Copping C-cell
Responses to community questions
August 2014

1. Any info on the design not already given to EPA is appreciated (considering the request for little detail provided because of the cost).

The EPA was provided with all available information of the concept design of the landfill. Detailed design of the landfill will be prepared by experienced engineers who will prepare detailed construction specifications with exacting quality control and quality assurance requirements. The construction of the liner system will be undertaken by specialist contractors who have relevant experience and who will be required to meet the construction specifications as part of their contract.

2. Can we talk about why the sandstone presence is not important for the site (horizontal positioning or dolerite on top of sandstone)?

The C-cell will be located in solid, impermeable dolerite rock, which will be excavated to form a secure basin which will then be lined by the double compound liner system. The C-cell design does not rely on the impermeability of the dolerite and it would achieve its design specifications on any geological substrate.

The dolerite within which the C-cell will be excavated is inherently impermeable, apart from the possibility of there being fissures. These fissures, if they exist, would be plugged by the initial 1 m thick compacted clay liner that will be laid down before the remainder of the liners are installed. For leachate to enter the fissures, if they exist, it would have to pass through the overlying liner layers and then through the 1 m thick clay layer, including any fissure plugging.

If leachate managed to get into any fissures, for it to then reach sandstone the fissures would have to extend vertically or laterally into that sandstone. The amount and rate at which any leachate could achieve this migration would be very small and slow and it would be quickly diluted (see question 8).

3. Describe use of electrico-survey equipment:
- **a) How it works**
- **b) Is it used after or during construction**

HDPE membranes are non-conductive to electricity, so if an electrical potential (voltage) is applied across the membrane between conductive material (eg. water or moist sand or clay) above and below the membrane, current should not flow. If electricity does flow, it must be doing so through a puncture hole or through an incomplete join between two membrane sheets.

Testing during construction will be undertaken with portable equipment. One electrode is placed in conductive material above the membrane and another in conductive material below the membrane, and a voltage is applied. By systematically testing the membrane sheets across a survey grid as they are laid, leaks can be detected and repaired as part of the construction quality control and assurance process.

This electrochemical testing will supplement vacuum testing, which tests joins for air leaks and therefore detects potential water leaks, also allowing them to be repaired as part of the construction quality control and assurance process.

4. Clay liner permeability - expected life of liner

Two of the C-cell's multiple layers will be clay: the geosynthetic clay liner (GCL) and the compacted clay liner (CCL).

The geosynthetic clay liner (GCL) will made of bentonite clay sandwiched between geotextile sheets with fibres needle-punched through the bentonite to create a reinforcing matrix of fibres. The GCL is around 5 - 10 mm thick. When the clay is hydrated it swells and seals to form a barrier with very low permeability to leachate. If the GCL is punctured, clay particles will move into the puncture area to self-seal.

A GCL used as part of a composite liner system (as at Copping) can be expected to have a service life of thousands of years[1], provided that:

- there is no significant loss or thinning of bentonite during placement and hydration or during operations
- the edges of the GCL sheets are installed with sufficient overlap so that they do not open up during construction or waste placement – a minimum overlap of 300 mm is appropriate to prevent this and this requirement will be in the construction specification contract
- the GCL is not allowed to desiccate (GCL sheets need to be hydrated after placement and then need to be covered by their overlying HDPE membrane before they dry out).

These risks will be managed during construction as part of the quality control and assurance process. The design of the liner, with an impermeable HDPE membrane, placed above the GCL will thereafter protect the GCL from desiccation.

The GCL clay is sodium montmorillinite, which is particularly impermeable because the sodium ions have a great affinity for water, making the clay particles swell and close up the spaces between them. Under very acidic conditions (pH less than 2), the sodium ions in the clay can potentially be replaced by other ions, such as calcium ions, that might be in the leachate and the hydraulic conductivity (ie. permeability to leachate) could increase as a consequence[2]. Such low acidity is highly unlikely to occur in the C-cell and even if it did the hydraulic conductivity would still be below the EPA requirements of less than 1×10^{-9} metres/sec, an impermeability specification that is consistent with national and international best practice[3].

