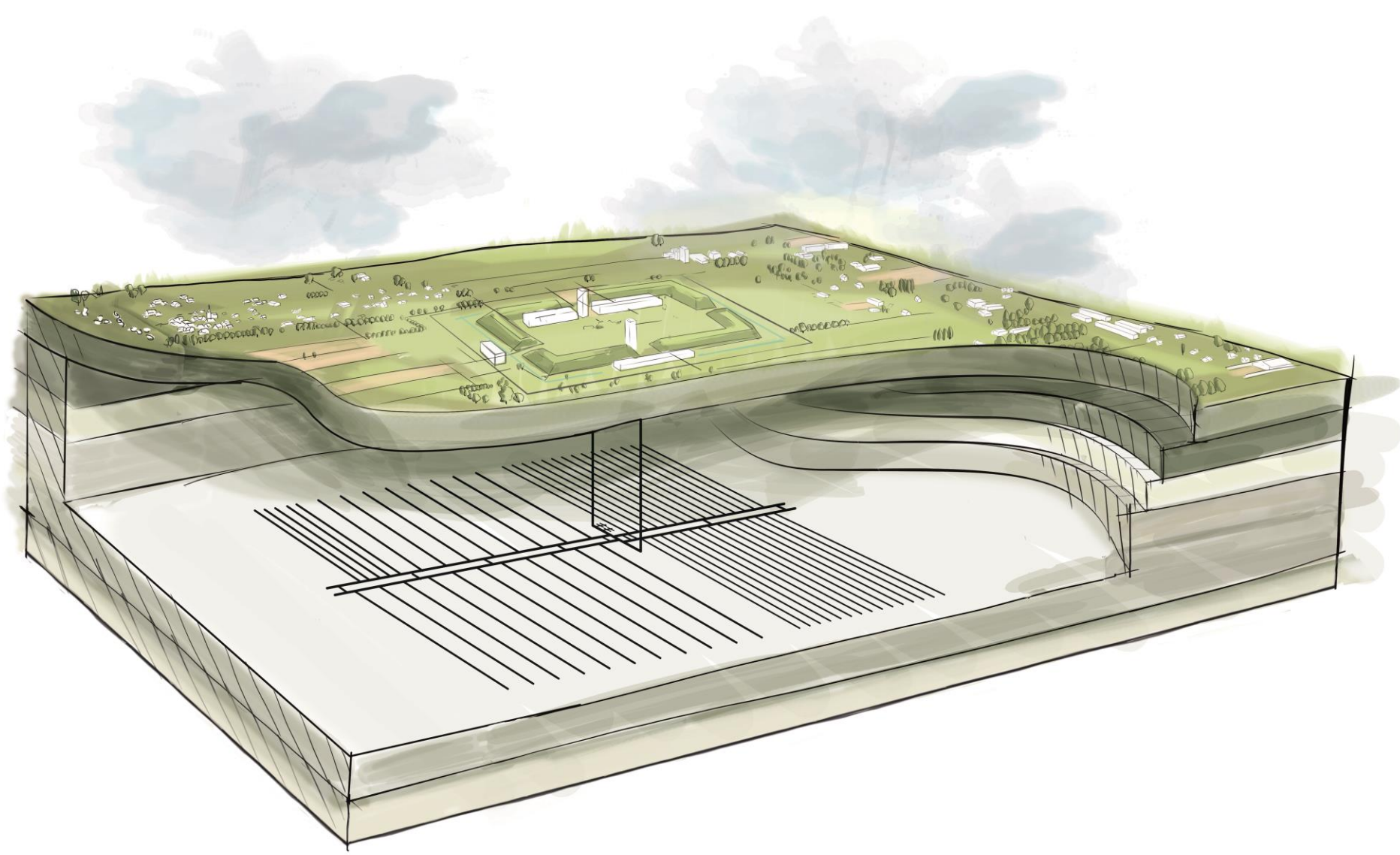


Les déchets de forte activité et/ou de longue durée de vie Le design et l'architecture du stockage géologique

Davina D'ORAZIO, TRACTEBEL ENGIE
Didier LEONARD, ONDRAF
Didier RAYMAEKERS, ONDRAF

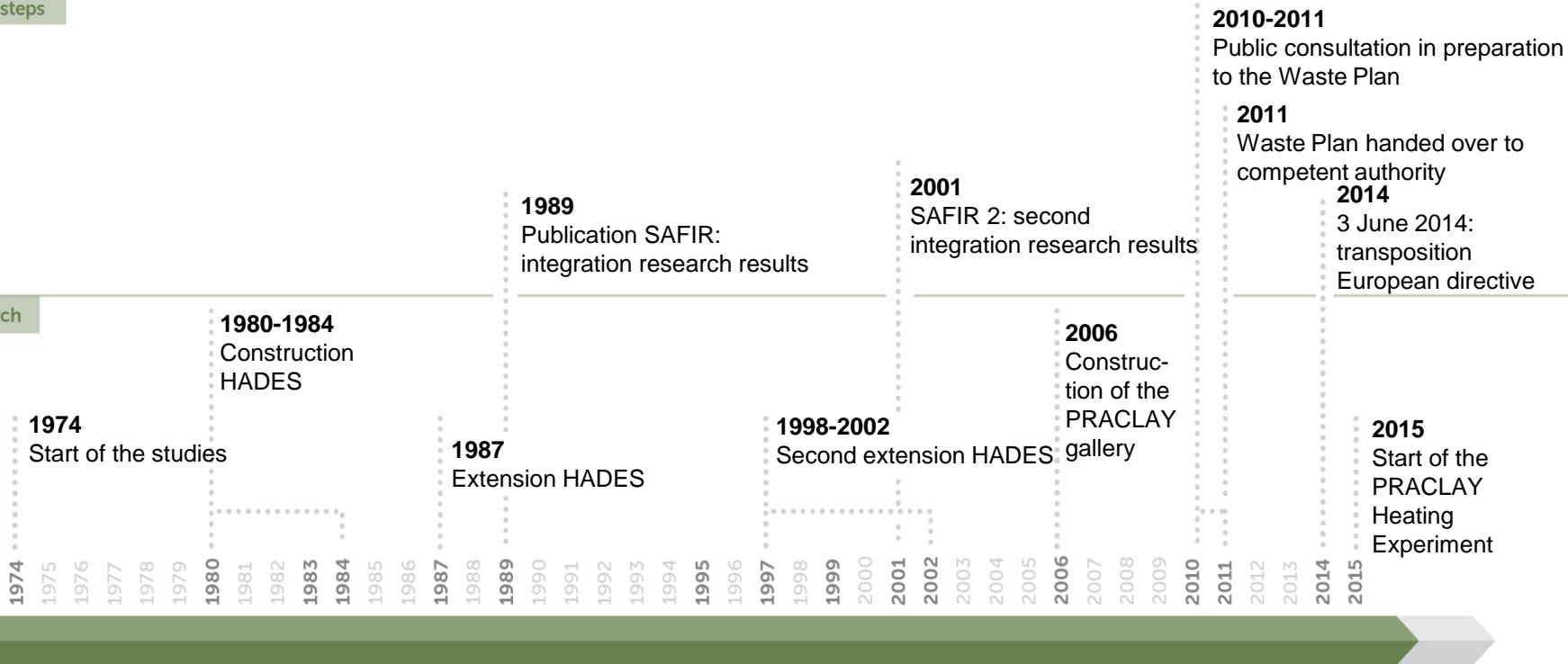
Journée d'étude SBGIMR - Le stockage des déchets nucléaires

