

The Long Goodbye

TAILINGS.WATER.WASTE.

Long-term exposed steep slope liners: a risk-based approach

ATC WILLIAMS

WHAT TO EXPECT IN THIS PRESENTATION

01

Exposure is not rare

Long, steep side slopes stay uncovered for long time — “cover it quickly” is often not an option.

02

What the evidence shows

Recent global case studies, field trials and laboratory work.

03

Where that leaves us

Mitigations, their practical limits, and a risk-based approach for the Australian context.

TAILINGS.WATER.WASTE.

Source: Thiel, R. (2025). Issues of steep sideslope liners that remain exposed and are later covered. E3S Web of Conferences, 644, 05001. https://doi.org/10.1051/e3sconf/202564405001

ATC WILLIAMS

THE LONG STEEP SIDE SLOPE

For context, ‘long steep side slope’ in this presentation:

- **For a basal/containment batter slope, combination of:**
- >15m long
- 1V3H or steeper
- **For a final landform batter slope, combination of :**
- >25m long
- 1V4H or steeper

TAILINGS.WATER.WASTE.

ATC WILLIAMS

THE LONG STEEP SIDE SLOPE, ARE THEY REAL?

YES!

It's not only in mining (tailings dam, pond, etc), they also exist in landfill.

Both in landfill cell and landfill cap.

Why do they exist?

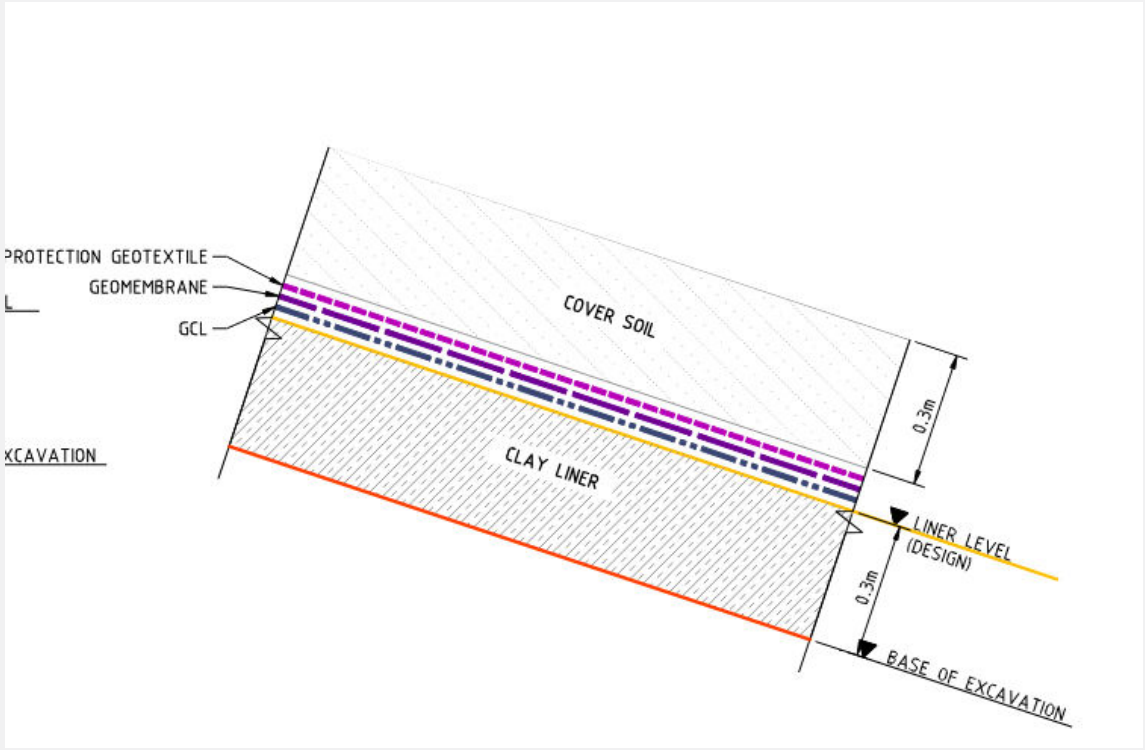
- **Airspace!**
- **Site selection. Some of active major landfills in QLD are ex-quarry, or ex open cut mining activities.**

TAILINGS.WATER.WASTE.

ATC WILLIAMS

EXAMPLE OF A SLOPE LINING PROFILE

Cell: Typically comprises of a single composite liner (GCL+geomembrane) and ≥0.3m thick cover soil



It may also include the following for cover soil stability:

- **Soil reinforcement (e.g. geogrid)**
- **Drainage Geocomposite**

Capping: variabilities of capping profiles. Long & steep batter: Have a long and careful consideration for geosynthetic-based cap!

