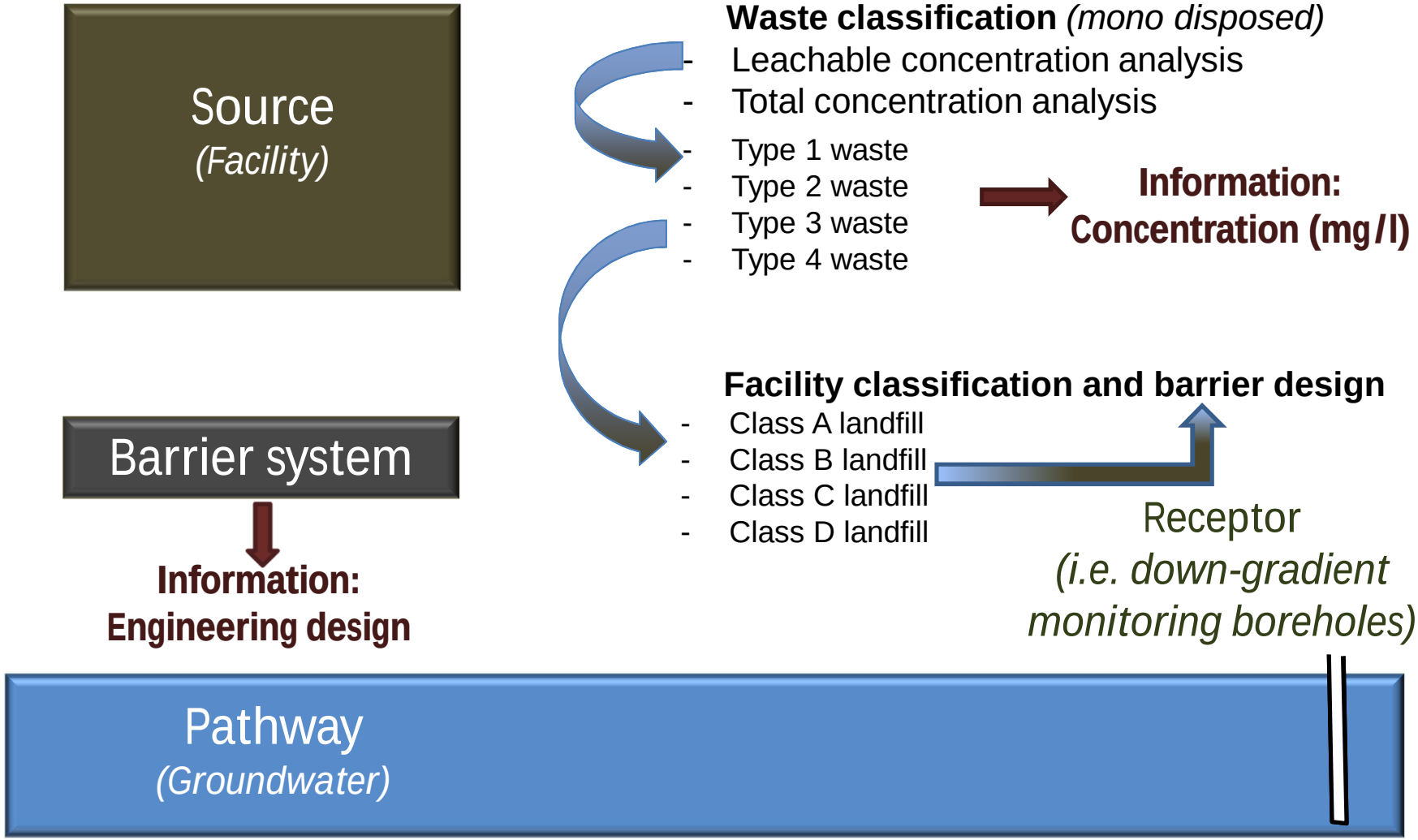
Institute of
Waste Management
of Southern Africa

UNSATURATED MODELLING AND COVERS FOR MINE RESIDUE

WASTE ACT REQUIREMENTS



GROUNWATER IMPACT MODELLING STUDIES

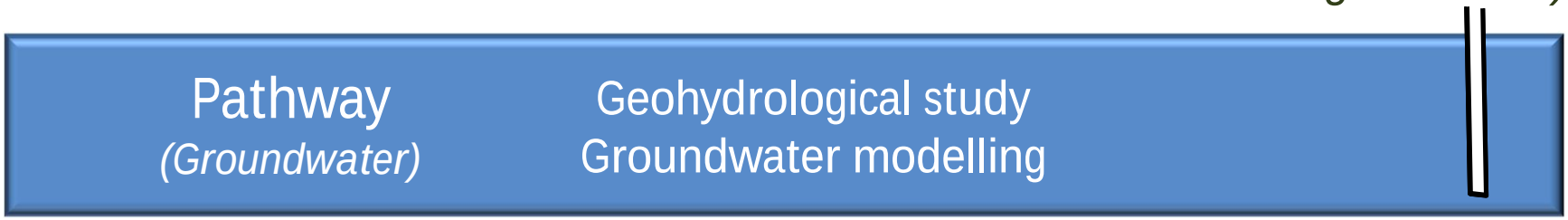
Source *(Facility)*
Geochemical study
Geochemical modelling

Leachate concentration (mg/l)
(Kinetic test and pore water equilibrium modelling results)

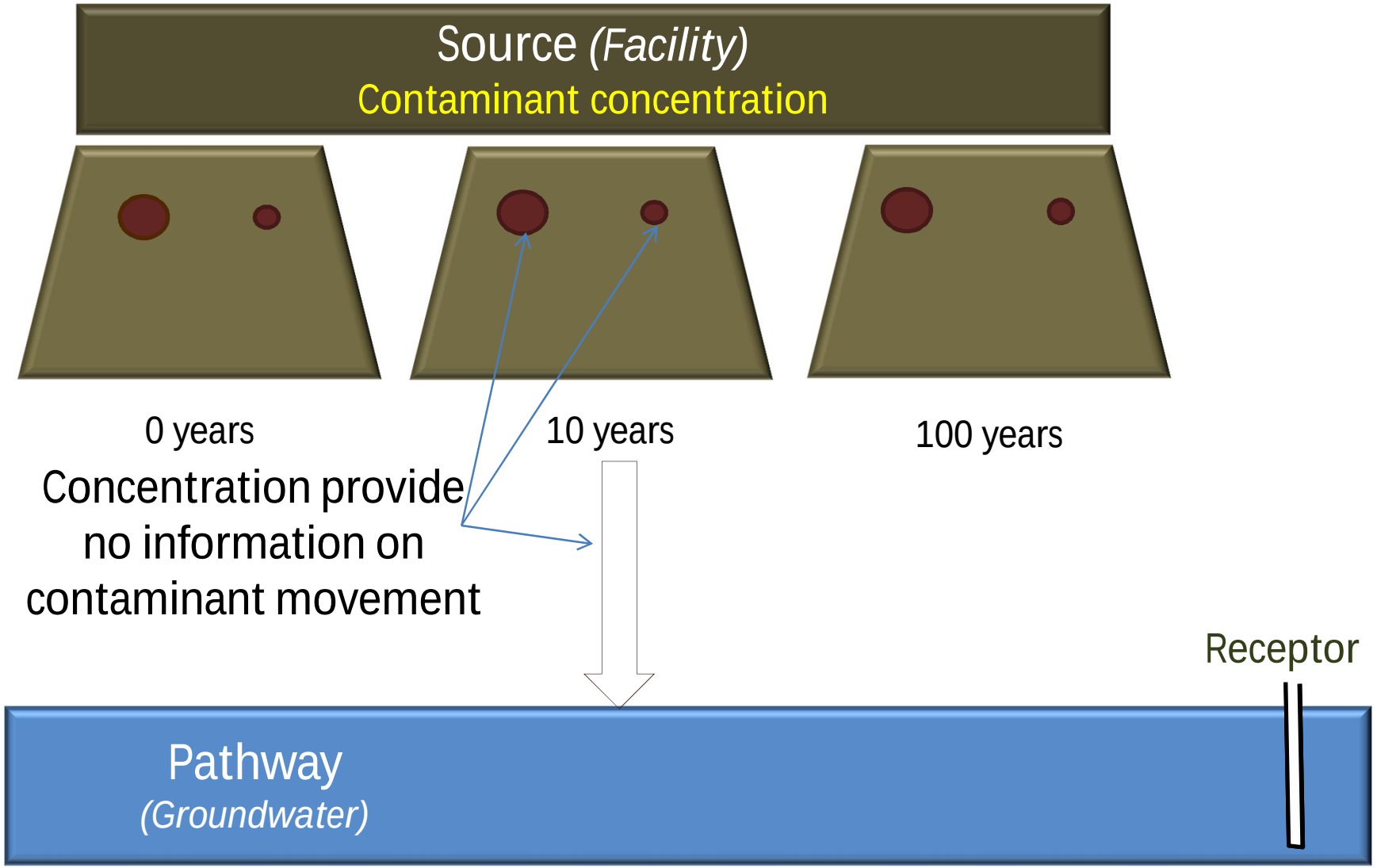
Source *(Facility)*
Waste classification

Leachate concentration (mg/l)
(Static test results)

Receptor
(i.e. down-gradient monitoring boreholes)



SEEPAGE IMPACT PREDICTION



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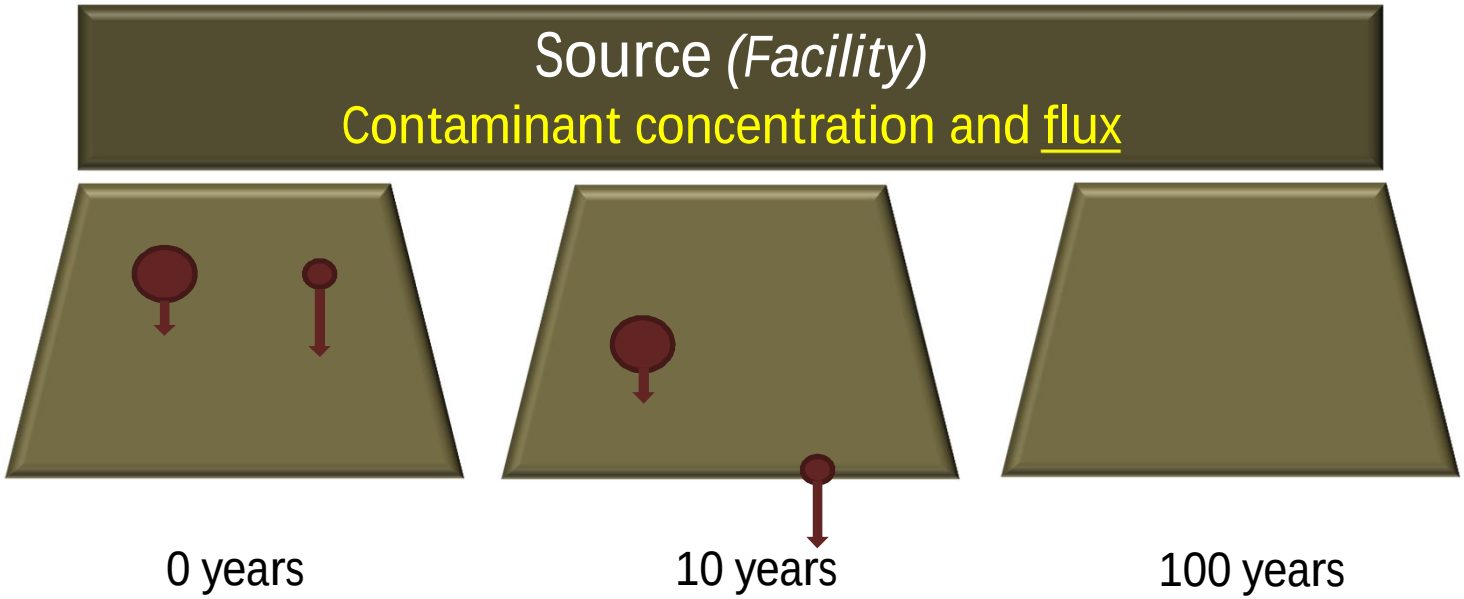
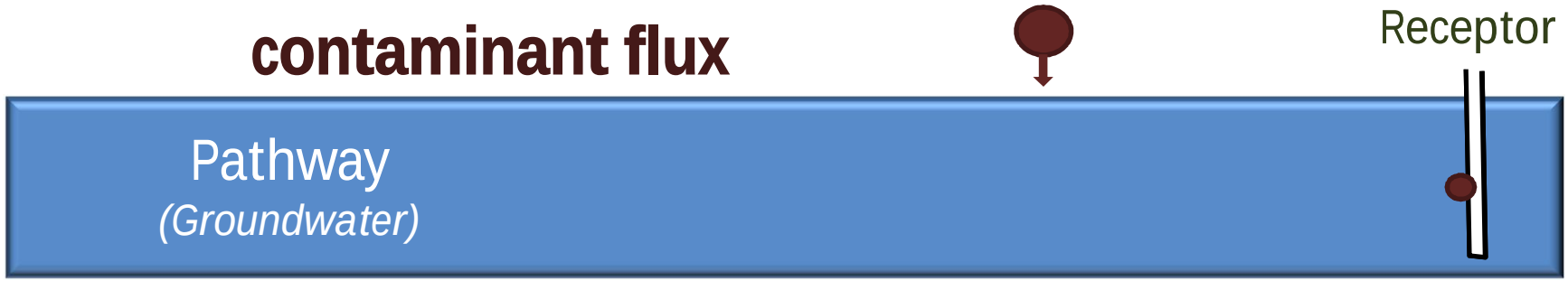
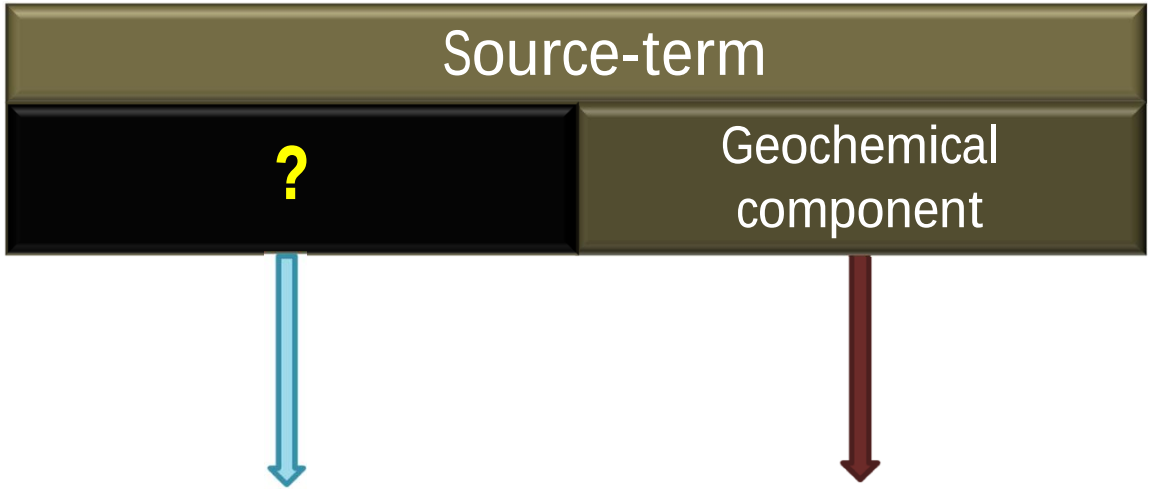