Liège, 21 février 2009



Policy steps

Research



Lay-out of the Belgian geological disposal facility

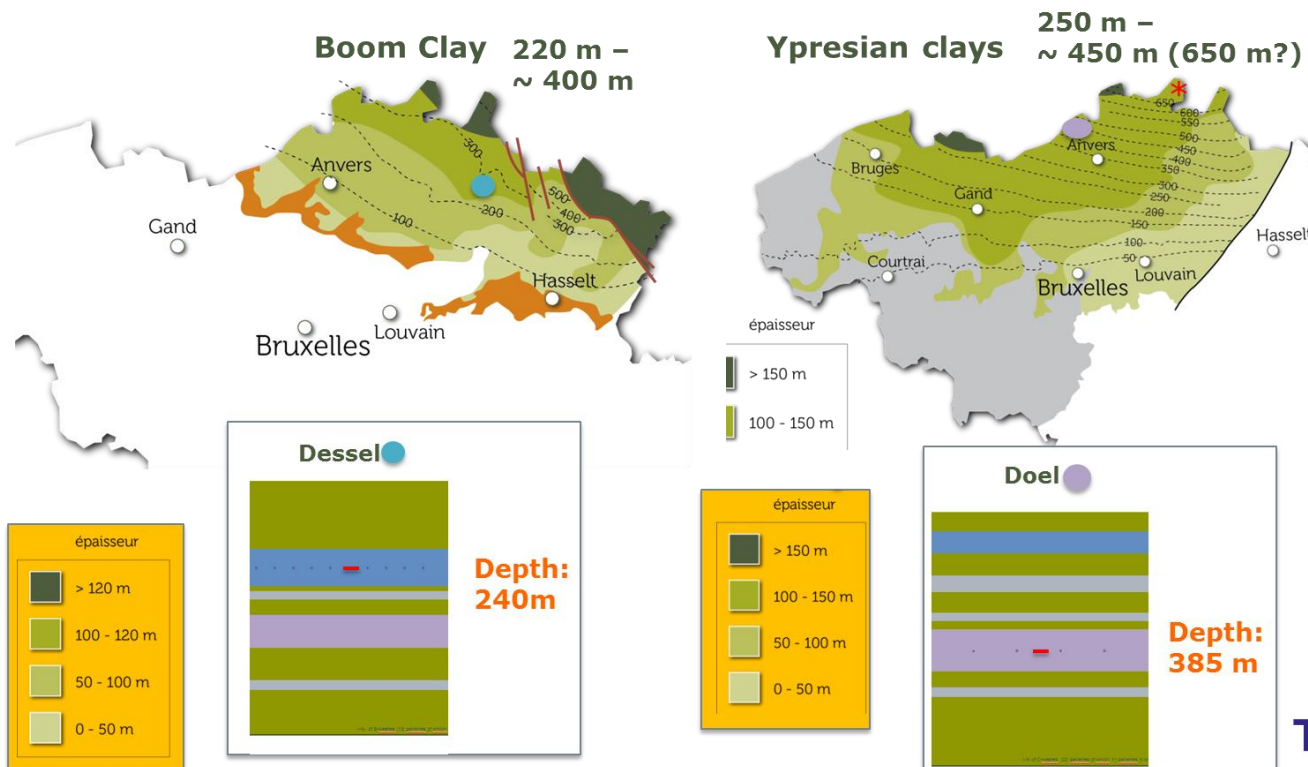
- **Context and ONDRAF/NIRAS Strategic choices**
- Previous reference lay-out of the geological disposal
- Evolutions 2012-2017
- Reference layout 2017
- Evolutions 2018
- Reference layout 2019
- Conclusions

Context

- No policy decisions on the long-term management of B&C waste in Belgium
 - No site available
 - No full and fixed regulation available
 - Reversibility & retrievability are legally requested, although not defined
 - Still uncertainties on B&C waste to be disposed of
- Uncertainties cannot be avoided
- Some strategic choices are made by O/N

ONDRAF/NIRAS Strategic choices

- 1) Solution on the national territory
- 2) Potential host formations = poorly indurated argillaceous formations (Boom Clay or Ypresian Clay)



ONDRAF/NIRAS Strategic choices for B&C

- 3) Waste types shall be divided into groups to be emplaced in separate sections of the disposal facility
- 4) There are preferences for permanent shielding of the waste and for minimization of operations in the underground
 - ➔ Monoliths and supercontainers, disposed in separated zones, no co-activity construction/operation and sequential work
- 5) All disposal galleries and disposal facility sections shall be closed (access routes backfilled and sealed) as soon as practically possible

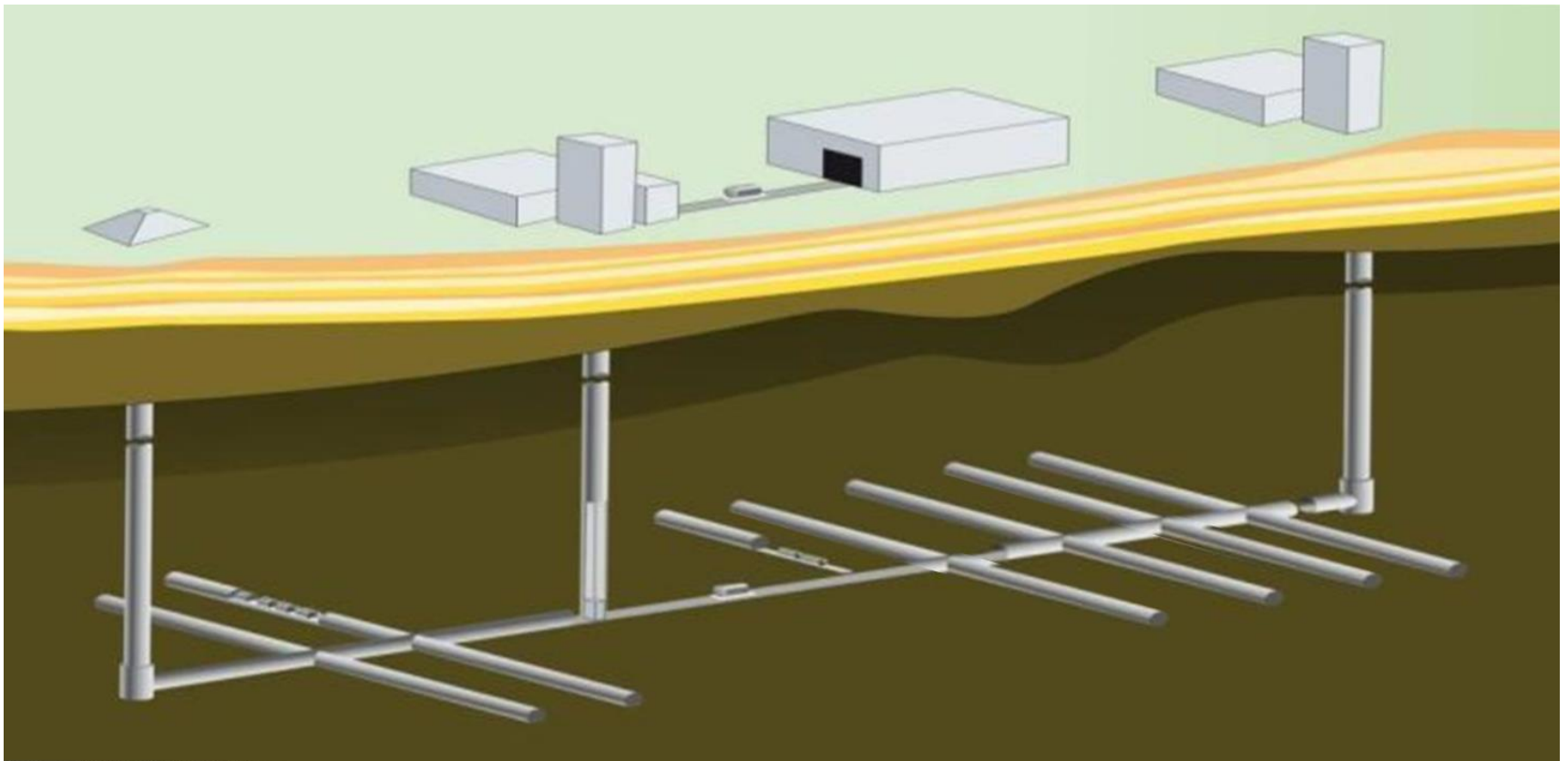
ONDRAF/NIRAS Strategic choices

- Taking into account societal consultations around the waste plan and confirmed by the law 2014, ONDRAF/NIRAS is committed to:
 - 6) Ensure reversibility during the operational phase
 - 7) Consider provisions to facilitate potential retrievability
 - ➔ R&R during operational phase (~100y) should be ensured
 - 8) Consider transfer of knowledge to next generations
 - 9) Controllability of the disposal facility (monitoring, ...)

