Closure of landfills with geosynthetics – solutions for challenging boundary conditions

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- Introduction: A society without landfills?
  – Aspects from Germany
- Contribution of geosynthetics in landfill engineering
- Quality aspects
- Examples for landfill engineering with geosynthetics
  – Design
  – Application
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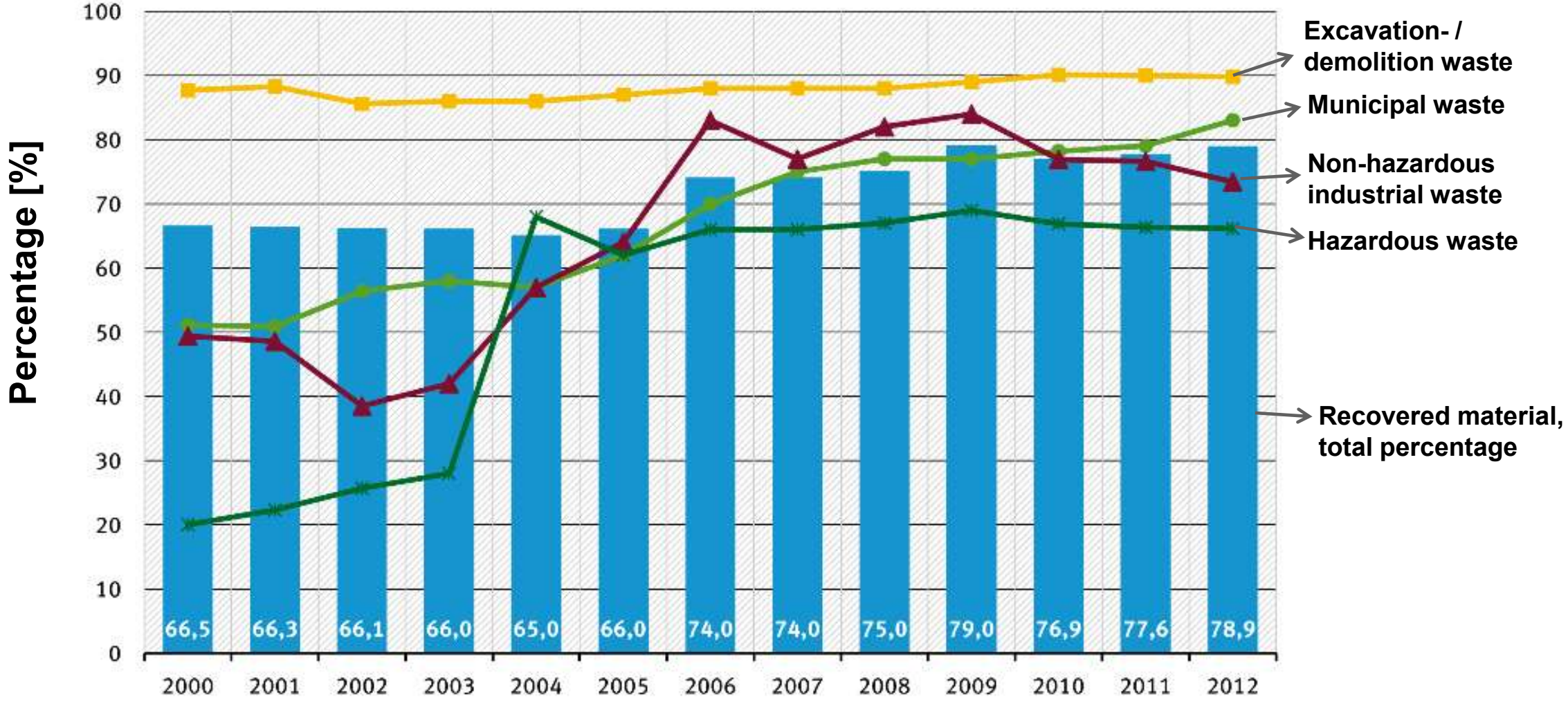
Generated waste – Federal Republic of Germany

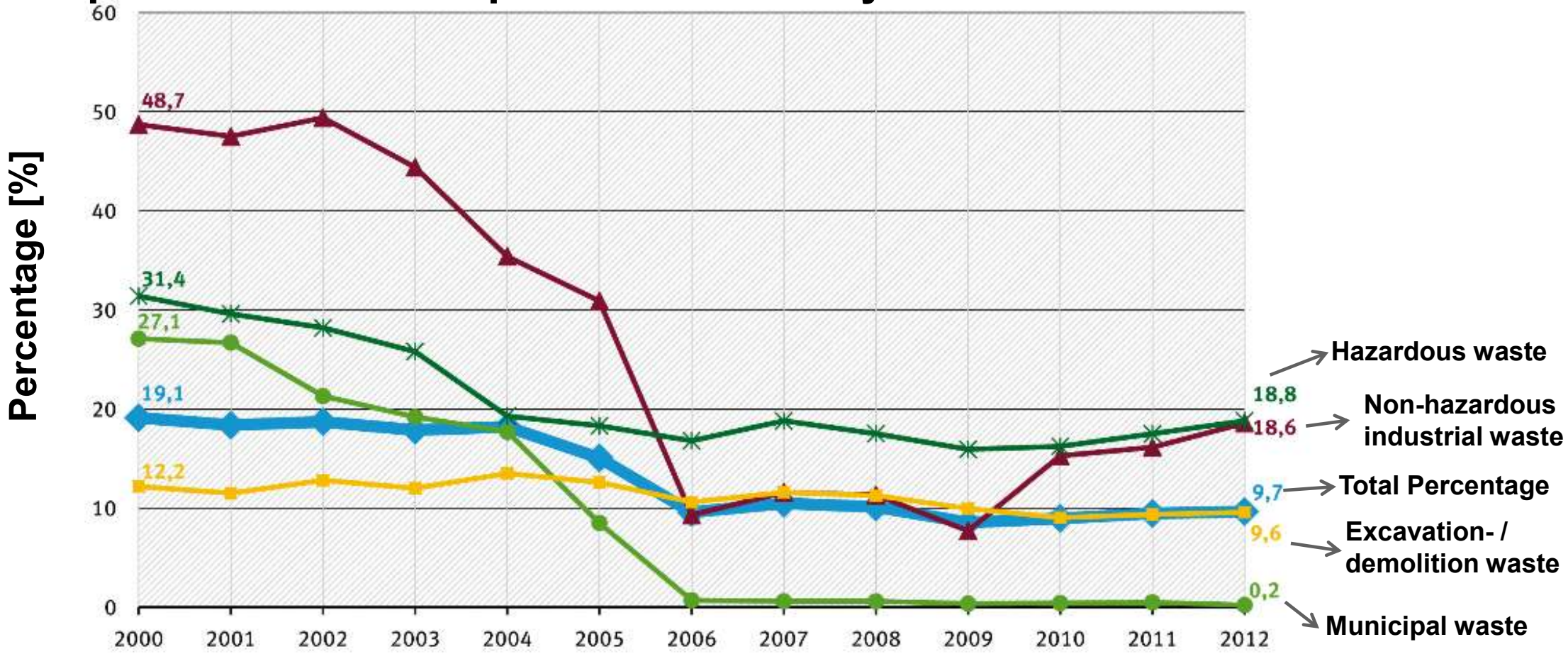
Source: German Federal Environmental Agency

