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## ***SEPA Interim Technical Guidance Note Capping for Landfill Sites***

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### **Summary**

All landfills will require a cap and operators should provide site specific justification for their proposals and any deviations from the landfill directive recommendations. As a minimum, the capping system should contain a low permeability/sealing layer (ie clay, LDPE, GCL), a surface water drainage system and cover soils. Whilst the cap design is to be based on a site specific assessment, for lined sites SEPA would generally favour a flexible membrane for gas control purposes and controlled recirculation of leachate to optimise waste decomposition.

### **1.0 Introduction and Scope**

- 1.1 This note provides interim guidance for SEPA staff on capping for landfill sites and may be provided to operators and designers as guidance to SEPAs requirements. The procedures described may be applied to both existing and new landfill sites.
- 1.2 This guidance document sets out a brief overview of the main aspects to be considered when establishing the capping standards at landfill sites. The Environment Agency has commissioned a research project on guidance for restoration of landfill sites and it is anticipated that a section on the engineering aspects of capping of landfills will be included in that research report. That report is not yet available although outline guidance on capping systems is provided in Waste Management Paper 26 B.
- 1.3 This guidance document covers landfill sites closing or closed under the Waste Management Licensing regime and landfill sites regulated under the PPC regime. Regardless of the regulatory regime, the standard of cap required is based on site-specific assessment. Operators will require to establish the site specific capping requirements for each landfill site based on the overall design and setting of the landfill. It is not possible to cover all the possible capping options available in this guidance.
- 1.4 The choice of capping should be made during the initial design of the site and details should be provided by the operator along with a permit application. Appropriate conditions may also be required to be included in the permit relating to capping of the site. For capping systems the design should be based on quantified calculation of the infiltration characteristics over the full life cycle of the landfill in context with the meteorological conditions at the site and all other aspects of the engineered control systems including gas management.

## 2.0 Regulatory Principles applicable to capping

- 2.1 This note covers landfill sites closing or closed under the Waste Management Licensing (WML) regime and landfill sites regulated under the Pollution Prevention and Control (PPC) regime. The implementation of the Landfill Directive leads to several scenarios, these are:

### Non Landfill Directive Compliant sites

- A: Closed before 16 July 2001 under WML and hence not subject to Landfill Directive (Site Conditioning Plan (SCP) not submitted)
- B: Closed after 16 July 2001 and before 16 July 2002 under WML and subject to Landfill Directive closure procedures only (SCP not submitted)
- C: Closed after 16 July 2001 and before 2007 under WML and subject to Landfill Directive closure procedures only (SCP submitted – either operator or SEPA initiated closure)

### Landfill Directive Compliant sites

- D: Existing sites transferred from WML to PPC permit and operating after 2007.
- E: New sites issued with WML or PPC permit after 16 July 2002

- 2.2 Sites that fall into scenario A are to be capped and closed in accordance with the requirements of their licence and the Waste Management Licensing regulations and are not affected by the Landfill Directive.
- 2.3 Sites that fall into scenarios B & C are also to be closed in accordance with their licence and the Waste Management Licensing Regulations and in addition will require to follow the closure procedures of the Landfill Directive. However, it is only the closure and aftercare procedures that apply to such sites as set out in article 13 of the Landfill Directive. This includes the monitoring requirements of annex III and the setting of 'trigger levels' of contaminants in groundwater (see SEPA Interim Technical Guidance Note: Hydrogeological risk assessment for landfills and the derivation of control and trigger levels). The capping standards at sites falling into scenarios B & C is to be established in accordance with the requirements of their licence and the Waste Management Licensing Regulations. The capping recommendations given in the Landfill Directive may be used as a guide to the options available for capping.
- 2.4 Sites falling into scenarios D & E must be fully Landfill Directive compliant both for operational and closed phases. This means that old closed phases of existing landfill sites that transfer to the PPC regime (including old phases technically connected to new phases) must comply with the capping requirements of the Landfill Directive. The standards of capping for closed phases can be established on a site specific risk based approach. Operators will require to justify retaining existing caps and consider any additional works that may be necessary to improve existing cap performance.
- 2.5 Nevertheless, regardless of the regulatory regime, the standard of cap required is to be based on site-specific assessment. The Directive requires that soil, groundwater and surface water are protected by the geological barrier and a top liner following closure. The Directive then goes on to provide recommendations for capping of non-hazardous and hazardous landfills but these can be established on a site-specific basis by risk assessment (standards can be increased as well as reduced). The need for and specification of a cap is also