Lay-out of the Belgian geological disposal facility

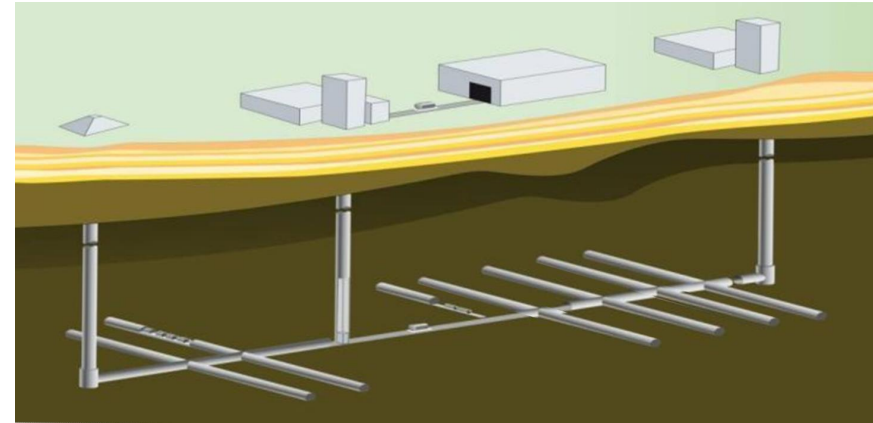
- Context and ONDRAF/NIRAS Strategic choices
- **Previous reference lay-out of the geological disposal**
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Previous reference lay-out of the geological disposal (2003-2015)



Previous reference lay-out of the geological disposal (2003-2015)

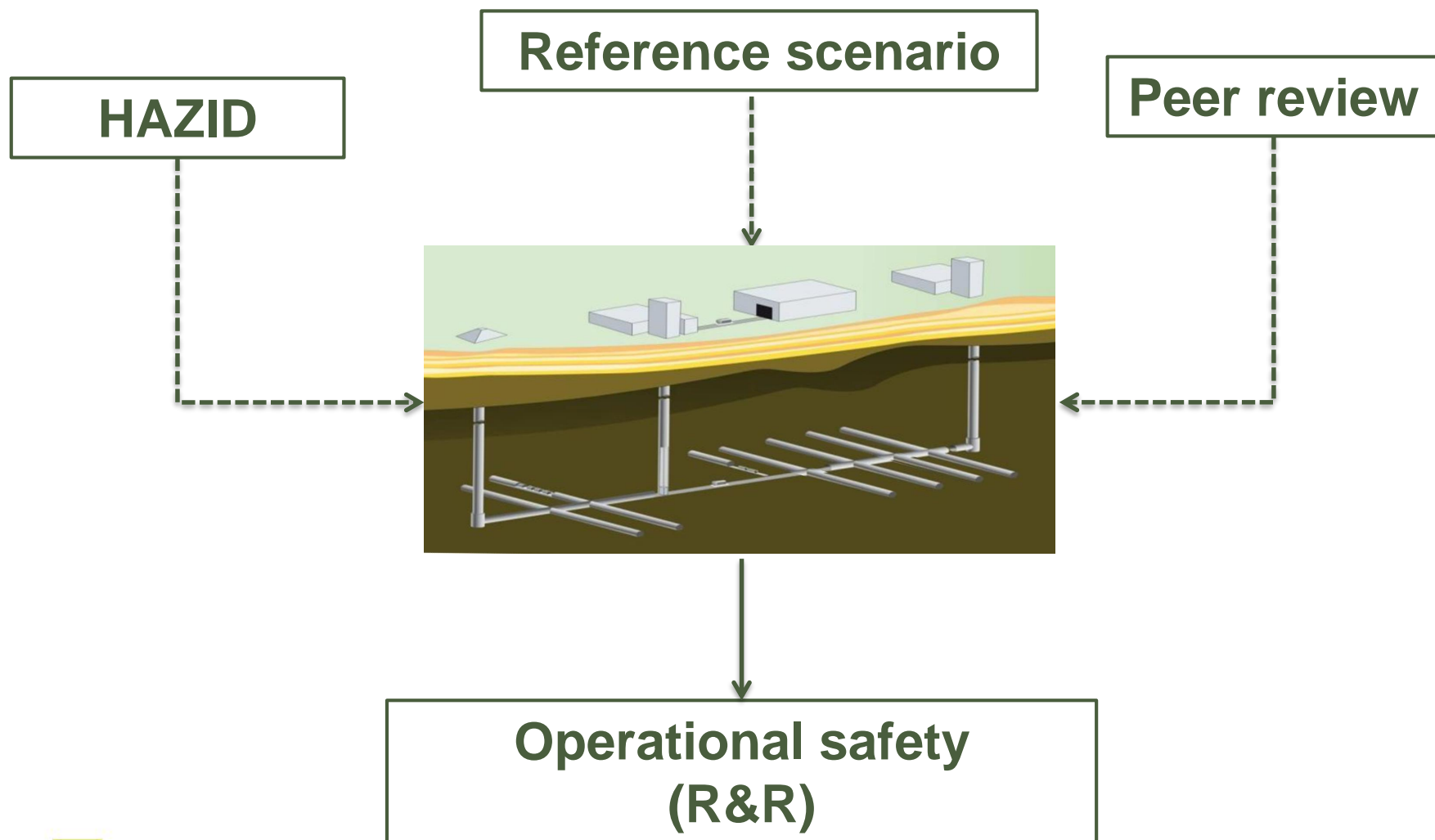
- Depth about 230 m
- 2 separated sections for B & C
- 1 access gallery (AG)
- 3 shafts (2 in operation)
- 1 km disposal galleries (DG)
- X-crossings between galleries
- Diameter of Waste / Transfer shafts: 8 m / 6 m
- Diameter of Access / Disposal galleries: 6 m / 3 m
- Distance between DG :
 - 50 m for B waste (gas)
 - 50 m for C waste (heat)



Lay-out of the Belgian geological disposal facility

- Context and ONDRAF/NIRAS Strategic choices
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- **Evolutions 2012-2017**
- Reference layout 2017
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Evolutions 2012-2017

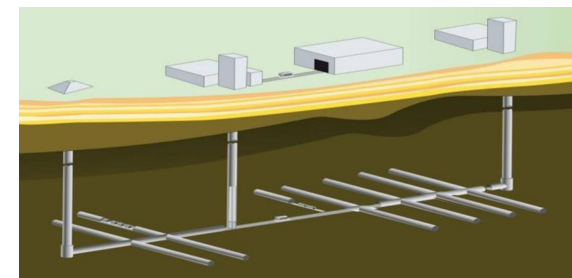


Modification of the reference scenario

- Waste inventory: disposal of reprocessed wastes (CSD-V) and spent fuels
→ Diameter of the access and disposal galleries not sufficient
- Enlargement of the host rock scope: poorly indurated clay (Boom clay and Ypresian clays) between 200 and 600 m

