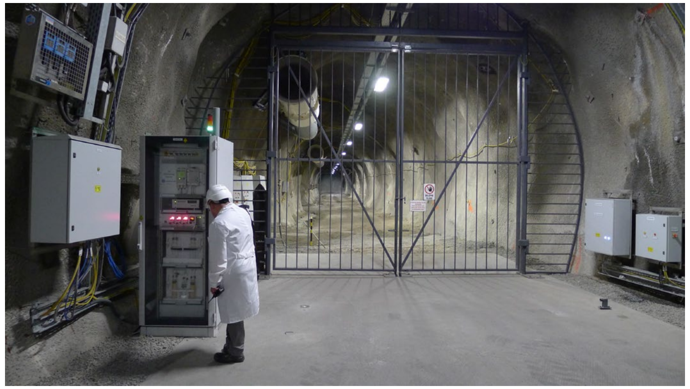

PURAM

PUBLIC LIMITED COMPANY FOR RADIOACTIVE WASTE MANAGEMENT

RD&D support for the operating Bátaapáti intermediate depth geological repository (Hungary)

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PURAM

The 10th IGD-TP Exchange Forum

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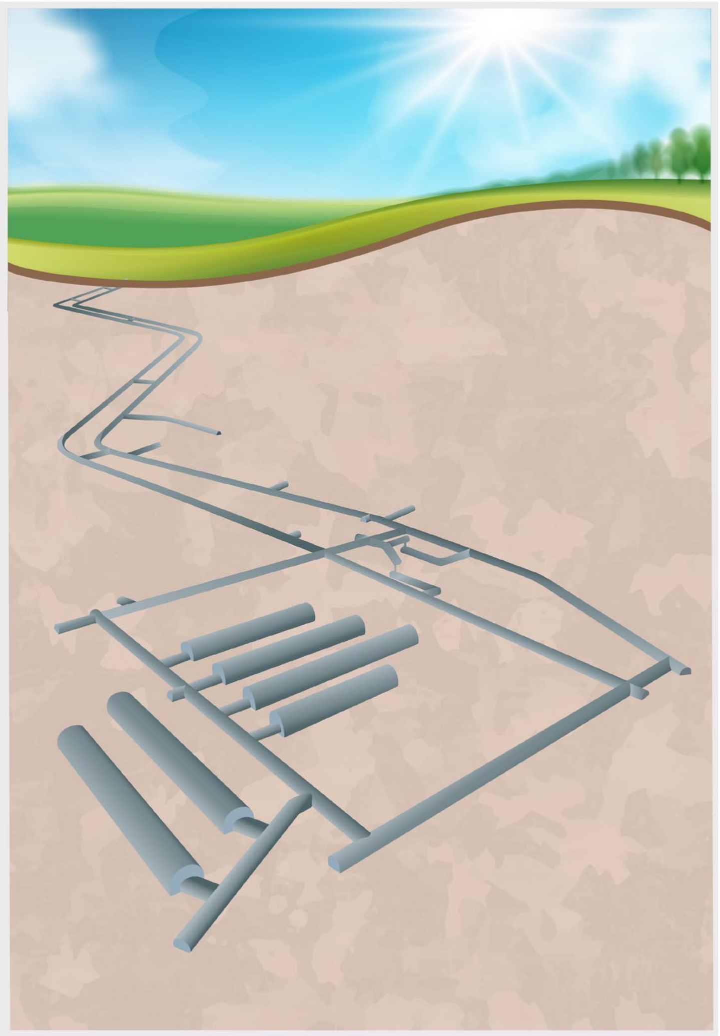
Bátaapáti repository

PURAM operates the Bátaapáti intermediate-depth geological repository (National Radioactive Waste Repository, NRWR) **since 2008**

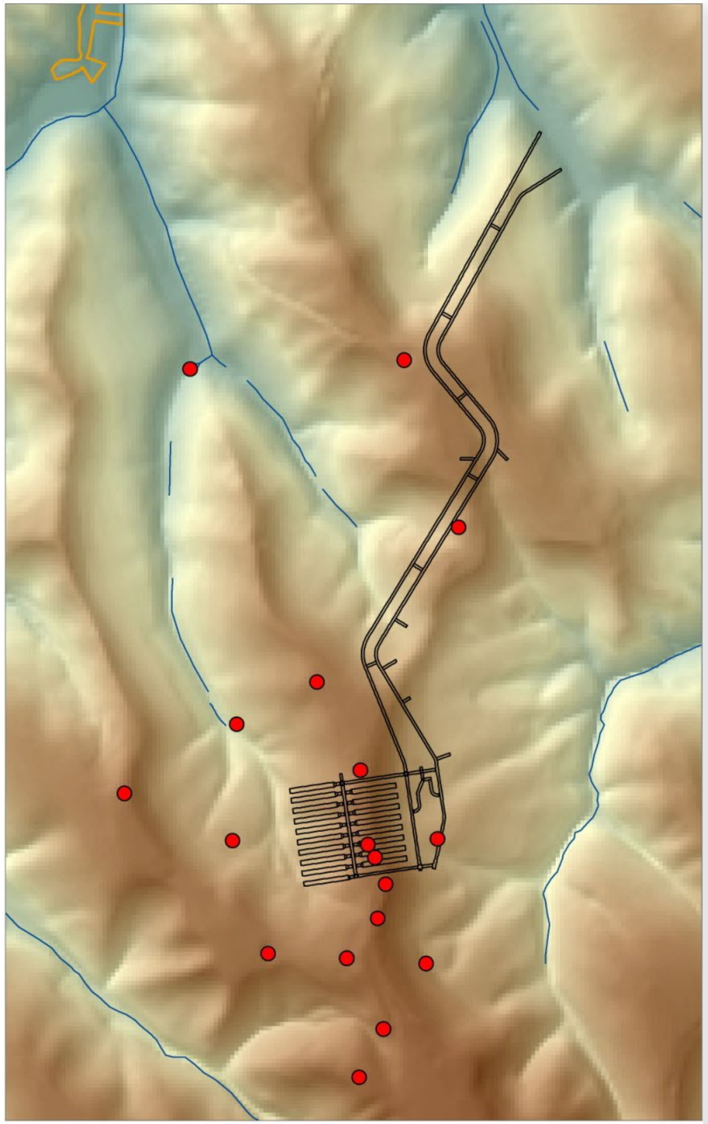
- **Located** in SW Hungary, 65km from Paks NPP
- **Depth:** 200–250m bgs
- **Host formation:** highly fractured granitic rock (350 Mln years old) with sealing fault zones (compartmented flow system)
- **Designed** for final disposal of **LILW**, mainly from NPP (operation, decommissioning)
- **Capacity:** 20,000m^3 of waste, +20,000m^3 with expansion
- **Consists of** an **administrative** and a **buffer storage building** at the surface, and in the underground space a par of **inclined access ramps** with a length of 1,700m each (average slope is 6° and size of the cross-section is 21-25m^2), **cross-tunnels** at every 250m, a **sub-horizontal tunnel system** (33m^2) and **6 disposal galleries** with a length of 80–120m and cross-section from 95 to 133m^2.
- **Excavated** using drill-and-blast method with 1.0-3.0 m spans, **support system** was developed according to the New Austrian Tunnelling Method (NATM), using grouted **rock bolts** and fibre-reinforced **shotcrete lining**. **Steel mesh** and **lattice girders** were applied additionally only in fracture zones and in the larges size galleries.



