Drilling in waste on landfill sites

Text agreed by Environment Agency technical staff and Landfill Regulation Group (Engineering Sub-Group) members[1]

1. Introduction

Where you propose to undertake drilling on your landfill, you must consider:

- the environmental risks of potential penetration of the liner
- the accuracy of construction records and survey data
- drilling methods, level of control and accuracy
- the heterogeneous and unpredictable nature of waste,
- the saturation by leachate towards the base of the cell
- likely perched leachate levels
- the contamination potential of wastes and leachate from the borehole
- landfill gas and odour emissions
- remedial actions in the event of damage to lining systems or other infrastructure

2. Planning your project

You must discuss your proposals with us before you start any drilling project on your landfill.

Both your design engineer and CQA Inspector must understand the risks and the ways to mitigate them. They must also understand the available technical options for the drilling and installation, and their limitations.

When designing the wells you must use the following information from the original site and cell design and its construction (where available).

- The original design and specification
- Construction records, including as-built drawings, which are usually found in the CQA Validation Report(s).
- Side slope and bund locations, especially the line of the toe of the slopes. Important when drilling above or close to a side slopes or bunds.
- Location of retro-drilling target pads, if present.
- Location of buried leachate and gas collection infrastructure if present.
- Assumptions and the basis for cell design can be found in the Environmental Setting and Installation Design, Hydrogeological Risk Assessment, Stability Risk Assessment and/or within the Permit. The latter includes restrictions on the maximum depth of leachate, waste types deposited etc.

[1] Note that this document will lose its draft status once hosting arrangements for landfill guidance are agreed and it is appropriately badged. There is no expectation that the text will change.

You must verify the accuracy of as-built surveys and drawings. For example by comparing base levels on the as-built drawings to leachate well dip-to-base records and verifying the accuracy of survey benchmarks and any temporary survey stations used and provide us with a record of the checks you undertake. You must also use the following information where your project is to remediate or replace existing infrastructure:

- Photographs taken during construction and operation of the cell. These can help you understand the stresses and movements of waste around damaged infrastructure, such as a leachate chamber. Survey of displacement of damaged leachate extraction manholes can help to understand causes of failure (Azimuth and inclination surveys
- Knowledge of any materials used infilling of leachate chambers (such as pipes and perhaps gravel) can assist in planning how to drill and install the replacement structure.
- Previous drilling records from gas wells etc. can also be of great assistance.
- Anecdotal evidence may also be usefully obtained from site staff.

You must review the leachate and gas monitoring data for the site to help you decide whether special precautions are needed. For example how you will manage drilling where there are high leachate levels or how landfill gas collection will be managed during drilling.

Your permit requires that you use competent persons and resources in all aspects of your activity. The knowledge and skills are very different from those required for other landfill engineering projects. You must therefore ensure that you use personnel for designing and supervising the work who are experienced in undertaking landfill drilling operations.

You must also ensure that you use a competent contractor to undertake the installation works and that they have experience of working with the equipment and materials you propose in your design. You must ensure that the lead driller provides a CV demonstrating their qualifications and experience for landfill drilling.

You must use suitable equipment and techniques. Some standard drilling techniques are ineffective where material has low density and can wrap around rotating bits or become slurry where the material is saturated with leachate. You must use a competent design engineer with experience of design using the drilling techniques used in this type of installation.

3. Zonal Drilling

You must use a zonal drilling approach for all holes drilled into the landfill. Best practice for zonal drilling is set out below:

- **Zone 1** The Low Risk Zone where the target depth is well above the predicted base of the waste (based on risk assessment of the quality of survey data). You can drill confidently without the need to confirm the position of drill bit or recover material

to confirm the materials you are drilling through. Standard drilling operations are acceptable where drilling is often advanced in 3 metre increments. In this zone you may also install spike wells for landfill gas which only penetrate into the upper layer of waste or use a continuous flight auger.