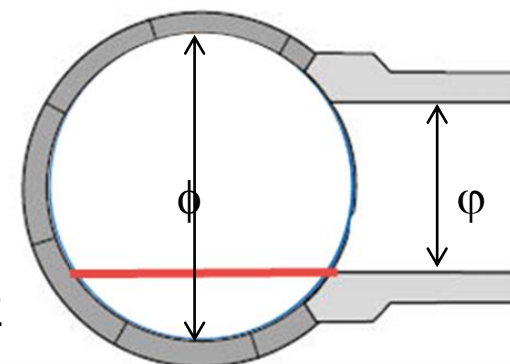
Results from peer reviews and HAZID

- Only 1 access gallery
 - Safety during construction / operation ?
 - Evacuation in case of fire/accident ?
 - REX from Germany (mining regulation) and France (CIGEO)
- Length of (dead end) disposal galleries = 1 km
 - Safety of the workers in case of accident
- X-crossings with large diameters seems today difficult to construct in poorly indurated clay
 - Change the concept to T-crossings and limitation of the ratio diameter

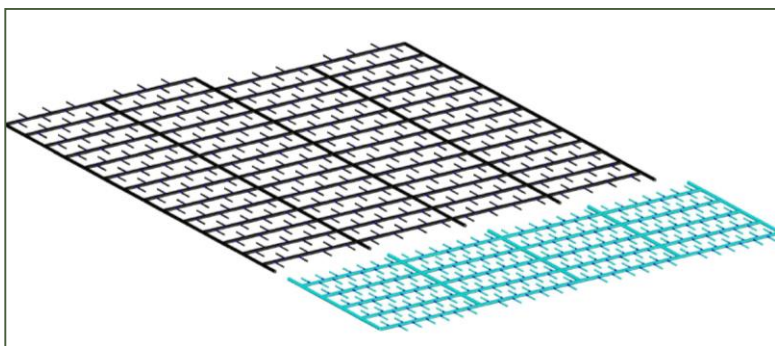
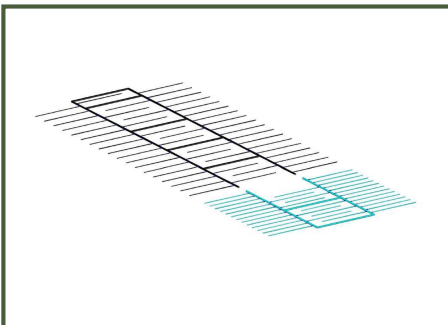
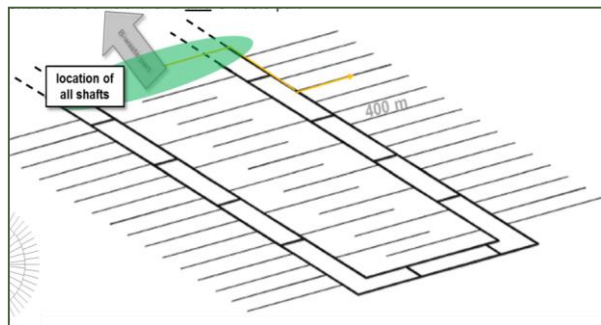
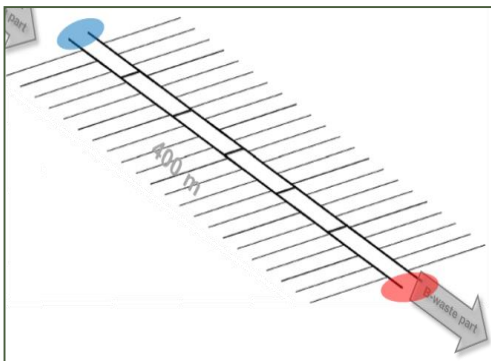
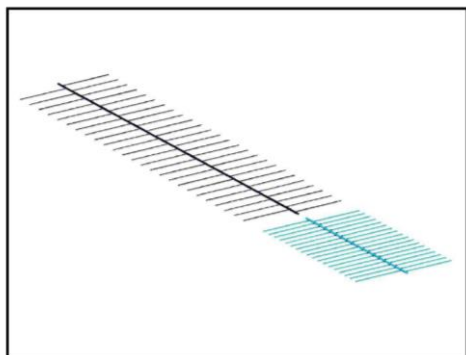


→ **Adaptation of the lay-out is necessary**

$$\phi/\varphi > 2$$



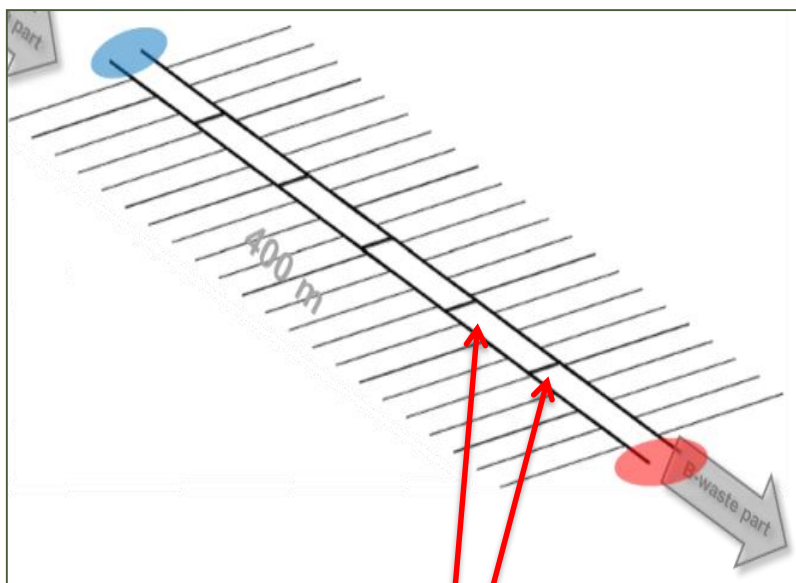
Evaluation of alternatives



- Workshop
 - ✓ Andra
 - ✓ BGE-Technology
 - ✓ ONDRAF/NIRAS
 - ✓ Tractebel
 - ✓ EURIDICE
- Multi-criteria analysis
 - ✓ Operational safety
 - ✓ Long-Term safety
 - ✓ Reversibility
 - ✓ Flexibility

Evaluation of alternatives

TYPE B: 2 AG – 400 M DG



Benefits/Advantages:

- only T-shape crossing
- benefits to operational safety

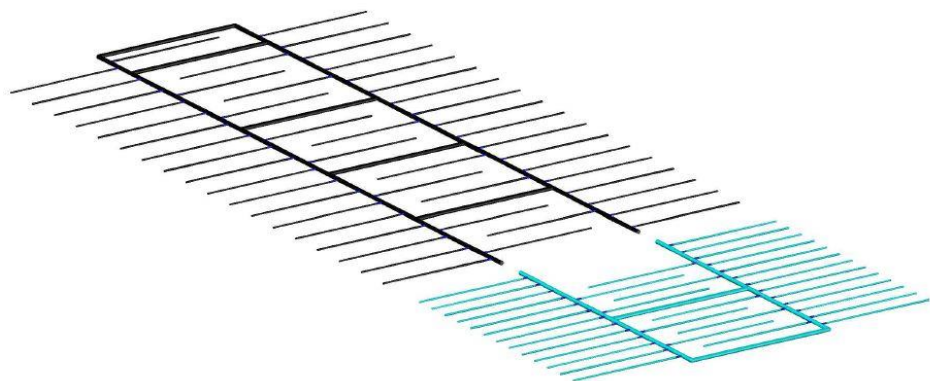
Disadvantages:

- very elongated footprint due to reduced length of DG 400m + long distances between shafts (→ separate surface installations)
- don't allow easy extension in case more underground place is necessary

**CROSSING PASSAGES
EVERY 400 M**

Evaluation of alternatives

TYPE C2: 1 AG – U-SHAPE – 400 M DG



Benefits/Advantages:


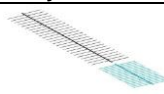
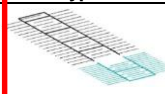

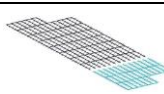
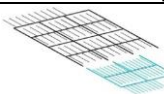
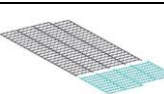
- high flexibility for location and number of the shafts
- reduction to two shafts possible
- concentration of all surface facilities in one area possible (limit security area)

Disadvantages:

- higher operational effort because of one additional turning process

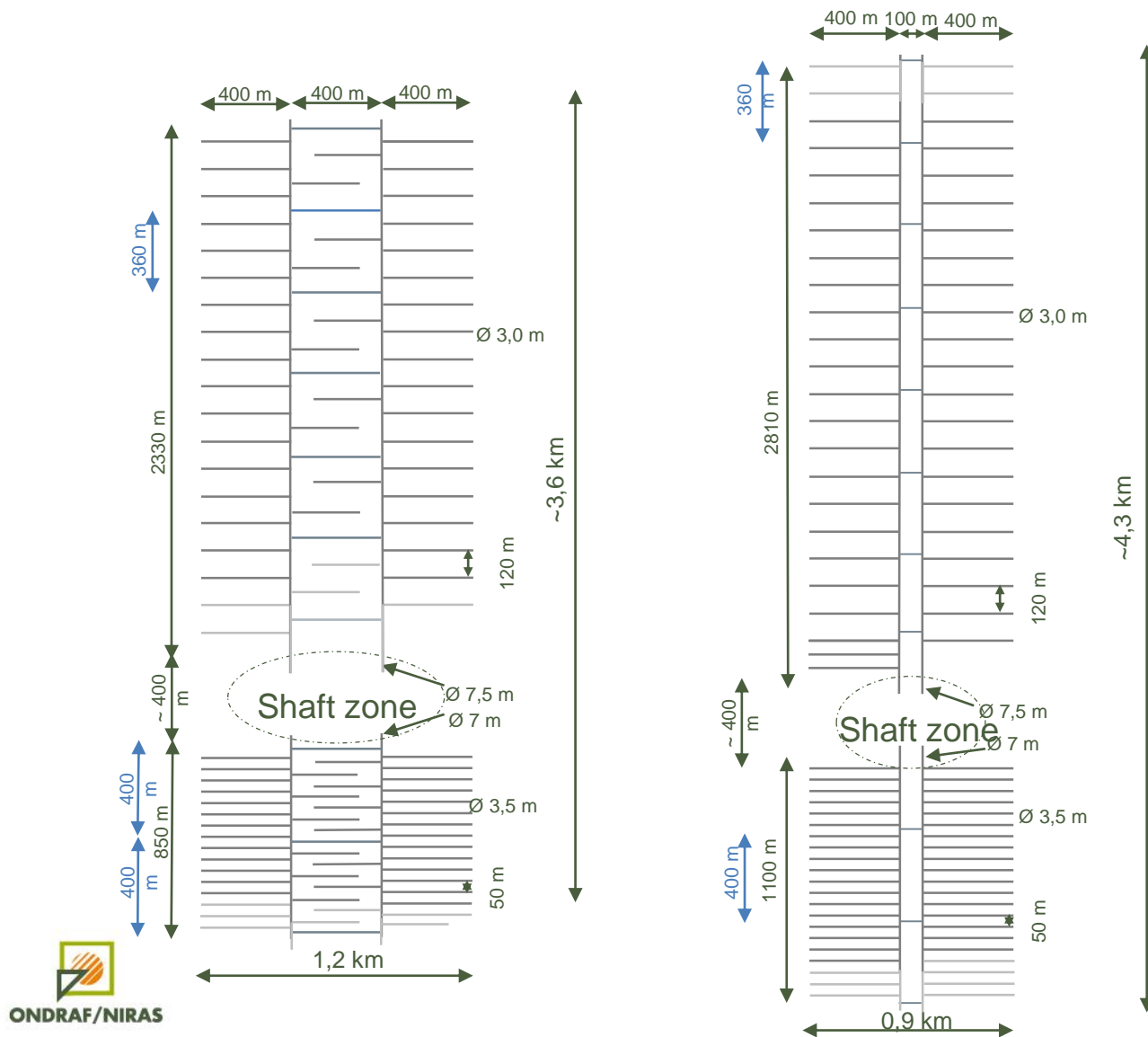
Evaluation of alternatives

Matrix Layout Evaluation

Evaluation Scale	1 - very bad	2 - bad	3 - indifferent	4 - good	5 - very good					
Weighting Scale	1 - low importance	2 - medium importance			3 - high importance					
evaluated by:		Reference Layout		Type C	Type D		Type E			
ONDRAF/NIRAS, DBE TECHNOLOGY GmbH, Tractebel Engineering s.a., EIG EURIDICE										
Criteria	Weight	1000 m DG	400 m DG	400 m DG	400 m DG	50 m DG	400 m DG	50 m DG		
Operational Safety	during Construction	4,00	3,50	3,75	3,00	1,50	3,00	1,50		
	during Operation	2,67	3,25	4,00	3,25	3,00	2,75	3,00		
		3	3,33	3,38	3,88	3,13	2,25	2,88	2,25	
Long-term safety	3	4,33	4,00	3,75	3,50	3,00	3,25	3,00		
Operation	Best available Technique	4,33	4,50	4,00	3,75	2,50	3,50	2,50		
	Time for Disposal per Package	4,67	4,50	4,25	3,50	2,00	3,25	2,00		
		3	4,50	4,50	4,13	3,63	2,25	3,38	2,25	
Reversibility ¹	2	1,67	2,25	2,25	2,25	5,00	2,25	5,00		
Flexibility	extension	1,67	1,50	3,50	3,50	3,50	3,50	3,50		
	separate pilot facility	3,00	3,00	3,50	3,50	3,50	3,50	3,50		
		1	2,33	2,25	3,50	3,50	3,50	3,50	3,50	
Surface area (Security)	1	2,33	1,75	4,75	4,50	4,50	4,50	4,50		
= Sum of (Weighting of Criteria * Value of Evaluation)		44,50	44,13	48,00	43,25	40,50	41,00	40,50		

¹ - Reversibility is defined as the possibility to safely take the waste out of the repository before the backfilling and sealing operations. In contrast to retrievability, it is assumed that retrieval can be achieved with similar techniques/equipment as used for waste package disposal.

Evaluation of alternatives and choice



2 rows !

- No discriminant criteria between the 2 options from construction and operation SWOT analyses
- Choice based on precautionary principle : option with 3 rows more complex