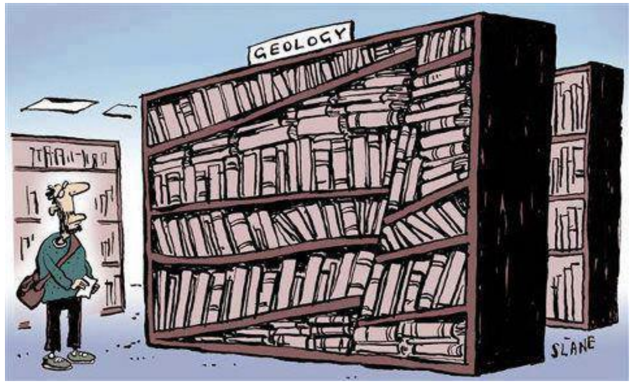
Implementation history of the Bátaapáti repository

- Operation of the Paks NPP started in 1982, **final disposal of LLW was not solved** then.
- **1990: Failure** in licencing of a near surface facility at Ófalu, due to the strong protest of the public; **no detailed legal requirements** for a repository **existed** that time. Until 1996 LLW from the Paks NPP was disposed at the operating near surface facility for institutional waste at Püspökszilágy.
- **1993–1996:** National Project for **site selection** (geological screening combined with voluntary participation); Bátaapáti site was selected from 3 final candidates in 1996, based on pilot borehole data, hydrogeological modelling and preliminary safety assessment.
- **1997–2004:** Surface-based **site characterisation**, **preliminary design**, **safety case** updates (2001, 2004).
- **2004–2008: Underground investigation** (R&D experiments) with the excavation of access ramps.
- **2005: Local memorandum** on facility acceptance and the **Parliament ratified** the Decision in Principle.
- **2008–2011: Construction permit**, excavation of the first two galleries (K1, K2)
- **2012–2015: Operational permit**, excavation of two new galleries (K3, K4)
- **since 2011: Optimisation** of the disposal concept, **multi-stage implementation** and **commissioning**.

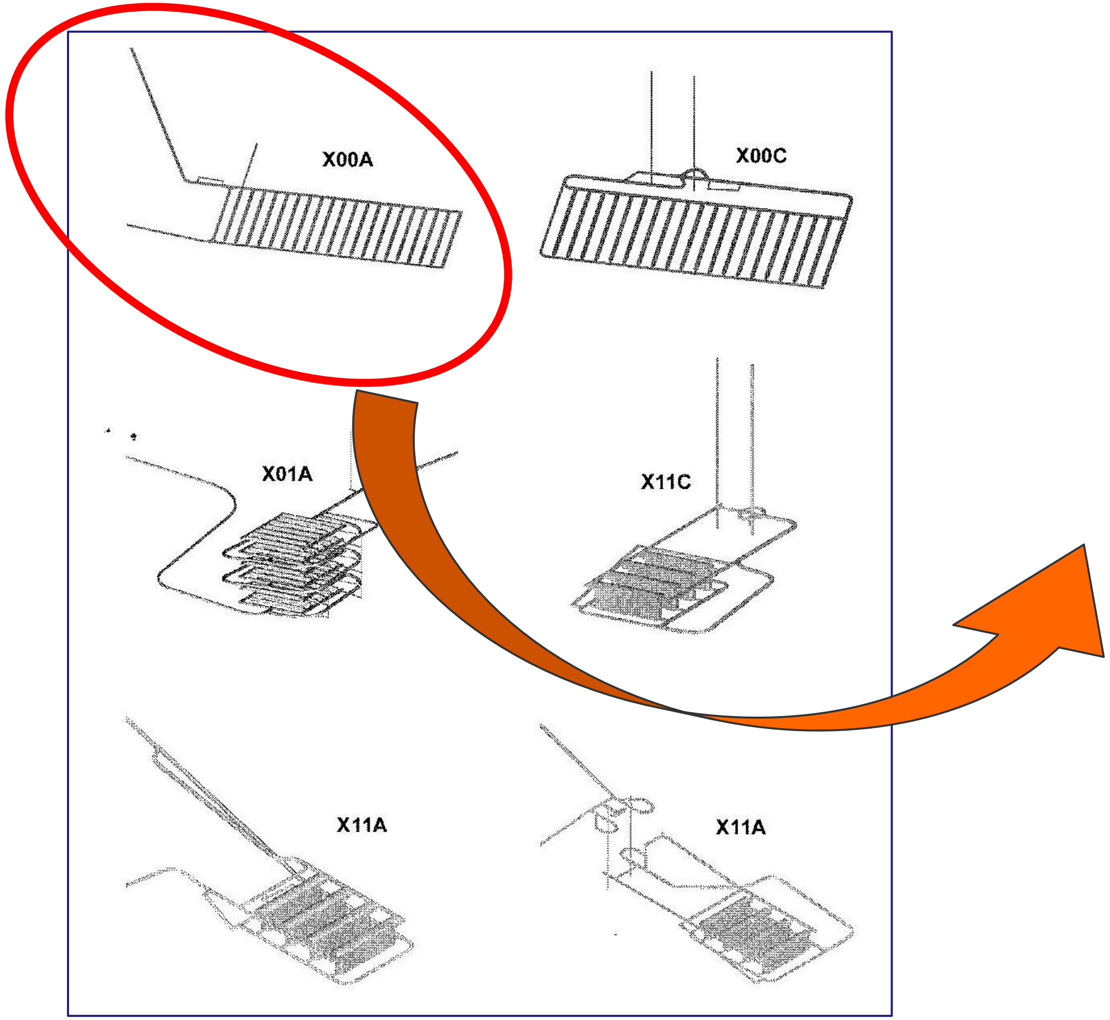
Site investigation & characterisation (1996-2011)



