- SPR 1, 7 and 8 Leachate migration to surface water receptors via combined groundwater and surface water pathways (42%), groundwater pathways (41%) and surface water pathways (47%);
- SPR 10 and 11 Lateral and vertical migration of landfill gas (70%).

Following the outcomes of the GQRA/DQRA, suitable remediation measures are proposed, and associated costs estimated.

This Tier 3 assessment report uses the following DQRAs to further assess the risks to surface waters, groundwater and to human receptors via gas migration:

- An assimilative capacity assessment and a mass balance calculation were carried out to predict the potential impact on surface water quality from a leachate discharge to the adjacent river;
- Groundwater contaminant dispersion modelling (EA Remedial Targets Worksheet) was undertaken to quantitatively assess the risk posed to groundwater quality. Migration of pollutants through the peat layer underlying the waste body was considered in this assessment;
- Predictive landfill gas modelling (LandGEM) was used to assess gas migration risks.

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

The DQRAs rely on information gathered as part of the Tier 2 investigations. Relevant environmental characteristics considered in evaluating the site and carrying out this Tier 3 investigation are discussed below.

2.2 Existing Geological, Hydrogeological and Hydrological Environment

The risks to surface water and groundwater from leachate migration and to human receptors from landfill gas migration were identified as the primary environmental risks associated with the site. The application of the EPA risk calculation and scoring methodology is reliant on understanding the geological, hydrogeological, and hydrological characteristics of the site and the surrounding environment.

The Tier 2 site investigation and risk assessment provided a firmer understanding of the site and surrounding environs and a summary of the relevant environmental characteristics considered in evaluating the site and carrying out this Tier 3 investigation are discussed hereunder.

The quaternary sediments at the site and within the estimated waste footprint area are identified as 'Cut over raised peat (Cut)'. To the north, east and west of the site, quaternary sediments are characterised as 'Till derived from limestones (TLs)'. Further west alluvium deposits are present following the River Clare. Boreholes previously excavated within the waste body showed that the waste body is underlain by a layer of peat, however the exact thickness of this peat was not confirmed.

The bedrock comprises two different formations the boundary of which transects the site. The site is underlain by a combination of undifferentiated Visean Limestones (CDVIS) and pale grey clean skeletal limestone Burren Formation (CDBURR). Further to the south-west, the site is underlain by Knockmaa Formation.
Bedrock described as 'grey limestone' was encountered at 6.4 m BGL (27.95 mAOD) during the installation of borehole GW02 (drill depth 12.0 bgl).

Previous site investigation conducted in 1999 included the installation of 3 no. rotary core boreholes RC1, RC2 and RC3, located outside of the waste body. Depth to bedrock is shown in Table 2.1:

Table 2-1: Existing Rotary Core Boreholes (Depth to Bedrock)

Borehole	Location (relative to waste body)	Depth to Bedrock (m bgl)	Depth to Bedrock (mAOD)
RC1*	South-west	4.4	-
RC2	North-west	4.75	30.78
RC3	North-east	17.9	19.18

*Ground elevation for RC01 is unknown

The locations of these boreholes are also presented in the CMP (see map extract below).

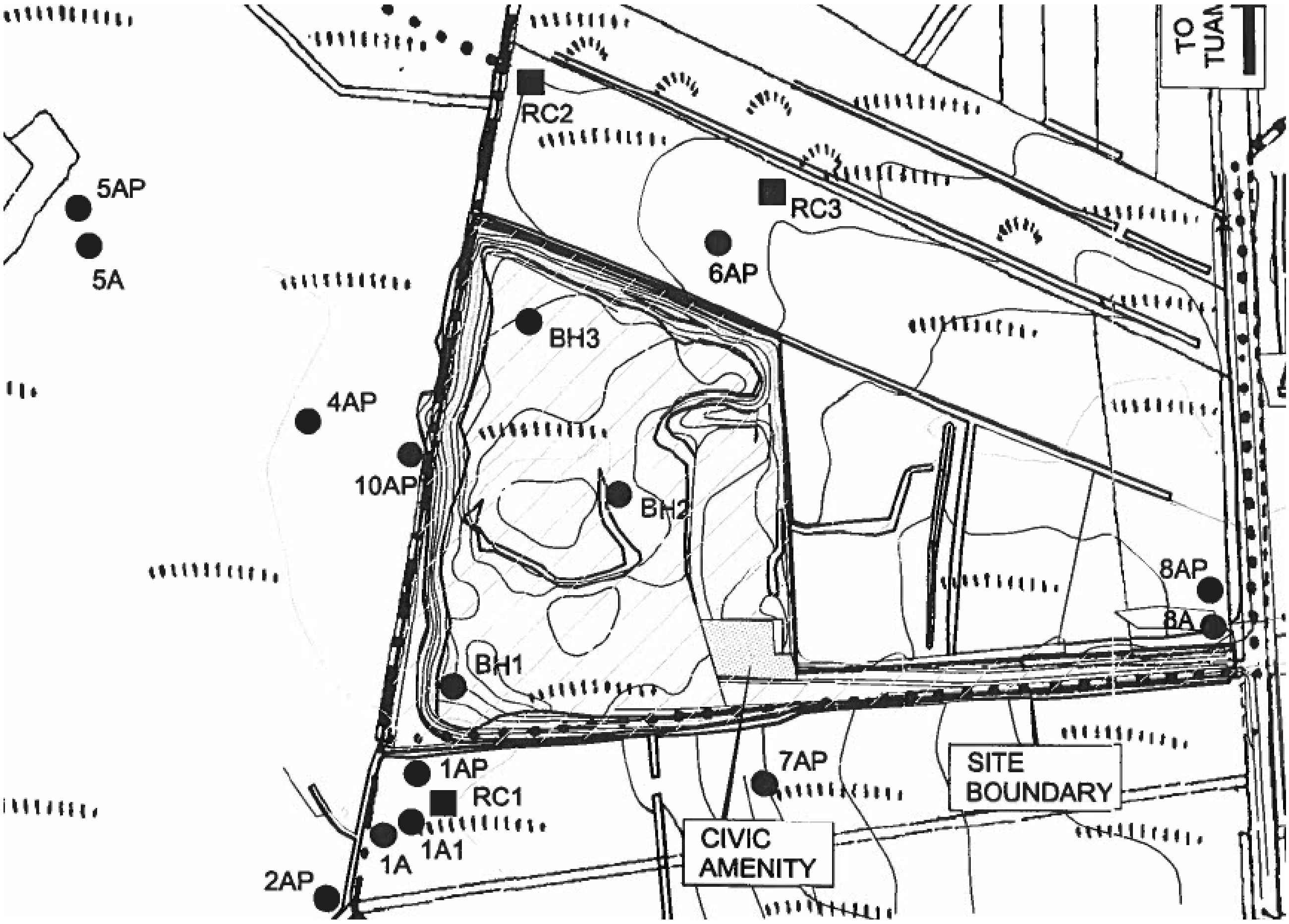

Figure 2-1: Site Investigation Location : Closure Management Plan 1999

The bedrock, groundwater aquifer is classified as a 'Regionally Important Aquifer - Karstified (conduit)'.

GSI data shows records of water supply wells in the area. No defined groundwater protection areas are identified, the recorded wells may no longer be in use for group scheme water supplies. No Groundwater Drinking Water Protection Areas are within the site boundary.

The groundwater body (GWB) is the Clare-Corrib GWB. The GWB is defined as being at Good Status under the Water Framework Directive (WFD). The risk to groundwater quality is currently stated as 'At risk'.

The groundwater vulnerability within the site area is classified as being primarily high (H). The area towards the north-west of the site is classified as moderate (M), before becoming low (L).

The site is located within the Corrib catchment (Hydrometric Area: 30), Clare (Galway)_SC_040 sub-catchment and Clare (Galway)_060 sub-basin. Surface water drains have been constructed around the boundary of the landfill. The northern section of the landfill flows into the River Suileen (EPA Name: Killeelaun). This flows west before turning sharply south and subsequently converges with the River Clare downstream. The southern section of the site flows into a stream (EPA Name: the Clare (Galway)_060) which is a tributary of the River Clare and converges with the River Clare downstream just north of Corofin. The River Clare flows in a southernly direction past Tuam into Turloughmore then turns west before flowing into Lough Corrib.

Surface water quality monitoring has historically been conducted by GCC along the River Suileen to the north (c. 320m upstream) and at three locations along an unnamed stream/land drain to the south (at the southwest corner of the site, c. 170m downstream and c. 550m downstream). Water monitoring was carried out at these locations up until 2013.

The nearest downstream EPA surface water monitoring station is located c. 6km downstream of the site in Corofin. The most recent biological (Q-Rating) for surface water quality at this location (2018) was Q3-4, Moderate status. The nearest upstream EPA surface water monitoring station is located c. 3.5km upstream where the River Nanny converges with the River Clare, and the most recent Q-rating assigned was Q4, Good in 2018.

2.3 Conceptual Site Model (CSM)

A revised conceptual site model has been prepared as part of the Tier 2 assessment and is included below for reference. The revised CSM illustrates the identified potential groundwater and surface water and landfill gas pathways from the site.

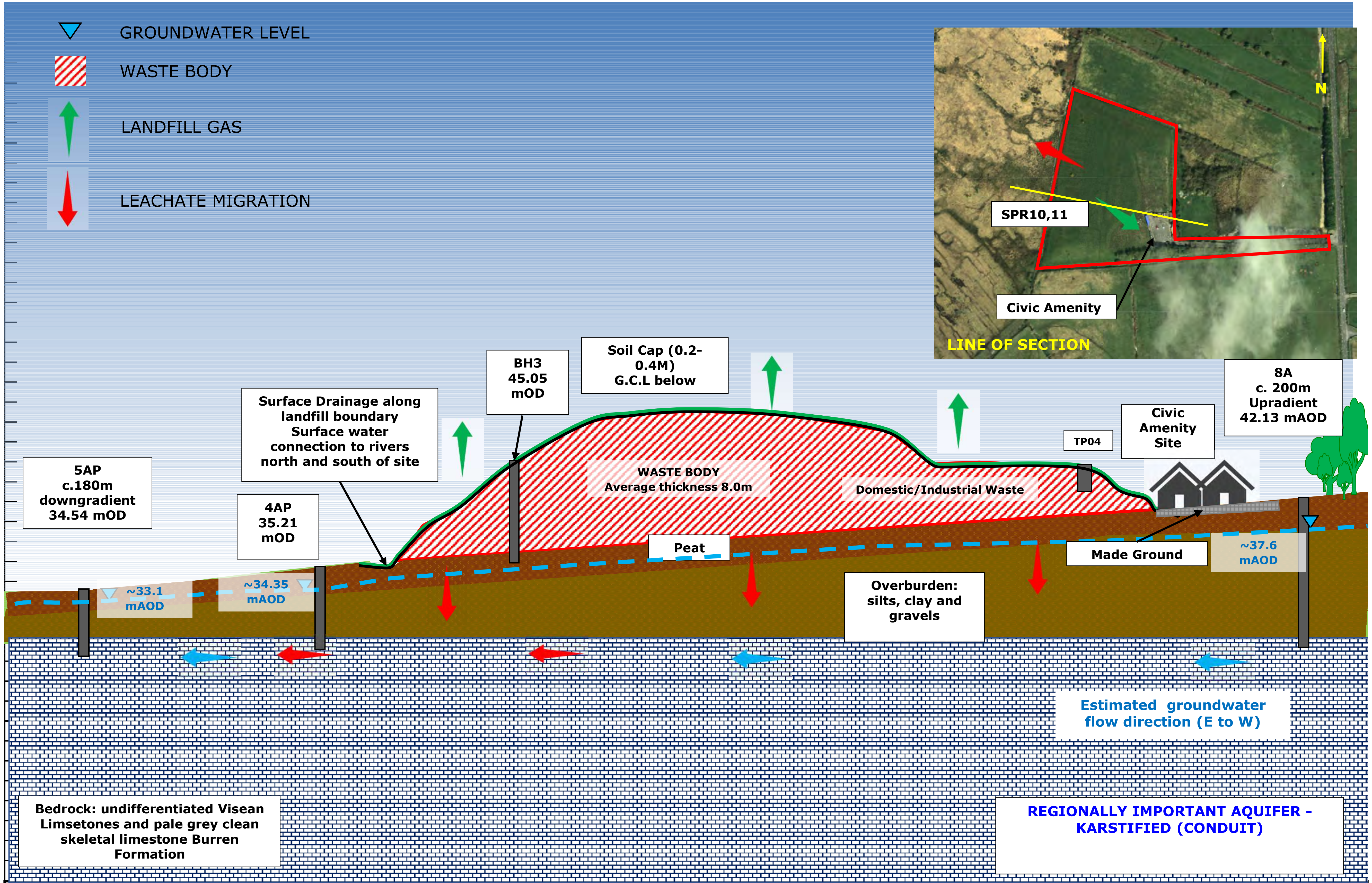

FIGURE 2.2 TUAM HISTORIC LANDFILL CONCEPTUAL SITE MODEL

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2.4 Impact of Leachate on Groundwater

2.4.1 Potential Leachate Generation

The GSI online mapping indicates that the site location is partially underlain by a both a 'Regionally Important Aquifer – Karstified (diffuse)' and a 'Locally Important Aquifer – Bedrock which is Moderately Productive only in Local Zones'. The aquifer vulnerability is classified as being high at the site, indicating that the aquifer at this location is highly vulnerable to and highly influenced by rainwater infiltration at the site, and subsequently by any pollutants migrating vertically to the bedrock aquifer. The generation of leachate via infiltration of rainwater through the cap and underlying waste and migration of that leachate to the underlying groundwater and potentially further migration to surface water is a risk.

As part of the Tier 2 site investigation, static groundwater levels in groundwater monitoring wells 3AP, 4AP, 5A, 5AP, 8A, 8AP, RC2, and RC3 were measured in July and August 2020. A summary of the calculated average groundwater levels is presented in Table 2-2:

Table 2-2: Groundwater Depth Analysis July -August 2020

Well ID	Static Groundwater Level (mAOD)
3AP	34.1
4AP	34.3
5A	33.1
5AP	33.1
8A	37.6
8AP	39.3
RC2	34.3
RC3	35.3

These measurements indicate that groundwater may be slightly below the waste body and is not transecting waste material. It is noted however that groundwater levels fluctuate seasonally and in response to precipitation regionally and so the static groundwater level may be below the waste or at higher elevations within the waste, influencing leachate generation and migration.

The generation and subsequent vertical migration of leachate is driven predominantly by rainfall percolation inputs through the waste body as opposed to the lateral movement of groundwater through the waste body.

In quantifying the potential impact that the leachate generated at the historical landfill may have on the groundwater or surface water receptors it is important to estimate the quantity of leachate or contaminated groundwater produced at the site.

The vertical infiltration of rainfall above the site to the underlying groundwater aquifer is determined by the groundwater recharge rate at this site.

Remediation works were previously completed at the site which included the installation of a GCL over the waste body covered with a thin layer of soil (c. 0.2m thickness).

This cap is likely already, significantly reducing infiltration of rainfall to the waste body, however for the purpose of this QRA conservative estimates with respect to groundwater recharge and leachate generation have been applied.

The recharge coefficient applied by GSI for the area is 20%, based on the classification of the subsoil as made ground with a low permeability, high groundwater vulnerability and classification of the underlying aquifer as regionally important - karstified. Applying an effective rainfall rate of 761 mm/yr equates to recharge rate of 152 mm/year.

