Geotechnical Design Report for Landfill Cap

Evergreen Farm

February 2019

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SUMMARY

Chris Pearce (the Client) is proposing to remediate a landfill site at Evergreen Farm, East Grinstead, West Sussex. The landfill is the former Standen Landfill.

Remediation will involve providing a capping layer over the waste to prevent contact with contaminants and reduce infiltration of rainfall through the waste material. This Geotechnical Design Report provides information on the slope stability analysis of the proposed capping layer and the design of the gas venting system below the capping layer.

The slope stability assessment has shown that the landfill cap can be designed to be stable on the existing slopes on the site. The angle of shearing resistance of the imported materials will have to meet defined limits to achieve this.

A gas venting and surface water drainage system will be required as part of the capping system.

Outline design drawings for the capping layer are provided.

The design has minimised construction hazards. However appropriate health and safety precautions will be required in respect of working on slopes, managing exposure to contaminants and landfill gas and avoiding buried services.

1. INTRODUCTION

1.1 Purpose

Chris Pearce (the Client) is proposing to remediate a landfill site at Evergreen Farm, East Grinstead, West Sussex. The landfill is the former Standen Landfill.

Remediation will involve providing a capping layer over the waste to prevent contact with contaminants and reduce infiltration of rainfall through the waste material. This Geotechnical Design Report provides information on the slope stability analysis of the proposed capping layer and the design of the gas venting system below the capping layer.

1.2 The site

The site is located at Evergreen Farm, West Hoathly Road, East Grinstead. It is situated approximately 1.8km south south-west of East Grinstead town centre.

The site is approximately centered around National Grid Reference 539018 136273. The location of the site is shown in Figure 1.

Figure 1: Site location (from Geo-Environmental Report)

1.3 Information sources

This report has been informed via the following sources of information:

- Geo-Environmental, Ground Investigation Report, for the site at Former Standen Landfill, Evergreen Farm, West Hoathly Road, East Grinstead, West Sussex, RH19 4NE on behalf of TJS Services Limited. Reference GE17326/GIRv1.2/JAN19, January 2019;
- Ged Duckworth Limited, Desk Top Study, Evergreen Farm. May 2018;
- Topographical Survey; and
- Marked up plan provided by client showing location of leachate outbreaks.

The information has been assessed and a conceptual site model developed to allow the chemical test results to be assessed using the Remedial Targets Spreadsheet.

1.4 Site Description

At the time of the site investigation by Geo-Environmental, the site comprised an irregular shaped parcel of land and generally comprised undeveloped agricultural land with several equestrian buildings, barns, and a residential property with an associated garden situated on the central western part of the site. The north eastern portion of the site was occupied by a woodland (designated as 'ancient') which had several pathways and clearings which were in use as camping pitches. Access to the site was via a gateway to the west.

The south west of the site generally comprised two fields, with the western-most comprising undeveloped grassland and the eastern field occupied by several mature trees. A concrete vehicle track was observed to the south of these two fields, leading from the gate in the west to the collection of buildings on the central western part of the site.

On the central western portion of the site, a single storey timber built residential property with associated private garden, timber built stable block and workshop, a two storey brick and timber barn and an equestrian sand school were observed. The central and northern portions of the site comprised undeveloped grassland which had previously been used for pasture. This area sloped downwards from the south west to the north east with a significant slope downwards (maximum 1 in 3 from site survey) to the north east on the central northern boundary of this parcel of land. Information from the desk study indicated the presence of a small stream running along the north eastern boundary at the foot of the steep slope, which was understood to flow in a north easterly direction. The majority of the flow entering the stream was anticipated to comprise run off from surrounding areas together with shallow groundwater/leachate flowing through the site. During the site walkover in May 2018 there was noted to be a slight flow within the stream, however during the site investigation works this stream was noted to be dry with the investigation works being undertaken during a period of prolonged dry and hot weather. Subsequent flow has since been encountered during the return monitoring visits undertaken on the site between August and September 2018.

A number of mature and semi mature trees were noted to be present across the site, along the site boundaries, stream bed and associated with the ancient woodland. However, several trees along the north and north eastern boundary along the site boundary with the steam and along the boundary between the field and the ancient woodland were noted to be dead and completely stripped of leaves.

2. BACKGROUND INFORMATION

A desk study and site investigation has been completed at the site. The relevant information is summarised in the following sections.

2.1 Site history

The Desk Study Report by Ged Duckworth indicates the site was filled in the 1960's and 70's. The site accepted inert general skip waste. It is unlikely to be inert by today's standards but any readily degradable material should have decomposed by now. The site landfilling took place to fill on the side of a former valley rather than filling in a quarry or sand pit.

2.2 Ground conditions

The waste material is inert waste from the 1960's and 70's. It is described in the trial pit and borehole records as a silty clayey gravelly sand and sandy silty gravelly clay with abundant concrete, brick, metal, tarmac, clinker, carbonaceous inclusions, timber, metal, fabric and glass. It is in excess of 5m deep and the depth was not proven. However, the depth of the waste has little influence on the slope stability design for the capping layer, so it is not critical to know the full depth.

The waste is underlain by Wadhurst Clay Formation which is described as firm to stiff silty clay, sandy clay and clay with siltstone inclusions and occasions roots.

