Government of Western Australia
Department of Water

Looking after all our water needs

Water quality protection note 26
August 2013

Liners for containing pollutants, using synthetic membranes

Purpose

Waste stabilisation ponds and holding compounds for solid materials are widely used to contain matter that is either undergoing microbiological stabilisation or needs to be contained to prevent leaching of harmful contaminants into the surrounding environment. Natural soils, such as sands and gravels, often provide poor seepage control and therefore constructed containment liners are needed to limit leakage. This note describes the properties of synthetic membrane lining materials, such as plastics or composites, used to contain wastewater or solids that may leach contaminants when exposed to rainfall.

The Department of Water is responsible for managing and protecting the State's water resources. It is also a lead agency for water conservation and reuse. This note offers:

- our current views on synthetic membrane liners for ponds and solid material holding systems used to contain fluids and potentially mobile contaminants
- guidance on acceptable practices used to protect the quality of Western Australian water resources
- a basis for the development of a multi-agency code or guidelines designed to balance the views of industry, government and the community, while sustaining a healthy environment.

Appendices provide additional advice relevant to this note, including:

A. Information on sensitive water resources, note limitations and updates
B. Relevant statutes and administering agencies
C. Materials commonly used in non-rigid waste containment systems, followed by references, note disclaimer and how to provide feedback.

Scope

This note applies to the synthetic lining of structures used for holding low hazard materials that may pollute sensitive water resources (Appendix A).

Holding structures may include:

- aquaculture ponds
- containment facilities for municipal sewage or animal wastes
- storage for mineral processing fluids

- contaminated dewatering effluent unsuitable for reuse or soakage disposal
- solid residue holding areas for mining or mineral processing waste or sediment. The liner forms a barrier to protect the environment, limiting residue escape that may harm the quality of water resources and assists with effluent recycling.

The note is not intended to apply to:

- Containment of matter that may present a high contamination risk to the surrounding environment or downstream water users such as the long-term storage of radioactive or persistent soluble toxins. Such containment systems may have specific design and operating requirements resulting from a comprehensive environmental impact assessment followed by ministerial conditions, works approval and/or licensing in accordance with the *Environmental Protection Act 1986*.
- Chemical, bitumen and asphalt materials applied to soil to produce surfaces that are trafficable, of low permeability and erosion resistant.
- Engineered soil liners (commonly referred to as clay liners). For guidance on soil liners see Water quality protection note (WQPN) 27 Liners for containing pollutants, using engineered soils (reference 3c).

Regulatory constraints

Synthetic liners may be required by regulatory agencies to contain or limit discharges from stored matter such as leachate from ponds or waters contained within solids storage pits. Details of statutory controls are summarised in Appendix B.

Advice and recommendations

1 Selection of any containment liner system should consider:

   a the hazard posed by the contained material
   b the liner's design minimum permeability
   c susceptibility of the liner material to chemical or insect attack, or deterioration while in service (such as resistance to ultraviolet solar radiation where liner is exposed)
   d tensile strength and elasticity
   e thermal stability
   f puncture, shear resistance and abrasion resistance
   g anticipated operational life required for effective containment
   h local environmental conditions, including subsoil stability
   i environmental values (uses) and vulnerability of local water resources.

2 Potentially harmful contaminant material storages near sensitive water resources should have more secure containment structures. Typically, mining and heavy metal residues stored near conservation reserves, wetlands or drinking water sources require more secure containment than animal waste slurry ponds in low sensitivity rural catchments.

3 If local soils are highly permeable (such as coarse sand, gravel or karst formations) more reliance is placed on the liner to contain leachate movement than in locations with natural low permeability, fine textured soils such as clays, silts or unweathered rock.

4 Commonly used flexible liner materials are:

   a polyvinyl chloride (PVC)

   b high density polyethylene (HDPE)

   c flexible polypropylene (FPP)

   d chloro-sulfonated polyethylene (CSPE) marketed as Hypalon®

   e ethylene propylene diene terpolymer (EPDM)

   f composite materials such as fibre reinforced plastics, combinations of polypropylene mats and bentonite, and chloro-sulfonated polyethylene.

