Wastewater lagoons

Draft for consultation

EPA 509/10: This guideline replaces EPA Guideline 509/04, Wastewater and evaporation lagoon construction. It advises those proposing to construct wastewater lagoons or similar infrastructure on construction techniques that should assist in meeting obligations under the Environment Protection Act 1993 and the Environment Protection (Water Quality) Policy 2003. The guideline is intended mainly for wastewater lagoon proponents and their engineers or consultants.

Introduction

Wastewater[1] management is an inherent aspect of many industrial operations. Lagoons (or ponds) have been used extensively in the past to naturally treat, store (prior to reuse or discharge) and dispose of wastewater via evaporation. The uses and applications of these lagoons have increased in recent times. However, poorly constructed lagoons can lead to surface and groundwater pollution as well as odour and health impacts.

The document provides basic guidance on the siting, construction and lining of wastewater lagoons and similar infrastructure. It covers:

- wastewater treatment, storage and evaporation lagoons used in sewage treatment facilities; food, beverage and agricultural processing industries; animal husbandry activities; and aquaculture purposes
- sedimentation basins, leachate ponds for composting and landfill activities, irrigation dams used for holding and mixing treated or untreated wastewater, and ponds on industrial sites used for capturing potentially contaminated stormwater runoff from their premises
- processing and wastewater lagoons for chemical, manufacturing and mining industries.

The term 'wastewater lagoon' will be used collectively in this document to refer to all of the above and other similar infrastructures.

The guideline does not include lagoon sizing, operation, biochemistry, sampling[2] and effluent reuse[3]. Proponents are advised to seek assistance from suitably qualified and experienced professionals[4] when designing and constructing wastewater lagoons, as well as when addressing the other aspects mentioned above.

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1 Wastewater includes (a) sewage, and septic tank effluent, whether treated or untreated, and (b) water containing commercial or industrial waste.

2 Guidance on wastewater and groundwater sampling are provided in EPA Guidelines, *Regulatory monitoring and testing—water and wastewater sampling* (June 2007) and *Regulatory monitoring and testing—groundwater sampling, (*June 2007) respectively.

3 Guidance on wastewater reuse for irrigation is provided in EPA Guideline, *Wastewater Irrigation Management Plan (WIMP) —a drafting guide for licensees (*June 2009).

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This guideline does not apply to constructed wetlands (such as those used for stormwater treatment in Managed Aquifer Recharge (MAR) schemes, and those used in wastewater polishing) due to the nature of processes occurring in these infrastructure.

Legislation

The principal legislation addressing pollution in South Australia is the *Environment Protection Act 1993* (the EP Act). In particular, section 25 imposes a general environmental duty on all persons undertaking an activity that may pollute to take all reasonable and practicable measures to prevent or minimise any resulting environmental harm.

Environment protection legislation also includes Environment Protection Policies (EPPs), which may specify required outcomes (enforceable by way of an environment protection order) or impose mandatory requirements for the protection of a particular aspect of the environment. Part 4, Division 2 of the *Environment Protection (Water Quality) Policy 2003* (Water Quality Policy) imposes obligations on certain industries to incorporate a wastewater management system[5], which may include a wastewater lagoon.

Persons intending to construct wastewater lagoons should also have regard to the requirements and provisions of the *Development Act 1993* (and Regulations) and the Development Plan for the area.

Approval and operational requirements

Wastewater lagoon proposals are normally referred to the EPA as part of wastewater treatment facility or industrial development applications.

The Guidelines for construction specifications and reports for landfills, composting facilities and wastewater lagoons (currently in draft) outline the technical documents that the EPA may require when assessing wastewater lagoon proposals. These may include engineering design drawings, a Construction Quality Assurance (CQA) Plan, and a Construction Management Plan. It should be noted that this guideline was designed for landfills, and major composting works and wastewater lagoon developments; hence some of the requirements may not be relevant in the case of small wastewater lagoons to be located in low-risk areas. The EPA recommends that proponents discuss these requirements with the EPA prior to lodging their application.

In addition, the EPA will also require other information to enable risk assessment. These additional requirements are outlined in the following sections.

In the case of EPA licensed facilities, the Authority may also include conditions for assessment or monitoring of the ongoing integrity of wastewater lagoons in the premises. This assessment could be in the form of water balances, or monitoring of groundwater or installed leakage detection devices.

Purposes of the guideline

The principal objectives of this guideline are to:

- safeguard the protected environmental values of surface or groundwater
- minimise the potential for site contamination
- provide consistency in the assessment of wastewater lagoon proposals, and
- assist wastewater lagoon proponents in meeting the requirements of the EP Act and the Water Quality Policy.

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4 Selected consultants must demonstrate competencies and experiences relevant to the work to be undertaken; comprehensive knowledge of the *Environment Protection Act 1993* and associated legislation, policies and guidelines; and knowledge of scientific literature and technologies relevant to the work to be undertaken.