Note that there is Ardingley Sandstone to the west of the site but the majority of the landfill is underlain by Wadhurst Clay and this is taken as the critical scenario for the slope stability analysis.

2.3 Groundwater

Comparison of the plan provided in Figure 2 with the site survey indicates leach ae outbreaks at points that are about 99m AOD.

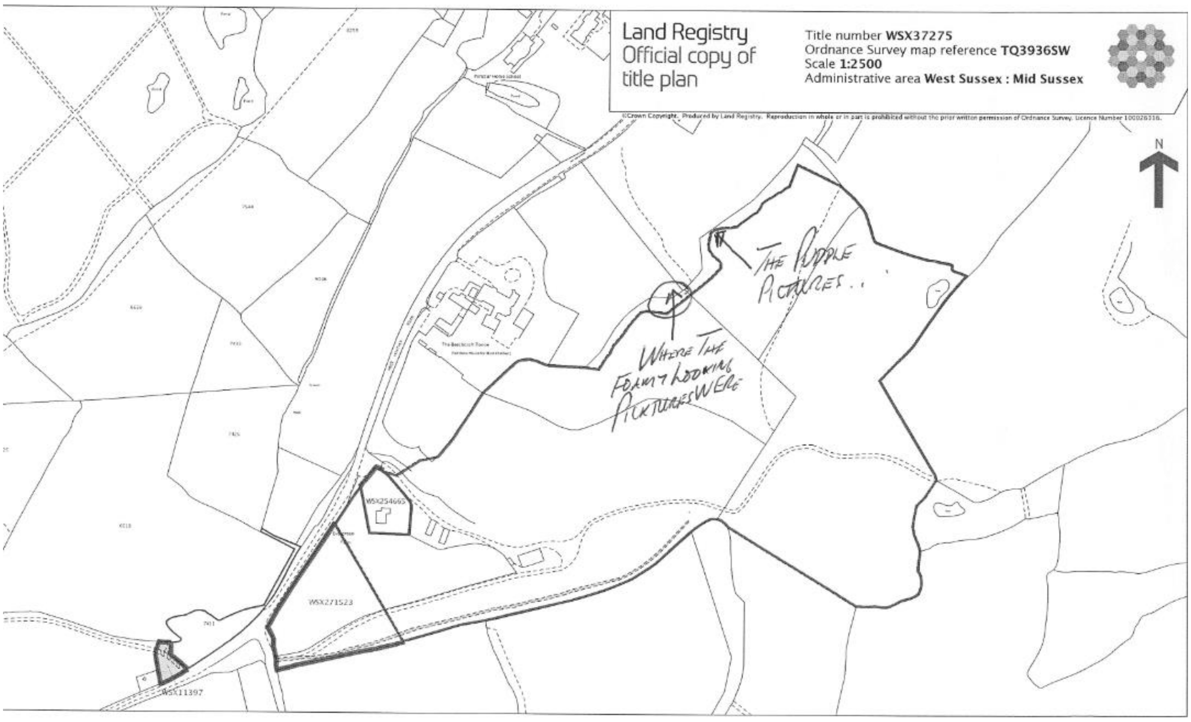

Figure 2 Plan of leachate outbreaks

Water levels in the monitoring wells within the landfill vary from 0.2m to 4.9m depth but are considered to represent localised perched water located over less permeable layers in the landfill mass, because the wells do not penetrate the full depth of the waste. The main water table is at depth. There have been leachate outbreaks at the toe of the slope at around 99m AOD. A stream occurs within the site during wetter periods of weather along a normally dry valley.

For the purpose of the slope stability analysis assume water will rise to 102m AOD and that drainage will be installed at the toe of the slope to maintain water levels below this.

2.4 Characteristic geotechnical parameters

2.5 Slope profile

Cross sections of the slope have been drawn using the site survey information (Appendix 1). These are shown in Figures 3 to 6.