Groundwater impact prediction should also consider contaminant flux



SEEPAGE IMPACT MODELLING



Seepage rate ($m/d/m^2$) X **Leachate concentration (mg/l)** = **Seepage flux ($kg/d/m^2$)**

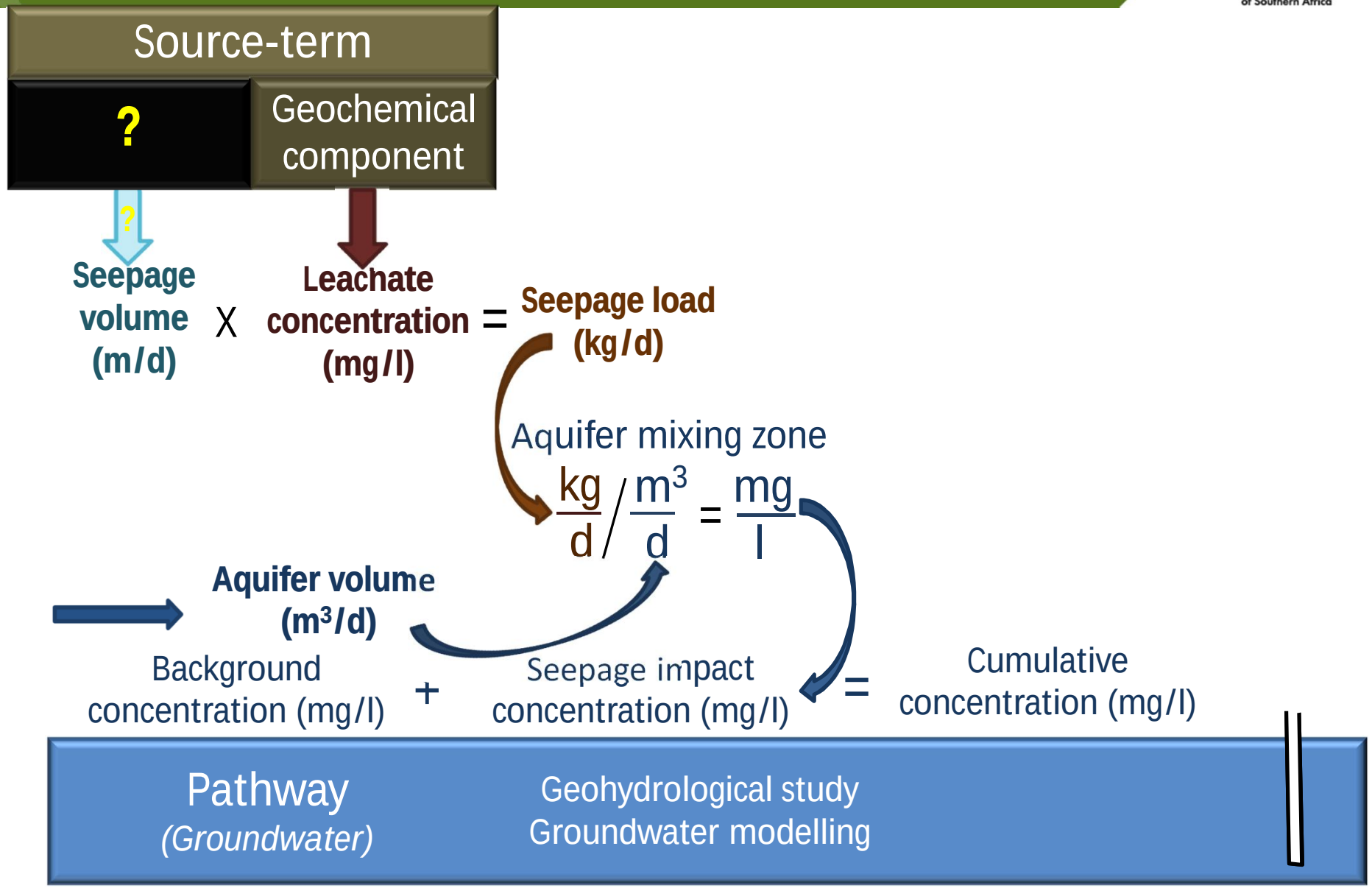
X

Footprint area (m^2)

=

Seepage volume (m/d) X **Leachate concentration (mg/l)** = **Seepage load (kg/d)**

GROUNDWATER SEEPAGE IMPACT MODELLING



SEEPAGE IMPACT MODELLING

Leachate concentration *(quantity component)*

Contaminant mass (kg) in facility

↓

Contaminant mass that will seep over time

Seepage load *(intensity component)*

Rate contaminant leaching (kg/d)

↓

Impact on groundwater quality over time

Contaminant mass / seepage load *(buffer component)*

Duration of seepage impact (yr)

↓

Period seepage mitigation measure(s) to function

COVERS

COVER OPTIONS

COVER OPTIONS FOR MINING RESIDUES *(relevant to South Africa)*

- Soil cover *(based on principle of store and release cover)*
- Clay capping *(based on principle of watershedding cover)*
- Geosynthetic cover *(based on principle of barrier system)*

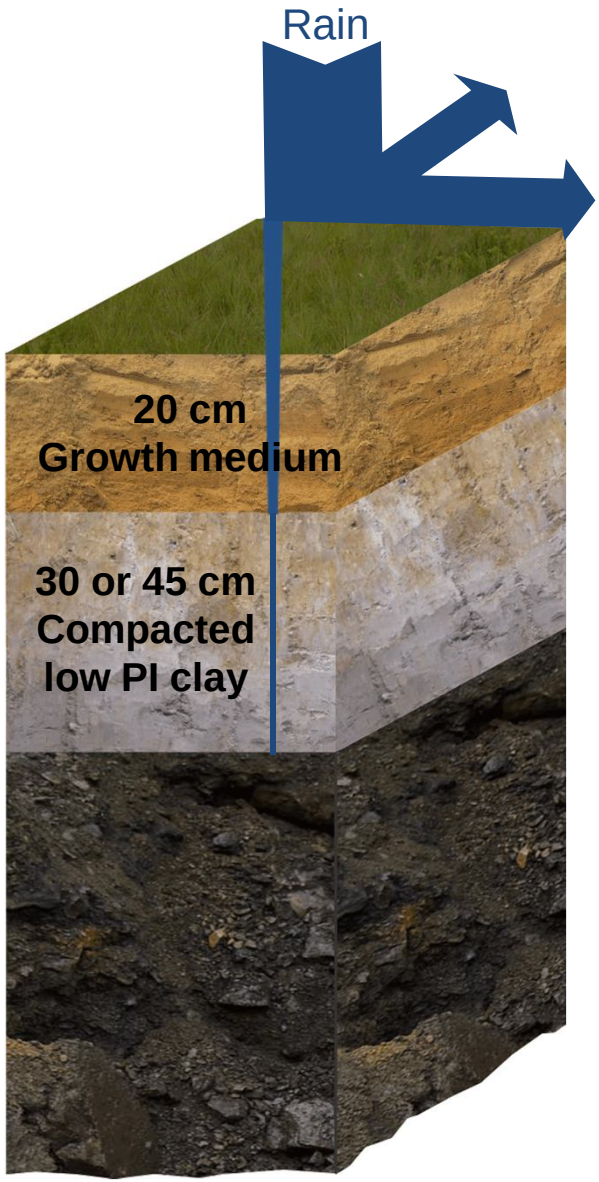
GOOD COVER DESIGN PRINCIPLES

- Simplest and most cost-effective *that*
- Meet environmental requirements *and*
- Perform in the long-term
  - Sustainable cover functioning
  - Cover resilience *(extreme events, droughts, fire, climate change)*

Long-term performance more relevant than initial performance considering period required for seepage mitigation

- Multi-functional cover
  - Water resource protection *(surface and groundwater)*
  - Landscape functioning
  - Ecological functioning
  - Nuisance related *(aesthetic value, dust, vapour)*
  - Other
- Optimised land use potential
- Potential to recover construction costs
  - Reduced pump and treatment costs
  - Reduced post closure care and maintenance
  - Higher land use potential / land capability
- Maximum use of site available materials
  - Soils
  - Softs
  - Rock-softs or rock soils mixtures

WATERSHEDDING *(clay capping)* COVER



Moisture losses through increased runoff

Concept

Shed rain of cover by limiting rain infiltration

MR, 1998 capping specifications

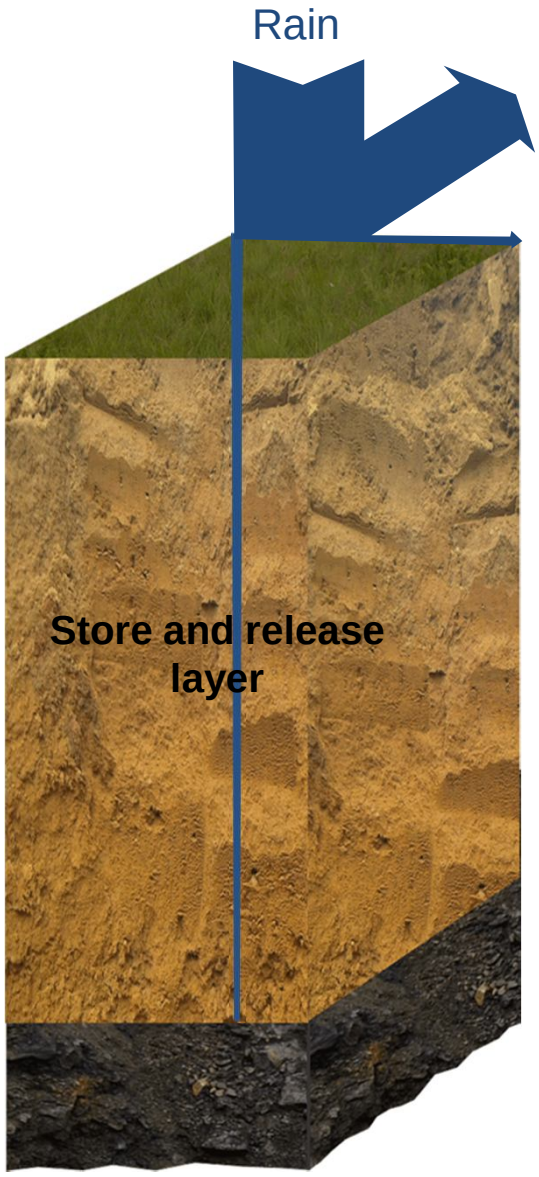
Arid and semi-arid climate

Desiccation cracks and associated preferential flows

↓

Increased moisture ingress in long-term

STORE AND RELEASE *(evapotranspirative)* COVER
THICK SINGLE LAYER



Moisture losses mainly through plant transpiration and soil evaporation

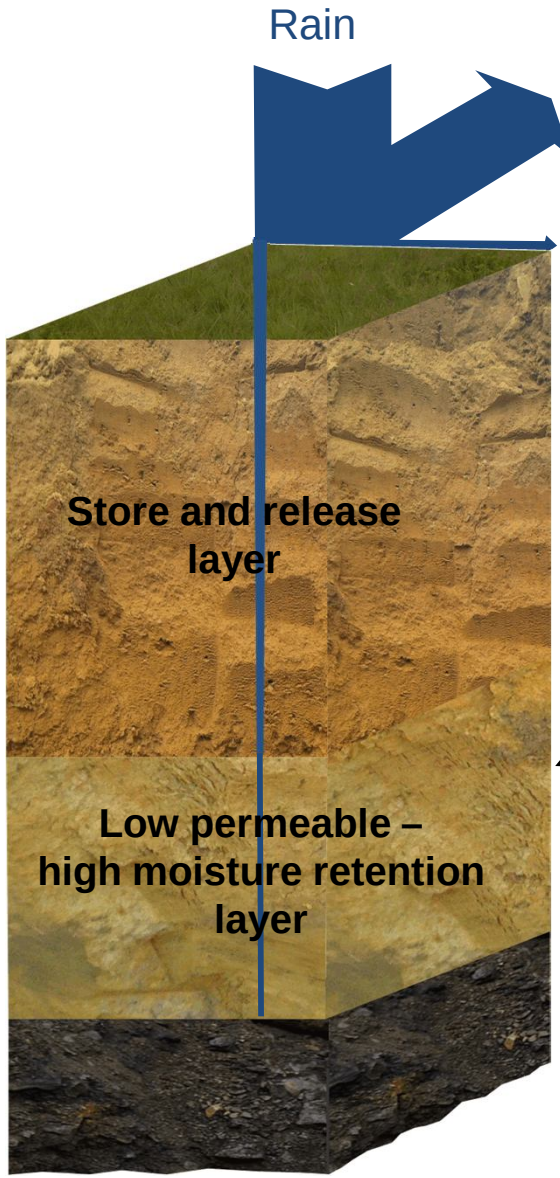
Concept

- Retain and store infiltrated rain during rain events
- Moisture losses through plant transpiration and evaporation between rain events