5 A wastewater management system is a system designed and operated for the purpose of collecting, storing and treating wastewater so as to minimise the adverse impacts of the wastewater to the environment.

A note on terminology:

- The term ***should*** is used where the guideline intends that a particular course of action is desirable if compliance is to be maintained.
- The term ***must*** is used where a failure to comply with the guideline will, in the EPA's view, expose the environment to a risk of harm or may lead to a breach of the EP Act or an Environment Protection Policy. In these cases, the EPA may consider that the circumstances of the failure to comply are sufficient to warrant the issuing of an environmental protection order in order to give effect either to the Water Quality Policy and the guideline or the general statutory duty under section 25 of the EP Act.

Primary considerations

The following factors should be considered prior to planning, design and construction of any wastewater lagoon.

Siting and separation distances

Construction of wastewater lagoons should be avoided in the following locations[6]:

- within the floodplain known as the '1956 River Murray Floodplain' or any floodplain that is subject to flooding that occurs, on average, more than one in every 100 years
- within 100 metres of a bank of a major watercourse (eg Murray, Torrens, and Onkaparinga Rivers), or within 50 metres of a bank of any other watercourse[7]
- within 500 metres of a high-water mark
- within an area where the base of the lagoon would be less than 2 metres above any seasonal water table
- within 200 metres of a busy public road (>50 vehicles per day), or within 50 metres of other public roads (<50 vehicles per day), and
- in areas where a Potentially Contaminating Activity[8] has been undertaken.

Construction of wastewater lagoons will only be allowed in these areas if proponents can demonstrate that no other locations are suitable, and appropriate engineering measures are to be undertaken to manage the risks.

The *Guidelines for separation distances* (December 2007) provides recommended buffer distances to prevent odour impacts from aerated and non-aerated lagoons in sewage treatment works and Community Wastewater Management Systems (CWMS), and wineries or distilleries. The guideline also outlines recommended separation distances for many industrial operations. However, as these recommendations do not generally address odour impacts from wastewater lagoons that may be associated with these industries, the EPA will make an assessment on a case-by-case basis. In some cases, the EPA may require the proponent to undertake odour measurements in accordance with the EPA Guideline, *Odour assessment using odour source modelling* (April 2007).

Groundwater

The major environmental concern in wastewater lagoons is the potential leakage to groundwater. The level of lagoon lining and construction will depend on the type of aquifer, occurrence and depth to groundwater in the proposed location,

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6 Proponents are advised to seek guidance from other agencies about other possible siting restrictions.

7 Ideally, suitable separation distance from a watercourse should be determined based on site topography and vegetation cover in the proposed location. Useful information is provided in *Water Quality Risk Assessment of Winery and Ancillary Development in the Mt Lofty Ranges Watershed, Stage 2—Technical Report* (February 2003).

8 A potentially contaminating activity (PCA) is an activity that has an increased risk of introducing chemical substances on or below the surface, above background concentrations, that may result in site contamination. Potentially contaminating activities are prescribed in the *Environment Protection (Site Contamination) Regulations 2008*. Further information is provided in the Information Sheet, *Site contamination: Potentially Contaminating Activities (in preparation)*.

and groundwater usage and quality. Further information on groundwater characteristics that are relevant for risk assessment is provided in Appendix 3.

Nature of wastewater

Wastewaters from industries contain a range of pollutants (eg organics, nutrients, salts, metals and microbiological organisms) depending on inputs and the processes being undertaken. Some industries may also generate highly variable wastewater characteristics due to the various production cycles involved. One of the most important factors to consider when determining the appropriate type of lagoon lining is the 'reactivity' of wastewater. Acidic, alkaline, or saline wastewater (such as those from wineries, distilleries and reverse osmosis plants) could react with clay and compromise the long-term integrity of clay liners. Chemical and manufacturing industries often involve hazardous substances that require the highest level of lagoon lining and construction. In the case of lagoons used in mining projects, innovative testing, design and construction approaches are often required to cope with harsh conditions in these environments[9].

Nature of lagoons

The contained wastewater exerts 'hydraulic head' or water pressure, which is proportional to the depth of water in the lagoon. This pressure could impact on liner performance. Depth could vary depending on the type of lagoon and the capacity requirements of the site. Further information on types of lagoons is provided in Appendix 3.

Evaporative lagoons are normally less than 1 metre in depth as they are designed for the purpose of wastewater disposal by evaporation. Hydraulic head is often not an issue in evaporative lagoons, however clay lining may not be suitable as the liner may shrink and crack if the lagoon dries out. In such circumstances geosynthetic liners may be more appropriate. Alternatively, regular watering or the installation of cover protection layer could be undertaken to prevent desiccation of the clay liner.

Treatment lagoons on the other hand, rely on either mechanical aerators (eg aerated lagoons, activated sludge lagoons, sequencing batch reactors), or natural biological processes (eg aerobic, anaerobic, facultative lagoons) to remove organics and nutrients[10].

