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ELSTOW SOUTH LANDFILL SITE

LANDFILL GAS GENERATION AND RISK ASSESSMENT

Prepared for:

Anti-Waste Limited

ELSTOW SOUTH LANDFILL SITE

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ELSTOW SOUTH LANDFILL SITE

LANDFILL GAS GENERATION AND RISK ASSESSMENT

CONTENTS

DRAWINGS

Environmental Monitoring Plan – ESID 12

1. INTRODUCTION

1.1 Report Context

The purpose of this report is to provide a qualitative landfill gas generation / risk assessment (LGRA) for the Elstow South Site. The permit application proposes to allow for disposal in the two partially flooded voids. The voids are excavations within the Oxford Clay.

The application facilitates the restoration of the site to allow for the import of wastes suitable for quarry restoration. HM Revenue and Customs (HMRC) made specific allowance for quarry restoration identifying a very limited list of suitable wastes in accordance with The Landfill Tax (Qualifying Material) Order 2011 (as amended). It is proposed to accept wastes consisting of excavation, construction and demolition wastes and potentially some similar industrial wastes that are inert or have a low level of contamination.

Under the requirements of the Landfill Directive, landfill gas must be collected from all landfills receiving biodegradable waste. The gas must be treated and if possible, used. The Directive also requires that landfill gas that cannot be used to produce energy must be flared.

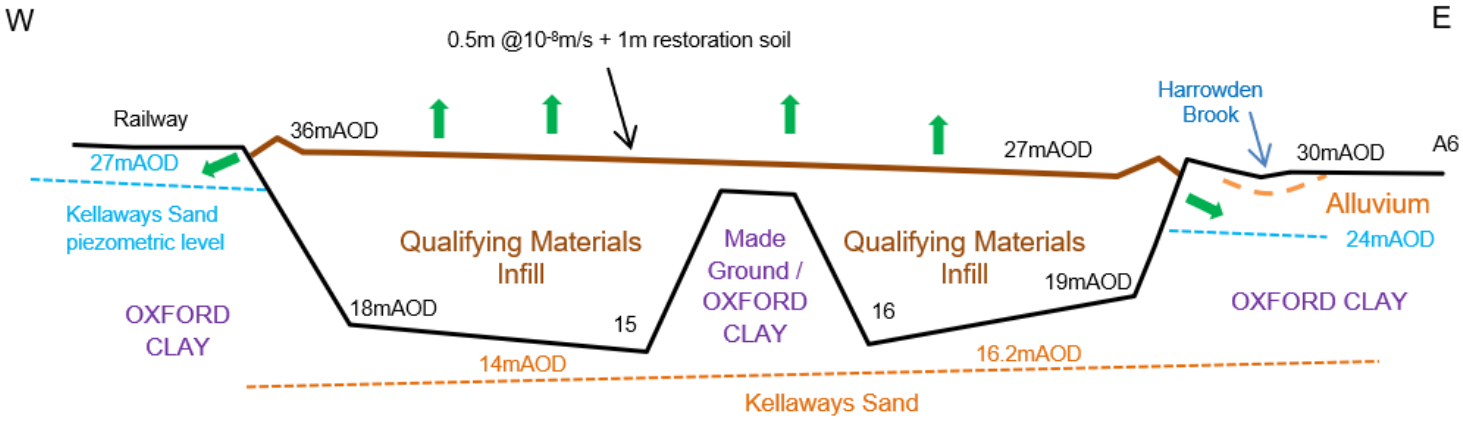
The biodegradable Elstow North Landfill Site is located directly to the north of the site, no gas risk assessments have been made available for review. Only Elstow South (the proposed site) will not be considered as part of this landfill gas risk assessment (LGRA).

1.2 Conceptual Site Model

The Conceptual Site Model (CSM) as used for this LFGRA is built on the site design, waste types and environmental setting data provided in the Environmental Setting and Installation Design Report (ESID) for the Site and on the principles of the conceptual model provided in GasSim 2.5 and the schematic site model for the Site shown below in Figure 1.

A Source-Pathway-Receptor philosophy is used to establish whether gas emissions from the proposed site pose a risk to the surrounding environment.

Figure 1 Schematic Conceptual Site Model



Source

The eastern and western void have been designed as per the detail specified in the supporting ESID (reference 5192/R/004/01) and will be constructed with a geological barrier comprising re-engineered and compacted 'in-situ' Oxford Clay across the base and sidewalls at a depth of 500 mm to a maximum permeability of $1x10^{-8}$ m/s.

An engineered design with a cut / fill balance (to reduce the requirement for clay importation) has defined the overall volumes of the eastern and western voids as 985,000m^3 and 1,470,000m^3 respectively (overall volume of 2.5Mm^3 which equates to a tonnage of ~5M tonnes). The infilling is anticipated to have a duration of 8 years although material availability may alter the initial assumptions. Input rates are expected to be 750,000t/y for 3 years followed by ~500,000t/y.The existing separation from the Elstow North landfill will be maintained. The site will accept waste consisting primarily of excavation, construction/demolition wastes and similar materials that are inert or have a low level of contamination.

This will be enforced by rigorous waste pre-acceptance procedures, ensuring a low-risk source term, resulting in negligible volumes of gas and leachate generation within the waste mass. This is in comparison to the waste types deposited at Elstow North which have a higher gas producing potential, controlled by the gas extraction and management system on that Site.