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[1] Rowe, R.K. (2005) *Long term performance of contaminant barrier systems*. 45th Rankin Lecture. Geotechnique 55(9):631-678)
[2] Benson, C.H. (2000) *Liners and covers for waste containment*. Proc. Fourth. Intl. Geotechnical Forum.
[3] Pichtel, J. (2014) *Waste Management Practices: Municipal, Hazardous, and Industrial*. CRC Press.

The compacted clay liner (CCL) will be made from clay (clay naturally present on site or brought in from elsewhere if necessary). It will be 1 m thick and compacted in 15 cm layers. Compaction will be done with the clay wetted to optimum moisture content.

A 1 m thick layer of clay protected from the elements by the overlying liner and waste would have an indefinite physical life, in the order of tens to hundreds of thousands of years. Like the GCL, the service life, which is the ability of the clay to continue to maintain its design impermeability, will be thousands of years[1] provided it is prevented from drying out. As with the GCL, the overlaying composite liner and waste will prevent desiccation.

The thousands of years service lives of the GCL and the CCL are hundreds of times longer than the expected working life of the C-cell, which is less than 10 years. After the cell closure and capping, leachate generation will progressively diminish and then cease because rain will no longer be able to enter the cell. The service life of the clay liners is therefore hundreds of times longer than what is required for leachate management.

5. Expected life of geomembrane liner

HDPE membranes have very good resistance to chemical attack, including for a pH of from 2 (very acid) up to 13 (very alkaline)[4,5].

The service life of the HDPE geomembrane liner is primarily dependent on its exposure to stress cracking and to elevated temperatures. HDPE performance can also be diminished by exposure to ultraviolet radiation but this will not occur because the HDPE liners will be covered by other layers.

Stress cracking risks may arise if an HDPE membrane is not properly installed and wrinkles form. Stress cracking is a brittle cracking that may occur as a consequence of the same semi-crystalline microstructure that makes HDPE strong and resistant to chemical attack. This risk can be mitigated by careful installation with appropriate quality control and assurance procedures.

The relationship of HDPE service life with temperature is shown in the table below[6]. Higher temperatures accelerate aging of the HDPE by increasing oxidation rates.

Temperature (^{o}C)	Service life (years)
20	565-900
30	205-315
35	130-190
40	80-120
50	35-50
60	15-20

[4] Benson, C.H. (2000) *Liners and covers for waste containment*. Proc. Fourth. Intl. Geotechnical Forum.
[5] Geotas Chemical Resistance Chart for High Density Polyethylene
[6] National Research Council (2007) *Assessment of the Performance of Engineered Waste Containment Barriers*. Washington, DC: The National Academies Press.

Elevated temperatures could occur in a landfill due to heat generated by decomposition of putrescible wastes (eg. such as typical domestic wastes) or heat generated by chemical reactions.

The C-cell will not take putrescible domestic wastes, so there will not be any significant generation of decomposition heat. Wastes going to the C-cell will be deposited separately and will not be mixed, so there will also be no significant generation of reaction heat (see also question 12). If reactions occur within the leachate itself, they are most likely to occur within the collection pipes, where leachate from all different areas of the cell collects, and the reaction heat would be removed from the cell with the leachate.

The heat exposure is therefore expected to be similar to the range of ambient temperatures that naturally occur at Copping. The average annual temperature at HDPE membranes is therefore likely to be the same as the average annual ambient temperature, which is 17.5^{o}C based on 56 years of Hobart Airport temperature records[7].

At this average temperature, the service life of the HDPE membranes is likely to be more than 500 years (see the table above). This is more than 50 times longer than the expected operational life of the C-cell. After the cell closure and capping, leachate generation will progressively diminish and then cease because rain will no longer be able to enter the cell. The service life of the HDPE membranes is therefore around 50 times longer than what is required for leachate management.