Leachate Generation at 20% recharge

20% x 761mm/year = 152 mm/year or 0.152m/year (available rainfall for recharge over the landfill area);

Aquifer Recharge Volume = Recharge x area of landfill;

Aquifer Recharge Volume = 0.152 m/year x 23,300 m^2[estimated waste footprint area];

Aquifer Recharge Volume over landfill area = 3,541m^3/year ***[9.7 m^3/day] [0.011 l/s].***

The historic landfill is underlain by the Clare-Corrib GWB according to GSI mapping. The Clare-Corrib GWB is described as being approximately 1422km^2 in area. The Tuam historical landfill waste footprint was determined to be 23,300 m^2 (0.0277 km^2) in area based on the findings of the site investigation.

This accounts for <0.1% of the Clare-Corrib GWB area indicating the generation of leachate and migration to the underlying aquifer is unlikely to have an impact on the groundwater regionally and on the groundwater body as a whole, however a potential risk to groundwater quality locally remains.

2.4.2 Leachate Dispersion Modelling and Assessment

To determine the potential downstream concentration of leachate generated at the site and the potential risk it may pose to downstream groundwater and surface waters, the Hydrogeological Risk Assessment for Land Contamination - Remedial Targets Worksheet developed by the UK Environment Agency's Science Group was utilized.

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

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

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

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

Groundwater monitoring conducted by FT at the site in July and August 2020 showed elevated concentrations of ammoniacal nitrogen at all groundwater monitoring wells upgradient and downgradient of the waste body, with concentrations ranging from 0.1 mg/l to 3.56 mg/l ammoniacal nitrogen. With the highest concentrations measured at well RC3 located in an adjacent field to the north of the waste body.

Results of historical groundwater monitoring at the site (as included within the previously prepared Closure and Remediation Plan), upgradient and downgradient also showed evidence of migration of leachate and a leachate plume from the site and leachate impacting on groundwater quality at monitoring locations downgradient e.g. at locations 4AP and 10AP. Pollutant concentrations do decrease however further downgradient at the site i.e. at monitoring location 3AP, c.200m south-west of the site. The results of this assessment suggest that, at the time of monitoring the migration of leachate from the site and contamination of groundwater downgradient of the site was more likely to be a local issue and was not likely to significantly impact on groundwater quality further from the (>200m).

Ammoniacal nitrogen was used in the development of the groundwater dispersion model to provide an indication as to the potential downgradient impact of leachate migration on groundwater quality. A summary of model inputs is presented in Table 2-3:

Table 2-3: Remedial Targets Worksheet Model Inputs

Input Parameter	Unit	Ammoniacal Nitrogen	Source
Target Concentration	*mg/l*	0.065 - 0.175[1]	S.I No. 9 of 2016 and EPA IGV
Initial contaminant concentration in groundwater at plume core	*mg/l*	1019[2]	Maximum groundwater concentration measured by GCC at in waste well BH3
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*	210	Approximate width of site/waste extent based on site investigation
Plume thickness at source	*m*	4	assumed based geophysical survey and site investigation. At least 2m of peat in area
Saturated aquifer thickness	*m*	8	Assumed aquifer thickness greater than peat thickness
Bulk density of aquifer materials	*g/cm3*	1.018	assumed natural bulk density for peat

Input Parameter	Unit	Ammoniacal Nitrogen	Source
Effective porosity of aquifer	*fraction*	0.9	assumed based on range of literature values for peat
Hydraulic gradient	*fraction*	0.0085	estimated based on measured static gw levels at 8A and 5A
Hydraulic conductivity of aquifer	*m/d*	0.2	Assumed based on literature values for peat
Distance to compliance point	*m*	300	Hypothetical compliance point distance
Time Since Pollutant entered groundwater	*days*	25, 50, 100 years [9,125, 18,250,36,500, days]	Time intervals selected
Soil Water Partition Co-efficient	*l/kg*	1.25	Assumed based on literature

Note 1: 0.065 - 0.175 refers to overall threshold value range as per S.I No. 366 of 2016. 0.065 mg/l refers to '*assessment of adverse impacts of chemical inputs from groundwater on associated surface water bodies*', 0.175 mg/l refers to '*assessment of the general quality of groundwater in a groundwater body in terms of whether its ability to support human uses has been significantly impaired by pollution*'. The lower threshold has been considered in this assessment due to potential risk to surface waters.

Note 2: Source concentration applied is considered conservative as measurement was taken in 1999 shortly after site closure, leachate strength likely reduced since then.

2.4.3 Results - EA UK Remedial Targets Worksheet

This model was used to estimate the dispersion of ammoniacal nitrogen. Predicted groundwater concentrations at a range of distances from the source at different time intervals are presented in Table 2-4 and Appendix 1. The model assumes no mitigation is in place with respect to reducing infiltration of rainfall to the waste body, subsequent generation of leachate and migration of leachate downgradient e.g. presence of a low permeability landfill cap.

The range of distances are automatically generated by the model based on the percentages of the hypothetical compliance point distance (300m) i.e. 15m [5%], 75m [25%], 150m [50%] and 300m [100%].

Table 2-4: Modelled Downstream Concentrations (UK EA Remedial Targets Worksheet)

Ammoniacal Nitrogen (mg/l)			*Groundwater threshold Value (GTV) = 0.065 - 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	1019	293.321	0.24	0.00	0.00
50	1019	408.39	8.70	0.001	0.00
100	1019	523.53	59.93	0.56	0.00

2.4.4 Discussion of Results

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

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

Modelling assumed a source concentration based on sampling and monitoring results at existing leachate monitoring well BH3 (maximum 1019 mg/l). The EA UK Leachate Inventory was also reviewed for typical leachate concentrations. The initial source concentration applied in this model is within the 'minimum' to 'maximum range of values (4.37 - 3640 mg/l) as per the EA UK Leachate Inventory and so was deemed suitable albeit a conservative assumption of the source concentration.

The model predicts dispersion of ammoniacal nitrogen beyond the site with concentrations exceeding the upper threshold value at 150m from the source after 100 years of dispersion.

Overall, the models suggest that in the absence of any mitigation to reduce leachate generation and migration the site is not likely to impact groundwater quality >300m from the site, within 100 years. Within 50 years of dispersion leachate migration is more likely to only impact on groundwater locally.

The model results have been compared against groundwater monitoring data most recently obtained by FT in 2020.

As the model suggests concentrations of ammoniacal nitrogen are predicted to be greater closer to the source (at 15m) with concentrations decreasing significantly at 75m and 150m from the source, at all-time intervals. This further indicates that migration of the ammoniacal nitrogen is relatively slow and leachate migration would not be expected to negatively impact on groundwater quality at greater distances from the site i.e. at 300m downgradient, even after 100 years of dispersion.

The predicted decrease is pollutant concentrations is consistent with monitoring results obtained from 4AP, 5A, 5AP and 3AP.

A single sample from 4AP in 2020 yielded an ammoniacal nitrogen concentration of 2.04 mg/l while samples from 5A, 5AP and 3AP yielded ammoniacal nitrogen concentrations of 1.31 mg/l, 1.24 mg/l respectively. It is noted however that ammoniacal nitrogen concentrations were also found to be elevated at upgradient wells 8A and 8AP (1.8 mg/l, 0.854 mg/l), therefore other sources may be contributing to the elevated concentrations measured at well 4AP.

This trend is also observed with other select monitoring parameters amongst groundwater monitoring results obtained for wells 4AP, 5A and 5AP. A summary of results for select parameters showing decreasing concentrations between 4AP and 5A and 5AP are shown in Table 2-5.

Table 2-5: Summary of Groundwater Results (2020) for Select Parameters (4AP, 5A, 5AP & 3AP)

Parameter	Units	4AP	5A	5AP	3AP
Distance from Site Boundary (m)	m	65m	160	160	190
Chloride	mg/l	48.5	12.5	13.1	14.7
Barium	µg/l	138	53.1	53.7	9.75
Lead	µg/l	1.58	<0.2	0.668	<0.2
Manganese	µg/l	876	91.9	146	181
Sodium	µg/l	88	27.2	10.3	6.46
Potassium	µg/l	53.7	1.56	0.916	0.466

2.5 Impact of Leachate on Receiving Surface Waters

The potential impact of leachate emissions to the adjacent streams/drains and subsequently to the Clare River located to the south/south-west of the site was identified as being a primary risk associated with the site. Surface water monitoring conducted by FT in 2020 shows elevated concentrations for some parameters namely, BOD, ortho-phosphate, ammoniacal nitrogen, chromium and nickel. With the exception of chromium and nickel, elevated concentrations (above the surface water regulations thresholds) were also detected in upstream samples with no clear variation between upstream and downstream samples. A significant variation between upstream and downstream samples i.e. upstream samples consistently showing lower concentrations than downstream samples would otherwise indicate that the site and leachate migration was a negatively impacting downstream surface water quality. However, the elevated concentrations of metals, chromium and nickel were not observed upstream therefore indicating possible leaching of these metals and migration to surface water downstream of the site. The EPA CoP requires a conservative approach to be adopted when conducting a QRA.

2.5.1 Potential Leachate Generation and Discharge

The generation of leachate via infiltration of rainwater through the shallow soil cap, underlying waste and migration to groundwater and possibly to surface water is a risk.

No flow data is available for the nearby streams. The potential impact of leachate discharge on the Clare River was determined by conducting an assimilative capacity assessment and mass balance calculation with ammoniacal nitrogen chosen as a representative potential pollutant. The leachate breakout/discharge rate is based on the estimated leachate generation rates shown in Section 2.4.1. It is conservatively assumed that all leachate is entering the river. This calculation does not take into account attenuation of pollutants and further dilution and dispersion of leachate that may occur downstream, between the site and the Clare River which would otherwise reduce the rate of pollutant discharge to the river.

To assess the potential efficacy of an improved cap on the waste material, the leachate discharge rate, is based on a significantly reduced rainfall infiltration rate to the site. For the purpose of this calculation an assumed reduced recharge of 10% is applied. This assumes that 90% of rainfall on the site does not infiltrate the underlying waste and does not contribute to leachate generation.

Leachate Generation at 10% recharge

10% x 761mm/year = 76.1 mm/year or 0.0761 m/year (available rainfall for recharge over the landfill area);

Aquifer Recharge Volume = Recharge x area of landfill;

Aquifer Recharge Volume = 0.0761 m/year x 23,300 m^2[estimated waste footprint area];

Aquifer Recharge Volume over landfill area = 1,773 m^3/year **[4.8 m^3/day] [0.056 l/s].**

2.5.2 Assimilative Capacity Assessment

The following analysis was applied to determine the assimilative capacity of the Clare River, see Appendix 2.

Table 2-6 shows the assimilative capacity of the Clare River in relation to ammoniacal nitrogen to be **16.86 kg/day**.

Table 2-6: Clare River Assimilative Capacity Assessment

Assimilative capacity (AC) = (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)	0.021	Applied 2017 baseline total ammonia concentration at EPA monitoring station at Cloonmore Bridge (Station ID: RS30C010700) upstream of the site.
F95 = the 95%ile flow in the river (m^3/s)	1.64	Obtained from online EPA Hydrotool for river segment/catchment upstream of site.
Assimilative Capacity kg/day	**16.86**	AC (kg/day) = (0.14 - 0.021) x 1.64 x 86 .4

2.5.3 Potential Impacts of Leachate Breakouts on Receiving Surface Waters

To determine potential impact that leachate surface breakouts from the landfill could have on the assimilative capacity of the receiving surface water body, the mass of ammonia discharging from the site is calculated applying the following equation:

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

Assumed criteria:

- *Flow range of assumed leachate breakouts:* *12 m^3/day, 5.8 m^3/day*
- *Concentration of ammonia in leachate:* *4.97l ammoniacal nitrogen (maximum concentration measured at SW2 in 2020*
- *Significant pollution threshold if:* *> S.I. No. 77 of 2019 ('Good' status 95%-ile 0.140 mg/l)*

As shown in Table 2-6 this calculation conservatively assumes low flow conditions (95%-ile) flow conditions within the receiving river. By applying the 95%-ile flow, the assessment assumes the worst-case scenario whereby minimum dilution of the discharge is assumed within the receiving river waterbody.

Based on potential leachate generation rates, an assumed leachate breakout and discharge flow (12 m^3/day) was applied and the percentage of the assimilative capacity removed from the receiving water was calculated (Daily Mass Emission ÷ Assimilative Capacity).

It is noted that no leachate breakouts were observed by FT during the site walkover and this assessment is an especially conservative assessment of the potential impacts on the water quality in the Clare River should an uncontrolled leachate breakout at assumed discharge rates occur.

A discharge concentration of 4.79 mg/l ammoniacal nitrogen (maximum recorded concentration at SW2 in 2020) was assumed for this calculation. Surface water monitoring location SW2 is located on the adjacent stream, located immediately south-west of the waste body.

These concentrations were applied as they are considered to be representative of concentrations within this stream that ultimately discharges to the Clare River. The calculations conservatively assume that there is no further dilution of ammoniacal nitrogen between the site and the confluence of the stream and the Clare River.

This concentration is also within the range of typical ammonia concentration in landfill leachate. The calculated mass emissions and the impacts on the assimilative capacity, for assumed discharge rates based on potential generation rates at the site (see Section 2.4.1 and 2.5.1) , of the receiving water are shown in Table 2-8.

2.5.4 Mass Balance Assessment

A mass balance calculation determines the potential change in ammonia concentration within the receiving water downstream of the discharge. The following calculation as shown in Table 2-7 was applied.

Table 2-7: Mass Balance Calculation

T = (FC + fc)/(F + f)			
Where:			*Source*
F is the river flow upstream of the discharge (95%ile flow m^3/s);	1.64		Obtained from online EPA Hydrotool for river segment/catchment upstream of site
C is the concentration of pollutant in the river upstream of the discharge (mean concentration in mg/l);	0.021		Applied 2017 baseline total ammonia concentration at EPA monitoring station at Cloonmore Bridge (Station ID: RS30C010700) upstream of the site.
f is the flow of the discharge (m^3/s);	0.000139 0.000671	12 m^3/day, 5.8 m^3/day	Assumed discharge rate based on estimates of leachate generation and breakout to surface water. Assumed reduced discharge based on reduce rainfall percolation to waste.
c is the maximum concentration of pollutant in the discharge (mg/l);	4.79		4.79 mg/l = maximum recorded concentration measured at SW2 in 2020, (considered representative of potential concentration in surface water from the site that could discharge to the Clare River)
T is the concentration of pollutant downstream of the discharge.	Varies for discharge flows		n/a
Water Quality Standard (mg/l)	0.140		'Good' Status 95%-ile as per S.I No. 77 of 2019 (95% of results are below this concentration)

Table 2-8: Assimilative Capacity and Mass Balance Calculation Results

Assumed Leachate Breakout Flow (m^3/day)	Daily Mass Emission (kg/day) assuming NH_4 concentration 4.79 mg/l	% Impact Breakout has on of Assimilative Capacity (% consumed)	Estimated Downstream Concentration Ammoniacal nitrogen (mg/l)
12	0.057	0.3%	0.021
5.8[3]	0.028	0.2%	0.021

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

Note 2: *Assimilative capacity estimated to be 16.86 kg/day ammonia (Table 2-6)*

Note 3: *Reduced discharge based on lower rainfall percolation*

2.5.5 Discussion of Results

Table 2-8 results show that at a leachate discharge flow rate of 12 m^3/day and at a concentration of 4.79 mg/l ammoniacal nitrogen the predicted downstream concentrations are compliant with S.I. No. 77 of 2019 'Good' status 95%-ile (<0.140 mg/l) with predicted downstream concentration of 0.021 mg/l (0% increase).