Mechanically aerated lagoons[11] are normally deeper with a wider radius to accommodate the aeration equipment and facilitate the mixing process. Geosynthetic liner manufacturers and suppliers normally provide recommended engineering designs for equipment and pipe-work installations. In such cases, the EPA recommends that proponents engage a suitably qualified engineer experienced in geosynthetic lining systems.

For very large lagoons, the environmental consequences of liner failures are also very high. It is recommended that smaller lagoon sections are constructed to minimise impacts to groundwater from accidental damages, and to facilitate desludging, repair and regular maintenance.

Availability of materials

The availability of suitable clay on site or other localities within reasonable proximity to the proposed location is another factor to consider in the selection of clay over geosynthetic liners. Although clay lining may be adequate for a specific application, the cost of clay transport could exceed the cost of geosynthetic liner installation. Suitable material is also

[9] Common challenges in mining applications include very high loads, harsh environments, remote locations, compressible subgrade fills and foundation stabilisation over historic mine workings (Lupo et al 2003).

[10] It should be noted that such treatments alone are not adequate to remove the nutrients and salts in wastewater. In the case of nutrient-rich wastewaters, tertiary (or polishing) treatment is often necessary to further reduce the nitrogen and phosphorus components. In the case of saline wastewaters, cleaner production alternatives or advanced treatment (eg reverse osmosis) is necessary to reduce the salt loads.

[11] In the case of mechanically aerated lagoons lined with geosynthetic liners, they also require ballast on the liner to prevent the uplift of liner and to support the aerator when the water level is lowered (Peggs 2007).

required for subgrade preparation. The various types of available geosynthetic materials for lagoon lining and subgrade preparation are provided in the following sections.

Health and safety

Proponents should consult with Department of Health and other relevant agencies for storage of substances that could pose health and safety risks to site employees or neighbouring communities.

Lagoons lined with synthetic liners could be very slippery when wet. For OH&S purposes, it is necessary to ensure that safety provisions (eg access rope or stairs, inflatable safety gear) are available. The EPA recommends that proponents consult with Safework SA for further information on this matter.

EPA risk assessment process

The EPA uses a risk-based approach when determining the level of construction and type of liner required for a particular lagoon proposal. For this purpose, the EPA has developed a Risk Assessment Matrix (Appendix 1) to be used in conjunction with the Table of suggested construction and lining categories (Appendix 2). Explanation of criteria and terminologies used in both appendices are provided in Appendix 3.

The matrix was developed based on groundwater considerations, wastewater characteristics, and nature of lagoons as discussed earlier. The table outlines the suggested category levels including the type of lining, Construction Quality Assurance (CQA) and leakage detection requirements based on assessment outcomes using the matrix. Proponents must supply the relevant information to facilitate this assessment. The EPA encourages proponents and their consultants to consult the EPA before finalising the lagoon lining and construction details.

It should be noted that this matrix was developed primarily as a tool to ensure consistency and to expedite the assessment process. The EPA may consider a lower construction and lining category than the one suggested using the matrix if appropriate risk treatment measures are to be implemented.

Construction

Subgrade preparation

In the case of compacted clay-lined ponds and ponds lined with synthetic liners, good subgrade preparation is necessary to provide a sound and stable base for liner construction. The subgrade should be compacted to achieve a minimum dry density ratio of 95% relative to standard compaction (AS 1289 5.1.1) to a minimum depth of 150 mm. The prepared subgrade should be proof rolled to determine the presence of zones (such as uncontrolled fill, voids and weak or compressible materials that are susceptible to collapse) that may require subgrade improvement.

Clay lining

In-situ clay lining

Where the natural geology of the site is proposed as the barrier system, an extensive investigation should be conducted by a geotechnical professional to confirm the efficiency of this barrier. This assessment should include:

- the distribution of aquifers, groundwater flow and groundwater quality,
- the depth, extent, geotechnical integrity of the material, eg presence of any imperfections that may compromise its effectiveness (such as root holes, cracks, gravel layers), and dispersivity[12] when wet,
- the permeability of the material to water at varying water contents and bulk densities[13]

[12] The physical separation of primary soil particles from one another.

[13] The oven-dry mass of a soil divided by its total volume.

- any possible reactions between the material and the wastewater to be stored.

Constructed clay lining

The material used as a clay liner should be well graded, highly impervious, and conform to the particle size distribution and plasticity limits listed in Appendix 4.

If materials complying with the indicated plasticity limits are not readily available, clays having LL between 60% and 80% may be used as lining material, provided the clay lining is covered with a layer of compacted sand or gravel (minimum thickness of 100mm), or other suitable alternative materials to protect from mechanical damage and to prevent cracking and drying as indicated earlier.