Recovery of materials – Federal Republic of Germany



Source: German Federal Environmental Agency

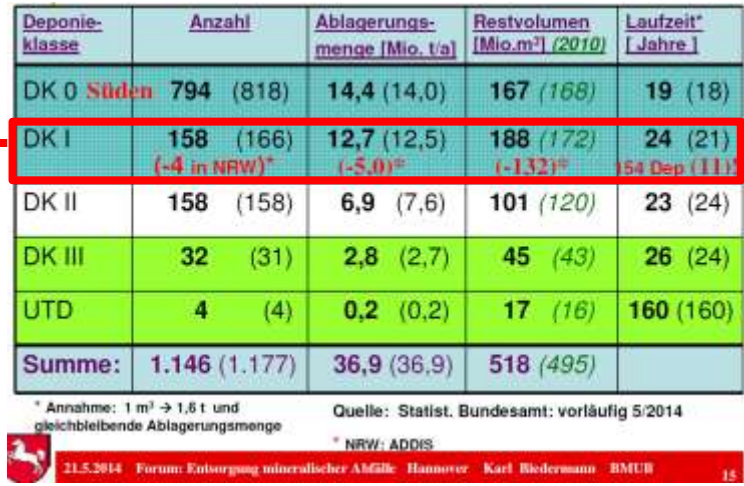
Waste disposal – Federal Republic of Germany



Source: German Federal Environmental Agency

Landfill Capacity issue – Federal Republic of Germany

Landfill Class	Total Number	Annual deposit [Mio. t/a]	Capacity remaining [Mio. m³]	Remaining term [a]
DK I (slightly contaminated soil / demolition waste)	158	12.7	188	24
MINUS: Open-cut mining dumps / ash-dumps	- 4 154	- 5.0 7.7	-132 56	11 (!)



Deponie-klasse	Anzahl	Ablagerungs-menge [Mio. t/a]	Restvolumen [Mio.m³] (2010)	Laufzeit* [Jahre]
DK 0 Süden	794 (818)	14,4 (14,0)	167 (168)	19 (18)
DK I	158 (166) (-4 in NRW)*	12,7 (12,5) (-5,0)*	188 (172) (-132)*	24 (21) 154 Dep (11)
DK II	158 (158)	6,9 (7,6)	101 (120)	23 (24)
DK III	32 (31)	2,8 (2,7)	45 (43)	26 (24)
UTD	4 (4)	0,2 (0,2)	17 (16)	160 (160)
Summe:	1.146 (1.177)	36,9 (36,9)	518 (495)	

* Annahme: 1 m³ → 1,6 t und gleichbleibende Ablagerungsmenge

Quelle: Statist. Bundesamt: vorläufig 5/2014

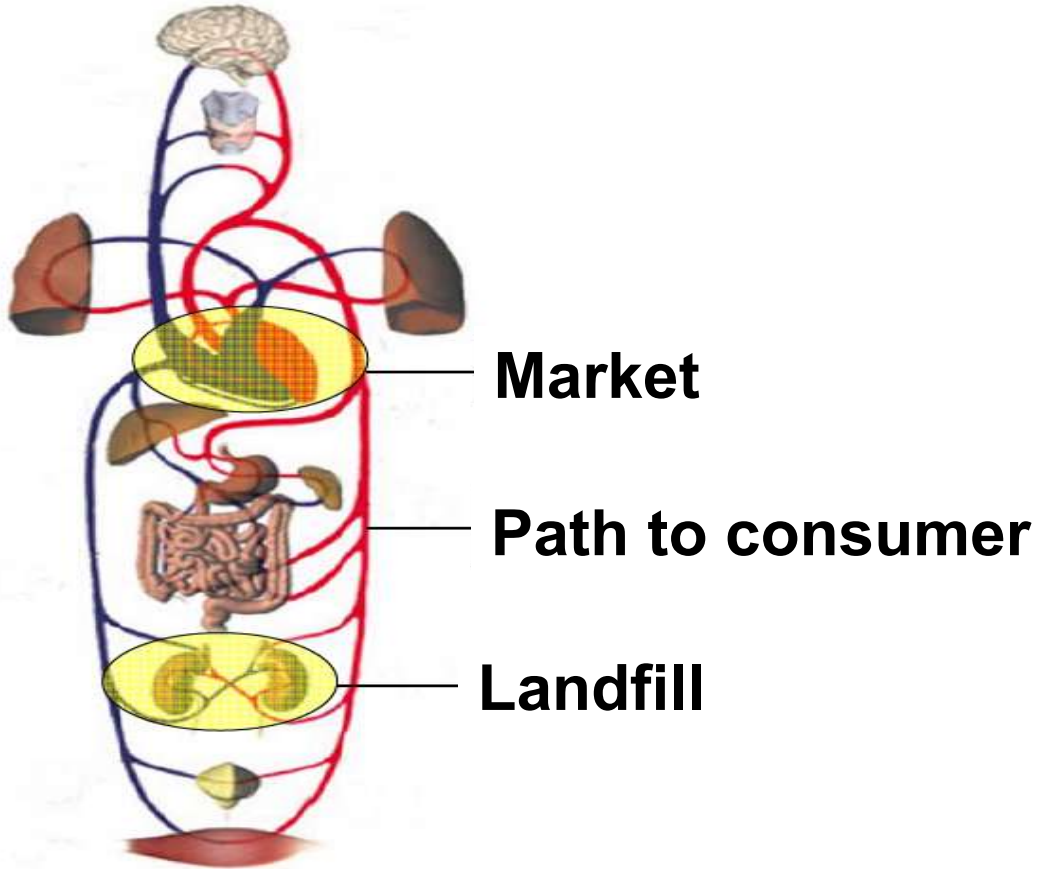
* NRW: ADDIS

21.5.2014 Forum: Entsorgung mineralischer Abfälle Hannover Karl Biedermann BMUB

Statistic numbers on total landfill volume and capacitiy reserves for Germany

Dr.-Ing. Karl Biedermann (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety)

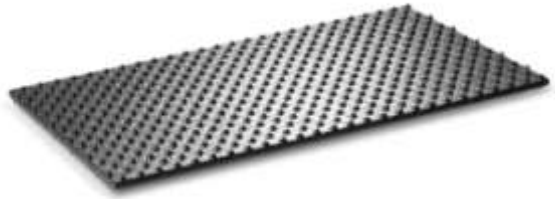
ANALOGY: Circulatory systems – Human body and resources management



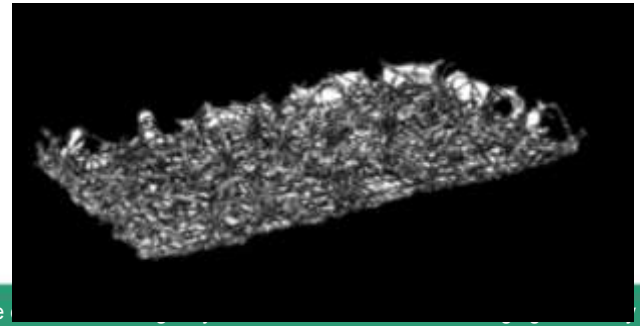
No landfills – no extraction of pollutants from material cycle!

