Guideline

Landfill siting, design, operation and rehabilitation

Queensland Government

Prepared by: Regional & Regulation Support, Department of Environment, Science and Innovation

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Acknowledgements

This guideline has been prepared by consideration of a number of landfill guidelines and information sheets prepared by the former Queensland Department of Environment and Heritage Protection in addition to various codes of practice and guidance produced nationally and internationally.

This guideline has used information contained in the Best Practice Environmental Management: Siting, Design, Operation and Rehabilitation of Landfills, Victoria Environment Protection Authority, Victoria 2010. This information was current as at the date of original publication; however, care must be exercised as references contained within this document may vary over time. Persons wishing to use this information should consult the reference directly where possible, for example the EPA Victoria website at https://www.epa.vic.gov.au/ and search for 788 to obtain the current version of the information.

This guidance has also used information produced by the UK Environment Agency (UKEA) and available on their website https://www.gov.uk/government/organisations/environment-agency. Generic technical information and descriptions from the UKEA documents have been used and only where it is applicable.

August 2021

Contents

Version history

Version	Date	Description of changes
1	9 JUN 2004 30 AUG 2012	Original publication Document rebranded
2	11 DEC 2013	Major document update
2.01	15 AUG 2016	Minor reformatting and rebranding
3.00	6 MAR 2017	Included details of submitting applications electronically to the department in Connect
3.01	3 JUL 2017	Updated references from *Sustainable Planning Act 2009* to *Planning Act 2016*.
3.02	15 JUN 2018	Document rebranded to align with machinery of government changes
3.03	30 JUL 2018	Deleted sentence in section 6.4.8 about floc as it is not appropriate cover material.
4.00	23 NOV 2018	Updated for the Environmental Protection (Waste ERA Framework) Amendment Regulation 2018
4.01	08 OCT 2019	Updated for the Environmental Protection Regulation 2019 remake.
5.00	12 AUG 2021	Updated section 3 to reflect Connect being renamed Online Services and provide details of how to obtain the form to apply to be a registered suitable operator as applications can no longer be made electronically to the department.
5.01	12 FEB 2024	Document rebranded to align with machinery of government changes.

Introduction

This guideline has been produced by the Department of Environment, Science and Innovation (the department). It focuses only on the development, operation and rehabilitation of a waste disposal facility in Queensland, and specifically only the environmentally relevant activity (ERA) that falls within the definition contained in Schedule 2 of the Environmental Protection Regulation 2019 for waste disposal, namely ERA 60 (formerly ERA 75 under the Environmental Protection Regulation 1998). The term waste disposal facility in this document relates only to a landfill site and the terms are used interchangeably.

This guideline is concerned only with waste disposal at a landfill and does not address the design, operation or management of any non-waste disposal activity such as the rehabilitation and restoration of quarries and mines or any other ERAs such as:

- waste transfer stations
- regulated waste storage, treatment, recycling or reprocessing
- crushing, milling, grinding or screening
- organic material processing by composting
- the operations of a transfer station or resource recovery area that are also frequently conducted at a landfill site.

Guidance and information on these activities can be sought from the Queensland Government's Business Queensland website www.business.qld.gov.au using 'environmental licences and permits' as a search term.

The objective of this guideline is to provide current and future operators of landfills, planning authorities and regulatory bodies with:

- information on the potential risks to the environment from waste disposal activities and how they should be mitigated
- guidance to assist:
    - applicants in the preparation of information that should be provided when applying for an environmental authority for a landfill activity (ERA 60)
    - the administering authority in the assessment of applications seeking to conduct a landfill activity (ERA 60) and the subsequent performance monitoring of a landfill site from conception to restoration.
- transparency and consistency in the measures that the department expects to be taken to meet the environmental performance objectives and expected standards of operation relevant to environmentally safe landfill waste disposal.

1 Who is this guideline applicable to?

This guideline is applicable operators seeking to develop a new landfill site, regardless of size, threshold or location and to operators of existing landfill sites extending their facility, constructing new disposal cells and seeking information on current standards of operation.

1.1 How will the department use this guideline?

The department expects the environmental outcomes detailed in the guideline to be achieved by landfill operators to ensure the protection of the environment from all waste disposal activities regardless of size, threshold or location.

By moving to a risk based approach, as described later in this document, this guideline recognises that existing and proposed landfill sites are each subject to a different suite of individual site-specific circumstances. The environmental outcomes required by the department are fixed and must be met; however the way in which the outcomes are achieved is not fixed.

The department is also committed to introducing elements of best practice environmental management to existing landfilling operations (where they can reasonably be introduced) with the objective of raising the standard and reducing the risk of pollution. Best practice environmental management is defined in Section 21 of the *Environmental Protection Act 1994* (EP Act), as '…the management of the activity to achieve an ongoing minimisation of the activity's environmental harm through cost-effective measures assessed against the measures currently used nationally and internationally'. The department will work with landfill operators wherever possible, or use the enforcement tools available under the EP Act if necessary, to introduce best practice environmental management and ultimately increase the level of environmental protection.

Note: some sections of this guideline (community engagement, traffic considerations and site security), have been provided for operational completeness; however are not relevant to the assessment of a development application or an environmental authority application by the department.

1.2 Structure of the guideline

This guideline covers four broad areas as shown in Figure 1. These areas include the three key phases of the landfill life cycle:

1. development
2. operation
3. rehabilitation.

This document sets the outcomes to be achieved for each of the above phases and provides guidance on suggested measures that could be used as part of the strategy to meet the required outcomes.

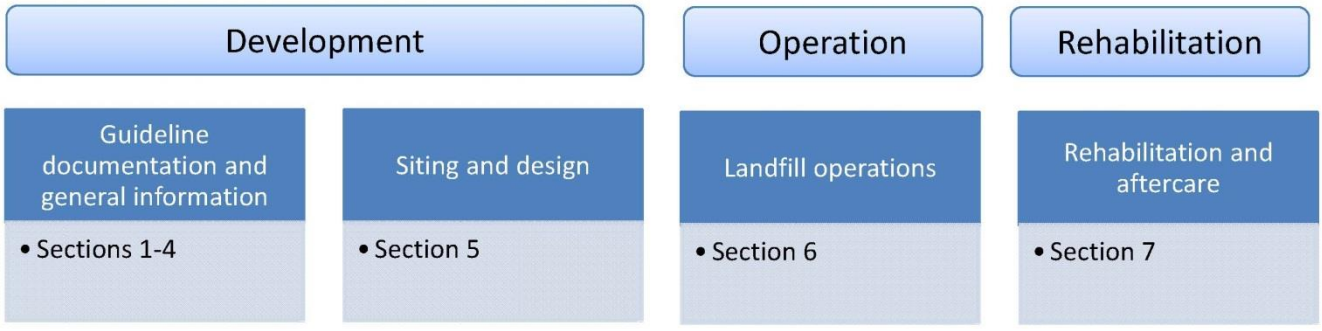

Figure 1: Structure of this guideline

1.3 How to use this guideline

This guideline covers site selection, development, design, construction, operation, rehabilitation and aftercare management of all landfill sites. It is intended to provide guidance for how landfill operators can meet the environmental protection outcomes.

The structure of this guideline is set up according to a framework of outcomes and suggested measures for each relevant aspect of environmental management for landfill sites (see Figure 2). The outcomes must be achieved for each element of the landfill operation. An outcome may be achievable in different ways and it is the responsibility of the applicant/operator to ensure that a proposed methodology will achieve the desired outcome. The suggested measures represent some of the acceptable methods to aid in achieving the required outcomes.

Suggested measures may not necessarily be appropriate for every landfill site. Where landfill sites are located in particularly sensitive environments, the outcome of the risk assessments for the landfill site may indicate alternative measures to those suggested in order to achieve the required outcomes.

All information presented in this guideline is likely to be applicable throughout the entire life cycle of a landfill; however, there will be different levels of emphasis and relevance according to the particular life cycle stage of each landfill, ranging from project development and gaining regulatory approval, to rehabilitation and aftercare management. As such, this guideline is not intended to be read sequentially. It is the responsibility of the landfill proponent to satisfy themselves as to their obligations under the guideline. The following sections are presented as a starting point for operators and proponents in using the guideline.

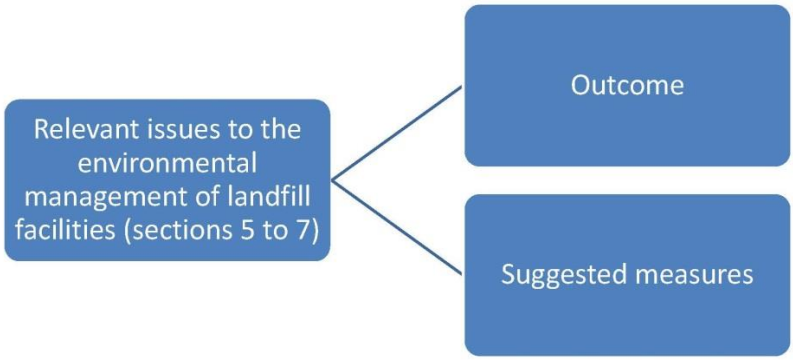

Figure 2: Queensland landfill guideline framework

1.4 Relevant environmental laws

The Queensland environment is protected by a range of legislation that includes Acts and subordinate legislation (regulations and policies). Acts are usually general in nature, establishing the broad goals and principles whereas subordinate legislation is a generic term for a variety of legislative instruments that includes regulations and policies. It is the subordinate legislation that will generally contain the many details necessary to ensure that the Act will operate successfully.