This corresponds with the assimilative capacity calculation which determined that, assuming low flow conditions in the river at a discharge rate of 12 m^3/day, 0.3% of the assimilative capacity of the river for ammoniacal nitrogen/total ammonia would be consumed at a discharge concentration of 4.79 mg/l.

A review of EPA catchment mapping and monitoring data shows the nearest water quality monitoring station located downstream of the landfill, approximately 5km south of Tuam historical landfill (station Name: Corrofin ridge, ID: RS30C010800.

Water quality data for this monitoring location provided by the EPA shows a 2017 baseline concentration of 0.025 mg/l total ammonia and a most recent 2018 mean concentration of 0.020 mg/l total ammonia. The most recent 2018 concentration is below those predicted by the mass balance calculation. This monitoring data indicates that potential discharges from the site that could be occurring are not having a significant deleterious effect on the water quality of the Clare River downstream of any discharge from the site.

Both the mass balance calculation and downstream EPA monitoring results show that downstream concentrations remain below the 'good' status surface water quality thresholds values for total ammonia (mean ≤0.065, 95%-ile, ≤0.140 mg/l).

The application of the reduced rainfall, infiltration rate (with an improved engineered cap) of 5.8 m^3/day shows that the predicted downstream remains below the 95%-ile threshold value of 0.140 mg/l ammoniacal nitrogen with predicted downstream concentrations of 0.021 mg/l ammoniacal nitrogen at a discharge concentration of 4.79 mg/l. This equates to no increase in concentrations at a discharge ammoniacal nitrogen concentration of 4.79 g/l from the applied background concentration of 0.021 mg/l, showing that with the installation of an engineered cap achieving a significant reduction in rainfall infiltration to the waste, the potential impact to water quality would be low.

2.6 Landfill Gas Assessment - LandGEM

Monitoring for landfill gases from BH3, 2AP, 3AP, 4AP, 5A, 5AP,8A,8AP, RC2 and RC3 was conducted in July and August 2020 as part of the Tier 2 site investigation as outlined in Table 2.9 T). Methane was not detected at any of monitoring locations. In accordance with the EPA Landfill Manual - Landfill Monitoring the trigger level for methane concentrations at locations outside the waste body is 1.0% v/v and 1.5% v/v for carbon dioxide.

The only concentrations measures above these trigger levels are for carbon dioxide at monitoring locations 8A, 8AP and RC3, with concentrations detected only marginally above or at the trigger level.

This Tier 3 risk assessment estimated landfill gas production using LandGEM.

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

The model relies on a limited number of inputs, some of which are supplied within the model as a variety of default values and site-specific information provided by the user. A summary of the model inputs used for this Tier 3 assessment are presented in Table 2.10.

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

Table 2-9: Landfill Gas Monitoring Results (July and August 2020)

Date: 01/07/2020						
Sample Station	CH_4 (% v/v)	CO_2 (% v/v)	O_2 (% v/v)	Atmospheric Pressure (mbar)	Staff Member	Weather
BH3	0	0.6	22.3	1005	Daniel Hayden	Overcast, Warm, 16-18°C
2AP	0	0.9	21.9			
3AP	0	0.3	22.1			
4AP	0	0.6	22.4			
5A	0	1.2	20.8			
5AP	0	1	21.2			
8A	0	**1.8**	20.4			
8AP	0	**1.7**	20.5			
RC2	0	0.9	21.2			
RC3	0	**1.5**	21.5			
Date: 27/8/2020						
Sample Station	CH_4 (% v/v)	CO_2 (% v/v)	O_2 (% v/v)	Atmospheric Pressure (mbar)	Staff Member	Weather
BH3	0	0.2	20.8	998	Daniel Hayden	Overcast, Rain, 14-16°C
2AP	0	0.4	20.6			
3AP	0	0.1	21.8			
4AP	0	0.9	22.4			
5A	0	0.8	20.8			
5AP	0	0.6	21.2			
8A	0	1.4	19.8			
8AP	0	0.8	20.5			
RC2	0	0.6	21.2			
RC3	0	0.4	21.5			

Although the majority of concentrations are shown to be below the EPA trigger levels for offsite locations the proximity of the civic amenity area presents a pathway to human receptors and a potential risk.

Table 2-10: LandGEM Model Inputs

Landfill Characteristics	Input	Source
Landfill Open Year	1955	Open year assumed. Exact open year is unknown. landfill was operated from 1950's up to 1998.
Landfill Closure Year	1998	Landfill was closed in 1998.
Have Model Closure Calculate Closure Year	Yes	
Waste Design Capacity (megagrams/tonnes)	232,652	Mass based on upper estimated waste volume determined as part of Tier 2 assessment and site investigation [145,407.7 m^3 multiplied by assumed 1.6 tn/m^3 waste density].
Determining Model Parameters		
Methane Generation Rate, k ($year^{-1}$)	CAA Conventional – 0.05	Default value – maximum values applied as a conservative worst-case scenario approach
Potential Methane Generation Capacity, L_0 (m^3/Mg)	CAA Conventional – 1070	
NMOC Concentration (ppmv as hexane)	CAA – 4,000	
Methane Content (% by volume)	CAA – 50% by volume	
Select Gases/pollutants		
Gas/Pollutant #1	Total Landfill Gas	Standard – No other specific gases of concern
Gas/Pollutant #2	Methane	
Gas/Pollutant #3	Carbon Dioxide	
Gas/Pollutant #4	NMOC	
Enter Waste Acceptance Rates (Mg/year)		
1955 – 1998	8058	Exact waste acceptance quantities per year are unknown. Assumed waste design capacity was filled equally over 1955 to 1998 (44 year) period

2.6.1 Results - LandGEM

As an output, LandGEM produces a report on the model inputs and outputs. This report is included in Appendix 3. LandGEM estimates the mass and volume of landfill gases generated both during the operational/filling phase of the landfill and beyond.

The estimated quantity of gas generated for the current year (2020) and after 10 years of further degradation (2030) are presented in Table 2-11. The model predicted that the site is currently generating 20 m^3/hr of methane across the entire site area. This will reduce to 12 m^3/hr by 2030.

Table 2-11: Estimated Landfill Gases Generated (2020 and 2030)

Gas/Pollutant	Tonnes/year		m^3/year		tonnes/hour		m^3/hour	
	2020	2030	2020	2030	2020	2030	2020	2030
Total Landfill Gas	430	261	344679	209059	0.05	0.03	39	24
Methane	115	70	172340	104529	0.01	0.01	20	12
Carbon dioxide	315	191	172340	104529	0.04	0.02	20	12
NMOC	5	3	1379	836	0.001	0.000	0.16	0.10

The approximate maximum waste deposition footprint was estimated to be approximately 23,300m^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 2-12.

Table 2-12: Estimated Gases Generated/Released per m^2 (2020)

Gas/Pollutant	Tonnes/year/m^2	m^3/year/m^2	tonnes/hour/m^2	m^3/hour/m^2
Total Landfill Gas	0.018	15	$2.11x10^{-6}$	$1.69x10^{-3}$
Methane	0.005	7	$5.63x10^{-7}$	$8.44x10^{-4}$
Carbon dioxide	0.014	7	$1.55x10^{-7}$	$8.44x10^{-4}$
NMOC	0.000	0.059	$2.42x10^{-8}$	$4.10x10^{-6}$

2.6.2 Discussion of Results

The outcome of the LandGEM model predicts a relatively low rate of landfill gas generation in 2020 (39 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.

LandGEM estimated that in the year (2020) 39 m^3/hour of landfill gas across the whole site will be generated and assuming 50% percent of that volume is methane (19.5 m^3/hr). This estimated production rate is considered low. In 2020, landfill gas monitoring identified no methane present in any offsite migration monitoring well. The LandGEM model predicts methane production is still occurring in low quantities and will continue for a number of years.

Figure 2-3 shows the predicted landfill gas generation rates per year during the assumed operational phase (c.1955 to 1998) and predicted generation rates from 1998 onwards following closure of the site. The model assumes equal production rates for both methane and carbon dioxide both being represented by the magenta trendline.

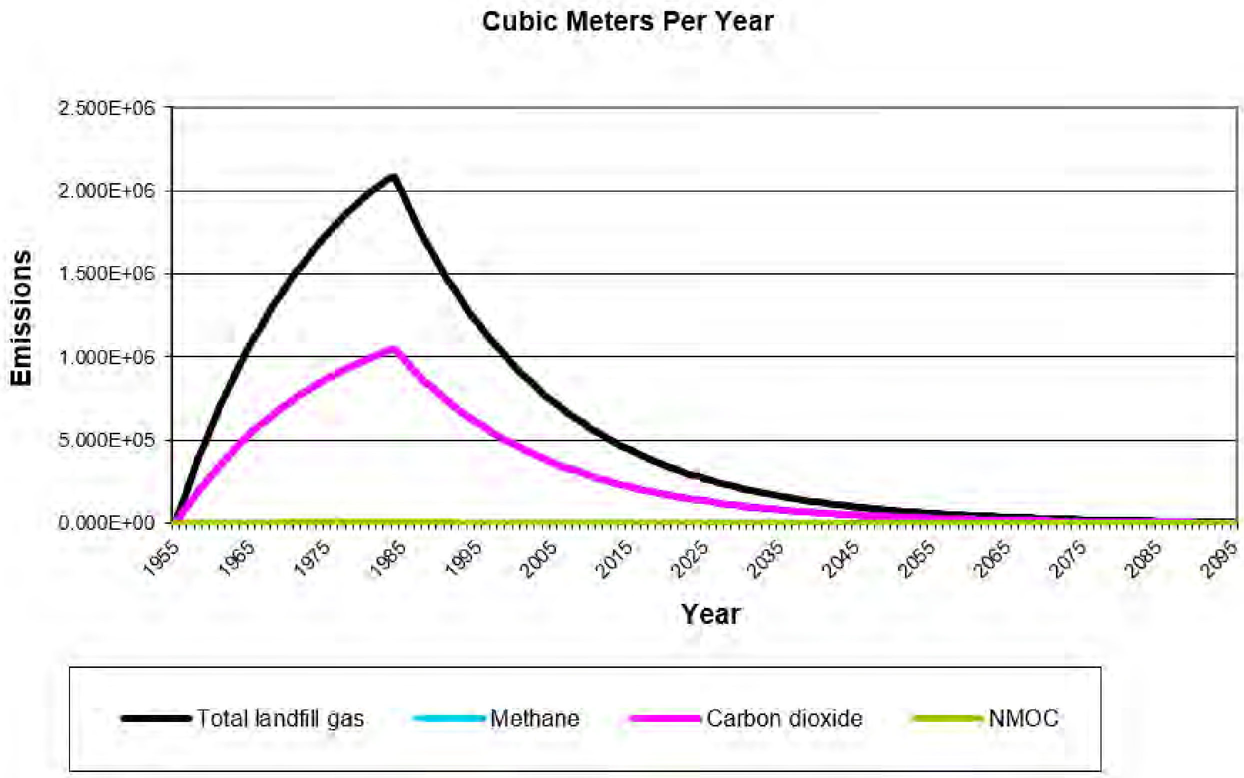

Figure 2-3: LandGEM Landfill Gas Volume Generation Rate

A summary report of the model inputs and outputs generated by LandGEM is included in Appendix 3.

The DQRA assessment predicts low gas production flow rates at the site. Landfill gas monitoring did not detect methane at offsite monitoring wells which suggests gas lateral migration of landfill gas may be limited.

However, the presence of the CA facility immediately adjacent to the landfill and continued production of landfill gas means the potential risk of landfill gas migration to the CA facility and human receptors remains.

2.7 Conclusions

2.7.1 Impact of Leachate on Groundwater

Dispersion modelling and calculations shows that:

- On a wider, regional scale the migration of leachate from the historical landfill to groundwater is unlikely to impact on the overall quality of the underlying Clare-Corrib groundwater body.
- The dispersion of leachate from the site has the potential to impact on groundwater quality only at a local scale due to the natural containment provided by the underlying peats and clays.

- Leachate migration is not likely to impact on groundwater quality further downgradient from the site e.g. >200m downgradient

2.7.2 Impact of Leachate on Surface Water

The assimilative capacity assessment and mass balance calculations indicates that:

- Leachate breakouts discharging to the Clare River via adjacent land drains is unlikely to negatively impact on water quality of the Clare River with modelling predicting low consumptions of assimilative capacity (<50%) of the river with respect to ammoniacal nitrogen. The assimilative capacity assumes a hypothetical discharge rate and estimated leachate generation rates based on information provided by the GSI spatial mapping resource. It is noted that no leachate breakouts were observed by FT during the site walkover and as such discharge rates are very conservative.
- The predicted downstream concentrations remain below the water quality threshold value of 0.140 mg/l ammoniacal nitrogen.
- The installation of a lower permeability cap limiting the infiltration rate to the landfill yielded a reduction in leachate generation and subsequently a reduction in both the impact on assimilative capacity and downstream ammoniacal nitrogen concentrations.

Surface water monitoring results do provide evidence of potential leachate migration to the stream immediately adjacent to the landfill, to the south-west with metals, chromium and nickel present at concentrations not observed upstream. This suggests that although leachate migration to surface water is not likely to impact on receiving waters i.e. the Clare River further downstream of the site it may impact on water quality locally.

2.7.3 Impact of Landfill Gas Migration

The landfill gas generation model and assessment indicate that:

- Landfill gas is likely continuing to be produced at the site at relatively low levels;
- Landfill gas monitoring conducted did not indicate high levels of landfill gas migration offsite to the north and west, with no methane detected in all wells monitored;
- Although monitoring did not detect methane in offsite wells the continuation of landfill gas generation however presents a potential risk to nearby human receptors and the accumulation of gases in enclosed spaces within the immediately adjacent CA facility.

2.7.4 Site Capping

The previously prepared CMP outlined the proposed cap to be installed following the sites closure (see Section 1.3.1).

Excavation of trial pits as part of the Tier 2 site investigation and assessment showed that the site comprises a thin soil cap (0.2 - 0.4m) overlying a GCL liner above the waste body.

The thickness of topsoil identified conforms with the proposed thickness (minimum: 200mm) as per the CMP. However, slippage, erosion of the final topsoil cover and exposure of the underlying GCL along the side slopes was observed during the site walkover conducted in May 2020. Heavy poaching of the topsoil capping was also observed.

It is understood, from review of the CMP that due to material testing conducted on soils intended to be used as a low permeability cap clay layer determining that the material was not suitable for this purpose and alternative material i.e. the GCL was installed to achieve the desired low permeability ($1x10^{-9}$ m/s) final cap.

So as not to compromise the integrity of or damage the GCL trial pits excavations did not extend deeper below the GCL once encountered, therefore it was not possible to confirm the presence of a 'regulation layer' as described within the CMP directly above the waste body.

2.7.5 Mitigation of Risks to Surface Waters, Ground Waters and from Landfill gas migration (SPR1, SPR5, SPR7, SPR8, SPR10, SPR11)

The Tier 1 and 2 risk assessments deemed the site to have a High Risk (Class A) rating because of the potential risk of landfill gas migration from the site. The Tier 2 assessment also identified moderate risks to groundwater and surface water receptors via leachate migration based on the EPA risk scoring.

The historical landfill has potential to:

- Encourage lateral migration of landfill gas by limiting diffuse vertical migration of landfill gas through existing cap and GCL;
- Contaminate adjacent surface water drains/streams locally;
- Impact groundwater quality immediately downgradient of the site.