Design and feasibility studies 2016-2017

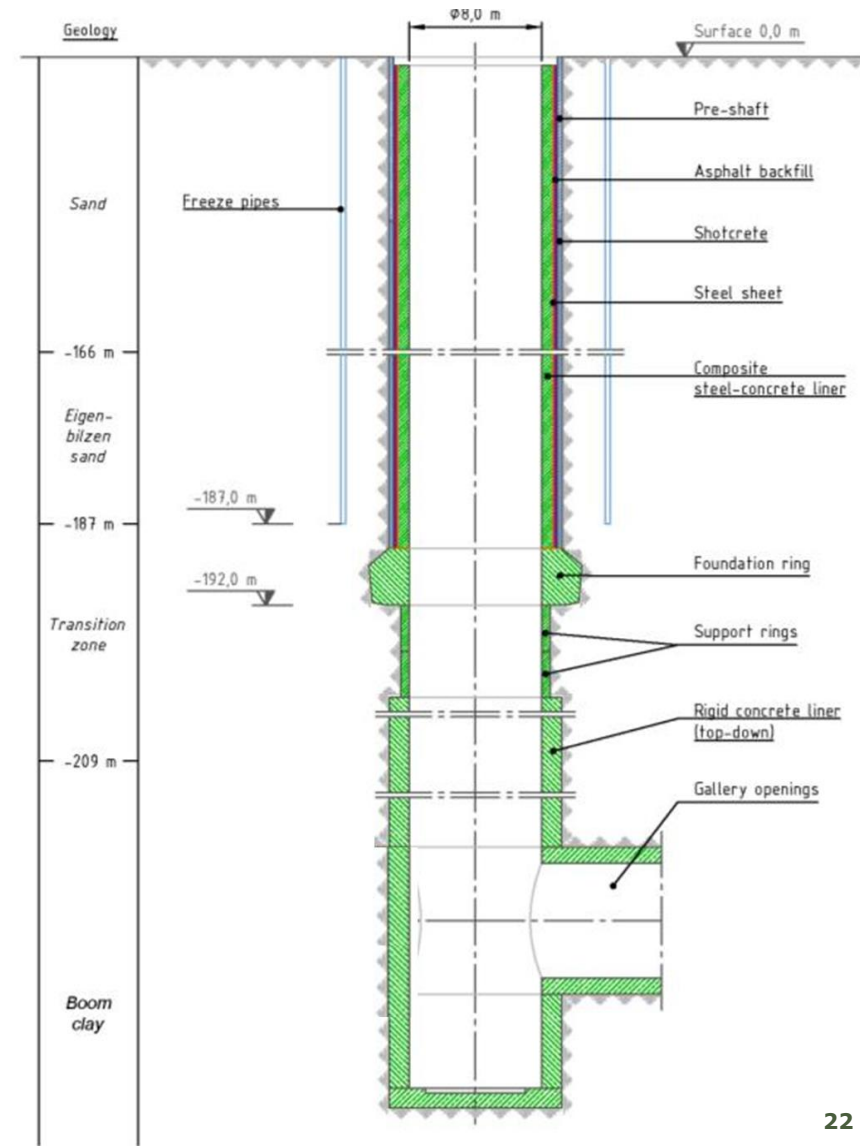
▪ **Operational feasibility:**

- Check that the dimensions of shafts and galleries are suitable for the construction phase (material transfer) and the operational phase (disposal of monoliths B and supercontainers)
- Estimation of the construction duration
- Estimation of the disposal duration

Design and feasibility studies 2016-2017

■ Shaft:

- The same method as for the Hades laboratory is considered (conventional excavation and freezing of the sandy aquifer)
- Steel-concrete composite lining with asphalt backfill in the aquifer section
- Rigid top-down concrete lining in the clay section

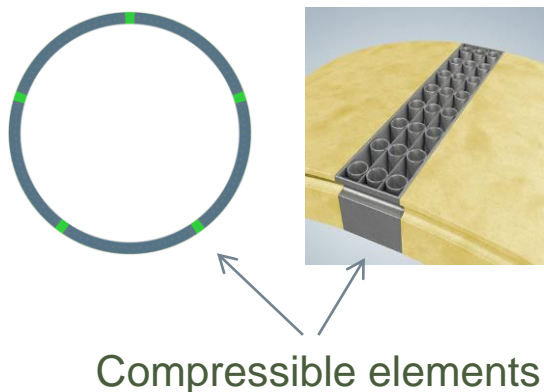


Design studies 2016-2017

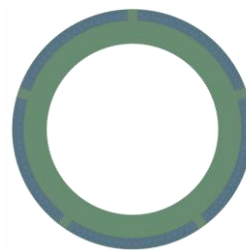
▪ Galleries:

- Excavation by TBM and installation of a concrete lining system
- Access galleries: A double liner (0,5 m concrete segments with compressible elements + 1 m cast in-situ concrete) is necessary to support the pressure

1) Concrete liner



2) Cast in situ concrete



- Disposal galleries: A single liner with UHPC segments is acceptable



Design studies 2016-2017

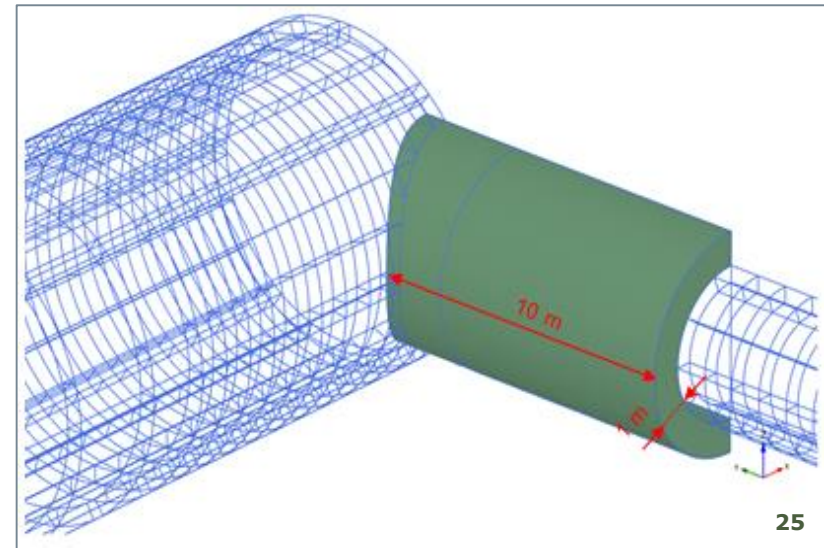


Hades laboratory
External diameter: 4.7 m
Internal diameter: 3.5 m

Design studies 2016-2017

▪ T-crossings:

- The design and construction of the T-crossings between galleries having diameters of 7,5 and 3,5 m is a challenging point
- Installation of a temporary circular steel frame to stabilise the AG at the crossing during construction of the lateral opening for the DG. Then TBM excavation



Lay-out of the Belgian geological disposal facility

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Reference layout 2017

max 400 m

B-Zone

- MON-BITUM-R: 1
- MON-CEMENT-R: 4
- MON-MECA-B: 1
- MON-MOSA-B: 8
- MON-BITUM1-B: 11
- MON-BITUM2-B: 2
- MON-CEMENT-B: 7
- MON-GLASS: 3