The material should be free of topsoil, tree roots and organic matter, and compacted to achieve a minimum dry density ratio of 95% relative to standard compaction (AS 1289 5.1.1). The compacted clay liner must have a minimum thickness of 300 mm (or two compacted layers of 150 mm minimum thickness each) and achieve an in-situ coefficient of permeability of less than 1×10^{-9} ms^{-1}. A geotechnical professional must confirm the lining thickness against specifications, and the finished lining must be tested to ensure that it meets the permeability criteria. Regular maintenance should be undertaken to ensure this permeability is maintained throughout the lifetime of the lagoon.

Successive layers should be of compatible materials and of similar moisture content and the underlying layer should be scarified before placing the next layer, to improve bonding and prevent short circuiting pathways. Bonding of successive layers is an important factor; otherwise liquid can move through a vertical crack in the compacted clay and then travel along the interface between two layers until it finds another crack through the clay lining. The thickness of each layer, the compaction technique and the moisture content of the clay in each layer should be carefully controlled to achieve the required density and coefficient of permeability.

Clay lining should be maintained to avoid desiccation during construction. Also if water is encountered during earthworks preparation[14], the site should be dewatered and dried to an appropriate dryness before being lined with clay.

Further considerations for assessment of materials and methodology for construction of clay liners are presented under Attachment 3 of the EPA Guideline, *Environmental management of landfill facilities (Municipal Solid Waste and Commercial and Industrial Solid Waste)* (January 2007).

Geosynthetic liners

Geosynthetic liners may be used as an alternative or supplement to a compacted clay liner when suitable clay materials are not readily available. and could be in the form of:

- geosynthetic clay liner (GCL)
- geomembrane
- combination of GCL and geomembrane
- combination of GCL or geomembrane and compacted clay liner.

Geosynthetic clay liners

A GCL is normally fabricated by incorporating bentonite or other clay into a woven fabric. GCL could be used as a replacement for clay lining in wastewater lagoons. However, due its nature, the material is not suitable for reactive wastewaters.

[14] The suitability of the site and design of the lagoon may need to be reconsidered if perched water table is encountered.

Geomembranes

Common geomembranes used for wastewater lagoon lining include PVC (polyvinyl chloride) and HDPE (high-density polyethylene). Each material has different characteristics which determine appropriate installation procedures, performance and lifespan. PVC geomembranes are very flexible and can be installed on uneven surfaces; however, PVC could crack from loss of plasticiser at high temperatures and under UV radiation exposure. HDPE is normally preferred due to its durability, however this material could also fail due to stress cracking[15] and extended UV exposure.

Other installation requirements

Additional requirements in the installation of geosynthetic liners include the following:

- A layer of geosynthetic liner must cover the entire floor and all sloping sides of the lagoon.
- All welded joints and seals on geomembranes must be watertight.
- Geomembranes must be free of pinholes, blisters and contaminants.
- Geosynthetic liners must be laid in accordance with manufacturer's specification.
- Geomembranes and GCL should be covered with a minimum of 100 mm of suitable material to extend their life. The cover must not contain sharp, jagged rocks, roots, debris or any other material that may be abrasive or may puncture the geomembrane. The cover must be applied in a manner that does not damage the lining and must allow access of machines to desludge the lagoon without damage to the geomembrane.

Appendix 4 provides the relevant specifications for GCL and HDPE geomembranes. Further guidance on the installation of geosynthetic liners is provided in the Guidelines on environmental management of landfill facilities (Municipal Solid Waste and Commercial and Industrial Solid Waste).

The EPA may require documentation confirming that the geomembrane liner used complies with the specified requirements for the purpose and has been installed in accordance with the specifications and manufacturer's requirements. Product and installation warranty documentation should also be retained, and inspection and maintenance requirements associated with the warranty should be followed. Products with guaranteed service life of not less than 20 years are preferable.

Volume and overflow

The capacity of the lagoon should be such that, in addition to the stored wastewater arising from an average year's net inflow and discharge, it can deal with rainfall runoff without overflowing. The EPA requires a minimum 600-mm freeboard to prevent overflow arising from normal rainfall events and wind-driven waves. A one-in-25-year, one-day duration storm event on the contributing catchment (with rainfall intensity based on the local catchment area and runoff estimated in accordance with procedures set out in *Australian Rainfall and Runoff—a guide to flood estimation*) has traditionally been used as a guide. However, as consequences of overflow could vary depending on location and community sensitivities, it is recommended that a risk assessment be undertaken to determine the appropriate lagoon capacity or freeboard allowance for a particular scenario.

The cost of wastewater management is proportional to the volume of water handled by the system. The EPA strongly recommends that stormwater inflows from other areas be minimised by raising lagoon embankments and diverting clean stormwater from the lagoon.

Any overflow should be treated as contaminated wastewater and captured on site. This overflow could be returned to the lagoon when capacity permits, or transported to an EPA licensed wastewater facility capable of accepting the liquid.

[15] Stress cracking within seams, which is a function of the stress cracking resistance of the specific HDPE resin and the effectiveness of its antioxidant additives often arises from overheating of the seams and geomembrane during installation (Peggs 2003).

