Department of Environment and Resource Management

Guideline

ERA 60—Waste disposal

Landfill siting, design, operation and rehabilitation

The guideline is focussed on siting criteria along with design and operational requirements for conventional landfill facilities that accept general waste and/or some regulated waste for co-disposal.

Table of contents

Department of Environment and Resource Management
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1.0 Scope

The guideline is focussed on siting criteria along with design and operational requirements for conventional landfill facilities that accept general waste and/or some regulated waste for co-disposal. It does not discuss the design and operation of regulated waste monofils (except for monocells within the existing landfill units), bioreactor landfills or pre-treated waste landfills.

The guideline focuses primarily on both putrescible and non-putrescible landfill facilities designed to accept more than 20,000 tonnes, but less than 75,000 tonnes per year of waste (medium size landfills). However, operators of smaller or larger landfill facilities can follow most of the guideline’s requirements. It is noted that some guideline requirements can not be applicable to smaller or non-putrescible landfill facilities. In contrast, additional guidance with respect to large putrescible landfill facilities in the coastal areas should be sought from the Department of Environment and Resource Management (DERM) operational policy *When will liners and gas collection be required for landfills?* ‘Conditioning assessment triggers’ which accompany this guideline contain guidance regarding modifications of streamlined conditions for smaller or larger facilities.

Environmental monitoring

Environmental monitoring requirements are included in the streamlined landfill development approval and not discussed herein. Technical guidance in these matters is also included in other relevant DERM guidelines.

Financial assurance

This financial assurance issue is also outside the scope of the guideline. The DERM operational policy *Circumstances for requiring financial assurance on a development approval* explains circumstances in which financial assurance is warranted.

2.0 Introduction

This guideline forms part of the ‘Streamlined landfill package’ for environmentally relevant activity (ERA) 60 – Waste disposal as defined in schedule 2 of the Environmental Protection Regulation 2008. Figure 1 depicts the licensing process flow diagram that shows the interaction between the streamlined development approval and other documents forming the package.

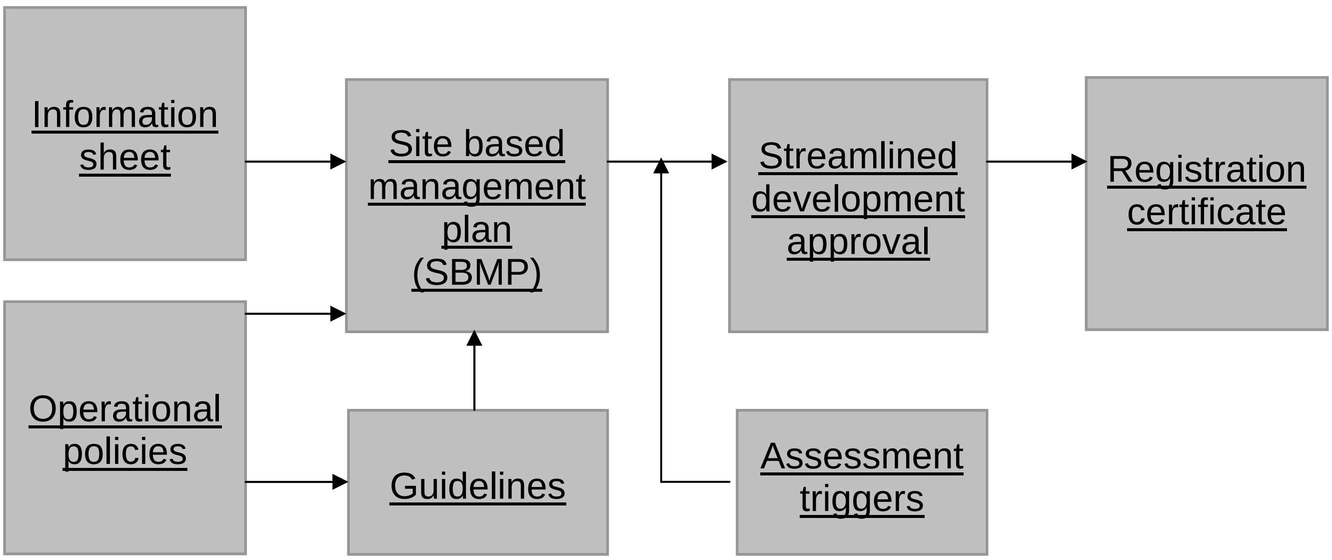


Figure 1: Licensing process flow diagram

This guideline was primarily developed for landfill operators including local government. When a contractor operates a landfill for the local government, the DERM operational policy *When should a contractor hold a registration certificate?* applies.

Further advice about the licensing requirements including how the existing landfill operators can convert their existing development approvals into the streamlined format can be obtained from the DERM licensing officers (see the information sheet *Contact details for environmental licensing - including Council areas* available on the DERM website <www.derm.qld.gov.au>).

2.1 Objectives

The primary and practical objectives of this guideline are to:

- provide technical information to assist applicants for a development approval for landfills to prepare a site based management plan (SBMP);
- provide direction, certainty, transparency and consistency of the standards required for landfill management in Queensland; and
- provide clarity on optional and not exhaustive acceptable solutions to environmental issues identified in the information sheet *Waste disposal – ERA 60* without impeding any future innovations in the landfill management.

This guideline does not provide guidance with respect to the general framework of SBMPs as this framework is outlined in the DERM guideline *Site based management plan (SBMP)*. The *Environmental Protection Act 1994* does not require that a SBMP submission be, or be part of, a certified environmental management system. Nevertheless, one way for an organisation with extensive operations or many sites to demonstrate that it can effectively manage all the environmental impacts of the activities would be to implement a certified environmental management system or equivalent.

Other objectives of this guideline are to:

- promote and encourage a focus on waste avoidance and minimisation and alternative waste management practices rather than landfilling;
- minimise the risk of environmental harm (including environmental nuisance) which may be caused when unsuitable sites have been selected or landfills are underdesigned or badly operated; and
- encourage rationalisation in the number of landfill facilities.

2.2 Waste hierarchy and principles

The assessment of any new application for a new landfill or extension of an existing landfill follows guidance provided in the DERM procedural guide *Assessing applications for waste disposal facilities* which addresses the waste management hierarchy and principles of the Environmental Protection (Waste Management) Policy 2000.

Landfilling is the least preferred option for the management of unwanted material. Every opportunity must be taken to avoid waste production and remove recyclable material from the waste stream before it arrives at the landfill. This is particularly so for wastes generated in significant volumes at a single site, such as construction and demolition waste from large projects.

Material presented at a landfill should be sorted either by the waste generator or at some intermediate facility such as a transfer station to remove and recover recyclable material prior to deposition in the landfill. Economies of scale may develop where a particular material can be stockpiled at a landfill over a period of time in sufficient quantities to make material recovery feasible. Segregated inert wastes may be monofilled for recovery in future when required.

Landfill alternatives such as waste pyrolysis, gasification, anaerobic digestion, composting or waste-to-energy projects are placed higher on the waste hierarchy. Options more superior to the conventional putrescible landfilling may also include mechanical-biological pre-treatment of waste before interring it in landfill and operation of a bioreactor landfill to recover energy from wastes.

The details of an investigation into alternative waste management practices must therefore be provided to support every application. The conditions of a development approval will also require implementing a waste management plan that addresses at least the following matters:

- waste management practices that will ensure that recyclables are diverted from landfill;
- procedures for identifying and implementing opportunities to improve the waste management practices employed including information and education packages for waste generators to assist in maximising the diversion of recyclable materials from landfill;
- details of any accredited management system employed, or planned to be employed, to implement the waste management practices;
- training programs and guidance for waste transport contractors in the identification and source separation of recyclable materials;
- procedures for auditing waste loads to identify material to be removed for recycling;
- how often the performance of the waste management practices will be assessed (at least annually);
- the indicators or other criteria, taking into account economic, social and environmental factors on which the performance of the waste management practices will be assessed;
- the recovery of energy from any methane collected in a landfill gas collection system; and
- annual reporting by 31 August each year any new measures adopted or materials newly diverted from landfill disposal.

Source, volumes and composition of all waste materials accepted at the landfill facility, recyclable materials recovered, fate of recyclable materials (e.g. transported off site for reuse/recycling, reused/recycled on site or stored on site), and calculated percentage diversion rates for the materials must be recorded by the landfill operator. These values must be included in a specified form to the administering authority by 31 August each year. Unless required otherwise, the annual report must have the following format:

- total amount of waste converted to useable energy;
- amount of green and organic waste collected and recycled;
- amount of green and organic waste disposed to landfill;
- amount of green and organic waste recovered for energy;
- amount of biosolids collected and recycled;
- amount of biosolids recovered for energy;
- amount of construction and demolition waste collected and recycled;
- amount of construction and demolition waste disposed to landfill;
- amount of commercial and industrial waste (including agricultural) recycled;
- amount of commercial and industrial waste (including agricultural) disposed to landfill;
- number of scrap tyres collected for recycling (Equivalent Passenger Units - EPUs);
- number of scrap tyres recovered for energy;
- amount of waste oil recycled;
- total amount of paper – white office, newsprint and mixed paper waste recycled;
- total amount of cardboard recycled;
- total amount of liquid paperboard recycled;

- total amount of glass containers recycled;
- total amount of PET recycled;
- total amount of HDPE, clear & opaque (dairy) recycled;
- total amount of HDPE, coloured recycled;
- total amount of PVC recycled;
- total amount of polypropylene recycled;
- total amount of mixed plastics recycled;
- total amount of other plastics (please specify) recycled;
- total amount of aluminium cans recycled;
- total amount of steel cans & tins recycled;
- other types and quantities of recyclables (please specify) recycled;
- amount of waste disposed to landfill;
- amount of domestic waste disposed to landfill; and
- total amount of landfill cover material used.

2.3 Acknowledgments

This guideline has been prepared by consideration of a number of landfill guidelines and codes of practice developed at the national level and interstate (see Section 5 – References).

Specifically, it is substantially reliant upon information contained in the DERM Victoria guideline *Best Practice Environmental Management: Siting, Design, Operation and Rehabilitation of Landfills*, Environment Protection Authority, Victoria 2010 <www.epa.vic.gov.au/waste/landfill.asp>. This information was current as at the date of publication; however, it may have been amended since this publication was published. Persons wishing to use this information should consult the DERM Victoria website at <www.epa.vic.gov.au> to obtain the current version of the information.

2.4 Definitions

air pollution dispersion model means a model that:

- is developed under the computer program 'AUSPLUME' or a similar program; and
- mathematically models the impact of releases of contaminants into the environment.

aquifer means a saturated permeable geologic unit that can transmit significant quantities of water under ordinary hydraulic gradients.