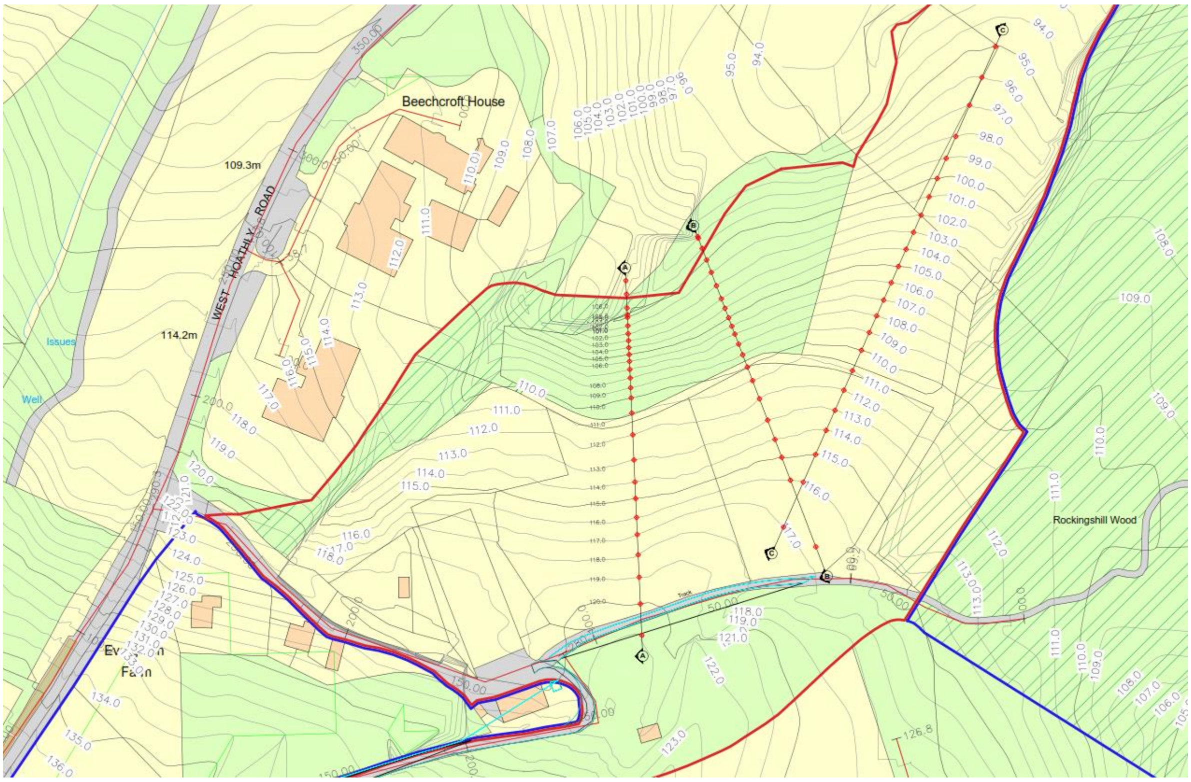

Figure 3 Location of cross sections

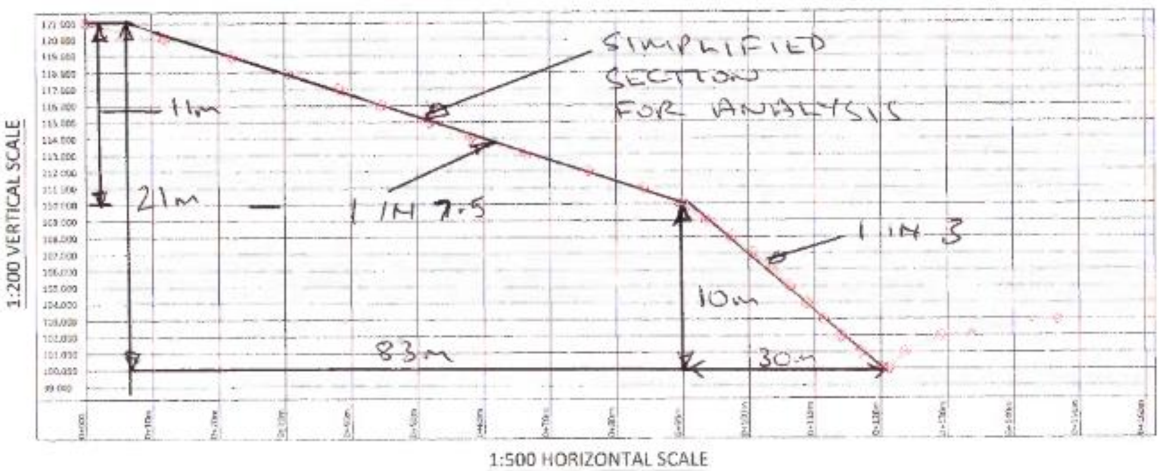

Figure 4 Section A-A

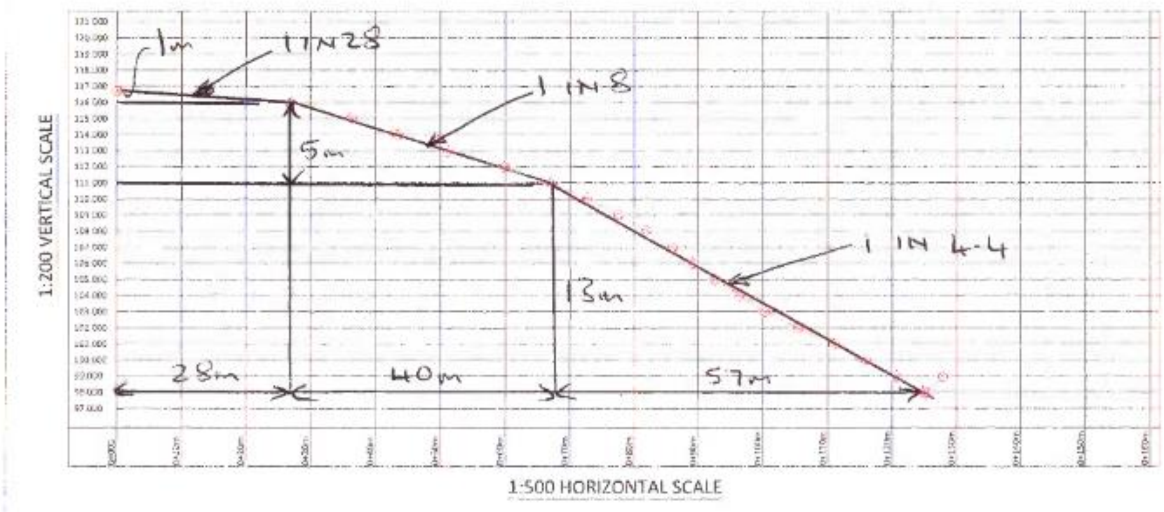

Figure 5 Section B-B

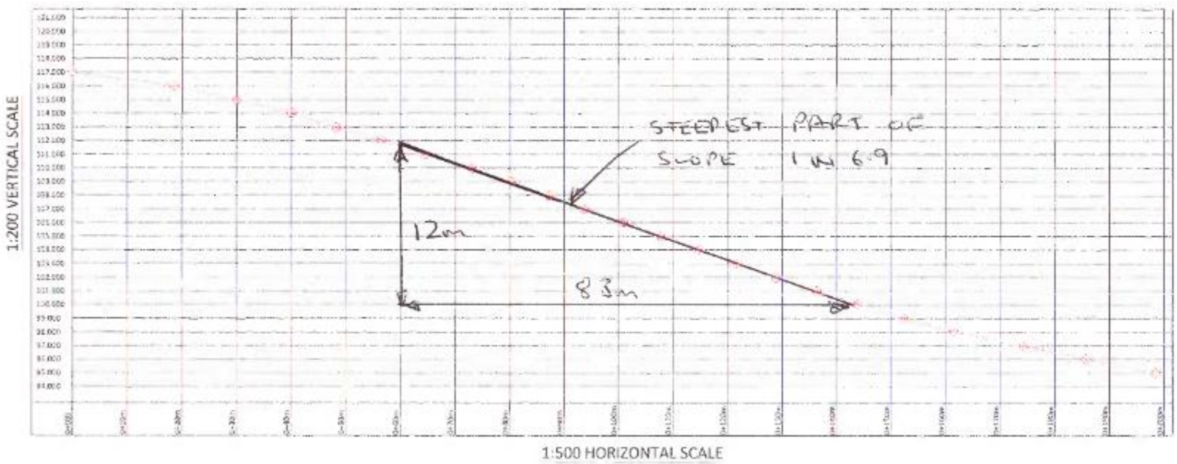

Figure 6 Section C-C

For the analysis the site has been split into the upper and lower slopes. The lower slopes are steeper and the upper ones are shallower. The following slope angles have been assessed:

Lower slopes maximum of 1 in 3 = 18.4^{o}

Upper slopes maximum of 1 in 7 = 8.1^{o}

2.6 Characteristic geotechnical parameters – slope stability

For slope stability purposes the landfill material can be split into paste and fibres. Given the high proportion of gravel, concrete, brick, etc the shearing resistance is likely to be dominated by the gravel or fibres and not the paste (ie the clay in this case). The current slopes are stable at a maximum of 1 in 3. The shear strength parameters of landfill waste depend on its composition and state of degradation. Given the age of the waste in this landfill the waste is likely to be well decomposed. Diaz-Beltran