- **Zone 2** – The Intermediate Zone - As the base is approached drilling increments are reduced to 300mm. The driller should be aware of changes to drilling environment such as increase in torque and vibration in the drill string. For example between 2 and 1 metre above your target. Arisings for each increment must be inspected on removal.

- **Zone 3** – The High Risk Zone - Proceed carefully in small increments. Increment distance is related to the accuracy of the drilling method and should be less than the thickness of the target layer (e.g. if a 300mm layer of gravel, increments might be 200mm) as the base is approached closely, 150 or 100mm increments are used, dependent on risk. The driller should be even more aware of changes to drilling environment such as increase in torque, vibration in the drill string and the drilling rate. Arisings must be checked carefully for signs of drainage material when removed.

- **Arisings** - To enable arisings to be removed from the borehole, in the likely leachate saturated conditions, additives may have to be added.

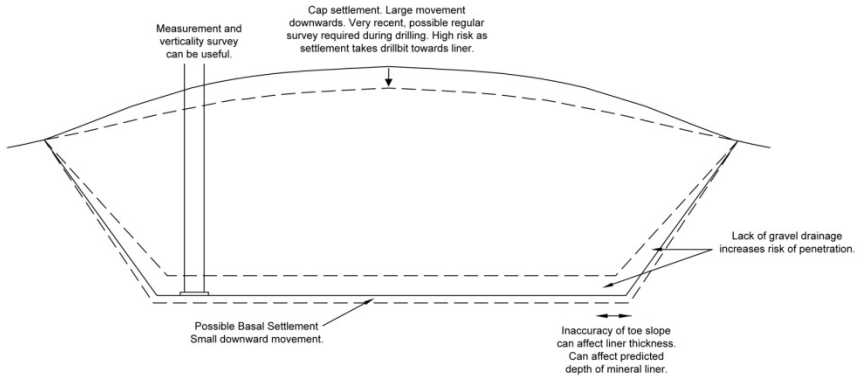
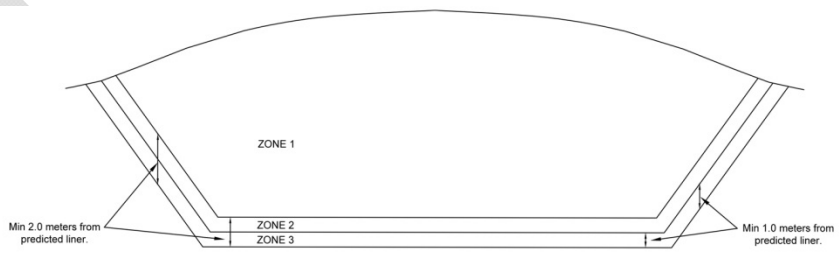


FIGURE 1: RISK ISSUES IN PREDICTING DEPTH OF LINER



ZONE 1 - Any form of drilling
ZONE 2 & 3 - Incremental drilling required

Note
Vertical thickness dependant upon risk assessment.

FIGURE 2: ZONAL DRILLING

You must specify the depths of each zone for each borehole. This will be borehole and cell specific, based on your confidence in the available survey data and other available 'as-built' information. Zone thicknesses may vary across the site due to differences in geometry, basal engineering and confidence in the survey data.

You must agree the drilling techniques with your drilling contractor and describe them in a Method Statement. You must submit the Method Statement as part of the construction quality assurance plan for the work.

Where you plan to drill in Zones 2 and 3 you must prepare a remediation and be able to implement this immediately.

3.1. Surveying

You must assess the accuracy of existing survey data and use this assessment to design your borehole and drilling method. Relying on poor initial survey data may lead to a perforation of the liner system.

The depth to the drill bit must be known when drilling leachate boreholes to a far greater accuracy when compared to gas boreholes which rarely extend to the base of the site. A few centimetres of error can cause a breach of the lining system.

You must undertake a survey of the top surface of the cell or phase you intend to drill in, as this can change regularly due to waste settlement.