Landfills are inevitable to prevent accumulation of harmful substances within the material cycle

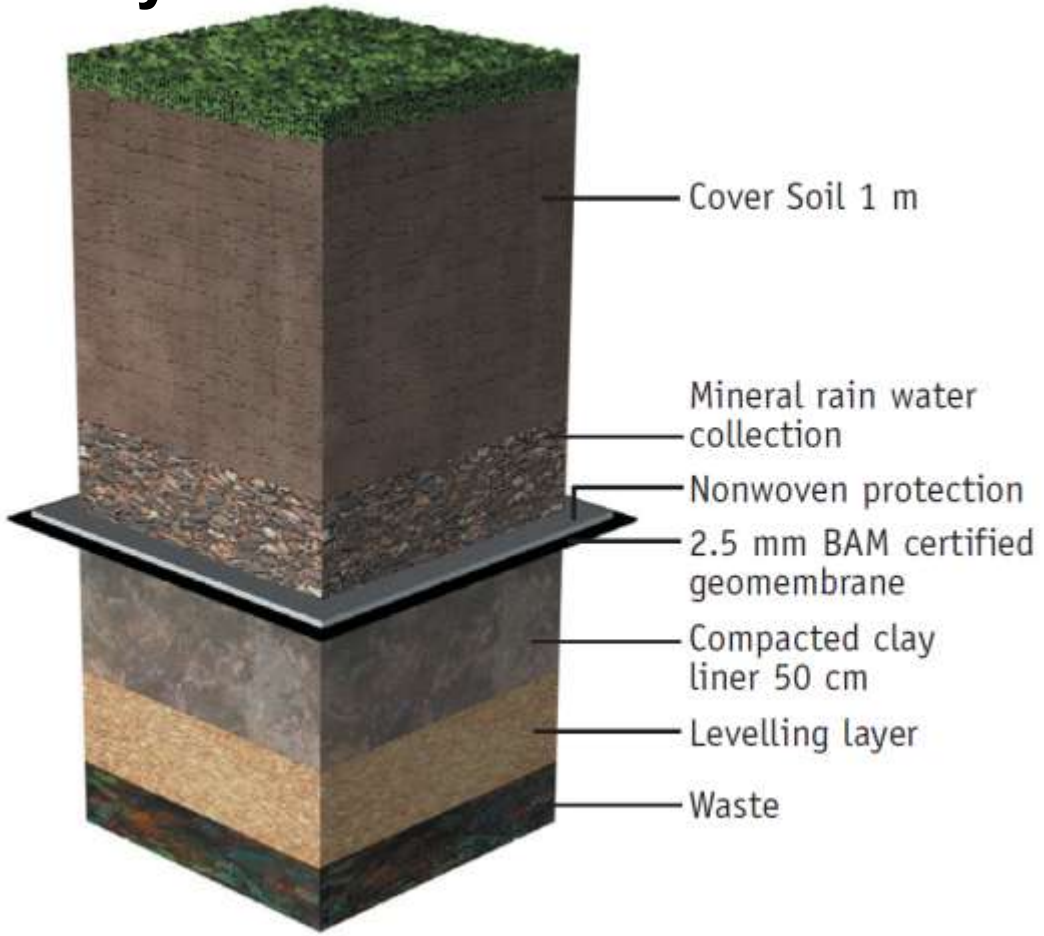
Analogism of circulatory systems – human body and resources management, created by *Dr.-Ing. Heinz-Ulrich Bertram (Ministry of Enviroment, Energy and Sustainability of Lower Saxony)*

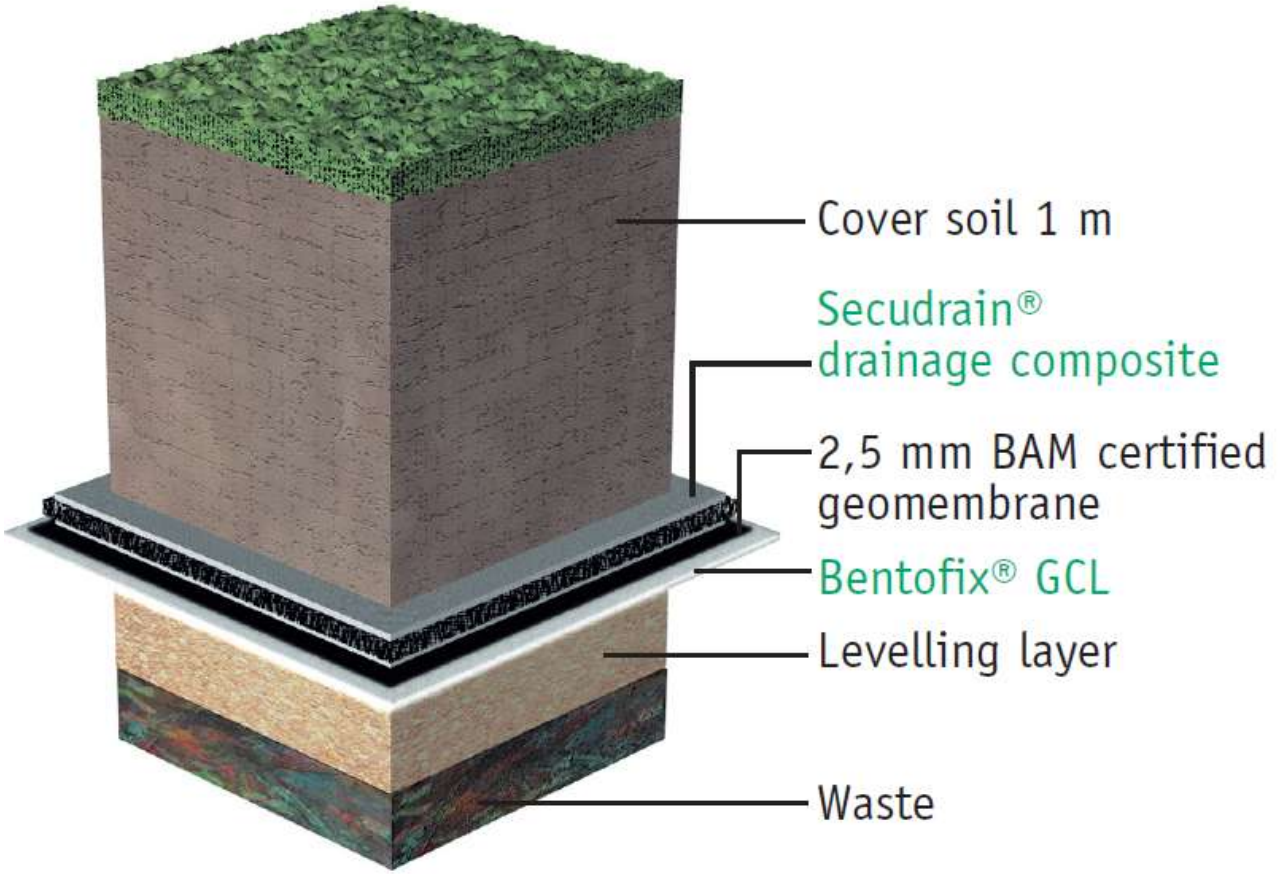


Geosynthetics contribution to Landfill engineering – central aspects



Geosynthetics increase landfill volume





→ **Landfill volume increases by 0.8 m³ (per m² of surface sealing system)**

Geosynthetics allow installation for challanging boundary conditions

Steep inclination of cap sealing system on salt slag landfill (Furth im Wald, Germany)