Embankments

The sides should generally have batter slopes not exceeding a gradient of one vertical to three horizontal (1:3:) to enable proper access during compaction of the liner and embankment fill, and during subsequent sampling, testing and maintenance activities. The embankments must be constructed to prevent leakage beneath the wall. In the case of clay-lined lagoons, the mechanical strength of the wall must be able to withstand erosion from rainfall and stormwater runoff. The internal faces must also be protected from erosion that might be caused by wind-driven waves. Lagoon banks must be kept free of vegetation to prevent liner damage. Trees must not be allowed to grow in either the base or banks of the lagoon.

Construction Quality Assurance (CQA)

The EPA may require *Level 1 Supervision* for clay-lined lagoons. The primary objective of Level 1 inspection and testing is for the Geotechnical Inspection and Testing Authority (GITA) to be able to express an opinion on the compliance of the work. GITA will have competent personnel on site at all times while earthwork operations are undertaken. Under *Level 1 Supervision*, GITA is required to provide a report setting out the inspections, sampling and testing it has carried out, and the locations and results.

The EPA may accept *Level 2 Supervision* if it could be justified that the risks posed by the proposed lagoon is low, or if appropriate engineering measures are to be incorporated for risk management. In the case of *Level 2 Supervision*, a GITA officer will be appointed to carry out sampling and testing as required. On completion of the earthworks, GITA may be required to provide a report; however GITA will not be in a position to express any opinion as to the compliance of the works with the specifications or their suitability for any particular purpose.

Guidance on EPA CQA requirements for clay lining installation, geosynthetic liner placement and subgrade preparation is provided in Guidelines for construction specification and documents for landfills, composting facilities and wastewater lagoons (currently in draft).

Other design considerations

Lagoon design and construction consideration should include provisions for desludging, access for sampling and inspection, leakage monitoring, and security provisions.

Sampling and inspection access

In general, a geomembrane liner which is normally exposed to sunlight and weathering will have a shorter service life than one which is submerged. The performance of the liner should be evaluated through regular leakage monitoring and visual inspections to ensure that it remains an effective pollution barrier. The manufacturer's product warranty and advice on the anticipated service life should be considered when undertaking repairs and scheduling replacements. Regular sampling and monitoring of wastewater quality is often necessary to assess ongoing lagoon effectiveness and determine pollutant loads. Proper access should be provided to enable these activities to be undertaken.

Leakage detection

Leakage detection can be undertaken using a number of methods including water balances and groundwater monitoring. Electrical methods are also available for leakage detection in geomembrane-lined lagoons[16]. However, to date the installation of leakage detection systems during construction has proved to be the most effective method to assess the ongoing integrity of the liner. Such systems are normally designed using geocomposite drainage layers under the top liner, draining at a minimum grade of 1% to a sump, which must be located at the lowest point of the lagoon. Liner

[16] These methods are based on the premise that a geomembrane liner is an effective insulation, and that if an electrical potential is applied across the thickness of a geomembrane, the only way a significant current can flow is through a hole in the seam (Peggs 1990)

manufacturer and installers can recommend lagoon leakage detection technologies that are suitable for a specific application.

Desludging provisions

When deciding on the size and shape of the lagoon, consideration should be given to how the lagoon will be emptied and desludged. The lagoon should be designed to allow access for desludging. In the case of large lagoons, access from a number of locations may be required. Lagoons that are too large are normally difficult to desludge. If desludging equipment is to be used within the lagoon, care must be taken to avoid liner damage and to immediately repair any damage sustained.

Lagoons with synthetic liners are often more difficult to clean out. Proponents are advised to seek guidance from their liner manufacturer or installer on appropriate desludging methods. Sludge normally contains organics and nutrients that may be beneficial to crops as a soil enhancer. However, lagoon sediments could also accumulate toxic metals and other potentially hazardous substances over time. Prior to spreading this material onto land, reference must be made to the *Standard for the production and use of waste derived soil enhancers* (currently in draft).

Security provisions

Lagoons can attract both humans and animals for water supply. Well-formed crusts can also conceal the presence of anaerobic ponds. Lagoons used in mining projects can contain hazardous materials and are often located in remote areas. For these reasons, the EPA recommends that adequate fencing, bird deterrents and signage be installed around lagoons where appropriate. Fencing would also ensure that wandering livestock and other animals cannot damage the membrane liner.

Decommissioning

Prior to decommissioning a lagoon, an Environmental Site Assessment (ESA) may be required to check the suitability of the site for any intended future use. Guidance on ESA is provided in *EPA Guidelines for the assessment and remediation of groundwater contamination* (February 2009).

Further reading

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——2007, *Regulatory monitoring and testing—Groundwater sampling*, EPA, Adelaide.

——2007, *Regulatory monitoring and testing—Water and wastewater sampling*, EPA, Adelaide.