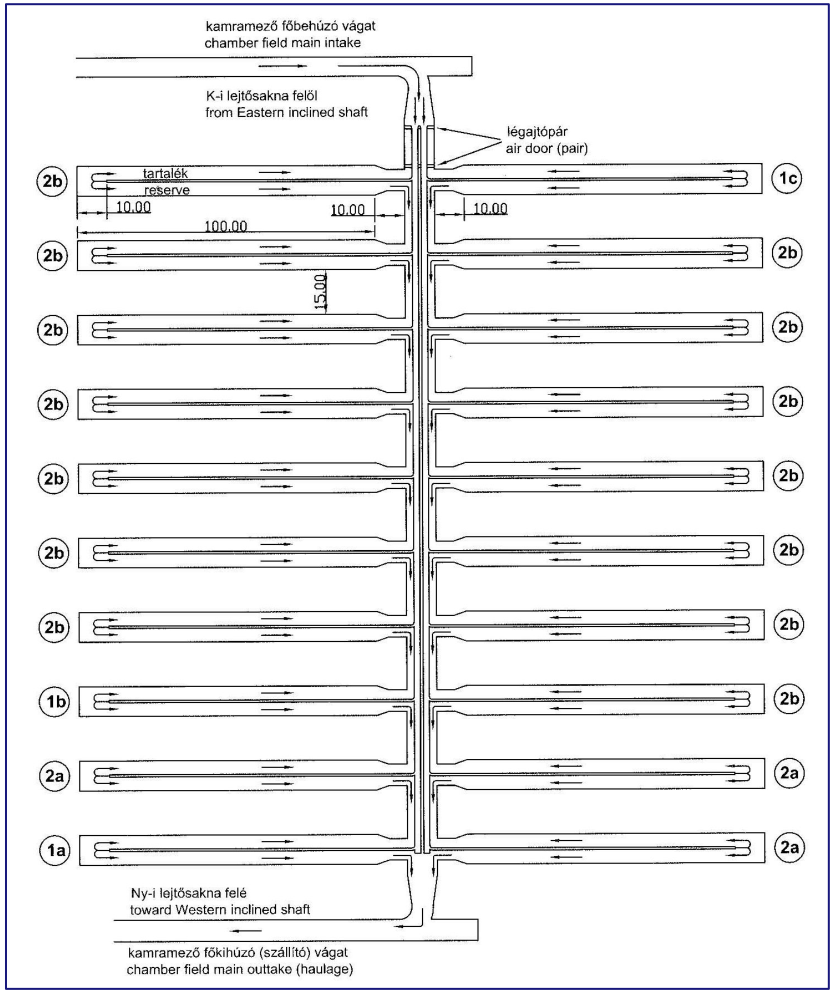
- geological, hydrogeological mapping
- trenches, shallow shafts
- 60 shallow (10-100m) and 20 deep boreholes (250-500m), 7,500m total depth
- surface and borehole geophysics (cross-hole tomography, acoustic BHTV, flow logging)
- hydraulic packer testing, groundwater sampling, installation of multi-packer systems
- underground excavations, documentation, in-situ and lab. geotechnical measurements, underground drilling (12,000m)
- EDZ-characterisation, transport experiments (tracer tests)
- environmental monitoring
- data analysis, modelling, evaluation



Initial design of the repository layout (1996–2003)