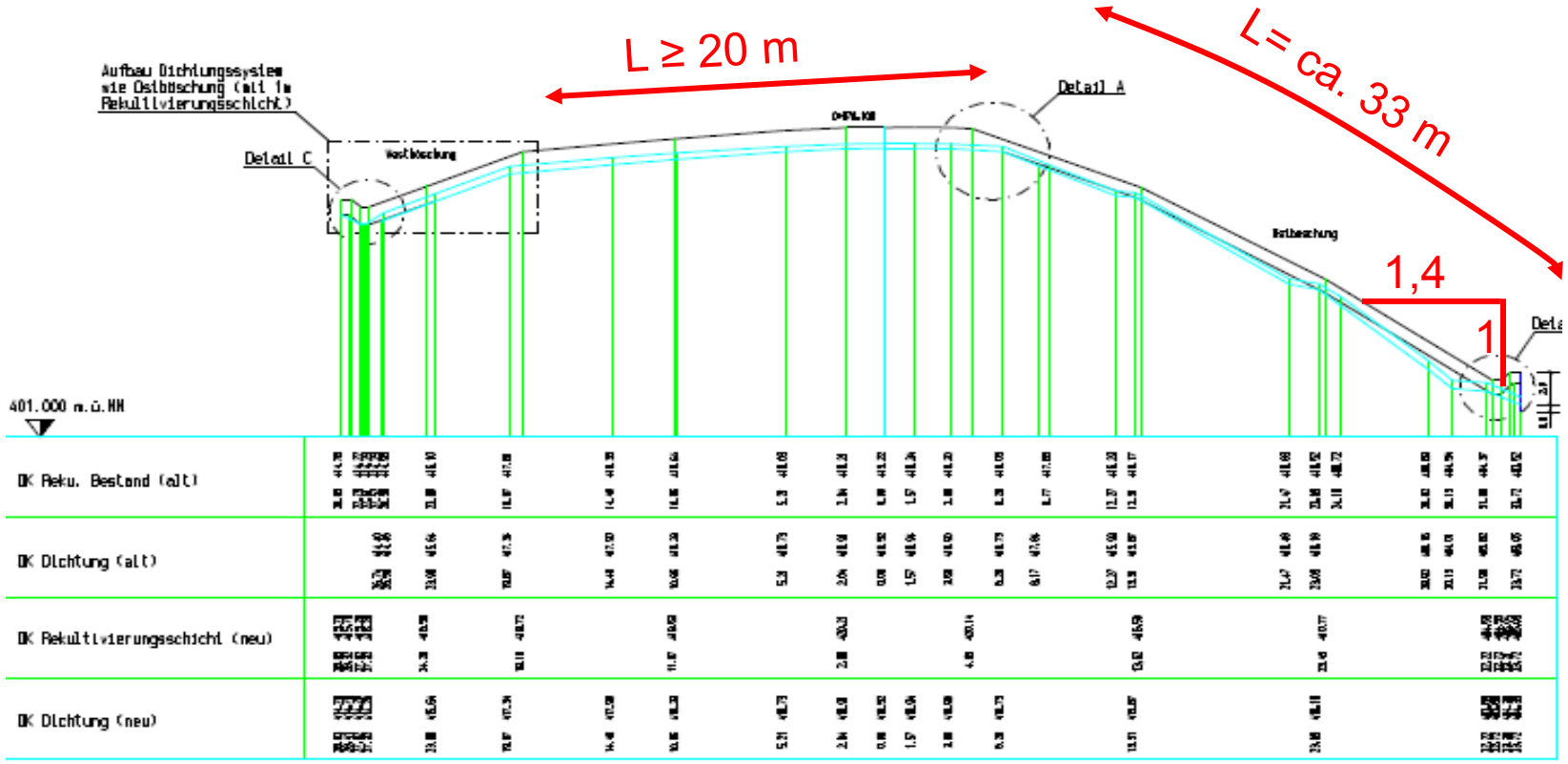
Installation of compacted clay liner and mineral drainage layer on this slope merely impossible.

Geosynthetic solution:

- Geosynthetic clay liner (GCL)
- Geomembrane
- Geosynthetic drainage mat
- Geogrid

✓ Easy to install
✓ Less transportation
✓ Ecologically efficient
✓ Economically efficient

Geosynthetics allow installation for challanging boundary conditions



Berechnungsquerschnitt Deponie Furth im Wald

- Steep inclinations of slopes - 1(H):1,4(V) (ca. 35,0°)
- Long slopes (ca. 33,0 m)
- Long plateau area (L ≥ 20.0 m)

Sustainability: Geosynthetics reduce total energy consumption

Table 1: Comparison of energy consumption per square meter between GCLs/geosynthetic drainage systems and compacted clay liner/gravel collection system using the Hillern landfill as an example (values are in kWh)

	GCL	Drainage membrane	Compacted Clay Liner	Gravel Collection system
Mining	3.40E-03	-	0.68	2.60
Transport	4.25	-	-	-
Feedstock	6.47	15.53	-	-
Manufacturing	0.95	1.96	-	-
Transportation	0.47	0.51	23.83	14.30
Installation	0.89	0.63	6.19	5.69
Total	13.03	18.63	30.70	22.59
Total for landfill (A=32,853 m²)	**428,065**	**612,073**	**1,008,598**	**742,149**

Geosynthetic quality

- For landfill engineering, the quality aspect is of central interest to ensure sufficient functionality in the long-term
- Reputable manufacturers of geosynthetics provide continuous quality surveillance over the whole production chain from feedstock to finished product
- Indipendent institutes carry out external quality surveillance on manufactured products
- Product installation is supervised by third-party inspection on site

BAM – Federal Institute for Materials Research and Testing

- higher federal authority under supervision of the Federal Ministry of Economics and Technology
- head office located in Berlin
- key note: “safety in technology and chemistry”
- for all geosynthetics used on German landfill sites, a BAM approval is mandatory