Where there is recent waste deposited and especially where you are drilling close to the base of a site it is likely that settlement of the waste will take place during the operation due to the vibration of the heavy drilling rig operating on top of compressible waste. You must survey immediately before the start of the drilling, and provide a suitable stable and protected temporary bench mark off-site which can be readily used over an extended period. You may have to undertake periodic surveys during the drilling operation and survey readings may be required several times during a day in some cases – dependent upon the rate of settlement.

If drilling near the base you must research the proposed base area of the well, looking in particular at the thickness of any target pad, any cover materials, the nature and thickness of the drainage stone layers and the stone specification.

You must specify the following in your CQA plan:

- responsibility for surveying
- surveying frequency (including conditions where you will increase the frequency)
- the method of survey
- accuracy in the CQA plan.

During drilling operations the frequency of surveying may be increased if any rig settlement is observed.

4. Borehole design

4.1. Retro drilled leachate extraction and monitoring boreholes.

Where your landfill permit requires that you monitor and control leachate levels, you must maintain site infrastructure to allow you to do this. You must repair or replace damaged leachate extraction points and leachate monitoring points. You must ensure that your retro-drilling proposals will allow you to continue to meet these limits once new extraction and monitoring points are installed. Where you cannot install leachate extraction boreholes to a depth that will allow leachate control to be reinstated in compliance with your permit, then you must review your risk assessments and/or make an application to vary the leachate level limits in your permit.

Many of the older landfill extraction points (also known as leachate chimneys) and monitoring points were not robustly designed and have suffered severe damage, sheared, or been distorted by waste settlement or operational activities, to a point where they are unserviceable. We accept that replacement of an extraction or monitoring point by excavation is impractical and many landfill cells have had to be re-engineered by drilling new leachate extraction boreholes from ground level. To be effective the new borehole must terminate in close proximity to the base of the cell (preferably in contact with the drainage blanket) and at a low point in the cell to allow accurate leachate level measurement or extraction. The term “retro-drilling” is commonly used to describe the drilling operation to replace a leachate extraction/monitoring chamber.

You will generally need to use temporary casing to progress the borehole, in particular below leachate level where drilling through saturated waste, which has very low shear strength. This will minimise inflow into the borehole of waste fines and allow placement of the designed backfill of gravel/bentonite and negate the need to de-sludge the borehole afterwards.

The replacement perforated casing must be designed and placed precisely to the agreed design to be effective. It must not cause damage to the lining system either during placement or subsequent operational life with inherent long-term settlement and negative skin friction.

Your design will be dependent upon the available data and your understanding of the nature of the failure of the original chamber

A failed leachate chimney must be surveyed as far as possible and the top centre compared to its base centre. In some difficult situations down-the-chamber photographs, video and surveys can be useful in understanding the mode of failure and this service can be provided by borehole logging companies.

You must review the information available to determine the cause of failure and inform your design to avoid repetition of failure. The design of your replacement structure will depend on the cell design and your investigation of the failed structure. You must follow the steps below:

1. Where your landfill cell has target pads installed during the cell construction at the base of your site (*link to target pads in 1. Building your landfill)*, you must base your design on drilling to these targets.

2. Where you do not have target pads installed, you must decide whether it is feasible to use the existing chamber base or drill adjacent to an area where there is no protective concrete but to stop at the drainage layer. It is sometimes possible to drill into and/or out of old concrete chambers or to angle drill to a position on the base. Drilling through gravel filled chambers has also been accomplished.

3. Where it is not possible to use the existing extraction/monitoring point, you must consider drilling your replacement structure adjacent to the failed structure.

Your design engineer must consider the function of the new leachate extraction or monitoring borehole. A replacement leachate extraction borehole may well have most of its length backfilled with gravel pack whereas a leachate monitoring borehole may require a short response zone to measure leachate head acting on the liner and exclude perched leachate.

The design engineer must consider:

- end-bearing and negative skin friction when in service.
- any specific loadings during construction such as potential damage to the lining system by, for example, dropping the casing on the liner system during installation.