CAMBA means the China-Australia Migratory Bird Agreement. Information about wetlands protected under CAMBA can be obtained from www.ea.gov.au/water/wetlands/.

commercial place means a place used as an office or for business or commercial purposes.

corrosive material means a material which on dissolution exhibit a pH of 2 or less or 12.5 or greater.

design standard for odour means the odour concentration at any odour sensitive place calculated using an air pollution dispersion model which is:

- 1.0 OU (determined as per the Australian and New Zealand Standard AS/NZS 4323.3:2001) expressed as a three minute average and 99.5 percentile; or
- equivalent to the intensity level of "weak".

double lined landfill means a landfill designed to a standard (or equivalent) outlined in the DERM operational policy *When will liners and gas collection be required for landfills?*

dust sensitive place means:

- a dwelling, mobile home or caravan park, residential marina or other residential place;
- a motel, hotel or hostel;
- a kindergarten, school, university or other educational institution;
- a medical centre or hospital;
- a protected area;
- a park or gardens; or
- a place used as an office or for business or commercial purposes.

and includes the curtilage of any such place.

dwelling means any of the following structures or vehicles that are principally used as a residence:

- a house, unit, motel, nursing home or other building or part of a building;
- a caravan, mobile home or other vehicle or structure on land; or
- a water craft in a marina.

equivalent passenger tyre unit (EPU) means a unit which allows for the following conversions:

- passenger tyre 1 EPU (9.5kg);
- light and medium commercials 2 EPU (19kg);
- truck and bus tyres 5 EPU (47.5kg);
- earthmoving and agricultural 50 EPU (475kg); and
- large earthmoving 100 EPU (950)kg.

general waste means waste other than regulated waste.

ignitable material means a material that is capable of causing a fire when ignited through friction, absorption of moisture, or spontaneous chemical changes under standard temperature and pressure.

JAMBA means the Japan-Australia Migratory Bird Agreements. Information about wetlands protected under JAMBA can be obtained from www.ea.gov.au/water/wetlands/.

landfill facility means all contiguous land and structures, other appurtenances, and improvements on the land used or associated with the disposal of waste.

landfill unit means a discrete area of land or an excavation that receives solid waste.

leachate means a liquid that has or is likely to have percolated through or emerged from waste, and which contains soluble, suspended or miscible materials derived from such waste or decomposition of such waste.

limited regulated waste means any of the following regulated wastes: animal effluent and residues, including abattoir effluent and poultry and fish processing waste, asbestos, food processing waste, quarantine waste that has been rendered non-infectious, sewage sludge or residue produced in carrying out an activity to which schedule 2, section 63 applies (ERA 63 Sewage treatment under schedule 2 of the Environmental Protection Regulation 2008)**,** treated clinical waste, or tyres.

liquid or semi-liquid waste means a waste which failed the paint filter liquid test described in the document *SW-846 Test Methods for Evaluation of Solid Wastes Physical/Chemical Methods* published by the United States Environmental Protection Agency, Revision 6, February 2007 or updated version thereof (e.g. published by the United States Environmental Protection Agency <www.epa.gov/epawaste/hazard/testmethods/index.htm>.

lower explosive limit means the lowest percent by volume of a mixture of explosive gases in air that will propagate a flame at 25°C and atmospheric pressure.

noise sensitive place means:

- a dwelling, mobile home or caravan park, residential marina or other residential premises; or

- a motel, hotel or hostel; or
- a kindergarten, school, university or other educational institution; or
  - a medical centre or hospital; or
  - a protected area; or
  - a park or gardens;

and includes the curtilage of such place.

noise affected premises means a "noise sensitive place" or a "commercial place".

non-putrescible waste landfill means categorised as ERA 60(b) (schedule 2 of the Environmental Protection Regulation 2008) accepting waste containing 5 percent or less of putrescible waste component (i.e. a commercial and industrial waste landfill or construction and a demolition waste landfill).

odour sensitive place has the same meaning as a 'dust sensitive place'.

public health problem means an adverse effect or likely adverse effect on the health of any person(s) which results from the carrying out of the environmentally relevant activity and includes transmission of disease(s), and breeding and/or harbourage of flies, mosquitoes, rodents and other pests.

putrescible waste means waste food or waste animal matter (including dead animals and animal parts), or unstable or untreated bacterial (sewage) sludge, and includes any mixtures of such wastes.

putrescible waste landfill means a landfill categorised as ERA 60(a) or 60(b) (schedule 2 of the *Environmental Protection Regulation 1998)* accepting waste containing more than 1 percent of putrescible waste component.

RAMSAR means the Convention on Wetlands, signed in Ramsar, Iran in 1971, dedicated to the conservation and "wise use" of wetlands. Information about wetlands protected under RAMSAR can be obtained from <www.environment.gov.au/water/topics/wetlands/database/index.html>

reactive material means a material that has any of the following properties:

- react violently with water; and/or
- form potentially explosive mixtures with water and other substances likely to be disposed of in the landfill facility; and/or
- generate toxic gases, vapours, or fumes dangerous to human health or the environment when mixed with water and other substances likely to be disposed of in the landfill facility; and/or
- contain substances which generate toxic gases, vapours or fumes when exposed to pH conditions between 2 and 12.5; and/or
- are capable of detonation or explosive reaction when subjected to a strong initiating source or if heated under confinement; and/or are readily capable of detonation or explosive decomposition or reaction at standard temperature and pressure.

regulated waste means non-domestic waste mentioned in Schedule 7 of the Environmental Protection Regulation 2008 (whether or not it has been treated or immobilised), and includes:

- for an element – any chemical compound containing the element; and
- anything that has contained a regulated waste.

special burial of waste means a disposal method where earth moving equipment pushes the wastes to the bottom of the working face or into an excavated hole, and immediately covers it with earth or other waste material.

toxicity characteristic leaching procedure (TCLP) means the test described in the document SW-846 *Test Methods for Evaluation of Solid Wastes Physical/Chemical Methods* published by the United States

Environmental Protection Agency, Revision 6, February 2007 or updated version thereof <www.environment.gov.au/water/topics/wetlands/database/index.html>.

toxic material means:

- cytotoxic wastes;
- drugs and poisons as cited in the Standards for Uniform Scheduling of Drugs and Poisons (Schedules 8 and 9 drugs as per the Health (Drugs and Poisons) Regulation 1996); and
- any other material that:
  - has contaminant concentrations in the waste exceeding the allowable levels in table 1 of Appendix A; or
  - has leaching contaminant levels in the waste when measured in accordance with toxicity characteristic leaching procedure (TCLP), exceeding the concentrations prescribed in table 2 of Appendix A.

upper explosive limit means the highest percent by volume of a mixture of explosive gases in air that will propagate a flame at 25^{o}C and atmospheric pressure.

3.0 Landfill siting criteria

An investigation of the sites that have the best potential for landfilling should be conducted in two steps:

- a broad approach to identify all potential sites for new facilities from a broader group of all possible sites; and
- a ranking of the potential sites in terms of their preference for use as a landfill.

The hierarchy of aspects to be considered when screening for potential landfill sites is:

1. community needs and expectations;
2. landfill type and ancillary activities;
3. adjacent existing and future land uses;
4. groundwater resources;
5. surface water system;
6. biodiversity;
7. external infrastructure; and
8. geological setting.

3.1 Community needs and expectations

A landfill should not be located where it is not needed for the disposal of a community's waste.

It is also important to liaise with the community in the assessment process, as this enables early identification of the issues that are important to the local community and environment, and as a result, has a significant influence on the siting, design and operation of the landfill.

3.2 Landfill type and ancillary activities

The hierarchy of preference of four landfill types is as follows:

1. the ‘area method’ where an existing hole such as a former quarry is filled;
2. the ‘trench-and-fill method’ where a hole is dug and back filled with waste using the excavated material as cover;
3. the ‘mound method’ where most of the landfill is located above the natural ground level; and
4. the ‘valley or change of topography fill method’ where a natural depression is filled.

Ancillary activities (e.g. composting of organic waste) should also be identified and their impacts fully assessed as they can have a more significant effect than the landfill itself.

3.3 Adjacent existing and future land uses

Adjacent existing and future land uses should be investigated to identify sensitive areas and other protected activities that are likely to be adversely impacted by the landfill operations.

To protect sensitive areas from any impacts resulting from routine and non-routine operating conditions, such as offensive odours, noise, litter and dust, an adequate separation (buffer) distance should be maintained between the landfill and incompatible land uses.

A buffer area is not an alternative to adopting management practices recommended in this guideline, but provides for contingencies that may arise with typical management practices. Where this buffer is not available, management practices need to be significantly increased to provide the same level of protection. However, it is unlikely that the landfills can be managed with the minimal adverse impacts if the buffer distances are inadequate. Table 1 shows indicative buffer distances.

Table 1: Indicative buffer distances

Landfill type	Recommended buffer distances
Putrescible landfill	100 metres from surface waters and the ‘100 year flood plain’; 500 metres from a noise, dust or odour sensitive place; 100 metres from an unstable area; 1,500 metres from an aerodrome for piston-engined propeller-driven aircraft; and 3,000 metres from an aerodrome for jet aircraft.
Non-putrescible landfills	100 metres from surface waters and the ‘100 year flood plain’; 200 metres from a noise or dust sensitive place; 100 metres from an unstable area; 1,500 metres from an aerodrome for piston-engined propeller-driven aircraft; and 3,000 metres from an aerodrome for jet aircraft.

Reduction of the indicative buffer distances is only possible if it is demonstrated to DERM that sensitive areas and other protected activities will not be adversely impacted by the landfill operations.

3.4 Groundwater resources

Landfills should be sited in areas where impacts on water quality objectives of groundwater will not be compromised. In particular, landfills should not be located:

- in areas of potable groundwater, groundwater recharge areas or in Proclaimed Sub-Artesian Districts established under the *Water Act 2000*; and
- below the regional watertable.

Landfills below the regional watertable are generally not recommended due to an increased risk of groundwater contamination and perpetual requirement to:

- maintain and operate pumps;
- manage an increased volume of groundwater or leachate; and
- intensively monitor both groundwater and leachate quality and levels.

The most preferred site for a landfill is a site that provides a natural unsaturated attenuation layer beneath the liner for contaminants that may leach through the liner to the aquifer. This means that sites with naturally attenuating soils, such as sites in clayey areas, are preferred to those that do not have such soils, such as sites in sandy areas. Recommended minimum thicknesses of attenuation zones in relation to the highest seasonal watertable at the site are tabulated in table 2.

Table 2: Minimum thicknesses of unsaturated attenuation zones

Landfill type	Minimum thickness of attenuation zone (metres)
Putrescible landfills	2
Non-putrescible landfills	0
Fill material, potential waste acid sulfate soil or separated non-putrescible (inert) parts of construction and demolition waste	Below watertable

The recommended thicknesses should be increased if unconfined aquifers bear water suitable for potable purposes or irrigation, or discharge to sensitive surface waters. They can only be reduced if it is demonstrated to DERM that the receiving environment will not be adversely impacted by the landfill operations.

3.5 Surface water system

Landfilling should not occur:

- in wetlands protected under RAMSAR, JAMBA and CAMBA treaties;
- in control districts declared under the *Coastal Protection and Management Act 1995*;
- in water supply catchments; and
- within 100 metres of surface waters or the ‘100 year flood plain’.

3.6 Biodiversity

The development of landfills may impact on the biodiversity of the local area. The potential impacts on biodiversity can include:

- clearing of vegetation;
- loss of habitat and displacement of fauna;
- loss of biodiversity by impacts on rare or endangered flora and fauna;
- potential for spreading plant diseases and noxious weeds;
- litter from the landfill detrimentally impacting on flora and fauna;
- creation of new habitats for scavenger and predatory species;
- erosion; and
- alteration of watercourses.

In particular, landfilling should not be carried out in:

- protected areas or areas identified under conservation plans and critical habitats, whether or not special management considerations and protection are required, under the *Nature Conservation Act 1992;* and
- areas where landfilling is likely to have a significant impact on threatened species and ecological communities as identified in the *Environment Protection and Biodiversity Conservation Act 1999*, except with the approval of the Commonwealth Environment Minister.