et al (2016) suggested landfill waste will have a mean value of 27°. Gomes et al (2013)[1] found that as waste ages the frictional resistance increases and cohesion reduces. The friction angle also increases with increasing displacement or strain and with increasing inert and fine fraction (Figure 7). Peak values occur at about 20% axial strain (Kaushal et al 2017[2]). Therefore, from the Gomes study the peak friction angle for this site (which is predominantly inert) is assumed to be 34° (which is at the low end of the range determined by Gomes et al for 20% axial strain). When combined with c'=0 (see below) this is suitably precautionary.

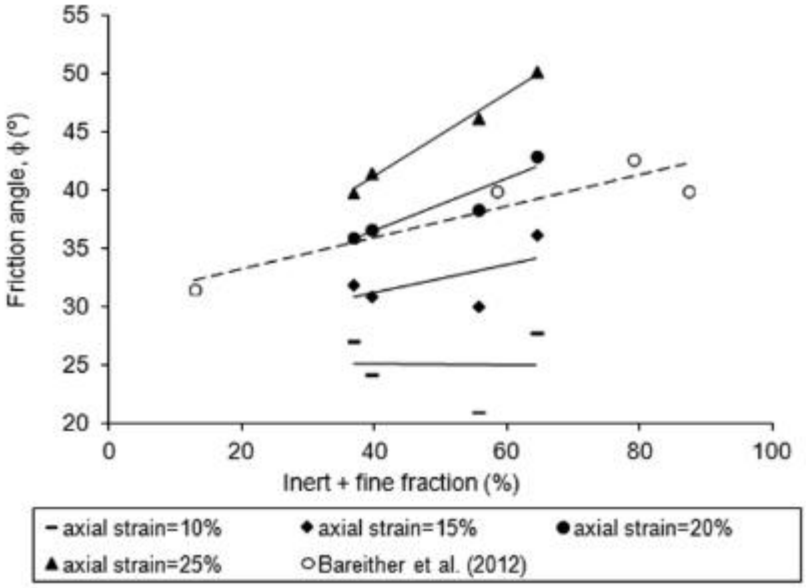

Figure 7 Angle of friction and proportion of inert and fine fraction

The evidence is that landfill waste will have some significant cohesion(Figure 8). Diaz-Beltran et al (2016) suggested landfill waste will have a mean value of 15kPa. However, in the absence of test data on the waste at this site it is conservatively assumed that c' = 0kPa. This is a significantly conservative assumption in the analysis.