Approval procedure for geosynthetics in German landfills

Crucial aspect:
Long-term behavior
for lifetime > 100 years

Dep V German Landfill Ordiance

Manufacturer

Application for approval

Approving Authority

BAM Bundesanstalt für Materialforschung und -prüfung

Advisory comitee

BAM Bundesanstalt für Materialforschung und -prüfung

Federal representatives
Institutes
Consultants Supervisors
Manufacturers

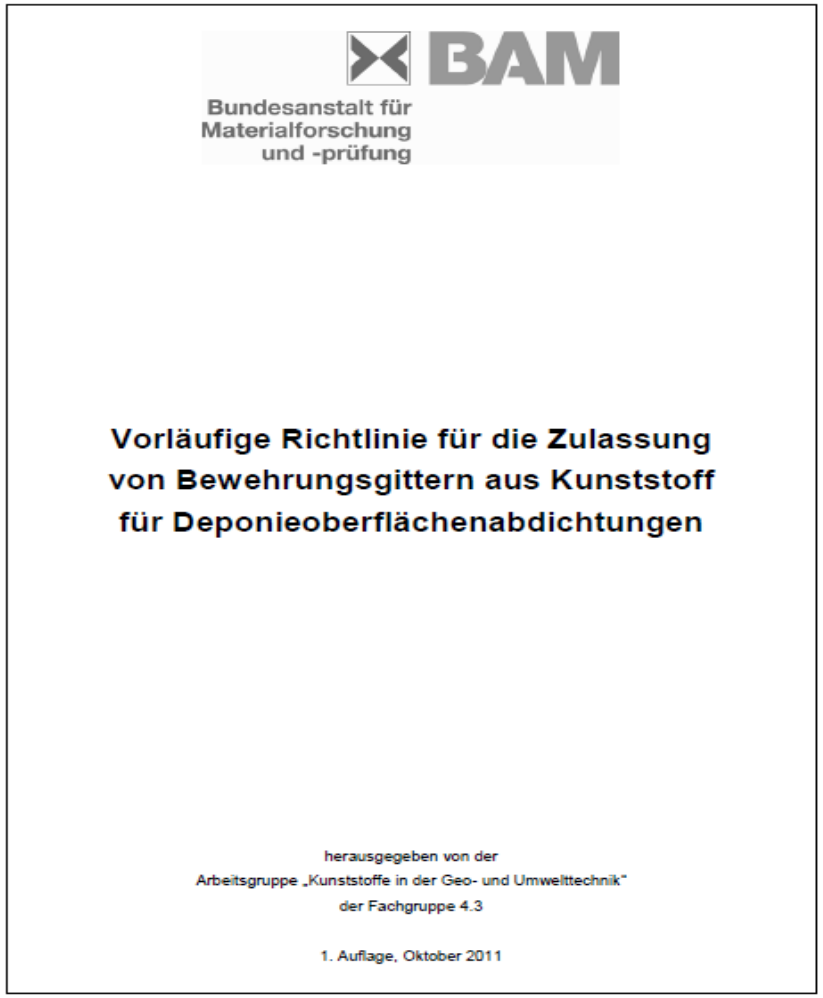
Test certificates

Certification Guidelines for each product group

Approval

For application on landfill sites

Application Standards


BAM
Bundesanstalt für Materialforschung und -prüfung

Vorläufige Richtlinie für die Zulassung von Bewehrungsgittern aus Kunststoff für Deponieoberflächenabdichtungen

herausgegeben von der
Arbeitsgruppe „Kunststoffe in der Geo- und Umwelttechnik"
der Fachgruppe 4.3

1. Auflage, Oktober 2011

Example: Certification guideline for geogrids

Refers to geogrids used for cap sealing and retaining constructions

Emphasizes the complex behaviour of geogrids in interaction with soil

Differs geogrids by the load transfer mechanisms within the anchorage area:

- Load transfer due to surface friction between geogrid and soil (friction geogrids)
- Load transfer due to surface friction between geogrid and soil and passive earth pressure of soils against the transversal elements of the geogrid (earth pressure geogrids) – **demands for high stiffness of the product**

http://www.bam.de/de/service/amtl_mitteilungen/abfallrecht/abfallrecht_medien/zulassungsrichtlinie-geogitter-beschluss-fachbeirat-b.pdf

Steep slopes

Standard inclination up to 1:3

common systems
usually without geogrid reinforcement

Interim inclination 1:3 … 1:2,5

special systems, most commonly geogrids
restrictions in earth works
partially cable-guided

Steep areas 1:2,5 … 1:1,4

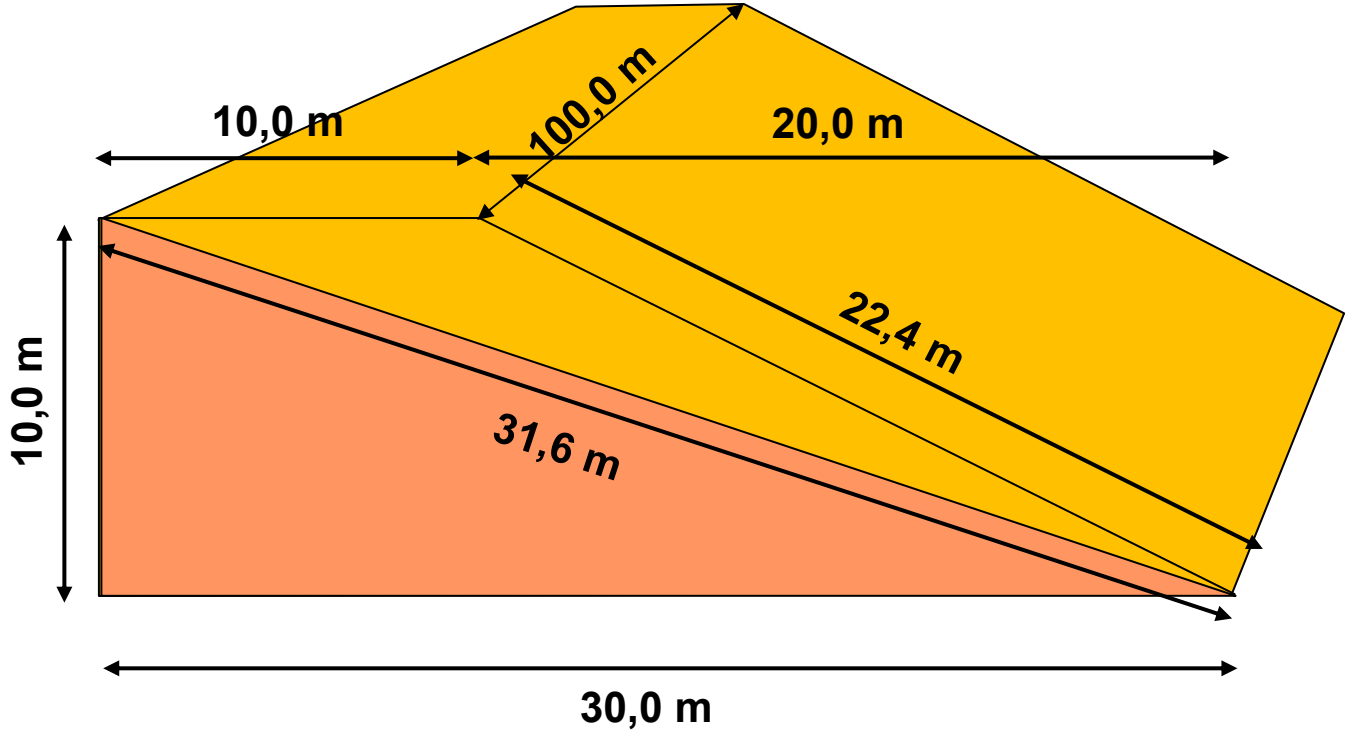
geogrids
long arm excavator
cable-guided operation of
earth moving machinery