Detailed quantitative risk assessments carried out as part of the Tier 3 investigation deemed that the environmental impacts to receiving surface water and ground water quality further downstream and downgradient of the site presented low risks owing to the:

Potentially low source contaminant levels present.

- Attenuation of contaminants within underlying peat and limited groundwater dispersion of contaminants downgradient of site;
- Modelled discharges will have a low impact on the assimilative capacity of the Clare River.

3. REMEDIAL ACTION PLAN

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

3.1 S-P-R Linkages

Following comprehensive desktop review, a site investigation and a Tier 2 assessment identified the primary source-pathway-receptors (S-P-R) linkages for the site to be lateral and vertical migration of landfill gas to adjacent human receptors (civic amenity site) and leachate migration through surface water pathways and groundwater pathways. Proposed remedial measures for each of these linkages are discussed below.

3.1.1 Leachate Migration to surface water receptor via surface water and groundwater pathways (SPR1, SPR7, SPR8)

The adjacent land drains, streams and Clare River were identified as being a potential receptor for leachate discharge/breakout from the site. Although leachate breakout wasn't observed during the site walkover the proximity of the adjacent streams to the site and measured elevated concentrations of some surface water monitoring parameters at locations downstream of the site leachate migration to surface water is considered a potential risk.

3.1.2 Leachate Migration to groundwater via groundwater pathway (SPR5)

The dispersion modelling in conjunction with groundwater monitoring conducted at the site provides evidence that the site has the potential to impact on groundwater quality immediately downgradient of the site. This impact is likely to be localised however and the migration of leachate downgradient is not likely to have an impact on wider, regional level.

The overall objective of the Water Framework Directive (WFD) is to prevent the deterioration of the status of groundwater. Further, the European Union Environmental Objectives (Groundwater) Regulations 2010, as amended outline duties of public authorities with respect to promoting compliance with the requirements of the regulations including to:

'…take all reasonable steps including, where necessary, the implementation of programmes of measures, to:

a) *prevent or limit, as appropriate, the input of pollutants into groundwater and prevent the deterioration of the status of all bodies of groundwater;*
b) *protect, enhance and restore all bodies of groundwater and ensure a balance between abstraction and recharge of groundwater with the aim of achieving good groundwater quantitative status and good groundwater chemical status by not later than 22 December 2015;*
c) *reverse any significant and sustained upward trend in the concentration of any pollutant resulting from the impact of human activity in order to progressively reduce pollution of groundwater;*

d) *achieve compliance with any standards and objectives established for a groundwater dependant protected area included in the register of protected areas established under Regulation 8 of the 2003 Regulations by not later than 22 December 2015, unless otherwise specified in the Community legislation under which the individual protected areas have been established.'*

Regarding the *'Prevention and Control of Groundwater Pollution'* the regulations also state that '*Point source discharges and diffuse sources liable to cause groundwater pollution shall be controlled so as to prevent or limit the input of pollutants into groundwater.'*

In order to limit further leachate generation at the site and subsequent migration of leachate downgradient of the site landfill capping works at the site are proposed (see Section 3.1.2.1).

3.1.2.1 Landfill Capping

The proposed capping works will be subject to Certificate of Authorisation, detailed design and agreement with existing site users and private landowner(s) and will be cognisant of the future site use as historical landfill.

The site walkover conducted by FT in 2020 recorded erosion and poaching of the final capping layer and exposure of the underlying GCL at locations on the surface and side slopes of the landfill.

It is proposed that the existing landfill cap be repaired where required. Additional soil may be required for repairs and resurfacing of final cap.

The existing landfill cap is already likely significantly reducing the generation of leachate via percolation of rainwater and subsequently the potential migration of leachate to surface water and groundwater.

3.1.3 Landfill gas migration to human receptors (SPR10, SPR11)

The existing GCL and soil cap is likely limiting diffuse vertical migration of landfill gas which can force landfill gas to migrate laterally.

Both the recent landfill gas monitoring results and LandGEM modelling indicate that the potential level of landfill gas production is low. It is therefore proposed the remediation measures with respect to landfill gas are limited to routine monitoring for landfill gas at the nearest sensitive receptor, the CA facility adjacent to the landfill.

Proposed monitoring is discussed in further detail in Section 3.1.5 below.

3.1.4 Environmental Monitoring: Existing Locations

It is recommended that groundwater and surface water monitoring continue at select existing monitoring locations at the site specifically:

- Groundwater (Groundwater Quality and Landfill Gas Migration):
    - 8A (upgradient)

    - 8AP (upgradient)
    - GW01 (down gradient)
    - GW02 (down gradient)
    - 4AP (down gradient)
    - 5AP (down gradient)
    - RC2 (cross gradient)
    - RC3 (cross gradient)
- Surface Water (Surface Water Quality):
    - SW1 (upgradient)
    - SW2 (downgradient)
    - SW3 (downgradient)
    - SW4 (downgradient)

Continued environmental monitoring should be undertaken on an annual basis up until the recommendations of the Certificate of Authorisation are known and remediation works are complete.

Monitoring data should be available prior to detailed remediation design to confirm the findings of this report and for use post remediation as baseline data for comparative analysis.

3.1.5 Environmental Monitoring: Proposed New Locations

The following additional groundwater monitoring locations are recommended:

- GW03-S - upgradient shallow well (screened in overburden) (quarterly);
- GW03-D - upgradient deep well (screened in bedrock) (quarterly).

The following additional landfill gas migration locations are recommended:

- LFG1 – South Eastern Corner of site (adjacent to Civic Amenity Site).

Due to the presence of buildings immediately adjacent to the historical landfill and the risk that these buildings may also be underlain by waste and human activity on the site it is recommended that continuous gas monitors be installed onsite. It is recommended that Continuous Emissions Monitors (CEMs) be installed within all fully enclosed internal areas within buildings above the site.

This will ensure that in the extremely unlikely event of the build-up of landfill gas in occupied spaces above acceptable limits, these exceedances will be detected, and additional appropriate measures implemented if required.

A typical fixed gas monitor and control panel unit are shown below. Monitors such as these are regarded as being relatively low cost are simple to install and maintain. They are robust in terms of the variety of analytes that can be monitored for and probes that can be applied.

Figure 3-1: Typical Fixed Gas Monitor (Xgard fixed point gas detector)

Figure 3-2: Typical Gas Monitor Control Panel (Vortex Control Panel)

It is recommended a full internal survey of all buildings and spaces potentially at risk is undertaken to identify all enclosed rooms and spaces, attention should be paid to smaller enclosed spaces such as maintenance cupboards/ server rooms and storage areas where no ventilation may exist.

3.1.6 Proposed Groundwater, Surface Water and Landfill Gas Monitoring Regime

The EPA Landfill Monitoring landfill manual outlines recommended, minimum monitoring requirements for ground and surface waters. These parameters are shown in Table 3-1 below and are as presented in Table C.2 of the EPA's *Landfill Manuals - Landfill Monitoring, 2nd Edition (2003).*

Groundwater monitoring shall be carried out at existing wells 8A, 8AP, GW01, GW02, 4AP, 5AP, RC2 and RC3 in accordance with Table 3-1.

Surface water monitoring shall be carried out at the existing surface water monitoring locations SW1, SW2, SW3 and SW4 quarterly in accordance with parameters listed in Table 3-1.

Table 3-1: Parameters for Monitoring of Groundwater, Surface water and Landfill Gas

Monitoring Parameter[1]	Frequency	Surface Water	Groundwater and Landfill Gas
Location		SW1, SW2, SW3, SW4	8A, 8AP, GW01, GW02, 4AP, 5AP, RC2, RC3 (existing), GW03-S, GW03-D (proposed), LFG01[2]
Fluid Level	Quarterly and Annually[3]	-	-
Flow Rate		-	-
Temperature		✓	✓
Dissolved Oxygen		✓	-
pH		✓	✓
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		✓	✓

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

[2] Only landfill gas will be monitored at the proposed well LFG01

[3] Surface water monitoring will be conducted at all locations on a quarterly basis, groundwater monitoring will be conducted at existing wells 4AP, 5AP, GW01, GW02 and proposed wells GW03-S, GW03-D on a quarterly basis. Groundwater monitoring will be conducted annually at wells RC2, RC3, 8A and 8AP.

[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.

Monitoring Parameter[1]	Frequency	Surface Water	Groundwater and Landfill Gas
Location		SW1, SW2, SW3, SW4	8A, 8AP, GW01, GW02, 4AP, 5AP, RC2, RC3 (existing), GW03-S, GW03-D (proposed), LFG01[2]
Landfill Gas		-	✓
• *Methane (CH_4)*			
• *Carbon Dioxide (CO_2)*			
• *Oxygen (O_2)*			
• *Atmospheric Pressure*			
• *Temperature*			

3.2 Remediation Design

The preliminary remediation design is presented in the following drawings:

- P2282-0000-0101-0001 Drawing Schedule (Tuam Historic Landfill);
- P2282-0101-0001 Site Location Map (Tuam Historic Landfill);
- P2282-0101-0002 Existing Site Survey (Tuam Historic Landfill);
- P2282-0101-0003 Proposed Repairs to Existing Landfill Capping (Tuam Historic Landfill);
- P2282-0101-0004 Existing & Proposed Monitoring Locations (Tuam Historic Landfill);
- P2282-0401-0001 Existing and Proposed Fencing (Tuam Historic Landfill).

Drawings are included in Appendix 4 to this document.

3.2.1 Landfill capping

Landfill capping works are limited to the repair of the existing cap where erosion, poaching and exposure of the GCL has occurred, as shown on Drawing nr. P2282-0101-0003.

3.2.2 Landfill Gas Management

Landfill gas management measures are limited to additional monitoring for landfill gas as outlined in section 3.1 above. Existing and proposed monitoring locations as shown on Drawing nr. P2282-0101-0004.

3.2.3 Site Security

Suitable fencing and secure access should be installed along the site perimeter and site entrance to prevent access to the site from animals which may otherwise lead to further poaching of the landfill surface and damage to the site capping, as shown on Drawing nr. P2282-0401-0001.

3.2.4 Objectives of the Proposed Remediation Plan

Quantitative risk assessments determined the risks associated with leachate impacting receiving surface and groundwaters to be relatively low, capping works are limited to repair of the existing cap. Site fencing is to be improved to prevent future damage to the cap.

The proposed remediation plan objectives will be to:

- Monitor potential leachate migration to groundwater using existing groundwater monitoring wells;
- Monitor potential leachate migration to surface water at existing surface water monitoring locations on adjacent surface water drains and streams;
- Monitor gas migration through the installation of a gas monitoring well on the western perimeter of the CA facility, between the CA facility at the capped waste body;
- Monitor potential gas migration and accumulation through the installation of CEM within identified enclosed spaces at risk.

In the event that subsequent landfill gas emissions increase beyond those observed during the Tier 3 assessment, appropriate control measures shall be selected in accordance with the EPA Guidance document: *Management of Low Levels of Landfill Gas*

3.3 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.

The cost estimate for Tuam Historical Landfill remediation was prepared based on similar recent works completed by FT. The remediation cost estimate is presented in Table 3.2. The proposed capping is as per the EPA Landfill Design manual recommendations as presented previously.

Table 3-2: Remediation Cost Estimate for Tuam Historical Landfill

Item	Quantity	Unit	Rate	Cost
Design				
Allowance for 3 No. New Monitoring Well Installation	1	Rate	€8,000.00	€8,000.00
Detailed Design and Supervision	1	Rate	€5,000.00	€5,000.00
General Site Clearance and Demolition Works	***1.7***	***ha***		
General Site Clearance	1.7	ha	€4,000.00	€6,800.00
Landfill Capping Works	4500	m^2		
Preparation of Exposed Surfaces	4500	m^2	€0.30	€1,350.00
Importation of 200mm Topsoil to repair existing cap	4500	m^2	€3.50	€15,750.00
Security and Fencing	650	m		
Demolish Existing Perimeter Fence	650	m	€8.00	€5,200.00
Install New Stock Proof Fencing (Concrete post and wire mesh)	650	m	€34.00	€22,100.00
New Field Gate	1	nr	€550.00	€550.00
Mechanical and Electrical				
Continuous Emissions Monitoring Control Panel	1	No.	€2,200.00	€2,200.00
Methane Detection Unit in Building Above the Site	2	No.	€250.00	€460.00
Carbon Dioxide Detection Unit in Building Above the Site	2	No.	€750.00	€1,460.00
Audio Visual Alarm Mounted in Building Above the Site	2	No.	€100.00	€140.00
Installation	1	Sum	€5,000.00	€5,000.00
Commissioning and Testing	1	Sum	€1,500.00	€1,500.00

Item	Quantity	Unit	Rate	Cost
Sub-Total 1				**€75,650.00**
Add 10% Contractor Prelims	10.0%			€7,565.00
Sub-Total 2				**€83,215.00**
Add 12.5% Contingency	12.5%			€10,401.88
Grand Total (excl VAT)				**€93,616.88**

In making this Cost Estimate FT advises the following:

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

Prices may change subject to prevailing market conditions.

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APPENDIX 1

Remedial Targets Worksheet Inputs

Remedial Targets Worksheet , Release 3.2

Level 3 - Soil

See Note

Input Parameters	Variable	Value	Unit	Source
Contaminant		ammoniacal nitrogen		from Level 1
Target Concentration	C_T	0.175	mg/l	from Level 1
Dilution Factor	DF	1.00E+00		from Level 2

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

Ogata Banks — **Equations in HRA publication**

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 value, l

	Variable	Value	Unit	Source of parameter value
Enter source concentration		Soil leachate concentration as mg/l		
Enter soil leachate concentration		1019	mg/l	
Half life for degradation of contaminant in water	$t_{1/2}$	1.00E+100	days	
Calculated decay rate	λ	6.93E-101	$days^{-1}$	calculated
Width of plume in aquifer at source	Sz	2.10E+02	m	from Level 2
Plume thickness in aquifer at source	Sy	8.00E+00	m	from Level 2
Bulk density of aquifer materials	ρ	1.02E+00	g/cm^3	
Effective porosity of aquifer	n	9.00E-01	fraction	
Hydraulic gradient	i	7.61E+04	fraction	from Level 2 (adjusted)
Hydraulic conductivity of saturated aquifer	K	2.00E-01	m/d	from Level 2
Distance to compliance point	x	3.00E+02	m	
Distance (lateral) to compliance point perpendicular to flow direction	z	[redacted]	m	
Distance (depth) to compliance point perpendicular to flow direction	y	[redacted]	m	
Time since pollutant entered groundwater	t	9.13E+03	days	*time variant options only*
Parameters values determined from options				
Partition coefficient	Kd	0.00E+00	l/kg	*see options*
Longitudinal dispersivity	ax	30.000	m	*see options*
Transverse dispersivity	az	3.000	m	*see options*
Vertical dispersivity	ay	0.300	m	*see options*

Parameter values should be checked against Level 1 and 2

Calculated Parameters	Variable		
Groundwater flow velocity	v	1.69E+04	m/d
Retardation factor	Rf	1.00E+00	fraction
Decay rate used	λ	6.93E-101	d^{-1}
Hydraulic gradient used in aquifer flow down-gradient	i	7.61E+04	fraction
Rate of contaminant flow due to retardation	u	1.69E+04	m/d
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	4.43E-01	fraction
Attenuation factor (C_0/C_{ED})	**AF**	**2.26E+00**	**fraction**
Soil leachate concentration	Co	1.02E+03	

Remedial Targets

Level 3 Remedial Target		**3.95E-01**	**mg/l**	For comparison with measured pore water concentration.
Ogata Banks		**or**		This assumes Level 1 Remedial Target is based on Target Concentration.
		#DIV/0!	**mg/kg**	For comparison with measured soil concentration. This
Distance to compliance point		**300**	**m**	assumes Level 1 Remedial Target calculated from soil-water partitioning equation.
Ratio of Compliance Point to Source Concentration	C_{ED}/C_0	**4.43E-01**	**fraction**	Ogata Banks

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

Enter method of defining partition co-efficient (using pull down list)

Calculate for ionic organic chemicals (acids)

Entry if specify partition coefficient (option)			
Soil water partition coefficient	Kd	[redacted]	l/kg
Entry for non-polar organic chemicals (option)			
Fraction of organic carbon in aquifer	foc	[redacted]	fraction
Organic carbon partition coefficient	Koc		l/kg
Entry for ionic organic chemicals (option)			
Sorption coefficient for related species	$K_{oc,n}$	0.00E+00	l/kg
Sorption coefficient for ionised species	$K_{oc,i}$	0.00E+00	l/kg
pH value	pH	0.00E+00	
Acid dissociation constant	pKa	0.00E+00	
Fraction of organic carbon in aquifer	foc	0.00E+00	fraction
Soil water partition coefficient	Kd	0.00E+00	l/kg

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

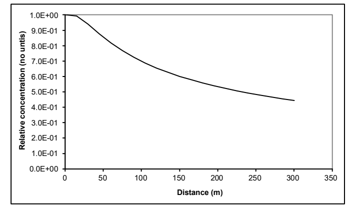
Dispersivities 10%, 1%, 0.1% of pathway length

		Enter value	Calc value	Xu & Eckstein	
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-02	m

Note values of dispersivity must be > 0

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

Note
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 O_2, NO_3, SO_4 etc than an alternative solution should be used



Note: 'Relative concentration' is the ratio of calculated concentation at a given position compared to the source concentration. The calculations assume plume disperses from the top of the aquifer. An alternative solution assuming the centre of the plume is located at the mid-depth of the aquifer is presented in the calculation sheets.