   Naturally occurring or engineered low permeability soils are described in WQPN 27 *Liners for containing pollutants, using engineered soils* (reference 3c).

5 Liner support systems include:

   a geotextiles used to prevent incompatible soils from blending, while allowing for the passage of fluids

   b contaminant filtering substances such as crushed limestone, activated carbon beds and sandy loams.

   A summary of properties of commonly used liner systems is provided at Appendix C.

6 All liners should be installed on a stable soil sub-base. The underside of the lowest liner should be at least 2 m above the highest wet season watertable, unless:

   a effective underdrainage measures are installed to prevent upward water pressure on the liner

   b allowance is made for any mounding of the watertable that may result from seepage from the containment compound.

7 All lined storage compounds should have stormwater control facilities to minimise embankment erosion. They should also have sufficient freeboard (at least 50 cm) maintained to prevent unintended overflow of water from storms with an average return frequency of at least 20 years (see reference 4), plus capacity to store rainfall resulting from a 90 percentile wet season, after allowance for any evaporative water loss and the effects of any water reuse recovery system.

Lining materials

8 All synthetic fluid containment liners should have a coefficient of permeability of less than 2×10^{-10} m/s (which equates to about 6 mm/year seepage) when tested using the American Society for Testing and Materials (ASTM) method D4716 (reference 1). For non-specified materials test methods, refer to US EPA recommendations on materials testing (reference 7a).

9 Liners should be constructed on gradients of less than 1 in 3**,** unless appropriate engineering methods are used to prevent liner slippage.

10 Liners that adequately resist shear forces should be used as seepage barriers to cover degradable or partly compacted materials likely to shrink or consolidate over time.

High density polyethylene geo-membranes

11 HDPE liners should have the following properties:

a minimum thickness of 0.75 mm (tolerance of up to 5%) for low hazard waste containment with mechanical jointing

b HDPE liners of 1.5 mm thickness are recommended for long-term containment facilities with heat welded joints

c specific gravity of 0.94 or more (ASTM method D1505)

d melt index of 0.05 g to 0.30 g in 10 minutes (ASTM method D1238, condition E 190/ 2.16)

e carbon black content of 2–3% (ASTM method D1603)

f minimum tensile strength at yield of 16 000 kN/m^2

g minimum tensile strength at break of 550 kN/m^2 (ASTM method D638, type IV 2)

h minimum elongation at yield of 10%, and at break 300% (ASTM method D638).

12 The liner should be fabricated to form the shape of excavation. All seams and joins made on site should be continuous. Panels of the liner should be overlapped by a minimum of 100 mm, prior to heat welding or mechanical jointing.

13 Any membrane welding materials should be supplied by the liner manufacturer, and should be identical with the liner membrane.

14 All seams and joins should be constructed and tested as watertight over their full length using a vacuum test unit, air pressure testing or other approved method used in the HDPE membrane industry.

15 Where fluid recovery from consolidating slurries and/or monitoring of integrity against seepage for multi-liner containment systems is needed, liners should grade to sumps connected to accessible monitoring or recovery wells to permit seepage collection by gravity. The liner should grade at not less than 1 in 100 to the sump. Herringbone pipe-work underdrainage systems may be used to assist fluid recovery.

16 HDPE liners should not be used on soils subject to differential movement (settling) as they have a low resistance to shearing and stress cracking. Low density polyethylene liners have recently been introduced to lessen these problems, but may be less resistant to abrasion, ultraviolet light and chemical attack than HDPE.

17 HDPE liner shear resistance should be tested in accordance with ASTM D5321-02.

Polyvinyl chloride liners

18 PVC liners should have a minimum thickness of 0.5 mm for low hazard waste containment, with a tolerance of 5% for short-term containment applications. A minimum thickness of 0.75 mm is recommended for long-term containment applications.

19 PVC exposed to sunlight during its operational life should be restricted to short-term projects (i.e. less than three years) due to susceptibility to ultraviolet radiation damage. Longer operational life may be achieved if the liner is buried.