TAILINGS.WATER.WASTE.

WHEN "COVER IT QUICKLY" IS NOT AN OPTION

Built in campaigns

The entire slope cannot be constructed in one campaign — high initial capital cost and material deterioration rule it out.

Cover soil can't follow



Steep, long sideslopes preclude safe plant access for overliner placement during or straight after construction.

Months, sometimes years

That is how long the geomembrane stays ‘exposed’ without cover soil on real sites.

The exposed condition is a design case — not a gap in the design.

We’ll work through that exposed condition next.

*Capping is not discussed further in this presentation — there, the geomembrane is quite often covered quickly.

TAILINGS.WATER.WASTE.

ATC WILLIAMS

GCL DEGRADATION BELOW AN EXPOSED GEOMEMBRANE

ONE MECHANISM

Wet–dry cycling driven by solar heating

1. Downslope bentonite erosion along the geomembrane–GCL interface

2. Panel shrinkage and seam separation

3. Loss of swell and permeability property (minimal impact if GCL remains moist, but moist dry cycle when in contact with soil is bad)

Thiel, R. (2025). *Issues of steep sideslope liners that remain exposed and are later covered*. E3S Web of Conferences, 644, 05001. https://doi.org/10.1051/e3sconf/202564405001

TAILINGS.WATER.WASTE.

ATC WILLIAMS

DOWNSLOPE BENTONITE EROSION



TAILINGS.WATER.WASTE.

ATC WILLIAMS

GLOBAL CASE STUDIES: THE NUMBERS BEHIND THE RISK

3–30%

of panel width lost to GCL shrinkage in field exhumations

1.2 m

maximum shrinkage recorded on a single panel

0.4 m

seam separation after only 2 months exposed

3%

Grade and erosion still occurred — not just steep slopes

HOW FAST IT HAPPENS

2 mo

Seam separation observed

3.5 mo

Bentonite onset erosion

6 mo

Erosion definitive

28 mo

PP-coated GCL: no erosion

TAILINGS.WATER.WASTE.

Rowe, R. K., Brachman, R. W. I., Take, W. A., Rentz, A., & Ashe, L. E. (2016). *Field and laboratory observations of down-slope bentonite migration in exposed composite liners*. Geotextiles and Geomembranes, 44(5), 686–706. https://doi.org/10.1016/j.geotexmem.2016.05.004

Rowe, R. K., Rentz, A. K., Brachman, R. W. I., & Take, W. A. (2016). *Effect of GCL type on downslope erosion in an exposed composite liner*. Journal of Geotechnical and Geoenvironmental Engineering, 04016074.

Thiel, R., Bryk, J., Criley, K., Giroud, J. P., & Erickson, R. (2006). *Laboratory measurements of GCL shrinkage under cyclic changes in temperature and humidity conditions*. Proceedings of the 8th International Conference on Geosynthetics, Yokohama, Japan.

Thiel, R. (2025). *Issues of steep sideslope liners that remain exposed and are later covered*. E3S Web of Conferences, 644, 05001. https://doi.org/10.1051/e3sconf/202564405001

ATC WILLIAMS

WIND UPLIFT: PUBLISHED RECOMMENDATIONS



Geomembrane strength

Thicker geomembrane or reinforcement to increase stiffness.

Anchor trenches

At the crest and midslope.

Ballast design

Midslope ballast reduces the effective exposed, unanchored length.

Interfere with the uplift airfoil

An additional geosynthetic layer to disturb airflow (?)

TAILINGS.WATER.WASTE.

WRINKLES: PUBLISHED RECOMMENDATIONS



Manage wrinkle formation through construction sequencing:

Anchoring

Anchor the geomembrane at the crest.

Afternoon tensioning

Pull out slack during the hottest part of the day.

Seaming and ballast

Tie in the seam, then place ballast.

TAILINGS.WATER.WASTE.

ATC WILLIAMS

DOWNDRAG: PUBLISHED RECOMMENDATIONS



Influenced by many factors, including: length, slope steepness, waste settlement, interfaces shear strengths.

Slope geometry

Flatten the slope.

Reinforcing layer

Reduce strain in sideslope GM (useful for near crest).

Slip surface

Create a slip surface above the geomembrane.

TAILINGS.WATER.WASTE.

ATC WILLIAMS

GCL DEGRADATION – SOME POTENTIAL RISK MITIGATIONS – BUT…

01

Light-coloured / white-surfaced upper geosynthetics (e.g. white geomembrane) to reduce wet-dry cycle magnitude.