This sheet calculates the Level 3 remedial target for soils(mg/kg) or for pore water (mg/l), 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 (e.g. 9E99) it will give the steady state solution, which should always be used when calculating remedial targets.

The measured soil concentration as mg/kg or pore water 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 9.9E+99.

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

Calculated (relative) concentrations for distance-concentration graph

Ogata Banks
From calculation sheet

Distance	Relative concentration (No units)	Concentration mg/l
0	1.0E+00	1.02E+03
15.0	9.92E-01	1.01E+03
30.0	9.41E-01	9.59E+02
45.0	8.76E-01	8.93E+02
60.0	8.18E-01	8.33E+02
75.0	7.67E-01	7.82E+02
90.0	7.24E-01	7.37E+02
105.0	6.86E-01	7.00E+02
120.0	6.54E-01	6.67E+02
135.0	6.26E-01	6.38E+02
150.0	6.01E-01	6.12E+02
165.0	5.78E-01	5.89E+02
180.0	5.58E-01	5.68E+02
195.0	5.39E-01	5.50E+02
210.0	5.22E-01	5.32E+02
225.0	5.07E-01	5.16E+02
240.0	4.92E-01	5.02E+02
255.0	4.79E-01	4.88E+02
270.0	4.66E-01	4.75E+02
285.0	4.54E-01	4.63E+02
300.0	4.43E-01	4.51E+02

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APPENDIX 2

Assimilative Capacity Assessment

Tuam Tier 3 Assimilative Capacity Assessment

Assimilative capacity = (Cmax – Cback) x F95 x 86.4 kg/day — **Ammoniacal Nitrogen**

Where:

C_{max} = maximum permissible concentration (EQS – 95%ile value) (mg/l) — 0.14

C_{back} = background upstream concentration (mg/l mean value) — 0.021

Q95 = the 95%ile flow in the river (m^3/s) — 1.64

Note: (60x60x24)/1000 = 86.4

AC kg/d	=	**(Cmax**	**-**	**Cbak)**	**x**	**F95**	**x**	**86.4**
	=	0.14	-	0.021	x	1.64	x	86.4
	=		0.119		x	1.64	x	86.4
AC kg/d	=	**16.86 kg/day**						

Emission Concentration (mg/l)	4.79				
m3/sec	l/s	**Flow (m3/day)**	**Daily Mass Emission (kg/day)**	**%-age of AC**	
0.000139	0.1388892	12	0.057	0.3%	
0.000671	0.6712978	58	0.278	2%	
6.71E-05	0.06712978	5.8	0.028	0.2%	

Mass balance Equation:

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

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

F =	1.64	m^3/sec
C =	0.021	mg/l
f =	12	m^3/day
	0.000	m^3/sec
c =	4.790	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. (1.64 x 0.021 + 0.000 x 4.790) / (1.64 + 0.000)
2. 0.03444 / 1.6401 + 0.000
3. 0.035 / 1.640
4. **T = 0.021 mg/l**

EQS (mg/l)

0.14 *Good' Status 95%-ile EQS*

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APPENDIX 3

LandGEM Summary Report

Summary Report

Landfill Name or Identifier: Tuam Historical Landfill - Tuam, Co.Galway

Date: Wednesday 26 October 2022

Description/Comments:

About LandGEM:

First-Order Decomposition Rate Equation:

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

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	**1955**	
Landfill Closure Year (with 80-year limit)	**1983**	
Actual Closure Year (without limit)	***1983***	
Have Model Calculate Closure Year?	**Yes**	
Waste Design Capacity	**232,652**	*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)*
1955	8,058	8,864	0	0
1956	8,058	8,864	8,058	8,864
1957	8,058	8,864	16,116	17,728
1958	8,058	8,864	24,174	26,591
1959	8,058	8,864	32,232	35,455
1960	8,058	8,864	40,290	44,319
1961	8,058	8,864	48,348	53,183
1962	8,058	8,864	56,406	62,047
1963	8,058	8,864	64,464	70,910
1964	8,058	8,864	72,522	79,774
1965	8,058	8,864	80,580	88,638
1966	8,058	8,864	88,638	97,502
1967	8,058	8,864	96,696	106,366
1968	8,058	8,864	104,754	115,229
1969	8,058	8,864	112,812	124,093
1970	8,058	8,864	120,870	132,957
1971	8,058	8,864	128,928	141,821
1972	8,058	8,864	136,986	150,685
1973	8,058	8,864	145,044	159,548
1974	8,058	8,864	153,102	168,412
1975	8,058	8,864	161,160	177,276
1976	8,058	8,864	169,218	186,140
1977	8,058	8,864	177,276	195,004
1978	8,058	8,864	185,334	203,867
1979	8,058	8,864	193,392	212,731
1980	8,058	8,864	201,450	221,595
1981	8,058	8,864	209,508	230,459
1982	8,058	8,864	217,566	239,323
1983	7,028	7,731	225,624	248,186
1984	0	0	232,652	255,917
1985	0	0	232,652	255,917
1986	0	0	232,652	255,917
1987	0	0	232,652	255,917
1988	0	0	232,652	255,917
1989	0	0	232,652	255,917
1990	0	0	232,652	255,917
1991	0	0	232,652	255,917
1992	0	0	232,652	255,917
1993	0	0	232,652	255,917
1994	0	0	232,652	255,917

WASTE ACCEPTANCE RATES (Continued)

Year	Waste Accepted		Waste-In-Place	
	(Mg/year)	*(short tons/year)*	*(Mg)*	*(short tons)*
1995	0	0	232,652	255,917
1996	0	0	232,652	255,917
1997	0	0	232,652	255,917
1998	0	0	232,652	255,917
1999	0	0	232,652	255,917
2000	0	0	232,652	255,917
2001	0	0	232,652	255,917
2002	0	0	232,652	255,917
2003	0	0	232,652	255,917
2004	0	0	232,652	255,917
2005	0	0	232,652	255,917
2006	0	0	232,652	255,917
2007	0	0	232,652	255,917
2008	0	0	232,652	255,917
2009	0	0	232,652	255,917
2010	0	0	232,652	255,917
2011	0	0	232,652	255,917
2012	0	0	232,652	255,917
2013	0	0	232,652	255,917
2014	0	0	232,652	255,917
2015	0	0	232,652	255,917
2016	0	0	232,652	255,917
2017	0	0	232,652	255,917
2018	0	0	232,652	255,917
2019	0	0	232,652	255,917
2020	0	0	232,652	255,917
2021	0	0	232,652	255,917
2022	0	0	232,652	255,917
2023	0	0	232,652	255,917
2024	0	0	232,652	255,917
2025	0	0	232,652	255,917
2026	0	0	232,652	255,917
2027	0	0	232,652	255,917
2028	0	0	232,652	255,917
2029	0	0	232,652	255,917
2030	0	0	232,652	255,917
2031	0	0	232,652	255,917
2032	0	0	232,652	255,917
2033	0	0	232,652	255,917
2034	0	0	232,652	255,917

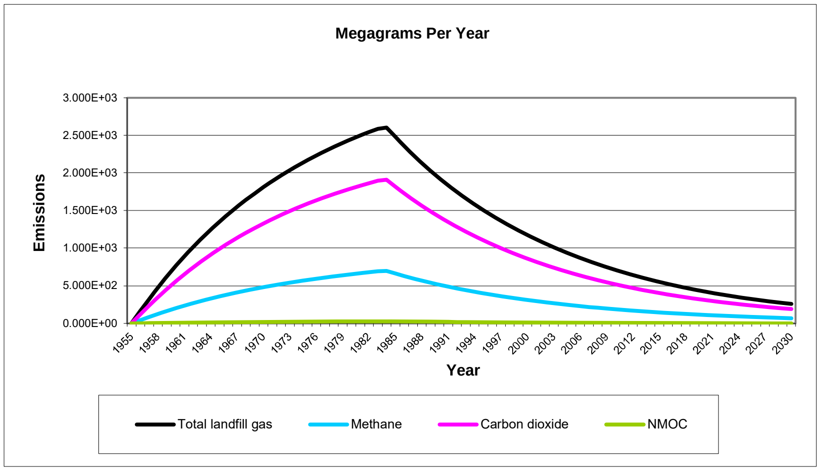
Pollutant Parameters

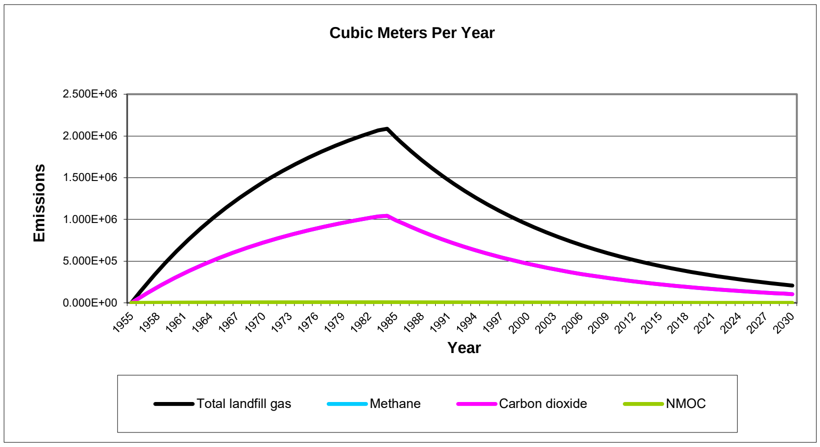
		Gas / Pollutant Default Parameters:		User-specified Pollutant Parameters:	
	Compound	Concentration (*ppmv*)	Molecular Weight	Concentration (*ppmv*)	Molecular Weight
Gases	Total landfill gas		0.00		
	Methane		16.04		
	Carbon dioxide		44.01		
	NMOC	4,000	86.18		
Pollutants	1,1,1-Trichloroethane (methyl 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		

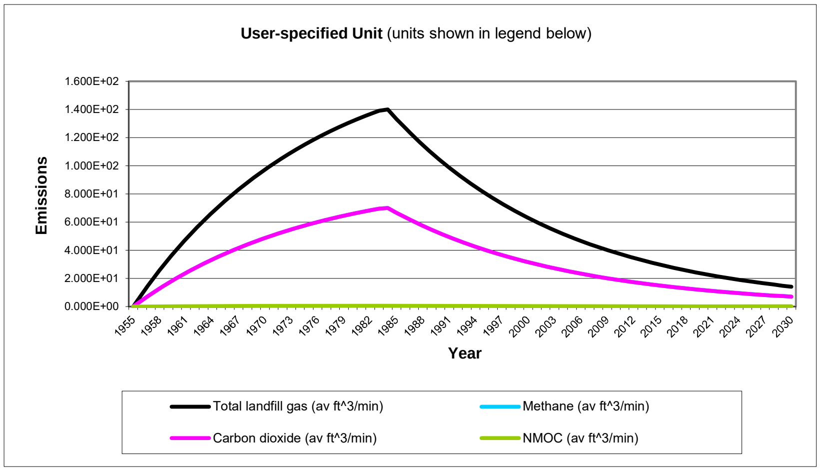
Pollutant Parameters (Continued)

		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
Emissions
Year
Total landfill gas
Methane
Carbon dioxide
NMOC


Cubic Meters Per Year
Emissions
Year
Total landfill gas
Methane
Carbon dioxide
NMOC


