10 November 2017

Luke Maloney
Upper Lachlan Shire Council
PO Box 10
Crookwell NSW 2583

Our ref: 2125974-35296
Your ref:

Dear Luke,

Crookwell Landfill
Alternative cap design justification

1 Overview

GHD have proposed a landfill cap arrangement for the Crookwell Landfill site that includes the following layers (from top to bottom):

- Topsoil/revegetation layer: 0.1 m topsoil
- Subsoil layer: 0.5 m subsoil
- Subsoil drainage layer: geonet geocomposite layer
- Barrier layer: 2 mm thick LLDPE geomembrane
- Seal bearing layer: 0.3 m thick existing cover materials

The proposed cap is an alternative design to that presented in Section 9.1 of the NSW Environment Protection Authority (2016); *Environmental Guidelines: Solid Waste Landfills* (the landfill guidelines).

With this in mind, GHD has undertaken a comparison of the preferred cap arrangement against the requirements of Section 9.1 of the landfill guidelines to confirm that the preferred cap arrangement achieves the relevant requirements.

2 Purpose

The purpose of this memorandum is to document:

- the comparison of the proposed landfill cap arrangement with the recommendations of Section 9.1 of the landfill guidelines
- an assessment of the equivalence and justification of deviations from the proposed landfill cap arrangement with the recommendations of the landfill guidelines

3 Reliance

In preparing this document, GHD has relied on the following documents:

- GHD (2016), Crookwell Landfill, *Leachate Management Plan*

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- NSW Environment Protection Authority (2016); *Environmental Guidelines: Solid Waste Landfills* (the 'landfill guidelines')

4 Section 9 of the landfill guidelines

4.1 Overview

Section 9 of the landfill guidelines present NSW EPA's recommendations in relation to final capping and revegetation of landfill sites. Further information on the recommendations relevant to this memorandum are provided in the following sections.

4.2 Required outcomes

The required outcomes of Section 9 of the landfill guidelines are as follows:

All completed landfill cells must be capped and revegetated as soon as practicable after the final delivery of waste to the cell. The final capping must:

- *Reduce rainwater infiltration into the waste and thus minimise the generation of leachate (infiltration from the base of the final cap should be less than 5% of the annual rainfall)*
- *Stabilise the surface of the completed part of the landfill*
- *Reduce suspended sediment and contaminated runoff*
- *Minimise the escape of untreated landfill gas*
- *Minimise odour emissions, dust, litter, the presence of scavengers and vermin, and the risk of fire*
- *Prepare the site for its future use; this includes protecting people, fauna and flora on or near the site from exposure to pollutants still contained in, or escaping from, the landfill.*

During the post-closure period, the occupier must monitor the integrity and performance of the final cap.

The following sections contain acceptable designs and monitoring programs for final capping. Alternatives may be proposed—see section 9.3 for the procedure when proposing an alternative.

4.3 Final cap requirements

Section 9.1 of the landfill guidelines presents the final capping requirements. These are presented in Appendix A.

4.4 Justification of alternative capping

Section 9.3 of the landfill guidelines presents the approach required for the proposal of landfill cap designs that are alternative to the specification presented in Section 9.1 of the landfill guidelines.

The requirements of Section 9.3 of the landfill guidelines are as follows:

Alternatives may be proposed to the designs and specifications in section 9.1. The proposal should address the following requirements:

- *The alternative proposal must be able to achieve the required outcomes for final capping and be compatible with achievement of the required outcomes for all other environmental issues.*
- *The proposal should be prepared by a suitably qualified and experienced person. This person should give an opinion that the alternative design can meet the required outcomes for final capping and is compatible with achievement of all other required outcomes.*
- *Clear reasons should be given for proposing an alternative in preference to the acceptable measure(s) in these guidelines.*
- *The proposal must fully describe the properties and predicted performance of the alternative capping. For each alternative capping layer, this includes (but is not limited to) thickness, hydraulic properties, strength, resistance to degradation, long-term behaviour, compatibility with adjoining layers, slope stability (where relevant), and construction methods (including around penetrations and protrusions). Performance predictions should be supported by all necessary test results, calculations and modelling.*
- *The site's leachate management system must be able to manage leachate volumes at the site. Water balance modelling should be conducted in accordance with section 2.3 of these guidelines.*
- *Some alternative materials may require minimum depths of cover soils placed over them to reduce mechanical or other damage; this must be addressed in the alternative design.*
- *In some cases, the EPA may require a peer review of the proposal by a suitably qualified and experienced person. Examples of these situations are when the proposal involves a major departure from the acceptable measure(s) in section 9.1, or when the landfill is located near sensitive receptors.*
- *If the alternative cap is a phytocap, the proposal must address the requirements in section 9.4.*

5 Comparison of preferred landfill gas with requirements of section 9.3 of the landfill guidelines

Table 1 below presents the requirements of Section 9.3 of the landfill guidelines and how the preferred landfill cap option addresses them.