BUT it won't completely eliminate it.

02

Use coated or polymer-enhanced GCLs.

BUT what about interface shear strength (long-term, short-term, downdrag)? And polymer elution risk?

03

Heat-tacking of GCL seams to prevent shrinkage from occurring.

BUT is it practical? What about onsite quality control and cost?

04

Design the exposed condition explicitly — set a maximum exposure duration in the specification.

BUT is it practical? Set on what basis?

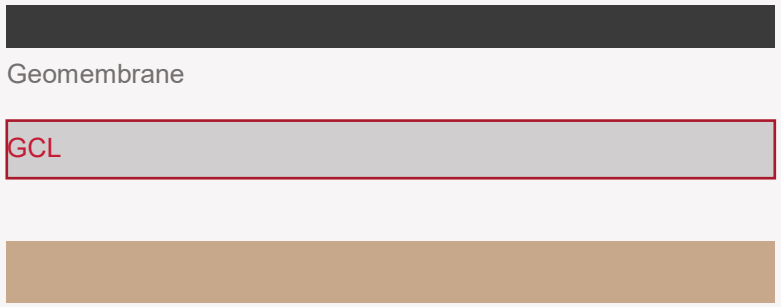
TAILINGS.WATER.WASTE.

ATC WILLIAMS

ALTERNATIVE IDEA FOR THE AUSTRALIAN CONTEXT – RISK BASED APPROACH

CURRENT PRACTICE

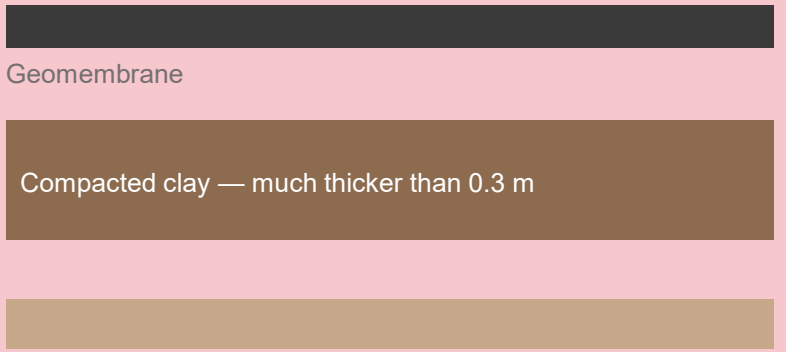
Geomembrane + GCL



Risk: bentonite erosion and degradation while exposed

THE ALTERNATIVE IDEA

Geomembrane + thick clay



Still a composite lining system — side slopes only

Would you take this to your next design review?

Removes the unknown

No ‘known issue, unknown magnitude’ GCL risk carried into operation.

Still composite

Clay beneath the geomembrane keeps the composite liner function.