related to the gas management system and also the potential need to physically separate the waste from the environment, even if there is no leachate risk (e.g. for asbestos waste). However, as a minimum, the capping system should contain a low permeability/sealing layer (ie clay, LDPE, GCL), a surface water drainage system and cover soils. All hazardous and non-hazardous landfills will require a cap and operators should provide site specific justification for their proposals and any deviations from the landfill directive recommendations.

2.6 The Landfill Directive recommendations for capping are:

Landfill Category	Non-hazardous	Hazardous
Gas Drainage Layer	Required	Not-required
Artificial sealing liner	Not-required	Required
Impermeable mineral layer	Required	Required
Drainage layer >0.5m	Required	Required
Top Soil cover >1m	Required	Required

2.7 The presence of a gas drainage layer has been excluded from the hazardous landfill. However, depending on the hazardous waste types received, gas management may still be required, and this may or may not include a gas drainage layer.

2.8 An artificial sealing liner (such as LDPE) may well be required at a non-hazardous site in order to act as a seal for gas collection purposes or to minimise rainfall infiltration. An impermeable mineral layer is recommended in the Directive for both non-hazardous and hazardous sites. Unfortunately, the term 'impermeable' when used in the context of a mineral layer, does not lend clarity to the regulatory requirements. Mineral layers cannot be impermeable but will have a certain permeability depending on the mineral used and the field conditions.

2.9 A drainage layer, is a layer that is above either the low permeability mineral layer or artificial sealing liner. It does not necessarily require to be a blanket of drainage stone to be an effective drainage layer but could be a layer of material with, for example, a herringbone network of field drains lain in that layer. Similarly the thickness can be established on a site specific basis. There are, for example, geocomposite systems that can provide drainage of a cap but are only 10 or 20 mm thick. The drainage layer and the effectiveness of the drainage system is the most important aspect of the cap in terms of controlling infiltration into the waste mass. All sites will require some form of drainage system.

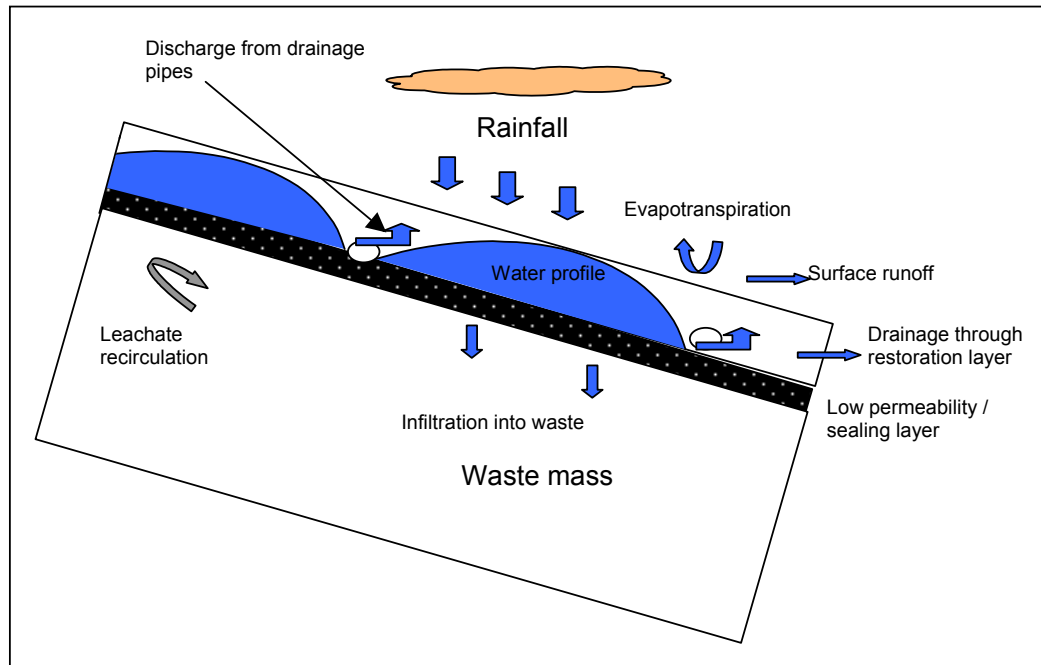
2.10 Restoration and topsoil cover will require to be established on a site specific basis depending on restoration and after use proposals. A difference is drawn between the terms 'Top soil' used in the Directive and 'topsoil' used as a soil classification. The Directive appears to mean a top layer of soil as a cover rather than a 1m thickness of topsoil material. The Environment Agency has commissioned a research project to prepare guidance on landfill restoration as an update to WMP26E (draft).