Table 1 Requirements of Section 9.3 and how preferred landfill cap options addresses them

Requirement number	Requirements of Section 9.3	How preferred landfill cap option addresses relevant requirement
1	The alternate proposal must be able to achieve the required outcomes for final capping and be compatible with achievement of the required outcomes for all other environmental issues	The preferred landfill cap option will achieve the required outcomes presented in Section 9 of the landfill guidelines and will be compatible with the required outcomes for all other environmental issues (as presented in Section 1 to 8 and 11 of the landfill guidelines)
2	The proposal should be prepared by a suitably qualified and experienced person. This person should give an opinion that the alternative design can meet the required outcomes for final capping and is compatible with achievement of all other required outcomes	This memorandum has been prepared by Adrian Roberts. Adrian is an environmental engineer with more than 12 years' experience in landfill design and construction including landfill capping. As such, GHD is of the view that this memorandum has been prepared by a suitably qualified and experienced person. Adrian is of the opinion that the preferred landfill cap option will achieve the required outcomes presented in Section 9 if the landfill guidelines (landfill capping) and will be compatible with the required outcomes for all other environmental issues (as presented in Section 1 to 8 and 11 of the landfill guidelines)
3	Clear reasons should be given for proposing an alternative in preference to the acceptable measure(s) in these guidelines	The preferred option has been identified by GHD as being a technical improvement on both the landfill guideline cap and the GCL cap put forward in the leachate management plan. • Clay material of sufficient quality and quantity is unlikely to be available for the sealing layer. An LLDPE geomembrane would be readily available. • Using an LLDPE geomembrane would reduce rainfall infiltration and hence leachate generation compared to a 600 mm clay sealing layer • A geonet drainage geocomposite will be included as an infiltration drainage layer, in accordance with the recommendations in Section 9.1 of the landfill

Requirement number	Requirements of Section 9.3	How preferred landfill cap option addresses relevant requirement
		guidelines. This reduce the head on the geomembrane barrier layer, further reducing leachate generation. • The geonet drainage geocomposite will have geotextiles heat bonded to both sides. These geotextiles will act as a protection layer for the geomembrane below and as separation from the subsoil material above, as recommended in Section 9.1 of the landfill. • A 600 mm revegetation layer (100 mm topsoil with 500 mm subsoil) would provide equivalent environmental outcomes to the 1000 mm revegetation layer through the promotion of water removal by evapotranspiration and protection of the sealing layer. • The site accepts less than 20,000 tonnes of waste per annum and therefore a combination landfill cap is not required based on the recommendations in Section 9.1 of the landfill guidelines. • A series of gas collection trenches is proposed as part of the design, replacing the need for a landfill gas collection layer as recommended in Section 9.1 of the landfill guidelines.
4	The proposal must fully describe the properties and predicted performance of the alternative capping. For each alternative capping layer, this includes (but is not limited to) thickness, hydraulic properties, strength, resistance to degradation, long-term behaviour, compatibility with adjoining layers, slope stability (where relevant), and construction methods (including around penetrations and protrusions). Performance predictions should be supported by all necessary test results, calculation and modelling	Tabulated description of each of the layers is included in Table 2 (Appendix B). A Technical Specification will address the required material properties. The proposed capping system is expected to be stable based on the proposed maximum grades of 1(v) in 4(h) and batter heights. Slope stability calculations will be undertaken as part of the detailed design. Appropriate construction details will be included in the drawing set for the works. The hydraulic performance of a cap with 600 mm revegetation layer and a geosynthetic barrier layer (GCL) was undertaken for the site and included in the leachate management plan (Appendix C). This leachate management plan has previously been provided to EPA for comment. Based on GHDs experience, an LLDPE geomembrane barrier layer with an infiltration drainage layer above will provide a much lower leachate generation rate compared to the previously proposed GCL barrier layer.