6. What if a breach in liner is found?

- **a) can it be patched/sewn?**
- **b) are there circumstances in which it might have to be exhumed?**
- **c) Is there money to do that**
- **d) one community member suggested that the promise of $8 million for 'aftercare' has been retracted - will the money still be there?**

If a breach of the liner is found it would be repaired. If the breach is overlain by waste, the waste would need to be removed or moved aside to allow this work to occur. This would be an operational cost.

The aftercare funds have not been retracted. They form part of SWS's budget for the C-cell.

7. How long is it expected that the cell will need to be personally monitored?

The cell would be routinely monitored during operations. Monitoring would continue after closure for at least as long as is required by the EPA.

At the end of the operational phase, the closure and capping (with an impermeable membrane) will prevent any further rain ingress, and leachate generation would progressively diminish and then cease as the residual moisture in the waste drains away. Monitoring frequency is likely to similarly diminish until there is no more leachate being generated and then monitoring can be replaced by inspections.

[7] Bureau of Meteorology weather station 94008

Inspections would include inspection of the witness sump for leachate and checking of the vegetation on the cell capping to remove any trees that might develop deep roots, which could damage the cap liner.

Southern Waste Solutions, or its successor(s), is likely to have an operational presence on the site for a hundred years or more would and will undertake periodic inspections throughout this period as part of its general operations. If and when operations finished, the member Councils would assume responsibility for inspections, which would continue indefinitely.

8. In the unlikely event that contaminated bores or water sources are found - apart from telling the community to stay out of area/water - what is the procedure?

Finding contaminated monitoring bores or water sources is certainly an unlikely event.

The multiple layers of the liner and the leachate collection system are specifically designed to prevent this occurring and the witness sump is specifically designed to detect and collect any leakage that nevertheless does occur, before it reaches the final compacted clay layer, which the leachate would still need to pass through before it could enter groundwater.

If it hypothetically did make it through to the base of the final clay layer, which will have a hydraulic conductivity of less than 10^{-9} m/sec, its exit velocity through the clay is likely[8] to be in the order of only 3 cm/year.

Emerging at this almost imperceptibly slow rate below the base of the clay liner, it would then still need to find its way several metres more vertically through dolerite rock (which could only occur through fissures, if they exist) before it intercepted the underlying groundwater, where it would be entrained and quickly diluted.

A simple calculation of dilution rates can be made by noting that groundwater tests at the site showed aquifer transmissivities of between 0.2 and 20 m^2/day (reported in the DPEMP). At these transmissivities, underneath a square metre of the compacted clay liner, between 0.2 and 20 m^3 of groundwater could pass each day in the top 1 m of the aquifer, or between 73 and 7300 m^3 per year. If leachate was leaking out of this square metre of liner at 0.03 m^3 per year (3 cm across 1 square metre), the immediate dilution rates underneath the cell in the top 1 m of the aquifer would be between 73/0.03 = 2,400 and 7300/0.03 = 240,000 times. As the groundwater moved horizontally (and vertically) away from the cell, dilution by surrounding groundwater would continue by entrainment and concentrations would quickly become immeasurably low, if they weren't already.

The likelihood of leachate being found in detectable quantities in monitoring bores is therefore negligible.

Nevertheless, in the hypothetical situation that it was detected in monitoring bores, a risk assessment of the contaminant concentrations and potential exposure pathways would be

[8] Gartung, E. & Ramke, H-G. (2009) *Toolkit Landfill Technology Chapter 2.2 Principles of Bottom Barrier Systems*. German Geotechnical Society Technical Committee Landfill Technology.

undertaken in accordance with the national ANZECC *Water Quality Guidelines for Fresh and Marine Water Quality* and appropriate response measures would be implemented.

9. What if there is too much waste for the c cell?

When the cell is full, no more waste would be accepted unless and until a second C-cell is constructed, which would need to be approved through a development application and EPA assessment.