2.11 Inert landfills will require some form of cap but this may not be required to control infiltration or gas emissions and may just be required for restoration purposes. In addition an inert landfill may have accepted non-inert wastes in the past and the capping system should take such previous activities into account.

### 3.0 Technical Objectives of capping

- 3.1 In terms of hydraulic control, the capping details should be established from a risk assessment basis considering the whole life cycle of the landfill site. The SEPA guidance document 'Framework for Risk Assessment for Landfill Sites: The Geological Barrier, Mineral Layer and the Leachate Sealing and Drainage System' sets out the key steps in carrying out a risk assessment. That risk assessment procedure is used to establish the appropriate basal liner standards by estimating emission levels of potential pollutants to the groundwater.
- 3.2 To allow full life cycle analysis of a landfill, the performance of the cap is also of crucial importance. It is the degree of infiltration of rainwater through the cap that dictates the leachate generation from the waste. Once the infiltration rate has been estimated then the water balance for the site can be calculated (including any recirculation) and from this, the emissions to the environment can be quantified. The design of the cap must also take into account, gas management at the site and the proposed aftercare and restoration activities.
- 3.3 As stated above, the cap primarily requires to fulfill a dual purpose in terms of environmental protection. To control infiltration rates and as part of the gas control system. Both aspects must be satisfactorily addressed within any design and will require a number of engineering components. The final arrangement will differ from site to site depending on the degree of control required. In addition, the capping specification may vary from one area of a landfill to another as different degrees of control may be required. The management of gas is covered in other SEPA guidance. (ref Guidance on the Management of Landfill Gas)
- 3.4 The infiltration rate of rain into the waste through the capping system is dependent on a number of factors (see figure 3.1) including:
- Rainfall characteristics
  - Surface slope
  - Restoration and grass/plant cover
  - Drainage system
  - Low permeability layer
- 3.4 The interrelationship between these factors is complex but there are methods available to estimate the performance of a capping system. A computer modeling programme, HELP 'Hydraulic Evaluation of Landfill Performance' is a useful tool for estimating infiltration rates through a cap. However, that model does not have default Scottish rainfall patterns and if used, advice should be sought from a hydrologist to derive site specific rainfall characteristics for the landfill under study. Operators should justify capping performance on the basis of a quantified calculation of infiltration. Such analysis would not generally be required for inert landfills.
- 3.5 However, more simplistic methods are available and based around making conservative estimates of some of the variables. Whatever method is used, the operator should justify their specific choice.
- 3.6 It is not appropriate to specify a low permeability layer in isolation of the overlying drainage system, as it is the composite performance of these two components that provides infiltration control in a cap. The basis of the design is that the low

permeability layer retains the infiltrating rainwater in the drainage layer in order that it can be carried away within drains for discharge beyond the landfill.