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[1] Gomez C, Lurdes Lopes M and Venda Oliveira PJ (2013). Municipal solid waste shear strength parameters defined through laboratorial and in situ tests. Journal of the Air and Waste Management Association, 63(11) 1352-1368.

[2] Kaushal RK, Kumar R, Yadav R, Rai R and Kumar Shakya S (2017). Shear strength of municipal solid waste for stability analysis. International Journal of Civil Engineering and Technology Vol 8 Issue 7 July 2017.

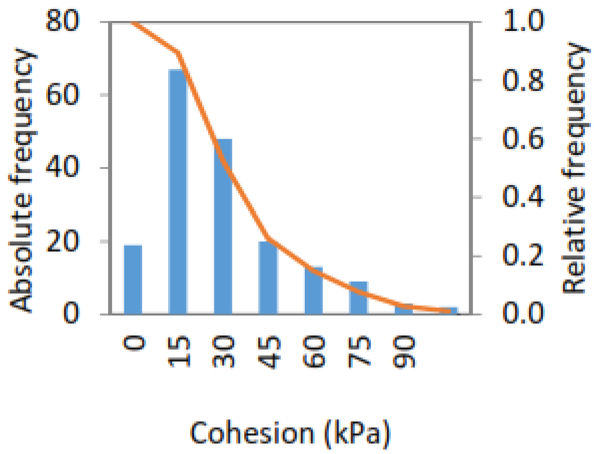

Figure 8 Cohesion in landfill waste (Diaz-Beltran et al, 2016[3])

Therefore, for the existing waste material assume $\phi' = 34^o$ and $c' = 0$kPa.

The Wadhurst Clay Formation lies below the waste and is described as firm to stiff silty clay, sandy clay and clay with siltstone inclusions and occasions roots. From Pugh and Weeks(1991)[4] the following properties are appropriate for the Wadhurst Clay:

$c' = 0$

$\Phi' = 34.5^o$

These values are for an effective stress less than 170kPa (approx. 8.5m depth) which is appropriate for the failures likely to occur on this site at the toe of the slope where the Wadhusrt Clay may influence the failure. At greater depths $c'= 25$kPa and $\phi' = 25^o$. The greater cohesion will increase the factor of safety of any failure surface at depth but the analysis shows that the critical surfaces are most likely to occur in the waste. Therefore, using $c'= 0$ and $\phi' = 34.5^o$ is suitably precautionary.

[3] Díaz-Beltrán JJ, Iguarán-Fernández JJ, Larrahondo JM and Jaramillo LA (2016). Shear Strength of Municipal Solid Waste (MSW): Beyond the Raw Values of "Cohesion" and Friction Angles. Geo-Chicago 2016.

[4] Pugh RS and Weeks AG (1991). Landslip and remedial works in Wadhurst Clay. Proceedings of ICE Conference on Slope Stability Engineering Developments and Applications pp353-360.

These are peak values and are for material that does not contain pre-existing shear planes. It is unlikely that pre-existing planes will affect the stability of the slopes on this site because of the depth to the Wadhurst Clay.

A summary of the geotechnical parameters for the slope stability analysis is provided in Table 1.

Table 1: Summary of characteristic geotechnical parameters for slope stability

Stratum	Bulk unit weight (kN/m^3)	Effective cohesion, c', (kPa)	Effective angle of shearing, ϕ', (°)
Landfill waste	20	0	34
Capping layer impermeable clay	20	0	Determined by stability analysis
Wadhurst Clay	20	0	34.5
Geotextile separation layers	N/A	0	Determined by stability analysis

Groundwater/leachate level is assumed to be at 102mAOD.

2.7 Characteristic geotechnical parameters – gas venting

The gas monitoring data shows generally low methane and carbon dioxide concentrations (less than 30% v/v methane). Methane varies from 0.1% v/v to 53% v/v and was not detected in some wells. It is generally less than 30% v/v except in WS09. This well recorded hydrocarbon odours and the methane is most likely caused by degradation of the hydrocarbons. The maximum carbon dioxide in WS09 was 0.7% v/v which is consistent with this. Elsewhere carbon dioxide concentrations are between 0.1% v/v and 11% (Note one value is recorded as 62% but inspection of the records indicates this is a typographical error and should be 6.2%. There are corresponding low oxygen results.

The results indicate that the gas is being generated from degradation of hydrocarbons, oxidation of organic material and possible some slow methanogenic degradation of organic material. This is consistent with the age of the waste. The generation rates will be very low and will be insufficient to cause a large volume of gas emissions. Therefore, a full gas extraction and flare system is not warranted on this site. However, in order to prevent gas build up below the new cap a gas venting system is required. The most practical way to achieve this will be by constructing a series of gas vent trenches below the cap. The spacing and size of the gas vent trenches is to be determined by analysis (see later in this report).

The gas venting system design is based on the following parameters.