10. I understand the filter layer will be rocks and that these sit below the waste to filter leachate - how can you tell if the filter layer is clogged?

a)how do you calculate the rate of clogging? (One paper I read suggested that normal extrapolation was difficult because too many factors might affect the rate)

Granular and geotextile drainage mediums can become clogged due to soil infiltration, biological activity and chemical precipitation. Clogging reduces the drainage porosity and hydraulic conductivity of the drainage material and slows the infiltration of leachate into the drainage pipes that remove it from the cell.

Clogging risk is greatest if the drainage layer remains saturated. In unsaturated drainage gravel, clogging of spore space is likely to be in the order of 10% over 10 years (the life of the C-cell) but could be greater than 50% over 10 years if the gravel was continually saturated[9].

The aggregate that will be used for the drainage layer will be 20± mm rounded aggregate, which is coarser than sand or gravel systems and which will therefore be less prone to clogging. Although undesirable, partial clogging will not prevent leachate collection but simply slow down the drainage time of rainfall pulses as they move down through the waste into the collection pipes.

The base and composite liner of the C-cell, and therefore the drainage layer pipe network, will be shaped and sloped to quickly remove leachate and prevent the gravel from becoming saturated.

Clogging would be indicated by changes in the water balance between rainfall and waste moisture inputs and leachate outputs. If more detailed measurements were necessary, piezometers could be installed down through the waste to the base of the drainage layer to measure the standing height of the leachate.

In the unlikely event that clogging became problematic during the 10 year life of the C-cell, clogging material could be removed by flushing or internal scraping of the leachate collection pipes and/or by physical removal and replacement of clogged sections of geotextiles.

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[9] McIsaac, R. & Rowe, R.K. (2007) *Clogging of gravel drainage layers permeated with landfill leachate*. J. Geotechnical & Geoenvironmental Engineering 133(8):1026-1039.

11. The 6 litres of leakage - deemed acceptable by EPA - where is it getting out (even in such small amounts)

Geomembrane liners can have manufacturing defects or can be damaged during the construction process. Clay liners have very low hydraulic conductivity but are not completely impermeable. Leachate leakage could occur through the geomembrane defects and by advection (bulk movements) and diffusion (molecular movements) through the clay (leakage can also occur by molecular diffusion through the geomembrane but this is negligible compared to that through the defects).

Leachate that is not collected by the collection system may move downward through the underlying composite liner through defects or by advection or diffusion. At any given layer the proportion passing through will be very small, so the leakable leachate in each successive layer becomes progressively smaller – successively very small proportions of successively much smaller volumes.

The purpose of the composite liner is to ensure that these successively smaller volumes become environmentally inconsequential if, despite all the layers, some leachate nevertheless makes it all the way through. In addition to the composite layers, the C-cell has a further safeguard by having a witness sump above the final compacted clay layer, which will not only allow the leakage rate to be measured but will remove most, if not all, of that leaked leachate before it could pass into the final clay layer.

The leakage volume is a conservative calculation conducted using the HELP (Hydrologic Evaluation of Landfill Performance) model using well-accepted assumptions about the density of manufacturing and construction imperfections in membrane liners.

HDPE geomembranes typically have a manufacturing pinhole density of 1 to 2 per hectare[10] and for the modelling the upper value of 2 was conservatively assumed.

An installation defect density also of 2 per hectare was assumed. The geomembranes will be installed under strict quality control and quality assurance procedures and extensive studies of post-construction leak detection surveys have shown that under strict procedures a density of 0.5 per hectare is more likely[11], so the assumption is conservatively high.

The manufacturing and installation defects and the diffusion processes ultimately lead to some loss of leachate to the environment. The predicted overall loss is so small because of the multiple layer design and the secondary leachate collection system (the witness sump).

If, despite the multiple safeguards of the composite liner, leachate does make it into the final compacted clay layer it would need to pass through 1 m of compacted clay before it could enter the environment.

[10] Technical note on using HELP model (ver. 3.07)

[11] National Research Council (2007) *Assessment of the Performance of Engineered Waste Containment Barriers*. Washington, DC: The National Academies Press.

The diffusion of leachate through the compacted clay liner would be very slow. The time taken for leachate to pass through it will depend on the clay's hydraulic conductivity and the hydraulic head of the leachate above the clay.