There is a considerable increase in the loading on a basal liner from a casing as the thickness of the underlying drainage stone reduces. Therefore, minimising removal of the underlying gravel drainage layer during drilling is important. Many factors need consideration, including the design and installation of the existing chamber and its proximity, the nature of the wastes, the state of waste compaction and likely subsequent settlement

The final calculations may vary from the theoretical projection as the final depth of the borehole may change from the original plan. Variations will need to be explained in the CQA validation report.

We will accept the following types of casing for retro-drilled boreholes:

- HDPE threaded or butt fused
- HDPE telescopic
- Steel threaded
- Steel telescopic

You must use calculations to demonstrate how you have considered the following:

- The anticipated stresses on the casing based on the nature, age and depth of waste.
- The effect of additional loading on the existing basal lining and drainage system.

Your casing specification must include:

- The perforation specifications

- the perforated and non-perforated lengths of pipework
- the wall thickness and the diameter (the available diameters are a restricted range)
- the base design
- gravel pack design to the base
- the length of bentonite seal to ground level
- method statement of installation

We will accept open hole drilling to completion for cases where the waste is sufficiently stable to allow this. Where waste is not stable, for example where it is saturated you must support the borehole using temporary steel casing to prevent the borehole collapsing.

You must backfill the annulus between the replacement casing and the drilled borehole with gravel and seal to the surface with a bentonite and/or bentonite cement.

The purpose of the gravel pack is to reduce the stresses due to movement of the waste. and to prevent waste material entering the borehole. Poor gravel pack installation may allow slurried waste to enter the borehole and require the borehole to be cleaned or de-silted before it can be used and regularly thereafter.

During gravel installation you must extract temporary steel casing carefully as the gravel is placed to ensure:

- the gravel pack does not bridge within the hole
- the gravel completely fills the void left between the permanent casing and the bore.

You may need to use a tremmie pipe for this on some boreholes but other methods are available..

You must calculate and record the volume of materials to be placed from the design and the actual amount placed.

You must state the depths and drilling techniques for Zones 1, 2 and 3 for each proposed borehole.

The CQA validation report should provide borehole records with the actual installed lengths and dimensions and record the theoretical and actual volumes of gravel and sealing mix.

4.2. Landfill gas collection and monitoring boreholes

Gas collection and monitoring boreholes are generally shorter than leachate extraction/monitoring boreholes. As they rarely need to approach the base they are usually drilled using open hole drilling techniques.

It is likely that such boreholes will be drilled in Zones 1 and 2 as described above. You must determine the zones for each location and include this in your the CQA plan. You must take extra care when determining zones close to side slopes or over inter-cell bunds. You must provide a table in your CQA plan showing the required stand-off between the base of the waste and the base of each borehole.

Techniques used to construct gas wells may be rotary drilling, percussion drilling or spike wells inserted under static or dynamic pressure. “Spike Wells”, installed by static or dynamic means are only suitable for installation within Zone 1.

The intended drilling technique must be included in the CQA plan

The casing size must be stated. You must consider whether your gas wells needs to be sized to accommodate leachate pumps to remove perched leachate. We will accept HDPE, threaded or butt fused casing. Steel casing is not normally used for gas extraction boreholes unless there have been incidents of underground fires in the vicinity. The lower end of the casing must be sealed with a robustly fixed cap. These can be fused (butt or electrofusion or threaded if HDPE or welded (taking into consideration DSEAR limitations) or threaded if steel has been selected.

A gas well head, (link monitoring your landfill) should be installed on borehole completion. In situations where a well head cannot be installed immediately a temporary cap should be used to prevent fugitive emissions.

The design for each borehole should provide:

- The depths of relevant Zones 1 & 2 at each location
- Predicted length and diameter
- Perforation specification
- Length of solid and perforated sections of the casing and SDR rating,
- Length of gravel pack and the length of cement/bentonite seal to be installed and their approximate volumes.