3.7 External infrastructure

Local infrastructure must be able to sustain the operation of a landfill. The capacity of the road network to cope safely with increased traffic and with a minimum of disturbance to the local community should be assessed.

The preferred transportation route should minimise the transport of waste through residential and other sensitive areas. This consideration may influence the placement of the entrance to the landfill.

A transportation study may reveal the need for additional road infrastructure such as interchanges, turning lanes or signals. The availability of services such as reticulated water, sewerage and power will influence the facilities provided for staff at the landfill and perhaps indicate a need to provide additional services, such as water storage for fire-fighting purposes.

3.8 Geological setting

Landfills should be constructed in geologically stable areas to ensure the long-term integrity of the landfill capping and liner systems over the life and post-closure care period.

Sites within 100 metres of a fault line displaced in the Holocene period should be avoided to ensure the long-term earthquake protection. The land should also be capable of supporting the landfill, with or without engineering assistance. Landfills other than landfills in former quarries, should not therefore be sited in areas with slopes greater than 10 percent. In the underground mining areas, the landfill site should not be prone to subsidence. Karst regions, characterised by sinkholes, caves and possibly large water springs, are generally unsuitable for siting landfills.

The mineralogy of the area should also be considered. In particular, the shrink/swell characteristics of the landfill substrate should be assessed to minimise the potential for differential movement of the liner resulting from changes in the moisture content of the substrate. The suitability of the local material for liner construction should also be assessed.

4.0 Activity specific environmental assessment

A comprehensive environmental assessment of the preferred site is required to gain a thorough understanding of the receiving environment. This assessment must examine the impact of the landfill on the air, water, land and noise environments and suggest relevant waste management and environmental management practices (see the information sheet *Waste disposal – ERA 60* for information to be addressed in this assessment and provided with application). If, following an environmental assessment, the site is identified as unsuitable for a landfill, then the proposal should not proceed any further.

4.1 Air issues

Landfill facilities pose a risk to air quality through landfill gas comprising methane, other hazardous and odorous compounds and dust. The objectives for air quality management at a landfill are to minimise:

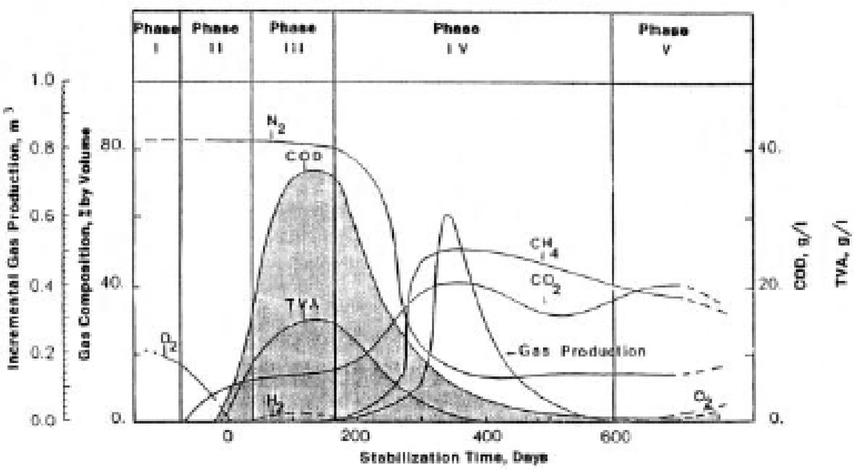
- the release of noxious or offensive odours;
- the potential for global warming and the risk of the landfill gas subsurface migration and accumulation; and
- the release of dust and particulate matter causing nuisance and health impact.

With the exception of pit burning of vegetation, open burning of waste is not supported. Pit burning of vegetation constitutes ERA 61 (threshold 1) and requires a development approval and registration certificate. Therefore, air emission from waste burning is outside the scope of this guideline.

4.1.1. Odour management

Landfill odour is a key consideration in deciding whether a putrescible landfill will adversely impact on odour sensitive places. It also affects the design and operation of the site. At all times, the landfill must be managed to prevent offensive or noxious odours being released beyond the boundary of the landfill facility. For these reasons, every new putrescible landfill or an extension of an existing landfill that is likely to impact on odour sensitive places must be assessed for compliance with the DERM 'design standard for odour' (see Section 2.4 – Definitions).

The landfill stabilisation phases decide the type and intensity of landfill odours. These phases are shown in figure 2.



Phase I aerobic; phase II anaerobic, non methanogenic; phase III anaerobic, development of methane; phase IV anaerobic, steady methane; phase V recovery

Figure 2: Landfill stabilisation phases

Three types of odour characters can typically be distinguished at the putrescible landfill that are associated with these phases:

1. a harsh, sour, high intensity, highly offensive odour deriving from 'fresh' waste as delivered to landfill and evident in trucks moving on and off site (Phase I gas releases from specific waste types (e.g. ammonia from poultry manure) and some Phase II odours);
2. a sharp acetic odour with overtones of 'fresh' waste odour, deriving from waste exposed in wheel ruts or decaying in moist cover and from the leachate side wall drainage layer (Phases II and III). Ketones, esters, volatile fatty acids, hydrogen sulphide and mercaptans are released in this phase. Phase III is the primary source of odours at the landfill; and
3. a low intensity musty odour of methanogenically degrading waste (Phases IV and V).

Type 1 and 2 odours can be reduced by practices and procedures outlined in this section. When the methanogenic phase commences, odours can be managed more effectively by landfill gas collection and flaring or reuse (see Section 4.1.2 – Landfill gas). Despite the fact that odours from this phase are of lower intensity, landfill gas purges strong odours from fresher wastes.

Bin odour mitigation

Bin odour can only be effectively reduced by:

- increasing the frequency of collection;
- reducing the bin size so that they are regularly collected;
- reducing the load of putrescible material sent for waste disposal by stimulating home composting schemes;
- by requiring residents to use deodorants in their bins; or
- keeping bins in cool places.

The use of plastic bin liners and wrapped putrescible garbage reduces waste odours in the bin, but the same odours emerge either in the compactor trucks, at the transfer station, or at the active face where the bags and wrapping are penetrated.

Working face operation

The odour generated on receipt can be minimised by:

- keeping the working face small;
- covering the waste as quickly as possible;
- using effective odour suppressant chemicals; and
- using odour suppressant cover materials.

A number of odour suppressants can be effective if applied correctly. Alternative cover materials (e.g. plastic and acrylic foams) can also reduce the odour releases. Various mixtures of mulched woody material and earth in layers up to 300mm thick can be very effective as a biofilter and also produce an appropriate trafficable surface.

With respect to the opening of the landfill window at the active face, the odours emerging can only be reduced by:

- avoiding the need for opening the window; or
- reducing the landfill gas pressure by gas interception systems.

If the window needs to be opened, the material exposed should be covered with fresh waste forthwith.

Landfill gas condensate should not spray irrigated water at the working face.

Cell size

Odour release is largely a function of the surface area emitting the odour. If the uncovered area of waste can be reduced, odour will be reduced commensurately.

The area required for operation at any time is that required by the compactors to achieve efficient compaction. The area of uncovered waste can therefore be reduced to a smaller size if the compacted daily lift height was reduced and if the waste was compacted in sections and covered progressively rather than only at the end of the day.

Waste coverage

Intermediate cover is to ensure:

- the continued encapsulation of the previously buried waste;
- the diffuse dispersion of landfill gas;
- the minimisation of rainfall infiltration; and
- reasonably efficient seal to allow efficient gas interception operation.

To be effective, at least 300mm of compacted low permeability soil should be placed upon any area of waste not subject to active waste placement for over three months. When spreading cover, methods that will not expose old waste should be used.

Both final and intermediate cover should be regularly inspected to identify areas where surface cracking is evident. Where surface cracking is a problem, the area should be consolidated by moistening the cover and consolidating it using a roller to close any cracks that have formed.

The visual inspection should also be accompanied by surface landfill gas monitoring. This is to ensure that the release of methane does not exceed 500 parts per million at a height of 50mm above the final and intermediate cover surface including the batter slopes of the landfill unit.

Ponding of water or leachate on the cover surfaces should be prevented.

Waste truck handling

Unemptied trucks should not ever be parked at the landfill site. Emptied trucks should be regularly cleared of all remnant garbage, washed and deodorised.

An area of each subcell section subject to active filling should be compacted and prepared as a turning area. The waste units should be able to reverse from this site to the edge of the tipping area in a straight line along similarly prepared material. This is to avoid exposure and ‘pumping’ of the waste into the cover. Preparing the turning circle using a mulched woody material layer can also improve trafficability in these areas.

An area for waste disposal in wet weather should also be provided at which load bearing material is used to avoid exposing waste from heavy vehicle movement.

4.1.2. Landfill gas

During the anaerobic methanogenic phase (phase IV), non-odorous methane and carbon dioxide, both greenhouse gases, are the major constituents of the gas produced. This emission sweeps odorous gases deriving from the acetogenic phase in the upper layers of the landfill unit along with non-methane volatile organic compounds (NMVOC) that can impact on human health and contribute to smog formation. The significant production of methane starts after 3 -15 months of the waste deposition and continues for in excess of 15 years.

The rate of emissions from a landfill is governed by gas production and transport mechanisms.

An estimate of the methane generation rate from a typical landfill can be made using the USEPA landfill air emissions estimation model (LandGEM) from www.epa.gov/oar/oaqps/landfill.html.

The migration of landfill gas may constitute an environmental and safety risk. Methane is explosive when present in the range of five percent (lower explosive limit, LEL) to 15 percent (upper explosive limit, UEL) by volume in air. Gravel or sand layers, or even man-made drains, provide ideal migration routes for landfill gas, particularly after the site is capped. Methane concentrations must not exceed:

- 25 percent of the LEL when measured in facility structures (but excluding facility structures used for landfill gas control and landfill gas recovery system components); and
- the LEL at the landfill facility boundary.

Landfill gas collection systems

All putrescible landfills with the annual disposal rate exceeding 20,000 tonnes must have a passive (venting) or active collection system installed. A passive system relies upon the pressure difference between atmospheric pressure and the pressure of the landfill gas. In the active collection system gas is drawn off under a vacuum.

Non-putrescible waste landfills may require a passive venting system if larger landfills are located very close to residencies or at environmentally sensitive locations, or when landfill gas is found or suspected to be migrating off-site at unacceptable levels.

For a passive gas system, wells need to be spaced not more than 20 to 30 metres apart, whereas for an active system wells may be up to 50 metres apart. In both cases, the cessation of extraction of landfill gas while the gas is being generated may cause offensive odours beyond the site boundary, so auxiliary systems need to be installed to maintain continuous extraction in the event that the main extraction system fails. The use of zeolite or activated carbon filters may assists in the odour control.

Where landfill gas is to be actively collected, gas wells may be vertical or horizontal.

Vertical gas wells are typically installed after the filling of a landfill. They are 300mm in diameter and are drilled into the waste. A pipe, perforated for all but the top three to five metres, collects the gas. Leaving the top section of the pipe unperforated minimises air being drawn into the pipe, as does maintaining a good quality cap and installing a barrier about the well (such as a geomembrane extending radially from the gas well). After inserting the collection pipe, the space between the pipe and the outer wall of the hole is back-filled with coarse crushed rock, with clay or bentonite sealing the top few metres. Wells extend down to near the base of the landfill or to above the watertable, whichever is closer to the surface.