Maximise plant transpiration

- Vigour vegetative growth
- Deep rooting system *(important for wet years)*

STORE AND RELEASE *(evapotranspirative)* COVER
DUAL LAYER



Moisture losses mainly through plant transpiration and soil evaporation

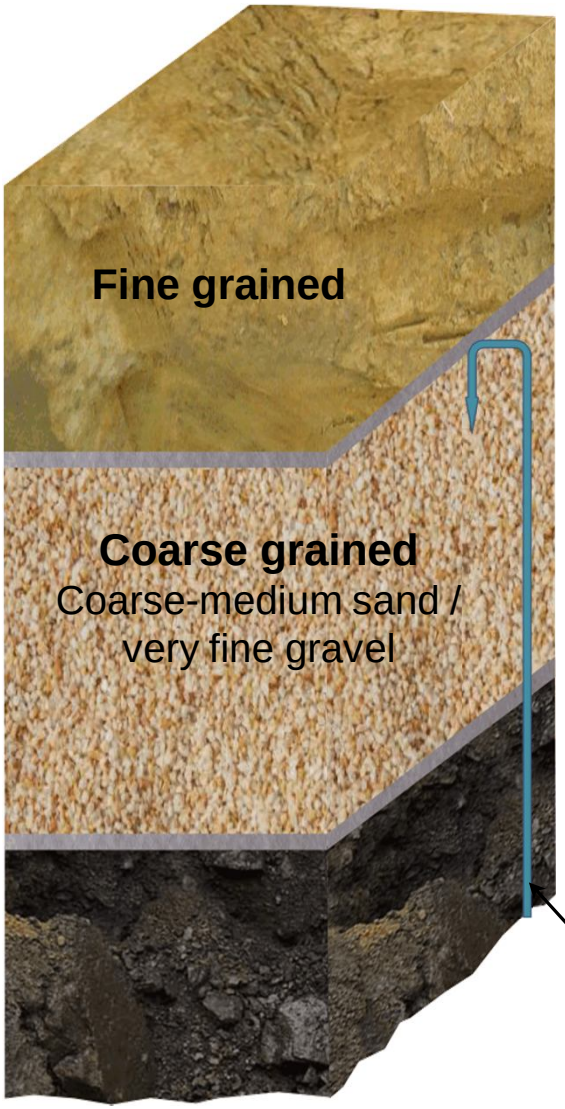
Concept

- 2nd Low permeable-high moisture retention layer temporally store deep percolated moisture during high rainfall events
- Upward movement of moisture from 2nd layer into rooting zone in 1st layer during drier period for plant transpiration

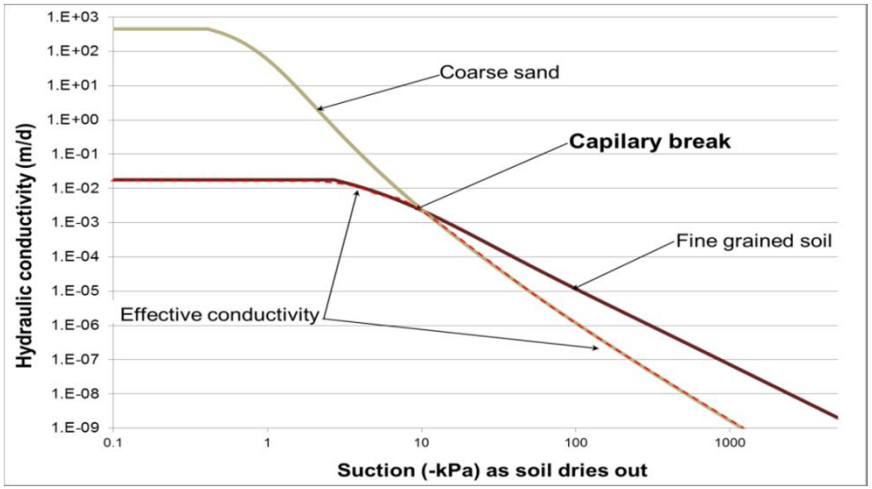
Not flow limiting layer

Not suitable for steep slopes *(i.e. outer slopes)* due to risk for lateral flow

CAPILLARY BREAK



Concept



Requires strict construction quality assurance

- Capillary breaker material grading specifications
- Abrupt boundary transition *(geotextiles to create abrupt effect)*

- Effective for convective *(capillary-flow)* **salt/acid transport**

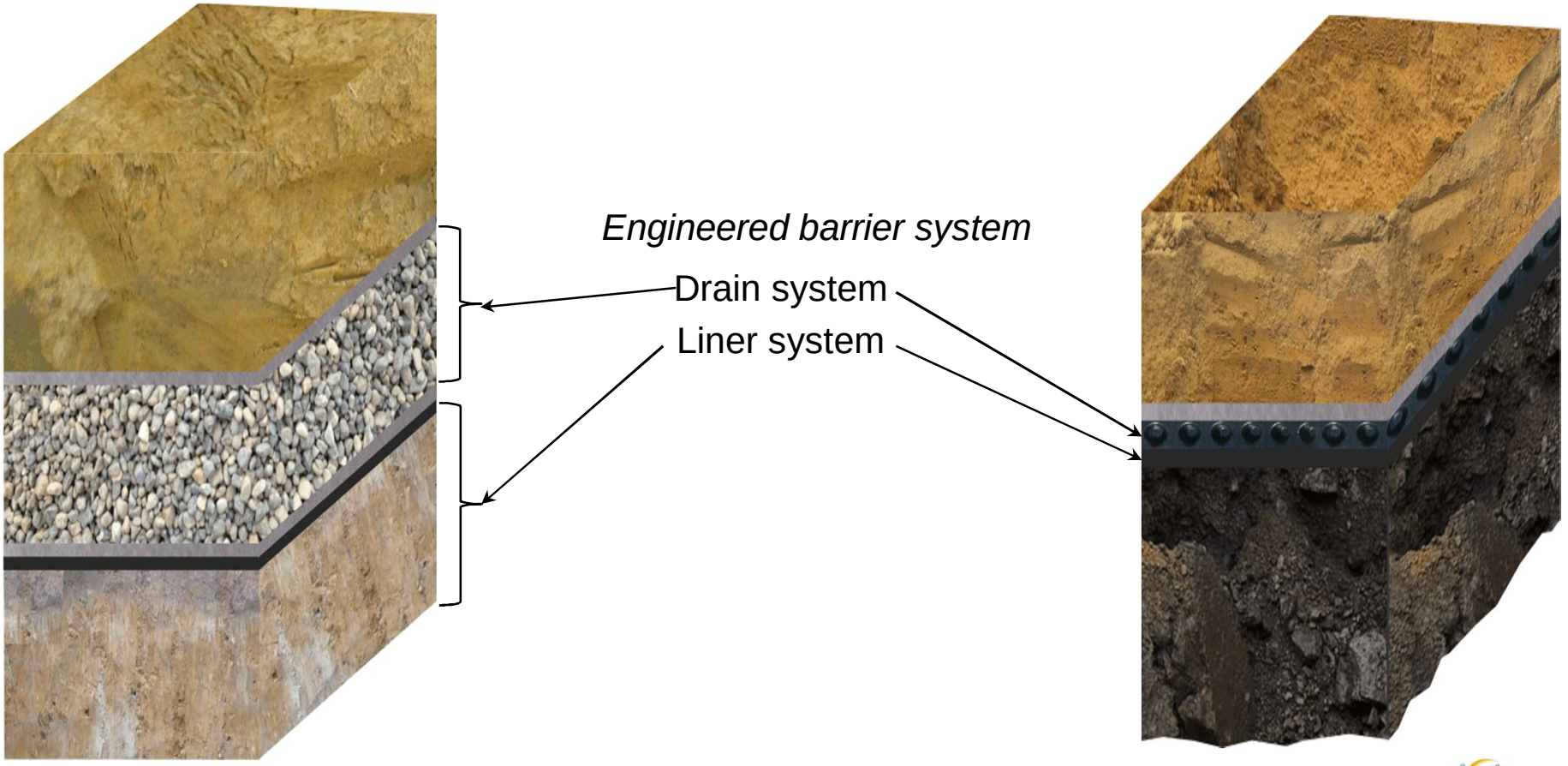
- Not effective for advective *(due to concentration gradient)* **salt/acid transport**