Pathways

The pathways are defined as the environmental transport processes by which the pollutants move from the source to the receptors. In the case of landfill gas there are two transport processes that should be considered: atmospheric dispersion and lateral migration.

Atmospheric dispersion of landfill gas emitted from the site is influenced by the prevailing wind direction and speed. Fugitive landfill gas emissions from uncapped wastes, exposed flanks or failures in an active landfill gas management system (pipework, gas wells, flare or gas engines) are most likely to be conveyed to receptors along this pathway.

Wind velocity and direction will affect the distance a fugitive gas emission travels and where it travels to. The presence of undulating topography, large structures, bunds and woodland in the vicinity of a site will increase the effective surface roughness i.e. turbulence. Higher wind speeds will also aid beneficial dispersion of emissions. Surface emissions are considered highly unlikely due to the negligible volume of gas predicted to be produced as a result of the low gas generation potential of the wastes to be accepted.

The deposited low permeability wastes will have a low/negligible biodegradable content and as such will not generate landfill gas. Lateral migration describes the transverse migration of landfill gas through an unsaturated subsurface by advection and diffusion. The wastes to be deposited will be of low permeability and low gas generation potential therefore lateral mitigation is not considered likely to occur. The lateral transport pathway (through the engineered sidewall liner) and then in-situ Oxford Clay is extensive.

The Elstow South void will have an engineered basal and sidewall liner of low permeability clays which will prevent any potential lateral gas migration however it is not considered likely due to low gas generation potential of the wastes to be accepted.

Hydraulic conductivities for the surrounding Oxford Clay is typically estimated as 1x10-10 - 2.5x10-10m/s, whilst test data for the engineered clay from other FCC sites demonstrated that the compacted clay can attain a hydraulic conductivity of 1.6x10-11 - 3.6x10-10m/s. Any groundwater in the surrounding glacial drift deposits (off site) are anticipated to be close to ground surface hence further reducing the available pathway near surface.

Receptor

The surrounding geological system (and any contained groundwater beneath, or laterally) are not considered receptors. Receptors are discussed in further detail in section 1.3.

1.3 Receptors

Sensitive Receptors

A number of potential receptors need to be considered with respect to landfill gas. The generic categories are listed below:

- Domestic dwellings;
- Other occupied buildings (offices, public buildings, schools etc.);
- Sensitive habitats and environmental areas e.g. SSSIs;
- Public footpaths or bridleways;
- Major highways and minor roads;
- Open spaces, parks and farmland (crop damage);
- Air quality management zones.

A review of the sensitive receptors has been completed in relation to the site, a list of receptors listed in Table 1 below. Sensitive receptors within 2km have been identified and designated sites within 10 km have been considered. A Sensitive Receptor Location Plan (reference ESID 2 and ESID 3) accompanies this application and should be referenced in conjunction with this risk assessment report.

Table 1 Proximity of Environmental Receptors to Site Boundary

Receptor No.	Receptor	Receptor Type	Approx. Distance from Site Boundary (m)	Direction from Site	Freq (%) Prevailing Wind Direction
1	Shanks WTS & Recycling Facility	Industrial	<10	N	12.3
2	Bedfordshire C C - Elstow Landfill Site A6	Industrial	<10	N	12.3
3	Tarmac Elstow Asphalt	Industrial	<10	W	0.9
4	B&M Bedford Distribution Centre	Commercial	35	SW	4.3
5	Wixams Retirement Village	Residential	40	ESE	3.2
6	Public Footpaths	Footpaths	<10 – 650	Surrounding Site	0.9-17.2

7	Supreme Concrete	Industrial	410	W	0.9
8	Lakes (West)	Watercourses	480	W	0.9
9	Lakes (East)	Watercourses	55	E	6.8
10	River Great Ouse	Watercourses	940	NW	7.3
11	Motorway Services	Commercial / Residential	660	N	12.3
12	Properties off Bedford Road	Residential	295	SE	2.5
13	Wilstead Industrial Park	Commercial	350	S	4.5
14	Lakeview School	School	800	SE	2.5
15	Wixams Academy / Wixamtree Primary	School	840	S	4.5
16	Elstow Lower School	School	1,170	NE	17.2
17	Springfield Primary School / Daubeney Academy	School	1,500	NNW	9.7
18	Properties of Wilstead Road / High Street including listed buildings	Residential	620	NE	17.2
19	Pear Tree Farm	Agricultural / Residential	590	NNE	11.8
20	Medbury Lane	Agricultural / Residential	930	E	6.8
21	Kempston Hardwick	Commercial / Residential	1,580	SW	4.3
22	Retail Park	Commercial	870	N	12.3
23	Woburn Road Industrial Estate	Commercial	1,200	NW & W	0.9-7.3
24	Properties off The Silver Birches	Residential	1,260	NW	7.3
25	Railway	Railway	165-1,280	W	0.9
26	Wilstead Road / Bedford Road	Road	<10	E	6.8
27	The Causeway	Road	250	SE	2.5
28	A6	Road	75	E	6.8
29	A421	Road	760	N	12.3
30	Ampthill Road	Road	340	W	0.9
31	Harrowden Brook	Watercourses	30	E & S	4.5-6.8
32	Elstow Pit CWS	LWS	On-Site	Surrounding Site	0.9-17.2

Distances in accordance with Elstow South boundary
Frequency stats from **https://wind.willyweather.co.uk/ee/bedfordshire/bedford-airfield.html**

2. LANDFILL GAS RISK ASSESSMENT

2.1 The Nature of the Landfill Gas Risk Assessment

This risk assessment takes a qualitative approach to assess the impact of the site on sensitive receptors. Elstow North will not be considered further as part of this assessment, it is assumed that landfill gases are actively controlled and managed by BCC. A qualitative risk screening exercise is proposed for Elstow South.