The design criterion for the compacted clay liner is that the hydraulic conductivity is less than 10^{-9} metres/sec. The leachate drainage collection layer will be designed and constructed to quickly remove leachate, thereby preventing leachate accumulating within it. Also, the multiple underlying layers act to break the hydraulic head. The hydraulic head of the leachate is therefore unlikely to be greater than the thickness of the gravel layer, which is 0.3 m, and if fact typical[12] leachate heads in landfills are 0.01 to 0.1 m.

Conservatively assuming a 0.3 m leachate head, the travel time for leachate to pass through the 1 m thick compacted clay liner (assuming steady state conditions) would be 9.7 years[13]. This is the same order as the expected life of the cell, so that by the time any leachate reached the base of the compacted clay liner, if it had managed to get through the multiple layers above in the first place, the cell is likely to have by then been capped and the generation of new leachate would have ceased.

12. How long is the waste active for. I read it could be UP TO thousands of years and I realise this isn't quite 'toxic' enough for that but what is the expected time? Is it reduced if waste is not mixed?

As with any substance, waste or otherwise, a waste type is only 'active' in the sense that it might react with some other type of substance if they were brought together and their chemical makeup was suitable for a reaction to occur. Unless and until that bringing together occurred, the potential for that reaction to occur will remain indefinitely. If they were deliberately brought together by mixing, the reaction would occur and thereafter that potential would no longer exist.

However, by design, waste mixing is not proposed, for the following reasons.

Firstly, chemical reactions generate heat and prolonged exposure to heat would reduce the service life of HDPE material (see question 5), which would be undesirable.

For the same reason, some wastes may need to be moistened before they are placed in the cell because they may arrive at the landfill with a latent heat of hydration. An example is a waste that contained quicklime, with is inherently reactive with water. Moistening the waste outside the cell would exhaust the heat of hydration, so that it could not be generated inside the cell where it might damage the HDPE liner.

Secondly, keeping the wastes separate will assist with the monitoring of the leachate because leachate from a particular waste type is likely to be characteristic of that waste. The position of each waste type within the C-cell will be recorded by 3-dimensional GPS. If unexpected volumes of leachate start appearing in the witness sump, suggesting a liner

[12] Giroud, J.P., Badu-Tweneboah, K. and Soderman, K.L. (1997) *Comparison of leachate flow through compacted clay liners and geosynthetic clay liners in landfill liner systems.* *Geosynthetics International*, Vol. 4, Nos. 3-4, pp. 391-431.

[13] Calculated using the methodology of Giroud et al (1997)

leak, chemical analysis of that leachate for comparison against waste chemistry could assist in locating the source of the leak to allow repairs to be made.

Thirdly, while materials that will be placed in the C-cell are by definition currently waste because no beneficial reuses can be found, in future they may become an asset as new technologies or industrial processes emerge. Mixing the wastes would diminish these future recovery and reuse opportunities. In this context, maintaining the waste's capacity to react is a desirable outcome because it could enhance its future usefulness in industrial processes.

13. What is the likely procedure of getting waste out? ie it has GPS etc but who will make the decision? The owner of the waste (and will they have to pay) or SWS or Govt legislation requiring you to? What's the most likely scenario?

The type, volume, original and deposition date of each load of waste will be recorded, together with the load's 3-dimensional position within the C-cell. This will make later relocation for removal straightforward.

Two scenarios for removing waste from the cell are possible.

Firstly, waste might need to be removed (or simply moved aside) to repair a damaged liner, a circumstance that would be triggered by an unexpected increase in leachate reporting to the witness sump. In this scenario, SWS would bear the cost.

Secondly, waste might need to be removed because it was wanted for beneficial reuse that might be made possible by currently unforseen processes or technologies. In this scenario, the cost would be borne by the reuser, who would need to factor the removal cost into their value assessment of the waste.

Waste types coming to site require prior EPA approval and it is expected that waste removal from the site will similarly require EPA approval.