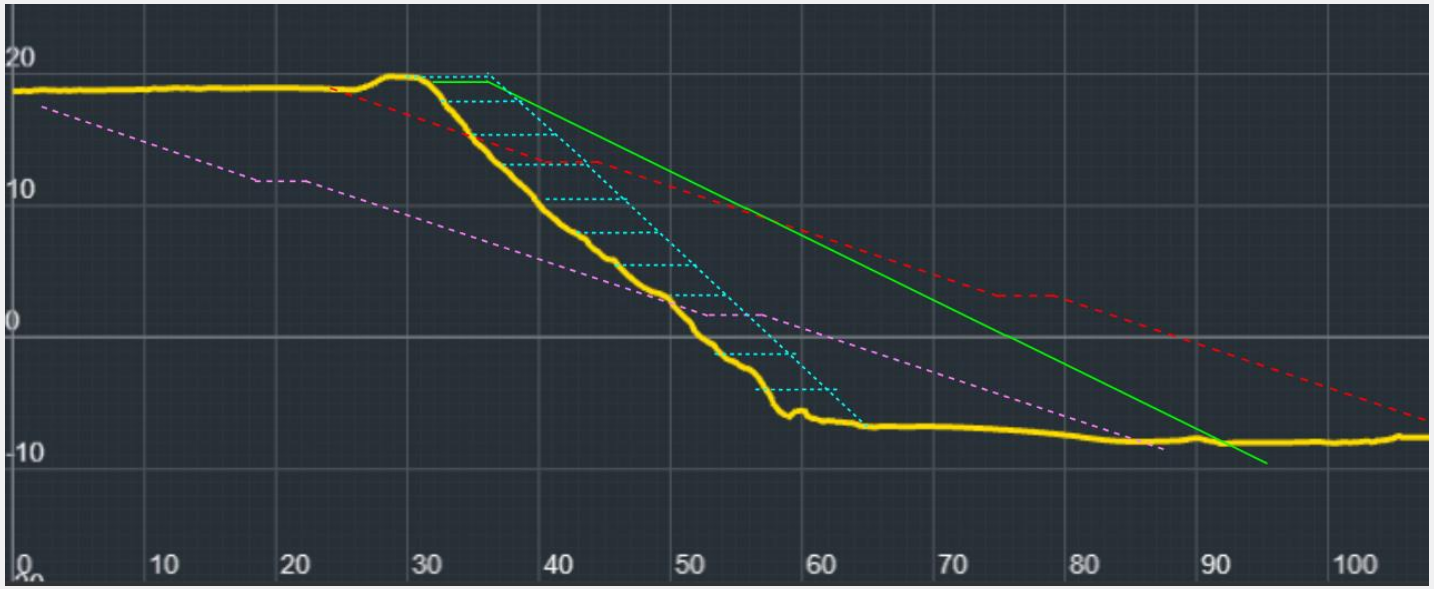
Side slopes only

Not proposed for the floor — apply the risk assessment site by site.

Disclaimer: There will always be competing goals that work against each other, therefore always assess the risks accordingly by an experienced person.

ALTERNATIVE IDEA FOR THE AUSTRALIAN CONTEXT – RISK BASED APPROACH

- **Practicality considerations:**
- Construct in lifts.
- Can improve airspace (no benches required, or may maintain some steepness)



Disclaimer: There will always be competing goals that work against each other, therefore always assess the risks accordingly by an experienced person.

TAILINGS.WATER.WASTE.

ATC WILLIAMS

KEY TAKEAWAYS

- Exposure on steep slopes is normal, not exceptional — design for it
- Wet–dry cycling is the single driver behind three distinct GCL failure modes
- Site with long steep side slope comes with a cost (i.e. there will always residual risks to accept). Exposed slope is also an operational commitment (inspection, monitoring and repair for the period the liner is exposed)
- Recognise there may not be one solution fits all (e.g. solution in the prescriptive standard) and risk assessment should be considered in a whole site risk.
- There may be alternative solution for this specific case that does not require GCL.

TAILINGS.WATER.WASTE.

ATC WILLIAMS

REFERENCES

- Thiel, R. (2025). *Issues of steep sideslope liners that remain exposed and are later covered*. E3S Web of Conferences, 644, 05001. https://doi.org/10.1051/e3sconf/202564405001
- Thiel, R., Bryk, J., Criley, K., Giroud, J. P., & Erickson, R. (2006). *Laboratory measurements of GCL shrinkage under cyclic changes in temperature and humidity conditions*. Proceedings of the 8th International Conference on Geosynthetics, Yokohama, Japan.
- Brachman, R. W. I., Rowe, R. K., & Take, W. A. (2018). *Reductions in GCL overlap beneath an exposed geomembrane*. Journal of Geotechnical and Geoenvironmental Engineering, 144(12), 04018094.
- Rowe, R. K., Brachman, R. W. I., Take, W. A., Rentz, A., & Ashe, L. E. (2016). *Field and laboratory observations of down-slope bentonite migration in exposed composite liners*. Geotextiles and Geomembranes, 44(5), 686–706. https://doi.org/10.1016/j.geotexmem.2016.05.004
- Rowe, R. K., Rentz, A. K., Brachman, R. W. I., & Take, W. A. (2016). *Effect of GCL type on downslope erosion in an exposed composite liner*. Journal of Geotechnical and Geoenvironmental Engineering, 04016074.
- Bradshaw, S. L., Benson, C. H., & Scalia, J. (2013). *Hydration and cation exchange during subgrade hydration and effect on hydraulic conductivity of geosynthetic clay liners*. Journal of Geotechnical and Geoenvironmental Engineering, 139(4), 526–538. https://doi.org/10.1061/GT.1943-5606.0000793
- Thiel, R., & Thiel, C. (2009). *GCL shrinkage: A possible solution*. Geosynthetics Magazine, IFAI, St Paul, MN, Feb./Mar., 10–21.
- Rowe, R. K., Bostwick, L. E., & Thiel, R. (2010). *Shrinkage characteristics of heat-tacked GCL seams*. Geotextiles and Geomembranes, 28, 352–359.

This presentation contains graphic created by Copilot.

TAILINGS.WATER.WASTE.

ATC WILLIAMS