Calamites Kft., 1999

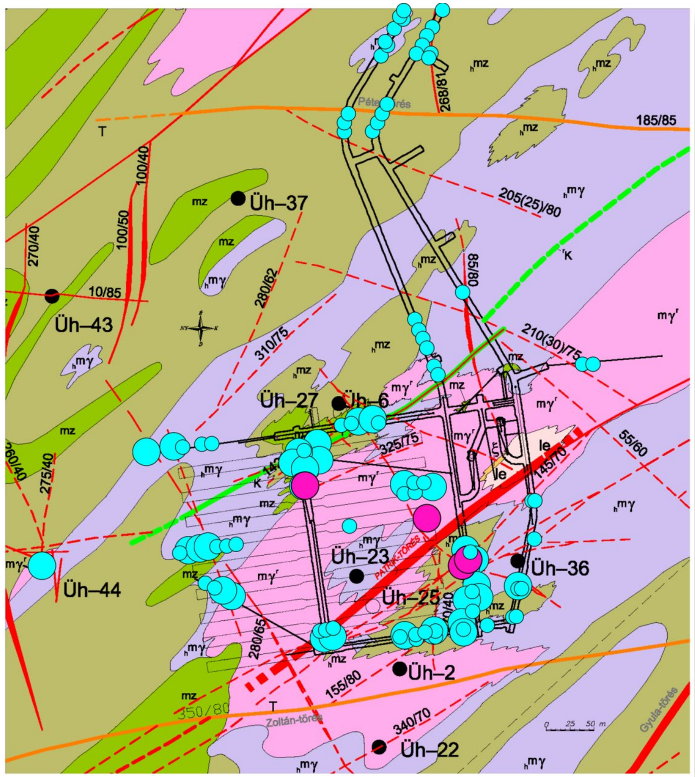


ETV-Erőterv Zrt., 2003

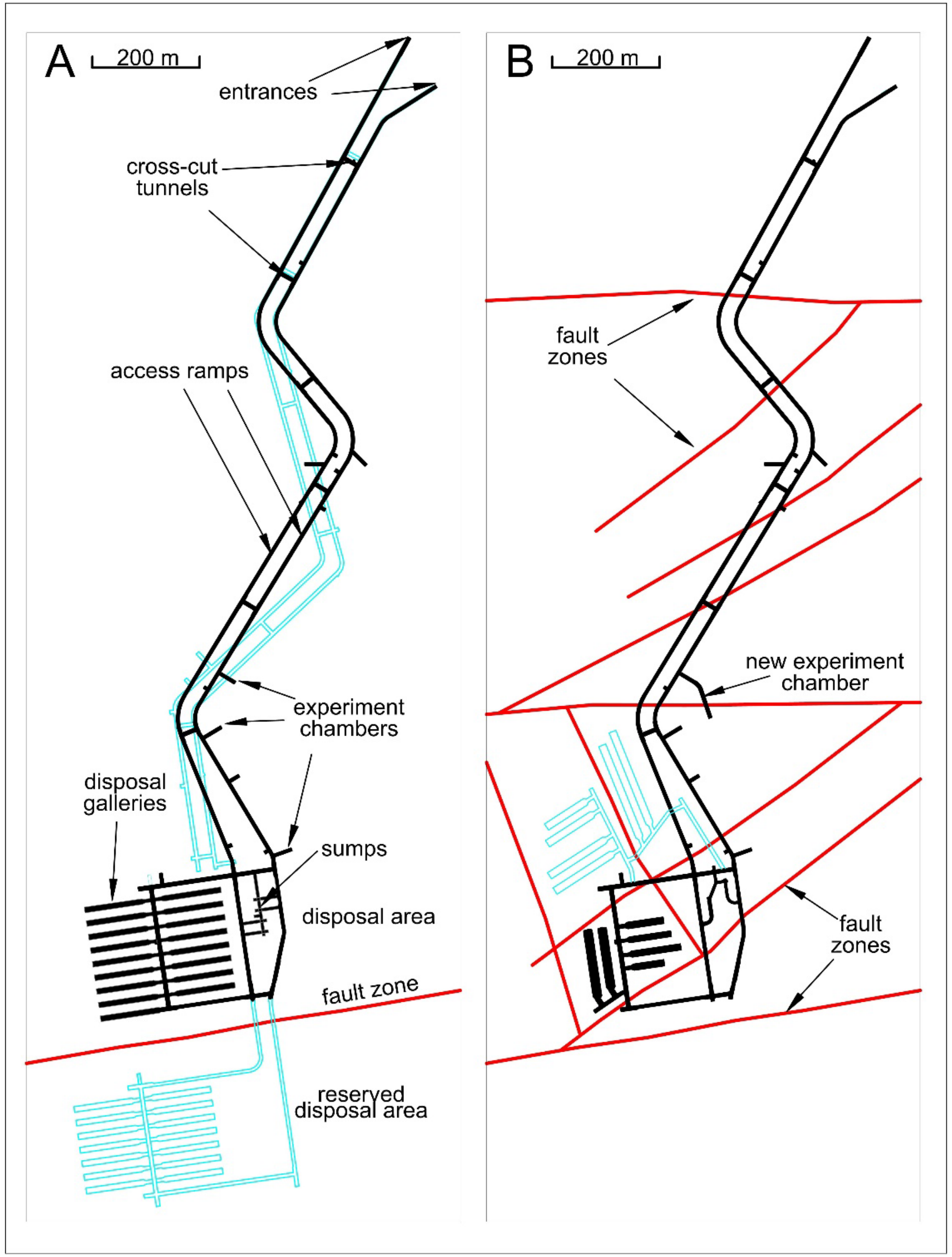
Development of the layout

A – initial design **in 2003 with the original extension concept** and **in 2008 for the construction license**

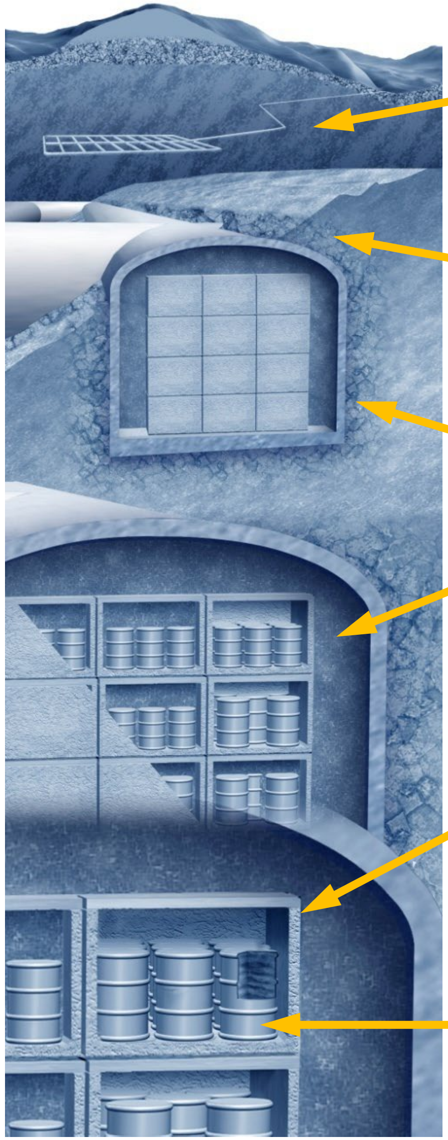
B – final design **in 2020** and the **new extension concept**



- in case of **complicated geological settings**, it is necessary to **adapt the layout** to the real conditions
- **„DESIGN AS YOU GO”**



Initial disposal concept (2004)



2 inclined access ramps and horizontal tunnel system

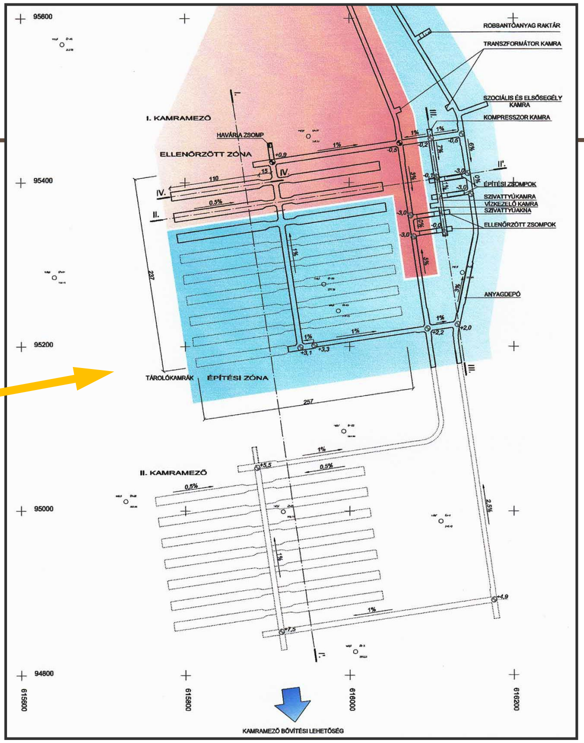
17 disposal galleries with 95m^2 cross-section and an extension area