2.2 Proposed Assessment Scenarios

Due to the low biodegradable content of the waste a qualitative screening exercise has been developed to assess the risk from landfill gas utilising a source-pathway-receptor approach.

The permitted wastes proposed to be accepted comprise non-hazardous wastes with low organic content and negligible biodegradability consisting primarily of excavation, construction/demolition wastes and similar materials that are inert or have a low level of contamination.

This will be enforced by rigorous waste pre-acceptance procedures, ensuring a low risk source term, resulting in negligible volumes of gas and leachate generation within the waste mass.

Lifecycle Phases / Scenarios
This assessment considers the landfill over all stages of its life, from first emplacement of waste at the site to the cessation of gas production at the site. It is considered that this assessment is representative of the predicted performance of the landfill over this time period.

The infilling volume is circa 2.5Mm^3. The commencement of infilling is dependent on issue of planning and permit approval however it is envisaged that void preparation (base liner engineering) will take place in 2023. This infill is expected to take 8 years however based on actual waste inputs these timescales are subject to change.

Accidents and their Consequences
As required by LFTGN03 the Landfill Gas Risk Assessment should consider accident and failure scenarios. However due to the nature of the waste types to be accepted it is considered that none of the general categories of accident for landfill are applicable.

2.3 Landfill Gas Source Term

The Environment Agency guidance[1] states that biodegradable fraction (mainly cellulose and hemicellulose) is the portion of the waste which will undergo microbiological degradation to produce gas and liquids, although not all of this will be available for degradation. Inert landfills in contrast by their nature will have a minimal organic (biodegradable) content to the waste.

Section 4.4.1 of the above guidance references the degree to which waste composition can influence the generation of significant volumes of landfill gas. It states that a site that contains 75% or more inorganic wastes will produce minimal volumes of landfill gas (although this may still represent an environmental impact).

[1] Environment Agency (2004). LFTGN03: Guidance on the Management of Landfill Gas.

Consequently, risk assessment of sites which have accepted or will accept a low proportion of organic wastes is not expected to extend beyond the risk screening stage. The guidance recommends that the emphasis of a risk assessment be placed on rigorous waste acceptance procedures to control the nature of the wastes accepted to the site.

The types of waste to be deposited at Elstow South will comprise non-hazardous soils and construction/demolition wastes with a low biodegradable content. Some residual Total Organic Carbon (TOC) is expected but this will tend to comprise of "hard" organic compounds such as resins and lignins which do not give rise to significant landfill gas production.

As such, a risk screening and hazard identification approach has been adopted to provide an assessment of potential impacts on local environment, health and amenity by:

1. developing an understanding of Elstow South in its environmental setting (the conceptual model), including the identification of the possible sources of a risk, the pathways and the potential receptors; and,
2. consideration of the sensitivity of receptors in the vicinity of site as identified in Section 1.3.

Elstow North: Landfill Gas Source Term

Elstow North accepted a mixture of wastes (including domestic / biodegradable) as defined by the requirements of the associated environmental permit. There is no requirement to consider this source term further.

Elstow South: Landfill Gas Source Term

The site will predominantly receive will be non-hazardous soils and construction/demolition wastes with a low biodegradable content and similar in physical characteristics to inert wastes. This will be very similar in nature to the material deposited at waste recovery sites and comprise mainly a mixture of excavated natural soils and made ground. The main components in these wastes will be clay, soil, silt, rock, brick, concrete, glass, sand, ash, clinker and slag. The majority of the materials will be derived from HS2.

Gas generation from any waste is associated with the proportion of organic matter which can be broken down by microorganisms. The organic content of natural soils varies greatly as described in the British Standard for Soil Descriptions BS5930:1999+A2:2010 and paragraph 41.4.6 of the standard provides details of the typical organic content of soils. An organic clay or silt can contain between 5 and 10% organic material. Table 2 below describes the range between slightly organic and very organic soils.

Table 2 Organic content of soils (BS5930:1999 Para 41.4.6)

Term	Organic Content Weight % of dry mass
Slightly organic	2-6
Organic	6-20
Very organic	>20

One method of measuring the organic content of soils is the assessment of the Total Organic Content (TOC) as determined by laboratory testing. TOC analytical technique however does not accurately reflect the organic component of a soil that is readily biodegradable.

The method first involves quantification of the proportion of inorganic carbon in the material by acidification. A separate sample of the same material is then subject to high temperature combustion and catalytic oxidation with quantification of the organic carbon by measurement of the liberated carbon dioxide. The inorganic proportion is accounted for in subsequent calculations prior to the TOC value being reported.

The TOC testing will not give an indication of the readily biodegradable potential of the material nor can it be used to determine how much gas will be produced. The TOC test is therefore likely to be an over-estimate of the gassing potential of the waste and should not be considered in isolation.