User-specified Unit (units shown in legend below)
Emissions
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)*
1955	0	0	0	0	0	0
1956	1.673E+02	1.340E+05	9.000E+00	4.468E+01	6.698E+04	4.500E+00
1957	3.264E+02	2.614E+05	1.756E+01	8.719E+01	1.307E+05	8.781E+00
1958	4.778E+02	3.826E+05	2.571E+01	1.276E+02	1.913E+05	1.285E+01
1959	6.218E+02	4.979E+05	3.345E+01	1.661E+02	2.489E+05	1.673E+01
1960	7.587E+02	6.075E+05	4.082E+01	2.027E+02	3.038E+05	2.041E+01
1961	8.890E+02	7.119E+05	4.783E+01	2.375E+02	3.559E+05	2.391E+01
1962	1.013E+03	8.111E+05	5.450E+01	2.706E+02	4.055E+05	2.725E+01
1963	1.131E+03	9.055E+05	6.084E+01	3.020E+02	4.527E+05	3.042E+01
1964	1.243E+03	9.953E+05	6.687E+01	3.320E+02	4.976E+05	3.344E+01
1965	1.350E+03	1.081E+06	7.261E+01	3.605E+02	5.403E+05	3.631E+01
1966	1.451E+03	1.162E+06	7.807E+01	3.876E+02	5.810E+05	3.904E+01
1967	1.548E+03	1.239E+06	8.326E+01	4.134E+02	6.196E+05	4.163E+01
1968	1.639E+03	1.313E+06	8.820E+01	4.379E+02	6.564E+05	4.410E+01
1969	1.727E+03	1.383E+06	9.290E+01	4.612E+02	6.913E+05	4.645E+01
1970	1.810E+03	1.449E+06	9.737E+01	4.834E+02	7.246E+05	4.869E+01
1971	1.889E+03	1.512E+06	1.016E+02	5.045E+02	7.562E+05	5.081E+01
1972	1.964E+03	1.573E+06	1.057E+02	5.246E+02	7.863E+05	5.283E+01
1973	2.035E+03	1.630E+06	1.095E+02	5.437E+02	8.150E+05	5.476E+01
1974	2.103E+03	1.684E+06	1.132E+02	5.619E+02	8.422E+05	5.659E+01
1975	2.168E+03	1.736E+06	1.167E+02	5.791E+02	8.681E+05	5.833E+01
1976	2.230E+03	1.785E+06	1.200E+02	5.956E+02	8.927E+05	5.998E+01
1977	2.288E+03	1.832E+06	1.231E+02	6.112E+02	9.162E+05	6.156E+01
1978	2.344E+03	1.877E+06	1.261E+02	6.261E+02	9.385E+05	6.305E+01
1979	2.397E+03	1.919E+06	1.290E+02	6.402E+02	9.597E+05	6.448E+01
1980	2.447E+03	1.960E+06	1.317E+02	6.537E+02	9.798E+05	6.583E+01
1981	2.495E+03	1.998E+06	1.342E+02	6.665E+02	9.990E+05	6.712E+01
1982	2.541E+03	2.035E+06	1.367E+02	6.787E+02	1.017E+06	6.835E+01
1983	2.584E+03	2.069E+06	1.390E+02	6.903E+02	1.035E+06	6.952E+01
1984	2.604E+03	2.085E+06	1.401E+02	6.956E+02	1.043E+06	7.005E+01
1985	2.477E+03	1.983E+06	1.333E+02	6.616E+02	9.917E+05	6.664E+01
1986	2.356E+03	1.887E+06	1.268E+02	6.294E+02	9.434E+05	6.339E+01
1987	2.241E+03	1.795E+06	1.206E+02	5.987E+02	8.974E+05	6.029E+01
1988	2.132E+03	1.707E+06	1.147E+02	5.695E+02	8.536E+05	5.735E+01
1989	2.028E+03	1.624E+06	1.091E+02	5.417E+02	8.120E+05	5.456E+01
1990	1.929E+03	1.545E+06	1.038E+02	5.153E+02	7.724E+05	5.190E+01
1991	1.835E+03	1.469E+06	9.873E+01	4.902E+02	7.347E+05	4.936E+01
1992	1.746E+03	1.398E+06	9.391E+01	4.663E+02	6.989E+05	4.696E+01
1993	1.660E+03	1.330E+06	8.933E+01	4.435E+02	6.648E+05	4.467E+01
1994	1.579E+03	1.265E+06	8.498E+01	4.219E+02	6.324E+05	4.249E+01
1995	1.502E+03	1.203E+06	8.083E+01	4.013E+02	6.015E+05	4.042E+01
1996	1.429E+03	1.144E+06	7.689E+01	3.817E+02	5.722E+05	3.845E+01
1997	1.359E+03	1.089E+06	7.314E+01	3.631E+02	5.443E+05	3.657E+01
1998	1.293E+03	1.035E+06	6.957E+01	3.454E+02	5.177E+05	3.479E+01
1999	1.230E+03	9.850E+05	6.618E+01	3.286E+02	4.925E+05	3.309E+01
2000	1.170E+03	9.369E+05	6.295E+01	3.125E+02	4.685E+05	3.148E+01
2001	1.113E+03	8.912E+05	5.988E+01	2.973E+02	4.456E+05	2.994E+01
2002	1.059E+03	8.478E+05	5.696E+01	2.828E+02	4.239E+05	2.848E+01
2003	1.007E+03	8.064E+05	5.418E+01	2.690E+02	4.032E+05	2.709E+01
2004	9.580E+02	7.671E+05	5.154E+01	2.559E+02	3.835E+05	2.577E+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)*
2005	9.112E+02	7.297E+05	4.903E+01	2.434E+02	3.648E+05	2.451E+01
2006	8.668E+02	6.941E+05	4.664E+01	2.315E+02	3.470E+05	2.332E+01
2007	8.245E+02	6.602E+05	4.436E+01	2.202E+02	3.301E+05	2.218E+01
2008	7.843E+02	6.280E+05	4.220E+01	2.095E+02	3.140E+05	2.110E+01
2009	7.461E+02	5.974E+05	4.014E+01	1.993E+02	2.987E+05	2.007E+01
2010	7.097E+02	5.683E+05	3.818E+01	1.896E+02	2.841E+05	1.909E+01
2011	6.751E+02	5.406E+05	3.632E+01	1.803E+02	2.703E+05	1.816E+01
2012	6.421E+02	5.142E+05	3.455E+01	1.715E+02	2.571E+05	1.727E+01
2013	6.108E+02	4.891E+05	3.286E+01	1.632E+02	2.446E+05	1.643E+01
2014	5.810E+02	4.653E+05	3.126E+01	1.552E+02	2.326E+05	1.563E+01
2015	5.527E+02	4.426E+05	2.974E+01	1.476E+02	2.213E+05	1.487E+01
2016	5.257E+02	4.210E+05	2.829E+01	1.404E+02	2.105E+05	1.414E+01
2017	5.001E+02	4.005E+05	2.691E+01	1.336E+02	2.002E+05	1.345E+01
2018	4.757E+02	3.809E+05	2.559E+01	1.271E+02	1.905E+05	1.280E+01
2019	4.525E+02	3.624E+05	2.435E+01	1.209E+02	1.812E+05	1.217E+01
2020	4.304E+02	3.447E+05	2.316E+01	1.150E+02	1.723E+05	1.158E+01
2021	4.095E+02	3.279E+05	2.203E+01	1.094E+02	1.639E+05	1.101E+01
2022	3.895E+02	3.119E+05	2.096E+01	1.040E+02	1.559E+05	1.048E+01
2023	3.705E+02	2.967E+05	1.993E+01	9.896E+01	1.483E+05	9.967E+00
2024	3.524E+02	2.822E+05	1.896E+01	9.413E+01	1.411E+05	9.480E+00
2025	3.352E+02	2.684E+05	1.804E+01	8.954E+01	1.342E+05	9.018E+00
2026	3.189E+02	2.553E+05	1.716E+01	8.518E+01	1.277E+05	8.578E+00
2027	3.033E+02	2.429E+05	1.632E+01	8.102E+01	1.214E+05	8.160E+00
2028	2.885E+02	2.310E+05	1.552E+01	7.707E+01	1.155E+05	7.762E+00
2029	2.745E+02	2.198E+05	1.477E+01	7.331E+01	1.099E+05	7.383E+00
2030	2.611E+02	2.091E+05	1.405E+01	6.974E+01	1.045E+05	7.023E+00
2031	2.483E+02	1.989E+05	1.336E+01	6.634E+01	9.943E+04	6.681E+00
2032	2.362E+02	1.892E+05	1.271E+01	6.310E+01	9.458E+04	6.355E+00
2033	2.247E+02	1.799E+05	1.209E+01	6.002E+01	8.997E+04	6.045E+00
2034	2.138E+02	1.712E+05	1.150E+01	5.710E+01	8.558E+04	5.750E+00
2035	2.033E+02	1.628E+05	1.094E+01	5.431E+01	8.141E+04	5.470E+00
2036	1.934E+02	1.549E+05	1.041E+01	5.166E+01	7.744E+04	5.203E+00
2037	1.840E+02	1.473E+05	9.898E+00	4.914E+01	7.366E+04	4.949E+00
2038	1.750E+02	1.401E+05	9.416E+00	4.675E+01	7.007E+04	4.708E+00
2039	1.665E+02	1.333E+05	8.957E+00	4.447E+01	6.665E+04	4.478E+00
2040	1.584E+02	1.268E+05	8.520E+00	4.230E+01	6.340E+04	4.260E+00
2041	1.506E+02	1.206E+05	8.104E+00	4.023E+01	6.031E+04	4.052E+00
2042	1.433E+02	1.147E+05	7.709E+00	3.827E+01	5.737E+04	3.854E+00
2043	1.363E+02	1.091E+05	7.333E+00	3.641E+01	5.457E+04	3.666E+00
2044	1.296E+02	1.038E+05	6.975E+00	3.463E+01	5.191E+04	3.488E+00
2045	1.233E+02	9.875E+04	6.635E+00	3.294E+01	4.938E+04	3.318E+00
2046	1.173E+02	9.394E+04	6.312E+00	3.133E+01	4.697E+04	3.156E+00
2047	1.116E+02	8.935E+04	6.004E+00	2.981E+01	4.468E+04	3.002E+00
2048	1.061E+02	8.500E+04	5.711E+00	2.835E+01	4.250E+04	2.855E+00
2049	1.010E+02	8.085E+04	5.432E+00	2.697E+01	4.043E+04	2.716E+00
2050	9.604E+01	7.691E+04	5.167E+00	2.565E+01	3.845E+04	2.584E+00
2051	9.136E+01	7.316E+04	4.915E+00	2.440E+01	3.658E+04	2.458E+00
2052	8.691E+01	6.959E+04	4.676E+00	2.321E+01	3.479E+04	2.338E+00
2053	8.267E+01	6.620E+04	4.448E+00	2.208E+01	3.310E+04	2.224E+00
2054	7.863E+01	6.297E+04	4.231E+00	2.100E+01	3.148E+04	2.115E+00
2055	7.480E+01	5.990E+04	4.024E+00	1.998E+01	2.995E+04	2.012E+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)
2056	7.115E+01	5.698E+04	3.828E+00	1.901E+01	2.849E+04	1.914E+00
2057	6.768E+01	5.420E+04	3.641E+00	1.808E+01	2.710E+04	1.821E+00
2058	6.438E+01	5.155E+04	3.464E+00	1.720E+01	2.578E+04	1.732E+00
2059	6.124E+01	4.904E+04	3.295E+00	1.636E+01	2.452E+04	1.647E+00
2060	5.825E+01	4.665E+04	3.134E+00	1.556E+01	2.332E+04	1.567E+00
2061	5.541E+01	4.437E+04	2.981E+00	1.480E+01	2.219E+04	1.491E+00
2062	5.271E+01	4.221E+04	2.836E+00	1.408E+01	2.110E+04	1.418E+00
2063	5.014E+01	4.015E+04	2.698E+00	1.339E+01	2.007E+04	1.349E+00
2064	4.769E+01	3.819E+04	2.566E+00	1.274E+01	1.910E+04	1.283E+00
2065	4.537E+01	3.633E+04	2.441E+00	1.212E+01	1.816E+04	1.220E+00
2066	4.316E+01	3.456E+04	2.322E+00	1.153E+01	1.728E+04	1.161E+00
2067	4.105E+01	3.287E+04	2.209E+00	1.097E+01	1.644E+04	1.104E+00
2068	3.905E+01	3.127E+04	2.101E+00	1.043E+01	1.563E+04	1.050E+00
2069	3.714E+01	2.974E+04	1.998E+00	9.922E+00	1.487E+04	9.992E-01
2070	3.533E+01	2.829E+04	1.901E+00	9.438E+00	1.415E+04	9.505E-01
2071	3.361E+01	2.691E+04	1.808E+00	8.978E+00	1.346E+04	9.041E-01
2072	3.197E+01	2.560E+04	1.720E+00	8.540E+00	1.280E+04	8.600E-01
2073	3.041E+01	2.435E+04	1.636E+00	8.123E+00	1.218E+04	8.181E-01
2074	2.893E+01	2.316E+04	1.556E+00	7.727E+00	1.158E+04	7.782E-01
2075	2.752E+01	2.203E+04	1.481E+00	7.350E+00	1.102E+04	7.403E-01
2076	2.618E+01	2.096E+04	1.408E+00	6.992E+00	1.048E+04	7.041E-01
2077	2.490E+01	1.994E+04	1.340E+00	6.651E+00	9.969E+03	6.698E-01
2078	2.368E+01	1.897E+04	1.274E+00	6.326E+00	9.483E+03	6.371E-01
2079	2.253E+01	1.804E+04	1.212E+00	6.018E+00	9.020E+03	6.061E-01
2080	2.143E+01	1.716E+04	1.153E+00	5.724E+00	8.580E+03	5.765E-01
2081	2.039E+01	1.632E+04	1.097E+00	5.445E+00	8.162E+03	5.484E-01
2082	1.939E+01	1.553E+04	1.043E+00	5.180E+00	7.764E+03	5.216E-01
2083	1.845E+01	1.477E+04	9.924E-01	4.927E+00	7.385E+03	4.962E-01
2084	1.755E+01	1.405E+04	9.440E-01	4.687E+00	7.025E+03	4.720E-01
2085	1.669E+01	1.336E+04	8.980E-01	4.458E+00	6.682E+03	4.490E-01
2086	1.588E+01	1.271E+04	8.542E-01	4.241E+00	6.356E+03	4.271E-01
2087	1.510E+01	1.209E+04	8.125E-01	4.034E+00	6.046E+03	4.063E-01
2088	1.437E+01	1.150E+04	7.729E-01	3.837E+00	5.752E+03	3.864E-01
2089	1.366E+01	1.094E+04	7.352E-01	3.650E+00	5.471E+03	3.676E-01
2090	1.300E+01	1.041E+04	6.993E-01	3.472E+00	5.204E+03	3.497E-01
2091	1.236E+01	9.901E+03	6.652E-01	3.303E+00	4.950E+03	3.326E-01
2092	1.176E+01	9.418E+03	6.328E-01	3.142E+00	4.709E+03	3.164E-01
2093	1.119E+01	8.959E+03	6.019E-01	2.988E+00	4.479E+03	3.010E-01
2094	1.064E+01	8.522E+03	5.726E-01	2.843E+00	4.261E+03	2.863E-01
2095	1.012E+01	8.106E+03	5.446E-01	2.704E+00	4.053E+03	2.723E-01

Results (Continued)