Prevent/limit upward movement of salts and acids into growth medium

GEOSYNTHETIC COVER

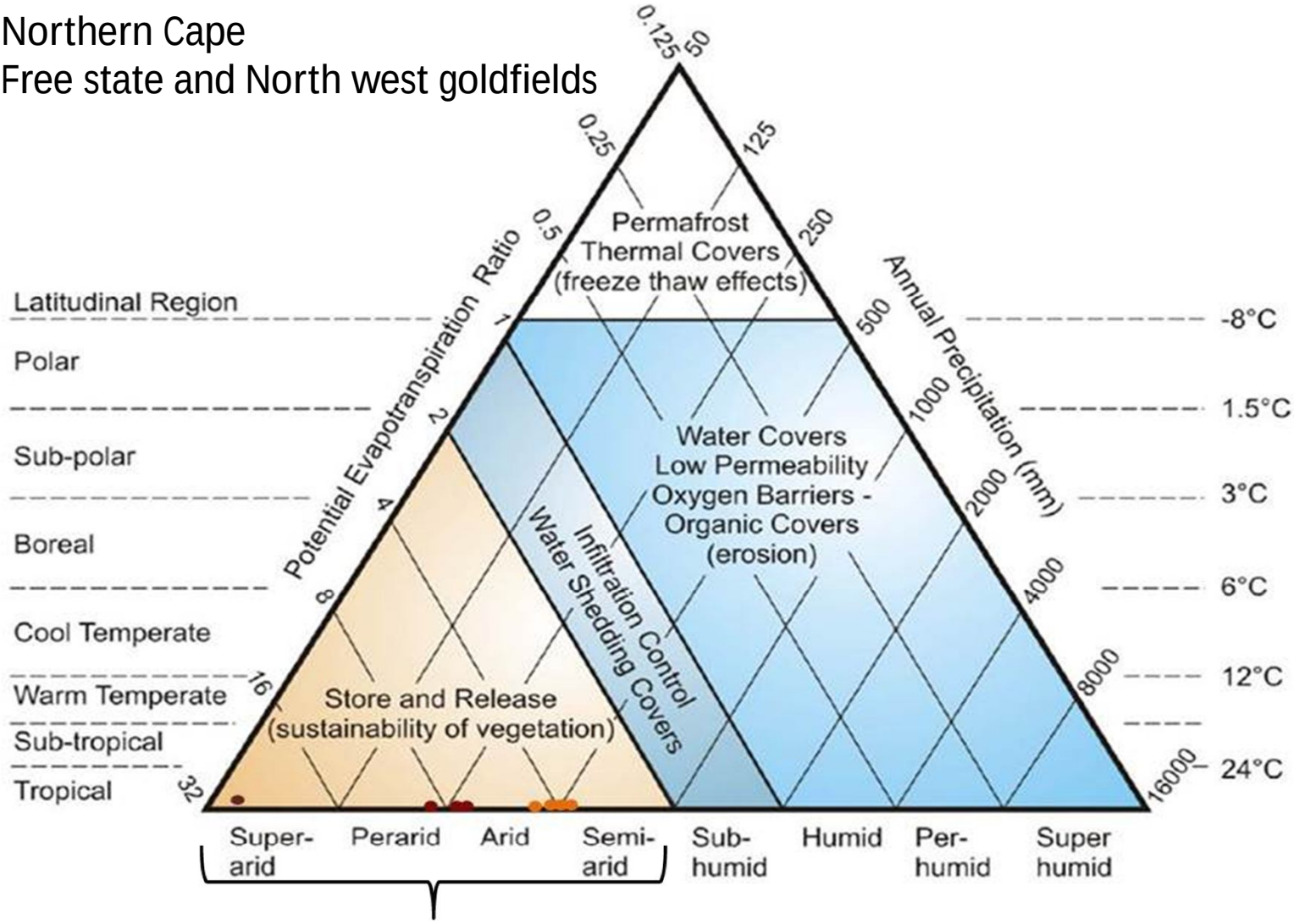
Concept

Intercept infiltrated rain with engineered barrier system



CLIMATE AND COVER TYPES *(IGARD, 2009)*

- Northern Cape
- Free state and North west goldfields



±90% of South Africa

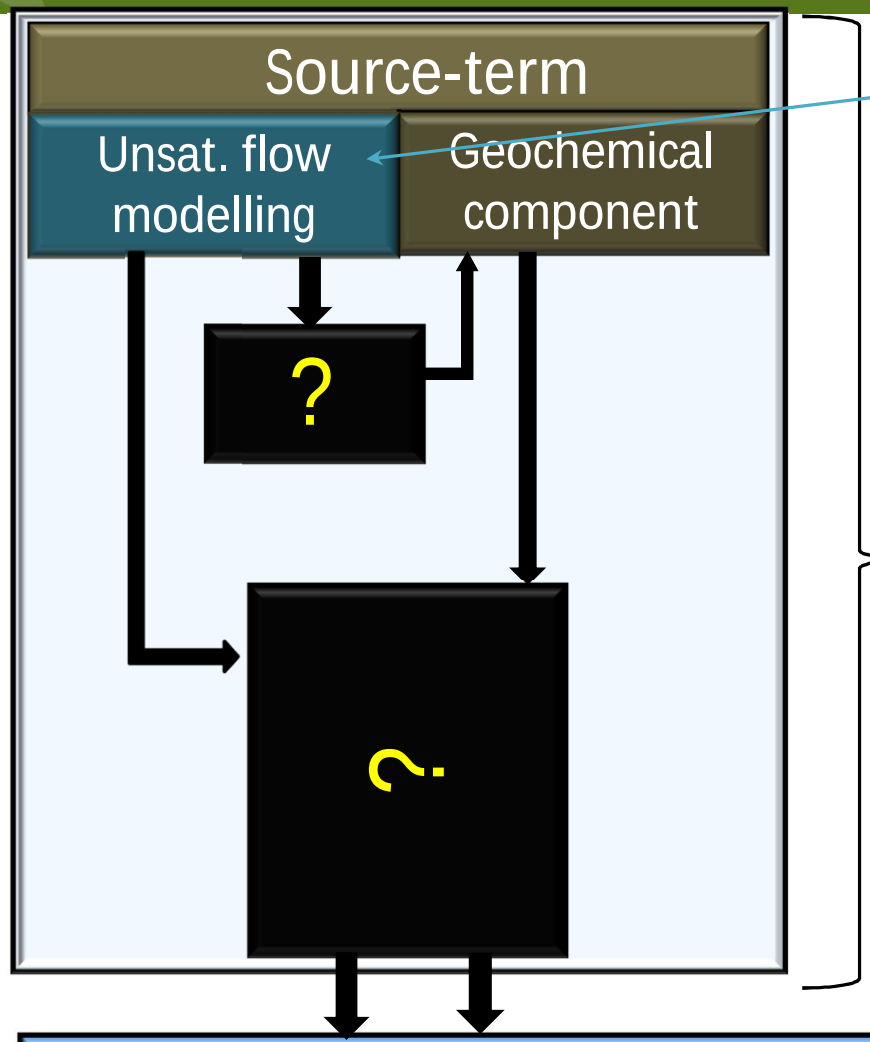
CLIMATE AND COVER TYPES *(IGARD, 2009)*

- Steelpoort
- West and East rand
- Mpumalanga highveld
- Mpumalanga escarpment
- Kwa-Zulu Natal coalfields
- Kwa-Zulu Natal coast

Border case – Determination of site material hydraulic properties important to determine if store and release or watershedding cover

MOISTURE INGRESS PREDICTION

UNSATURATED FLOW MODELLING

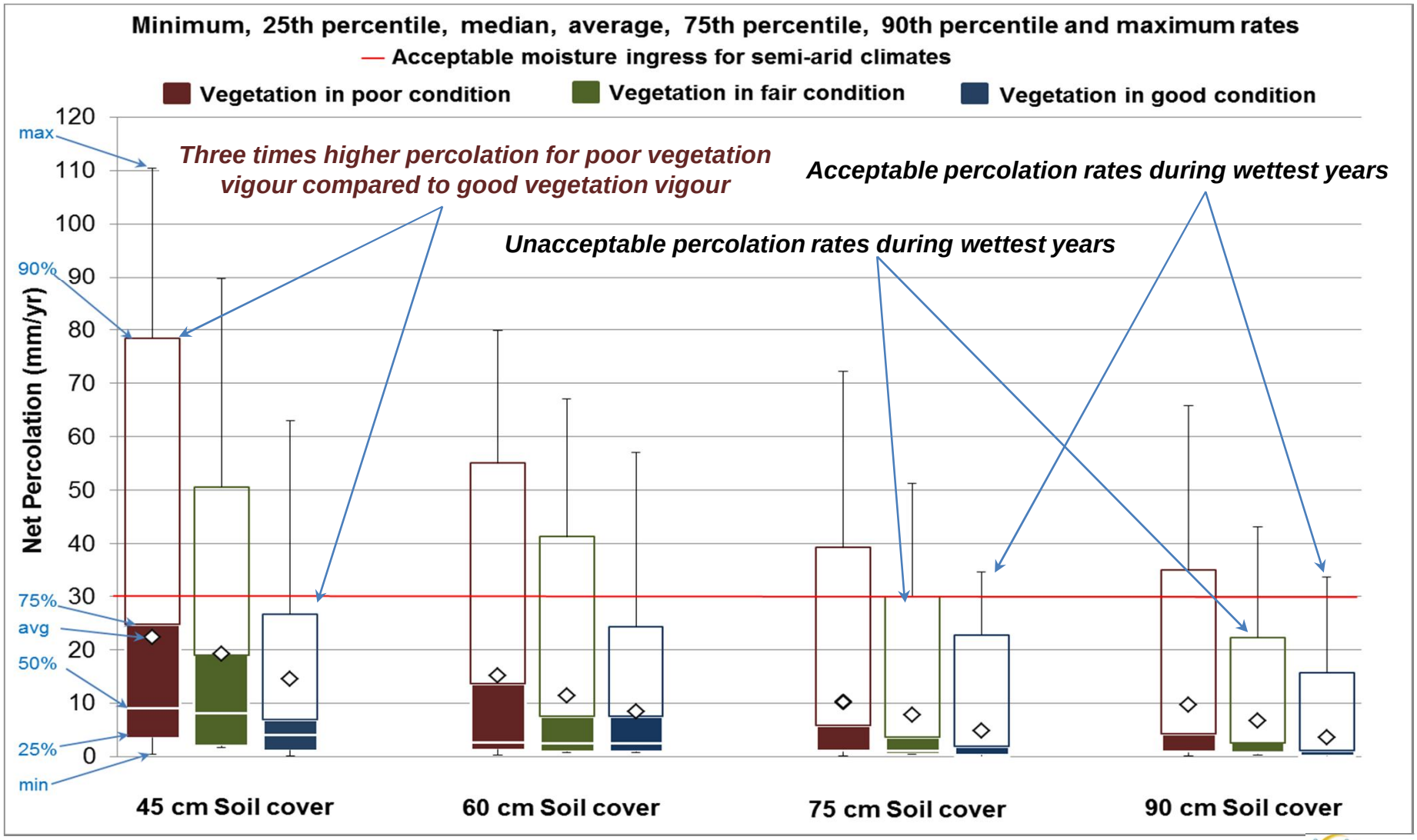


Unsaturated flow modelling

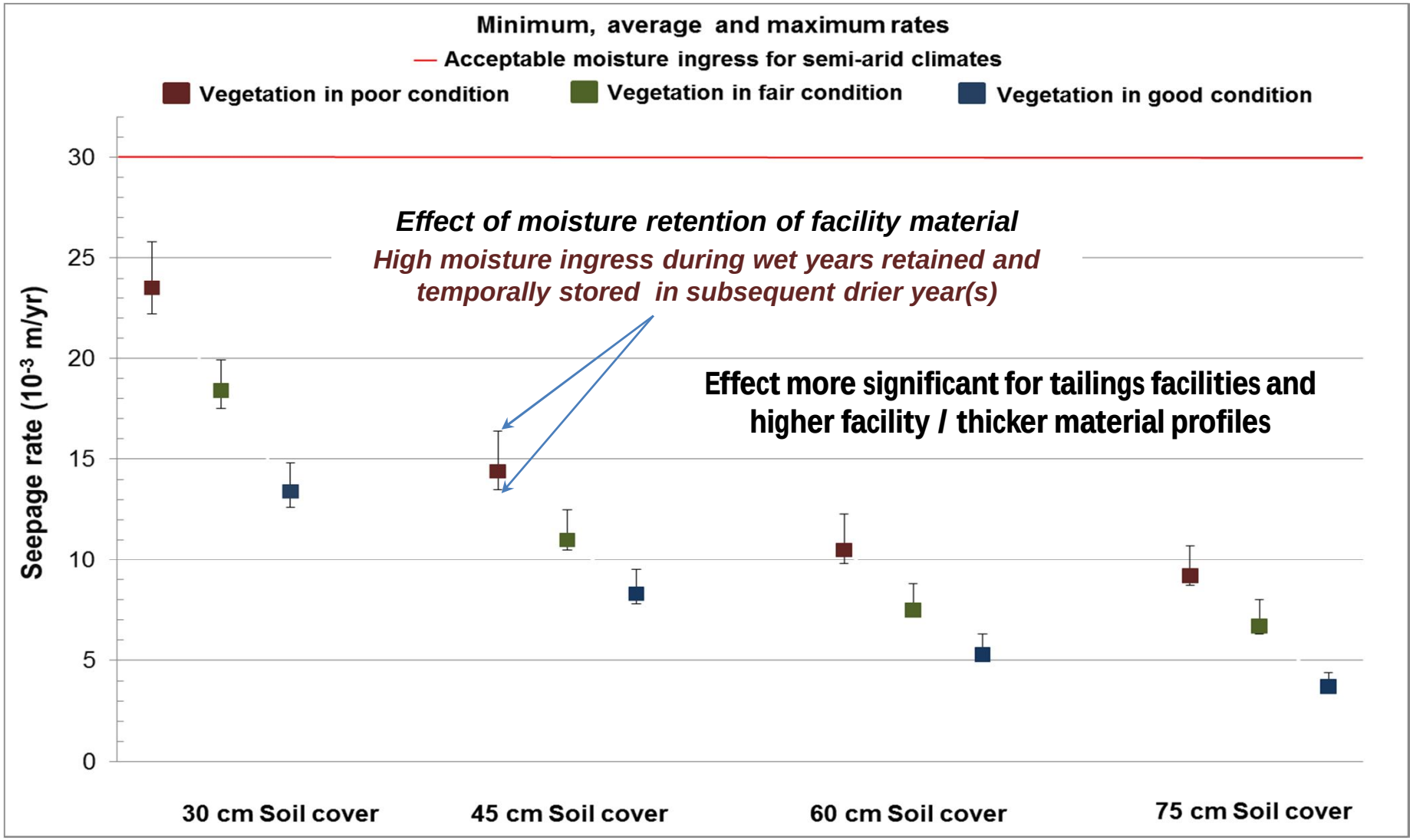
- Moisture ingress into facility
- Seepage from facility
- Moisture conditions
  - Oxygen ingress modelling
  - Predict pore-water (leachate) concentrate

Unsaturated zone above groundwater table

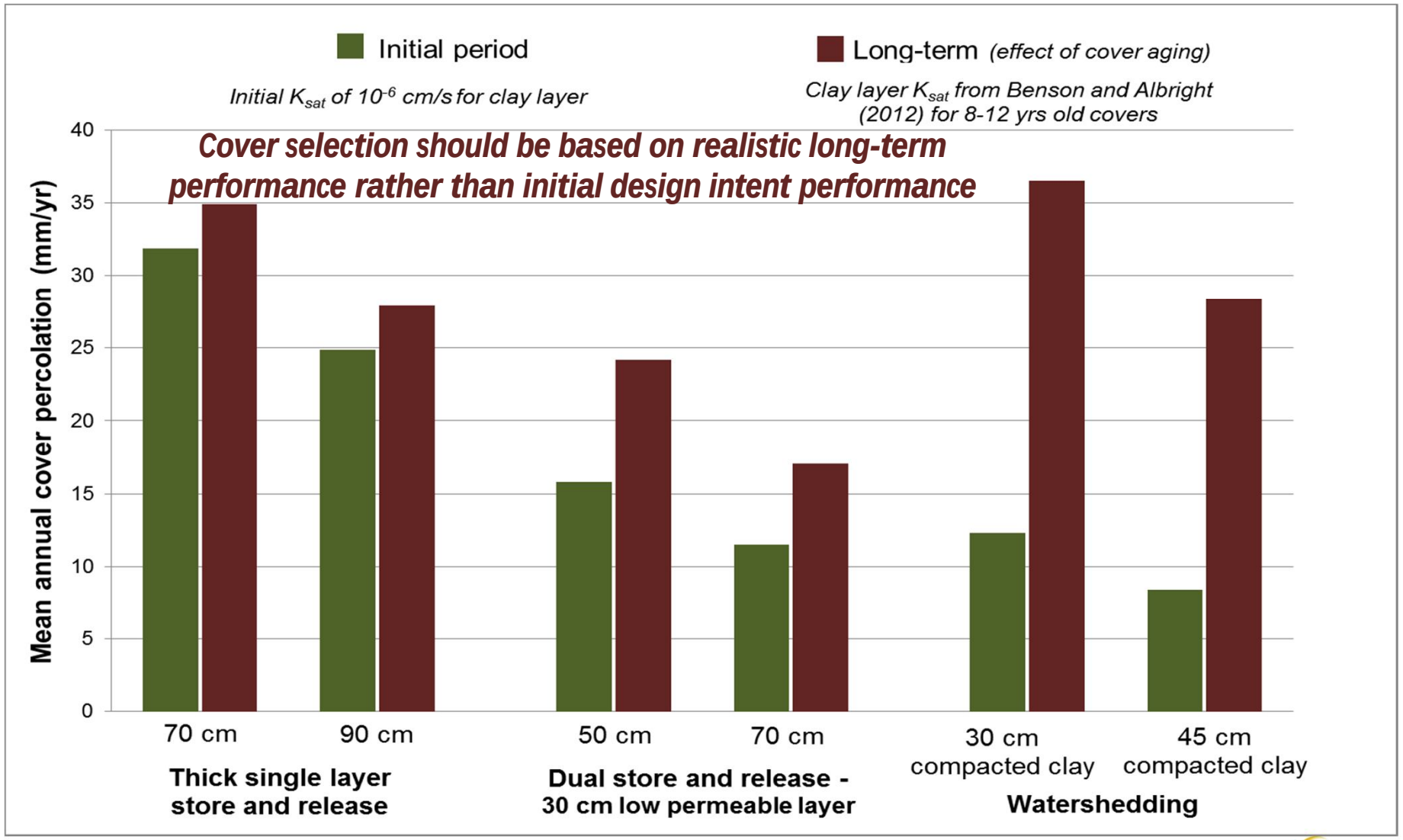
COVER PERCOLATION
(Moisture ingress into facility)