——2007, *Environmental management of landfill facilities (Municipal Solid Waste, and Commercial and Industrial General Waste),* EPA, Adelaide.

——2009, *Wastewater Irrigation Management Plan—a drafting guide for licencees,* EPA, Adelaide.

——in preparation, *Code of practice for wastewater overflow management,* EPA, Adelaide.

Legislation

Development Act 1993 (and Regulations)

Environment Protection Act 1993

Environment Protection (Water Quality) Policy 2003

Environment Protection (Site Contamination) Regulations 2008

Disclaimer

This publication is a guide only and does not necessarily provide adequate information in relation to every situation. This publication seeks to explain your possible obligations in a helpful and accessible way. In doing so, however, some detail may not be captured. It is important, therefore, that you seek information from the EPA itself regarding your possible obligations and, where appropriate, that you seek your own legal advice.

Further information

Legislation

Legislation may be viewed on <www.legislation.sa.gov.au>

Copies of legislation are available for purchase from:

Service SA Government Legislation Outlet	Telephone:	13 23 24
Adelaide Service SA Centre	Fax:	(08) 8204 1909
108 North Terrace	Website:	<shop.service.sa.gov.au>
Adelaide SA 5000		

For general information please contact:

Environment Protection Authority	Telephone:	(08) 8204 2004
GPO Box 2607	Facsimile:	(08) 8124 4670
Adelaide SA 5001	Freecall (country):	1800 623 445
	Website:	<www.epa.sa.gov.au>
	Email:	<epainfo@epa.sa.gov.au>

APPENDIX 1 Risk Assessment Matrix

Instructions: Select one category under each criteria by inserting 'Y' in the blue column opposite the category. Additional explanations are provided in Appendix 3. The required information must be provided by proponents or their consultants to complete the assessment. Seek assistance from a hydrogeologist or wastewater expert if required.

	Assessor:	Site:			
		Points	**Yes/No**	**Score**	**Notes**
1	**Groundwater occurrence**				
1a	none	0			
1b	confined	0.2			
1c	semi-confined	2			
1d	unconfined (covered)	6			
1e	unconfined	10			
2	**Aquifer type**				
2a	Clay or crystalline rock	0.25			
2b	Silt, fractured rock or limestone	3.75			
2c	Sand,gravel or Fill	10			
3	**Min distance of groundwater from base of lagoon liner**				
3a	greater than 50m	0			
3b	>20 m to 50 m	0.1			
3c	>10 m to 20 m	1			
3d	>5 m to10 m	2			
3e	>2 m to 5 m	6			
3f	2 m or less	10			
4	**Groundwater usage**				
4a	Not Likely	0.5			
4b	Possible	2.5			
4c	Current	10			
5	**Groundwater salinity**				
5a	>10 000 mg/L	0			
5b	>5,000 to10,000 mg/L	0.2			
5c	>1,500 to 5,000 mg/L	3			
5d	1,500 mg/L or less	10			
6	**Volume of wastewater**				
6a	Small (5 ML or less)	0.2			
6b	Medium (>5 ML to 10 ML)	1.2			
6c	Large (>10 ML to 30 ML)	4.8			
6d	Very Large (>30 ML)	10			
7	**Max lagoon water level** (normally relates to the type of lagoon)				
7a	1 m or less (evaporative)	0.2			
7b	>1 m to 3 m (aerobic/facultative)	1.2			
7c	>3 m to 6 m (anaerobic)	4.8			
7d	deeper than 6 m	10			
8	**Nature of wastewater** (see IOP for examples and definitions)				
8a	contaminated stormwater	0.2			
8b	treated wastewater	0.8			
8c	composting/landfill	4.2			
8d	organic/nutrient	4.2			
8e	reactive	6.4			
8f	hazardous	10			

Rating 0.0

Preliminary category 1

A. Lagoon within 100 m of a watercourse?

Don't forget to select appropriate button

N	
	1

B. Groundwater <2m from base of lagoon liner?

Don't forget to select appropriate button

N	
	1

FINAL CATEGORY 1

FOR ASSESSOR: If result is not supported, notify relevant officer on 8204 2016

Suggest Recommended Category:

FOR MANAGER/PEER REVIEWER:

Result/recommended category supported (circle relevant option) Signature_________________________ Date: ________________

Appendix 2 Table of suggested construction and lining categories

1 The EPA may consider an alternative lining technology other than those suggested in this table provided the proponent can demonstrate that it would achieve a similar or better outcome than that prescribed under the relevant category.

2 The EPA may consider an alternative level of supervision for clay lining if proper engineering controls are to be put in place for risk management.