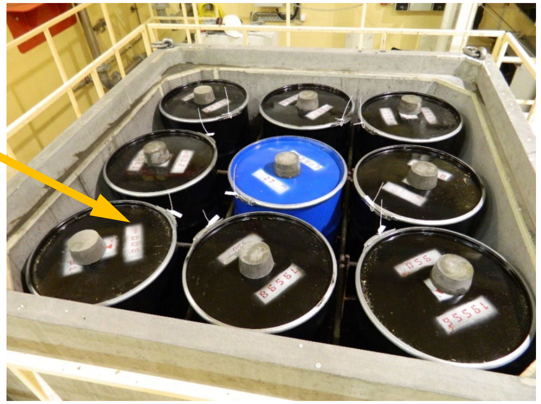
shotcrete lining and EDZ

self-compacting concrete backfill

steel reinforced concrete overpacks (**7 m³**) with 9 drums in each, the inner space filled up with inactive mortar at the Bátaapáti facility

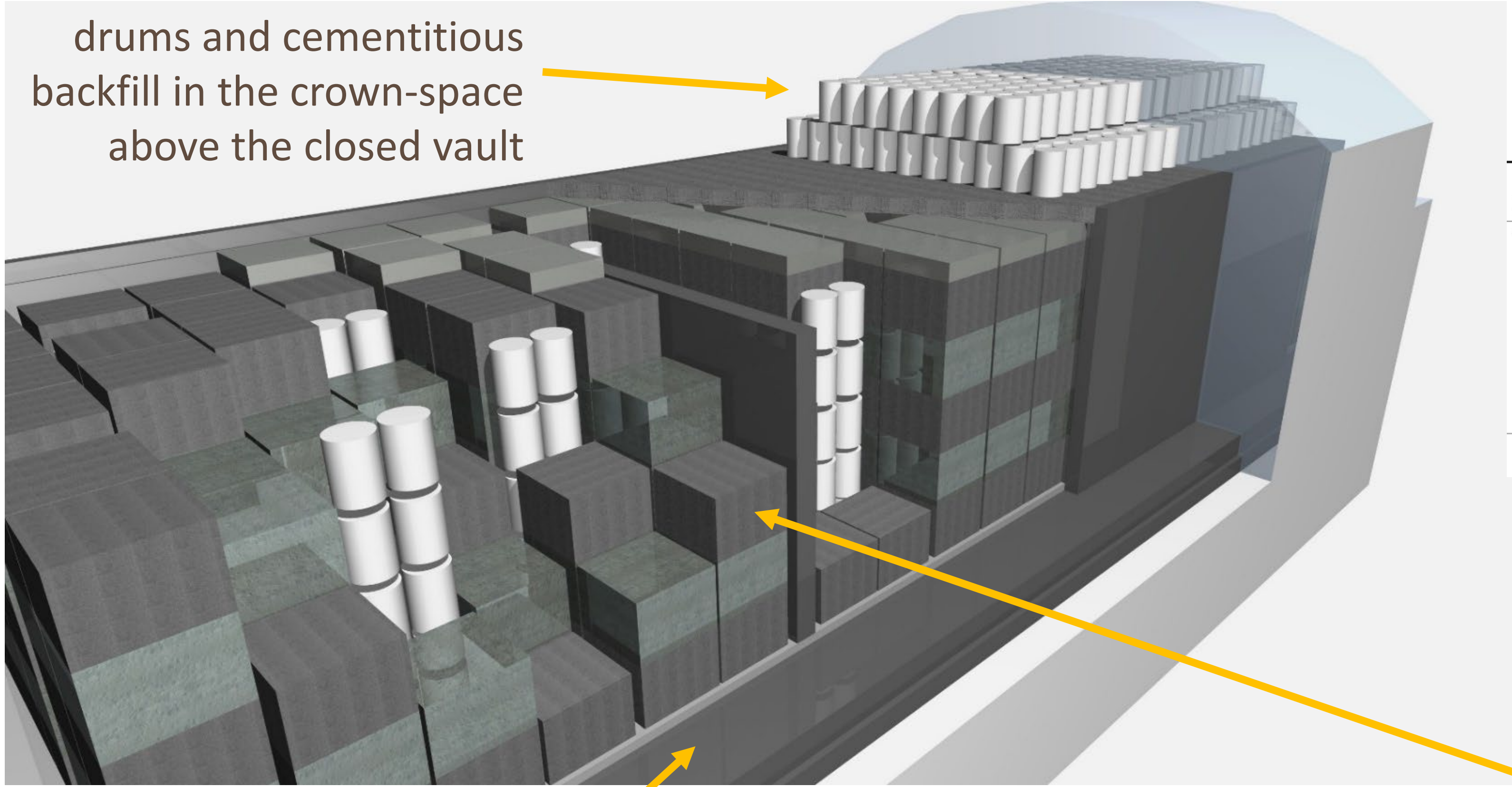
compacted solid waste in 200 l steel drums (**waste volume 1.8 m³**)