20 PVC liners should not be used to contain materials incompatible with PVC such as cyanide or petroleum hydrocarbons.

21 PVC is better suited to disturbed ground than HDPE, as the properties of PVC liners allow considerable stretching before liner shear failure.

22 Where PVC is used, appropriate protection should be in place to reduce the possibility of rodent or termite attack on the liner material. Mesh barriers or approved residual pesticides should be considered.

Composite membranes

23 Composite liner systems involve 'sandwiches' made up of several different materials. They include polypropylene mesh encasing bentonite (absorbent aluminium silicate clay) commonly referred to as a geo-synthetic clay liner (GCL), ethylene inter-polymer alloy with high strength reinforcing fibres and fibre reinforced plastics e.g. CSPE (Hypalon ®). The use of these materials should be considered on a case-by-case basis, based on their suitability for the intended containment use, operational life and the local environmental setting.

Other membranes

24 Other synthetic membranes available include reinforced chlorinated polyethylene (CPER), ethylene propylene diene monomer (EPDM), butyl rubber and polyurethane coated geo-textile. Each membrane exhibits differing tensile strength, elasticity, resistance to degradation and chemical attack characteristics. These membranes should be selected on the basis of their suitability to the containment application and have a minimum thickness of 0.75 mm for long-term containment applications.

Geo-textiles

These consist of woven or felt fabrics designed to separate soils with differing particle sizes or properties, while allowing the passage of water.

25 Fabrics should be designed to resist deterioration or microbial attack over indefinite periods when buried.

26 Any geo-textile used as a backing to a liner should be a minimum thickness of 2.5 mm, be certified as needle free and weigh a minimum of 280 g/m^2.

27 Geo-textiles should be lapped or bonded in accordance with manufacturer's recommendations to provide a continuous protective layer.

Monitoring

28 The effectiveness of any lined containment should be determined by monitoring contained fluid balances, standing watertable levels and groundwater quality adjacent to the site. For guidance on monitoring, see WQPN 30 *Groundwater monitoring bores* (reference 3d).

Appendix A: Information on sensitive water resources, note limitations and updates

Sensitive water resources

Our water resources sustain ecosystems, aquatic recreation and aesthetic values as well as providing drinking, industry and irrigation supplies. Along with breathable air, uncontaminated water is essential for viable communities. Natural water resources should remain within defined quality limits to retain their ecological, social and economic values. Hence they require appropriate protection measures to minimise contamination risks.

Information on water quality parameters and processes to maintain water values are published in the Australian Government's national water quality management strategy papers. These papers are available online at <www.environment.gov.au> select *water* > *water policy and programs* > *water quality.*

The Department of Water strives to improve community awareness of catchment protection measures (for both surface water and groundwater) as part of a multi-barrier protection approach to sustain acceptable water resource quality. Human activity and many land uses pose a risk to water quality if contaminants in significant quantities are washed or leached into water resources.

Sensitive waters include estuaries, natural waterways, wetlands and groundwater. These waters support one or more of the environmental values described below.

Public drinking water sources

Overview

Public drinking water source area (PDWSA) is the collective name given to any area proclaimed to manage and protect a community drinking water source. PDWSA include underground water pollution control areas, water reserves and catchment areas administered by the Department of Water under the provisions of the *Metropolitan Water Supply, Sewerage and Drainage Act 1909* or the *Country Areas Water Supply Act 1947*.

For online information on the location of PDWSA, see <www.water.wa.gov.au> select *tools and data* > *maps and atlases* > *geographic data atlas*, then open *environment* > *public drinking water source areas.*

Within PDWSA, priority areas are defined (P1, P2 or P3) via publicly consulted drinking water source protection plans or land use and water management strategies. Priority areas are used to guide land planning, rezoning and development approval processes. Priority areas are assigned considering the current local planning scheme zoning, land tenure, the water source's strategic value and its vulnerability to harm. Each priority area is managed using a specific risk-based strategy to provide for effective water resource protection. The Department of Water develops these documents in consultation with other government agencies, landowners, industry and the community.