Horizontal wells can not be installed unless sufficient waste has been placed over the top of the pipe and gas can be extracted without too much air being drawn into the system. A typical depth of waste required for effective gas collection is five metres.

If a landfill does not have a landfill gas venting or an extraction system, the design and maintenance of a landfill cap can assist in reducing methane emission. Methane-oxidising bacteria in the soil of the landfill cap can oxidise methane in landfill gas migrating through the cap. The degree of methane oxidation is a function of the time it takes the gas to migrate through the cap; the longer it takes to pass through the capping system, the greater the degree of oxidation.

The oxidation process can be enhanced by the maintenance of the capping system to prevent it from cracking and the addition of mulched green waste material above the low permeability liner.

Landfill gas flaring or collection for power generation

Landfill gas should be flared or used for power generation if NMVOC emission exceeds 50 tonnes (Mg) per year. The NMVOC emission can also be estimated with LandGEM. Default values used for Australian landfills are the methane generation decay rate, k=0.058/yr, and potential methane generation capacity of waste, L_o =79m^3/tonne. If certain sections of a putrescible landfill contain, or the landfill accepted, a significant proportion of non-biodegradable waste, this amount of waste can be subtracted from the landfill capacity and/or landfill disposal rate.

Figure 3 illustrates a case study for a putrescible waste landfill having a capacity of 600,000 tonnes and annual disposal rate of 40,000 tonnes that commenced operation in 2001. The NMVOC emission was estimated using LandGEM. In this case, landfill gas flaring or collection for use is recommended no later than after 14 years of the landfill operation. It is worthwhile noting that if the landfill considered in this case study had a slightly smaller disposal rate, it would not be required to introduce gas flaring or collection for use.

If flaring or collection for reuse is impractical, at least, a site-specific screening risk assessment should be carried out for NMVOC estimated with LANDGEM. A simple risk assessment spreadsheet is downloadable from www.state.ma.us/dep/ors/files/pswf-sf.xls and can assist in this assessment.

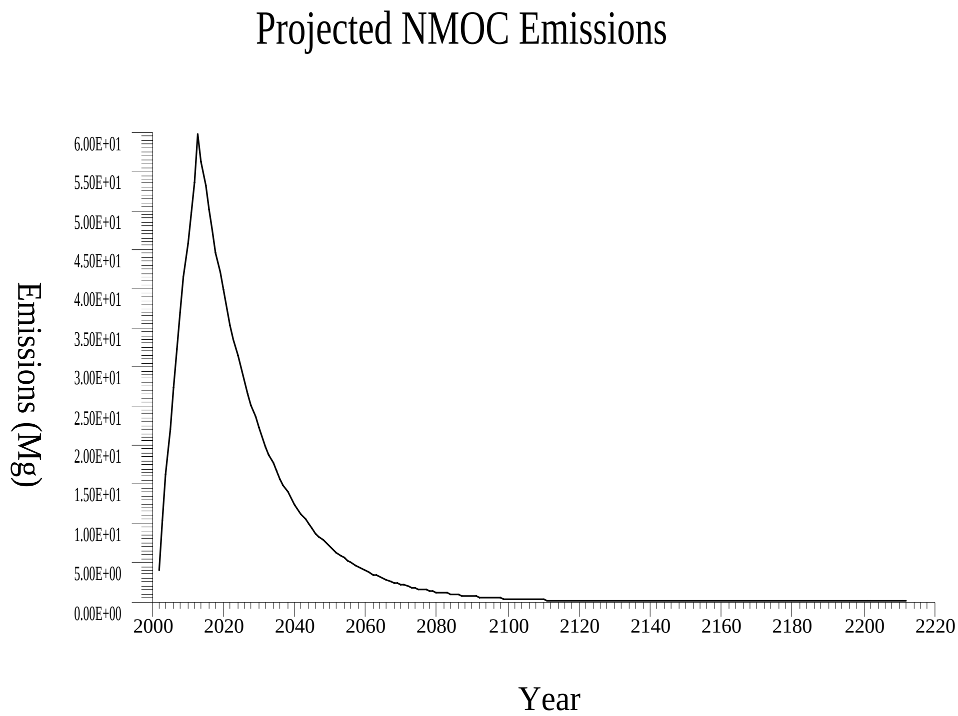


Figure 3: The projected NMVOC emission for a putrescible waste landfill having a capacity of 600,000 tonnes and annual disposal rate of 40,000 tonnes

Where landfill gas is to be flared, the landfill gas flares should be designed to reduce emissions of NMVOC by 98 percent. In addition, the flare should be fitted with auto ignition to ensure that it ignites upon the build-up of gas, and has a flame arrestor beneath the combustion zone to prevent the combustion of the landfill itself.

Larger flares or on-site power stations may require separate development approvals for the carrying out of ERA 15 (Fuel burning).

4.1.3. Dust and particulate matter emissions

Any large area where the land has been disturbed and is subject to vehicular traffic has the capacity to generate dust and particulate matter. Other potential sources are earthen material stockpiles (e.g. coverage material) and the delivery of dusty loads of waste.

The magnitude of the impact will depend on the:

- type and size of the operation;
- prevailing wind speed and direction;
- location of dust sensitive places;
- occurrence of natural and/or constructed wind breaks; and
- wind-abatement measures or buffers.

Dust mitigation measures can include the following:

- minimising the area of land disturbed at any one time;
- revegetation of disturbed areas;
- restricting access to areas awaiting rehabilitation or being rehabilitated by suitable barriers to prevent disturbance of these areas;
- avoiding movement and/or handling dusty waste and earthen materials on windy days;
- maintaining any earthen material stockpiles to minimise wind-blown emissions to the atmosphere from these sources by minimisation of stockpile sizes, enclosures, wind breaks, tarping or watering (or treating with a chemical dust suppressant);
- minimising dust generating surfaces by sealing roads;
- minimising dust arising from sealed trafficable areas by regularly sweeping and/or watering (or treating with a chemical dust suppressant) these areas; and
- watering (or treating with a chemical dust suppressant) any unsealed roadways whether used on a temporary or permanent basis and including roadways used for haulage of waste and/or earthen materials.

Leachate, landfill gas condensate and waste oil (see also the DERM operational policy *The use of waste oil*) must not be used for dust suppression.

4.2 Water issues

Water management practices must address the waste evaluation procedure of the *Environmental Protection (Water) Policy 1997* (waste prevention and recycling options are the most desirable; waste treatment and disposal the least desirable). The practices must therefore prevent water contamination in the first instance. This can be attained by:

- prevention of disposal of waste into surface and groundwater; and
- separate management of the following water streams with the intention of minimising the volumes to be managed and avoiding mixing these water streams:
  - leachate and contaminated runoff;
  - clean and sediment laden stormwater; and
  - groundwater.

4.2.1. Leachate and contaminated water runoff

A leachate management system must be installed for all medium size putrescible and non-putrescible landfills with the exception of fill material, potential waste acid sulfate soil (below groundwater table) or separated non-putrescible (inert) parts of construction and demolition waste. This system should include a liner system and a leachate collection system to reduce hydraulic head of leachate over the liner system.

The primary function of a liner system is to protect groundwater from impacts of leachate by reducing the vertical seepage of leachate and facilitating its collection and removal by the leachate collection system. The liner may also attenuate leachate constituents to the point where the leachate that makes contact with the aquifer beneath the landfill has minimal adverse impact on groundwater. A further function of the liner is to retard the lateral movement of landfill gas from the landfill and the infiltration of groundwater.

The design objective of the liner and leachate collection system is to protect water quality objectives of groundwaters. An attenuation zone is permitted, but it can only extend 150 metres from the landfill unit or the boundary of the landfill facility, whichever is the closer.

For most locations, a simple earthen liner consisting of a prepared sub-base, compacted clay layer and leachate drainage layer is sufficient. The landfill performance is affected by the clay liner thickness and hydraulic conductivity and leachate hydraulic head over the liner.

Leachate management systems should at least have a performance capability equivalent to the performance capability of the following system:

- a clay layer of at least 600mm thickness, placed in at least two lifts on a prepared sub-base, achieving a maximum permeability of not greater than 1×10^{-9} m/s; and
- a leachate collection system incorporating a drainage layer capable of maintaining the level of leachate over the uppermost layer in the liner at not greater than 300mm.

The sub-base and clay liner construction should be accompanied by level 1 geotechnical testing as set out in Appendix B of AS 3798-1996 *Guidelines on earthworks for commercial and residential developments*.

The recommended minimum requirements for a liner system are illustrated in figure 4.

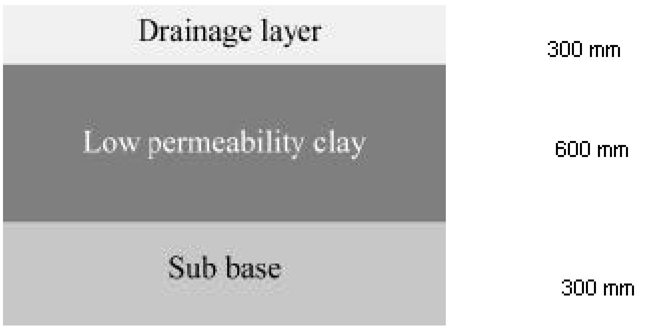


Figure 4: The recommended minimum liner requirements

A thicker clay liner or even a double liner system (or their equivalent) outlined in the DERM operational policy *When will liners and gas collection be required for landfills?* should be considered for putrescible landfills at sensitive locations. The design of a landfill unit to the double liner standard will also allow for acceptance of more contaminated regulated wastes (see Section 4.4.1 – Waste acceptance criteria).

Sub-base

The performance of the landfill liner and leachate collection system is dependent on the integrity of the sub-base. The sub-base should be well-consolidated, with minimal settlement to provide a firm platform for the compaction of the clay layer and to ensure that the drainage system effectively collects leachate throughout the life of the landfill. The sub-base should also have the ability to further attenuate leachate constituents.

Where the sub-base is undisturbed material (rock or soil) at the base of a quarry, it is likely to be well-consolidated. Where the sub-base has been installed prior to the liner and leachate collection system, it needs to be installed in such a manner that it is geotechnically stable. Therefore, it should be placed and compacted in thin layers.

If inert waste is used as a sub-base, it should be limited to crushed and compacted hardfill material (clean rock, soil, concrete or masonry material).

Clay layer

The ability of clay to retard water movement and absorb exchangeable cations makes it a suitable natural construction material for a low-permeability liner.

In the assessment of suitability of soil as a low-permeability liner, soil properties such as particle size distribution and plasticity (described by the soil plasticity index) and cation exchange capacity should be determined. Another factor that also needs to be considered is the potential for desiccation and subsequent cracking.

Clay used for the liner construction should have the following properties:

- no rock or soil clumps greater than 50mm in any dimension;
- > 70 per cent passing through a 75mm sieve;
- > 30 per cent passing through a 19mm sieve;
- > 15 per cent passing through a 2mm sieve;
- soil plasticity index > 10;
- CEC > 10 mEq/100g; and
- minimal long-term degradation with exposure to leachate.

The minimum test frequencies are:

- properties of the clay (grain size distribution, plasticity index and moisture content) tested once every 5,000 m^3;
- plasticity index and moisture content, tested once every 5,000 m^3; and
- field testing for liner density and moisture content at a frequency the greater of:
  - 1 test per 500 m^3 of soil;
  - 1 test per 2,500 m^2 area per clay lift; or
  - 3 tests per site visit.