Requirement number	Requirements of Section 9.3	How preferred landfill cap option addresses relevant requirement
5	The site's leachate management system must be able to management leachate volumes at the site. Water balance modelling should be conducted in accordance with section 2.3 of these guidelines.	A description of the existing and proposed leachate management system for the site was included in the leachate management plan (Appendix C). A LLDPE geomembrane barrier layer with an infiltration drainage layer above is expected to result in less leachate generation than the modelled GCL barrier arrangement. As such, the proposed leachate management system will be adequate to manage the predicted leachate volumes generated at the site.
6	Some alternative materials may be require minimum depths of cover soils placed over them to reduce mechanical or other damage; this must be addressed in the alternative design.	Not applicable
7	In some cases, the EPA may require a peer review of the proposal by a suitably qualified and experienced person. Examples of these situations are where the proposal involves a major departure from the acceptable measure(s) in Section 9.1, or when the landfill is located near sensitive receptors.	Not applicable
8	If the alternative cap is a phytocap, the proposal must address either requirements in Section 9.4.	Not applicable

6 Conclusion

Based on Table 1 above, GHD is of the view that the proposed cap arrangement is an appropriate alternative to the recommended landfill cap profile identified in Section 9.1 of the landfill guidelines.

7 Closing

Should you require any further information on the content of this memorandum, please do not hesitate to contact me on the number below.

Sincerely
GHD Pty Ltd

Adrian Roberts
Team Leader, Design Element - Waste Management
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Appendix A: Extracted pages, Section 9.1 of NSW EPA landfill guidelines

Appendix B: Properties and predicted performance of alternative capping

Appendix C: Leachate management plan

Appendix A

Extracted pages, Section 9.1 of NSW EPA landfill guidelines

The Regulation also contains requirements for landfilling clinical and related waste at unlicensed sites. The waste must be buried, or be immediately contained, in a way that prevents the waste from coming into contact with any person or animal.

9. Final capping and revegetation

Required outcomes

All completed landfill cells must be capped and revegetated as soon as practicable after the final delivery of waste to the cell. The final capping must:

- reduce rainwater infiltration into the waste and thus minimise the generation of leachate (infiltration from the base of the final cap should be less than 5% of the annual rainfall)
- stabilise the surface of the completed part of the landfill
- reduce suspended sediment and contaminated runoff
- minimise the escape of untreated landfill gas
- minimise odour emissions, dust, litter, the presence of scavengers and vermin, and the risk of fire
- prepare the site for its future use; this includes protecting people, fauna and flora on or near the site from exposure to pollutants still contained in, or escaping from, the landfill.

During the post-closure period, the occupier must monitor the integrity and performance of the final cap.

The following sections contain acceptable designs and monitoring programs for final capping. Alternatives may be proposed—see section 9.3 for the procedure when proposing an alternative.

9.1 Final capping requirements

The final capping of general and restricted solid waste landfills should comprise, from bottom to top:

- a seal-bearing surface consisting of a properly designed and engineered layer of material at least 300 millimetres thick to support the sealing layer; the material should meet recognised specifications for engineered materials, such as QA Specification 3071: Selected Material for Formation (NSW Roads and Maritime Services, December 2011), as amended from time to time
- a sealing layer, comprising a compacted clay layer at least 600 millimetres thick, with an in situ saturated hydraulic conductivity of less than 1×10^{-9} metres/second
- a revegetation layer at least 1000 millimetres thick and comprising clean soils and vegetation with root systems that will not penetrate into lower layers; the upper 200 millimetres should be a topsoil layer, which can include compost to help with vegetation establishment and growth.

The revegetation layer should promote water removal by evapotranspiration and runoff; protect the sealing layer from desiccation and/or damage; and sustain microbial populations that oxidise a proportion of any methane passing up through the cap.

For all restricted solid waste landfills and for general solid waste (putrescible) landfills receiving more than 20,000 tonnes of waste per year, the sealing layer should include a geomembrane liner over the compacted clay. The geomembrane should meet the specifications in section 1.2. In capping, linear low-density polyethylene may be used instead

of high-density polyethylene: it may be better able to withstand the differential settlement and strains experienced by landfill capping materials.

To achieve the required in situ hydraulic conductivity of less than 1 x 10^{-9} metres/second, the clay should have high plasticity and a suitable particle-size distribution, with no particles greater than 50 millimetres in any dimension. Source testing of the material should confirm these properties. A relationship should also be established between the material's density, moisture content and hydraulic conductivity, showing how it can meet the required in situ hydraulic conductivity.

A geosynthetic clay liner may be used as an alternative to compacted clay, provided it is used in composite with a geomembrane. It should meet the specifications in section 1.3 of these guidelines. The cover soils should be chemically compatible with the geosynthetic clay liner to prevent deterioration of the liner's performance as a result of cation exchange.