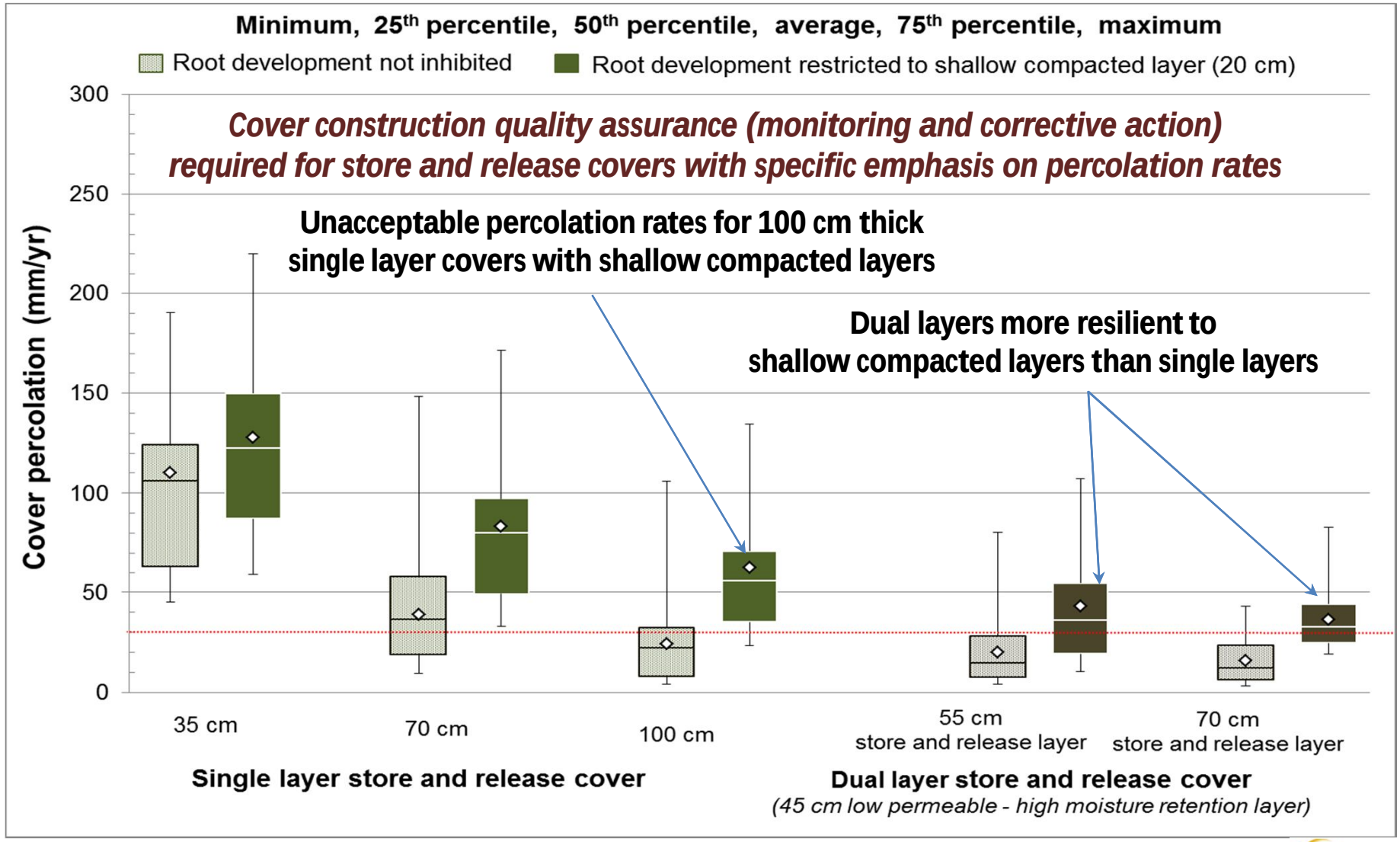
SEEPAGE AT FACILITY FOOTPRINT
(Climate equilibrated – i.e. receded phreatic surface)



EFFECT OF COVER AGING

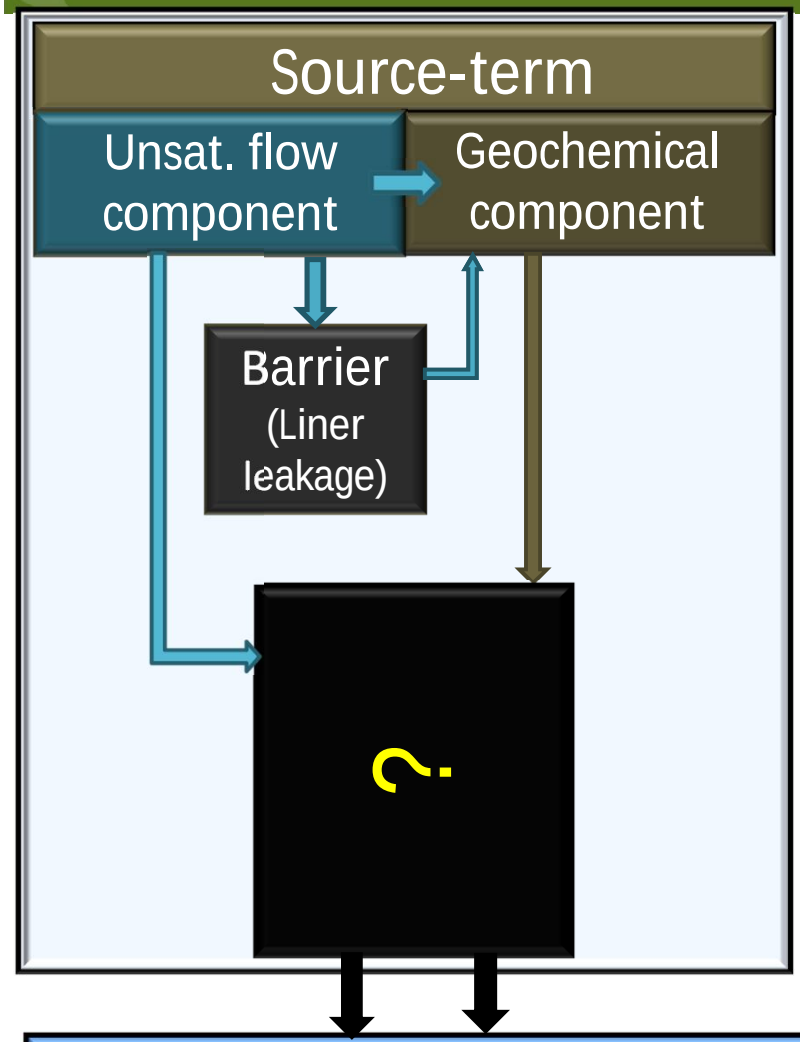


EFFECT OF POOR COVER CONSTRUCTION



FACILITY SEEPAGE PREDICTION

INTEGRATED SOURCE-TERM MODELLING



Integrated unsaturated flow-geochemical modelling

Lower ingress rates → lower degree of saturation
higher acid rock drainage ← higher oxygen ingress

Lower ingress rates → lower moisture content
higher pore water concentrations (leachate quality)

Liner leakage modelling

- Geosynthetic cover or liner system
- Based on:
  - Liner and drainage systems configuration
  - Properties of various layers
  - Level of construction quality assurance
  - Reduction in drain layer permeability
  - Geomembrane degradation rate

PROPOSED CAPPING STANDARDS

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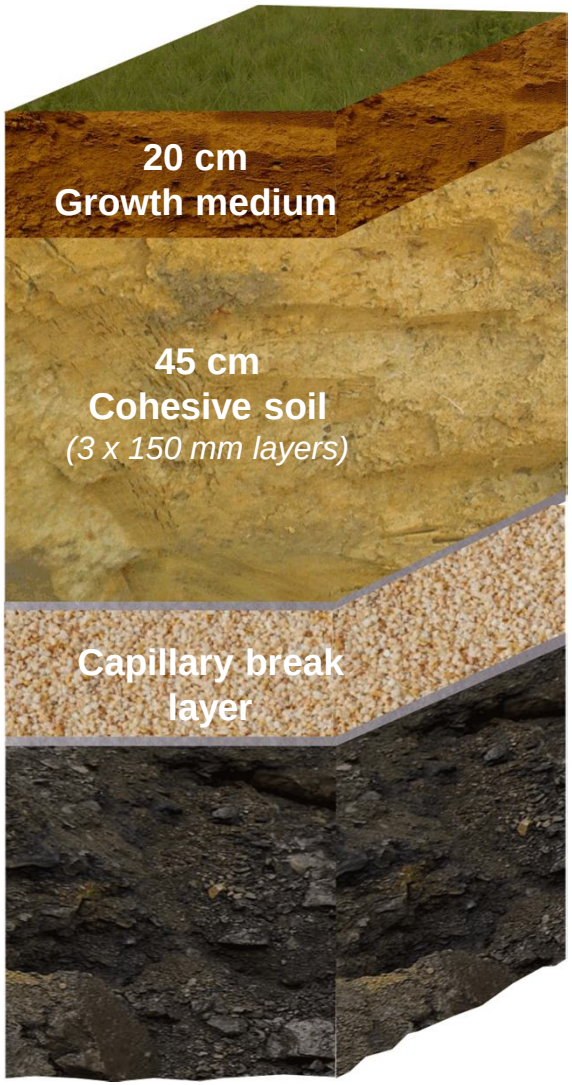
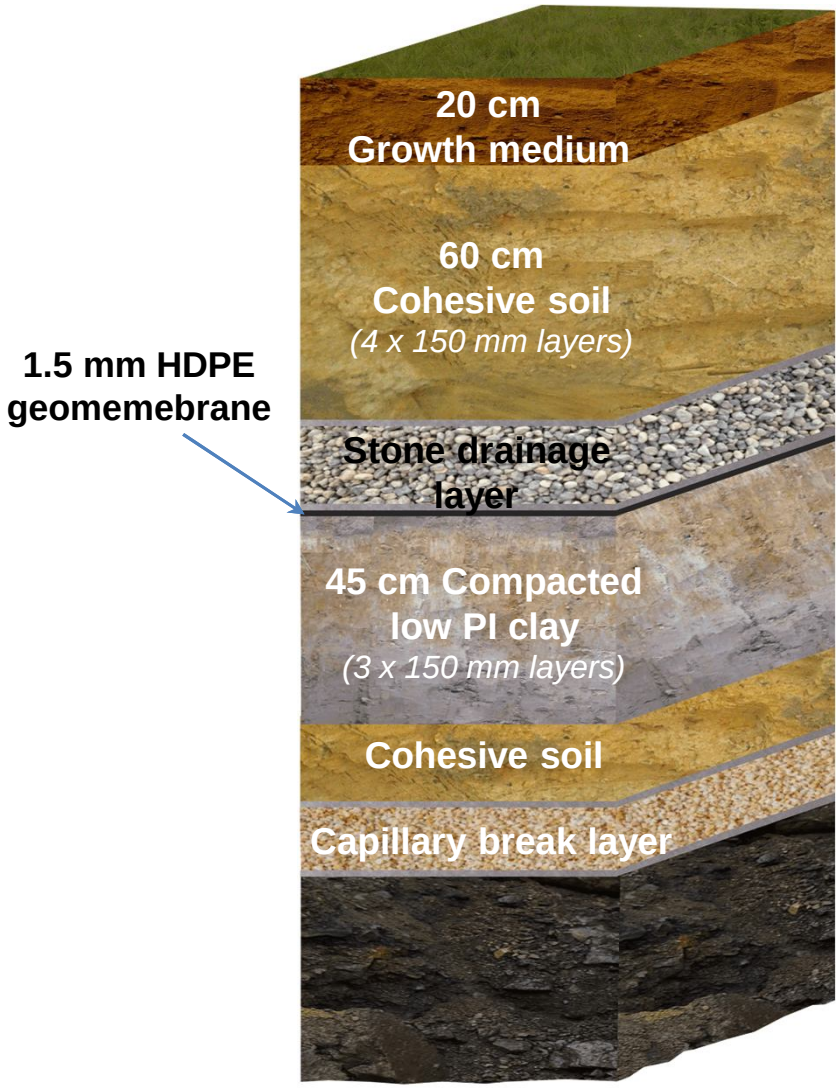
Infiltration cap