A CL:AIRE research bulletin[2] also discussed TOC in natural soils.

It describes the prevalence of large complex organic compounds (stabilised organic matter) such as resins, lignins, waxes or heavy molecular weight hydrocarbons which few microbes can degrade. Other more degradable compounds are bound up in the soil structure and cannot be reached by microbes.

These compounds can be exposed during ground disturbance and could explain initial high concentrations of methane recorded from boreholes after they have been recently drilled. These concentrations subsequently reduce to negligible values which are more reflective of the low gas generation potential ground they were installed into.

TerraConsult Ltd carried out a review of waste testing data from site investigations undertaken across the northwest of England from 2002 to 2014. This data is considered to be representative of the demolition and excavation waste typically available to a landfill activity of this type. 280 TOC values had associated Dissolved Organic Carbon (DOC) values (from 2:1, 8:1 and 10:1 leachability tests expressed as mg/l).

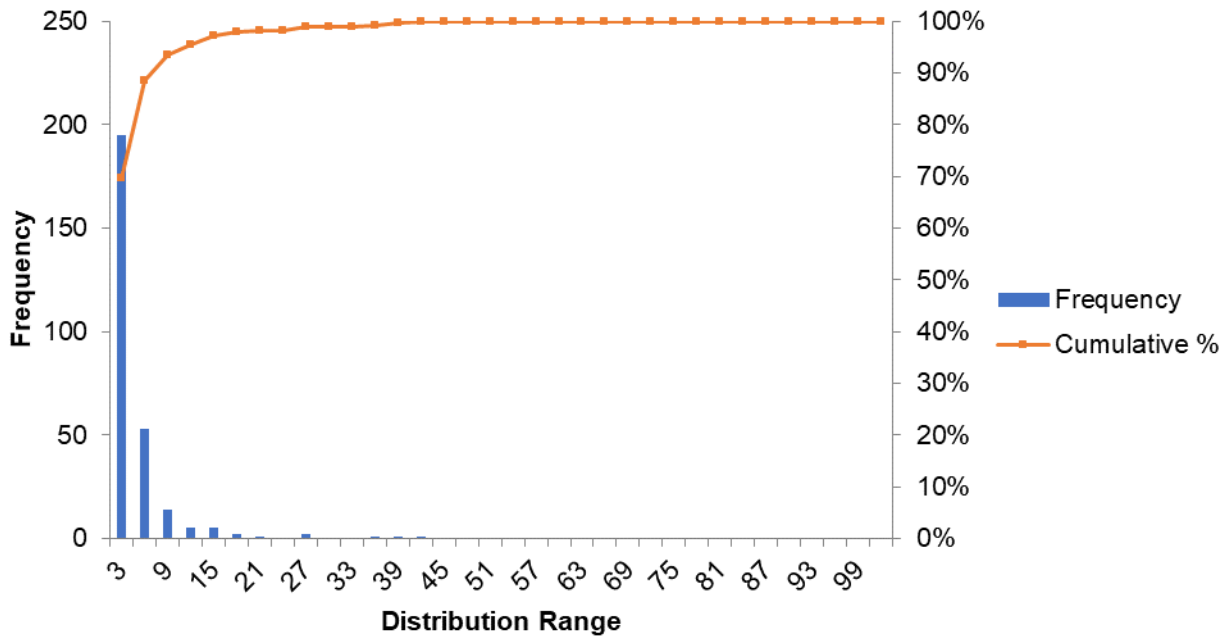
Figure 2 shows the frequency distribution of TOC values recorded.

The significant majority of TOC values are less than 3 % (WAC for inert landfill sites) at 70 % of the sample group and 93 % were less than 10 %. The most likely value to be recorded was 2 % or less (53 % of the sample group). The highest TOC recorded was 41.2 %. The majority of TOC values recorded are comparable with the figures for naturally occurring slightly organic material given in Table 2. A much smaller proportion compare well with organic material.

Based on the data from the TerraConsult review, it is likely that the type of material to be brought to site will have a TOC of less than 10 %. This material is likely to have a low DOC potential and would meet the WAC for inert landfill sites (even where the TOC would not).

[2] CL:AIRE (2012). A Pragmatic Approach to Ground Gas Risk Assessment. CL:AIRE Research Bulletin RB17. November 2012.