**Figure 3.1: Factors affecting infiltration through a cap**

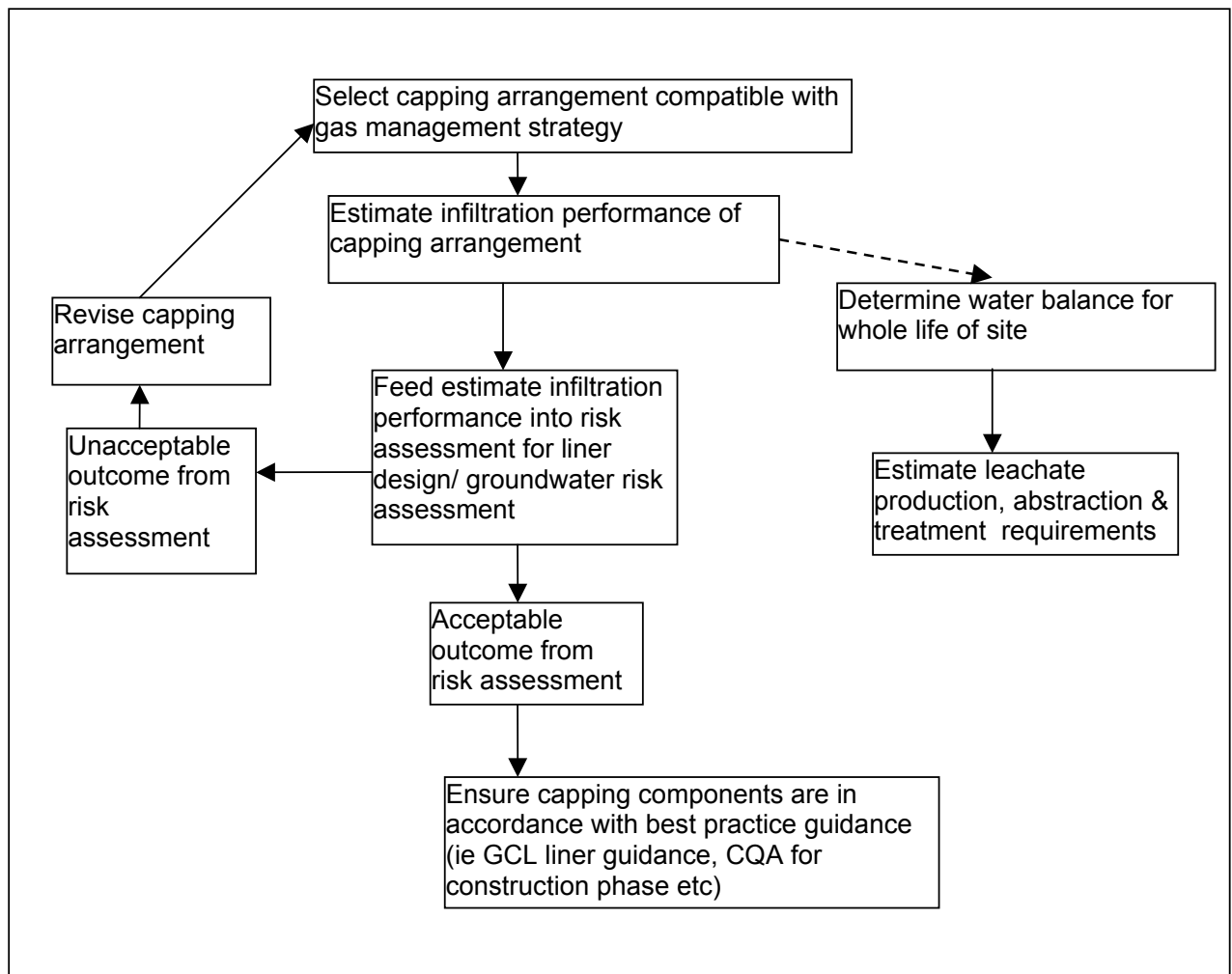
- 3.7 Ultimately, there will always be a degree of uncertainty over the estimated infiltration through a capping system. Modelling programs such as Landsim, allow this uncertainty of input parameters to be reflected in the model. As the infiltration rate is primarily the input into calculating the leachate generation at the site and hence leachate emissions from the site, it is advisable that the sensitivity to infiltration rate is investigated.
- 3.8 For example, reducing the infiltration rate into a contained landfill may serve to increase the polluting lifespan of the landfilled waste mass but reduce the rate of emissions from that site, and hence reduce the peak pollutant concentration. Conversely, by increasing the infiltration rate, the polluting lifespan of the site may be reduced but an increase in the rate of emissions from the site during that shorter period could occur.
- 3.9 In general, sites with gas abstraction (all non-hazardous sites and some hazardous sites) will require a Flexible Membrane cap using synthetic polyethylene materials (eg LLDPE, VLDPE, HDPE). Depending on the gas management system, this may require to be welded, to control air ingress into the gas abstraction system. Low permeability clay may be used in some circumstances but it is not as effective at controlling gas emission rates as a flexible membrane, but this does not preclude its use as a capping material.
- 3.10 The air/gas permeability of a clay will be several orders of magnitude higher than the permeability of that clay to water due to the difference in viscosity between air/gas and water. The rate of gas (or air intrusion) release through a clay cap will also be affected by other factors such as the degree of saturation of the clay

layer, atmospheric pressure changes etc. In addition, any surface cracking in the capping system due to differential settlement or desiccation effects, may become routes for emissions of gas. Ultimately, the choice of materials and arrangement will be determined on a site specific basis depending on the gas management proposals for the site.