Landfill operators must have an awareness of the laws, and in particular, demonstrate how they meet with the criteria detailed in the Environmental Protection Policies (EPPs) relevant to their activity. The following Queensland Acts (together with subordinate legislation) are relevant to landfill activities in Queensland:

- *Planning Act 2016*
  - Development Assessment Rules
  - Planning and Environment Court Rules 2010
  - Planning Regulation 2017
- *Environmental Protection Act 1994*
  - Environmental Protection Regulation 2019
  - Environmental Protection (Air) Policy 2019
  - Environmental Protection (Noise) Policy 2019
  - Environmental Protection (Water and Wetland Biodiversity) Policy 2019
- *Waste Reduction and Recycling Act 2011*
  - Waste Reduction and Recycling Regulation 2011
- *Petroleum and Gas (Production and Safety) Act 2004*
  - Petroleum and Gas (Safety) Regulation 2018

These Acts, together with the subordinate legislation, are available at https://www.legislation.qld.gov.au/browse/inforce.

The list above, states relevant Queensland environmental legislation. There may be other Federal and State legislation applicable to landfill operations. However these are outside the scope of this guideline.

2 Risk based approach

A risk based approach must be used in all aspects of landfill development, operation and rehabilitation. Risk assessments are undertaken to identify and determine the significance of the risks. This assists operators and regulators to make decisions on the acceptability of an activity or action. A risk assessment helps to determine the level of environmental risk by looking at the probability (likelihood/frequency) of an event happening and the consequences (impacts). A risk assessment may be qualitative or quantitative and, as well as considering environmental impacts, it can also consider economic, social and other impacts. A risk assessment is a useful tool for the evaluation of possible environmental outcomes and the identification and consideration of potential alternative control systems/measures.

The degree of additional work and resources that might be needed will be proportional to the potential environmental risk from the activity. The risk assessment and any supporting information provided as part of an environmental authority application must provide sufficient evidence to allow the department to make a reasonable decision. Measures included in this guide could help demonstrate how the environmental hazards of a particular landfill could be managed and the environmental risks potentially reduced to an acceptable level.

There are a number of common steps involved in the risk assessment process, these include:

- identifying all the hazards
- determining what or who may be impacted
- evaluating the risk from the hazard (severity and likelihood)
- evaluating and introducing control measures that demonstrate the risk will be reduced
- ongoing review of the risk assessment throughout the landfill lifecycle.

There are a range of risk assessment styles and templates available for use and the department will expect a structured approach to be used. Standards Australia produce a number of documents concerning risk management that should be understood and followed where applicable, these include: AS/NZS ISO 31000:2009 titled, Risk management—principles and guidelines (supersedes AS/NZS ISO 4360:2004) and a handbook HB 203:2006 titled Environmental risk management—principles and process that provides guidance on understanding and implementing environmental risk assessments based on the principles of AS/NZS ISO 31000:2009.

There are numerous hazards associated with a landfill operation; these may range from a one-off local environmental nuisance hazard (odour, litter or dust) to a serious and long term environmental hazard (landfill gas migration or leachate contamination of surface or groundwater). The environmental hazards and potential risks posed by a landfill site will vary due to the types of waste accepted and the location of the site. Generally the types of hazard present at a landfill will be common to all types of site, noise, odour, litter, vectors, leachate, landfill gas etc. It is the pathways and likelihood of these hazards reaching and adversely impacting on sensitive or commercial places that will differ from site to site. Therefore the potential level of risk a landfill hazard presents will be site specific; while the hazard cannot be eliminated the risk from it can be reduced. Operators can introduce a number of control measures to reduce the risk from a hazard. More than one control measure may be applied to each hazard to reduce the risk to an acceptable level.

Risk assessments are required to be undertaken to identify the hazards associated with a landfill operation and assess the potential level of risk and outline the control measures that will be implemented to reduce the risk level. These risk assessments should be undertaken by an appropriately qualified person and will include, but not be limited to, the following:

- hydrogeological risk assessment
- stability risk assessment
- landfill gas risk assessment.

It is expected that these risk assessments will be reviewed and updated based on the changing site conditions and operations. Where the environmental risk of the waste stream is significant, a third party certification should be completed prior to making an application for an environmental authority to ensure that the methods used are

appropriate for the risk.

2.1 Quality assurance

Moving to a risk based approach will lead to environmental licences for landfill sites, being less prescriptive and requiring the landfill owner/operator to better identify and manage the environmental impacts of their landfill sites.

This may result in increased documentation, such as risk assessments and designs, to be prepared by landfill owners/operators to ensure that they achieve the environmental outcomes set by the department. The department may also require auditing to be undertaken on documents such as:

- risk assessments
- detailed designs
- construction quality assurance plans
- construction quality assurance completion reports.

Having an audit carried out by an appointed environmental auditor is a method that the department may use to ensure that it obtains reliable information on the condition of the environment and any risks posed. Auditors obtain this information through:

- determining actual or potential environmental impacts
- assessing compliance with regulatory or other responsibilities
- assessing environmental risk management
- understanding key environmental issues.

The department may seek external advice, as required, to assist with the assessment of documentation required to be provided by the landfill owners/operators.

2.1.1 Construction quality assurance

Construction quality assurance (CQA), implemented during construction of the landfill facility, will provide confidence that the construction meets the design requirements and specifications and that:

- quality assurances processes are in place for the landfill containment and capping system design and construction
- effective systems are in place to ensure the engineered systems will be to the agreed specification and standard
- material used in the landfill construction meets with the engineered system
- construction is undertaken by an appropriately qualified and experienced persons that ensure design requirements are met
- the CQA processes are well documented and records are available for regulatory purposes and public scrutiny.

The CQA plan should contain procedures that will be able to verify that:

- materials used comply with the engineer’s specifications
- the method of construction/installation is appropriate and, as a result, design requirements have been met.

The CQA plan should contain the material/construction specifications, testing methods, testing frequency, corrective action and provide for appropriate documentation procedures.

3 Environmental licences

Whilst this section summarises the current environmental licensing requirements, pre-lodgement meetings are recommended prior to making any application for a new landfill or making any changes to an existing approved landfill. Pre-lodgement discussions are encouraged to improve the quality of incoming applications and potentially reduce the requirement for information requests. Towards the end of this section, some guidance is given on who to contact to request a pre-lodgement meeting.

All activities that meet the definition for ERA 60 in Schedule 2 of the Environmental Protection Regulation 2019 (EP

Reg), will, regardless of threshold, require an environmental authority to be obtained under the EP Act prior to being able to operate the activity. Depending on the threshold, some will also require a development approval to be obtained under the *Planning Act 2016* (Planning Act).

To determine whether a development approval is required, applicants will need to firstly ascertain if the ERA 60 threshold is defined as a concurrence ERA. This can be determined by completing the 'Forms and Fee finder' on the Business Queensland website (www.business.qld.gov.au) or by referring to Schedule 2 of the EP Reg. If the ERA 60 threshold contains a 'C' in column 3 of Schedule 2, then the ERA 60 threshold will be a concurrence ERA. If the proposed development is a material change of use under the Planning Act it will require both a development approval as well as an environmental authority under the EP Act to operate.

If an application for a development approval for an ERA is required, the applicant will need to lodge the application material with the assessment manager and, once properly made, with the concurrence agency. The development approval application will also need to be accompanied with the consent of the land owner

The department is no longer performing the role of assessment manager or concurrence agency for development applications made under the Planning Act. For applications involving ERA 60, the chief executive of the Department of State Development, Infrastructure, Local Government and Planning (DSDILGP) will generally either be the assessment manager or concurrence agency. However, if the activity is also assessable under a local government planning scheme, the assessment manager will generally be the relevant local council and DSDILGP the concurrence agency. DSDILGP may request technical advice from the department when assessing the application for a development approval.

If an application for a development approval for an ERA is made, the application is considered to be an application for an environmental authority. The application requirements for the environmental authority form part of the Integrated Assessment Development System (IDAS) application forms. Specifically, the attachment to IDAS Form 8 collects the necessary information required to lodge an environmental authority application. Applicants will also need to address Module 4 of the State Development Assessment Provisions (SDAP) when making an application for a development approval for a material change of use for an ERA. The SDAP can be found on DSDILGP's website using 'SDAP' as a search term. If approved, the development approval will attach to the land and will contain land use conditions. The environmental authority will attach to the operator and will contain conditions pertaining to the operation of the activity.

If a development approval for an ERA is not required, an application for an environmental authority can be made direct to the department by:

- completing an application online through Online Services at https://business.qld.gov.au/running-business/environment/online-services; or
- completing the form "Site specific application for an environmental authority for a prescribed ERA" (available at www.qld.gov.au using the publication number ESR/2015/1792 as a search term) and submitting it to the Department of Environment, Science and Innovation using the details supplied in the form.