14. What if liner slips down into hole?

It is inconceivable that this could occur.

The cell will be constructed in dolerite, a geology that does not have large cavities. Any fissures in the dolerite that might be exposed when the cell basin is excavated would be plugged with clay during the placement of the 1 m thick compacted clay liner.

The compaction process (undertaken in 15 cm layers) will mean that the clay liner itself is free of cavities.

All the other liner layers will sit above this clay layer. There will be no holes for a liner to fall into.

The HDPE and the GCL liners and geotextiles will be anchored into the ground along the top of the C-cell perimeter and, subject to detailed design, likely also at an intermediate point part way up the cell walls. The top anchoring edges of the liners will be formed to be the lining of a surface water cut-off trench that will be the final diversion of surface run-off away from the cell (see the concept design detail in Appendix C of the C-cell design report that accompanied the DPEMP).

15. Will the blasting/fracking change the surrounding environment in any way eg seismically

If blasting needs to be used to construct the C-cell, a Blast Management Plan will be prepared and submitted to the EPA Director before construction commences. The Plan will meet the relevant overpressure and ground vibration limits specified by Australian Standard AS2187.2 and also will protect adjoining and nearby waste cells from damage. Blasting will not commence until the Plan has been approved by the EPA Director.

Although not the direct focus of the question, the following additional response is also offered in relation to the potential for natural seismic events to impact on the C-cell itself, which has previously been raised as a community concern.

Earthquakes cause damage to rigid structures by shaking. Flexible structures, like the liners that will be used in the C-cell, can readily adjust to movement in the underlying ground. The C-cell liners will be cupped inside a dolerite rock shell. Flexible structures built on bedrock are more resistant to earthquake damage than rigid structures built on loose soil.

If seismic activity shook the dolerite, the C-cell liners would simply shake within it, with no loss of integrity. For the liners to be damaged, the earthquake would need to be associated with a fault that lifted part of the C-cell liner by tens of centimetres relative to the other parts – this could overcome the shear strength of the synthetic liner components and tear it (and even then the underlying compacted clay liner it still likely to retain its impermeability).

Composite landfill liners have survived magnitude 6.7 earthquakes undamaged[14]. An earthquake of that size is much larger than the 2011 Christchurch earthquake, for example, which caused massive damage to buildings. Earthquakes of this size have shaking energies more than 16,000 times greater than the largest earthquake (less than magnitude 4) ever recorded in southeast Tasmania[15].

If an earthquake of a size and nature sufficient to damage the C-cell liner ever occurred, it would cause widespread devastation to buildings throughout southeast Tasmania.

The likelihood of an earthquake of this magnitude occurring at Copping, and specifically with its fault passing through the C-cell, is vanishingly small.

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[14] Matasovic, N., Kavazanjian, E. Jr., and Anderson, R. 1998, *Performance of solid waste landfills in earthquakes*, Earthquake Spectra, Issue #2, Vol. 14, p. 319-334.

[15] On the earthquake magnitude scale each 1 unit scale increase is a 10 fold increase in amplitude and an approximately 32 fold increase in energy: each 0.2 increase is approximately a doubling of the energy, so going from magnitude 4 to 6.7 is about 14 doublings or about $2^{14} \approx 16{,}500$ times more energy

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16. Can you explain how the stability of the waste mass will be assessed?

Waste types will not be tipped into the cell in a heap but will be individually placed in a controlled and systematic manner.

Waste mass stability is only relevant to material that either is heaped into a pile having sides steeper that the material's natural angle of repose or to material that is deposited loosely, forming voids into which overlying waste might collapse when the weight becomes sufficient.

Neither of these circumstances will occur: waste will not be heaped, and voids will be filled with more waste of the same type or a compatible (non-reactive) type and/or natural crushed rock (the latter being less preferred because of the cost of the rock and the loss of useable fill space).

Annual topographic surveys of the waste surface will be undertaken to measure waste compaction, fill volume and remaining available fill space.