Figure 2 TOC Frequency



DOC and TOC

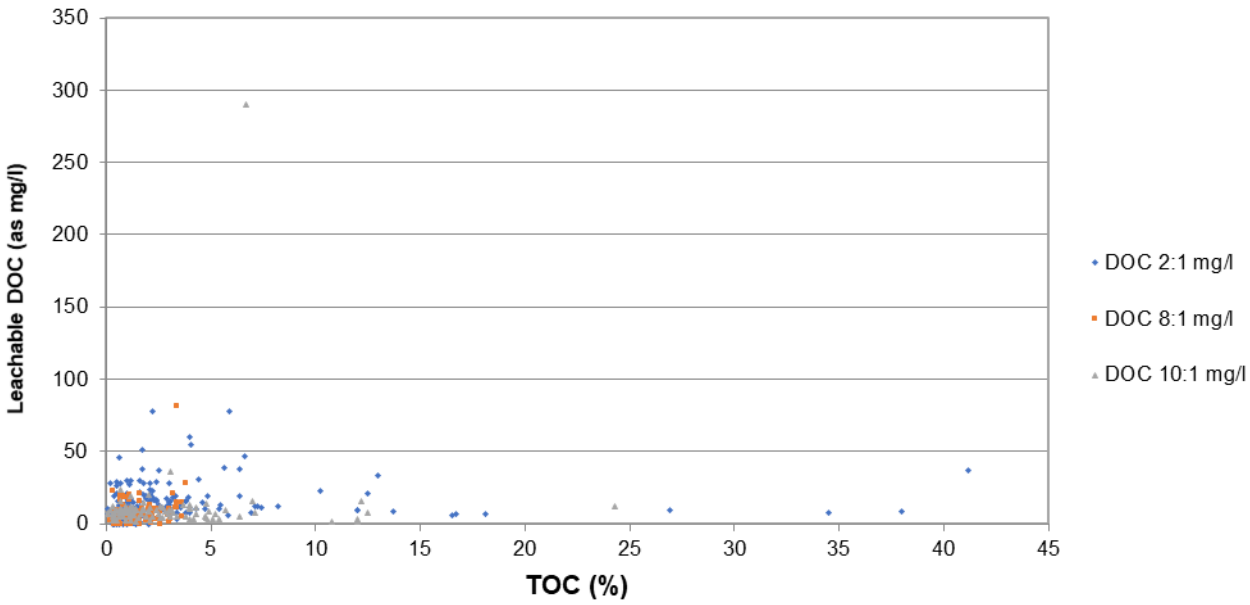
Figure 3 shows the relationship between TOC and DOC where appropriate data was available. Leachable DOC concentrations are largely comparable with up to 10 % TOC within each liquid to solid ratio (L/S) data set. DOC (mg/l) was lower at the higher TOC values. The highest total leachable DOC (10:1 L/S mg/kg) was half the WAC limit for inert landfill sites and appeared to reduce at concentrations higher than 10 % TOC, although this may reflect the size of the data set. It is likely that if the TOC content of the soils accepted at site was limited to 10 %, the DOC value will meet the WAC limit for inert landfill sites.

A recent study[3] reviewed the gas generation potential of Mechanical Biological Treatment (MBT) wastes. This material had previously been subject to biological treatment (e.g. composting or anaerobic digestion) resulting in a stabilised material with a lower biodegradable potential. This material was then placed in Lysimeters under a variety of conditions to establish how much methane may be produced when landfilled.

Although the age and type of waste will be different, the stabilised MBT residue is considered to be a very conservative representation of gas generation from excavated soils.

[3] S. Bohn And J. Jager (2011). Low Gas Emissions of Mechanically and Biologically Treated Waste and Microbial Methane Oxidation as an Adapted Method for Mitigation of Emissions. Proceedings Sardinia 2011, Thirteenth International Waste Management and Landfill Symposium S. Margherita di Pula, Cagliari, Italy; 3 - 7 October 2011

Figure 3 Leachability of DOC in relation to TOC



The study found that waste with a TOC of ≤ 18 % and DOC of ≤ 300 mg/l were inhibited from producing significant volumes of gas. Water content was the primary limiting factor, followed by TOC / DOC and other factors such as temperature.

The calorific value of the gas produced from MBT residue was found to be negligible and it was suggested conventional techniques for gas treatment may not be economical. Simple oxidation of the gas through the cap or soil layers was proposed as a sustainable solution for oxidation of gas produced from landfills containing MBT or old landfills.

DOC represents the readily soluble proportion of the tested material released under quite aggressive laboratory conditions i.e. mechanical size reduction and subsequent continual agitation. Its solubility means it may be more susceptible to microbiological assimilation and biodegradation, which under anaerobic conditions may result in methane generation. The absence of a strong relationship between increasing TOC and DOC from excavated soils suggests gas generation from these types of waste may be low due to the low leachability and otherwise biodegradable DOC.

The evidence from landfill sites taking mainly excavated soils with comparable TOCs to the above data is that they do not give rise to significant gas production. Average bulk gas flows recorded from boreholes installed in a hazardous landfill site (Eardswick Hall) and a soils site (Sea View Farm 2) were 0.5 to 0.6 l/hr.

The hazardous landfill WAC limits TOC in waste inputs to Eardswick were 5 %. Sea View Farm 2 was permitted to accept inert waste with no more than 5 % in any one load of materials with a biodegradable potential such as wood or wood products.

2.4 Landfill Gas Generation

Gas data collected by the Operator for Calvert Pit 6 (identical environmental conceptualisation), which accepts waste types directly comparable to those proposed to be accepted at Elstow South, consistently records methane at less than the limit of detection with no recordable gas flow. This is considered to be representative of the negligible gas production expected as a result of the low biodegradable content of the wastes to be accepted at Elstow. However, to allow the estimation of potential landfill gas generation in the site the flow rate from Eardswick and Seaview Farm has been extrapolated up to the proposed surface area of the Site (east and west void ~98,000 m^2 respectively). Assuming a uniform depth, a gas well zone of influence of 5 m radius (area 78 m^2) and a flow rate of 0.0006 m^3hr^{-1}, it can be estimated that Elstow South will produce 0.7 m^3hr^{-1} of bulk landfill gas. If the maximum flow rate recorded at Eardswick was used (35 m^3hr^{-1}) this would give a total of 8 m^3hr^{-1}. Although it is considered that this is an overly conservative estimate as the waste types accepted at Eardswick and Sea View Farm over predict the potential landfill gas production.