Having reviewed the gas monitoring data for EPG it is considered that the monitoring wells do not extended to the full depth of the waste. Therefore, EPG has adopted the peak gas monitoring results reported by Geo-Environmental, which is suitably precautionary and may be summarised as follows:

- Methane 53%v/v
- Carbon Dioxide 11%
- Flow 38l/hr

The design also depends on the permeability of the ground. From the soil descriptions a value of 1 x 10^{-5}m/s has been assumed (sandy clay matrix will determine permeability). A conservative approach has been adopted because the depth of the waste is not known. It has been assumed that 10m depth of waste is present below the whole area of site (approx. 130m by 300m). It is assumed that the waste was all placed in 1975 and that it was commercial waste with a density of 1.4t/m^3.

Infiltration from rainfall is based on the Met Office Average Annual Rainfall map for the UK (1981 to 2010) and a value of 800mm/yr is used.

2.8 Proposed capping layer construction

The proposed capping layer construction will require a 1m thick layer of clay with a minimum permeability of 1 x 10^{-8}m/s. Above this a protection layer or layers will be required to prevent desiccation of the clay, burrowing into it by animals, etc. Where the end use will be fields that are grassed or have similar low level vegetation the protection layer can be 1m thick. If trees are to be planted it should be 2m thick.

On the steeper slopes a surface water drainage blanket is required above the impermeable layer and a leachate collection blanket is required below it. Both will require draining to an outfall downstream of the landfill. The leachate collection outfall will require treatment via a swale and wetland system.

3. SLOPE STABILITY

3.1 Analysis

The slope stability analysis has considered two failure scenarios. A shallow translational slide failure and a deep seated global slope failure (analysed using Bishop's simplified method).

The analysis has been completed using a traditional global or lumped factor of safety and also using a limit state analysis following Eurocode EC7[5] and BS 6031: 2009[6].

3.2 Factors of safety and partial factors of safety

For the traditional lumped factor of safety analysis a minimum factor of safety of 1.3 has been adopted as acceptable for both translational and global stability. This is on the basis that any slope failure will not have a significant impact on nearby buildings, roads or critical infrastructure.

For the translational analysis the following partial factors of safety have been used:

- Analysis DA1.C1 with γ_g = 1.35 applied to soil density and $\gamma_{c \text{ and } \phi}$ = 1.00 applied to shear strength parameters (there are no variable actions applied in this analysis);
- Analysis DA1.C2 with γ_g = 1.00 applied to soil density and $\gamma_{c \text{ and } \phi}$ = 1.25 applied to shear strength parameters (there are no variable actions applied in this analysis);

In the Bishop's analysis the global factor of safety obtained is equivalent to a partial factor on the soil strength, providing that appropriate partial factors have been used on the actions. Therefore, for the "limit state" analysis of global stability the minimum allowable factor of safety is follows:

- Analysis DA1.C1 = 1.00, with γ_g = 1.35 applied to soil density (there are no variable actions applied in this analysis);
- Analysis DA1.C2 = 1.25, with γ_g = 1.0 applied to soil density (there are no variable actions applied in this analysis).

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[5] BSI (2004). British Standard BS EN 1997-1: 2004. Eurocode 7: Geotechnical Design – Part 1 General Rules.

[6] BSI 92009). British Standard BS6031: 2009. Code of practice for earthworks.

3.3 Results

The analyses are provided in Appendix 2 and are summarised in Tables 2 to 4.

Table 2 Summary of results for translational analysis on steep slope at 1 in 3

Analysis assumption	Global stability FOS	Limit state analysis – stable?	Comment
Failure in waste 3m cap, groundwater 1m below surface	1.35	Stable	Failure in waste is not critical driver for cap design
Failure in waste, 3m cap, groundwater below failure surface – maintained by gas vent trenches/drains	2.03	Stable	Install combined gas vent trenches and drains below cap. Link to outfall at base of slope. Surface water drainage from cap also required.
Failure in impermeable capping, 3m cap, groundwater below failure surface – maintained by gas vent trenches/drains	1.40	Stable	Impermeable capping material must have an effective angle of shearing resistance, $\phi' \geq 25^{o}$.
Failure in impermeable capping, 2m cap, groundwater below failure surface – maintained by gas vent trenches/drains	1.40	Stable	Impermeable capping material must have an effective angle of shearing resistance, $\phi' \geq 25^{o}$.
Failure along separation geotextile			Geotextile must have an interface shear resistance with adjacent materials $\phi' \geq 23.5^{o}$.

Table 3 Summary of results for translational analysis on shallow slope at 1 in 7

Analysis assumption	Global stability FOS	Limit state analysis – stable?	Comment
Failure in waste 3m cap, groundwater 1m below surface	3.16	Stable	Failure in waste is not critical driver for cap design
Failure in waste, 3m cap, groundwater below failure surface – maintained by gas vent trenches/drains	4.74	Stable	Install combined gas vent trenches and drains below cap. Link to outfall at base of slope. Surface water drainage from cap also required.
Failure in impermeable capping, 3m cap, groundwater below failure surface – maintained by gas vent trenches/drains	1.37	Stable	Impermeable capping material must have an effective angle of shearing resistance, $\phi' \geq 11^{o}$.
Failure in impermeable capping, 2m cap, groundwater below failure surface – maintained by gas vent trenches/drains	1.37	Stable	Impermeable capping material must have an effective angle of shearing resistance, $\phi' \geq 11^{o}$.