The CQA validation report should provide borehole records with the actual installed lengths and dimensions and record the theoretical and actual volumes of gravel and sealing mix.

5. Construction quality assurance

5.1. Supervision of the work

Typical permit condition
The operator shall manage and operate the activities using sufficient competent persons and resources.

You must use Independent, third party construction quality assurance (CQA) to ensure that the materials and workmanship for all landfill engineering meets the standards specified in your permit and CQA Plan.

You must outline the roles and responsibilities of each member of the CQA team within your CQA plan for the works.

The CQA personnel must be experienced with rotary drilling techniques. We will not accept CQA inspectors with only basal lining and capping supervision experience.

5.2. Construction quality assurance plan

Typical permit condition
No construction of any new cell of the landfill shall commence until the operator has submitted construction proposals and the Environment Agency has confirmed that it is satisfied with the construction proposals.

The CQA Plan (CQAP) is prepared by the Design Engineer and CQA Inspector and must be agreed by us. It must include the information set out in Table 1 below.

Table 1. CQA checks to be included in the CQA plan

Your CQA plan report must include following as a minimum:	
1	CQA personnel and their experience or if not determined these must be sent to us and be approved before commencing work on site
2	Description of the proposed works and the basis for the design
3	Design calculations
4	Specification of all proposed construction items
5	Operational survey responsibilities & requirements and tolerances
6	Sources of as-built information – for example as-built drawing references or photographs
6	Plan of proposed locations and recent elevation survey
7	Tabulated or diagrammatic proposed construction for each borehole including the location specific Zones.

Your CQA plan report must include following as a minimum:	
8	Proposed methods of drilling and construction
9	Methods for monitoring drilling progress
10	Borehole records
11	Procedure for dealing with emergencies

Your CQA Inspector must:

- check that the drilling schedule of depths and borehole locations are up to date.
- check there has been a recent survey and if required ensure that regular surveys are undertaken
- know the depth the drilling has reached at all times.
- regularly record the depth against survey data and compare to the target depth
- measure all drilling tools, including bit/auger. Note :lengths of casing may be supplied in random lengths and should therefore be measured individually.
- count and record the number of drill rods, and casing being installed.
- supervise the installation of borehole materials

5.3. Planning your working area

Your CQA plan must demonstrate that you will have a suitable working area for the drilling work. You must ensure you have:

- A level working area with enough room for the rig,, handling casing/rods and temporary storage of materials such as gravel and bentonite.
- access roads or tracks are needed for the access of the rig, for dumpers removing waste and equipment for moving heavy casing.

The working area can often be improved by building a platform or a temporary excavation. Where this work requires removal and reinstatement of capping you must agree how you will do this with us as part of your CQA plan.

5.4. Landfill gas and odour

You must review your landfill gas and odour management plans for the site. You must include the following in your CQA plan:

- Temporary management plan you will follow during the work.
- Clearly defined areas where gas extraction is reduced or switched off during the work

- Description of where you propose to use additional measures such as inert gas injection and/or odour suppression systems. You must consider the gas extraction system particularly where the cap is temporarily cut in the area of working.

5.5. Remediation strategy in case of liner penetration

Despite careful and controlled drilling there may be cases where the basal lining is inadvertently breached.

Your CQA plan must describe your action plan and remediation method. Where you intend to drill into Zone 2 or 3 you must have the materials and equipment required for remediation on site at all times during the operation. If the basal lining is penetrated you must notify us as soon as practicable.

5.6. Arisings

You must provide details of how you will handle and dispose of the arisings from the drilling. These are either non-hazardous or hazardous wastes and leachate brought to the surface during the drilling operation.

Arisings from drilling within saturated waste may be liquid (leachate) and/or slurry. You must describe in your CQA plan how you will contain and dispose of leachate and saturated wastes.

At closed sites you must make arrangements for off-site treatment and disposal of all arisings from the drilling.

5.7. Abandonment

Your CQA plan must consider occasions where a hole has to be abandoned. You must describe your method of backfilling/grouting the hole appropriate to where it is situated.