In the light of the above, the waste acceptance criteria for the installation will include for a number of restrictions to exclude readily biodegradable wastes at the site. The full criteria are set out in the operators Waste Acceptance Procedures but with respect to the Landfill Gas Risk Assessment the relevant restrictions are as follows:

- Exclusion of readily biodegradable wastes using EWC codes;
- On-site rejection procedures to visually identify and exclude waste loads that appear to contain cellulose based materials (paper, wood, vegetation, topsoil, cardboard); and,
- Imposition of a conservative 10% TOC maximum limit on waste soils accepted at the site.

It is also intended to adopt the additional restrictions on “active” waste types as relevant to the Landfill Tax (Qualifying Materials) Order 2011 (as amended) which will further control the biodegradable content of wastes deposited at the site.

The estimated maximum production of 35 m^3hr^{-1} is considerably less than the lowest indicative threshold level of 50 m^3hr^{-1} suggested in Environment Agency document LFTGN03 ‘Guidance on the Management *of Landfill Gas*’ (September 2004) below which active gas control and treatment is not required. Based on data from similar sites it is likely that volume of gas produced will be significantly lower than this.

2.5 Risks to the Environment and Human Health

Landfill Gas Emissions

The screening exercise of the potential landfill gas production based on the source term of similar sites suggest that landfill gas production will be negligible and peak directly after the end of landfilling. Based on the waste inputs commencing in 2023 and ceasing in 2031 (based on the maximum waste input) the peak production of landfill gas and peak methane production are estimated to occur in 2031.

The overall volumes of landfill gas to be produced are considered negligible yet representative of the potential landfill gas generation from the waste types to be accepted. In

risk assessment terms therefore the potential for environmental harm from Elstow South is negligible and in this respect the conditions are such that the surrender criteria would be met.

The data recorded from the Eardswick, Sea View Farm and Escrick sites (not operated by the applicant) indicates that the gas volumes are a very conservative estimate of landfill gas production. It is therefore not only likely that gas production will rapidly decline, it will also be to a level where the Elstow South site will fulfil the criteria for permit surrender (as set out in Environment Agency document Ref 5.02: *The Surrender of Permits for the Permanent Deposit of Waste. September 2012*). The site is surrounded by geology of Oxford Clay which will act to mitigate against lateral migration from the site. As Elstiow South is considered to produce negligible amounts of landfill gas the potential for lateral migration is considered negligible.

The closest domestic dwellings is the Wixams Retirement Village approximately 40 m to the south east of the site. Based on the negligible amount of gas production and supported by experience of similar soil sites it is considered the predicted likely concentrations of surface emissions at the site boundary to be negligible. It is concluded that landfill gas does not pose a significant risk to the surrounding environment specifically the receptors identified in Section 1.3.

Atmospheric Dispersion and Odour

The negligible volumes of landfill gas produced are not considered to give rise to any significant contribution to the effects of global warming or ozone depletion. Assessment of the potential for an odour nuisance is more subjective. Due to the nature of the waste types to be deposited comprising non-hazardous soils and construction and demolition wastes with low biodegradable content odour generation will be negligible as they will not contain materials or compounds that are likely to give risk to odour.

Sub-Surface Lateral Migration and Vegetation Stress

Sub-surface landfill gas migration beyond the boundary of the site can give rise to a number of potential risks, including explosion, asphyxiation, toxicity, and vegetation damage. Should the fugitive gas then be liberated to atmosphere, there are the additional risks of odour nuisance and contributions to global warming.

Lateral migration has not been considered due to the negligible gas production estimated for Elstow South. In addition the site will have an engineered basal and sidewall liner of low permeability clays which will prevent any potential lateral gas migration however it is not considered likely due to low gas generation potential of the wastes to be accepted.

Landfill Gas Completion Criteria

Gas production rates will be insufficient to support any active extraction or treatment.

Residual Gas Potential

A site's potential for future gas generation can be assessed via an analysis of the solid wastes remaining in the landform, with the results expressed as the biological methane potential (BMP). However due to the type of waste to be deposited the biological methane potential is negligible.

Gas Concentrations and Flow Rates

Environment Agency guidance document 'Landfill (EPR 5.02) and other permanent deposits of waste; How to surrender your environmental permit (version 2, 13th December 2012) provides criteria for assessing landfill completion based upon the results of monitoring of gas concentrations or flow rates. This gives three scenarios when the landfill gas surrender criteria for landfill can be met.

Scenario 1:

in-waste gas methane concentration of ≤1.5 % v/v and carbon dioxide of ≤5 % v/v (minimum 12 data sets over 2 consecutive years)

Scenario 2:

in-waste gas methane concentration of ≤5 % v/v and carbon dioxide of ≤10 % v/v (minimum 12 data sets over 2 consecutive years) and Qhgs* is <0.7 l/hr and the flow in any borehole is ≤ 70 l/hr

Scenario 3

in-waste gas methane concentration of ≥5 % v/v and carbon dioxide of ≥10 % v/v (minimum 24 data sets over 2 consecutive years) and Qhgs* is <0.7 l/hr and the flow in any borehole is ≤ 70 l/hr

*Qhgs: Site Characteristic hazardous gas flow rates as defined by BS 8485:2015.