If the development is a material change of use for other triggers under the *Planning Act 2016*, a development application must be made before applying for the environmental authority.

Where an activity that relates to the authority requires a development permit for a material change of use, the EA cannot take effect until the development permit takes effect. In addition, the EA cannot take effect before a State Development Area approval is granted (when required under the *State Development and Public Works Organisation Act 1971*).

All operators must be registered as suitable operators. The suitable operator application can be made using the form "Application to be a registered suitable operator" (available at www.qld.gov.au, using the publication number ESR/2015/1771 as a search term).

If a change is made to the activity, the operator will need to determine whether the change will require an amendment of the development approval and/or the environmental authority. Information on amendments to an environmental authority (and impacts on a development approval) can be found on the Business Queensland website.

Model operating conditions for environmental authorities

Model operating conditions have been developed for landfill activities. These conditions relate to the environmental authority only and are a consistent set of framework (or core) conditions for environmental authorities. Applicants are encouraged to review them prior to making an application for an environmental authority for the following

reasons:

- They can be used as a basis to propose environmental protection commitments. For example, water quality data could be provided to enable faster completion of surface water release limits.
- If an applicant cannot meet a particular condition, justification can be provided in the application documents for alternative limits or conditioning.

Model operating conditions are available from the Business and Industry Portal using 'Model operating conditions' as a search term.

Pre-lodgements

If a development application and an environmental authority are required (i.e. the application is for a concurrence ERA that is a material change of use under the Planning Act), a pre-lodgement meeting can be requested through your local DSDILGP regional office.

If only an environmental authority is required (i.e. the application is not a concurrence ERA or it is a concurrence ERA and the development is not a material change of use under the Planning Act), then a pre-lodgement meeting can be requested directly to the department via Permit and Licence Management (PaLM).

Notifiable activities

Common land uses which have been identified as likely to cause land contamination, are listed as 'notifiable activities' in Schedule 3 of the EP Act. This schedule includes landfills. As such, any land used for a landfill will need to be placed on the environmental management register (EMR) and operators must notify the department as soon as landfill operations commence.

The EMR is a land-use planning and management register. The EMR provides information on historic and current land use—including whether the land has been, or is currently used for, a notifiable activity, or has been contaminated by a hazardous contaminant. Sites recorded on the EMR pose a low risk to human health and the environment under the current land use. Entry on the EMR does not mean the land must be cleaned up or that the current land use must stop. However it does mean that if the current use was to stop or change, some land uses may not be suitable as the contamination present on site poses a risk to human health and/or the environment.

Information on how to notify the department as well as further information on the environmental management register can be found on the department's website www.qld.gov.au using 'contaminated land' as a search term.

3.1 Financial assurance

Financial assurances are intended to provide a guarantee that the costs of remediation, site closure and post-closure liabilities are not borne by the State/community in the event of the occupiers of a premises or operators of a landfill, abandoning the site, becoming insolvent, or incurring clean-up costs beyond their financial capacity. Section 308 of the EP Act permits the department to require a financial assurance, where applicable, through a condition of an environmental authority, as a security for environmental compliance and remediation costs.

Financial assurances may be applied to a number of activities which disturb land or may result in chemical releases and significant contamination of land. ERA 60 activities may require a financial assurance.

The department has produced a guideline, “Financial assurance under the *Environmental Protection Act 1994*” that is available at www.qld.gov.au using the publication number ESR/2015/1758 as a search term.

This guideline explains when financial assurance can be required, and includes mandatory information requirements, decision criteria and an approved methodology to support the process for calculating and deciding the amount and form of financial assurance for an environmental authority.

On completion of the works, the author of the CQA plan should provide a statement that the works comply (or not) with the requirements of the design and specifications.

4 Community engagement

Assessment of potential landfill sites will need to consider the concerns of the host community. This will allow information sharing and early identification of issues of interest that can be considered in the site screening process.

Once a development approval (if required) and an environmental authority have been obtained, a program of community participation can be continued for subsequent phases of the project. Effective engagement practices

help identify potential issues, impacts, opportunities, options and solutions for improvement and facilitate more efficient decision-making. The benefits of planned and well implemented engagement include:

- enabling the community to be better informed and encouraging local pride and active citizenship
- reducing the amount of misunderstanding and misinformation
- enabling all groups to have a better understanding of community and local needs
- enabling greater commitment to and ownership of decision-making by the community
- building mutual understanding and ownership of problems and solutions
- supporting more efficient and effective decisions, as actual community needs can be identified and community knowledge used throughout business phases
- supporting behavioural and attitudinal change in all groups
- enabling industry to be a good neighbour by building trust and confidence through its openness and transparency, and by listening and responding to community needs.

A range of community engagement tools and products are accessible through the Queensland Government including:

- http://www.getinvolved.qld.gov.au/
- https://www.qld.gov.au/web/community-engagement/guides-factsheets/methods-techniques/

Local councils also set minimum standards for consultation on major infrastructure projects within their communities. For more information on individual local council requirements for consultation, contact your local council office directly or through the Local Government Association of Queensland (LGAQ).

5 Siting and design

This section of the guidelines covers siting and design for new landfill sites and extensions to existing sites.

Table 1: Landfill siting and design outcomes

Outcome	**Suggested measures**
Environmental assessment	
To gain a thorough understanding of the environment where the landfill is to be sited to design the landfill to minimise impacts on the environment.	Assess meteorological data. Conduct a hydrogeological assessment to assess the potential for impacts on local groundwater quality. Investigate water management requirements. Investigate landfill gas and odour control options.
Landfill siting	
To identify and rank those sites that require the fewest engineering and management controls to meet the objects of all State environmental protection policies.	Ensure that the landfill is sited to protect groundwater, surface waters and flora and fauna. Ensure that sufficient buffer is available for the life of the landfill and until the landfill has stabilised. Consider the most appropriate landfilling type to meet the requirements imposed by the local conditions. Consider natural features that will reduce the visual impact of the landfill. Commence the community consultation process early.

Landfill design	
Site layout: To ensure that the site layout minimises impacts to environmental values, encourages recycling and makes the most efficient use of onsite resources.	Plan site layout and filling sequence to ensure that landfill cells are open for the shortest period of time and site operations are optimised. Minimise public access to the tipping face and, where appropriate, ensure that waste received at the landfill can be vetted and recycled. Install and operate a gatehouse, weighbridge and waste transfer station for the public. Design the gatehouse to facilitate the auditing of the incoming waste stream. Position site facilities to take into account haul-road gradients, the external road network and the availability of services.
Liner design: To avoid adverse impacts to groundwater quality.	Design and construct the most appropriate liner system practicable to contain leachate. Provide a geotechnically stable subgrade and liner. Design the lining system based on the outcomes of the hydrogeological risk assessment, stability risk assessment and landfill gas risk assessment. Use industry design standards to show how the proposed lining system will limit contaminate migration from the site and achieve the objectives and outcomes for the site. Ensure that the liner is sufficient to meet hydraulic coefficient. Maintain an adequate separation between the base of the liner and the highest expected groundwater level.
Leachate collection (where applicable): To avoid adverse impacts to groundwater quality.	Design and construct the most appropriate leachate collection system practicable to prevent contamination of groundwater. Minimise the head of leachate over the base of the liner. Provide a primary and secondary leachate extraction system. Use industry design standards to size the leachate collection systems. Use chemically resistant materials in construction of the leachate collection system. Ensure that the leachate collection system drains to an extraction point. Ensure that the liner is sufficient to meet hydraulic coefficient. Install monitoring wells.
Water management	
To protect environmental values of receiving waters and to avoid any adverse environmental impact on surface and groundwater.	Segregate stormwater, leachate and groundwater. Wherever practical, reuse water onsite. Manage and treat leachate to prevent it from escaping into surface water or groundwater, to prevent odours off site, and to minimise human contact with it. Use drains or bund walls to direct clean stormwater away from the landfill activities. Control erosion by minimising disturbed land, treating disturbed land as soon as practical, establishing flatter slopes or spreading the flow of water.

	Where sediment cannot be controlled at the source, install sediment control features. Capture and treat stormwater in accordance with the department's "Stormwater guideline for environmentally relevant activities" (ESR/2015/1653). Manage water from vehicle-washing areas as leachate. Model leachate treatment facilities to ensure that they have sufficient capacity to store and treat the required quantity of leachate. Use interception drains to intercept surface water or shallow groundwater. Assess potential impacts of rising water tables. Use cover materials that minimise likelihood of stormwater contamination.
Landfill gas	
Ensure that no adverse impacts to environmental values are caused by landfill gas (where landfill gas is generated).	Undertake a site-specific landfill gas risk assessment. Implement a landfill gas monitoring program. Ensure the landfill gas management system is updated and is in compliance with the landfill gas management hierarchy (refer to Figure 3). Include landfill gas management systems in the landfill design. Install the landfill gas management system progressively during the landfilling process, to minimise uncontrolled landfill gas emissions. Where there are multiple landfill sites in relative proximity, examine the options for higher order measures of landfill gas use of the combined landfill gas produced from the sites. Monitor air toxics where required.