3 Please refer to Appendix 3 for definition of key technical terminologies.

	Ponds lined with clay materials		**Ponds lined with geomembrane materials**			
	Category 1	**Category 2**	**Category 3**	**Category 4**	**Category 5**	**Category 6**
Suggested minimum requirements	• Minimum 300 mm thick low permeability clay liner (or 2 layers with minimum of 150 mm compacted thickness each) or 7 mm thick GCL. • Clay materials should be of such quality to prevent infiltration of wastewater beyond the thickness of the liner. • 150 mm of sand cushion above the subgrade if GCL is used. • Submit an As Constructed Report (ACR) to the EPA.	• Minimum 300 mm thick compacted clay liner with $k \leq 1x10^{-9}$ m/s* (or 2 layers with minimum of 150 mm compacted thickness each) or 7 mm thick GCL. • Clay materials used should have a Liquid Limit (LL) $\geq$30% and a Plasticity Index (PI) $\geq$10. • Level 1 supervision for clay lining • Construction Quality Assurance (QCA) plan for GCL placement if GCL is used • 150 mm sand cushion above the subgrade if GCL is used.	• 1 mm thick HDPE or greater[#] • Leakage detection required • Submit ACR to the EPA	• 1 mm thick HDPE or greater[#] • CQA plan for HDPE placement • CQA plan for subgrade preparation. • Leakage detection required. • Submit ACR to the EPA.	• Double HDPE lining (1 mm thick or greater for each liner)[#] **or** • A combination of HDPE liner as in category 4 with a clay liner as in category 2 • CQA plan for subgrade preparation. • CQA plan for HDPE placement. • Leakage detection required • Submit ACR to the EPA.	• Site generally not suitable for wastewater lagoon construction unless effective drainage control is put in place • If to be allowed, apply category determined following question(a) plus drainage provision.

	Ponds lined with clay materials		Ponds lined with geomembrane materials			
	Category 1	Category 2	Category 3	Category 4	Category 5	Category 6
		• CQA plan for subgrade preparation • Submit ACR to the EPA.				
Subgrade	minimum150 mm subgrade preparation to provide a sound and stable base for liner construction or installation. Subgrade preparation should include compaction until no rutting or pumping is observed. Workmanship should be supervised by a suitably qualified and experienced professional.					

* $1x10^{-9}$ m/s = 31.5 mm/yr

[#] Appropriate thickness of HDPE liner must be determined by the proponent's engineer/consultant based on wastewater characteristics, climatic factors, warranty considerations, etc.

Geosynthetic materials include High Density Polyethylene (HDPE) geomembranes and geosynthetic clay liners (GCL).

Appendix 3A Explanation of terms used in Appendix 1

Groundwater occurrence could be classified as:

- **Confined** – if aquifer is bound above and below by a confining bed with a low hydraulic conductivity that does not transmit water in any appreciable amount, if at all.
- **Semi-confined** – if aquifer is confined by a low permeability layer that permits water to flow through it slowly. Recharge to the aquifer can occur across the confining layer during pumping of the aquifer.
- **Unconfined** – if there are no confining beds between the zone of saturation and the surface. There will be a water table in an unconfined aquifer.
- **Unconfined (covered)** – if the same as unconfined aquifer but covered by permeable geologic formations, either solid rock or unconsolidated sediments.

Groundwater usage could be classified as:

- **Not likely** – if there is a low potential for the beneficial use of the local groundwater in the future.
- **Possible –** if the aquifer could be used for future potable, recreational irrigation and industrial uses.
- **Current** – if groundwater bores are present (whether in use or not) to draw water for the various uses outlined above.

Types of lagoons include:

- **Evaporative** – a shallow, uncovered lagoon with large surface area designed for the purpose of wastewater disposal by evaporation.
- **Aerobic** – a lagoon where wastewater is stabilised by biological activity utilising oxygen either through natural or enhanced aeration.
- **Facultative** – a lagoon that is generally deeper than aerobic pond, and where wastewater is treated by bacterial action occurring in an upper aerobic layer, middle facultative layer and lower anaerobic layer.
- **Anaerobic** – a deep lagoon generally free of dissolved oxygen to promote anaerobic conditions. Anaerobic lagoons are generally used to treat high-strength wastewater due to the lower energy requirement and lesser biomass production rates.

Nature of wastewater varies as follows:

- **Contaminated stormwater** – if stormwater contains pollutants above the concentrations listed in Schedule 4 of the *Enviroment Protection Water Quality Policy 2003* or any material that could be reasonably prevented from entering the pipes, gutters and other channels used to collect and convey the stormwater. Depending on pollutant nature and concentration in stormwater, it is also possible that this water could be classified more appropriately under the other categories listed below.
- **Treated wastewater** – if wastewater has undergone secondary and/or tertiary treatment and where the residual contaminants pose low risk to the receiving environment. This includes highly treated effluent from municipal treatment works and Community Wastewater Management Schemes (CWMS).
- **Composting/landfill leachate** – any liquid that has come into contact with or generated from composting or landfill activities.
- **Organic/nutrient-rich** – includes untreated or partially treated sewage or wastewater from food processing or agriculture-based industries such as abattoirs, rendering plants, dairies, cheese factories, fruit processing facilities, aquaculture, piggeries, saleyards, and cattle feedlots. These types of wastewater could also be classified as treated wastewater if further treatment or cleaner production measures have been undertaken to reduce nutrients and salts to levels comparable to secondary and/or tertiary treated sewage effluent.