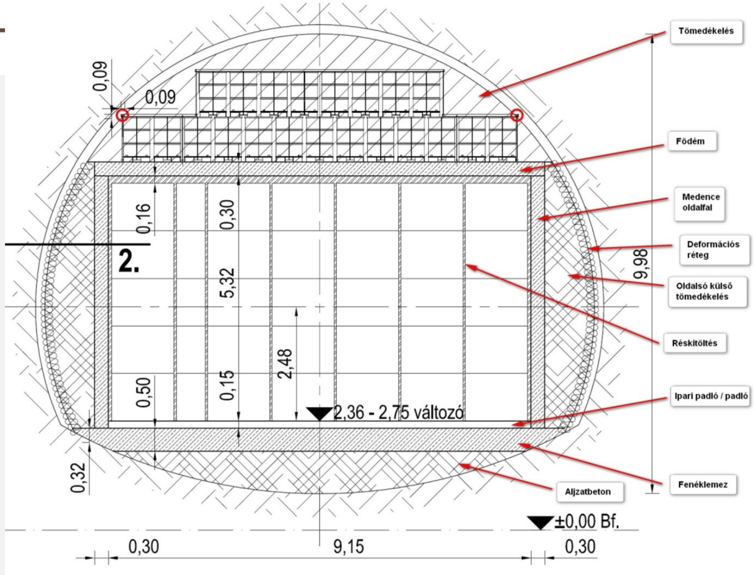


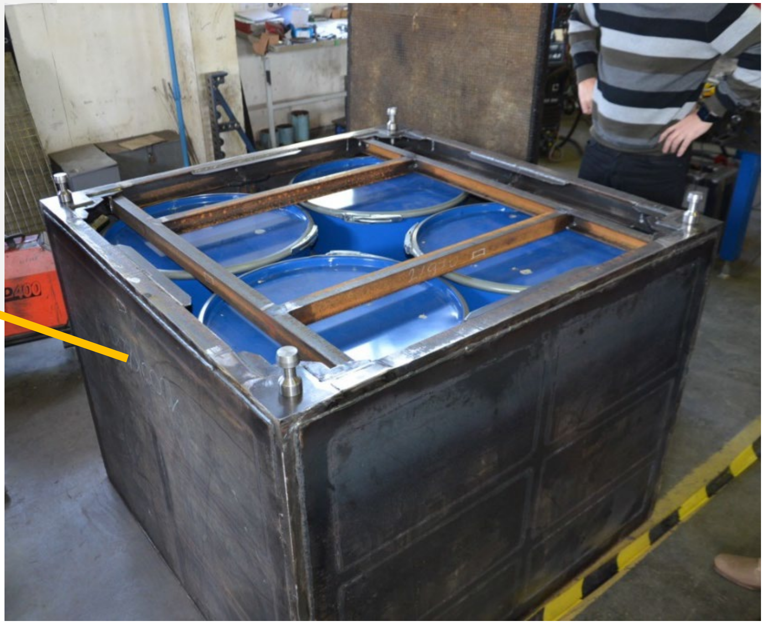


Optimised disposal concept (2011)

drums and cementitious backfill in the crown-space above the closed vault







concrete vault,
cementitious backfill between the steel containers and drums

carbon steel container (**2m³**) with 4 drums, inner space backfilled with active cement mixture prepared from **liquid radioactive waste** at the NPP (**waste volume 1.8m³**)

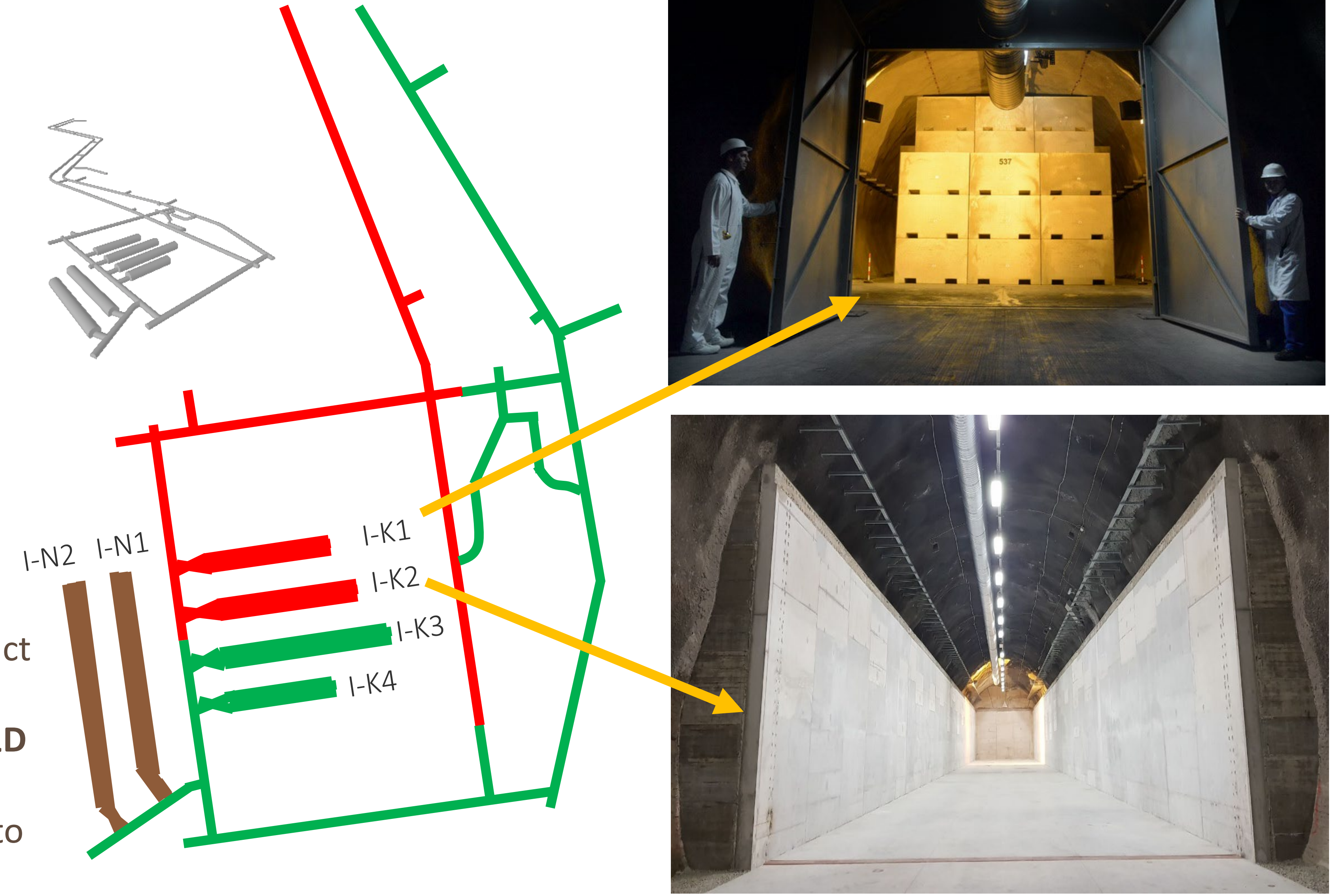
Phased implementation

As a result of optimisation:

- facility layout adapted to the geological structures
- number of disposal galleries reduced from 17 to 6
- their cross-section increased from 95m^2 to 133m^2
- useful space utilization in the galleries increased from 20% to 49% of the excavated volume