P1 areas are defined to ensure human activity does not degrade a water source. These areas are declared over land where the provision of high-quality drinking water for public use is the primary beneficial land value. P1 areas typically cover land controlled by the state government or one of its agencies. These areas are managed under the principle of *risk avoidance*, so most land development and human activity is normally opposed.

P2 areas are defined to ensure there is *no increased risk of pollution* to the water source once a source protection plan has been published. These areas are declared over land where low-intensity development exists (involving rural usage such as dry land grazing or cropping). Protection of public water supply sources is a high priority in P2 areas. These areas are managed in accordance with the principle of *risk minimisation*, and so the intensity of development should be restricted (via management conditions) and activities with a low water contamination risk are normally considered acceptable.

P3 areas are defined to *manage the risk of pollution* to the water source. These areas are declared over land where public water supply sources must co-exist with other land uses such as residential, commercial and/or light industrial development. Protection of P3 areas is mainly achieved through land use management measures e.g. contamination barriers. Environmental guidance (such as these notes) or site-specific development approval conditions are used to limit the water resources contamination risk from the land use or activity. If, however, the water source becomes contaminated, then water supplied from P3 sources may need to be more intensively treated or an alternative water supply source commissioned.

Additional protection zones are defined close to the point where drinking water is extracted or stored. These zones are called *wellhead protection zones* (WHPZ) and *reservoir protection zones* (RPZ). Statutory land use constraints apply to activities within these zones surrounding sources to safeguard these waters most vulnerable to contamination.

WHPZ are assigned around water production wells based on hydrological factors. Statutory land use restrictions apply within these zones as groundwater moves rapidly towards wells due to aquifer depressurisation by pumping. Any contaminants leaching from the ground surface in a WHPZ could rapidly migrate into scheme water supplies (before effective remedial action can occur). In sedimentary basins, WHPZ are usually circular, with a radius of 500 metres in P1 areas and 300 metres in P2 and P3 areas. These zones do not extend outside PDWSA boundaries.

RPZ are defined over and around public water supply storage or pipe-head reservoirs. Statutory access and land use restrictions apply in RPZ. The aim is to restrict the likelihood of contaminants being deposited or washing into water sources in any runoff. RPZ are normally within state-controlled areas encompassing land up to two kilometres measured outward from the reservoir top water-level and include the inundated area when the reservoir is full.

For additional explanatory information on PDWSA, see Water quality protection note (WQPN) 25 *Land use compatibility in public drinking water source areas,* WQPN 36 *Protecting public drinking water source areas,* WQPN 75 *Proclaimed public drinking water source areas,* note 76 *Land use planning in PDWSA* and WQPN 77 *Risk assessment in PDWSA.* These notes are available online at <www.water.wa.gov.au> select *publications > find a publication > series browse.*

Established activities within PDWSAs

Many land use activities were approved and established before publication of a source protection plan or land use and water management strategy.

Activity operators should ensure that modern environmental facilities and practices are progressively implemented and maintained so that the water resource contamination risk is minimised (within practicable and economic constraints).

New or expanded activities in PDWSA

Any development proposals that could affect a drinking water source should be referred to this department's local regional office with detailed supporting information for an assessment and written response.

The development proposal may be:

- approved (with or without conditions)
- delayed pending receipt of additional information before a decision is made; or
- opposed due to a statutory or policy conflict or inadequate protective measures provided to safeguard the water source.

To assist the assessment, operators should demonstrate that under all operating conditions the facilities and processes used on-site do not pose a significant water contamination risk.

Buffers to water supply sources

Native vegetation buffers should be used to separate compatible land use areas from the sources of drinking water including the full supply margins of reservoirs, their primary feeder streams and/or production bores. Advice on suitable buffer forms and dimensions is provided in WQPN 6 *Vegetated buffers to sensitive water resources*.

Within clearing control catchments

Controls on vegetation clearing for salinity management in country areas are provided under part IIA of the *Country Areas Water Supply Act 1947*.

These controls apply in the Wellington Dam, Harris River Dam, Mundaring Weir and Denmark River catchment areas and the Kent River and Warren River water reserves.

Details of clearing controls may be obtained from our regional offices, see online information at <www.water.wa.gov.au>, select *Contact us*.