In addition to this physical testing, visual inspections should check for the presence of oversized clods of clay, poorly compacted or dry areas and the homogeneity of the clay.

Clay used for the liner construction should also be tested to ensure that the hydraulic conductivity of the liner is less than 1×10^{-9} m/s using both fresh water and 50,000 ppm NaCl solution according to Australian Standard AS 1289.6.7.1–2001: Methods of testing soils for engineering purposes – *Soil strength and consolidation tests – Determination of permeability of a soil – Constant head method for a remoulded specimen*.

During the installation of the clay liner, hydraulic conductivity can also be assessed by testing dry density and moisture content. The results of this testing are then compared with the required zone for dry density and moisture content necessary to ensure that the clay meets the specified hydraulic conductivity.

Figure 5 shows the effect of moulding water content (moisture content of the clay when compacted) and the dry density of the clay (dry unit weight).

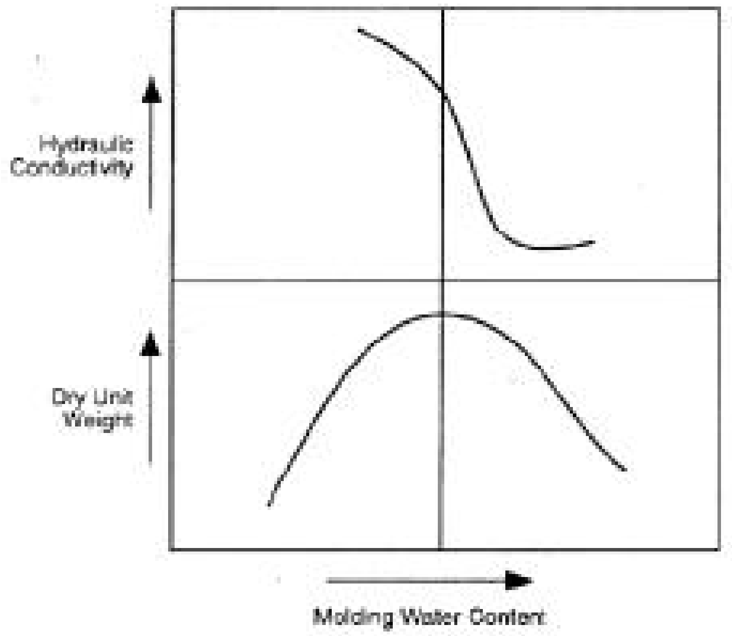


Figure 5: The effect of moulding water content (moisture content of the clay when compacted) and the dry density of the clay (dry unit weight).

Maximum dry density is achieved at the optimum moisture content. The lowest hydraulic conductivity of the compacted clay liner is achieved when the soil is compacted at a moisture content slightly higher than the optimum moisture content.

By specifying compaction to be undertaken at a percentage above optimum moisture content to achieve a density defined as a percentage of maximum dry density, an envelope or ‘acceptable zone’ of performance criteria can be derived for undertaking quality control checks in the field both during and after construction. Best practice is to compact the clay at about two to three per cent wet of optimum moisture content to a maximum dry density of 95 to 98 per cent of Proctor Standard.

To achieve bonding between each lift, the thickness of each lift should permit the compaction equipment (e.g. a sheepsfoot roller) to penetrate the top lift and knead the previous lift. To improve bonding, scarification of the previous lift may also be required.

Bonding is required to overcome the effects of the imperfections within individual lifts. A further factor is the thickness of the liner and the number of lifts used, with a greater number of lifts and greater total thickness minimising the probability that preferential flowpaths will align.

Following field compaction work, direct permeability testing in the laboratory and/or in the field should be undertaken on undisturbed clay liner samples.

The final surface of a compacted clay liner should be finished to a smooth surface. This promotes the rapid drainage of leachate on top of the liner and minimises the surface area of the liner thereby reducing the loss of moisture from the liner.

Leachate collection system

The design objectives of the leachate collection system are to ensure that it is:

- able to drain leachate such that the leachate head above the liner is minimised;
- appropriately sized to collect the estimated volume of leachate (predicted by water balance models);
- resistant to chemical attack, and physical, chemical and biological clogging;
- able to withstand the weight of waste and the compaction equipment without crushing; and
- able to be inspected and cleaned by readily available video inspection and pipe-cleaning equipment.

A leachate collection system typically comprises a high permeability drainage layer, perforated collection pipes, a sump where collected leachate is extracted from the landfill and geotextiles to prevent clogging of the drainage layer. The liner is sloped into the leachate collection pipes that in turn are sloped to the leachate collection sump. These slopes should be greater than three per cent to the pipes and one per cent to the sump. The leachate head in the sump may exceed 300mm as the sump is generally recessed below the level of the liner and some liquid may be necessary to protect the pump in the sump.

The drainage layer must be across the entire landfill and comprise at least 300mm of coarse aggregate or geosynthetic drainage material or equivalent performance. This ensures that leachate is contained within the drainage layer, thus minimising the potential for clogging of the drainage layer.

The drainage layer is a high-porosity medium providing a preferential flowpath to the leachate collection pipes and/or sump. To avoid clogging and capillary action holding water in the drainage layer, coarse material should be used. Coarse drainage material will also ensure leachate flow in the event of some clogging within the leachate collection pipes.

The hydraulic conductivity of the drainage layer must be greater than $1x10^{-3}$ m/s. Drainage layer aggregate should also have the following properties:

- rounded and smooth surfaced;
- $D_{85} \geq 40$mm;
- $D_{10} \geq 20$mm;
- uniformity coefficient < 2;
- fines content < 1 per cent; and
- containing no limestone or other calcareous material that would be subject to chemical attack.

A geotextile filter should be placed over the drainage layer to protect it from clogging as a result of solids transport. Leachate collection pipes should not be wrapped in a filter geotextile, as this can rapidly clog, rendering the collection pipes ineffective.

In designing the leachate collection system pipes, the key factors are the spacing between the pipes and the sizing of the pipes. Placing collection pipes close together minimises the head on the liner. Typical maximum pipe spacing is 25 metres.

Giroud’s equation can be used to design the liner slope and pipe spacing to ensure the maximum design leachate head is not exceeded. Giroud’s equation is as follows:

$$L = \frac{T_{max}(2\cos\beta)}{\sqrt{\tan^2\beta + 4\frac{q}{k}} - \tan\beta}$$

where:

L = spacing between drainage pipes (m)

T_{max} = maximum leachate head over liner (m)

k = permeability of drainage layer (m/sec)

β = slope of the liner

q = leachate seepage rate into drainage layer (m/sec).

The sizing of leachate pipes is based on leachate flow rates within the pipe and the diameter required for the passage of remote inspection and cleaning equipment. This equipment typically requires pipe diameters greater than 15 to 20 centimetres. Manning's equation is used to derive the required pipe size based on leachate flow rate and pipe slope. Leachate flow rate is derived from a water balance estimation.

The estimated volume of leachate generated should be based on a 1-in-20 year storm event after only one lift of waste has been placed in the landfill.

In designing the slope of the leachate collection pipes, a minimum pipe slope of one per cent should be used, though greater slopes will minimise the sedimentation in the pipe. To prevent clogging of the pipes, they should be designed to remain drowned in the leachate sump.

To reduce the risk of mechanical failure of the leachate collection pipes, they should be:

- flexible rather than rigid;
- placed in trenches;
- placed on evenly prepared bedding material; and
- protected by a traffic-control program minimising the movement of heavy vehicles across them until sufficient waste has been placed over the drainage layer to avoid puncturing.

Leachate recycling and disposal

Leachate must be stored and managed in a manner such that it will not escape into surface water or groundwater, will not cause offensive odours and will minimise human contact with the leachate. Management options for leachate are:

- evaporation;
- discharge to sewer, with or without pretreatment;
- treatment;
- surface irrigation of leachate outside the waste disposal area and subject to the contaminant content; or
- providing moisture for an enhanced biodegradation landfill.

In deciding upon any of the above management options, a water balance should be modelled over at least two consecutive wet years to ensure that the proposed system has sufficient capacity to deal with all leachate generated over the operational life of the landfill.

All ponds used for the leachate storage, treatment or evaporation must:

- be installed and maintained to prevent any release of the stored contaminants or wastes through the bed or banks of the pond(s) such that the likelihood of environmental harm being caused to any waters (including groundwaters) is minimised. To prevent seepage from the treatment system into groundwater, ponds are to be lined to the equivalent performance standard as the landfill;
- be installed and maintained so that a freeboard of not less than 0.5 metre is maintained at all times; and
- be installed and maintained to ensure the stability of the pond's construction.

If leachate ponds become anaerobic or where odour is a particularly critical issue due to surrounding sensitive land uses, leachate odours can become an issue. Where odour is an actual or potential issue, then the leachate pond may need to be covered or mechanically aerated.

If evaporation is to be used as the primary means of disposing of leachate, then an appropriately sized pond needs to be designed to ensure that the system can handle the volume of leachate expected to be generated over a year. This can be calculated by using the following formula:

$$A = \frac{1{,}000V}{0.8E - R}$$

Where:

A = pond surface area (m^2)

V = annual volume of leachate (kL)

E = median annual evaporation (mm class A pan)

R = median annual rainfall (mm).

The disposal of leachate to sewer requires the approval of the local government, which may impose restrictions on the quality of leachate permitted to be discharged.

Discharge of leachate to the receiving waters is not typically practical or possible because leachate must be treated to a high standard and this management option is the least preferred option of the waste evaluation procedure of the Environmental Protection (Water) Policy 2009. If the discharge is permitted, the development approval will prescribe release standards.

Waste management options, such as reducing the volume of water requiring disposal and examining alternatives for reuse onsite or off-site, should all be evaluated prior to seeking approval for an off-site release.

The principal method of treating leachate is degradation by aerobic bacteria. The efficiency of this treatment method depends upon keeping the bacterial floc in suspension and being able to inject sufficient oxygen for the needs of the bacteria.

A wide range of alternative leachate treatment methods have been developed, ranging from full physico-chemical treatment where the treated leachate is of an extremely high quality, to thermal treatment where leachate is evaporated by the combustion of landfill gas. Where other alternatives are not feasible or sufficiently protective of the environment, these need to be investigated on a case-by-case basis.

Where treated leachate is to be irrigated over land that has not received waste, it must be of a standard suitable for land irrigation that is prescribed in the development approval. Australian and New Zealand Environment and Conservation Council Guidelines for Sewerage Systems *Use of Reclaimed Water* (November 2000) can be of assistance in designing an irrigation scheme.

Spraying or otherwise disposing of leachate over any part of the site that has received waste is only to be considered if it forms part of the essential operation of an enhanced biodegradation landfill.

4.2.2. Clean and sediment laden stormwater

In accordance with the waste evaluation procedure, interception drains must direct external stormwater away from any disturbed areas. The sediment contamination of direct precipitation can be prevented or minimised by the following measures:

- minimisation of the area of soil disturbed or exposed at any one time to minimise contamination of stormwater runoff by sediment. All areas of soil disturbed and exposed should be managed to a standard to effectively minimise the loss of sediment, either through revegetation and/or use of other stabilisation techniques in accordance with the latest version of *Soil Erosion and Sediment Control Guidelines for Queensland* authored by the Institution of Engineers, Australia <www.engineersaustralia.org.au>;
- minimisation of the quantity of sediment being released from areas where soil is disturbed or exposed to the sediment control system (e.g. sedimentation ponds);
- ensuring that the size of any sedimentation pond is sufficient to contain the runoff expected from a 24 hour storm with an average recurrence interval of 1 in 10 years. The design storm shall be determined in accordance with the latest version of *Australian Rainfall and Runoff - A guide to flood estimation* authored by the Institution of Engineers, Australia. All ponds should have spillways with erosion-control measures such as rocks and erosion resistant vegetation; and
- implementation of an effective recycling system for reuse of stormwater on-site and implementation of practicable opportunities for off-site reuse by other persons of appropriately treated stormwater where reuse of the total expected volume on-site is not practicable.