Total: 37 DG

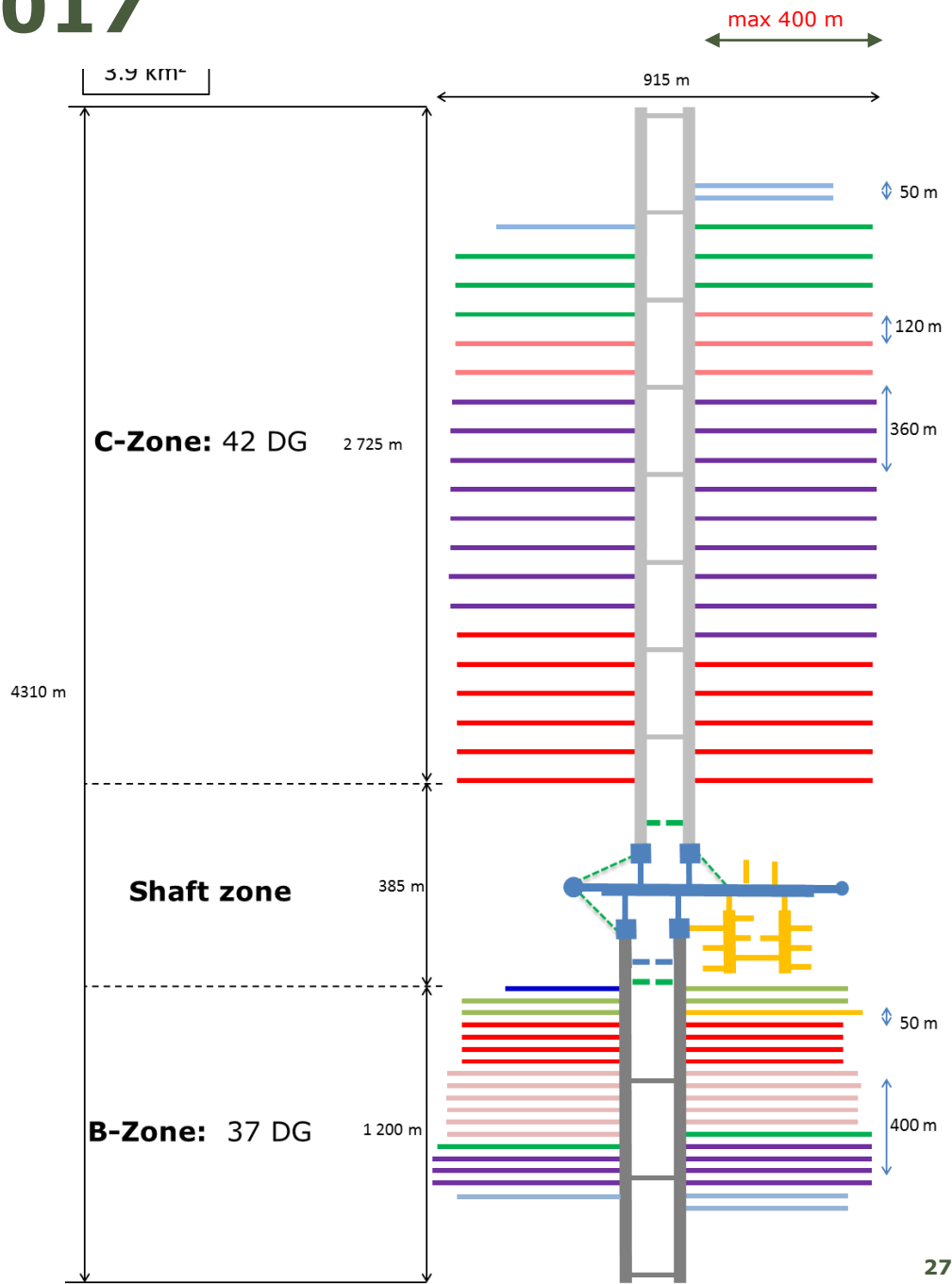
C-Zone

- SC-1 (actual): 3
- SC-1 (future): 6
- SC-2: 5
- SC-3: 17
- SC-4: 11

Total: 42 DGs

Dimensions

- 2 centralised shafts
- 4310 m x 915 m i.e. 3.9 km²
- Total length AGs: 8 360 m
- DG max 400 m
- Total length DGs: 29 406 m
- 11 crossing passages
- 127 T-crossings



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Evolutions 2018

- For the most important topics, an “optioneering process” was launched to reconsider several alternative solutions and select the most appropriate one
- **In 2018, three topics have been optimised:**
 - Topic #1 - Number and diameter of shafts (including ramp as alternative)
→ 2 shafts is confirmed as the reference solution
 - Topic #2 - Length of the disposal galleries
 - Topic #3 - Diameters of the access galleries and disposal galleries in the C-zone
→ Enlargement and uniformisation between the B and C-zones:
AGs = 7,5 m and DGs = 3,5 m

Maximum length of the disposal galleries

Operation safety studies

- DGs are dead-end galleries
- Workers must be present in DGs for some specific operations (backfilling, inspection)
- An evacuation distance of 400 m seems excessive
- Additional passive safety measures (mobile rescue chambers) are necessary
- Considering the use of rescue chambers, the maximal length (between 50 m and 2400 m) was reassessed and fixed to 1000 m



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- **Conclusions**

Reference layout 2019

B-Zone

MON-BITUM-R: 1
 MON-CEMENT-R: 2
 MON-MECA-B: 1
 MON-MOSA-B: 3
 MON-BITUM1-B: 5
 MON-BITUM2-B: 1
 MON-CEMENT-B: 3
 MON-GLASS: 1