Table 4 Summary of results for global stability

Analysis assumption	Global stability FOS	Limit state analysis – stable?	Comment
Failure extends over whole slope DA1, C1	2.85	Stable	Minimum factor of safety is greater than 1.0 so slope is stable
Failure limited to steeper part of slope DA1, C1	1.76	Stable	Minimum factor of safety is greater than 1.0 so slope is stable
Failure extends over whole slope DA1, C2	2.79	Stable	Minimum factor of safety is greater than 1.25 so slope is stable
Failure limited to steeper part of slope DA1, C2	1.64	Stable	Minimum factor of safety is greater than 1.25 so slope is stable

The translational stability analyses show that failure in the waste material is not critical. Any failure would take place in the placed materials. In order to maintain stability on the existing slopes and avoid regrading the slopes the angel of shearing resistance of the placed materials will need to be restricted as follows:

- On slopes ≥ 1 in 7 imported fill materials must have $\phi' \geq 25^{\circ}$. Some earthworks materials may not meet this requirement (eg high plasticity clays).
- On slopes ≥ 1 in 7 the geotextile separation layer used to protect the drainage layers must have an interface shear resistance $\phi' \geq 23.5^{\circ}$ in contact with the adjacent materials.
- On slopes < 1 in 7 imported fill materials must have $\phi' \geq 11^{\circ}$. In practice this means that most earthworks fill material should be suitable from a stability perspective (note they must meet any other criteria such as permeability and chemical requirements).

The results of the global stability analyses assess the risk of deep seated failures occurring through the waste and/or natural clay below the site. The results indicate the factor of safety varies between 1.64 and 2.85 depending on where the upper end of the failure is assumed to occur. These are above the minimum acceptable value of factor of safety of 1.3 for a lumped factor of safety analysis.

The global limit state analysis also shows that the risk of a deep seated failures is within acceptable limits. It should be noted that extremely an extremely conservative assumption that c'= 0kPa has been made in the analysis and the factors of safety are likely to be much higher than the analyses suggest.

4. GAS VENTING SYSTEM

The calculations to determine the spacing and sizing of the gas venting trenches are provided in Appendix 3.

Based on the results the most practical way to achieve a suitable gas venting system will be by constructing a series of gas vent trenches below the cap (in the existing slope) at 10m centres down the slopes (ie perpendicular to the slope). The trenches should be 450mm deep by 450mm wide and include a 150mm perforated pipe. The pipe should be surrounded with a course no fines granular fill (this could be crushed and screened concrete) but it must meet a specific grading criterion that meets the requirements of a Type B filter material in accordance with clause 505 of the Specification for Highway Works (essentially a coarse French drain infill that is 20mm to 40mm in size).

The perforated pipe (Polypipe land drain pipe) should be connected to a vent stack at the upslope end. A vent stack will be required at the top of each trench.

5. CONSTRUCTION REQUIREMENTS

5.1 Outline design of the capping and venting system

Outline design drawings are provided in Appendix 4. The design applies to a maximum 1 in 3 existing slope. Where the slope is greater than this localised regrading will be necessary to reduce the slope angle to 1 in 3 or less prior to construction of the cap.

At the upper edge of the cap it will be feathered down to existing ground levels. At the bottom end will continue over the existing value until it meets the opposite side, thus forming a new dry valley or swale (Figure 9).

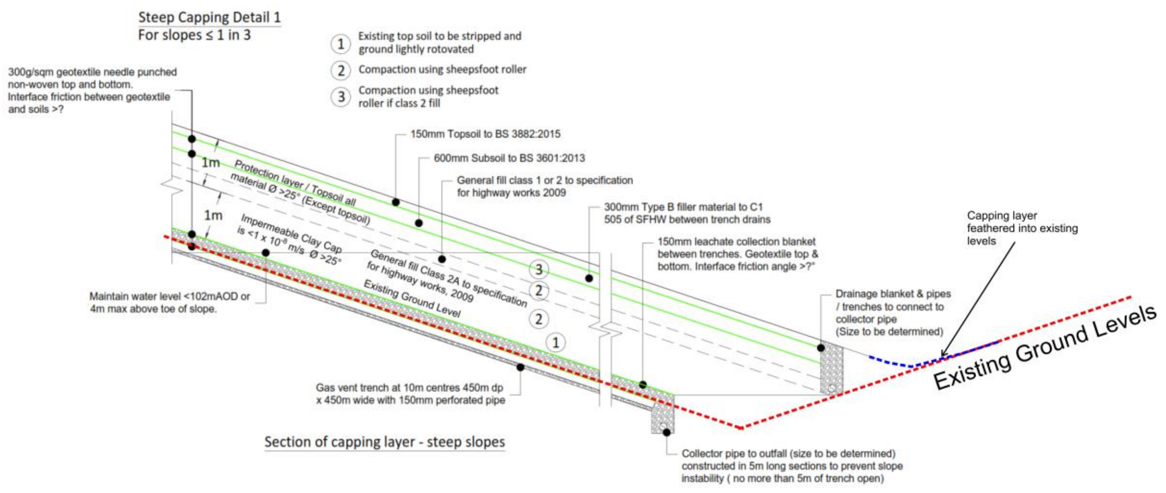

Figure 9 Lower capping edge detail

5.2 Earthworks specification

The slope stability has shown that the materials to be used to form the capping layer must have a minimum angle of shearing resistance. The Specification for the works should include a requirement that the angle of shearing resistance is determined for all imported materials (capping layer, general fill and subsoil).