Where a water supply pond is constructed to provide water for fire fighting, dust suppression or irrigation purposes, appropriately treated water from the sediment control system can be channelled into the water supply pond. This places an additional control on the discharge of potentially turbid water, thus ensuring that the environment is better protected. It also maximises the reuse of this water.

The release of stormwater from the site must only occur after confirmation by water quality testing that the stormwater conforms to the relevant development approval limits.

4.2.3. Groundwater management

The design of the landfill must consider the local hydrogeological conditions. Issues to be considered include:

- the potential for liner uplift; and
- the need for groundwater recovery bores.

The upward or outward force of groundwater through the base or sides of a landfill can cause a structural failure of the liner. Until the loading on the landfill liner due to waste placement exceeds any inward or upward force exerted by groundwater, this risk of liner uplift needs to be managed.

The key to managing this risk is to reduce the level of groundwater beneath the landfill by extracting groundwater. Two of the strategies that will enable this reduction are groundwater underdrains beneath the liner and groundwater extraction bores surrounding the landfill. If groundwater extraction ceases, the rebounding watertable will exert a force on the landfill that will need to be balanced by the force exerted by the waste for the liner to remain intact.

As an added level of protection for landfills in an area of potable groundwater, a groundwater recovery system provides a means of preventing the impact on the objectives for groundwater. The recovery system works by reversing or otherwise changing the direction of flow so that the contaminated water can be extracted.

The installation of recovery bores follows from a risk assessment focussed on the sensitivity of the aquifer to seepage from the landfill and the groundwater velocity. The spacing and size of the recovery bores are determined by their proximity to the landfill and hydrogeological conditions such as the transmissivity of the subsurface strata. In operating groundwater recovery bores, the landfill operator needs to be aware that the resulting change in groundwater flow direction will affect conclusions drawn from groundwater monitoring results.

The collected groundwater is often more saline than the local surface water system and therefore unsuitable for release to surface waters. It can also be unsuitable for irrigation. If it is the fact, groundwater reinjection or discharge to sewer may remain the only options.

4.3 Noise issues

Landfill operations generally involve noisy plant and equipment and may impact detrimentally on the amenity of surrounding areas. Sources of noise at a landfill include truck noise (body, engine and exhaust), reversing beepers, external telephone bells, and mobile machinery and equipment used for resource recovery operations such as concrete crushing equipment.

If the noise impact from the activity is likely to cause annoyance at any noise sensitive place, site specific background noise must be established and noise impact assessed using a recognised noise model as part of an application for a development approval.

To ascertain compliance with noise limits prescribed in the development approval, site operations may be required to introduce measures to minimise noise impacts by using natural and/or constructed features such as:

- fitting and maintaining appropriate mufflers on equipment;
- building enclosures around noisy fixed equipment;
- providing adequate noise attenuation screening;
- earthen bunds and depressions;
- minimising steep-haul roads; and
- restricting the hours of operation for noisy operations such as traffic, earth moving, landfill construction, waste transfer/disposal and landfill rehabilitation.

4.4 Waste management practices

4.4.1. Waste acceptance

Waste acceptance/rejection procedures

Landfill staff must ensure that only permitted wastes are deposited at the landfill facility. Loads containing prohibited wastes can sometimes be identified by visual inspection, such as observing drums on a truck or other unusual characteristics.

Facilities such as elevated mirrors, viewing platforms or video cameras may be used to screen incoming waste loads. Random inspections of incoming loads should also be conducted. Records of these inspections should be kept. In particular, a random inspection program should be developed for all waste loads not from secure sources such as transfer stations. The frequency of inspection will depend on the type and quantity of waste received and whether problems have previously been identified. A representative sample of vehicles must be physically inspected.

There should be a communication system linking staff at the landfill tipping area to the gatehouse. Procedures should be developed to deal with the dumping of prohibited or non-conforming wastes at the landfill, and should contain procedures for the identification of the waste dumper, isolation of the waste and notification of DERM.

These procedures should be contained in the SBMP and implemented where such wastes are deposited. Where regulated wastes are received at the landfill, a sampling and analysis program is needed to assure landfill operators that the waste has been correctly classified and accords with their acceptance criteria.

Non-putrescible landfills must have more stringent control requirements on the waste received as certain design requirements are not required (e.g. gas treatment or odour controls). Periodic waste composition surveys at these landfills, at least three times per year to check compliance with the waste acceptance criteria are therefore recommended.

Prohibited and permitted wastes

The development approval will prescribe waste types (including regulated wastes) that are permitted to be accepted and/or prohibited at a landfill. Disposal of contaminated soils must only be conducted with a disposal permit (Chapter 7, Part 8, Division 7 of the *Environmental Protection Act 1994*).

Putrescible landfills licensed for ERA 60(b) are typically allowed to accept up to 10 percent of limited regulated wastes; non-putrescible landfills accept some of these wastes such as tyres or asbestos. Putrescible waste landfills licensed for ERA 60(a) can be permitted to accept other regulated wastes for co-disposal. In either case, the prohibited wastes (including prohibited contaminated soils) include:

- liquid or semiliquid waste, other than liquid or semiliquid waste which has been produced in the carrying out of the environmentally relevant activity;
- hot ash;
- material that is smouldering or aflame;
- material containing a substance which is ignitable, corrosive, reactive or toxic (other than materials containing a toxic substance from domestic premises) unless this material is to be deposited into a dedicated monocell with a written approval of the administering authority;
- all radioactive wastes, unless otherwise approved under the *Radiation Safety Act 1999* or approved contaminated soil;
- an explosive;
- ammunition, other than ammunition that no longer contains explosives, pyrotechnics or propellants apart from trace residues that are no longer capable of supporting combustion or an explosive reaction; and
- whole scrap tyres at the rate exceeding 10,000 equivalent passenger-tyre units (EPU) per annum.

In some circumstances, non-conforming regulated and contaminated soils containing a substance that is ignitable, corrosive, reactive or toxic can be deposited into a dedicated monocell with the written approval of the administering authority. The monocell is to be situated within the existing landfill unit and installed with:

- at least a 0.3 metre thick basal and side earthen liner that has been compacted to achieve hydraulic conductivity of less than 1×10^{-9} m/s; or
- any other basal and side liner of a thickness and a hydraulic conductivity to achieve the equivalent performance to that of the earthen liner.

The free space within the monocell is to be minimised to the greatest extent practicable. After the regulated waste deposition ceases, the monocell is to be immediately installed with:

- at least a 0.3 metre thick earthen cap that has been compacted to achieve hydraulic conductivity of less than 1×10^{-9} m/s; or
- any other cap of a thickness and a hydraulic conductivity to achieve the equivalent performance to that of the earthen cap.

The capping system of the monocell is to be peaked in the centre to prevent incidental rainfall or leachate from pooling or ponding on the top of the monocell cap.

Soil contaminated by radioactive substances that is approved for landfill disposal, is contaminated soil:

- that has enhanced radiation levels due to activities (such as mineral sand processing) provided that the radiation levels of the material to be disposed of are less than or equal to 0.2 micro Sieverts per hour (μSv/h) above natural background levels measured at the site where the material is being removed from; and
- that notwithstanding the above clause, soil that DERM may approve on a case by case basis solid waste contaminated with radioactive material that has radiation levels greater than 0.2 μSv/h above natural background levels.

If contaminated soil is used as coverage material at the landfill facility, it must not exceed:

- the maximum contaminant levels in table 1 (other than for contaminants listed in table 3) and allowable leaching contaminant levels (TCLP) in table 2 for clay lined landfills included in Appendix A; and
- not exceed the maximum concentration limits in table 3 of Appendix A.

4.4.2. Waste placement and compaction

By maintaining tight controls on waste placement, propagation of diseases, pathogens, fly breeding, mosquito breeding, and harbouring and/or breeding of rats and other pest organisms, and/or vectors can be controlled and the degree of waste compaction maximised.

At putrescible landfills, the size of the working face must be kept as small as possible. The width of the working face can be estimated by allowing about 4–5 metres per truck, though trucks with trailers may require more space. An all weather internal road must be provided and maintained at all times to the working face of the landfill unit.

Waste should generally be placed at the base of the face, with a compactor pushing waste up the face and compacting it in thin layers. The thickness of the waste layer should not generally exceed 2 or 3 metres and depends on the type of compactor used. Large metal articles intended to be buried at the landfill facility must be compacted to the greatest extent practicable prior to being deposited in the landfill unit.

The amount of landfill space and land used to dispose of waste can be minimised by proper compaction. Waste should be compacted to achieve a density of at least 700 kg/m^3 excluding cover material. The compactor should therefore make three to five passes over the waste. Cover should be applied at the same time to maintain the length of the working face at less than 30 metres.

Operating a landfill on a cellular basis, particularly in a former extractive industry site, will often mean that at least one face or side of the cell will not be confined. In these circumstances, waste should be placed so that it is stable and can be covered by earth or other approved cover materials.

The limiting factor for the gradient of an unconfined volume of waste within a landfill will usually be governed by the stability of the cover soil placed over that exposed area. Gradients steeper than two horizontal to one vertical units should be avoided. An initially safe, dry cover may subsequently slide down a slope due to water saturation that increases the weight of the cover and decreases the friction resistance along the waste. The stability of waste and cover material may be further enhanced by terracing the unconfined face.

The following wastes must be handled and disposed of as a special burial of waste:

- all putrescible waste (other than putrescible waste from domestic premises) where that putrescible waste comprises the total waste load;
- waste loads containing putrescible waste (other than putrescible waste from domestic premises) commingled with other waste where the quantity of that other waste (both individually and in aggregate) is insignificant (less than around 10 percent);
- fibrous asbestos, mixed asbestos and/or bonded asbestos (all chemical forms); and
- waste, which if not buried as soon as practicable, would be likely to cause environmental harm when placed in an exposed position.

4.4.3. Waste coverage

An essential part of landfilling operations is the placement of cover over wastes. The purpose of cover is to:

- minimise landfill odours;
- control litter;
- prevent the spread of fire;
- control disease vectors such as birds, flies, mosquitoes and rodents; and
- ensure that the landfill is trafficable.

To achieve these outcomes at a putrescible landfill, deposited waste must be covered:

- with earthen material to a thickness of at least 200 metres; or
- with an alternative dense and incombustible material of sufficient thickness and nature to ensure that there is no exposure of waste.

The coverage must be carried out:

- at least at the end of every operating day; and
- at more frequent intervals if putrescible waste is deposited at a frequency necessary to ensure that such waste is not left in an exposed state.

Alternative materials such as foams, mulch, paper-mâché, gravel or cover mats may also meet these purposes and may meet other operational needs such as landfill gas collection and enhanced biodegradation. Wet material and acid sulfate soil must not be used.

With the lateral movement of the working face across the landfill unit, it may be some time before the next lift of waste is placed over an older area. Cover material rich in clay may dry and crack during dry weather, thus releasing landfill gas and odours. The increased thickness of the placed coverage material and other measures may be necessary to reduce these releases (see Sections 4.1.1 – Odour management and 4.1.2 – Landfill gas).