Dry cap



TERRASIM EARTH TECHNOLOGIES

STORE AND RELEASE COVER COMBINATION

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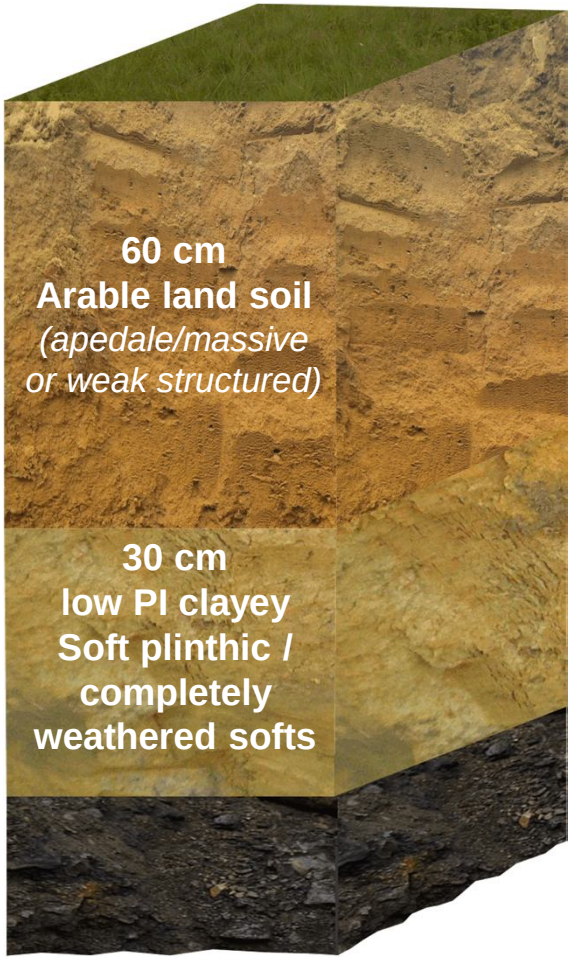
Dual layer for upper surface

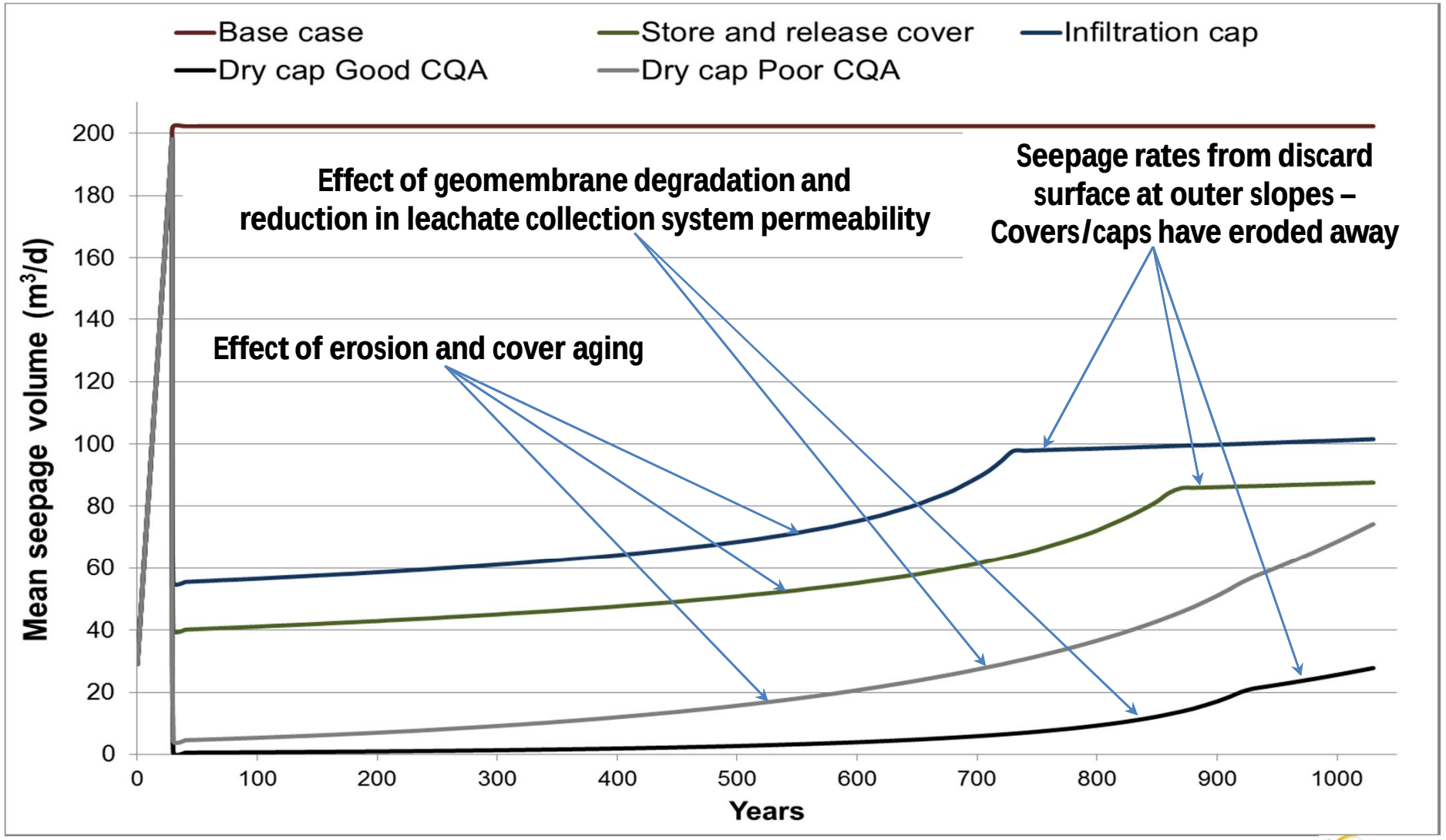


Not suitable for steep slopes due to risk for lateral flow

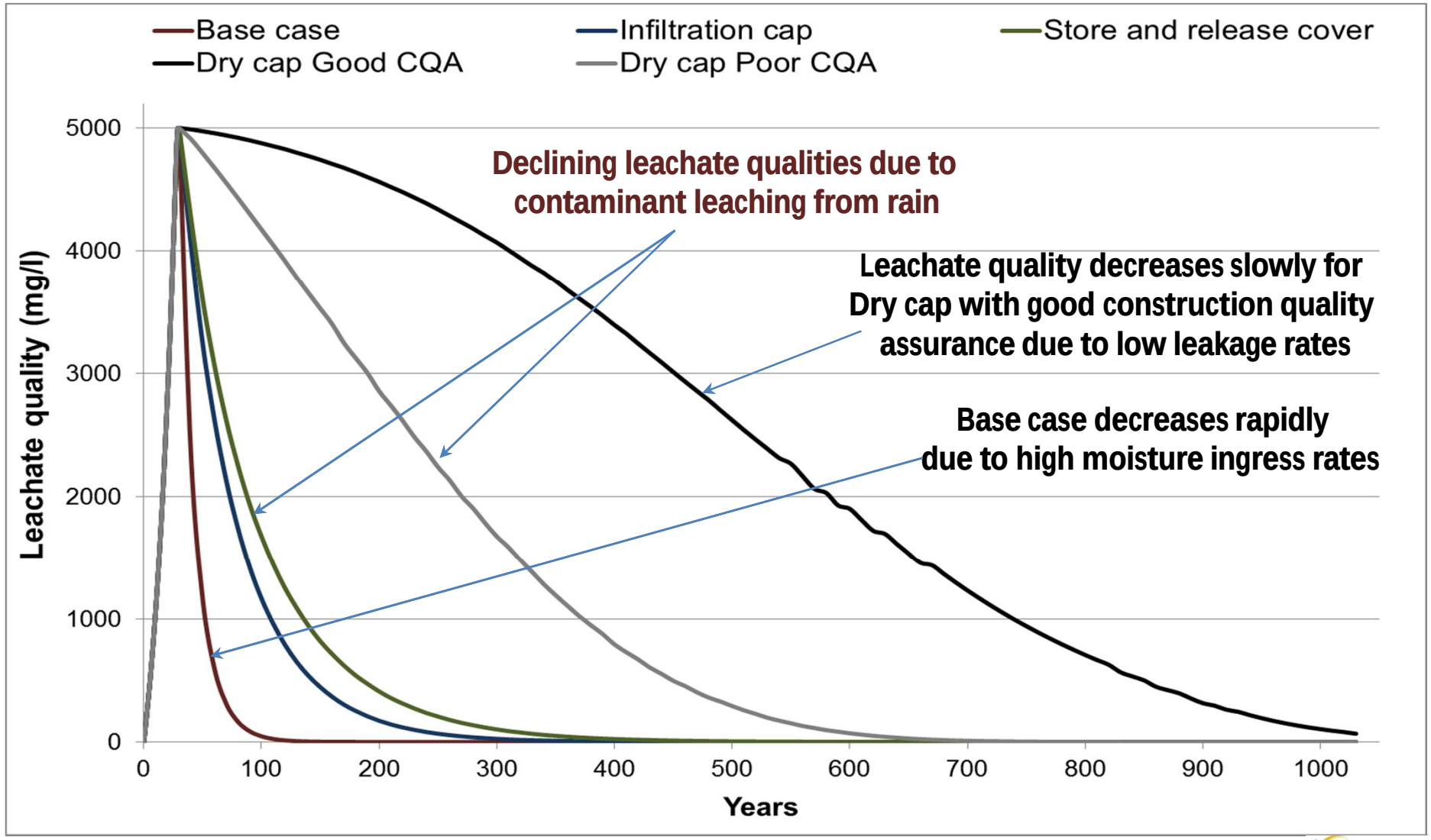
Thick single layer for slopes

Usually insufficient materials volumes to construct required thickness over total facility