It is proposed that such assessment criteria are considered in a site-specific context within a Completion Risk Assessment for the site which will be submitted to the Agency at an appropriate point in the site's lifecycle.

It is likely that Elstow South will be surrendered prior to Elstow North. No gas data review has been undertaken for Elstow North.

3. LANDFILL GAS MANAGEMENT PLAN

3.1 Control Measures

Based on a review of GasSim modelling exercises undertaken for Sites with similar waste composition inputs, the predicted volume of landfill gas produced by the site is considered highly likely to be significantly lower than the indicative threshold level of 50 m^3hr^{-1} suggested by Agency guidance where active gas control and treatment (flaring and utilisation) would be required. The nature of the waste deposits (low permeability soils and construction and demolition wastes) to be deposited will also make it very difficult to extract gas from the site.

The main control on the production on gas is by ensuring that the waste received at the site contains low proportions of biodegradable materials. Additional controls on the deposit of wastes that contain odorous substances will prevent any potential odour nuisance. These would include exclusion of such wastes or rapid covering during placement.

Notwithstanding this, measures will be implemented to ensure that the landfill gas production is monitored to confirm the basis of the qualitative risk model. As a precautionary measure,

the site design provides for the installation of retro-drilled in-waste gas monitoring points and additional gas monitoring boreholes around the perimeter of the site.

3.2 Monitoring and Sampling Plan

In-Waste Boreholes

It is intended to provide the site with in-waste monitoring installations. As the waste is expected to be inactive, the in-waste gas monitoring regime will meet the current landfill gas surrender criteria monitoring requirements. Following completion of capping in-waste gas monitoring boreholes / probes will be retro-installed (2 per hectare) with a 3 m stand-off from the top of the Artificial Geological Barrier. The indicative locations of these monitoring points are shown on the Environmental Monitoring Location Plan drawing reference ESID 12,

The specifications of the borehole installations will be agreed with the Environment Agency as part of the CQA process. Following installation of gas wells / probes, gas will be monitored in accordance with Table 3.

Table 3 In-waste Gas Monitoring Schedule

Monitoring Point	Monitoring Frequency		
	Operational	Post-Operational	Parameter
In-waste gas monitoring boreholes / probes ELS-GP01 to ELS-GP37	Quarterly	Quarterly	Methane, Carbon Dioxide, Oxygen and Gas Balance (% v/v), Gas Flow (l/hr), Relative pressure (mBar), Atmospheric Pressure (mBar) Water level and base level

The area for the western lake is approximately 9.5 ha hence 19 probes are proposed. The area for the eastern lake is approximately 9 ha hence 18 probes are proposed.

Perimeter Boreholes

4 perimeter gas boreholes will be installed around the site, strategically placed adjacent to the primary receptors to sample ground gas conditions. Further details are provided in the monitoring plan that supports this application, report 5192/R/006/01. The gas monitoring schedule is detailed in Table 4 below.

Table 4 Perimeter Gas Monitoring Schedule

Monitoring Point	Monitoring Frequency		
	Operational	Post-Operational	Parameter
At landfill gas monitoring boreholes shown on drawing number ESID 12 ELS-BHG01, ELS-BHG02, ELS-BHG03 and ELS-BHG04	Monthly	Quarterly	Methane, Carbon Dioxide, Oxygen and Gas Balance (% v/v), Gas Flow (l/hr), Relative pressure (mBar), Atmospheric Pressure (mBar)
	Quarterly	Quarterly	Water level and base level

3.3 Landfill Gas Data Review

A review of monthly in-waste gas monitoring data from Calvert Pit 6 between July 2018 to April 2019 has been undertaken due to the directly comparable waste types accepted at Calvert to those proposed to be accepted at Elstow South. Methane was recorded consistently at 0% v/v and carbon dioxide was recorded at 0 % v/v excluding two readings of 0.1% v/v.

No flow has been recorded in any of the in-waste gas wells. This is considered to be representative of the low gas generation due to the low biodegradable content of the wastes accepted.

3.4 Contingency Action Plan

The action plan is to be implemented by the Site Manager or in his absence the Environment Manager in the event of the following:

- Methane concentrations in the perimeter boreholes breaching the permit compliance level;
- Abnormal, adverse trends in monitoring data;
- Operational problems or failure of the control system;
- Reported events (e.g. odour complaints);
- Confirmed migration events or uncontrolled releases of landfill gas; and,
- Confirmed adverse impacts on local air quality.

The timescales for implementing remedial actions at the Site, which is considered a low-risk site, are presented in Table 5.