A phased implementation is

- more economical
- reduces the environmental impact
- provides option for further optimisation, **supported by RD&D**
- but the risk of simultaneous operation and construction has to be considered and assessed



RD&D support for a disposal facility in operation

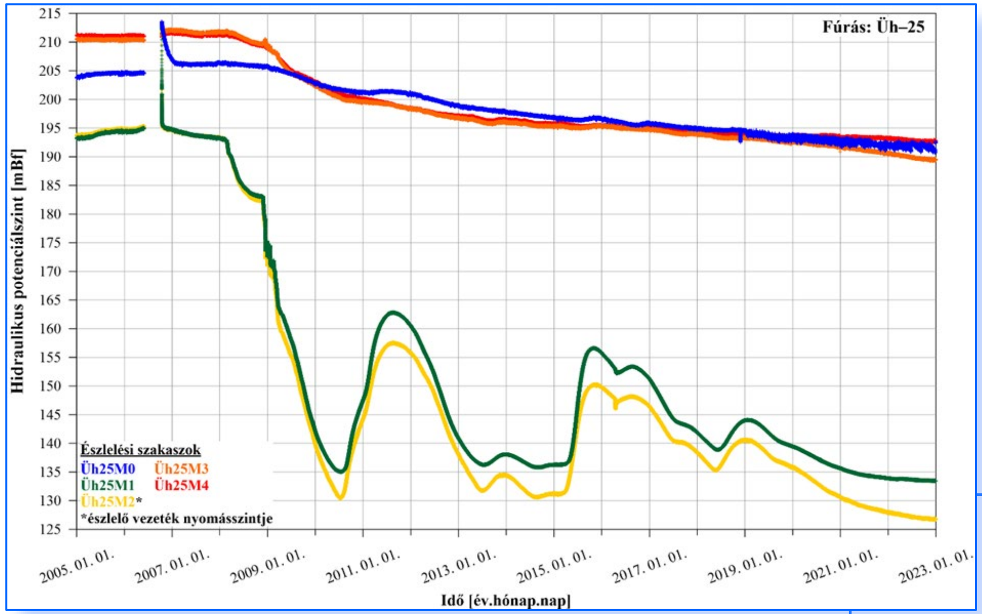
RD&D support for a disposal facility should continue during its operation!

During the operational phase, RD&D is necessary for several purposes:

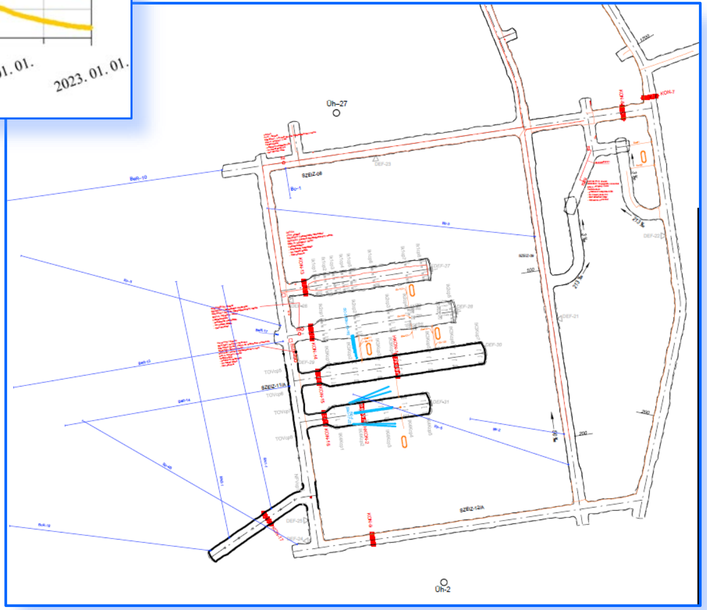
- **long-term hydrogeological and geotechnical monitoring data** will improve the understanding of site conditions, helps to update and better calibrate numerical flow and static models
- necessary to **verify and increase accuracy of site-specific data** obtained during the site characterisation phase, in order to reduce conservatism for further assessments of post-closure safety
- **investigate reasons of deviations** from the designed/expected state of the implemented structures of the engineered barrier system (EBS), develop preventive measures
- **continue long-term experiments** with materials and processes under repository conditions
- **testing and utilise latest achievements** of scientific and technical development (new materials, methods etc.), demonstrate their suitability and applicability, **support optimisation measures**
- **reduce radiation exposure** of the operating personnel (by shielding, logistics etc.) and better control of radiological discharges
- **reduce operational costs**

Long-term hydrogeological monitoring (1)