17. Will it be shallow or steep gradient and hence which kind of liners? If steep slope - as much info as possible on risk mitigation

The gradient of the cell side slopes will be designed to meet the specifications of the HDPE and GCL liners.

The cell wall gradients will reflect the material specifications for internal shear strength of the HDPE membranes and the GCL clay liner, recognising strains imposed at anchor trenches, slopes, potential differential settling and point loading. The gradients will also reflect the expected interface friction between adjacent layers, which must be sufficient to prevent slumping and sloughing.

Side slope will be part of detailed engineering design and the liner material specifications will form part of the construction tender specifications.

18. When considering all the mitigation in landfill now - what remains outstanding as a perceived weakness of landfill for storing haz waste (BTW - nothing is not an acceptable answer - all engineering has risks/weaknesses).

Controlled waste is currently stored in an *ad hoc* manner under many different circumstances at many different locations by many different entities throughout the state.

A purpose-designed landfill operated by a single management authority, backed by municipal councils, has far fewer and less significant engineering and management weaknesses than any other storage method, and certainly compared to the current *ad hoc* situation.

The term 'weaknesses' suggests that the landfill might have an unacceptable vulnerability, which ignores the multiple safeguards built into the design. A more informative term is 'risk' and then the question becomes: have all significant risks been identified and adequately and appropriately mitigated? The answer is: yes.

The primary performance determinants are the design and construction quality. The design meets contemporary international best practice. Construction quality will be controlled by detailed construction quality specifications that the construction contractor will be required to meet. Examples of the types of requirements can be found in the Victorian EPA landfill guidelines[16]. The construction tender specifications will require a detailed inspection and testing plan to be prepared and implemented for the manufacture, delivery and installation of the liners and leachate collection system.

The principal risk for the landfill is damage to the geomembranes and GCL liner by heavy machinery during construction and operation. These risks become progressively lower as waste accumulates in the cell because the waste will protect the underlying liners from physical damage. During construction and in the early stages of filling, soil then waste will be used to form a protective layer for machinery to track over.

19. If there is a liner failure - when is this most likely? During construction? During waste placement? In bad weather? During aftercare?

See questions 18 and 20.

20. Which type of liner is most likely to fail? Clay one, geo one? Why?

The HDPE liners are the most impermeable of the liners but they are also the most vulnerable to failure by physical damage and aging.

Physical damage could occur during construction, for example by puncturing by heavy machinery or sharp rocks or by incomplete joins between sheets. Future physical damage could also be made more likely if the construction practices are poor and wrinkles are allowed to form while the sheets are being laid – wrinkles increase vulnerability to stress cracking and also increase permeability if cracks do occur because wrinkles have an underlying void (rather than the hole being flush tight against the underlying layer).

These physical damage risks will be mitigated by demanding high quality installation practices, including quality control and quality assurance, from the construction contractor through tender specifications.

Physical damage by machinery could also occur during the deposition of waste within the cell. The greatest risk of this is in the early stages of filling, before a substantial cushioning layer of waste has built up. This risk will be mitigated by the laying of an initial layer of soil and/or waste to protect the liner and by very careful placement of the initial waste.

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[16] EPA Victoria (2010) *Best Practice Environmental Management: Siting, Design, Operation and Rehabilitation of Landfills*. EPA Victoria Publication 788.1.

Aging damage to the HDPE liners could arise from prolonged exposure to ultraviolet (UV) light or to heat, although even with direct and continuous UV exposure the service life of HDPE geomembranes is still decades[17].

The HDPE membranes will not be exposed for long periods during the construction process and they will be covered by other layers and will have no ongoing exposure to UV after construction is complete. The liners will not be exposed to high temperatures for prolonged periods because heat-generating waste decomposition and chemical reactions will be minimal (see questions 5 and 12).

Geosynthetic clay liners can fail if they are not properly manufactured or installed. The GCL that will be used for the C-cell will be the highest quality design, comprising geotextile sheets with fibres needle-punched through the bentonite to create a reinforcing matrix of fibres. The gradient of cell side slopes will be designed to be well within the stress limits of the GCL liner. Installation will be undertaken in accordance with strict quality control and quality assurance procedures.