Where soil is used for cover, a stockpile of soil to be used as cover material needs to be provided. Sufficient material must be available at the working face for at least two weeks of operations. As a guide, this is estimated to be one cubic metre of soil for every six tonnes of waste received.

4.4.4. Progressive rehabilitation and capping

The development approval will require preparation of a site management plan pursuant to Chapter 7, Part 8, Division 5 of the *Environmental Protection Act 1994* which will need to be submitted before the closure of a landfill unit takes place. However, to ensure that the objectives of rehabilitation are achieved, a conceptual rehabilitation plan should be developed as part of the initial landfill design and included in the SBMP.

This is specifically so if a progressive rehabilitation is proposed. While wastes are deposited in the new cell, the old landfill cell is rehabilitated and depending on the life span of the new cell, construction of the next cell may commence. The advantages of progressive rehabilitation include:

- full cost recovery during the economic life of the landfill;
- collection and treatment of landfill gas during its peak generation period;
- a clear demonstration to the community that the site will be rehabilitated; and
- minimising the generation of leachate and offensive odours.

The initial rehabilitation plan should include:

- discussion of future land use;
- final contours; and
- final capping system.

Future land use

In considering options for future land use, the location of the landfill, the needs of the local community, the surrounding land uses and the nature of the operation should all be considered. All stakeholders should be consulted in this process.

Proposals for the future use should be flexible enough to allow for changes in community attitudes or planning requirements in the long period between commencement of landfilling and final rehabilitation.

Regular reviews of options are a good way of ensuring that the operation of the landfill does not alienate desired future land uses of the site. In particular, understanding the future land use during operation ensures that the final surface profile of the landfill is consistent with the desired use.

Common uses of former landfills include sports grounds, public open space and golf courses. Depending on the age of the landfill and the type of waste deposited, some landfills have been developed for commercial or industrial building development, though this requires particular consideration of the impacts of settlement on buildings and services such as water mains, gas and roads.

Water features, such as ornamental lakes or ponds, should be avoided on landfills as they may leak due to cracking of their liner from differential settlement of the landfill over time. This leakage will release significant volumes of water to the landfill, thus generating significant volumes of leachate.

Final contours

The proposed final contours should be included in the SBMP including contours before and after settlement.

The settlement of a landfill, as waste decomposes and consolidates, has significant impacts on the final surface profile, the landfill capping system and future land uses for the site. The rate and degree of settlement are dependent upon:

- proportion of putrescible wastes;
- thickness of the landfill;
- period over which wastes were placed in the cell;
- the degree of compaction;
- the moisture content of the wastes, and
- the degree of surcharging or loading placed on the cap.

Long-term settlements for well-compacted landfills vary significantly and can range from 10 to 30 percent. Most of the settlement occurs within the first few years of the cell closure, the result of waste compressing under its own weight and the weight of the cap. After this initial compression, settlement will continue for many years as a result of consolidation and biodegradation processes within the waste. In general, non-putrescible landfills will have a lower rate of settlement.

Since compaction of wastes along near-vertical side walls is difficult, the wastes along the walls of the landfill may exhibit the highest initial rate of settlement. The landfill cap needs to make allowance for this by providing sufficient thickness of the cap to ensure that runoff from the cap is not collected in depressions along the perimeter of the landfilled area.

The landfill post-closure program must include inspections of the capping system, checking for differential settlement and indicators that the integrity of the capping system has not been compromised. The frequency of the inspection program will be largely determined from the observed rate of settlement.

When buildings are constructed on a filled landfill, special support and protection from landfill gas may also need to be provided. Where structures are to be built on landfills, the landfilling should be planned to provide for selective disposal of wastes, special compaction and a thicker cap. These will all increase the bearing capacity of the landfill, making the construction of these structures more viable.

Landfill capping system

A key element of the rehabilitation is the capping of the landfill. The design objectives for the final landfill surface or capping are preventing or minimising:

- infiltration of water into the landfill unit;
- the likelihood of any erosion occurring to either the final cover system or the landfilled materials; and
- uncontrolled release of landfill gas.

The capping system must be designed such that the infiltration through the cap does not exceed the calculated seepage rate through the landfill liner. This avoids the so-called ‘bathtub’ effect, in which leachate levels within the landfill build up and eventually break out through the surface of the landfill. A typical capping system is depicted in figure 6.

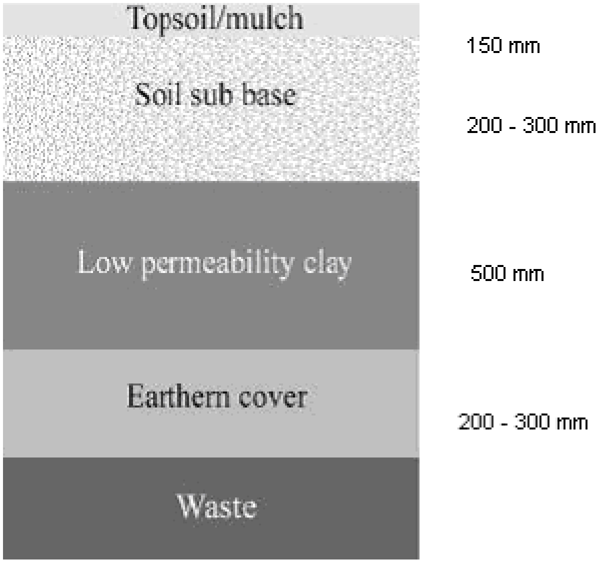


Figure 6: Typical capping system

To limit infiltration, a 500mm layer of low-permeability clay compacted to achieve hydraulic conductivity $K = 1 \times 10^{-8}$ m/s can typically be sufficient. If a sufficient amount of clay is not available or if a landfill is located in a sensitive environment, a flexible membrane liner and drainage layer liner can also be incorporated into the design.

Caps should not be steeper than 20 percent. Caps steeper than this can cause erosion problems and can be more difficult to maintain than flatter caps. Steep caps will require specific engineering controls to ensure that they are stable; these controls will, typically, relate to relieving any seepage water pressures within the cap.

They will also require features such as cut-off drains and rock beaching on drainage lines to control water erosion and, therefore, erosion. In addition, the surface layer should be vegetated as quickly as possible to further control erosion. Until the vegetation becomes established, this revegetation program should be augmented with measures such as mulch or erosion mats to control erosion.

Where the future land use of a landfill requires vegetation of the site, the top-most layer must be able to support vegetation and be of sufficient depth to ensure that roots do not penetrate the cap, thus providing a conduit for water into and out of the landfill.

The surface layer should reflect the type and depth of top soils normally found in the local area. Where it is not possible to duplicate the local topsoil conditions or the natural soil is too thin to support adequate vegetation for erosion control, then an appropriate mix of soils, at least 150mm thick should be used provided it is capable of sustaining vegetation. Where small trees and shrubs are to be planted on the landfill, the cap will need to be thicker to ensure that the roots do not penetrate the cap. The thickness of the cap will also affect the species selected.

The construction and maintenance of a low permeability clay layer of the capping system is difficult for a number of reasons, including:

- the spongy foundation of waste on which it is built;
- differential settlement of the waste causing cracking of the clay; and
- desiccation of the clay from above due to evapotranspiration and below due to heat released from the landfill.

All of these significantly increase the effective hydraulic conductivity of the clay; the estimate of seepage rates through the cap should make allowance for this.

4.4.5. Site security and fencing

A gatehouse must be installed at the entrance to the site or at a point that cannot be bypassed when travelling to the landfill. The incoming waste loads are assessed at the gatehouse to detect prohibited wastes and/or divert other materials to the recycling area. A viewing platform, elevated mirrors or video camera can assist the gatehouse attendant to readily assess the incoming waste load.

A weighbridge must be also installed to facilitate accurate waste record keeping.

A transfer station with recycling and drop-off areas should be provided at putrescible waste landfills so that the public has no need to unload their vehicles at the working face. This will encourage waste sorting and minimise safety risks to the public. Less supervision of the working face will also be necessary.

Active landfill sites may present a safety risk to the public and livestock. The site must be securely fenced to prevent the unauthorised entry of people or livestock.

When unattended, the gates must be securely locked. When designing a fence, consider the probability that unauthorised people will want to gain entry to the site. All extractive industry sites must typically have a wire mesh fence at least 1.8 metres high constructed around the landfill site perimeter; other landfill sites require a wire mesh fence at least 1.8 metres high constructed around the tipping area and storages of hazardous wastes, tyres and fuel and a stock proof fence around the perimeter of the site or other measures to prevent vehicular access. Fencing must be regularly inspected and any damage to the fence that would allow unauthorised access be repaired as quickly as possible.

Signs must also be prominently displayed at the landfill facility specifying:

- that unlawful entry and unauthorised scavenging is prohibited;
- the appropriate locations at which specified waste may be deposited and any requirements as to the deposition of such waste;
- the waste which is permitted to be deposited at the landfill facility and advising that other waste must not be deposited at the facility;
- that lighting of fires is prohibited; and
- the hours and days the facility will be open for the receipt of wastes.

Any particularly dangerous areas, such as leachate ponds, must also have signs to indicate the danger posed.

4.4.6. Public health and safety problems

Flies, mosquitoes, rats, dogs, cats and birds (typical disease vectors) are attracted by food wastes or still waters at landfills. If uncontrolled, these pests can propagate diseases and can cause public health problems. The main mechanisms for the control of disease vectors are the use of cover material to cover waste daily (see Section 4.4.3 – Waste coverage) and eliminating any water bodies that are not required for fire, sediment and leachate control. However, other measures (e.g. scare devices and traps) may be used to reduce or control infestations. Accredited pest exterminators should be employed to reduce problem infestations of vermin (other than birds) if required.

Landfills located near airports, close to a surface water supply, or industrial or residential areas that may be affected by bird droppings need a high level of bird control.

The most successful bird deterrent strategies rely upon a variety of techniques. While the immediate spreading of cover material over the wastes may not entirely deter birds, it can be supplemented with other options such as nets or monofilament wires over glide-paths or water ponds, anti-perch strips on buildings, and active measures such as acoustic bird scaring devices (gas guns or mimicking distress calls), predator decoys or even using dogs. Since birds become accustomed to one particular measure, some variation in the active measures used is necessary.

4.4.7. Litter management

Municipal waste, especially plastic bags can be spread over wide areas by the wind. This litter looks unsightly, but might also foul drains and waterways, as well as interfere with neighbouring activities such as quarrying or farming.

Litter controls at landfills will vary throughout the year depending on wind strength and the orientation and elevation of the tipping area. No single control option will be entirely successful for the entire life of the landfill. A litter control strategy must, therefore, be flexible and include both engineering solutions and management options.

The minimisation of the size of the working face will significantly reduce the litter. Where litter is blown or washed from the landfill facility in amounts that are not insignificant in scale or extent, actions are needed to retrieve the litter and ensure that it is disposed of in an appropriate manner. It may include at least a daily litter program in which fences and surrounding areas are cleaned of any litter. It will also have contingency plans for which resources are engaged to deal with extreme events that cause gross litter problems.

Landfills with litter problems must use litter screens and train staff in the appropriate placement of the screens to trap as much litter as possible. These litter screens should be portable to be able to follow the tipping area, and should be capable of withstanding wind loads when loaded with litter. A dedicated litter crew, more frequent covering and enhanced litter screens can also be necessary in some instances. Such landfills may also have dedicated areas for waste deposition that are more sheltered from winds from particular directions, and therefore minimise litter from the landfill.