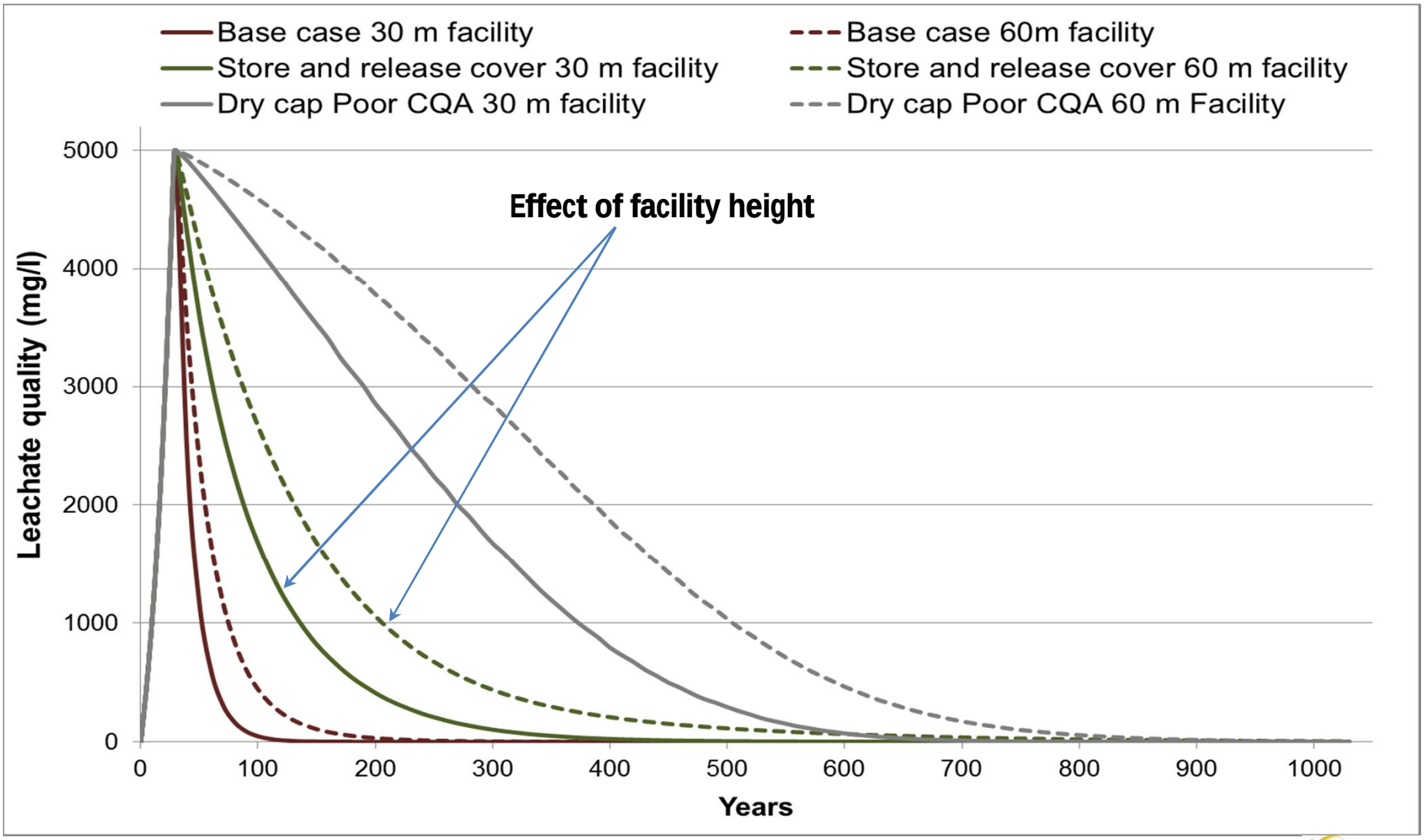
SEEPAGE VOLUME



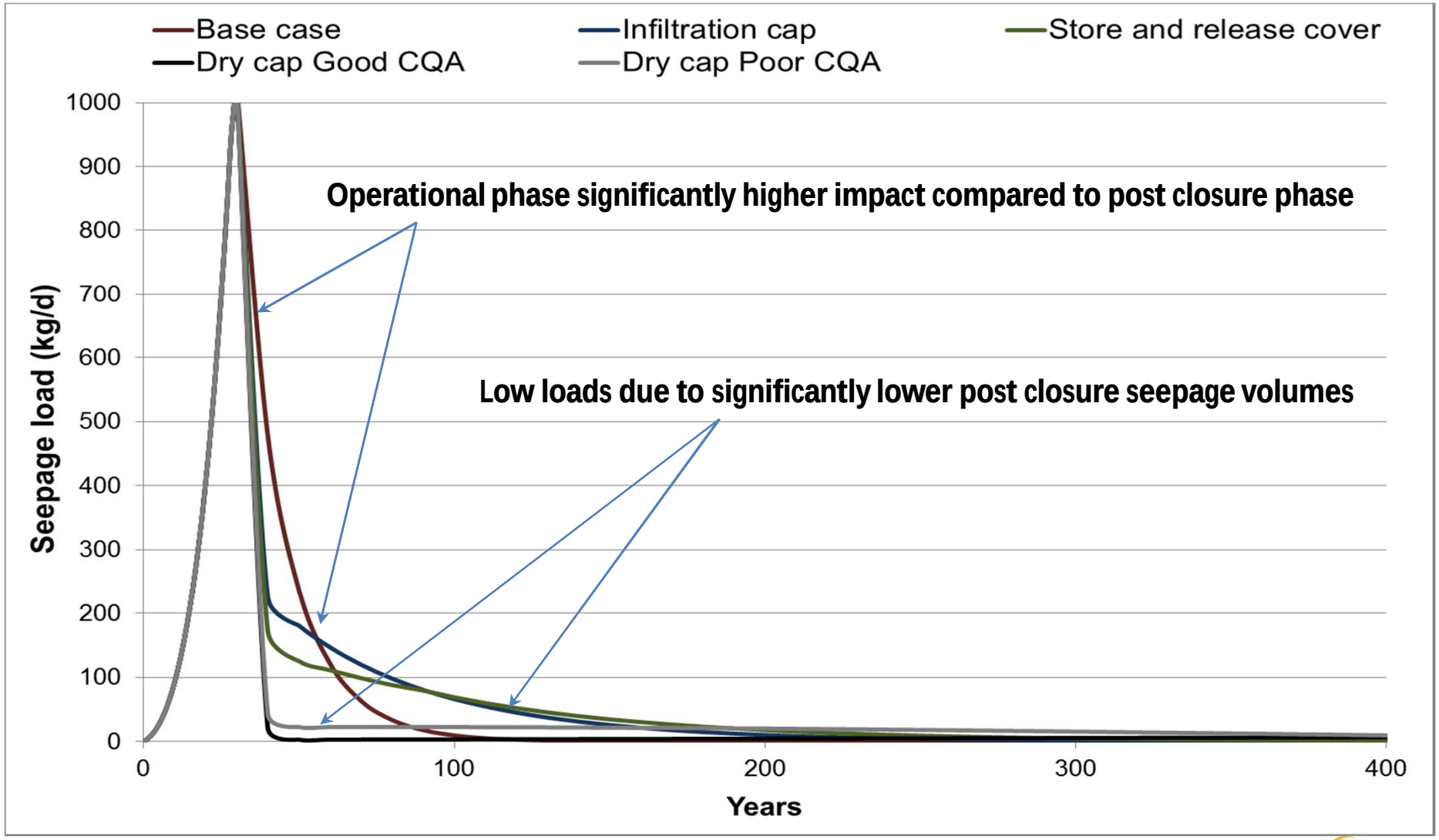
LEACHATE QUALITY



LEACHATE QUALITY

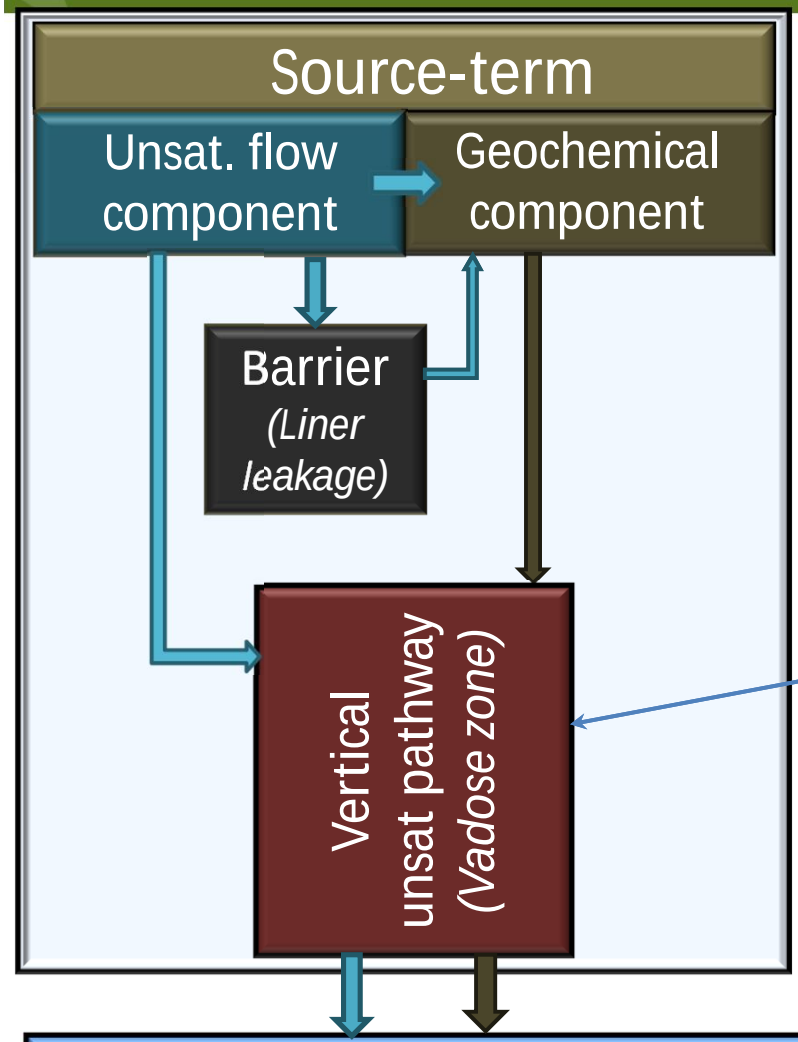


SEEPAGE LOAD



RECEIVING GROUNDWATER SEEPAGE IMPACT PREDICTION

VADOSE ZONE MODELLING



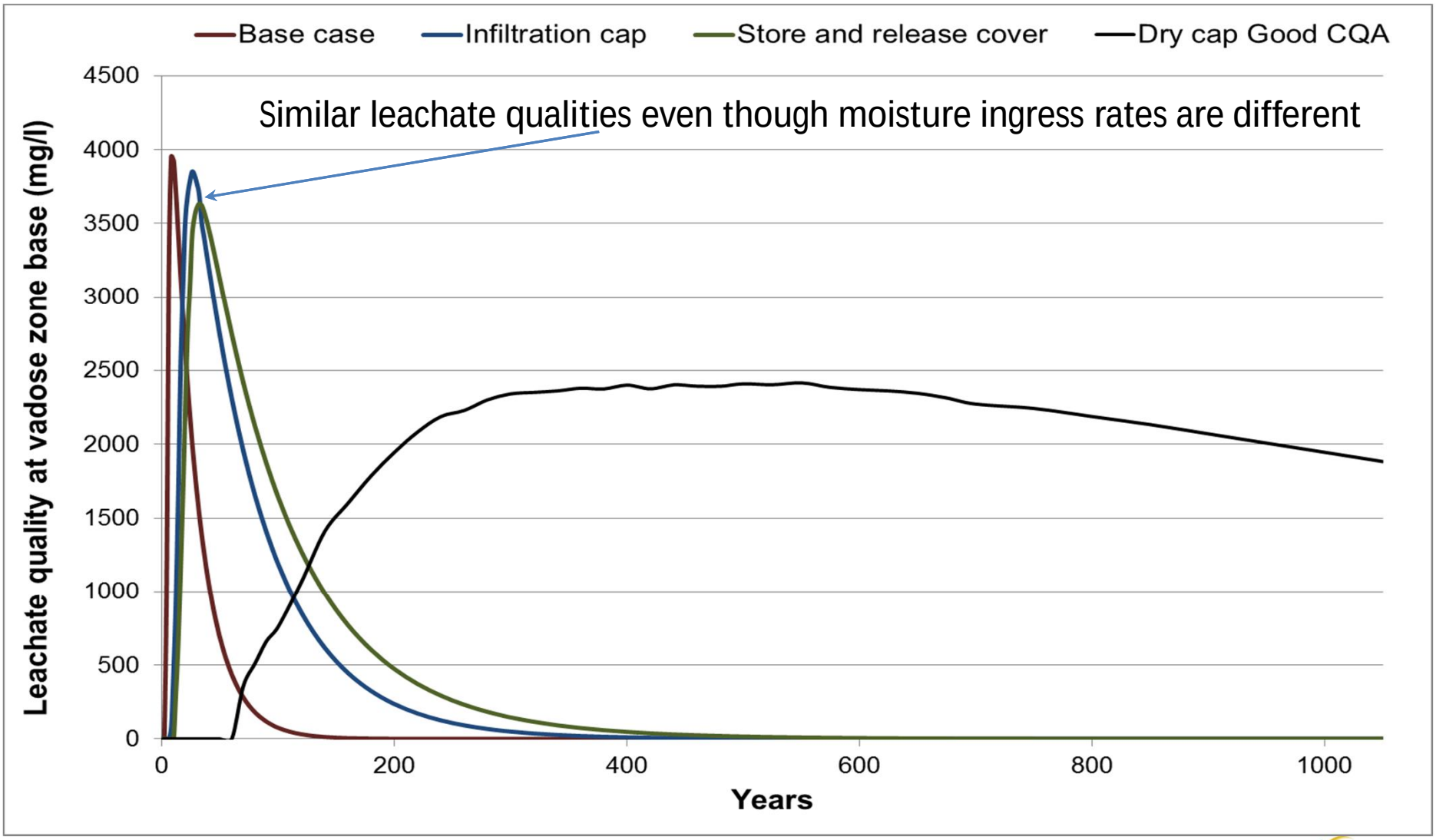
Integrated unsaturated flow-geochemical modelling

Liner leakage modelling

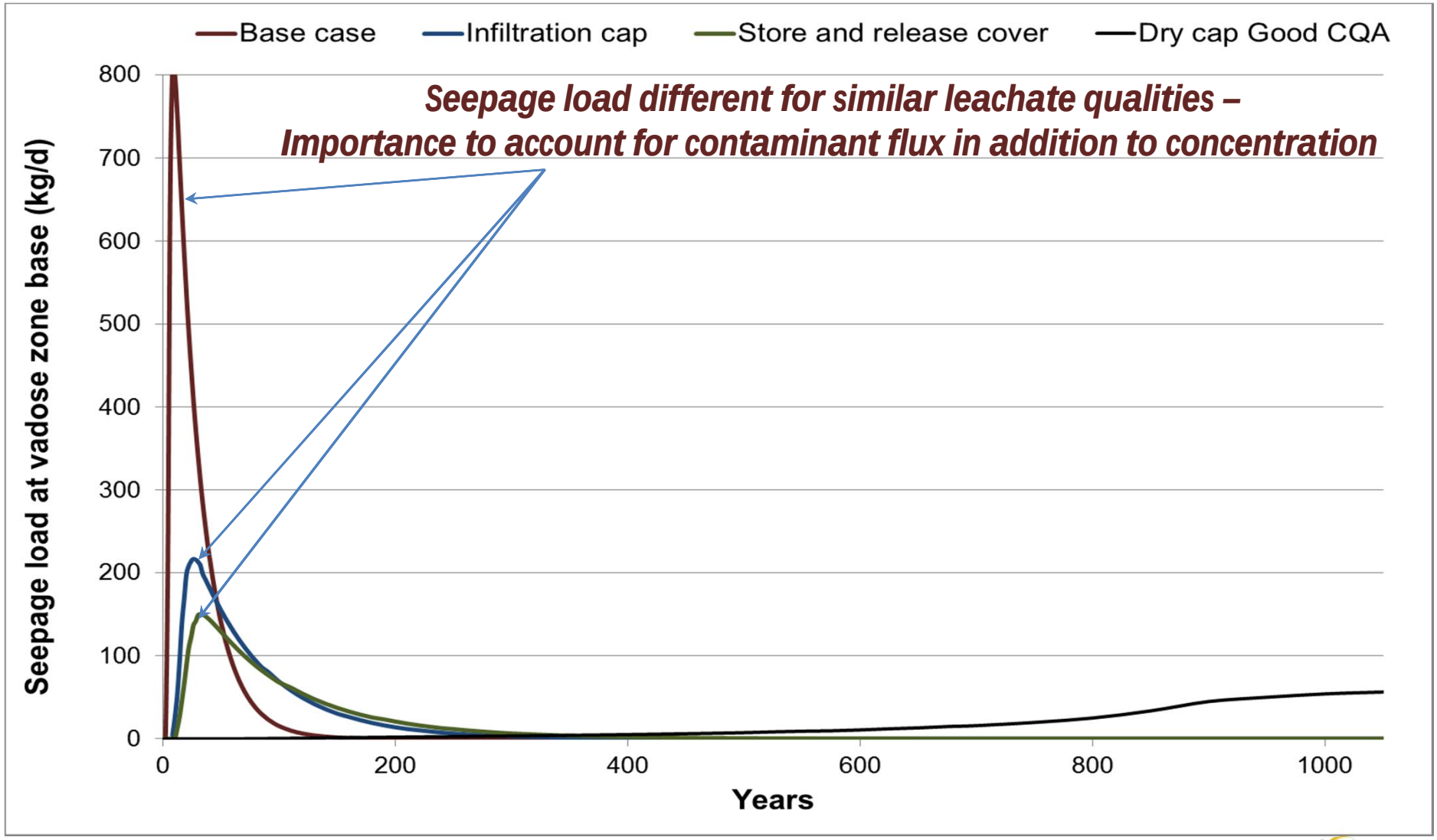
Contaminant transport modelling through vadose zone