Table 5 Site Monitoring Borehole Response Action Target Timescales (Recommended within ICoP Guidance)

		Site Risk		
		High	**Med**	**Low**
Outcome	**Action**	**Completion**		
Additional Monitoring - Exceedance of Action Level				
Conc above action level	Re-monitor	24hrs	48hrs	7days
	Check gas field	48hs	48hrs	7days
Conc still above action level	Verify conceptual model and plan for extended pathway assessment if required	1wk	1wk	2wk
Extended Pathway Assessment				
Conc above action level	Investigate sources and pathways	1wk FW 3wks Rep	2wk FW 4wks Rep	3wk FW 5wks Rep

	In depth assessment of containment performance	2wk FW 3wks Rep	3wk FW 4wks Rep	3wk FW 4wks Rep
Conc still above action level	Verify conceptual model and review system performance	4wks Rep	5wks Rep	6wks Rep
Outcome	**Action**	**High**	**Med**	**Low**
Additional Monitoring - Exceedance of Permit Limit				
Conc above compliance level	Re-monitor every day	6hrs	24hrs	48hrs
	Check gas field	24hrs	48hrs	1wk
	Verify conceptual model and plan for extended pathway assessment if required	48hrs	1wk	2wk
Extended Pathway Assessment				
Conc above compliance level	Off-site receptor analysis and risk action plan	1wk Rep	2wk Rep	3wk Rep
	Investigate sources and pathways	1wk FW 3wks Rep	2wk FW 4wks Rep	3wk FW 5wks Rep
	In depth assessment of containment performance	2wks FW 3wks Rep	3wks FW 4wks Rep	3wks FW 4wks Rep
Conc still above compliance level	Verify conceptual model and review system performance	4wk Rep	5wk Rep	6wk Rep
	Additional contingency actions	4wk Rep	5wk Rep	6wk Rep

FW - Field Work, Rep - Report. hrs - Hours, wk - Week

Response

If any of the events identified above occur, the following course of action will be implemented iteratively until the cause of the issue has been identified and any adverse effects have ceased or been remediated:

- Report to the Environment Agency in accordance with the permit if the methane compliance level is exceeded and on progress with any resulting actions detailed below:
- Review the monitoring data to identify any other associated rising trends in perimeter methane / carbon dioxide concentrations;
- Repeat the gas monitoring as soon as possible but no later than 7 days to confirm the reproducibility of data. If the repeat reading is below the compliance / action level then no further investigations are required. A watching brief will be maintained on all boreholes however;
- Review the in-waste monitoring data to identify if gas production has increased. The historic data set will be reviewed for trends which may indicate an increase in gas production;
- If in-waste gas production is within its normal range, / or leachate quality is within its normal parameters, then a review of alternative sources / causes of ground gas production will be instigated. This will include changes to site engineering e.g. capping

or lining, agricultural practices outside the site boundary such as manure spreading or drainage works;
- If migration is persistently observed in a specific borehole the monitoring data will be reviewed along with the gas field data and changes implemented as required. If the borehole is in a sensitive area e.g. close to housing then consideration will be given to increasing monitoring to a weekly frequency in that borehole or area;
- The surrounding area will be checked for signs of gas or leachate escaping or vegetation die back;
- If elevated levels continue, the area of the migration will be audited to establish potential remediation works to be carried out if required.

In the unlikely event that remedial action is required, a proposal will be provided to the Environment Agency for approval. This may include one or more of the following:

- A gas pumping trial in accordance with Environment Agency Guidance to confirm the assumptions of the Landfill Gas Risk Assessment and establish whether the gas is being produced at a significant rate;
- An options appraisal to establish the most practical and cost effective gas control methodology for the management of negligible volumes of landfill gas (e.g. biofilters, or low-calorific flares);
- Additional extraction or monitoring points as necessary based on the revised risk assessment / pumping trial.
- A report on the effectiveness of the revised control system after an appropriate period of monitoring.

3.5 Maintenance of Perimeter Monitoring Infrastructure

The gas monitoring installations shall be inspected during each routine monitoring visit to ensure that they are fit for purpose. In the event that repairs are required these shall be undertaken within a period of one month. Examples of the kind of issues to be considered are:

- **Wear and tear:** damage by machines, plant or through vandalism. Functioning of seals and valves;
- **Access:** are the monitoring points accessible safely;
- **Settlement:** is the installation leaning over, has it dropped noticeably;
- **Surface water ingress:** is there water pooling around the base of the installation, is there signs of previous ponding / rivulets of running water in the vicinity of the installation.

If any of the above is apparent at any of the installation, then the site manager and relevant personnel should be informed immediately. Should any of the monitoring points become damaged to such an extent that suitable data cannot be recorded; alternative monitoring locations will be proposed and agreed with the Agency. If no suitable alternatives are present, then the damaged wells will be either repaired or replaced if practicable. The nature and location of any replacement, as well as the methods to be used, would be approved by the Environment Agency prior to any works being undertaken.

4. CONCLUSIONS

An assessment of potential impacts on local environment, health and amenity of landfill gas from the site has been carried out using a risk screening and hazard identification approach.

A qualitative assessment of the potential volumes of landfill gas that may be produced at the site and the potential risk to receptors has been undertaken. The wastes are non-hazardous soils and construction demolition wastes with a low biodegradable content. and as such the expected volumes of landfill gas are considered to be negligible. The estimated peak production for bulk landfill gas is significantly lower than the Agency threshold which indicates that active management of landfill gas is not required.

Reference has been made to post-closure gas monitoring data recorded from a completed site filled with wastes similar to that proposed for the site. Actual gas production was found to be negligible and therefore the estimated gas volume is likely to be very conservative. This qualitative risk assessment does not include an assessment of the landfill gas production for Elstow North.

A number of receptors have been identified, however due to the negligible volumes of gas being produced it is concluded that landfill gas from Elstow South does not pose a significant risk to the surrounding environment. The potential for odours arising from the placement of wastes is negligible due to their low biodegradable content.

The gas management plan reflects the low risk that the site poses to the surrounding environment in that no gas flaring or utilisation will be required.