Calculation example: Slope gradient and landfill capacity

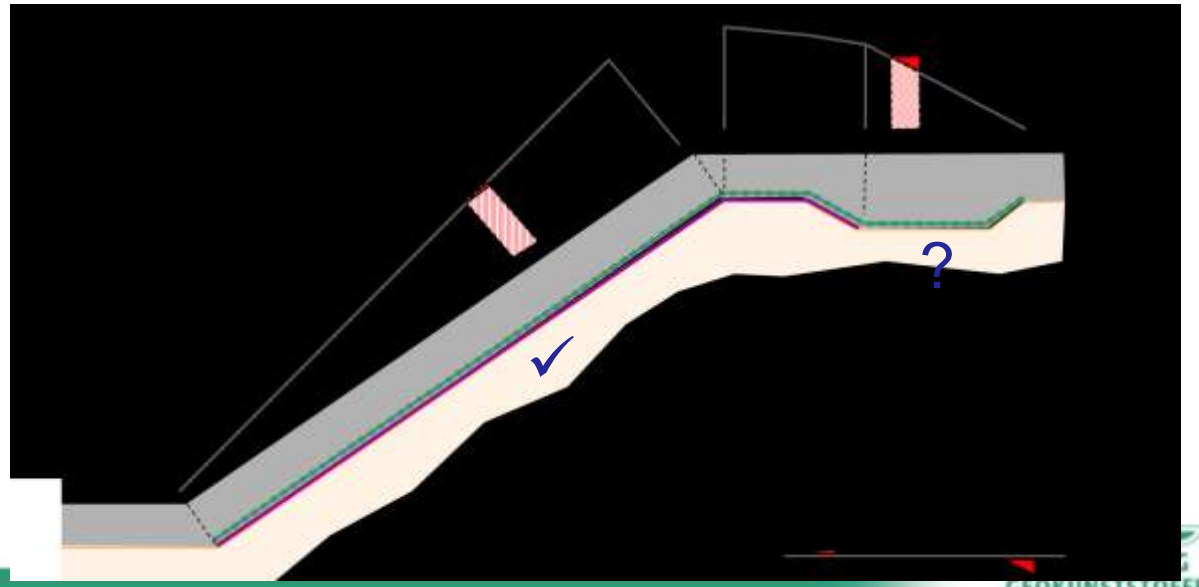
$V_{1:3}$ =
30,0 m * 10,0 m * 0,50 =
150 m³ / m

$V_{1:2}$ =
20,0 m * 10,0 m * 0,50 +
10,0 m * 10,0 m =
200 m³ / m

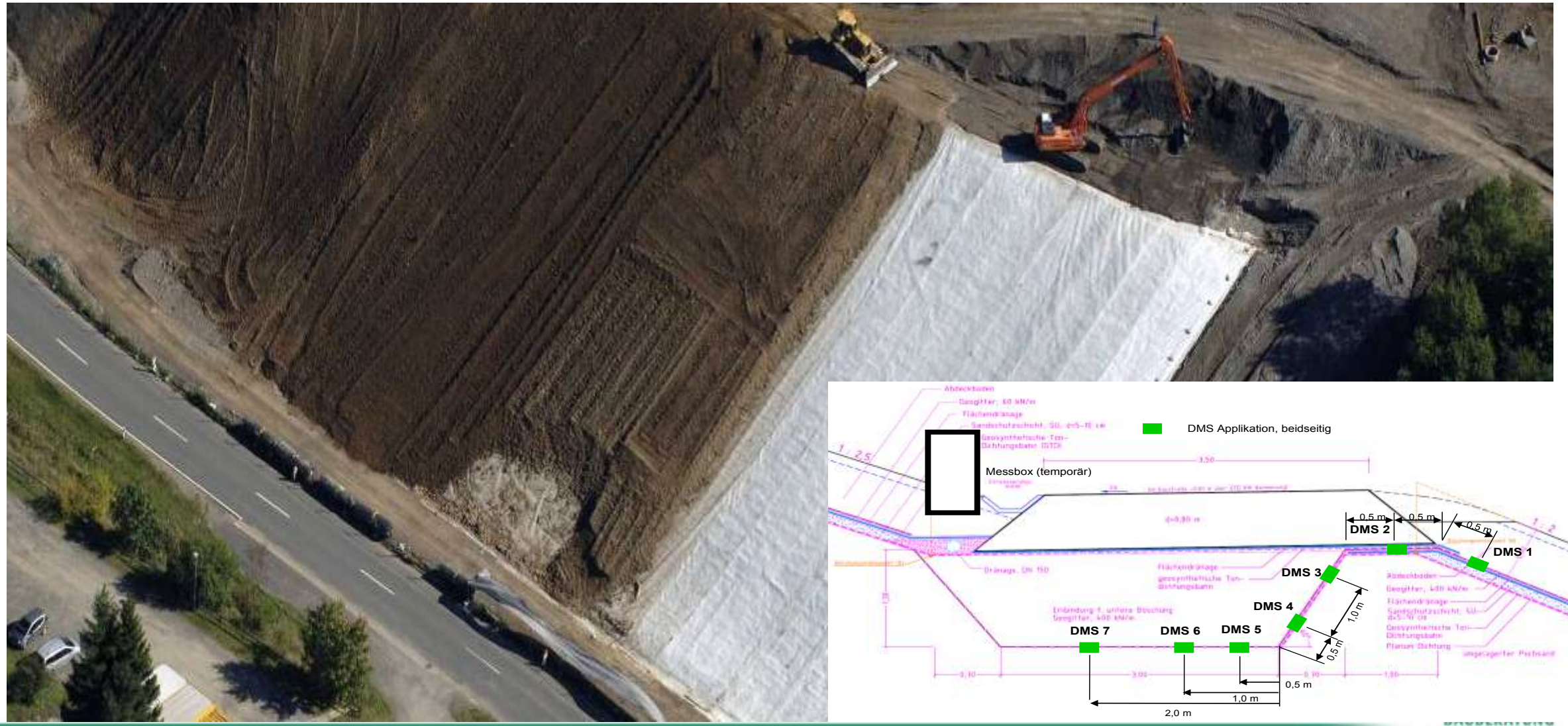
$\Delta V = V_{1:3} - V_{1:2} = 50$ m³ / m