Private water supply sources

Private water sources vulnerable to contamination include:

- drinking water sources for people or domesticated animals
- commercial or industrial water supply sources (requiring specific qualities that support activities such as aquaculture, cooling, food and mineral processing or crop irrigation)
- urban or municipal irrigation sources (where water quality may affect vegetation performance or people's health and wellbeing).

Underground ecosystems

Important underground ecological functions that may be at risk of contamination include groundwater- and cave-dwelling animals and microorganisms (generally located within soils that have open pore spaces such as sand, gravel and limestone).

Waterway ecological and social values

Waterways that have high social and conservation significance are described in the Western Australian Environmental Protection Authority (EPA) Guidance statement 33 *Environmental guidance for planning and development*, section B5.2.2. This statement is available online at <www.epa.wa.gov.au> select *policies and guidelines* > *environmental assessment guidelines* > *guidance statements.*

The Department of Water manages natural waterways under Section 9 of the *Water Agencies (Powers) Act 1984* and the *Rights in Water and Irrigation Act 1914*. For online information, see <www.water.wa.gov.au> and select *managing water*. Apart from aquatic ecosystems and water sources, waterways provide social values including aesthetic appeal, drainage pathways and recreational opportunities for watercraft use, fishing, tourism, swimming and related aquatic activities. Engineered drains and constructed water features are normally not assigned ecological values because their primary function and operational factors outweigh their ecological value.

This department also administers the *Waterways Conservation Act 1976* which defines Western Australian waterways subject to specific regulatory controls. Currently proclaimed waterways include the Avon River, Peel-Harvey Inlet, Leschenault Inlet, Wilson Inlet and Albany waterways management areas.

Within the Swan-Canning Estuary catchment

The Swan River Trust is responsible for the protection and management of the Swan-Canning River system. The trust safeguards ecological and social values under the *Swan and Canning Rivers Management Act 2006.* Written approval is needed for any land- or water-based development within the Swan, Canning, Helena or Southern rivers and their associated foreshore areas within the *Swan River Trust development control area (DCA*). Human activity and development close to these areas are likely to have an effect on the waters of the river system. Development proposals within or abutting the DCA should be referred to the trust for assessment.

Developments outside the DCA, but near river tributaries or drainage systems should also be referred to the trust for assessment and advice. This is because water quality within the area may be affected by chemicals leached into groundwater flow. For detailed information, see online advice at <www.swanrivertrust.wa.gov.au>, phone 9278 0900 or email: planning@swanrivertrust.wa.gov.au .

Wetland ecology

Many important wetlands have been given conservation status under the Ramsar Convention (described online at <www.ramsar.org>), Japan and Australia migratory bird agreement (JAMBA), China and Australia migratory bird agreement (CAMBA), and Republic of Korea and Australia migratory bird agreement (ROKAMBA).

Wetlands are also protected under various national and Western Australian government policies. Conservation wetland data to guide land planning and development activities is provided via the following publications:

- *Directory of important wetlands in Australia* defines wetlands scheduled by the Australian Government. It is available online at <www.environment.gov.au> select *water* > *water topics* > *wetlands.*

- Wetlands with defined high conservation significance are described in the EPA (WA) guidance statement 33 *Environmental guidance for planning and development* (section B4.2.2). This statement is available online at <www.epa.wa.gov.au> select *policies and guidelines > environmental assessment guidelines > guidance statements.*

The Department of Parks and Wildlife is the custodian of the state wetland datasets, and is responsible for maintaining and updating relevant information. These datasets are available online at <www.dpaw.wa.gov.au>.

Wetlands datasets identified for conservation value or for resource enhancement include:

- *Geomorphic wetlands of the Swan Coastal Plain*
- *South coast significant wetlands*
- *Geomorphic wetlands Augusta to Walpole* (this dataset awaits detailed evaluation).

Wetlands that are highly disturbed by land use, or have been landscaped to provide a social amenity or drainage control function in urban settings, may not be assigned conservation values unless they are actively managed to maintain these values.