4.4.8. Fire prevention

Landfill fires can cause significant impacts on the local air quality through odour and smoke. Once started, landfill fires are difficult to extinguish, so the primary objective must be to prevent a fire from starting. This is done by compliance with the waste acceptance criteria e.g. preventing hot ashes or other flammable or ignitable materials from being deposited within the landfill (see Section 4.4.1 – Waste acceptance). Other measures include prevention of waste burning and lighting fires on or near areas where wastes have or are being deposited. An effective fire break must also be provided and maintained which complies with any requirements of the Queensland Fire and Rescue Authority to prevent bushfire spreading to the landfill site. Finally, wastes must be covered with non-combustible material.

If a fire starts, every effort must be made to extinguish it before it gets established. Equipment to extinguish a fire must be readily available at any time to enable a prompt response to any part of the premises.

A water supply, either reticulated water or from ponds or tanks, combined with a means of delivery (pump and hoses or a tanker truck) allows the prompt extinguishment of a fire on the site. Clear access to the water supply for fire fighting vehicles must be provided at all times.

Groundwater and stormwater stored in ponds might be suitable for combating a fire, but advice with respect to their suitability as firewater should be sought from the Queensland Fire and Rescue Authority. Leachate should not be used because of a possible human exposure and damage to the fire fighting equipment.

Where reticulated water is not provided, at least 50,000 litres should be stored onsite for the purpose of combating small fires. In the event of a significant fire, this volume will need to be supplemented by another source of water.

It is not usually possible to extinguish deep-seated fires using water except where the operator has sufficient plant and water to excavate and extinguish all burning waste. Where extinguishment is not possible, adding water to the landfill exacerbates the fire because the water adds oxygen to the fire. To combat deep-seated fires, key elements are to minimise oxygen ingress to the fire by capping off the area, and displacing oxygen from the fire by injecting an inert gas, such as nitrogen, into the fire.

4.4.9. Wheel wash

The landfill facility may require a wheel wash facility to prevent pollution of roadways by vehicles exiting the site. Hand-held pressure washing hoses, drive-through immersion bunds and vibration grids are all options that may suit different operations.

Water used in vehicle and wheel washing must be managed as leachate.

4.4.10. Storage of hazardous wastes, tyres and fuel

Hazardous wastes (including regulated wastes), tyres and fuels are often stored at the landfill facility. If these are inappropriately managed they can impact adversely on the environment. They must be therefore stored at dedicated locations.

The storage and handling of flammable and combustible liquids must be in accordance with the provisions of the AS 1940-2004/Amdt 1-2004 *The Storage and Handling of Flammable and Combustible Liquids*. During storage, there must be no visible leakage of the contents from any storage vessels.

Batteries are only permitted to be stored in unroofed areas when palletised and plastic wrapped. Waste tyres must not be stored in the open for more than five days unless:

- the waste tyres are covered by an impervious membrane so as to totally exclude water; or
- waste tyres are made totally incapable of holding water; or
- the waste tyres are individually treated with larvicide. The concentration of the larvicide is to be of a strength to stop the breeding cycle of the mosquito.

The dimensions of each tyre stack/stockpile must not exceed:

- 5 metres as the maximum width of the base;
- 45 metres for the maximum length of the base; and
- 2 metres for the maximum height of the stack.

The minimum distance between the tyre stacks/stockpiles and any other flammable or combustible material including grass or weeds shall be at least 10 metres in any direction.

Regulated waste and fuel storage facilities may require separate development approvals. Storage of fuel in tanks or containers having combined capacity in excess of 10,000 litres is classified as ERA 11 (Crude oil or petroleum product storing). If regulated wastes are received from non-domestic sources, their storage is ERA 56 (Regulated waste storage). New development approvals for tyre storages are subject to the DERM operational policy *Conditioning new development approvals for storage of scrap tyres*.

5.0 References:

Institution of Engineers, Australia *Australian Rainfall and Runoff - A guide to flood estimation*

Institution of Engineers, Australia *Soil Erosion and Sediment Control Guidelines for Queensland*

Environmental Protection Authority - Victoria (2010) Best Practice Environmental Management: Siting, Design, Operation and Rehabilitation of Landfills, October.

Government of South Australia Environmental Protection Agency (1998) DERM Guidelines: Major Solid Waste Landfill Depots. October.

Environmental Protection Agency – New South Wales (1996) Environmental Guidelines: Solid Waste Landfills. January.

Waste Management Association of Australia (2000) National Code of Practice for Environmental Management of Landfills for Owners and Operators.

Woodward-Clyde (1998) Best Practice Odour Mitigation Options for the Brisbane Landfill, Gardner Road, Rochedale, Queensland, 19 February.

Brisbane City Council (1994) Liquid Industrial Waste Policy and Management Plans, November.

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Appendix A Acceptance criteria

Table 1 Maximum contaminant levels

Contaminant	Maximum contaminant level for clay lined landfills (mg/kg)	Maximum contaminant level for double lined landfills (mg/kg)
Monocyclic aromatic hydrocarbons (MAH)		
Benzene	10	20
Ethyl Benzene	500	1 000
Toluene	300	600
Xylene	250	500
Total MAH	500	1 000
Polycyclic aromatic hydrocarbons (PAH)		
Total PAH	500	1 000
Phenolic contaminants		
Non halogenated compounds:		
Phenol	100	250
m-cresol	250	500
o-cresol	250	500
p-cresol	250	500
Total non halogenated phenol	250	500
Halogenated phenol:		
Chlorophenol	1	5
Pentachlorophenol	5	20
Trichlorophenol	5	20
Total halogenated phenol	5	20
Chlorinated Hydrocarbons		
Chlorinated aliphatic compounds:		
Carbon tetrachloride	5	10
1,2 Dichloroethane	10	20
l,1 Dichloroethene	1	1
Tetrachloroethene	10	20
Trichloroethene	25	25

Contaminant	Maximum contaminant level for clay lined landfills (mg/kg)	Maximum contaminant level for double lined landfills (mg/kg)
Total chlorinated aliphatic compounds	50	50
Chlorinated aromatic compounds:		
Chlorobenzene	100	200
Hexachlorobenzene	1	1
Total chlorinated aromatic compounds	100	200
Non scheduled solid polychlorinated biphenyls (PCBs)	2	50
Pesticides		
Total organochlorine	5	50
Total herbicides	25	50
Total carbamates	25	50
Total organophosphorus	10	50
Petroleum hydrocarbons		
Total petroleum hydrocarbons (C_6-C_9)	500	1 000
Total petroleum hydrocarbons (C_{10}-C_{14})	5 000	10 000
Total petroleum hydrocarbons (C_{15}-C_{28})	10 000	50 000
Total petroleum hydrocarbons (C_{29}-C_{36})	10 000	50 000

Table 2 TCLP threshold concentrations

Contaminant	Allowable leaching contaminant levels (TCLP) for clay lined landfills (mg/l)	Allowable leaching contaminant levels (TCLP) for double lined landfills (mg/l)
Non specific contaminants		
Biochemical oxygen demand	20 000	20 000
Total organic carbon	10 000	10 000
Petroleum hydrocarbons	25	50
Metals/non-metals		
Antimony	0.5	5
Arsenic	0.5	5
Barium	10	100
Cadmium	0.05	0.5
Chromium	0.5	5
Cobalt	0.5	5
Copper	10	100
Lead	0.5	5
Mercury	0.01	0.1
Molybdenum	0.1	5
Nickel	0.5	5
Selenium	0.1	1
Silver	0.5	5
Thallium	0.1	1
Tin	0.3	3
Vanadium	0.5	5
Zinc	50	500
Inorganic anions		
Bromide	5	50
Chloride	6 000	6 000
Cyanide (total)	1	5
Fluoride	15	150
Nitrate	100	1 000

Contaminant	Allowable leaching contaminant levels (TCLP) for clay lined landfills (mg/l)	Allowable leaching contaminant levels (TCLP) for double lined landfills (mg/l)
Sulphate	2 500	4 000
Monocyclic aromatic hydrocarbon (MAH)		
Benzene	0.1	1
Ethyl benzene	5	50
Toluene	3	30
Xylene	2	20
Total MAH	5	50
Polycyclic aromatic hydrocarbons (PAH)		
Anthracene	0.07	0.7
Benz (a) anthracene	0.005	0.05
Benz (c) phenanthrene	0.005	0.05
Benzo (a) pyrene	0.002	0.02
Benzo (b) fluoranthene	0.005	0.05
Benzo (k) fluoranthene	0.005	0.05
Chrysene	0.10	0.1
Dibenz (a,h) anthracene	0.002	0.02
Dibenz (a,h) pyrene	0.01	0.1
Dimethylbenz (a) anthracene	0.005	0.05
Fluoranthene	0.02	0.2
Indeno (1,2,3-cd) pyrene	0.01	0.1
Naphthalene	0.07	0.7
Phenanthrene	0.01	0.1
Pyrene	0.07	0.7
Total PAH	0.1	1
Phenolic contaminants		
Non haloqenated compounds:		
Phenol	1	10
m-cresol	2	20
o-cresol	2	20
p-cresol	2	20

Contaminant	Allowable leaching contaminant levels (TCLP) for clay lined landfills (mg/l)	Allowable leaching contaminant levels (TCLP) for double lined landfills (mg/l)
Halogenated phenols:		
Chlorophenol	0.01	0.1
Pentachlorophenol	0.1	1
Trichlorophenol	0.1	1
Chlorinated hydrocarbons		
Chlorinated aliphatic compounds:		
Carbon tetrachloride	0.03	0.3
1,2 Dichloroethane	0.1	1
1,1 Dichloroethene	0.003	0.03
Tetrachloroethene	0.1	1
Trichloroethene	0.3	3
Chlorinated aromatic compounds:		
Chlorobenzene (total)	1	10
Hexachlorobenzene	0.002	0.02
Pesticides		
Organochlorine:		
Aldrin	0.001	0.01
Chlordane	0.006	0.06
Chlorpyrifos	0.01	0.03
Dieldrin	0.001	0.01
DDT	0.003	0.03
Endrin	0.001	0.01
Heptachlor	0.003	0.03
Lindane	0.1	1
Methoxychlor	0.1	1
Toxaphene	0.005	0.05
Herbicides:		
2,4-D	0.1	1
2,4-DB	0.2	2
2,4,5 -T	0.002	0.02

Contaminant	Allowable leaching contaminant levels (TCLP) for clay lined landfills (mg/l)	Allowable leaching contaminant levels (TCLP) for double lined landfills (mg/l)
MCPA	0.2	2
Carbamates:		
Carbaryl	0.06	0.6
Carbofuran	0.03	0.3
Organophosphorus:		
Diazinon	0.01	0.1
Methyl Parathion	0.006	0.06
Parathion	0.03	0.3
Triazines		
Atrazine	0.01	0.03
Simazine	0.01	0.03

Table 3 Maximum total contaminant levels in soils used as cover material

Contaminant	Maximum total contaminant levels in soils used as cover material (mg/kg)
Arsenic (total)	200
Beryllium	40
Cadmium	40
Chromium (iii)	240 000
Chromium (vi)	200
Copper	2 000
Lead	600
Manganese	3 000
Mercury (inorganic)	30
Methyl Mercury	20
Nickel	600
Zinc	14 000