If required, the final capping should also incorporate the following drainage layers:

- a gas collection layer, installed below the sealing layer, to collect gas and convey it to treatment or to the atmosphere. This layer may be needed if landfill gas is being generated in significant quantities. If the gas is not relieved, it could be diverted laterally and off site by the cap, or it could exert upward pressure and disfigure the geomembrane in the cap.
- an infiltration drainage layer, installed above the sealing layer, to remove infiltrating water and drain it away from the landfill. This layer may be needed if high rainfall and unfavourable climatic conditions are likely to generate high rainfall infiltration rates. Water balance modelling can help determine whether an infiltration drainage layer is required; see section 2.3 of these guidelines. This layer should be included in all caps for restricted solid waste landfills.

The designer should determine whether these additional layers are required.

These drainage layers, if required, should be 300 millimetres thick and should consist of hard, strong, durable and clean gravel with a saturated hydraulic conductivity to water of greater than 1 x 10^{-4} metres/second. They should have the particle size, chemical reactivity and shape properties specified for gravel drainage aggregate in section 1.4 of these guidelines.

If a drainage layer is required, a separation geotextile should be placed over the upper surface to prevent the ingress of fines from overlying soil, which can clog the drainage layer. See section 1.7 of these guidelines for the requirements for separation geotextiles.

If a drainage layer is adjacent to a geomembrane liner, a protection geotextile should be installed to protect the liner from damage. See section 1.6 of these guidelines for the requirements for protection geotextiles.

Geonet drainage geocomposites may be used as alternative drainage materials. See section 1.8 of these guidelines for the requirements for geonet drainage geocomposites.

For final capping installed on steep slopes, the capping elements should be demonstrated to have adequate slope stability. A slope stability analysis should demonstrate that there are adequate factors of safety for all relevant potential failure mechanisms (e.g. veneer and global stability), both at the proposed final landform and at interim stages during construction.

Final capping incorporating geosynthetic elements should be adequately designed to accommodate any penetrations and protrusions (e.g. landfill gas controls and leachate risers).

To facilitate runoff and minimise ponding of water, the cap should have a gradient of greater than 5% to defined drainage points. However, to reduce the risk of erosion, steep caps (greater than 20%) should be avoided.

The final capping should not permit water pooling and should not contain constructed water features such as ornamental lakes or ponds on areas over the waste mass. These features may leak and infiltrate the cap if the pond lining is compromised by differential settlement of the waste and/or desiccation if the pond becomes dry.

A construction quality assurance program should be implemented during construction of the final capping; see section 11 of these guidelines.

Where practicable, final capping should be installed progressively throughout the active landfilling stage of the landfill and should not be left to the post-closure period. The occupier should start capping completed filling areas as soon as practicable after the completion of landfilling.

9.2 Monitoring the cap's integrity and performance

To assess the continued integrity and performance of the final capping, post-closure monitoring should include the following components:

- regular visual inspections for deterioration of the capping's condition, including erosion, cracking, dead or stressed vegetation, ponding, differential settlement, slope instability, and damage to any pipes, drains and other works installed on the final capping
- regular surveys for indications of differential settlement, using appropriate techniques such as topographic surveys and settlement plates
- repair and/or replacement of portions of the final capping found to be damaged
- monitoring of leachate and rainfall volumes
- measurement of landfill gas emissions.

9.3 Justification of alternative capping

Alternatives may be proposed to the designs and specifications in section 9.1. The proposal should address the following requirements:

- The alternative proposal must be able to achieve the required outcomes for final capping and be compatible with achievement of the required outcomes for all other environmental issues.
- The proposal should be prepared by a suitably qualified and experienced person. This person should give an opinion that the alternative design can meet the required outcomes for final capping and is compatible with achievement of all other required outcomes.
- Clear reasons should be given for proposing an alternative in preference to the acceptable measure(s) in these guidelines.
- The proposal must fully describe the properties and predicted performance of the alternative capping. For each alternative capping layer, this includes (but is not limited to) thickness, hydraulic properties, strength, resistance to degradation, long-term behaviour, compatibility with adjoining layers, slope stability (where relevant), and construction methods (including around penetrations and protrusions). Performance predictions should be supported by all necessary test results, calculations and modelling.
- The site's leachate management system must be able to manage leachate volumes at the site. Water balance modelling should be conducted in accordance with section 2.3 of these guidelines.
- Some alternative materials may require minimum depths of cover soils placed over them to reduce mechanical or other damage; this must be addressed in the alternative design.

- In some cases, the EPA may require a peer review of the proposal by a suitably qualified and experienced person. Examples of these situations are when the proposal involves a major departure from the acceptable measure(s) in section 9.1, or when the landfill is located near sensitive receptors.
- If the alternative cap is a phytocap, the proposal must address the requirements in section 9.4.