Note limitations

Many Western Australian aquifers, waterways and wetlands await detailed scientific evaluation, present data on their quality is sparse and their values remain unclassified. Unless demonstrated otherwise, any natural waters that are slightly disturbed by human activity are considered to have sensitive environmental values. Community support for these water values, the setting of practical management objectives, provision of sustainable protection services and effective implementation are vital to protecting or restoring water resources for both current needs and those of future generations.

This note provides a general guide on environmental issues, and offers solutions based on data searches, professional judgement and precedents. Recommendations made in this note do not override any statutory obligation or government policy statement. Alternative practical environmental solutions suited to local conditions may be considered. This note's recommendations shall not be used as this department's policy position on a specific matter, unless confirmed in writing. In addition, regulatory agencies should not use this note's recommendations in place of site-specific development conditions based on a project's assessed environmental risks. Any regulatory conditions should consider local environmental values, the safeguards in place and take a precautionary approach.

Where a conflict arises between this note's recommendations and any activity that may affect a sensitive water resource, this note may be used to assist stakeholder negotiations. The negotiated outcome should not result in a greater water quality contamination risk than would apply if the recommended protection measures were used.

Water quality protection note updates

This note will be updated as new information is received, industry/activity standards change and resources permit. The currently approved version is available online at <www.water.wa.gov.au> select *publications > find a publication > series browse > water quality protection notes.*

.Appendix B: Statutory approvals relevant to this note

What's regulated?	West Australian statutes	Regulatory body/agency
Environmental Protection Policy	*Environmental Protection Act 1986 ,* Part III Environmental protection policies	Department of Environment Regulation <www.der.wa.gov.au>
Licensing of prescribed premises that may pollute	*Environmental Protection Act 1986,* Part V Environmental regulation	
Management of human wastes Community health issues	*Health Act 1911*	Department of Health <www.health.wa.gov.au> Local government authority
Transport, storage and handling of fuels, solvents, explosive and other dangerous goods	*Dangerous Goods Safety Act 2004* Dangerous goods safety regulations 2007	Department of Mines and Petroleum – Resources Safety Division <www.dmp.wa.gov.au>
Licence to take surface water and groundwater (in proclaimed areas)	*Rights in Water and Irrigation Act 1914*	Department of Water – Regional office <www.water.wa.gov.au>
Licence to discharge waters into a managed waterway	*Waterways Conservation Act 1976*	
Industrial sites in existing public drinking water source areas	*Metropolitan Water Supply, Sewerage and Drainage Act 1909 ;Country Areas Water Supply Act 1947*	
Impact on the values and ecology of land or natural waters	*Environmental Protection Act, 1986 ,* Part IV Environmental impact assessment	Minister for the Environment with advice from the Environmental Protection Authority <www.epa.wa.gov.au>
Discharges that could enter the Swan-Canning Estuary	*Swan and Canning Rivers Management Act 2006*	Swan River Trust <www.swanrivertrust.wa.gov.au>
Development approval	*Planning and Development Act 2005*	Western Australian Planning Commission Department of Planning <www.planning.wa.gov.au> Local government (Council)

Relevant statutes are available from the *state law publisher* at <www.slp.wa.gov.au>