Total: 17 DG

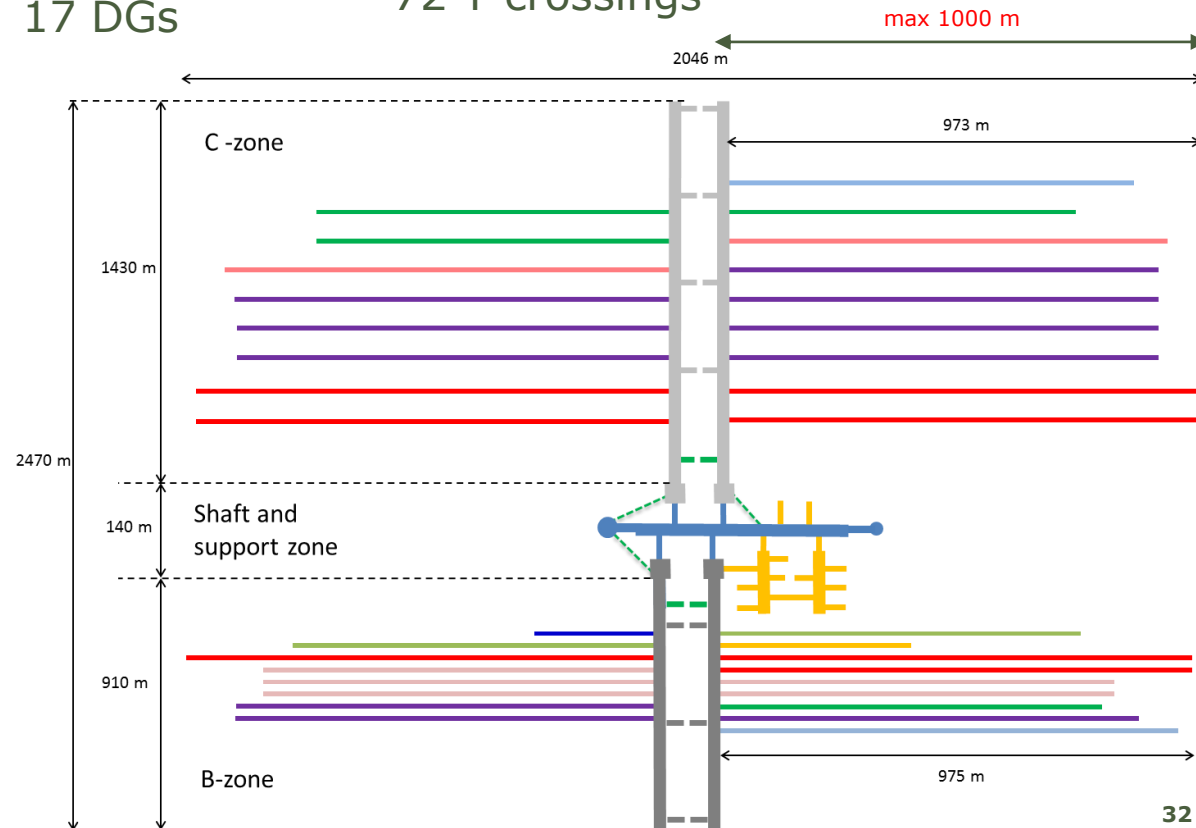
C-Zone

SC-1 (actual): 1
 SC-1 (future): 3
 SC-2: 2
 SC-3: 7
 SC-4: 4

Total: 17 DGs

Dimensions

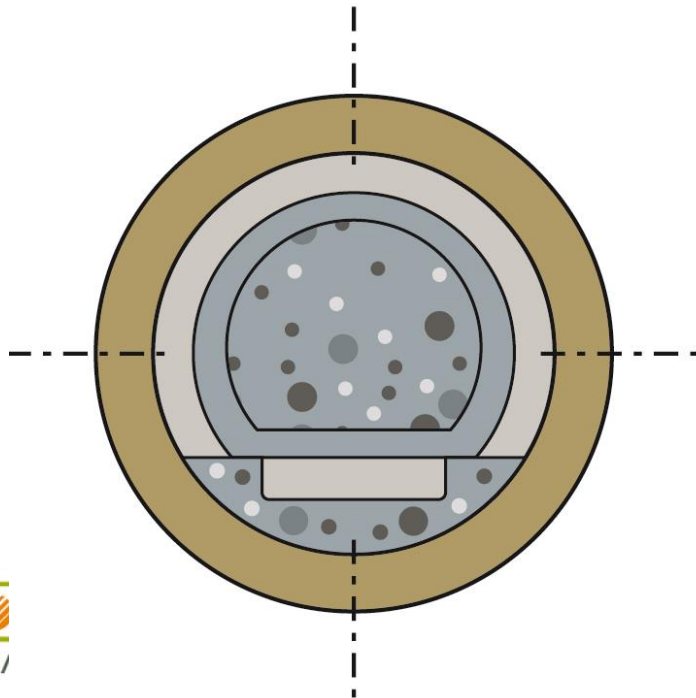
- 2 centralised shafts
- 2470 m x 2046 m i.e. 5.1 km²
- Total length AGs: 4 680 m
- Total length DGs: 28 633 m
- DGS max 1000 m
- 9 crossing passages
- 72 T-crossings



Reference layout 2019

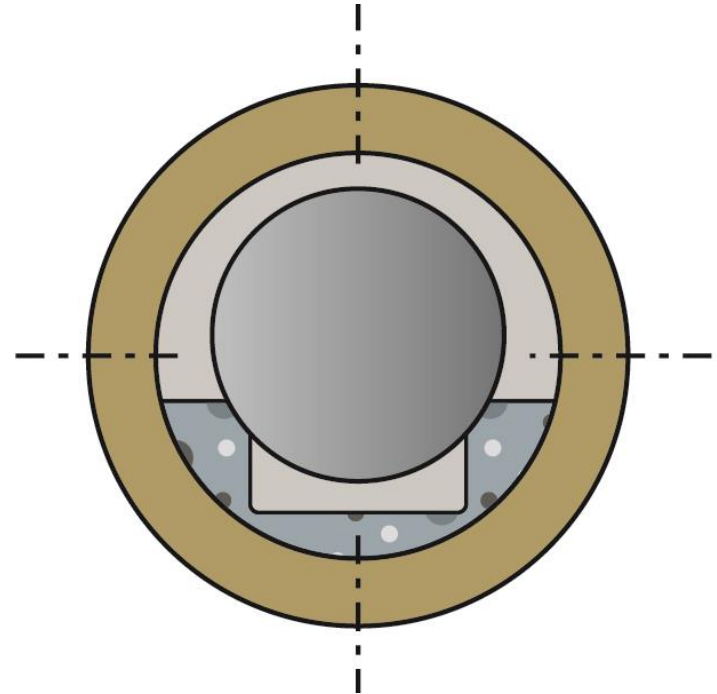
B-waste area

- DG length max 1000 m
- AG Int. Diameter of 7,5 m DG Int. Diameter: 3,5 m
- Inter-axis distance: 50 m (gas production)
- Distance between DWP of 10 cm
- Plug of 25 m in each DG



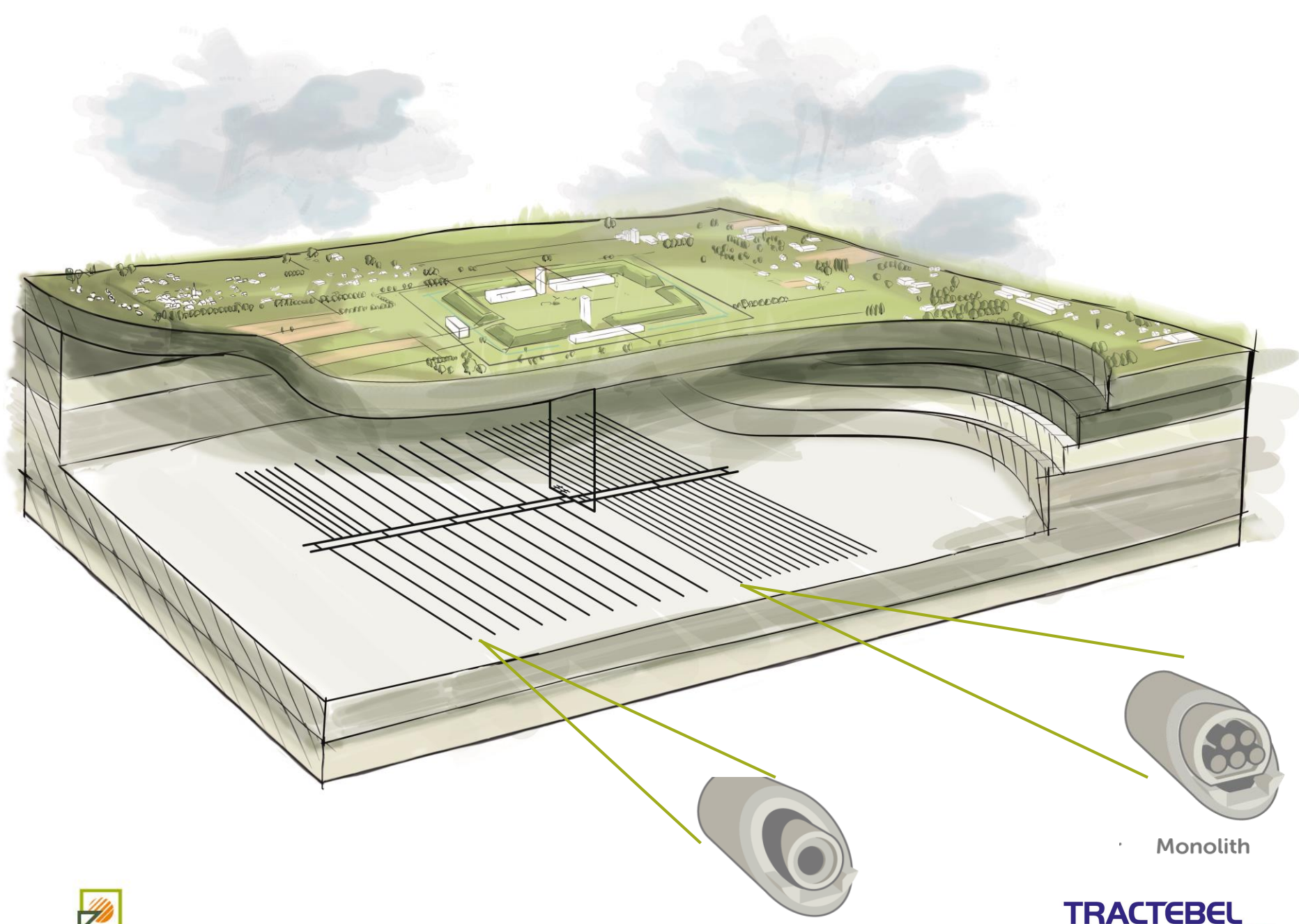
C-waste area

- DG length max 1000 m
- AG Int. Diameter of 7,5 m to turn SC
- DG Int. Diameter: 3,5 m
- Inter-axis distance: 50 m (C) & 120 m (SF)
- Distance between DWP of 10 cm
- Plug of 25 m in each DG



Lay-out of the Belgian geological disposal facility

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- **Reference layout 2019**
- **Conclusions**





Supercontainer



Monolith

Conclusions

- **A new layout, suitable for depths between 200 and 400 m, is now available**
- **The studies performed the last years allows to:**
 - Improve the operational safety during construction and operation
 - T-crossings
 - 2 access galleries
 - Use of rescue chambers
 - Confirm the feasibility
 - First engineering studies
 - Consider the R&R requirements
 - Improve the long term safety
- **This is only a step in a long term iteration process**