OPTIMIZATION OF MULTILAYER COVERS CONSIDERING FUTURE CLIMATE SCENARIOS

RELEVANT CLIMATE CHANGE IMPACTS FOR NEAR-SURFACE DISPOSAL SAFETY

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NEAR-SURFACE DISPOSAL IS CLIMATE-SENSITIVE

Near-surface facilities are directly exposed to changing surface conditions, while their long-term performance also depends on infiltration, groundwater behaviour and landscape evolution

ATMOSPHERE

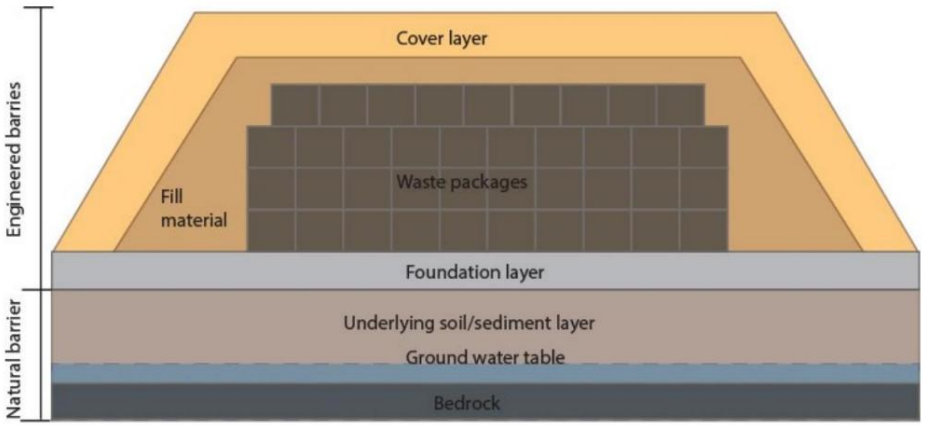
Heavy rainfall - heatwaves - drought - freeze/thaw

COVER

Runoff - erosion - desiccation - vegetation change - infiltration

SHALLOW HYDROGEOLOGY

Water-table variation - groundwater flow - saline intrusion



D. Jacques et al. (2025): Review of different designs/safety concepts and processes governing the performance of engineered barriers in near-surface disposal facilities. Final version as of 04.11.1025 of deliverable D14.1 of the European Partnership EURAD-2. EC Grant agreement n°:101166718.

PRIORITY CLIMATE STRESSORS IDENTIFIED BY CLIMATE

Heavy rainfall

Drainage exceedance, runoff, infiltration and temporary saturation.

Drought

Desiccation, vegetation stress and altered cover moisture.

Heatwaves

Affect operations, worker safety and material performance, and intensify drought-related cover desiccation.

Sea-level rise/coastal change

Marine inundation, saline intrusion, erosion and corrosion.

Groundwater variations

Barrier saturation, changing gradients and transport conditions.

Erosion

Progressive cover loss, slope instability and preferential pathways.

The intermediate time window is challenging. Well-informed scenarios between near-term projections and geological-scale climate states are often less developed.

SINGLE HAZARDS ARE NOT ENOUGH

1	**Sequential cascades**	Drought → vegetation loss → intense rainfall → runoff / erosion → increased infiltration
2	**Compound events**	Extreme rainfall + saturated ground or high groundwater → more severe flooding / saturation
3	**Infrastructure cascades**	Storm or flooding → power / drainage failure → loss of safety-supporting functions
4	**Temporal accumulation**	Repeated wet–dry or freeze–thaw cycles → progressive cracking / material degradation
5	**Spatial propagation**	Catchment or regional groundwater changes → altered flood or hydrogeological conditions at the facility

Scenario 1
Drought and heavy rain

Longer **dry periods and more heavy rain** events are predicted by recent climate models

How should this be taken into consideration in the next **Safety Case update** for near-surface repositories in the following three stages**:**

- **before construction**
- **in construction and/ or in operation**
- **after closure**

Scenario 2
Heatwaves

Heatwaves are expected to intensify, with **+6°C summer peaks** by the end of the century.

Assess the implication for the **repository safety**.

- Which **parts** of the repository are most **likely to be affected**?
- How should the **monitoring and inspection strategy be designed** to track and assess potential impacts?

Scenario 3
Accelerated extreme events

Recent climate models predict **more frequent droughts, heavy rain events, storms, and freeze/thaw** cycles starting mid-century (2050).

Discuss if the **cover design** has to be adapted and, if yes, how

Scenario 4
Long-term uncertainties

Climate projections diverge significantly after 2100 (high uncertainties).

Please define an **optimization strategy** that:

- remains **robust** under high climate uncertainties
- **balances** safety, cost, reversibility, and stakeholder trust