5.8. Reinstatement of Capping

Your CQA plan must describe your methods of welding/sealing the cap and any restoration as part of the design. Further guidance on best practice depending on the liner type can be found in Additional guidance for the landfill sector: 1. Building your landfill (to be issued)

5.9. Drilling method statement

Your CQA plan must include a drilling method statement.

The drilling method statement should where appropriate include the following:

- Mobilisation and rig set-up
- Precautions for protection of personnel and the environment
- Emergency procedures
- Drilling techniques
    - Routine operational issues of rig operations and safety.

    - Methodology of measurement of barrels and rods.
    - How you will implement zonal drilling including progress of the borehole close to the target elevation/predicted depth.
    - The drilling techniques to be utilised in extracting arisings (waste and leachate) from the borehole.
    - Methods for removal of arisings from the area of the rig.
    - Methods for handling of barrels, augers, rods and temporary casing.
    - Methods for maintaining verticality (or required angle in inclined drilling)
    - Methodology for removing saturated wastes.
    - Methodology for the installation of permanent casing system, including clamping and check systems to ensure fail safe installation, especially telescopic casing systems.
    - Methodology for the installation of gravel and bentonite seal and checking no bridging as installed.
- Drilling in saturated wastes
- Disposal of arisings.
- Installation of casing
    - Where you are installing telescopic systems your method must follow the manufacturers instructions for handling to ensure shear pins holding the casing together remain in place during assembly and placement.
    - You must describe the method of withdrawing the temporary casing whilst backfilling the annulus with gravel/bentonite. Calculated volumes and actual volumes of gravel must be stated.
- Rig movement & demobilisation

You must set out your procedure for dealing with emergencies. We accept that occasionally situations occur which require immediate action to ensure safety or environmental security. Where you need to implement emergency actions in a short time scale either for safety purposes or to prevent uncontrolled emissions, you may do so provided you submit construction/remediation proposals as soon as practicable. This does not remove the need for you to implement planned and foreseeable work in accordance with the CQA requirements

6. Validation report

Typical permit condition
The operator shall submit a CQA Validation Report as soon as practicable following the construction of the relevant landfill infrastructure.

You must provide a CQA validation report for the construction of the landfill infrastructure. The validation report presents the final 'as-built' construction and engineering details of the works including all test results and non-conformances. The as-built drawings form an important part of the permanent record you and we hold. It must provide a comprehensive record of the construction and be easily understood, particularly in terms of the technical

detail. You must specify what form of documentation and presentation you plan to use in your CQA Plan.

Your permit requires that you submit a validation report as soon as practicable following the construction of the landfill infrastructure. We will review the validation report and inform you whether it is satisfactory or whether further information is required. We will usually review the validation report within the period of four weeks from the date of receipt.

Table 2. Minimum information to be included in the validation report

Your validation report must include as a minimum:	
1	Details of how you have complied with your CQA plan, including measurements taken during the work.
2	Justifications for any changes or deviations from the agreed plan
3	Borehole records (see BS 5930: 1999+A2:2010) Construction records for the borehole Survey data with xyz co-ordinates for top of installations and if angled the settings and if possible bottom co-ordinates.
4	'As-built' plans and cross-sections of the works 'as-built' plans and cross-sections of the works.
5	Photographs of the works
6	Copies of the site engineer's daily records
7	Records of any problems or non-compliance and the solution
8	Any other site-specific information considered relevant to prove the integrity of the construction
9	Validation by the CQA/ Design engineer that the construction has been carried out in accordance with the construction proposals and CQA plan
10	A Chartered Civil Engineer or Chartered Geologist must sign the validation report.

7. Health and Safety

A Health and Safety Risk Assessment should be provided by the Contractor. It must comply with Control of Substances Hazardous to Health Regulations 2002 (COSHH), Control of Asbestos at Work Regulations 2012 (CAWR) and Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) 2002.