- **Reactive** – acidic, alkaline or highly saline wastewater such as untreated or partially treated wastewater from distilleries, wineries and reject streams from reverse osmosis plants.
- **Hazardous** – includes wastewater generated by chemical, manufacturing and mining industries.

Appendix 3B Explanation of terms used in Appendix 2

Plasticity Index	The Atterberg Limits consists of two parameters; the plastic limit and the liquid limit. The ***plastic limit*** (PL) is defined as the moisture content in percent, at which the soil crumbles, when rolled into threads of 3.2 mm in diameter. The plastic limit is the lower limit of the plastic stage of soil. The moisture content of a soil at the point of transition from plastic to liquid state is the ***liquid limit*** (LL). The ***plasticity index*** (PI) is the difference between the liquid limit and the plastic limit of a soil [PI = LL - PL]. Generally, clay soils for low plasticity liner construction would have a plasticity index of greater than 10%.
Permeability coefficient	The flow of water through porous medium can be expressed as follows: **v = ki** where: **v** = discharge velocity, which is the quantity of water flowing in unit time through a unit gross cross-sectional area of soil at right angles to the direction of flow; **k** = hydraulic conductivity (otherwise known as the coefficient of permeability); **i** = hydraulic gradient. Hydraulic conductivity is generally expressed in cm/sec or m/sec.
As constructed report (ACR)	A documentation of work performance and Construction Quality Assurance (QCA) associated with a construction project. Guidance on drafting an ACR is provided in Guidelines for construction specifications and documents for landfills, composting facilities and wastewater Lagoons (currently in draft).
Level 1 Supervision	A CQA requirement for clay-lined infrastructures. The Geotechnical Inspection and Testing Authority (GITA) needs to have competent personnel on site at all times while the following earthwork operations are being undertaken: • completion and removal of topsoil • placing of imported or cut material • compaction and adding/removal of moisture • trenching and backfilling, where applicable • test rolling • testing. On completion of the earthworks, the GITA is required to provide a report setting out the inspections, sampling and testing it has carried out, and the locations and results thereof. Further information on *Level 1* and *Level 2 Supervision* is provided in Guidelines for construction specifications and documents for landfills, composting facilities and wastewater Lagoons (currently in draft).

Level 2 Supervision	A lower level of QCA for clay-lined infrastructures. A Geotechnical Inspection and Testing Authority (GITA) officer will be appointed to carry out sampling and testing as required. The GITA is responsible for selecting the location of sampling and testing operations within each visit made to the site. The superintendent is responsible for advice as to when such visits are required and is responsible for ensuring that sufficient samples and tests are taken during the duration of the earthworks. On completion of the earthworks, the GITA may be required to provide a report; however the GITA will not be in a position to express any opinion as to the compliance of the works with the specifications or their suitability for any particular purpose. Further information on *Level 1* and *Level 2 Supervision* is provided in Guidelines for construction specifications and documents for landfills, composting facilities and wastewater Lagoons (currently in draft).

Appendix 4A Particle size distribution and plasticity limits of materials suitable as clay liners

Particle size distribution

AS metric sieve size (mm)	Percentage passing (by dry weight)
75	100
19	>90
2.36	>70
0.075	>30
Plasticity limits on fines fraction, passing 0.425 mm sieve	
Liquid Limit (LL)	30-60%
Plasticity Index (PI)	≥10%

Appendix 4B Specifications for GCL and HDPE liners

Minimum properties for various geosynthetic lining materials for base liner systems provided below are reproduced from the Guidelines on environmental management of landfill facilities (Municipal Solid Waste and Commercial and Industrial General Waste) (2007)

A Geosynthetic clay liner (GCL)

Property	Value	Test method ASTM
Mass of top and bottom geotextile	>100 g/m^2	D5261
Mass of sodium bentonite or	>3,000 g/m^2	D5993
Mass of calcium bentonite	>6,000 g/m^2	–
Bentonite swell index	>16 mL/2g	D5890
Peel strength	>300 N/m	D6496

B High Density Polyethylene (HDPE) geomembrane (smooth or textured)

Property	Value	Test method ASTM
Density	≥0.94 g/cm^3	D1505
Thickness	≥1mm	D5994
Elongation at break (smooth liner)	≥700%	D6693
Elongation at Break (textured liner)	≥100%	D6693
Elongation at yield	≥12%	D6693
Puncture resistance	≥400N	D4833
Notched content tensile test resistance	≥300 hours	D5397
Carbon black content	2–3%	D1603
Standard oxidative induction time (OIT)	>100 minutes	D3895
Oven aging at 85°C	>55%	D3895