Compacted clay liners can fail if there are lenses of coarse material embedded within them. This risk will be mitigated by detailed quality control and quality insurance procedures and by supervision during construction.

21. Rainfall - is it ready for 1:50 yr event or 1:100 (I have read both).

The EPA's Landfill Sustainability Guide require C-cells to be designed with surface water diversion drains sized for a 24 hour, 1 in 50 year rainfall event. The guidelines also require that control measures anticipate the likelihood of flooding from more severe 1 in 100 year events. These sizing specifications will form part of the detailed design.

The C-cell has only a small catchment above it and any run-off towards the cell from that catchment will be diverted away by the diversion drains.

In 2013, the landfill site was subjected to intense rainfall delivered 105 mm of rain in 90 minutes, which was a 1 in at least 2,000 year event (a 1 in 100 year event would be 40 mm). The C-cell site was above the flood level of this event.

22. What is the current failure rate of this type of design - specifically these types of liners - this refers to a failure at any time (Jones & Dixon catalogue over 20 failures and not all respondents replied).

The Jones and Dixon survey[18] was not a survey of the rate of landfill liner failures but a survey of the causes of selected known liner failures in the UK (at the time of that survey there were approximately 2,300 working landfill sites in the UK[19]).

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[17] Denis, R,. Tan, D. & Cao, D. (2012) *A literature review on lifetime prediction of thin HDPE geomembranes in the exposed environment*. Geosynthetics Asia 2012: 5th Asian Regional Conference on Geotechnics.
[18] Jones, D.R.V & Dixon, N. (2003) *Stability of Landfill Lining Systems: Report No. 1 Literature Review*. R&D Technical Report P1-385/TR1 to the UK Environmental Agency
[19] Jardine, C.N., Boardman, B, Osman, A., Vowels, J. & Palmer, J. (2003) *MethaneUK Chapter 5 Waste and Landfill*. Environmental Change Institute, University of Oxford.

I am not aware of any statistical survey of the 'failure rate' of composite landfill liners but in a very detailed 2005 review of landfill liners, Rowe[20] concluded that "composite liners have performed extremely well in field applications for a couple of decades".

Early composite liners, such as many of those used in the two decades preceding Rowe's report, were single layer designs and typically had a single geomembrane over a compacted clay liner or a single geomembrane over a GCL liner. Nevertheless, Rowe concluded that they performed extremely well.

The C-cell liner will reflect contemporary best practice and will be a double composite liner. It will have a geomembrane over a GCL liner and then another geomembrane over a compacted lay liner, providing even greater (double) security against failure. It will therefore perform even better than Rowe's "extremely well" assessment.

23. Nixon & Jones also discuss failures due to uncontrolled surface water in which the source of the water was never found. Is this possible at Copping? If not - why not (eg is technology more advanced or is there simply still some risk?).

The topography of the landfill site is simple and well understood – there is no significant risk of uncontrolled surface water emerging from an unlocatable source.

Surface water will flow towards the C-cell from a small catchment area upslope of the cell. Cut-off drains constructed across this slope above the cell will divert this surface water away from the cell.

24. What is the story with gas capturing? How? How much anticipated?

Gas will not be generated in the C-cell and therefore will not be captured. Methane gas generation is a feature of putrescibles waste landfills and is a result of organic decomposition processes. The use of landfill gas was identified in the DPEMP as a potential energy source for leachate evaporation but if it is used this gas would come from the existing B-cells, not from the C-cell.

25. Will there be any on-site performance tests carried out?

Performance tests (eg. see question 3) will be undertaken during construction, in accordance with the construction quality control and assurance plan. During operations, the performance of the landfill will be regularly tested, through leachate volume and quality monitoring and through surface water and groundwater monitoring.

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[20] Rowe, R.K. (2005) *Long term performance of contaminant barrier systems*. 45th Rankin Lecture. Geotechnique 55(9):631-678)