5.1 Environmental assessment

Screening and assessment of the suitability and relative merits of potential landfill sites will require a preliminary assessment of site conditions and potential impacts on the environment. This includes consideration of topography, surface water, drainage, hydrogeology (groundwater), geology, climate (including air quality and odour modelling) and flora and fauna. Further details of some of these items are presented below. Assessment of site conditions typically includes a review of available information and a program of site investigation.

5.2 Landfill siting (new sites)

The objective of this section of the guideline is to establish the criteria for identifying and ranking sites when locating a proposed landfill.

The aspects that the department require to be considered when screening for candidate landfill sites include:

- site layout
- landfilling methodology
- groundwater
- surface waters
- buffer distances
- encroachment
- geological setting
- flora and fauna protection.

Once a list of candidate landfill sites has been derived from a list of all possible landfill sites, this list should be

ranked to indicate the preferred order of development of potential sites as landfills.

It should be noted that there are additional aspects that should be considered when considering a new landfill site, such as the need for the landfill facility and the ability of the local infrastructure (such as roads) to sustain the operation of a landfill if it were to go ahead. These aspects may be assessed under the Planning Act.

5.2.1 Site layout

The landfill and associated facilities should be designed to:

- minimise potential environmental impacts
- minimise health and safety risks for landfill operators and the public
- encourage recycling in accordance with the waste management hierarchy
- make the most efficient use of resources on site.

Where required, a transfer station with recycling and drop-off areas should be provided so that the public has no need to unload their vehicles at the tipping area. This reduces the mixing of both private and commercial vehicles at the tipping face thereby minimising safety risks to the public.

Where practicable, a gatehouse at the entrance to the site, or at a point that cannot be bypassed when travelling to the tip face, should be provided. The gatehouse is the first line of active measures to check the incoming waste stream to detect non-conforming wastes and divert materials to the recycling area. It should include facilities such as a viewing platform, elevated mirrors or video camera which allows the gatehouse attendant to readily scrutinise the incoming waste load. A weighbridge is also recommended to facilitate accurate record keeping for the purposes of invoicing clients and monitoring waste disposal rates.

5.2.2 Landfilling methodology

An important aspect of screening for potential landfill sites is the type of landfilling operations to be developed. Some methods of landfilling include:

- area method, where an existing hole such as a former quarry is filled
- trench-and-fill method, where a hole is dug and backfilled with waste using the excavated material as cover
- mound method, where most of the landfill is located above the natural ground level
- valley or change of topography fill method, where a natural depression is filled
- a bioreactor landfill.

The most appropriate landfill methodology for a region will be determined based on local conditions and factors and these will be identified in the early stages of the site risk assessment process.

There are a range of proven engineering solutions that currently exist to overcome environmental issues and there is experience to show they can work. It is the job of the landfill designer to satisfactorily demonstrate to the department that the proposed design will afford an acceptable level of environmental protection.

5.2.3 Groundwater

Release of leachate, together with landfill gas migration, poses the greatest hazard and the most severe consequences for a landfill operation. All groundwater must be considered a valuable resource (whether it is currently used or not) and therefore must be protected from contamination by pollutants from the landfill.

A preferred site for a landfill is one that minimises the risk of groundwater pollution by providing a natural, unsaturated attenuation layer beneath the liner for contaminants that may leach through it. This means that sites with naturally attenuating soils, such as those in clayey areas, are preferred to those that do not have such soils, such as in sandy areas.

Regardless of the location, landfills should only be sited in areas where the potential impacts on groundwater have been properly assessed. Part of this assessment process involves development of a hydrogeological risk assessment. The outcomes from the hydrogeological risk assessment are expected to outline the potential risks to the groundwater and the engineering controls that will provide protection of the groundwater. This may include (but not limited to) the following:

- required separation from groundwater and attenuation layer

- groundwater recovery system
- containment barrier design
- design and management practices to protect groundwater quality.

Landfills that are, or have the potential to be, below the water table must ensure that the engineering controls to manage the potential impact of leachate on the groundwater (and vice versa) are implemented and managed/reviewed until it is demonstrated that the risk of pollutants migrating from the landfill has ceased.

Groundwater information for a proposed landfill site should always be verified by local field testing. It is vital to establish correct and long-term groundwater data in the vicinity of a landfill site. Ground water conditions and levels can and do frequently change, sometimes significantly. A landfill site incorrectly located in an area because its selection was based on recent groundwater data that showed reduced and uncharacteristic groundwater levels, would face serious issues if, and when, groundwater levels rebounded.

5.2.4 Surface waters

Since leachate can be toxic to aquatic organisms and cause eutrophication (nutrient enrichment of a water body) in the waterways, it must be managed so that it cannot escape to surface waters.

The distance a landfill is required to be from surface waters should be based on the outcome of a risk assessment.

Where landfills are within the 1% annual exceedance probability (AEP) floodplain, additional engineering and management controls must be in place to ensure that the facility will be protected from flooding, erosion by floodwaters and infiltration from perched water table. The controls should not cause adverse increases to upstream flood heights.

5.2.5 Buffer distances

Appropriate buffer distances should be maintained to protect environmental values, sensitive places and commercial places from any impacts resulting from a failure of landfill design, management or abnormal weather conditions. These failures might constitute discharge from the site of potentially explosive landfill gas, offensive odours, contaminated water, noise, litter and dust. Features that could be adversely affected by landfilling operations include surface waters, buildings and structures and airports.

Buffer areas should not be considered an alternative to providing appropriate management practices or infrastructure, but provide for contingencies that may arise with typical management practices.

A risk assessment for the site should be undertaken to determine the appropriate buffer distances. This risk assessment should demonstrate that the environment will be protected and the amenity of the sensitive areas will not be adversely affected, based on the design or operational control measures proposed. Some indicative buffer distances are listed below:

- 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-engine propeller-driven aircraft
- 3,000 metres from an aerodrome for jet aircraft.

Buffers are measured from the sensitive land use or impacted environmental value, to the edge of the closest cell. All cells, including closed cells, need to be considered in calculating buffers. For sites where there is uncertainty in the location of landfill cells, the boundary of the landfill site is the point of measurement.

Buffer measurement should also consider other activities and site infrastructure capable of causing a nuisance, such as the leachate storage and treatment ponds and facilities and landfill gas management systems (i.e. active pump and flare systems) and their proximity to the nearest sensitive land use. Land within buffer areas may be used for non-sensitive uses provided that the use is not adversely affected by landfilling

The buffer distance relating to buildings and structures applies to any building or structure (including subsurface structures such as storm water drains or service trenches) located near a landfill and is there to provide a protective zone around a landfill for subsurface landfill gas migration.

5.2.6 Encroachment

Where the adopted buffer distance for a site has been, or is proposed to be, encroached, either by the site owner/operator or surrounding developments, the site risk assessment should be reviewed. Where additional design and management practices are identified through the risk assessment as being required to provide the same level of protection to sensitive land uses, these should be implemented.

For landfills with an anticipated lifespan exceeding 10 years, an analysis should be conducted of the anticipated changes in the zoning or land use of the surrounding area during the life of the facility. Guidance on future land use intentions can often be found in the municipal strategic planning statement prepared by the local municipality.

5.2.7 Geological setting

Landfills should be constructed in areas where the landform is stable or engineering assistance can provide stability, thereby enabling the long-term integrity of the landfill liner and cap system. An initial desktop hydrogeological risk assessment and stability risk assessment, together with local knowledge, should quickly identify at the initial site screening stage, the likelihood of any geological issues being present at the locality, including but not limited to:

- seismic zones
- mines
- shafts
- bores
- fractured geology
- site geological considerations
- acid sulfate soils.

Preloading/surcharging may be considered to demonstrate stability of the site.

An additional hazard found at many landfill sites developed at former coal mining sites, is that of spontaneous combustion and underground fires.

Designers will need to demonstrate that the containment barrier integrity will not be placed at an unacceptable level of risk of failure based on the above site conditions.

5.2.8 Flora and fauna protection

Development of landfills may have an adverse impact on the flora and fauna of the local area. 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*
- 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.

A survey of the site and collection of comprehensive baseline environmental data are essential steps in the assessment of potential impacts from proposed landfilling operations. The nature and extent of this data should be site-specific, taking into account the size of the proposed operation and the risks posed to adjacent, sensitive areas. An expert in the field should be consulted for an assessment of potential impacts from scavenger birds or predatory animals.

5.3 Landfill design

Once a suitable site has been selected, the design stage may commence. This section sets the outcomes and suggested measures for achieving these outcomes.

All designs must be verified by a RPEQ in accordance with the *Queensland Professional Engineers Act 2002.*

5.3.1 Liner systems

The principal functions of a landfill liner system are to limit contaminant migration to groundwater and to control landfill gas migration. This is achieved by the landfill liner slowing the vertical and lateral seepage of leachate to allow collection and removal by the leachate collection system, and to contain landfill gas within the landfill for appropriate collection. The liner may also attenuate contaminants in leachate seeping through the liner. A further function of the liner is to control infiltration of groundwater.

The primary design objective of the liner and leachate collection system is to protect the environmental values of groundwater. This includes limiting the size of any attenuation zone that extends beyond the boundary of the premises.