Year	Carbon dioxide			NMOC		
	(Mg/year)	*(m^3/year)*	*(av ft^3/min)*	*(Mg/year)*	*(m^3/year)*	*(av ft^3/min)*
1955	0	0	0	0	0	0
1956	1.226E+02	6.698E+04	4.500E+00	1.921E+00	5.358E+02	3.600E-02
1957	2.392E+02	1.307E+05	8.781E+00	3.748E+00	1.045E+03	7.025E-02
1958	3.502E+02	1.913E+05	1.285E+01	5.485E+00	1.530E+03	1.028E-01
1959	4.557E+02	2.489E+05	1.673E+01	7.138E+00	1.991E+03	1.338E-01
1960	5.561E+02	3.038E+05	2.041E+01	8.711E+00	2.430E+03	1.633E-01
1961	6.515E+02	3.559E+05	2.391E+01	1.021E+01	2.847E+03	1.913E-01
1962	7.424E+02	4.055E+05	2.725E+01	1.163E+01	3.244E+03	2.180E-01
1963	8.287E+02	4.527E+05	3.042E+01	1.298E+01	3.622E+03	2.434E-01
1964	9.109E+02	4.976E+05	3.344E+01	1.427E+01	3.981E+03	2.675E-01
1965	9.891E+02	5.403E+05	3.631E+01	1.549E+01	4.323E+03	2.904E-01
1966	1.063E+03	5.810E+05	3.904E+01	1.666E+01	4.648E+03	3.123E-01
1967	1.134E+03	6.196E+05	4.163E+01	1.777E+01	4.957E+03	3.331E-01
1968	1.201E+03	6.564E+05	4.410E+01	1.882E+01	5.251E+03	3.528E-01
1969	1.265E+03	6.913E+05	4.645E+01	1.982E+01	5.531E+03	3.716E-01
1970	1.326E+03	7.246E+05	4.869E+01	2.078E+01	5.797E+03	3.895E-01
1971	1.384E+03	7.562E+05	5.081E+01	2.169E+01	6.050E+03	4.065E-01
1972	1.439E+03	7.863E+05	5.283E+01	2.255E+01	6.291E+03	4.227E-01
1973	1.492E+03	8.150E+05	5.476E+01	2.337E+01	6.520E+03	4.381E-01
1974	1.542E+03	8.422E+05	5.659E+01	2.415E+01	6.737E+03	4.527E-01
1975	1.589E+03	8.681E+05	5.833E+01	2.489E+01	6.945E+03	4.666E-01
1976	1.634E+03	8.927E+05	5.998E+01	2.560E+01	7.142E+03	4.799E-01
1977	1.677E+03	9.162E+05	6.156E+01	2.627E+01	7.329E+03	4.925E-01
1978	1.718E+03	9.385E+05	6.305E+01	2.691E+01	7.508E+03	5.044E-01
1979	1.757E+03	9.597E+05	6.448E+01	2.752E+01	7.677E+03	5.158E-01
1980	1.794E+03	9.798E+05	6.583E+01	2.810E+01	7.839E+03	5.267E-01
1981	1.829E+03	9.990E+05	6.712E+01	2.865E+01	7.992E+03	5.370E-01
1982	1.862E+03	1.017E+06	6.835E+01	2.917E+01	8.138E+03	5.468E-01
1983	1.894E+03	1.035E+06	6.952E+01	2.967E+01	8.277E+03	5.561E-01
1984	1.908E+03	1.043E+06	7.005E+01	2.990E+01	8.341E+03	5.604E-01
1985	1.815E+03	9.917E+05	6.664E+01	2.844E+01	7.934E+03	5.331E-01
1986	1.727E+03	9.434E+05	6.339E+01	2.705E+01	7.547E+03	5.071E-01
1987	1.643E+03	8.974E+05	6.029E+01	2.573E+01	7.179E+03	4.824E-01
1988	1.563E+03	8.536E+05	5.735E+01	2.448E+01	6.829E+03	4.588E-01
1989	1.486E+03	8.120E+05	5.456E+01	2.328E+01	6.496E+03	4.365E-01
1990	1.414E+03	7.724E+05	5.190E+01	2.215E+01	6.179E+03	4.152E-01
1991	1.345E+03	7.347E+05	4.936E+01	2.107E+01	5.878E+03	3.949E-01
1992	1.279E+03	6.989E+05	4.696E+01	2.004E+01	5.591E+03	3.757E-01
1993	1.217E+03	6.648E+05	4.467E+01	1.906E+01	5.318E+03	3.573E-01
1994	1.158E+03	6.324E+05	4.249E+01	1.813E+01	5.059E+03	3.399E-01
1995	1.101E+03	6.015E+05	4.042E+01	1.725E+01	4.812E+03	3.233E-01
1996	1.047E+03	5.722E+05	3.845E+01	1.641E+01	4.578E+03	3.076E-01
1997	9.963E+02	5.443E+05	3.657E+01	1.561E+01	4.354E+03	2.926E-01
1998	9.477E+02	5.177E+05	3.479E+01	1.485E+01	4.142E+03	2.783E-01
1999	9.015E+02	4.925E+05	3.309E+01	1.412E+01	3.940E+03	2.647E-01
2000	8.575E+02	4.685E+05	3.148E+01	1.343E+01	3.748E+03	2.518E-01
2001	8.157E+02	4.456E+05	2.994E+01	1.278E+01	3.565E+03	2.395E-01
2002	7.759E+02	4.239E+05	2.848E+01	1.216E+01	3.391E+03	2.278E-01
2003	7.381E+02	4.032E+05	2.709E+01	1.156E+01	3.226E+03	2.167E-01
2004	7.021E+02	3.835E+05	2.577E+01	1.100E+01	3.068E+03	2.062E-01

Results (Continued)

Year	Carbon dioxide			NMOC		
	(Mg/year)	*(m^3/year)*	*(av ft^3/min)*	*(Mg/year)*	*(m^3/year)*	*(av ft^3/min)*
2005	6.678E+02	3.648E+05	2.451E+01	1.046E+01	2.919E+03	1.961E-01
2006	6.353E+02	3.470E+05	2.332E+01	9.952E+00	2.776E+03	1.865E-01
2007	6.043E+02	3.301E+05	2.218E+01	9.467E+00	2.641E+03	1.774E-01
2008	5.748E+02	3.140E+05	2.110E+01	9.005E+00	2.512E+03	1.688E-01
2009	5.468E+02	2.987E+05	2.007E+01	8.566E+00	2.390E+03	1.606E-01
2010	5.201E+02	2.841E+05	1.909E+01	8.148E+00	2.273E+03	1.527E-01
2011	4.948E+02	2.703E+05	1.816E+01	7.751E+00	2.162E+03	1.453E-01
2012	4.706E+02	2.571E+05	1.727E+01	7.373E+00	2.057E+03	1.382E-01
2013	4.477E+02	2.446E+05	1.643E+01	7.013E+00	1.956E+03	1.315E-01
2014	4.258E+02	2.326E+05	1.563E+01	6.671E+00	1.861E+03	1.250E-01
2015	4.051E+02	2.213E+05	1.487E+01	6.346E+00	1.770E+03	1.189E-01
2016	3.853E+02	2.105E+05	1.414E+01	6.036E+00	1.684E+03	1.131E-01
2017	3.665E+02	2.002E+05	1.345E+01	5.742E+00	1.602E+03	1.076E-01
2018	3.486E+02	1.905E+05	1.280E+01	5.462E+00	1.524E+03	1.024E-01
2019	3.316E+02	1.812E+05	1.217E+01	5.195E+00	1.449E+03	9.739E-02
2020	3.155E+02	1.723E+05	1.158E+01	4.942E+00	1.379E+03	9.264E-02
2021	3.001E+02	1.639E+05	1.101E+01	4.701E+00	1.311E+03	8.812E-02
2022	2.854E+02	1.559E+05	1.048E+01	4.472E+00	1.248E+03	8.382E-02
2023	2.715E+02	1.483E+05	9.967E+00	4.254E+00	1.187E+03	7.973E-02
2024	2.583E+02	1.411E+05	9.480E+00	4.046E+00	1.129E+03	7.584E-02
2025	2.457E+02	1.342E+05	9.018E+00	3.849E+00	1.074E+03	7.214E-02
2026	2.337E+02	1.277E+05	8.578E+00	3.661E+00	1.021E+03	6.863E-02
2027	2.223E+02	1.214E+05	8.160E+00	3.483E+00	9.716E+02	6.528E-02
2028	2.115E+02	1.155E+05	7.762E+00	3.313E+00	9.242E+02	6.210E-02
2029	2.012E+02	1.099E+05	7.383E+00	3.151E+00	8.791E+02	5.907E-02
2030	1.913E+02	1.045E+05	7.023E+00	2.997E+00	8.362E+02	5.619E-02
2031	1.820E+02	9.943E+04	6.681E+00	2.851E+00	7.955E+02	5.345E-02
2032	1.731E+02	9.458E+04	6.355E+00	2.712E+00	7.567E+02	5.084E-02
2033	1.647E+02	8.997E+04	6.045E+00	2.580E+00	7.198E+02	4.836E-02
2034	1.567E+02	8.558E+04	5.750E+00	2.454E+00	6.847E+02	4.600E-02
2035	1.490E+02	8.141E+04	5.470E+00	2.334E+00	6.513E+02	4.376E-02
2036	1.417E+02	7.744E+04	5.203E+00	2.221E+00	6.195E+02	4.162E-02
2037	1.348E+02	7.366E+04	4.949E+00	2.112E+00	5.893E+02	3.959E-02
2038	1.283E+02	7.007E+04	4.708E+00	2.009E+00	5.605E+02	3.766E-02
2039	1.220E+02	6.665E+04	4.478E+00	1.911E+00	5.332E+02	3.583E-02
2040	1.161E+02	6.340E+04	4.260E+00	1.818E+00	5.072E+02	3.408E-02
2041	1.104E+02	6.031E+04	4.052E+00	1.729E+00	4.825E+02	3.242E-02
2042	1.050E+02	5.737E+04	3.854E+00	1.645E+00	4.589E+02	3.084E-02
2043	9.989E+01	5.457E+04	3.666E+00	1.565E+00	4.366E+02	2.933E-02
2044	9.502E+01	5.191E+04	3.488E+00	1.488E+00	4.153E+02	2.790E-02
2045	9.038E+01	4.938E+04	3.318E+00	1.416E+00	3.950E+02	2.654E-02
2046	8.597E+01	4.697E+04	3.156E+00	1.347E+00	3.757E+02	2.525E-02
2047	8.178E+01	4.468E+04	3.002E+00	1.281E+00	3.574E+02	2.401E-02
2048	7.779E+01	4.250E+04	2.855E+00	1.219E+00	3.400E+02	2.284E-02
2049	7.400E+01	4.043E+04	2.716E+00	1.159E+00	3.234E+02	2.173E-02
2050	7.039E+01	3.845E+04	2.584E+00	1.103E+00	3.076E+02	2.067E-02
2051	6.696E+01	3.658E+04	2.458E+00	1.049E+00	2.926E+02	1.966E-02
2052	6.369E+01	3.479E+04	2.338E+00	9.978E-01	2.784E+02	1.870E-02
2053	6.059E+01	3.310E+04	2.224E+00	9.491E-01	2.648E+02	1.779E-02
2054	5.763E+01	3.148E+04	2.115E+00	9.028E-01	2.519E+02	1.692E-02
2055	5.482E+01	2.995E+04	2.012E+00	8.588E-01	2.396E+02	1.610E-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)*
2056	5.215E+01	2.849E+04	1.914E+00	8.169E-01	2.279E+02	1.531E-02
2057	4.960E+01	2.710E+04	1.821E+00	7.771E-01	2.168E+02	1.457E-02
2058	4.718E+01	2.578E+04	1.732E+00	7.392E-01	2.062E+02	1.386E-02
2059	4.488E+01	2.452E+04	1.647E+00	7.031E-01	1.962E+02	1.318E-02
2060	4.269E+01	2.332E+04	1.567E+00	6.688E-01	1.866E+02	1.254E-02
2061	4.061E+01	2.219E+04	1.491E+00	6.362E-01	1.775E+02	1.193E-02
2062	3.863E+01	2.110E+04	1.418E+00	6.052E-01	1.688E+02	1.134E-02
2063	3.675E+01	2.007E+04	1.349E+00	5.757E-01	1.606E+02	1.079E-02
2064	3.495E+01	1.910E+04	1.283E+00	5.476E-01	1.528E+02	1.026E-02
2065	3.325E+01	1.816E+04	1.220E+00	5.209E-01	1.453E+02	9.764E-03
2066	3.163E+01	1.728E+04	1.161E+00	4.955E-01	1.382E+02	9.288E-03
2067	3.009E+01	1.644E+04	1.104E+00	4.713E-01	1.315E+02	8.835E-03
2068	2.862E+01	1.563E+04	1.050E+00	4.483E-01	1.251E+02	8.404E-03
2069	2.722E+01	1.487E+04	9.992E-01	4.265E-01	1.190E+02	7.994E-03
2070	2.590E+01	1.415E+04	9.505E-01	4.057E-01	1.132E+02	7.604E-03
2071	2.463E+01	1.346E+04	9.041E-01	3.859E-01	1.077E+02	7.233E-03
2072	2.343E+01	1.280E+04	8.600E-01	3.671E-01	1.024E+02	6.880E-03
2073	2.229E+01	1.218E+04	8.181E-01	3.492E-01	9.741E+01	6.545E-03
2074	2.120E+01	1.158E+04	7.782E-01	3.321E-01	9.266E+01	6.226E-03
2075	2.017E+01	1.102E+04	7.403E-01	3.159E-01	8.814E+01	5.922E-03
2076	1.918E+01	1.048E+04	7.041E-01	3.005E-01	8.384E+01	5.633E-03
2077	1.825E+01	9.969E+03	6.698E-01	2.859E-01	7.975E+01	5.358E-03
2078	1.736E+01	9.483E+03	6.371E-01	2.719E-01	7.586E+01	5.097E-03
2079	1.651E+01	9.020E+03	6.061E-01	2.587E-01	7.216E+01	4.849E-03
2080	1.571E+01	8.580E+03	5.765E-01	2.460E-01	6.864E+01	4.612E-03
2081	1.494E+01	8.162E+03	5.484E-01	2.340E-01	6.529E+01	4.387E-03
2082	1.421E+01	7.764E+03	5.216E-01	2.226E-01	6.211E+01	4.173E-03
2083	1.352E+01	7.385E+03	4.962E-01	2.118E-01	5.908E+01	3.970E-03
2084	1.286E+01	7.025E+03	4.720E-01	2.014E-01	5.620E+01	3.776E-03
2085	1.223E+01	6.682E+03	4.490E-01	1.916E-01	5.346E+01	3.592E-03
2086	1.164E+01	6.356E+03	4.271E-01	1.823E-01	5.085E+01	3.417E-03
2087	1.107E+01	6.046E+03	4.063E-01	1.734E-01	4.837E+01	3.250E-03
2088	1.053E+01	5.752E+03	3.864E-01	1.649E-01	4.601E+01	3.092E-03
2089	1.001E+01	5.471E+03	3.676E-01	1.569E-01	4.377E+01	2.941E-03
2090	9.526E+00	5.204E+03	3.497E-01	1.492E-01	4.163E+01	2.797E-03
2091	9.062E+00	4.950E+03	3.326E-01	1.420E-01	3.960E+01	2.661E-03
2092	8.620E+00	4.709E+03	3.164E-01	1.350E-01	3.767E+01	2.531E-03
2093	8.199E+00	4.479E+03	3.010E-01	1.284E-01	3.583E+01	2.408E-03
2094	7.799E+00	4.261E+03	2.863E-01	1.222E-01	3.409E+01	2.290E-03
2095	7.419E+00	4.053E+03	2.723E-01	1.162E-01	3.242E+01	2.179E-03

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APPENDIX 4

Remediation Plan Drawings

DRAWING SCHEDULE	
DRAWING NUMBER	DRAWING TITLE
P2282-0000-0101-0001	DRAWING SCHEDULE (TUAM HISTORIC LANDFILL)
P2282-0101-0001	SITE LOCATION MAP (TUAM HISTORIC LANDFILL)
P2282-0101-0002	EXISTING SITE SURVEY (TUAM HISTORIC LANDFILL)
P2282-0101-0003	PROPOSED REPAIRS TO EXISTING LANDFILL CAPPING (TUAM HISTORIC LANDFILL)
P2282-0101-0004	EXISTING & PROPOSED MONITORING LOCATIONS (TUAM HISTORIC LANDFILL)
P2282-0401-0001	EXISTING AND PROPOSED FENCING (TUAM HISTORIC LANDFILL)

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Rev.	Description	App By	Date
A	FOR INFORMATION	JON	20.01.21

PROJECT: ERA GALWAY HISTORIC LANDFILLS

CLIENT: GALWAY COUNTY COUNCIL

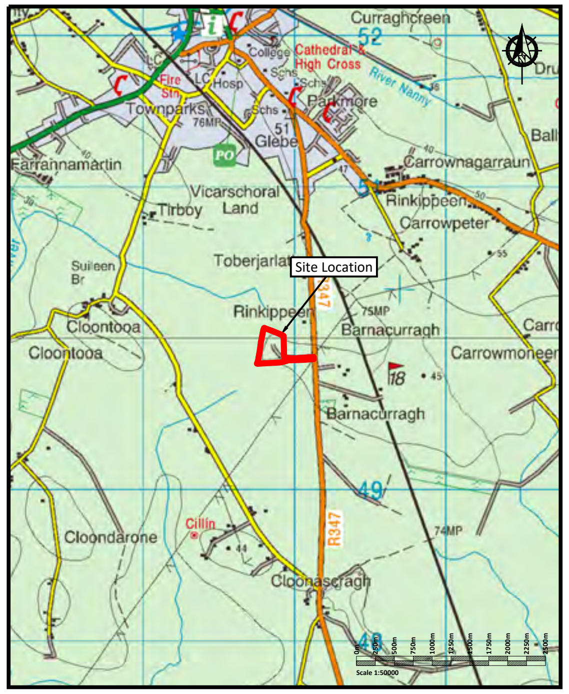
SHEET: DRAWING SCHEDULE (TUAM HISTORIC LANDFILL)

