Victorian Landfill BPEM Comparison Table - Appendices

Item	BPEM Requirement	Comment
A	**Appendix A - Summary of Implementation Requirements**	
	Nil technical content	
B	**Appendix B – Technical Guidance**	
B1	**Clay Properties**	
	Clay to be used in liners should have the following properties: • No rock or soil clumps greater than 50 mm in any direction. • More than 70 per cent passing through a 19 mm sieve. • More than 30 per cent passing through a 75 µm sieve. • More than 15 per cent passing through a 2 µm sieve. • Soil plasticity index exceeding 10.	Not applicable. No compacted clay liner.
	A cation exchange capacity (CEC) of 10 mEq/100g is a recommended level for clay to be used in a best-practice landfill.	Three samples of typical clay quarry base material were analysed by SGS Laboratory in November 2014. The samples recorded a cation exchange capacity of 3.3; 6.0 and 5.7 mEq/100g. The results are less than the threshold of "about 10 mEq/100", which is consistent with the natural material being more of a schist type material as opposed to a clay. The cation exchange capacity is a function of the natural occurring soils on site and cannot be influenced by design or engineering solutions. The laboratory analysis results are available if required.
	There is a potential for the clay to degrade through clay-pollutant chemical reactions over a long period of time. To guard against this risk, long-term permeation tests should be conducted on the clay to assess any variations in intrinsic permeability over the long term. Kodikara & Rahman (1997) suggest that using a 50,000 ppm NaCl solution over two to three months should indicate any such long-term variations.	Not applicable. No compacted clay liner.
B2	**Installation of Clay Liners**	
	Before a clay is used to construct a liner, samples of the clay to be used should be submitted to a laboratory for determination of the soil properties for a range of compaction efforts. This will enable the development of laboratory compaction and hydraulic conductivity curves, which should be assessed to determine the suitability or otherwise of the material as a low-permeability barrier.	Not applicable. No compacted clay liner.
	Figure B.1 shows the effect of moulding water content (moisture content of the clay when compacted) and the dry density of the clay (dry unit weight). Maximum dry density is achieved at the optimum moisture content. The	Not applicable. No compacted clay liner.

	lowest hydraulic conductivity of the compacted clay liner is achieved when the soil is compacted at a moisture content slightly higher than the optimum moisture content.	
	By specifying compaction to be undertaken at a percentage above optimum moisture content to achieve a density defined as a percentage of maximum dry density, an envelope or 'acceptable zone' of performance criteria can be derived for undertaking quality control checks in the field both during and after construction. Best practice is to compact the clay at about two to three per cent wet of optimum moisture content to a maximum dry density of 95 to 98 per cent of Proctor Standard.	Not applicable. No compacted clay liner.
	Clay liners are constructed in series of 'lifts' compacted to the required maximum dry density at the specified moisture content. To achieve bonding between each lift, the thickness of each lift must permit the compaction equipment, typically a sheepsfoot roller, to penetrate the top lift and knead the previous lift. Scarification of the previous lift may also be required to improve bonding. This bonding is required to overcome the effects of imperfections within individual lifts. By bonding each successive lift with the preceding lift and using a minimum of four to six lifts, the hydraulic conductivity of the liner can be optimised.	Not applicable. No compacted clay liner.
	The final surface of a compacted clay liner should be finished to a smooth surface. This minimises the surface area of the liner (thereby reducing the loss of moisture from the liner), promotes the rapid drainage of leachate on top of the liner and allows the installation of a geomembrane liner.	Not applicable. No compacted clay liner.
B3	**Drainage Aggregate**	
	Recommended properties are: • Drainage layer aggregate size to be less than 50 mm and greater than 20 mm. • Fines content to be less than one per cent. • Aggregate material should not contain limestone or other calcareous material that would be subject to chemical attack.	The construction specification confirms these requirements.
B4	**Giroud's Equation**	
	Giroud's equation is used to derive the required spacing between subsurface drainage pipes given the maximum permissible head over the pipes and a number of physical parameters.	With the leachate drainage aggregate having an extremely high permeability, the vast majority of the leachate will flow through the aggregate (path of least resistance) and not enter the drilled leachate collection pipes. Consequently, no pipe flow calculation has been conducted and the maximum pipe spacing of 25 m (Refer Section 6.3.5) has been adopted.
B5	**Calculation of Area Required for Evaporation of Leachate**	
	If evaporation is to be used as the primary means of disposing of leachate, then an appropriately sized pond needs to be designed to ensure that the system can handle the volume of leachate expected to be generated over a	This is the formula that has been used to calculate the evaporation area required.

	year. This can be calculated by using the following formula: *A = 1,000V/(0.8E-R)* Where: A= pond surface area (m^2) V = annual volume of leachate (kL or m^3) E = median annual evaporation (mm class A pan) R = median annual rainfall (mm).	
B6	**Landfill Gas Generation**	
	Figure B.3 – Idealised representation of Landfill Gas Generation	For information only.
B7	**Design of Landfill Gas Monitoring Bore Systems**	
B7.1	**Overview**	
	The aim of a landfill gas monitoring bore system is to intercept any landfill gas escaping laterally from the site and identify its location. As such, landfill gas monitoring bores must be installed at appropriate locations, drilled to depths suitable to intercept all gas movement paths, constructed appropriately to intercept gas and should be determined based on the findings of the landfill gas risk assessment. The following are key factors: • Bore location and spacing. • Bore depth. • Bore construction design. • Bore installation construction quality assurance.	Due to there being no non-landfill related structures within 250 m of the landfill (the BPEM only deals with structures within 250 m), there is no requirement for landfill gas monitoring bores. In addition, the naturally occurring low permeability soils and the fact that there are no interconnecting services between the landfill and the nearest non-landfill structure means that landfill gas impact on this structure is an extremely unlikely occurrence. The nearest structure is a single residential property 400 m to the south west.
	Typically, it is expected that a landfill gas monitoring bore system will: • Target sensitive receptors such as dwellings. • Encircle the entire landfilled waste mass. • Be installed into the local geology (not into waste or fill materials). EPA recommends that landfill gas monitoring bores are sited at least 20 metres from the boundary of the landfilled waste, to ensure validity of the landfill gas monitoring data subsequently obtained.	Not applicable. No landfill gas monitoring bores required.
B7.2	**LFG Monitoring Bore Location and Spacing**	
	The location and spacing of landfill gas monitoring bores are site-specific requirements and governed by the findings of the landfill gas risk assessment. Table B.2 provides recommended bore spacings. The audit of the site must include a site-specific monitoring network, that has been verified by an EPA-appointed environmental auditor.	Not applicable. No landfill gas monitoring bores required.
	Bore spacing greater than the recommended maximum distance must be justified with valid reasons and information.	
	Table B.2 – Recommended LFG Monitoring Bore Spacing: • Uniform low-permeability strata (e.g. clay); no development within	Not applicable. No landfill gas monitoring bores required.