9.4 Alternative caps: phytocaps

Phytocaps (also called evapotranspiration caps, water balance caps or store-and-release caps) do not use an impermeable sealing or barrier layer to resist water movement. Instead, these caps reduce rainwater percolation into the waste by storage and evapotranspiration processes. Water is stored in a deep soil layer during wetter periods and is removed during hotter, drier periods by evaporation from the soil surface and transpiration by plants in a diverse vegetation community.

The performance of phytocaps depends on the soils, vegetation and climate. These types of caps tend to perform better in arid and semi-arid climates than in humid climates. They are likely to struggle to limit percolation into the waste in climates where rainfall significantly exceeds evaporation and/or in climates where the annual distribution of rainfall is unfavourable to the water removal processes. Therefore, they may be unsuitable in such climates.

Phytocaps use a vegetation community containing deep-rooted species that can draw water from the full depth of the soil storage layer. This contrasts with the typical barrier cap, which uses shallow-rooting species so as not to penetrate the barrier layer. Phytocaps may be able to use locally available soils that do not have the engineering properties required for use in the sealing layer of a conventional barrier cap.

Design of phytocaps

Proposals to use a phytocap should address the following requirements:

- The proposal should be prepared in accordance with recognised guidelines, such as Guidelines for the Assessment, Design, Construction and Maintenance of Phytocaps as Final Covers for Landfills (Waste Management Association of Australia, 2011), or equivalent recognised guidelines. A useful text is Water Balance Covers for Waste Containment: Principles and Practice (Albright et al., 2010).
- The design should include numerical modelling of the anticipated cap performance in limiting rainfall percolation into the waste. The modelling should be conducted by using a recognised and proven unsaturated flow model, for example LEACHM (Leaching Estimation and Chemistry Model) or UNSAT-H (Unsaturated Soil Water and Heat Flow Model), or equivalent recognised models. The modelling should include a sensitivity analysis of critical input variables. The modeller should be experienced in using these water balance models.
- The modelling should demonstrate that the proposed phytocap design will transmit percolation at a rate not more than 5% of average annual rainfall for the locality. The design should also consider likely cap performance during wet years (i.e. 90th percentile wet years) and during the initial vegetation establishment stage.
- The modelling should use site-specific soil, vegetation and climate data. Climate data should be from the closest weather station with at least 50 years of rainfall and evaporation data, if one is available and suitable. The model inputs should be conservatively chosen, using sequences of the wettest years on record to model worst case scenarios.

Appendix B

Properties and predicted performance of alternative capping

Table 2 Description of cap layers

Layer Type	Material and thickness	Hydraulic properties	Strength	Resistance to degradation	Long term behaviour	Compatibility with adjoining layers	Slope stability (where relevant)	Construction methods (including around penetrations and protrusions)
Topsoil layer/ revegetation	0.1 m topsoil Specification to ensure material is suitable growing medium	N/A	N/A	High once revegetated	Stable once topsoil revegetated	Compatible	Stable based on anticipated grades of slopes to be capped	Standard earthmoving equipment
Subsoil layer	0.5 m subsoil	N/A	N/A	High once topsoil is revegetated	Stable once topsoil is revegetated	Compatible	Stable based on anticipated grades of slopes to be capped	Standard earthmoving equipment
Subsoil drainage layer	Geonet drainage geocomposite layer Specification to require geonet core with geotextile layers bonded to both sides	Required property to be calculated and reflected in technical specification	Required property to be calculated and reflected in technical specification	High once covered	Stable unless exposed to ultraviolet light	Compatible Geotextile layers provides separation from soil above and protection of geomembrane below.	Stable based on anticipated grades of slopes to be capped	Placed by specialist contractors

Barrier layer	2 mm thick LLDPE geomembrane layer Specification to require double-side textured geomembrane	N/A	Required property to be calculated and reflected in technical specification	High UV resistant	Stable	Compatible Protected by lower geotextile of geonet drainage geocomposite Specification to require appropriate surface finish to prevent damage from seal bearing layer beneath	Stable based on anticipated grades of slopes to be capped	Placed by specialist contractors
Seal bearing layer	0.3 m thick select fill material Specification to include restrictions on particle size	N/A	N/A	High once covered	Stable once covered	Compatible	Stable based on anticipated grades of slopes to be capped	Where already present, will be re-worked prior to placement of geomembrane on top of it to remove potential protrusions and vegetation.

Appendix C

Leachate management plan