The outcomes of the hydrogeological risk assessment, stability risk assessment and landfill gas risk assessment will influence the containment design features; however it will generally comprise, but not be limited to, a combination of the following components in Table 2.

Table 2: Liner system components and functions

Component	Function
Subgrade	To provide a well consolidated firm platform for the installation of the subsequent lining materials which will protect them from excessive strains, potentially resulting in failure of the materials, and to ensure that the drainage system drains effectively throughout the life of the landfill.
Clay	A low permeability clay layer in a lining system retards water movement and absorbs exchangeable cations. Some of the properties of the soil measured to determine its suitability as a low permeability liner are particle size distribution and plasticity (described by the soil plasticity index) and cation exchange capacity. A key consideration is the potential for desiccation and subsequent cracking.
Geosynthetic clay liner (GCL)	To provide a low permeability layer to limit contaminant migration, reduce water ingress into the landfill and to control landfill gas migration. They are generally used as a compliment with clay in the lining system. The assessment for the suitability of a GCL in a lining system should consider water and gas flow, contaminant transport and stability including the assessment of hydraulic conductivity, gas permeability, chemical compatibility, diffusion and shear strength.
Geomembrane	To limit contaminant migration, reduce water ingress into the landfill and control landfill gas migration. Key properties to consider when selecting a geomembrane include thickness, strength, the ability to resist or accept stress and deformation, tensile strength, puncture resistance, slope stability-interface friction, long term mechanical performance, durability and resistance to degradation.
Geotextile	Installed to protect the integrity of a geomembrane. It minimises the risk of the geomembrane being damaged/punctured during construction and operation of the landfill, and minimises the strains in the geomembrane, and hence the risk of future punctures forming due to environmental stress cracking.

5.3.2 Leachate collection system

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

- able to drain leachate sufficiently well so 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
- able to be inspected and cleaned by readily available video inspection and pipe-cleaning equipment.
- designed to be sufficiently robust to function and perform as required for the expected landfill life cycle.

A leachate collection system typically comprises a high-permeability drainage layer (coarse aggregate or geosynthetic), perforated collection pipes, a sump where collected leachate is extracted from the landfill, and geotextiles to protect any geomembrane and prevent clogging of the drainage layer. The liner is sloped into the leachate collection pipes which in turn are sloped to the leachate collection sump.

Leachate collection systems can fail in less than a decade, in several known ways including when:

- they clog with silt or mud
- micro-organisms clog the pipes
- precipitation from chemical reactions block the pipes
- the pipes are damaged during installation or early in the filling of the landfill
- the pipes are weakened by chemical attack (acids, solvents, oxidising agents, or corrosion) and are crushed.

Due to the above, adequate controls need to be considered to mitigate failure of the leachate collection system.

Where applicable, measures (such as monitoring points) must be installed to demonstrate that leachate depth across the landfill liner is minimised.

5.4 Water management

Water discharge from landfill sites into receiving waterways will require approval in the environmental authority. In assessing the environmental authority application, the department will consider the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (EPP Water) and local water quality objectives in developing site specific discharge limits from the site.

Landfill site water management relies upon the management of three water stream components—groundwater, stormwater and leachate—with the intention of minimising the volumes to be actively managed and avoiding mixing of the streams.

The primary objective of any site water management system must be to safeguard and protect the environmental values of surface and groundwater from potential negative impact from stormwater erosion, chemical contamination and leachate generated when water has come in to contact with waste.

The department produces some general water management guidance that is available on its website and is applicable to landfill activities. This general guidance is incorporated with specific landfill activity guidance below for the three water components.

5.4.1 Stormwater management

All sources of potential stormwater contamination should be identified and managed through a stormwater management plan and include the waste minimisation hierarchy within the EPP Water.

For stormwater management design, consider the latest version of the department's “Stormwater guideline for environmentally relevant activities” (ESR/2015/1653), as well as avoiding flooding of detention basins, waste areas and sensitive or commercial places.

5.4.2 Leachate management

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. A leachate management plan should be developed for a landfill site which provides:

- an estimation of leachate generation over the life of the landfill
- anticipated leachate quality
- monitoring of leachate quality
- measures for reducing leachate production
- disposal options
- emergency procedures

Disposal options for leachate can include:

- evaporation
- discharge to sewer, with or without pre-treatment
- providing moisture for a bioreactor landfill.

If approved by the department, alternative options for leachate disposal may be adopted.

The sizing of the proposed management/disposal system should be provided in the leachate management plan to ensure that the system has sufficient capacity to deal with all leachate generated over the life of the landfill until it has stabilised. It must also include a description of the processes that will be used to manage the expected (and increased) leachate arising.

Where ponds are used as part of the treatment system, they must be lined to the equivalent performance standard as the landfill.

5.4.3 Groundwater management

Since a landfill must not impact on environmental values of groundwater, the design of the landfill must consider the local hydrogeological environment. Issues to be considered include:

- basal heave
- liner uplift
- contaminant migration.

Groundwater conditions and proximity are highly likely to be different at each proposed site. Groundwater management must be tailored to these conditions and address and tackle the issues raised in the hydrogeological risk assessment.

5.4.4 Liner uplift

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 must be managed.

5.4.5 Groundwater monitoring

Monitoring should be undertaken in accordance with the Australian Standard (AS5667.11:1998: Water quality - Sampling - Guidance on sampling of groundwaters), namely:

- establish the groundwater background quality and levels (in mAHD)
- establish the local groundwater flow direction and rate
- act as an early indicator of leachate contamination in groundwater prior to offsite migration
- measure compliance with the site licence or notice
- provide an indication of the downstream groundwater quality that a permitted groundwater user may find.

The bore(s) to establish the background groundwater quality, should be placed up-gradient of the landfill, where they will not be influenced by seepage out or into the landfill or affected by surface water features, such as dams. The location of these bores should also take into account potential impacts from surrounding landfills, such as localised changes in groundwater quality or flow direction.

Monitoring should occur in all aquifers that may be impacted by the landfill. The number of monitoring bores should be commensurate with the size of the facility, the risk of contamination and the nature of the groundwater environment.

Permission must be obtained from the appropriate regional water authority and land owners to install a groundwater bore.

Landfills that are, or have the potential to be, below the watertable must ensure that the engineering controls to manage the potential impact of leachate on the groundwater (vice versa) are implemented and managed/reviewed until it is demonstrated that the risk of pollutants migrating from the landfill has ceased.

5.5 Landfill gas

The objectives for landfill gas management are:

- to ensure there are no adverse health, safety or environmental impacts due to landfill gas
- to minimise greenhouse gas emissions.

5.5.1 Landfill gas risk assessment

The landfill gas risk assessment should include, but not be limited to:

- quantity, rate and composition of the landfill gas generated
- potential landfill gas emission pathways from the landfilled waste
- potential risks/hazards presented by the landfill gas generated to all potential receptors both on and offsite.

The landfill gas risk assessment is an ongoing process that should be updated when any conditions change that have the potential to impact on the site (e.g. gas monitoring data or new receptors) and should be periodically reviewed.

5.5.2 Landfill gas monitoring

Landfill gas monitoring is an integral component in landfill gas management and should be developed and implemented based on the findings of a site-specific landfill gas risk assessment.

The location and number of landfill gas monitoring locations is site specific and should be based, as a minimum, on the following key factors:

- type of waste deposited at the site
- generation rate and composition of the landfill gas
- possible pathways for landfill gas migration
- nature and location of potential receptors for land fill gas emissions
- possible impacts on receptors
- travel time for gas migration from source to potential receptors.

In some cases, it may be appropriate to also monitor landfill gas present in groundwater and leachate.

Landfill gas action levels should be included as part of the application for an environmental authority.

5.5.3 Landfill gas management

To manage landfill gas and minimise greenhouse gas emissions, appropriate landfill gas containment (for example, landfill cap, basal and side liners) and landfill gas collection systems must be developed, installed and monitored. Guidance on landfill gas containment measures are provided in other sections of this document.

The selection of an appropriate landfill gas management system (and associated monitoring program) will be based on:

- the findings of a site-specific landfill gas risk assessment
- the landfill gas management hierarchy (Figure 3).

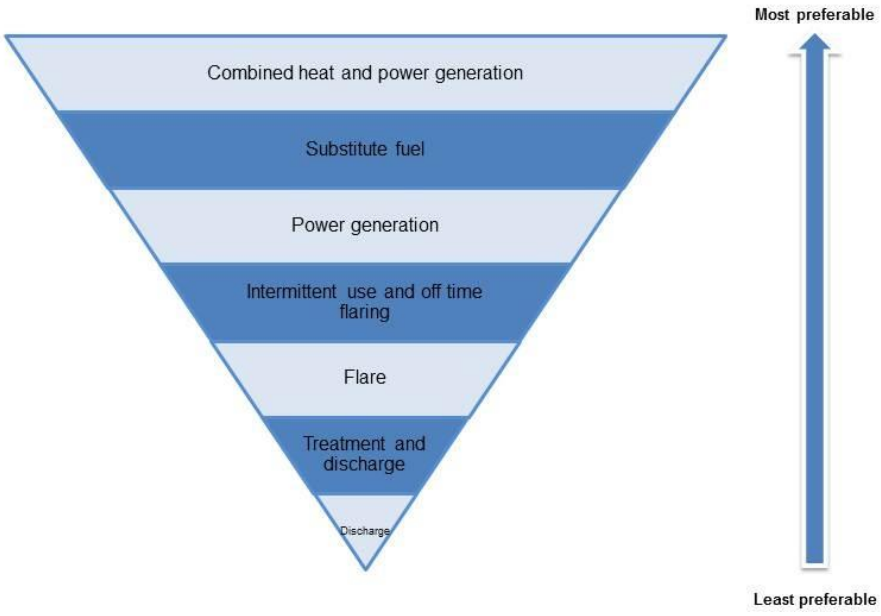

Figure 3: Landfill gas management hierarchy

The highest practical order use of the collected landfill gas should be established by conducting an analysis of the relevant environmental and economic factors. This analysis should be regularly reviewed.