Geotextiles used to separate the Type B filter material used to construct the leachate and surface water drainage blankets at the toe of the slopes must have a minimum interface shear angle with the soils on either side. The supplier should confirm the likely values to be achieved.

Construction will require earthworks to operate on steep slopes and the contractor needs to be aware of and take adequate safety precautions. The cap can be constructed by layering and mirroring the existing slopes. To avoid shear surfaces being formed the existing surface topsoil should be removed and the surface rotavated to roughen it up. Cohesive fill materials should be compacted with a sheep's foot roller.

5.3 Gas monitoring

During construction of cap there is a minor risk that sealing of the landfill surface and the weight of the cap could cause deeper gas migration to occur out of the site (this will not be prevented by the shallow gas vent system and would require a deep vent trench to prevent it. Given the low risk of this occurring the best way to manage the risk is to install a series of monitoring wells around the outside of the landfill to 10m depth. These should be monitored using Ambisense GasfluX continuous monitoring units that record gas concentrations and flow rates. The monitoring should commence 2 months prior to starting the cap construction to collect baseline data and should continue throughout construction of the cap. If the cap construction is to take place over a long period then after the first few months an assessment of the data may show that further monitoring is not required.

Contingency options will need to be developed in case gas found in the wells during construction but this cannot be developed until the baseline data is available.

There is no need for ongoing monitoring after construction of the cap.

5.4 Surface water and leachate management at toe of steep slopes

At the toe of the steep slopes the capping layer will require drainage blankets above and below the impermeable capping layer material. The purpose is as follows:

1. The surface water drainage blanket is to prevent the capping layers soils from becoming saturated, thus reducing the stability of the slope. The water collected and discharged by this system is rainwater runoff and it will not require any treatment before discharge.

2. The leachate collection blanket is required to stop leachate levels rising and thus reducing the stability of the slope. The outfall from this will contain leachate. From the test results on the groundwater on the site this is slightly contaminated. It should be treated via a swale (the existing dry watercourse) and a small wetland at the end prior to outfall into the stream.

Groundwater/leachate levels are to be maintained below 102m AOD or no greater than 4m above toe of slope.

The pipe size of the collector pipes and outfalls, as well the wetland size is subject to detailed survey work and drainage design.

The outfall from the leachate control system to the swale is likely to be intermittent. Therefore it is difficult to design the swale and wetland to treat the leachate using normal design methods which assume a constant discharge. Although the leachate does contain elevated contaminants it is not particularly strong. If the average residence time in the swales is greater than 9 minutes this will remove any sediment from the leachate. This can be achieved by placing check dams in the swale to slow the water down. The swale will remove the need for a sedimentation pond on the wetland system.

The wetland should be designed primarily as an ecological feature (as far as is possible given that leachate will enter it), and it will behave as a single free water surface flow system. It should be designed into the landscape so that as the strength of the leachate reduces over time it becomes an asset to the overall site. It should be designed in conjunction with ecologists so that it can be designed as far as possible to promote biodiversity. It may also be possible to direct clean surface water drainage from the cap into the wetlands to dilute the leachate and allow the wetlands to work more effectively. The wetland should be based on the following criteria:

Length to width ratio at least 4:1;

Mix of deep and shallow zones and planting to tolerate leachate, maximise pollutant removal;

At least 30% of area has 0.5m to 1m deep water;

At least 50% of area has less than 0.5m deep water;

Maximum depth of any area 1.2m;

Hydraulic retention time greater than 24 hours.

6. POST CONSTRUCTION MAINTENANCE

Post construction maintenance of the capping and venting system will be minimal.

Maintenance of the gas vents simply requires a 6 monthly inspection to ensure that the gas vents are not blocked or damaged and carrying out any necessary repairs.

Maintenance of the cap is minimal and again it will just require 6 monthly inspections to ensure that there is no damage from animals or for other reasons.

7. SUMMARY AND CONCLUSIONS

The slope stability assessment has shown that the landfill cap can be designed to be stable on the existing slopes on the site. The angle of shearing resistance of the imported materials will have to need defined limits to achieve this.

A gas venting and surface water drainage system will be required as part of the capping system.

Outline design drawings for the capping layer are provided in Appendix 4.

8. CDM ASSESSMENT

The construction hazards are minimal and the site is considered to be low risk. – There are no unusual hazards that would not be expected by competent contractor experienced in constructing landfill caps.

The following residual hazards are identified:

- There are no significant buried services on site, but a check should be made in any case before any excavations are made – residual risk is very low;
- Working on steep slopes is required. The alternative is to reprofile or bench the works. This will increase risk of exposure to contaminants and release of explosive, toxic or asphyxiating gases. Working on steep slopes to 1 in 3 is possible with an excavator working perpendicular to the slope. Benching would require working close to edge of steep slope which is considered a greater risk as the machine could tip over if it runs off the bench. Therefore, overall risk is minimised by constructing the capping layer over the current slopes (reprofile locally if > 1 in 3). Appropriate management and supervision will be required - residual risk is low;
- Exposure to contaminants and landfill gas. Exposure has been minimised by limiting excavation and avoiding the need for any work in deep trenches. Appropriate H&S precautions will be required by the contractor – residual risk is low.