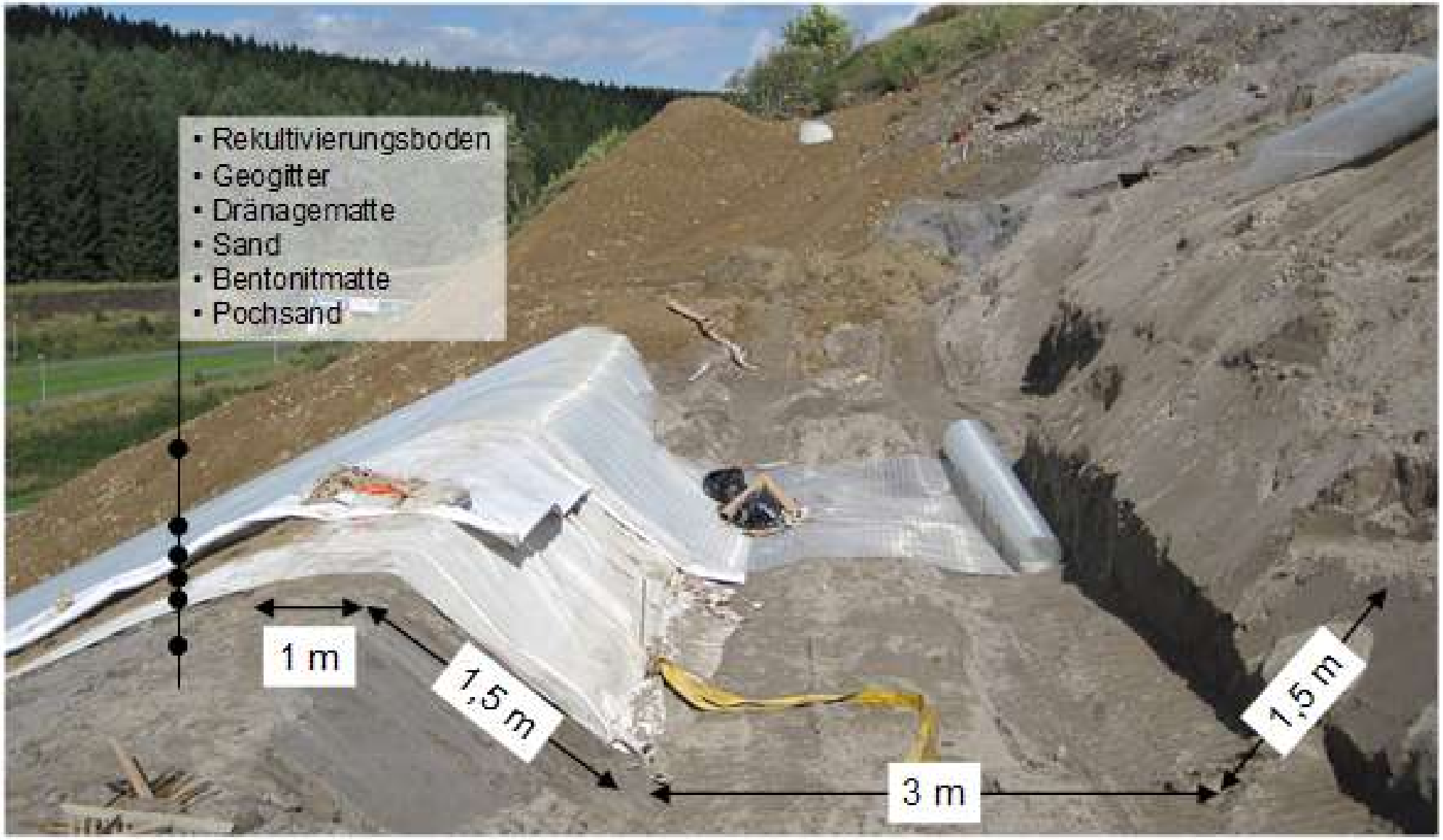
Landfill Duisburg-Sudamin (monitoring load introduction with strain gauges since 2008)



Slag heap „Zellerfelder Valley“ (monitoring load distribution in anchorage area with strain gauges)



Examples for landfill engineering with geosynthetics



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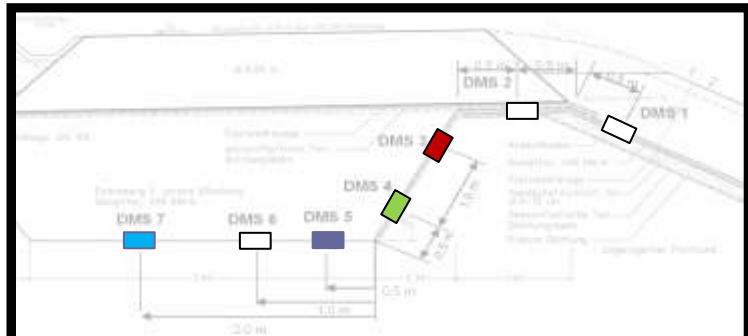
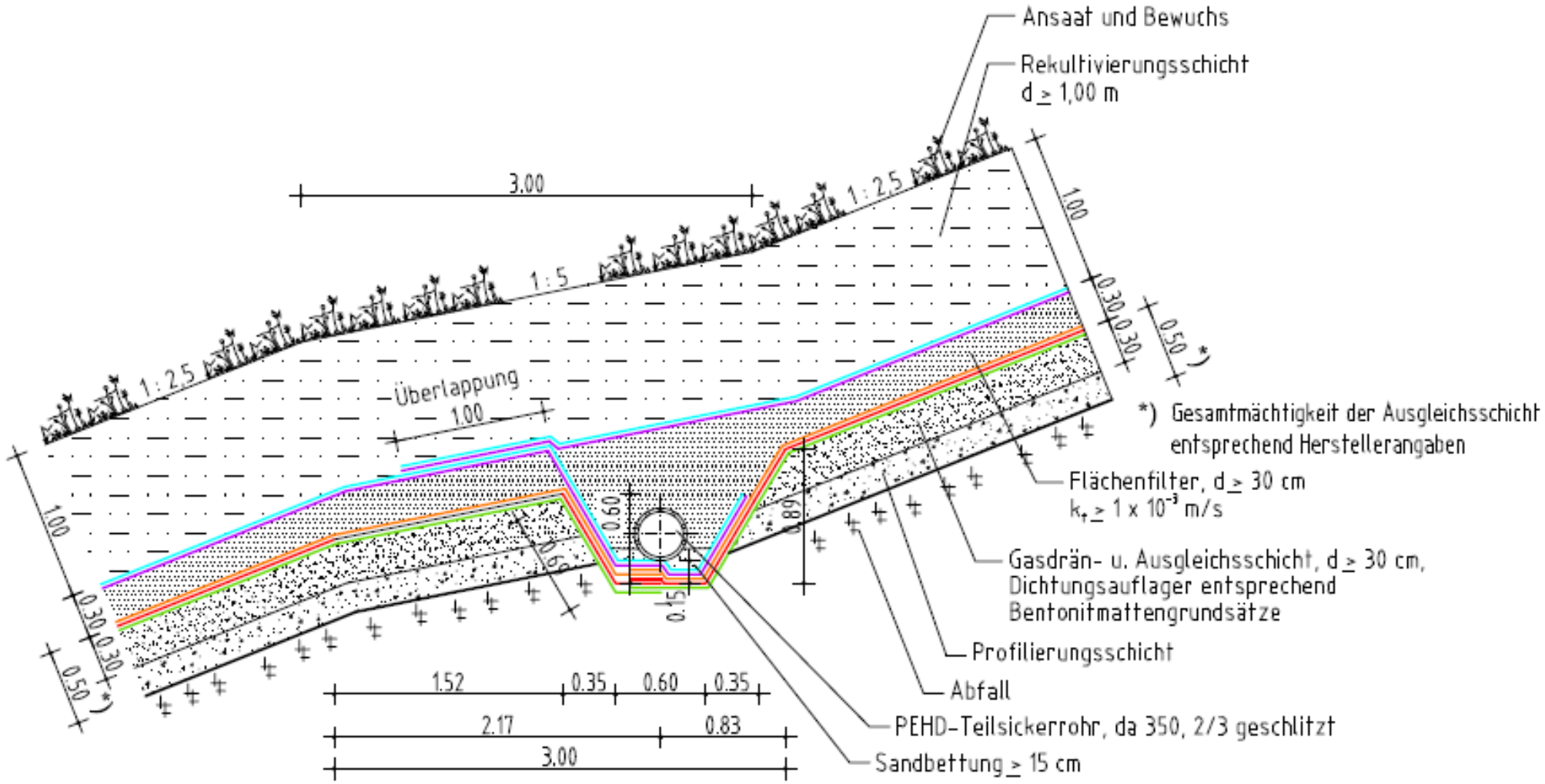