Date	Project number	Scale (@ A3)
20.01.21	P2282	1:2000

Drawn by	Checked by	Drawing Number	Rev
POR	AB	P2282-0000-0101-0001	A

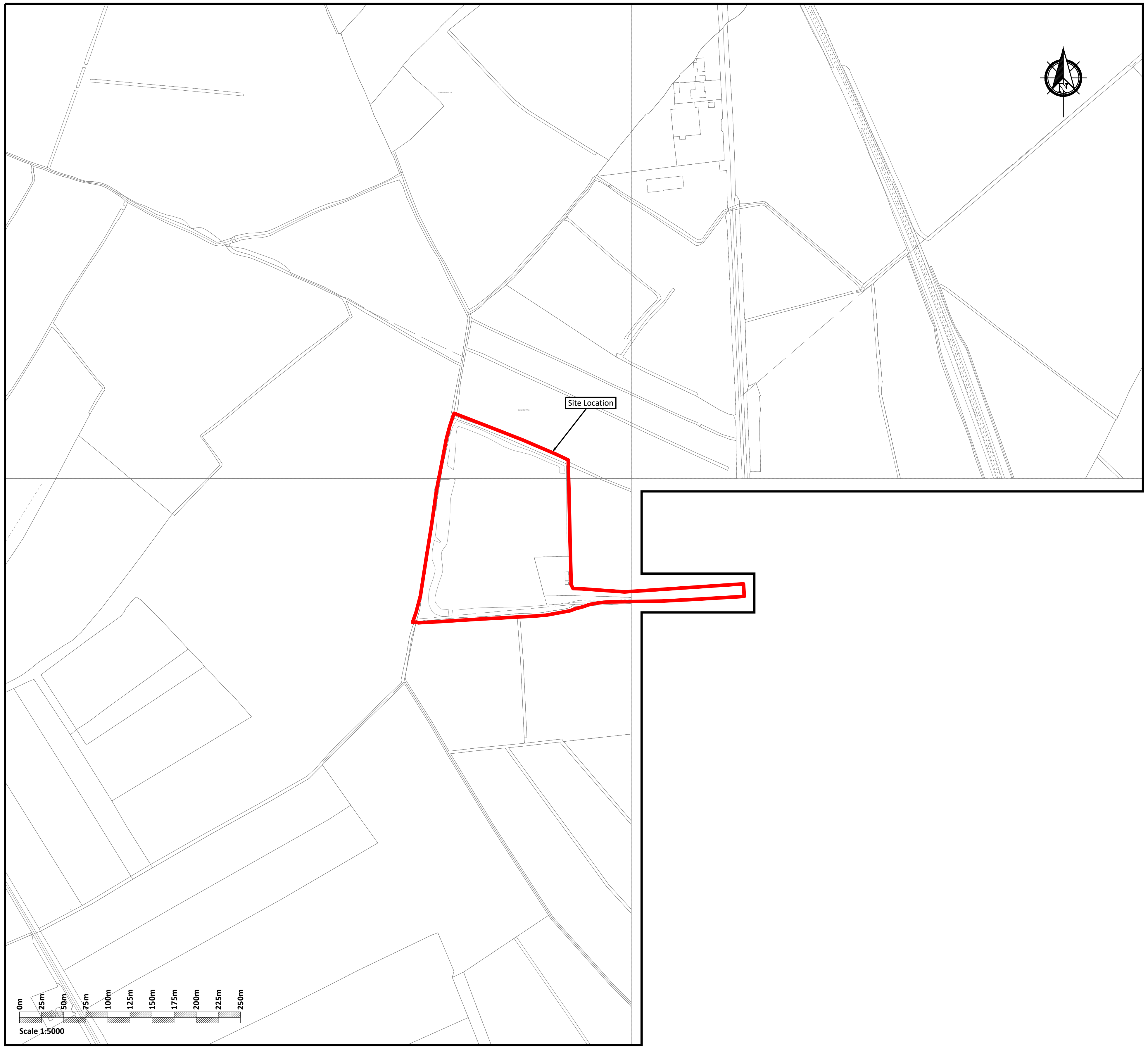
O:\ACAD\2020\P2282\P2282-0000-0101-0001

Wednesday 20 January 2021



SITE LOCATION

Scale 1:50000



SITE LOCATION

Scale 1:5000

If Applicable : Ordnance Survey Ireland Licence No. EN 0001220 © Ordnance Survey Ireland and Government of Ireland
2282,2813-04,2813-05,2813-09,2813-10,2813-14,2813-15,2813-19,2813-20,2813-A,2813-B,2813-C,2813-D,2814,2814-01,2814-06,2814-11,2814-16,2814-A,2814-C,2881,2881-A,2881-B,2881-C,3354,3802-22,3802-A,3802-B,3802-C,3802-D

Rev.	Description	App By	Date
A	FOR INFORMATION	JON	20.01.21

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PROJECT
ERA GALWAY HISTORIC LANDFILLS

CLIENT
GALWAY COUNTY COUNCIL

SHEET
SITE LOCATION MAP (TUAM HISTORIC LANDFILL)

Date	Project number	Scale (@ A3)	
20.01.21	P2282	1:5000	
Drawn by: POR	Drawing Number		Rev
Checked by: AB	P2282-0101-0001		A

O:\ACAD\2020\P2282\P2282-0101-0001

Wednesday 20 January 2021

Legend:

Site Boundary

PLAN

Scale 1:1200

0m 6m 12m 18m 24m 30m 36m 42m 48m 54m 60m

Scale 1:1200

If Applicable : Ordnance Survey Ireland Licence No. EN 0001220 © Ordnance Survey Ireland and Government of Ireland
2282,2813-04,2813-05,2813-09,2813-10,2813-14,2813-15,2813-19,2813-20,2813-A,2813-B,2813-C,2813-D,2814,2814-01,2814-06,2814-11,2814-16,2814-A,2814-C,2881,2881-A,2881-B,2881-C,3354,3802-22,3802-A,3802-B,3802-C,3802-D

FEHILY TIMONEY

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Rev.	Description	App By	Date
A	FOR INFORMATION	JON	20.01.21

PROJECT

ERA GALWAY HISTORIC LANDFILLS

CLIENT

GALWAY COUNTY COUNCIL

SHEET

EXISTING SITE SURVEY (TUAM HISTORIC LANDFILL)

Date 20.01.21	Project number P2282	Scale (@ A3) 1:1200	
Drawn by POR	Drawing Number P2282-0101-0002		Rev A
Checked by AB			

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Wednesday 20 January 2021

Legend:

- Existing Landfill Capping Area
- Localised Areas of Poaching to be repaired as required

PLAN

Scale 1:1200

0m 6m 12m 18m 24m 30m 36m 42m 48m 54m 60m

Scale 1:1200

If Applicable : Ordnance Survey Ireland Licence No. EN 0001220 © Ordnance Survey Ireland and Government of Ireland
2282,2813-04,2813-05,2813-09,2813-10,2813-14,2813-15,2813-19,2813-20,2813-A,2813-B,2813-C,2813-D,2814,2814-01,2814-06,2814-11,2814-16,2814-A,2814-C,2881,2881-A,2881-B,2881-C,3354,3802-22,3802-A,3802-B,3802-C,3802-D

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Rev.	Description	App By	Date
A	FOR INFORMATION	JON	20.01.21

PROJECT
ERA GALWAY HISTORIC LANDFILLS

CLIENT
GALWAY COUNTY COUNCIL

SHEET
PROPOSED REPAIRS TO EXISTING LANDFILL CAPPING (TUAM HISTORIC LANDFILL)

Date	Project number	Scale (@ A3)
20.01.21	P2282	1:1200

Drawn by	Drawing Number	Rev
POR	P2282-0101-0003	A
Checked by AB		

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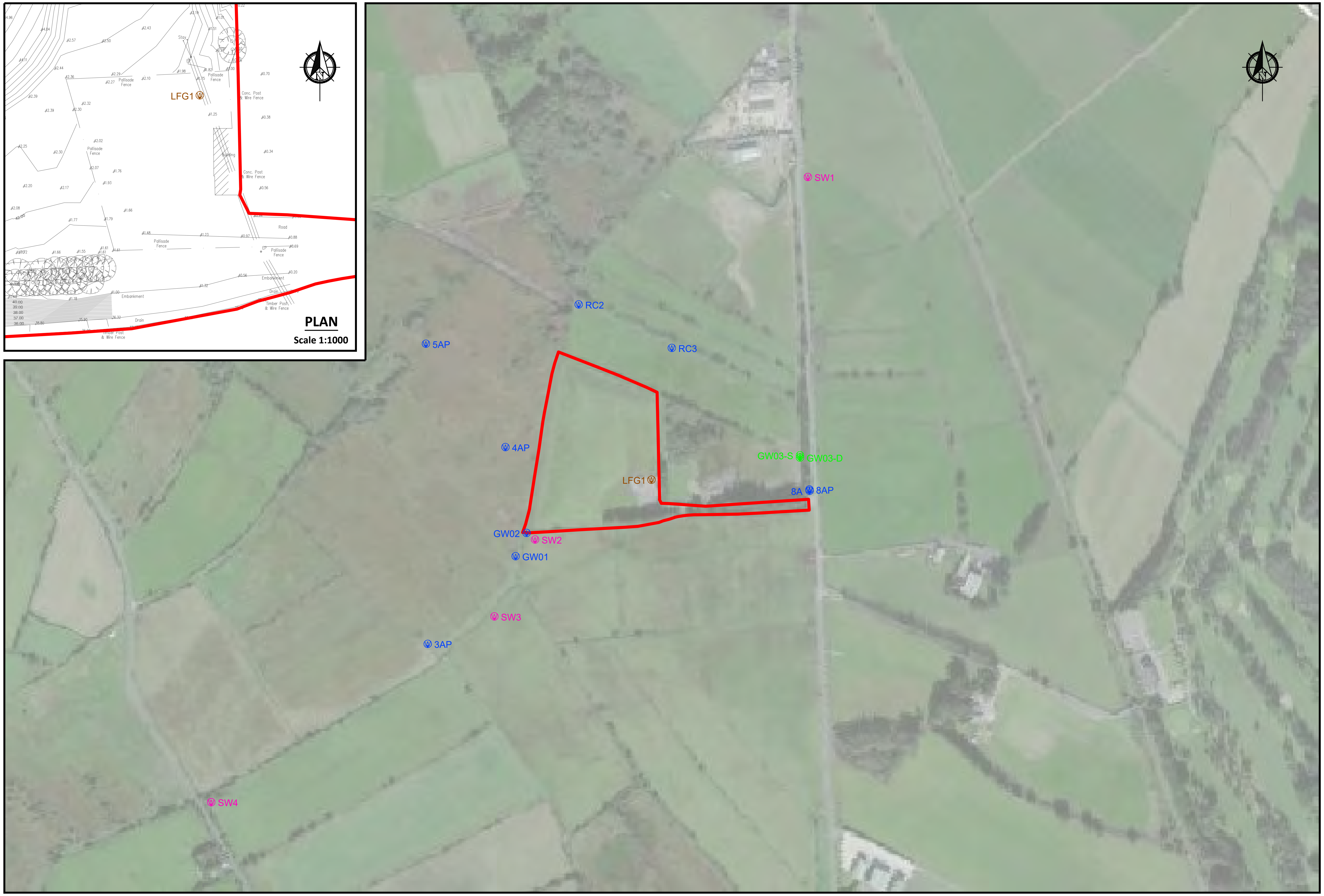
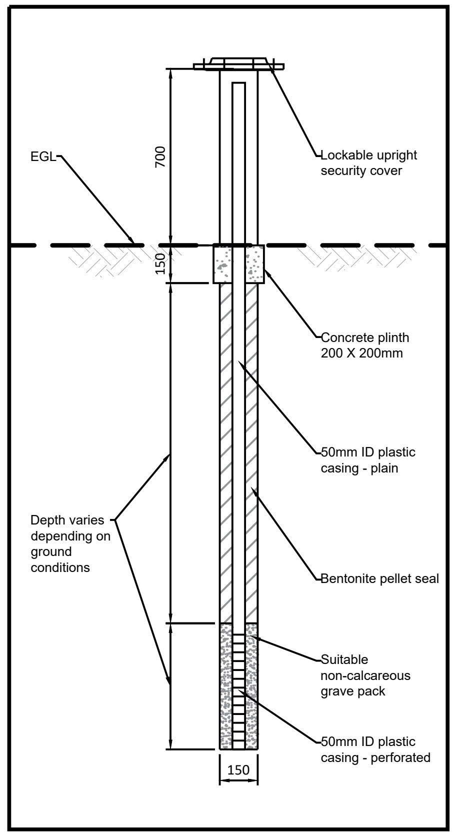
Thursday 21 January 2021



Legend:

- Proposed LFG Monitoring Well
- Proposed GW Monitoring Well
- Existing GW Monitoring Well
- Existing SW Monitoring Locations
- Site Boundary
- Building — Fully enclosed internal areas within buildings to be fitted with Continuous Emissions Monitors

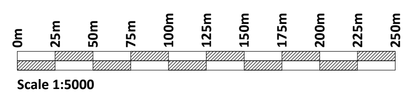


MONITORING WELL - TYPICAL DETAIL

Scale 1:30

PLAN

Scale 1:5000



2282,2813-04,2813-05,2813-09,2813-10,2813-14,2813-15,2813-19,2813-20,2813-A,2813-B,2813-C,2813-D,2814,2814-01,2814-06,2814-11,2814-16,2814-A,2814-C,2881,2881-A,2881-B,2881-C,3354,3802-22,3802-A,3802-B,3802-C,3802-D

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Rev.	Description	App By	Date
A	FOR INFORMATION	JON	20.01.21

PROJECT	ERA GALWAY HISTORIC LANDFILLS
CLIENT	GALWAY COUNTY COUNCIL
SHEET	EXISTING & PROPOSED MONITORING LOCATIONS (TUAM HISTORIC LANDFILL)
Date	20.01.21
Project number	P2282
Scale (@ A3)	As Shown
Drawn by	POR
Checked by	AB
Drawing Number	P2282-0101-0004
Rev	A

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Thursday 21 January 2021

Legend:

- Existing Fence to be Surveyed and Repaired as required
- Existing Fencing to be Retained
- Proposed Security Fence

PLAN

Scale 1:1200

0m 6m 12m 18m 24m 30m 36m 42m 48m 54m 60m

Scale 1:1200

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Rev.	Description	App By	Date
A	FOR INFORMATION	JON	20.01.21

PROJECT	ERA GALWAY HISTORIC LANDFILLS
CLIENT	GALWAY COUNTY COUNCIL
SHEET	EXISTING AND PROPOSED FENCING (TUAM HISTORIC LANDFILL)
Date	20.01.21
Project number	P2282
Scale (@ A3)	1:1200
Drawn by	POR
Checked by	AB
Drawing Number	P2282-0401-0001
Rev	A

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Wednesday 20 January 2021

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