Untreated emissions of landfill gas via vent pipes/trenches or similar infrastructure will not be permitted, unless:

- it can be demonstrated, to the department's satisfaction, that the landfill gas management hierarchy options are not reasonably achievable; and/or
- venting is required as a short-term (maximum three to six-month) emergency measure.

The landfill gas management system must be designed prior to establishing the landfill and should be progressively installed during the operational period of the landfill.

The design and location of the gas management infrastructure should minimise damage by settlement, vandals, animals, natural processes or operational machinery. Landfill gas extraction wells should be monitored and maintained or replaced as required.

6 Landfill operations

Daily landfill operations have the potential to give rise to short and long term environmental pollution issues. The purpose of this section is to provide guidance on the day to day landfill operational management requirements.

The key landfill operational management areas to be covered in this section are:

- waste checking and acceptance
- waste placement, compaction and cover
- environmental management and control measures
- waste disposal monitoring and record keeping.

Table 3: Landfill operations

Outcome	**Suggested Measure**
Waste checking and acceptance	
To ensure that only allowed wastes	Landfill operator to ensure that non-conforming waste is not disposed of

are deposited at the landfill.	at the landfill site. Provide signs advising the types of wastes allowed at the site. Implement a procedure to deal with the dumping of non-conforming waste at the landfill site. Ensure that the landfill is staffed at all times it is open for the receival of waste. Conduct random inspections and sampling of waste loads. Train landfill staff to recognise conforming and non-conforming waste.
Waste placement and compaction	
To place waste in a manner that is mechanically stable and controls litter, vectors and other pest species, and that maximises the degree of compaction.	Maintain an active tipping area that is as small as possible. Place waste so that all unconfined faces are mechanically stable and capable of retaining cover material. Compact all waste deposited in the landfill. Keep covering waste to maintain the active tipping area at less than 30 metres x 30 metres. Place wastes at the base of each lift and compact wastes in layers of less than 2 metres. Avoid unconfined waste slopes with gradients steeper than 2 horizontal to 1 vertical unit. Undertake surveys to monitor density being achieved and assess compaction efficiency.
Waste cover	
To ensure that wastes are covered appropriately to mitigate against any environmental or health impacts.	Cover the waste, at least daily (or otherwise agreed frequency), with soil, or another suitable cover material, for all sites that accept putrescible waste and maintain the cover. Close cracks in old, exposed cover layers to contain landfill gas and odour. Use 0.3 metres of soil, where soil is used as cover. Avoid creating low-permeability confining layers in the landfill by partial removal of low-permeability cover material prior to placement of wastes in that location. Stockpile sufficient cover material at the tipping face. Do not use acid sulfate soil as daily cover.
Litter	
To keep the landfill and surrounding environment in a litter free condition.	Minimise the size of the tipping area. Use litter screens to control litter. Deposit waste in areas of the landfill that are sheltered from the wind. Establish contingency plans to deal with extreme events that cause gross litter problems. Use an appropriate daily cover to reduce litter.
Odour	

To ensure that there is no loss of amenity from odour.	Ensure waste is covered appropriately. Implement odour abatement agents where appropriate. Manage landfill gas appropriately. Ensure special burials of highly odorous wastes.
Dust	
To ensure that air quality objectives in the Environmental Protection (Air) Policy are met and there is no loss of amenity from dust.	Meet requirements of the Environmental Protection (Air) Policy and relevant dust deposition standards. Vegetate exposed areas and form internal roads. Use water or other dust suppressants on roads or stockpiles that are not sealed or vegetated.
Noise	
To ensure that noise requirements are achieved and that there is no loss of amenity from noise from the landfill site.	Set the site out to minimise noise impacts. Use earthen bunds walls to provide an acoustic screen to homes. Manage operating hours.
Traffic considerations	
To minimise nuisance from traffic movement.	Encourage trucks to use access roads that will have the least impact on the surrounding community, where possible. Minimise noise and road grime on external roads. Locate trafficked areas away from sensitive land uses. Provide traffic-control devices and signage near the landfill entry. Ensure that all vehicles leaving the landfill have all soil removed from their wheels and underbody before entering public roads. Seal the road from the wheel wash to the public road where the public road is sealed.
Site security	
To prevent the unauthorised entry of people or livestock.	Design fencing to minimise unauthorised access to the site. Undertake a risk assessment for the site to determine the appropriate level of security measures to be implemented. Implement the outcomes of a site security risk assessment.
Vectors	
To minimise disease vectors emanating from the landfill by denying pests food and shelter.	Eliminate any still waters at the landfill that are not required for fire, sediment or leachate control. Cover waste daily. Use professional pest exterminators to reduce problem infestation of vermin. Vary bird scare methods to avoid any patterns in methods.
Fire	
To prevent landfill fires and	Maintain a water supply capable of being delivered to any point on the

efficiently extinguish any that should occur.	landfill. Do not light fires at the landfill or near areas where wastes have been or are being deposited. Ensure that all practical steps have been taken to prevent landfill fires. Develop a fire-management plan in conjunction with the relevant fire authority. Remove ignition sources such as hot coals and car and marine batteries from the waste at the tipping area. Cover combustible wastes with inert material. Construct a firebreak around the perimeter of the landfill to the satisfaction of the relevant fire authority. Where the reticulated water supply is not adequate for fire fighting purposes or not available, maintain an adequate supply of fire fighting water on site (tanks/dams).
Environmental monitoring and reporting	
To monitor and report on the performance measures taken to protect the environment from potential impacts from a landfill and to identify and address any arising environmental issues.	Prepare a landfill environmental monitoring plan for monitoring for landfill sites. Incorporate into the landfill environmental management plan, both on and offsite inspections by staff, to check on any emerging environmental problems or the effectiveness of existing controls. Monitor the environment in accordance with an approved landfill environmental monitoring plan. Submit an annual environmental report for the site. Develop a workplace culture of identifying any potential environmental issues and taking corrective action before any impacts occur.

6.1 Waste checking and acceptance

The landfill facility should install adequate signage to advise where each waste stream is to be deposited. Signs should also be provided to show where recyclable materials that have not been through a transfer station or municipal recycling facility may be placed.

Landfill staff must be vigilant to ensure that only the waste streams specified in the environmental authority are accepted and deposited at the landfill.

Loads containing non-conforming 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 must be conducted and records of these inspections must 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.

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

These procedures should be contained in the site environmental management procedure and implemented where such wastes are dumped.

In the case of regulated waste and trackable waste, a waste code may also be assigned to the waste type e.g. asbestos N220, tannery waste K140 or filter cake N190. Where the landfill is permitted to dispose of such wastes, the same waste type descriptions and codes may also appear in the environmental authority to assist in determining acceptability.

All reasonable and practicable measures must be undertaken to stop any unapproved waste from entering the site. Landfill staff should, where possible, immediately remove the unapproved waste from the waste stream and arrange for the waste to be transported to a facility that can lawfully accept the waste. If possible, landfill staff should notify the person who deposited the unapproved waste. Records should be kept that detail the type of unapproved waste received, the quantity, the date received. If possible, also record the name and address of the person who transported the unapproved waste to the landfill and the name and address of the person who generated the unapproved waste.

If unapproved waste does enter the facility, landfill staff should immediately inform the department in accordance with environmental authority conditions.

6.2 Waste placement and compaction

By maintaining tight controls on waste placement litter, vectors and pest species can be controlled and the degree of waste compaction maximised.

To contain litter, and to reduce the attraction to vectors and pests, the size of the active tipping area should be kept as small as practicable. The size of the tipping face will vary according to the volume of traffic.

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 exceed 0.5 metres and the compactor should make three to five passes over the waste to maximise compaction and thus minimise settlement.

To minimise the quantity of cover material used, the tipping face should be kept small, ideally less than 30 metres in length. The total height of the layers combined in the lift should be less than two 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 must 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, unless it can be demonstrated that both the waste and the cover material are mechanically stable.

The stability of waste and cover material may be further enhanced by terracing the unconfined face.

Whenever special wastes such as quarantine wastes are deposited, they should be immediately buried and covered. If trenches need to be excavated in the landfill to allow immediate burial of the waste, excavations should be made just before the arrival of the load.