- Contaminant attenuation *(inorganic)*
- Biodegradation *(organic)*
- Contaminant transport and dispersion
- Retarded *(lag time)* contaminant travel time

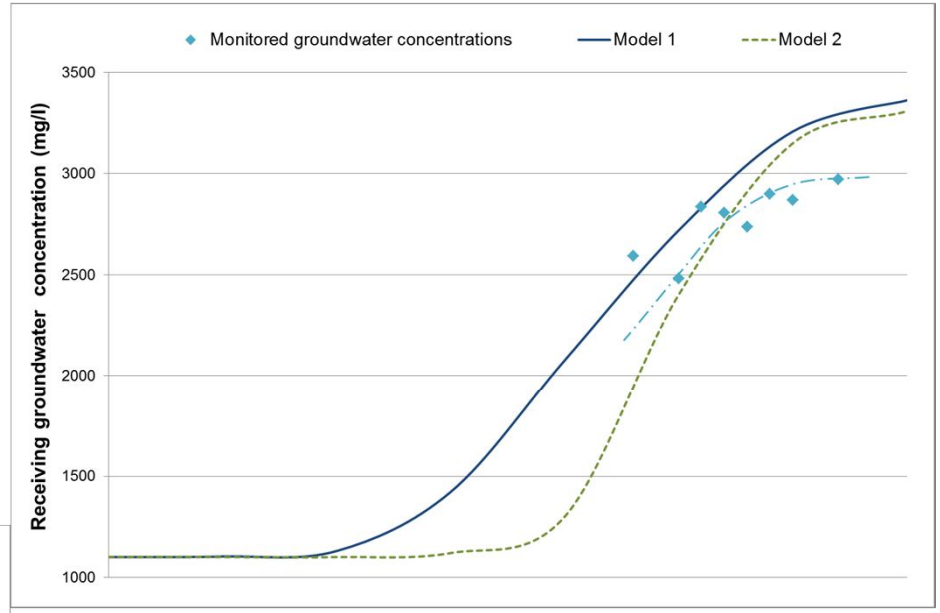
LEACHATE QUALITIES REPORTING TO GROUNDWATER TABLE

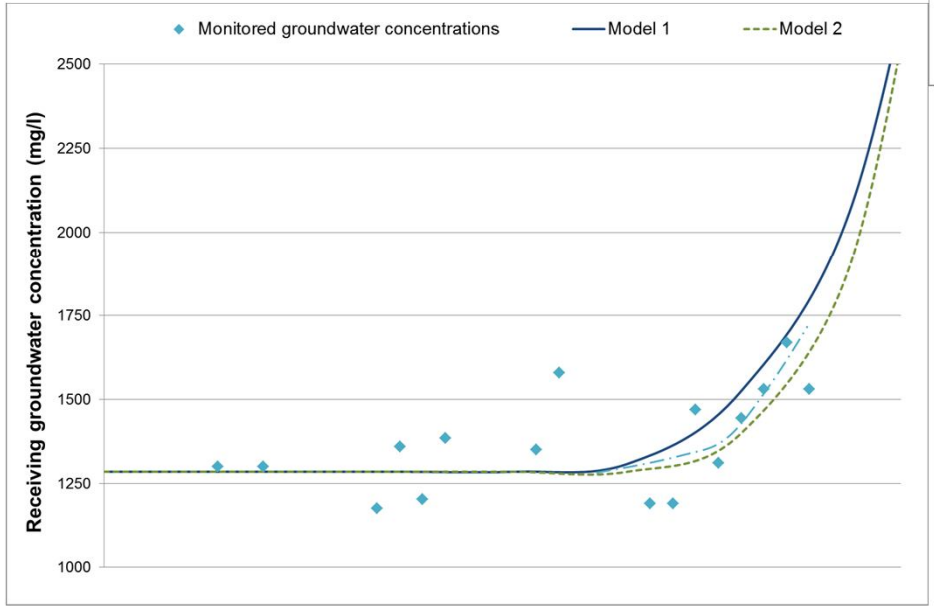


SEEPAGE LOADS REPORTING TO GROUNDWATER TABLE

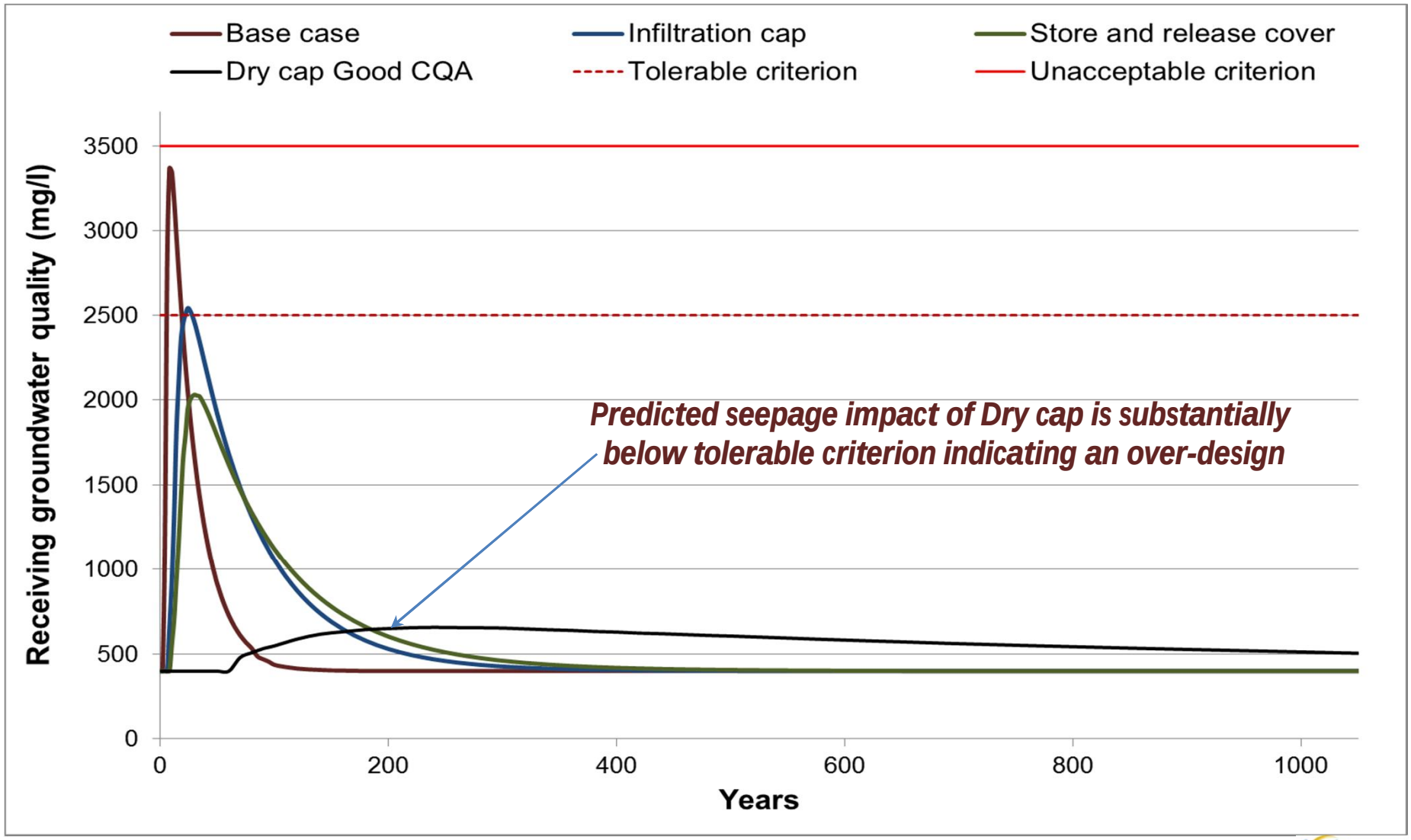


PREDICTED AND MONITORED RECEIVING GROUNDWATER QUALITIES

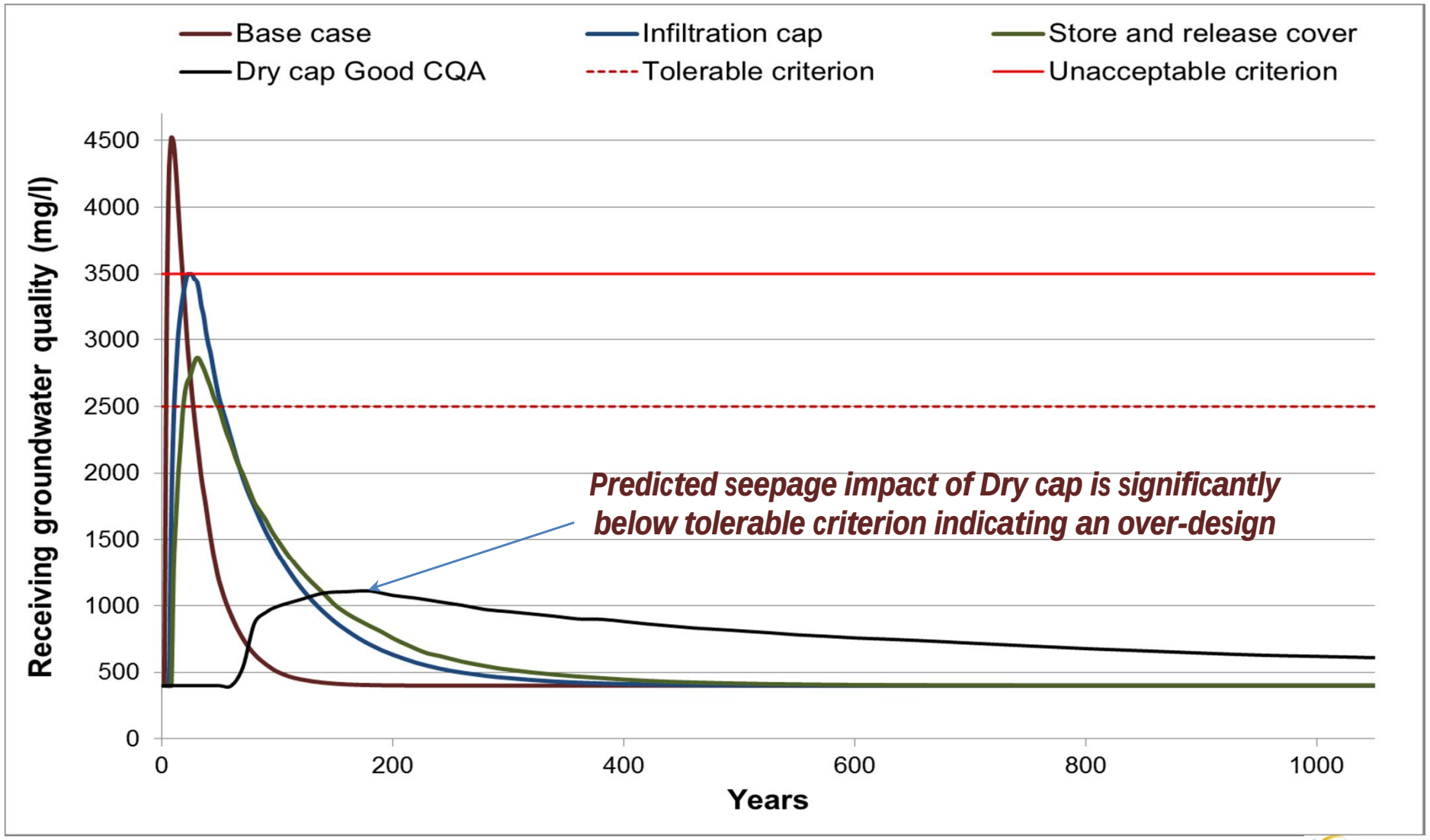




RECEIVING GROUNDWATER CONCENTRATION
LIKELY CASE



RECEIVING GROUNDWATER CONCENTRATION
90th PERCENTILE



CONCLUSION

ADVANTAGES OF SPR-UNSATURATED MODELLING

SITE SPECIFIC CONDITIONS

- Precipitation, rain distribution, climate
- Properties of materials available at site
- Geology, vadose zone and groundwater characteristics

FACILITY SPECIFIC CONDITIONS

- Increasing facility footprint/height, final rehabilitated topography
- Geochemistry
- Operational – decommission – rehabilitation – after care and maintenance schedule/time table

ADVANTAGES OF SPR-UNSATURATED MODELLING

POST CLOSURE SPECIFIC CONDITIONS

- Optimal use of site available materials for rehabilitation
- Vegetation type, realistic vegetation conditions
- Sustainable cover functioning and cover resilience aspects *(long-term cover performance)*
- Impact of cover degradation / aging
- Impact of liner degradation and reduction in drainage layer permeability

CLIENT SPECIFIC

- Post closure objectives and commitments
- Standard of cover and liner construction quality that can be achieved
- Cost implication

CONDITIONS OF INFORMATION PROVIDED

PRESENTATION CONTENTS

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THANK YOU

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