- 3.11 A Flexible Membrane Cap will require to be constructed under a CQA regime in such a fashion that it is protected from puncture and can accommodate the anticipated settlements. This will require protection layers both above and below the liner. Where the membrane is being used to control gas emissions and/or air entry as part of a gas abstraction scheme, the resultant rainfall infiltration rates will be insignificant in the early years of the membrane. However, there is a balance to be struck when using membrane capping. By sealing the waste mass from infiltration the rate of decomposition reduces, as does the gas generation rate.
- 3.12 Without some compensatory water management (ie below cap recirculation) the active lifespan of the site will increase. If moisture addition to the waste mass ceases, biodegradation will tend not to occur. One potential long term effect from this, is that sites which are capped with a flexible membrane to exclude all water ingress and do not have a planned aftercare water balance, pose a potential long term environmental liability. Should the membrane fail in the long term (ie through settlement damage, environmental stress cracking, etc) and rain water infiltrates into dry waste, then biodegradation would recommence, along with associated gas and leachate emissions. This may happen many years or decades after closure and does not tie in with the concept of achieving completion within a generation (30 years)
- 3.13 Mineral liners on the other hand, allow a far greater infiltration rate from an early stage in the post closure phase and would be more suited for sites where compensatory leachate recirculation was not planned. However, mineral liners are not as effective in terms of gas management control.

#### 4.0 Method of approach

- 4.1 The principal points to be considered when establishing the appropriate standards for a cap are the control required over water infiltration and the control required for gas management.
- 4.2 The level of control over rainfall infiltration required at the site is to be established from a consideration of the whole life cycle of the site, with the cap being a component of the sites pollution control measures. This should be addressed by the operators in their proposals for the operation of the site. The cap performance should be considered as an integral part of the leachate management strategy for the site.
- 4.3 There is no set method of capping that can be universally applied to all landfill sites and each must be considered in light of the operational and post closure conditions. Similarly, the capping requirements may vary for one area of a landfill to another (for example to deal with different final slopes) and may differ depending on the stage of biodegradation of the waste.



**Figure 4.1: Steps in determining capping standards**

- 4.4 The steps shown in figure 4.1 should be followed when considering the appropriate standards for capping at landfills. This process should be carried out at the design stage of the site and in parallel with the groundwater risk assessment modelling. See SEPA guidance on 'Framework for Risk Assessment for Landfill Sites: The Geological Barrier, Mineral Layer and the Leachate Sealing and Drainage System'.
- 4.5 For new sites and existing sites applying for a PPC permit, the operator should present their justified proposals along with the application. The full capping and restoration proposals must be agreed at the permitting stage. The operator should provide details of the estimated infiltration characteristics of the cap for the whole life cycle of the site and be based on the resultant leachate generation and emissions to the environment.
- 4.6 For existing landfill sites closed or closing under the WML, the operator should present their proposals as part of a closure plan and estimate the infiltration characteristics of the cap and resultant leachate emissions.
- 4.7 Once the general arrangement of the cap has been decided, each component should be constructed in accordance with best practice. This involves consideration of many aspects, including CQA, installation, operation etc. This is not discussed here and guidance on this aspect is given in other more detailed Agency guidance on engineering of landfill liner systems. Including:
- Earthworks on landfill sites: Guidance on the design, construction and quality assurance.
  - The use of nuclear density gauges for compliance testing of earthworks on landfill.
  - Guidance on the use of geomembranes in landfill engineering.
  - Guidance on the geophysical testing of geomembranes for landfill engineering.
  - Guidance on nonwoven protector geotextiles for landfill engineering.
  - Guidance on bentonite enriched soils for landfill engineering.
  - Guidance on the use of geosynthetic clay liners in landfill engineering.
  - A methodology for cylinder testing of protectors for geomembranes