6.3 Waste cover

An essential part of landfill operations is the placement of cover over deposited wastes. The purpose of cover at a landfill is to achieve the following environmental outcomes:

- minimise landfill odours
- control litter
- prevent the spread of fire
- control disease vectors such as birds, flies, mosquitoes and rodents
- minimise rainwater ingress (where possible)
- ensure that the landfill is trafficable
- ensure the visual appearance is not detrimental to the amenity of the area.

Site specific circumstances (location, waste types, past performance etc.) will dictate how, where and when cover should be applied to achieve the above outcomes. Typically waste should be covered at the end of every day, although landfills that receive significant volumes of waste in a day might need to progressively cover waste at more frequent intervals during the day.

Where soil is used as cover, the soil should contain some organic matter, as this helps to attenuate landfill odours. The thickness of soil applied should be sufficient to achieve the above points.

Acid sulfate soils are not appropriate for use as cover material, as they oxidise and produce acid run-off when

exposed to the atmosphere. Once started, this reaction continues in the absence of oxygen, that is, after the cover has been filled over.

Materials other than soil, such as foams, mulch, papier-mâché, gravel or cover mats, may also achieve these purposes and may meet other operational needs, including landfill gas collection and enhanced biodegradation.

Regardless of the material used as cover, sufficient material should be available at the tipping face.

Daily cover material usage should be such that the permeability of the waste and cover should (eventually) be sufficient to allow leachate to pass and gas to be extracted without creating perched conditions. If compacted, clay soils in particular can have a relatively low permeability, which results in partial containment of each layer of waste. This will make both landfill gas and leachate extraction more difficult. To avoid waste containment, low-permeability daily cover should be partially removed prior to waste placement.

There may be circumstances where cover is required to stay in place for an extended period of time requiring a more robust cover system. This is typically known as intermediate cover or a temporary cap. In these situations, operators should consider whether the materials being used have characteristics which ensure it will continue to meet its environmental objectives.

Regular monitoring checks should be made and recorded on the performance of the chosen cover material to ensure there are no gaps or cracks, especially in the case of intermediate cover.

6.4 Environmental management and control measures

6.4.1 Litter

Municipal waste, especially plastic bags, can be spread over a wide area by the wind. This litter not only looks unsightly, but might also foul drains and waterways, as well as interfere with neighbouring activities.

Litter control 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.

As a minimum, a landfill should 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.

Minimising the size of tipping areas and having at least a daily litter program in which fences and surrounding areas are cleaned can assist with litter management. Contingency plans may be developed where resources are engaged to deal with extreme events that cause gross litter problems.

In areas where litter is especially problematic, this may involve a dedicated litter crew, more frequent covering and enhanced litter screens. 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.

Where litter is blown or washed from the site, all reasonable and practicable actions must be made to retrieve the litter and ensure that is disposed of in an appropriate manner.

6.4.2 Odour

Odour from landfill has significant potential to cause of nuisance. The source of odours can generally be characterised as:

- refuse odours from tipped waste or material awaiting tipping
- odour from specific wastes where these are highly malodorous (such as biosoilds)
- landfill gas odours.

Leachate ponds can also be a source of odours. Effective operations and adequate buffers are essential for odour management.

At all times, a landfill should be managed to prevent odours travelling beyond the boundary of the premises. For existing landfills this will be assessed by community complaints that are verified by departmental officers. In particular, where sensitive receptors determined from the landfill gas risk assessment are identified, the highest degree of care must be taken to protect these areas from landfill odours. A properly designed and installed cap and gas management system is the only appropriate and long term solution for managing landfill gas odours. However correct waste handling of known odorous waste, via special burials, together with the correct use of an appropriate

cover material, will in most cases manage odours from fresh deposits.

Other measures that can help the management of odours may include:

- limiting waste acceptance criteria to exclude highly odorous materials/waste streams
- covering incoming odorous loads
- covering/capping odorous waste streams as soon as they are tipped on-site
- restricting the tipping of selected waste streams in certain atmospheric conditions
- limiting the tipping face
- restricting waste storage on-site (including restricting/limiting the parking of waste transport vehicles on-site)
- installing a meteorological station on-site to assist site personnel to identify and record climatic conditions
- using deodorising/masking agents.

Operators should investigate all odour complaints as soon as practicable and are strongly advised to periodically undertake odour monitoring on-site and at site boundaries. The frequency of this monitoring will depend on site proximity to sensitive and commercial places, previous complaints and site processes.

6.4.3 Dust emissions

The objective for management of dust at the site is to prevent the release of dust.

Any large area where the land has been disturbed and is subject to vehicular traffic has the capacity to generate dust. Other potential dust sources are stockpiles of earth 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
- adjacent land use
- the occurrence of natural and/or constructed wind breaks
- wind-abatement measures or buffers.

Dust suppression measures to be applied at the site may include:

- vegetating or mulching of exposed areas and formation of internal roads, including sealing roads that are used regularly
- the use of water or other dust suppressants on roads or stockpiles that are not sealed or vegetated.

6.4.4 Noise

Landfills generally involve plant equipment that can impact detrimentally on the amenity of surrounding areas. Sources of noise at a landfill include trucks (body, engine and exhaust noise), reversing ‘beepers’, external telephone bells and public announcements, mobile machinery and equipment used for resource recovery operations such as concrete-crushing equipment.

Where noise is considered an actual or potential concern (due to changing land use), an acoustics specialist should predict the noise levels at the nearest current or future sensitive or commercial place, and recommend measures to control the noise.

Site operations must be set out to minimise noise impacts by using natural and/or constructed features such as earthen bunds and depressions as well as minimising steep-haul roads.

6.4.5 Traffic considerations

The trafficking and accumulation of dirt on sealed external access roads can be avoided by vehicles exiting via a wheel wash or some other equivalent wheel and underbody cleaning mechanism. The road layout within the landfill should encourage the use of wheel-cleaning devices by truck drivers, and be placed so that the gatehouse attendant can visually check that the vehicle has been cleaned.

Where external access roads are sealed, the road from the wheel wash should also be sealed and regularly

cleaned to reduce the dirt re-entrained by the vehicle. Internal roads should also be sealed as far as possible into the site to reduce the amount of dirt accumulating on the vehicle and allow more time for dirt already accumulated on the vehicle to fall off before it leaves the site.

6.4.6 Site security

Active landfill sites can present a safety risk to the public and livestock. To determine the level of security suitable for the site, a security risk assessment should be undertaken. Suggested items for consideration in the security risk assessment may include:

- securely fencing the site to prevent the unauthorised entry of people or livestock
- locking gates when the site is unattended.

6.4.7 Vectors

Flies, mosquitoes, rats, cats and birds (typical disease vectors) are attracted by food wastes and still waters at landfills. If uncontrolled, these pests can affect public health and surrounding ecosystems.

The main mechanisms for the control of disease vectors are the use of cover material to cover waste daily and eliminating any water bodies that are not required for fire, sediment and leachate control. Other measures, such as scare devices and traps, can also be used to reduce or control infestations.

Professional pest exterminators should be employed to reduce problem infestations of vermin. The application and use of controlled chemicals must be appropriately monitored and be in accordance with relevant regulations.

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

The most successful bird-deterrent strategies rely on the use of 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 dams, anti-perch strips on buildings, and active measures such as acoustic bird-scaring devices (gas guns or mimicking distress calls), or predator decoys.

Since birds become accustomed to one particular measure, some variation in the active measures used is necessary.

6.4.8 Fire

Landfill fires can cause significant impacts on local air quality through odour and smoke. Fires can be on the surface or subterranean. Depending on fire point and size, any fire can also have a serious detrimental impact on site infrastructure such as a containment liner or leachate or gas management system. Fire and heat damage to such infrastructure can be long-term and significant and difficult to identify and repair. Fires can also spread outside the landfill, triggering a grass or bushfire.

Subterranean landfill fires within the body of previously tipped waste have the potential to burn for many years before they are detected. The smell of smoke or the presence of carbon monoxide in the landfill gas may be the first sign that a landfill is burning and, in some cases, the surface of the landfill may collapse as a result of the fire, creating a subsurface cavity. If this collapse is triggered by the passage of a vehicle over the cavity, it could be fatal for the vehicle's occupants. Access to areas of known subterranean fires (particularly in vehicles) must be by trained personnel only.

Once started, landfill fires are difficult to extinguish, so the primary objective should be to prevent a fire from starting. This is done, as far as is practical, by removing potential ignition sources, such as hot coals, from the tipping area. Other measures include not burning waste and not lighting fires on or near areas where wastes have or are being deposited.

The level of carbon monoxide within landfill gas provides some indication as to whether there is, or has been, a subsurface landfill fire. Carbon monoxide is produced when there is insufficient oxygen present to fully burn the fuel, such as within a landfill

Carbon monoxide levels in excess of 1,000 parts per million (ppm) strongly indicate that there is a fire burning within the landfill. Levels above 100ppm are not as conclusive but should be investigated as part of a fire investigation plan along with further gas and temperature measurements to determine if and where there is or was a fire.

Some field meters can provide false results for carbon monoxide due to other constituents of landfill gas such as

hydrogen and hydrogen sulphide. Fitting appropriate filters, or conducting laboratory analysis of the collected landfill gas, provides more accurate results.