Comparing boundary conditions

1:2 (β = 26,6°)	Slope inclination	1:2 (β = 26,6°)
25,6°	Minimum contact friction angle δ_k	24,7°
23,64 kN/m	Charakteristic tensile load on geogrid T_k	33,5 kN/m
237,68 kN/m	Charakteristic pull-out resistance of anchor trench R_k	188,2 kN/m

Covered berms for intermediate geogrid anchorage on long slopes

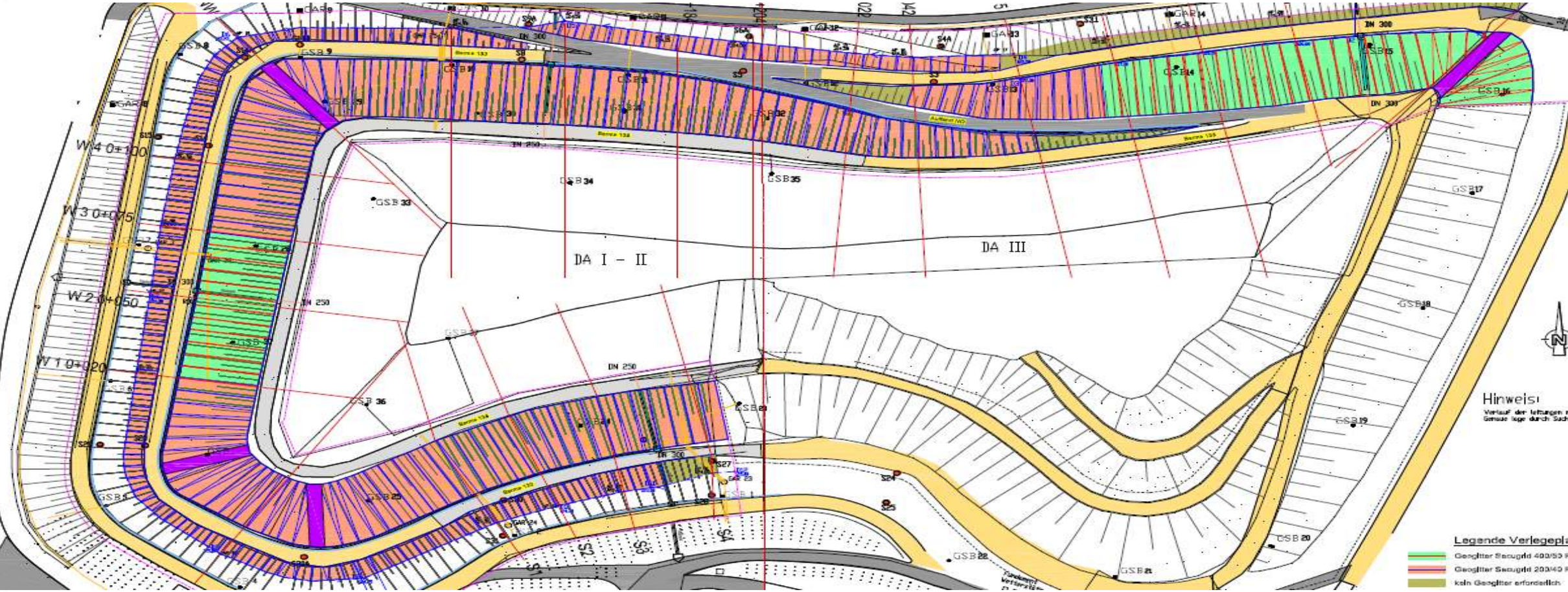


Anchor trench in berm: Landfill Kapiteltal

Landfill Berg

- Steep cap sealing system, inclination → 1(V):2(H)
- Sealing System:
  - Double-layered GCL (needlepunched, $m_A \geq 6000$ g/m²)
  - Structured HD-PE geomembrane
  - Geosynthetic drainage element
  - Geogrid reinforcement
  - 1.5 m recultivation soil

Landfill Berg: Geogrid panel layout plan



Green areas: Longitudinal tensile strength of geogrid 400 kN/m
Red areas: Longitudinal tensile strength of geogrid 200 kN/m
Violet: Anchor trenches on flanks

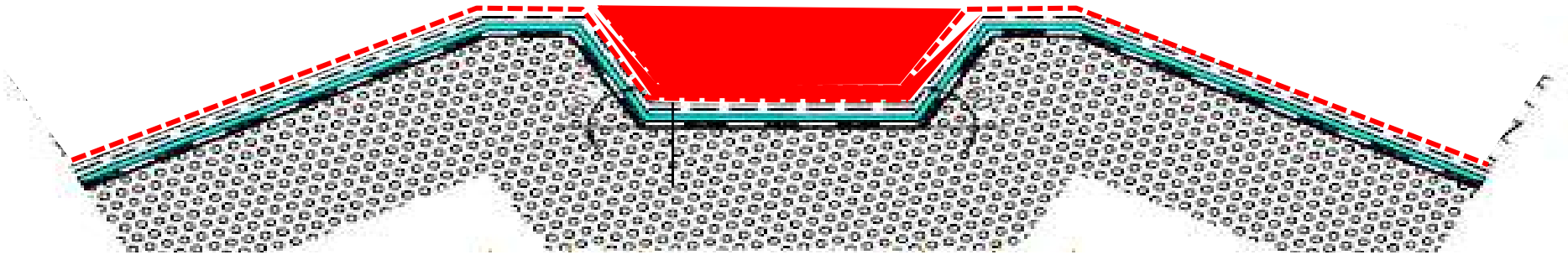
Anchor trench in a landfill flank

Anchor trench in a landfill flank

Construction of anchor trench in a landfill flank

Successive construction phases for anchor trench in a landfill flank:

- Installation of first geogrid layer
- Installation of interlocking layer
- Installation of second geogrid layer
- Filling the anchor trench



Landfill Hannover-Lahe

- Old landfill body, operational phase: 1937-1980
- Landfill-class „DK II“ – municipal waste
- Inclination 1(V):2.8(H) after profiling works
- Geometrical constraint situation at the north slope

Landfill Hannover-Lahe

Landfill Hannover-Lahe: Mechanically stabilized earth

Landfill Hannover-Lahe

Geosynthetic in landfill applications

- Landfills are an essential part of the public infrastructure
- Within the resource cycles, there must be a pollutant sink to extract environmentally harmful substances
- Geosynthetics ensure that waste is safeley encapsulated and prevents emissions from waste bodies
- Furthermore, geosynthetics help to ensure stability issues of landfill bodies or recultivation layers (reinforcement, drainage, filtration) even under challangeing boundary conditions

¡Muchas gracias por su atención!

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