Appendix C: Materials commonly used in non-rigid waste containment systems

Liner materials (top layer to bottom)	Attributes
Upper granular protective layer	– Protects liner/drain system during contained material deposition – Minimises drying out of compacted soil liners – Permits recovery of residue and minimises risk of liner damage – Prevents UV light damage to PVC liners
Subsoil drains over primary liner	– Aids depressurisation of primary liners – Enhances solid residue consolidation – Enhances fluid recovery from slurries – Normally requires protection against fine solid intrusion using fabric wrap
Primary liner	
Compacted clay soil (permeability less than 10^{-9} metres/second)	– Normally won't deteriorate when in contact with stored material (see reference 3, WQPN 27)
High density polyethylene (HDPE)	– Abrasion and ultra-violet light resistant – Heat welded or lapped mechanical joints
Polyvinyl chloride (PVC)	– Will stretch before shearing in disturbed ground – May lose plasticity with time – Susceptible to UV deterioration (unless treated) – Unsuitable for retention of some chemicals such as petroleum products, which cause liner deterioration
Composite synthetic	– Plastic coated outer/fibre reinforced mesh inner liner – Polypropylene mesh encasing bentonite
Under drainage/monitoring layer (between primary and secondary liners)	
Granular layer with drain pipes to collector pit	– Permits seepage monitoring – Permits seepage recovery – Depressurises secondary liners
Geo-textile mesh or net separator, drains to collector pit	– Ease of installation – Takes up little volume
Secondary liner	
Compacted soil	– Natural or imported low permeability soil (less than 10^{-9} metres/ second when compacted)
HDPE, PVC or composite synthetic	– Liner attributes as given above
Geo-textile underlay	– Used as necessary to separate incompatible soils or prevent perforation of synthetic liners.
Liner sub-base	
External underdrainage layer	– Where necessary to prevent groundwater pressure on liner or capture/monitor liner seepage

Liner materials (top layer to bottom)	Attributes
Natural soil base layer	– Surface cleared of vegetation, free of stones exceeding 25 mm diameter and any other material that may cause damage to a liner – Clean soil fill, well-graded and compacted to provide a firm unyielding foundation sufficient to permit the movement of vehicles and welding equipment without causing rutting or other deleterious effects – Layer should be greater than two metres above maximum wet season water table

1 The greater the environmental hazard posed by contained material, the greater the need for multi-layer liner systems.

2 For storage that is designed for controlled leakage, the primary liner may be replaced with a filter medium such as limestone or activated carbon designed to attenuate specific contaminants such as phosphorus or toxic organic matter.

References and further reading

1 American Society for Testing and Materials International – ASTM standard methods available for purchase online at <www.astm.org>

a *D638* *Tensile properties of plastics*
b *D751* *Standard test methods for coated fabrics*
c *D1238* *Melt flow rate of thermoplastics*
d *D1505* *Density of plastics*
e *D1603* *Carbon black in olefin plastics*
f *D4716* *Hydraulic transmissivity of geo-synthetics*
g *D5199* *Measuring nominal thickness of geotextiles and geomembranes*
h *D5321-02* *Shear resistance of geo-synthetics*
i *D5747-08* *Standard practice for tests to evaluate the chemical resistance of geomembranes to liquids*
j *D7465-08* *Draft standard for EPDM liners used in geo-membrane applications*
k *WK 2065* *PVC liners.*

2 Australian national committee of the International Commission on Irrigation and Drainage (ICID). Information on flexible membrane materials is available online at <www.irrigation.org.au> select *publications.*

3 Department of Water Environmental guidelines and WQPNs available online at <www.water.wa.gov.au> select *publications* > *find a publication* > *series browse*:

a *Environmental guidelines for mining and mineral processing*
b WQPN 6 *Vegetated buffers to sensitive water resources*
c WQPN 25 *Land use compatibility in public drinking water source areas*
d WQPN 27 *Liners for containing pollutants, using engineered soils*
e WQPN 30 *Groundwater monitoring bores*
f WQPN 36 *Protecting public drinking water source areas*
g WQPN 39 *Ponds for stabilising organic effluent.*

4 Engineers Australia publications available for purchase online at <www.engineersmedia.com.au> search *EA books.*

Australian rainfall and runoff (current edition).

5 Price, RE and Williams, DJ 1994 *Geomembrane lining systems,* proceedings of the third international conference on environmental issues and waste management in energy and mineral production, pp. 573-577, Curtin University of Technology, WA.

6 Standards Australia publications available for purchase at <www.saiglobal.com> select *publications* > *Australian standards*

AS 1289 – Methods of testing soils for engineering purposes.

7 United States Environmental Protection Authority Washington DC 1999

a *Proposed guide for industrial waste management for public comment* (EPA530-R-99-001).

b *Technical guidance document: Quality assurance and quality control for waste containment facilities* 1993.

Disclaimer

Feedback

We welcome your thoughts on this note. Feedback will help us prepare future versions.To comment on this note or seek any clarification, please contact our water source protection planning branch (details below), citing the note topic and version.

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