	250 metres: Min 50 m; Max 150 m. • Uniform low-permeability strata (e.g. clay); development within 250 metres: Min 20 m; Max 50 m. • Uniform low-permeability strata (e.g. clay); development within 150 metres: Min 10 m; Max 50 m. • Uniform matrix-dominated permeable strata (e.g. porous sandstone); no development within 250 metres: Min 20 m; Max 50 m. • Uniform matrix-dominated permeable strata (e.g. porous sandstone); development within 250 metres: Min 10 m; Max 50 m. • Uniform matrix-dominated permeable strata (e.g. porous sandstone); development within 10 metres: Min 10 m; Max 20 m. • Fissure or fracture flow-dominated permeable strata (e.g. blocky sandstone or igneous rock); no development within 250 metres: Min 20 m; Max 50 m. • Fissure or fracture flow-dominated permeable strata (e.g. blocky sandstone or igneous rock); development within 250 metres: Min 10 m; Max 50 m. • Fissure or fracture flow-dominated permeable strata (e.g. blocky sandstone or igneous rock); development within 150 metres: Min 5 m; Max 20 m. Note: The maximum spacing given in relation to the development relate to the zone of development (location of receptor) and not the entire boundary.	
B7.3	**LFG Monitoring Bore Depth**	
	Landfill gas monitoring bores must be drilled to an appropriate depth suitable to intercept gas movement adjacent to the landfill and should be based on the findings of the landfill gas risk assessment. The key considerations are: • The topography of the landfill site and the vicinity. • The hydrogeology (subsurface geology, aquifer types, watertable depths and flow direction etc.). • The depth(s) of the landfill (waste mass). • The construction details of landfill cells.	Not applicable. No landfill gas monitoring bores required.
	Bores must be designed and constructed to avoid connecting two different groundwater aquifers. Where gas monitoring is required across the depth of two aquifers, then multiple gas bores will need to be installed, with bores only open across one aquifer and sealed to prevent groundwater from the other aquifer from entering that bore.	Not applicable. No landfill gas monitoring bores required.
B7.4	**LFG Monitoring Bore Construction**	
	Landfill gas monitoring bores must be carefully designed to suit the situation and should be based on the findings of the landfill gas risk assessment.	Not applicable. No landfill gas monitoring bores required.

	The following aspects must be taken in to consideration in designing the bores: • A well screen interval that intercepts as much of the unsaturated (vadose) zone as possible whilst still allowing an adequate gas tight seal to be present/ constructed at the ground's surface. • Sealing of bore so that any gas accumulating will be retained for sampling. • Bore robustness and durability. • Accessibility of bore to ensure its suitability for ongoing use.	Not applicable. No landfill gas monitoring bores required.
	Table changed to comply with 8 October 2014 Vic EPA Changes Table B.3 provides typical material properties for landfill gas monitoring bores. These bores should be made of polyvinyl chloride (PVC) pipes. Table B.3 – Typical Construction Details for LFG Bore Construction **Bore & Casing** • Drilled bore diameter: 100 mm to 150 mm. • Pipework casing: outer diameter = 50 mm. • Depth of top bentonite seal = 1 m. • Length of solid casing below ground level* = 1 m. **Pipework Design & Gravel Backfill** • Perforated casing pipework (% open space) = 10% to 15%. • Pipework casing: size of perforations (must meet % open space required) = 2 mm to 4 mm, but no more than 5 mm. • Size range of gravel backfill = No greater than 10 mm. Must be sufficiently larger than pipework slots/perforations to prevent blocking. • Gravel type = Washed gravel to be rounded to sub-rounded, and non-calcareous (< 5% carbonate). *To match with depth of bentonite seal used.	Not applicable. No landfill gas monitoring bores required.
	Bores must have a suitably gastight seal to prevent any escape of landfill gas. This is normally achieved by a one-metre bentonite seal at the top of the bore. A sampling tap must be fitted to the top of the pipework casing to allow sampling of the gas. Due consideration to damage by vandals, animals, natural processes and operational machinery must be given in the bore design, and precautions incorporated as appropriate (such as by installing an appropriate security cover on the bore).	Not applicable. No landfill gas monitoring bores required.
	Landfill gas monitoring bores that have failed or appear to have failed must be investigated and replaced, as required.	Not applicable. No landfill gas monitoring bores required.
B7.5	**Bore Installation Construction Quality Assurance**	
	A construction quality assurance (CQA) process is required for the installation of landfill gas monitoring bores to ensure proper construction. Bores must have drilling and installation logs completed by a suitable qualified person.	Not applicable. No landfill gas monitoring bores required.