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, combined with a means of delivery (pump and hoses or a tanker truck), allows the prompt extinguishment of a fire on the site. Where reticulated water is not provided, the operator should ensure there is an appropriate volume of water stored on site (dams or tanks) for the purpose of combating fires. Groundwater and stormwater stored in dams might be suitable for combating a fire. Leachate should not be used unless all parties are aware of the possible risks and adequate measures are taken to reduce human exposure.

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. Attempts to dig out deep seated fires with inappropriate plant may exacerbate the situation by admitting air. To combat deep-seated fires, key elements are to minimise oxygen ingress to the fire by capping off the area and surcharging the area with claylike material. Landfill gas vents and extraction systems in the vicinity of the fire should be plugged.

A surface fire at a landfill is more likely due to the presence of large amount of combustible material and plant and machinery running over waste. Purpose built dozers and compactors are fitted with guards to prevent contact with hot vehicle components.

Surface fires at the tipping face can also be caused by the presence of incompatible materials (present within municipal solid waste or other waste streams) combining to produce an adverse chemical reaction or physical/chemical reaction (something as simple as a box of matches run over by the compactor). Whatever the source and cause of ignition, a surface fire needs prompt action to prevent its propagation. Once identified, the fire must be tackled in accordance with the site's fire management plan using the resources identified. The plan should include the necessary notification and evacuation procedures. Fire management drills should also be practiced regularly.

In some areas, the local fire authority might require a firebreak to prevent the spread of fire into, or out of, the site. This, in conjunction with developing a fire management plan with the local fire authority, is best practice in areas where grass or bushfires might be a concern. Fires can also occur as a result of arson. Operators should not hesitate in contacting Queensland Fire and Rescue Service or the Queensland Police Service as necessary, in addition to reporting to the department.

Finally, after any fire an investigation must be undertaken to assess the potential damage to any site infrastructure (liner, collection pipes etc.) and steps taken to make good any suspected damage.

6.4.9 Environmental monitoring and reporting

To assess the performance of the measures taken to protect the environment from any potential environmental impacts by the landfill, monitoring, assessment and reporting of the results are required. Conditions surrounding environmental monitoring will be included in the environmental authority for the site, and be proportional to the risk from the activities and the vulnerability of, and sensitivity of, the surrounding environment.

A site specific environmental monitoring plan should be designed and implemented identifying all the potential release points and strategic locations where environmental monitoring will be undertaken to check compliance against a permitted set of release limits. Results must be reported on an annual basis or when there is a non-compliance. A quality environmental management system is also generally required for larger, complex and high-risk sites.

All monitoring must be undertaken by an appropriately qualified person using calibrated equipment. Field and laboratory analysis must also be undertaken by an accredited analytical service.

7 Rehabilitation and aftercare

Rehabilitation and aftercare must be considered very early in the design and operation phase of the landfill and must be considered in, and form part of, the overall risk assessment for the site. This section of the guidance applies to all existing landfills and closed sites.

Table 4: Rehabilitation and aftercare objectives

Outcome	Suggested measure
Rehabilitation	
To ensure that landfills are rehabilitated to minimise the seepage of water into the landfill and maximise the collection and oxidation of landfill gas from the landfill.	Prepare, early in its design, a rehabilitation plan for the landfill, including a detailed consideration of afteruse options for the site. Design and construct the best cap practicable to prevent pollution of groundwater and degradation of air quality. Design and construct the most robust cap to ensure that the system will continue to protect the environment in the event of several components of the system failing. Progressively rehabilitate the landfill. Initiate rehabilitation of a landfill once: • the landfill cell contents have reached the approved pre-settlement contours, allowing sufficient height to build the landfill capping within the pre-settlement contours • further filling of the cell is operationally no longer required or feasible • there has been a lawful direction to cease filling the cell • the landfill is to be closed. Involve the community, regulatory and planning authorities in the development of the rehabilitation plan. Regularly review the rehabilitation plan and afteruse to ensure that changed circumstances are reflected in the plan. Design and operate the landfill to accommodate the desired afteruse. A phytocap design should include a monitoring and maintenance program to ensure integrity of the cap and for the survival of plants. Vegetate the cap or take other measure to minimise erosion as soon as possible. Consider impacts of settlement on any potential afteruses of the landfill.
Aftercare	
To manage the site after closures so that environmental protection and monitoring systems are maintained until the landfill has stabilised.	Prepare a landfill aftercare management plan. Ensure that the landfill aftercare management plan is implemented until the residual risk for the site is at a level that is acceptable to the department for surrender of the environmental authority. Inspect and maintain leachate collection and treatment and landfill gas extraction system. Conduct regular monitoring and analyse data for any trends. Ensure that no buildings interfere with the monitoring and maintenance of the landfill. Regularly inspect site to check the integrity of the cap and monitor the environmental impact of the landfill.

7.1.1 Rehabilitation

7.1.1.1 Rehabilitation Plan

To ensure that the objectives of rehabilitation are achieved, a conceptual rehabilitation plan should be developed as part of the initial landfill design. The rehabilitation plan should deal with afteruse options for the site and provide

a blueprint for the final surface contours and cap design of the landfill.

The rehabilitation plan should include:

- the potential afteruses of the site, taking into consideration current and likely future land use in the area surrounding the site
- operational requirements, to ensure that the capping is designed to suit the intended afteruse
- surface contours before and after settlement
- specifications and materials to be used in the final cap
- preservation/installation of environment performance control or monitoring features such a leachate and gas systems, surface water drainage features
- a way of achieving cost recovery for the rehabilitation works during the economic life of the landfill
- a way to meet financial assurance requirements
- an outline of timeline/triggers for rehabilitation.

7.1.1.2 Progressive rehabilitation

Progressive rehabilitation of a landfill involves the closure and rehabilitation of an area once filling has been completed. These works are effectively a staged closure of the landfill that occurs while the other active cells of the landfill are being filled.

Landfill cell rehabilitation works can include:

- capping and revegetation
- installation and maintenance infrastructure
- decommissioning of infrastructure that is no longer required.

There are a number of environmental and management benefits of progressive rehabilitation including:

- collection and treatment of landfill gas during its peak generation period
- minimising the generation of leachate and offensive odours
- facilitating materials budgeting through the staged use of capping materials over the life of the landfill.

7.1.1.3 Site after use

In considering options for the use of the site after landfilling, the location of the landfill, needs of the local community, surrounding land uses and nature of the operation should all be considered. The relevant regulatory and planning authorities should be consulted, as a strategic plan for the area could be in place that identifies future land use.

Proposals for the use of the filled landfill site should be flexible enough to allow for changes in community attitudes or planning requirements in the potentially long period between commencement of landfilling and final rehabilitation. Circumstances do change and potential afteruses may no longer be applicable or, in some cases, suitable.

Regular reviews of afteruse options are a good way of ensuring that the operation of the landfill does not alienate desired afteruses of the site. Understanding the afteruse during operation ensures that the final surface profile of the landfill is consistent with the desired afteruse. Any changes in potential afteruse must trigger a review of the previously undertaken risk assessments (hydrogeological, landfill gas or stability).

7.1.1.4 Landfill cap

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

- isolate the deposited waste from the immediate environment
- reduce leachate generation by limiting water infiltration
- reduce surface emissions of landfill gas and assist in odour management
- improve the efficiency and effectiveness of any gas collection or management system

- provide a stable and sustainable land form fit for its intended future purpose.

The performance of the capping system will be based on the outcomes from the risk assessments for the site.

Alternative landfill caps, such as evapotranspiration caps (also referred to as 'ET caps') or phytocaps are increasingly being proposed in Australia and used internationally. Ultimately, any proposed site capping system must undergo a robust design, assessment and construction process to ensure an acceptable level of environmental performance, proportional to the environmental risk from the site. Where satisfactory evidence of a conventional or alternative systems performance is demonstrated its use will not be unreasonably withheld.

7.1.2 Aftercare management

Until the waste within the landfill has sufficiently decomposed or stabilised such that it no longer presents a risk to the environment, the landfill must be managed to prevent any environmental impact.

An aftercare management plan should be developed for the site that proposes frequency of monitoring and inspection of the landfill and infrastructure. This frequency of monitoring and inspection should reflect the environmental risk posed by the landfill.

The following areas should be considered in preparing the aftercare management plan:

- maintenance of landfill cap, in particular to:
  - prevent/control erosion
  - restore depressions and seal and monitor cracks in the cap caused by settlement
  - restore/maintain vegetation.
- maintenance and operation of leachate collection and treatment system
- maintenance and operation of landfill gas-extraction system
- environmental monitoring of:
  - groundwater
  - surface water
  - landfill gas
  - leachate
  - settlement.
- achieve cost recovery for the aftercare management during the economic life of the landfill
- meet financial assurance requirement (if relevant)
- update the timeline for achieving a stable condition.

Aftercare will be required to ensure that the environmental risks associated with the landfilled wastes are addressed.

To ensure in the long term, that prospective owners of the land are aware that it was once a landfill, measures such as a caveat on the land title or a planning overlay can alert people to the prior use of the site. Landfill sites must also be included on the environmental management register so that future users will be aware of the activity that has taken place. Further information on the environmental management register can be found on the Queensland government's website www.qld.gov.au using 'contaminated land' as a search term.