multi-packer systems

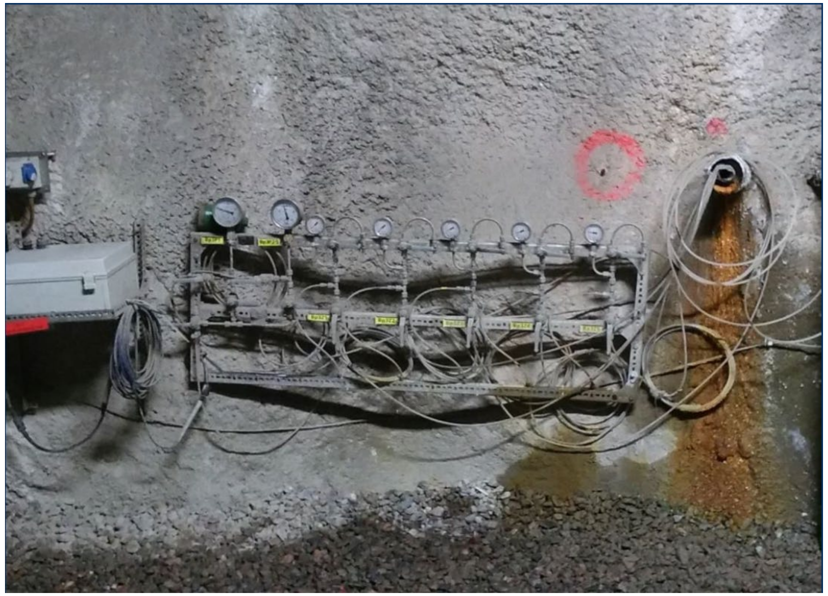


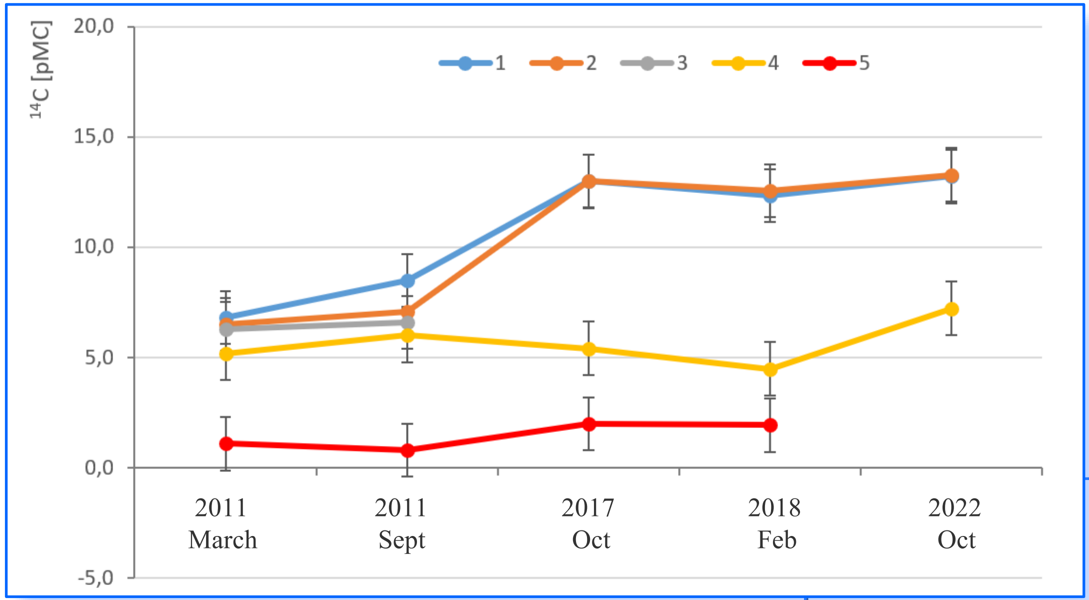
hydraulic effects of the excavation monitored by multi-packer systems – **„hydraulic tomography”**

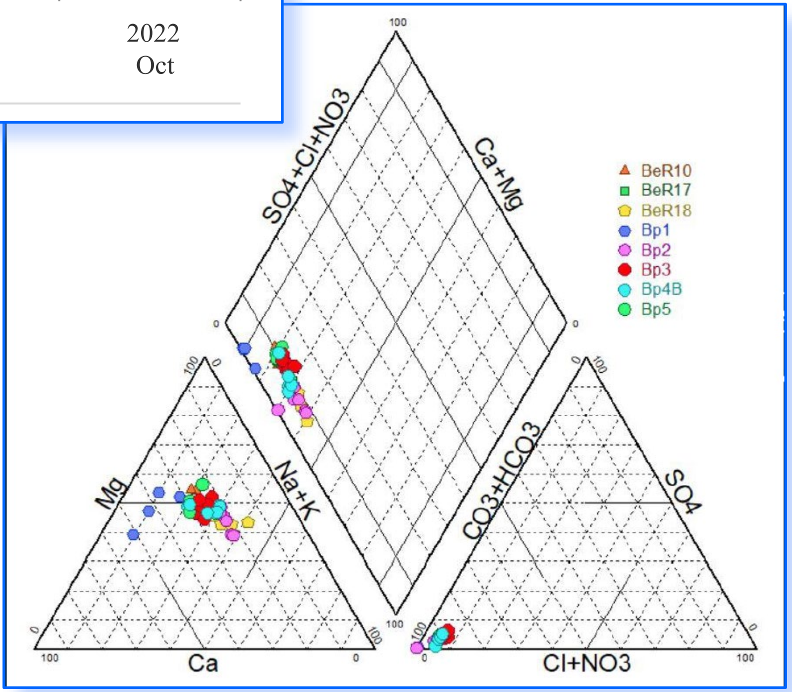


→ **calibration of numerical flow models against transient hydraulic heads**

Long-term hydrogeological monitoring (2)





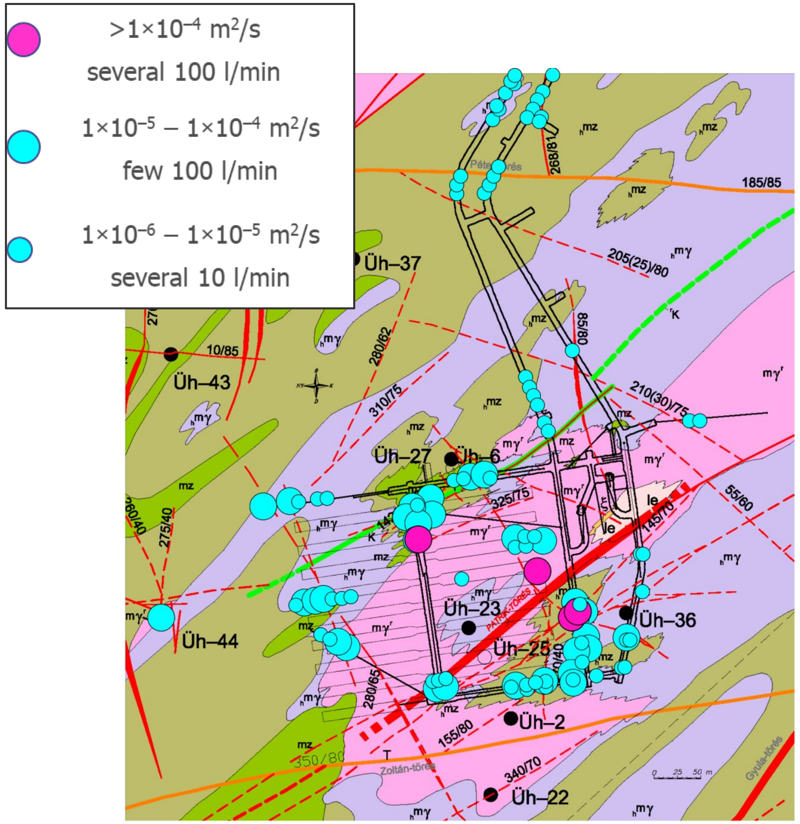


repeated groundwater sampling (ca. every 5 years) from the separated zones of the underground multi-packer systems – **monitoring of any changes in groundwater chemistry and age**

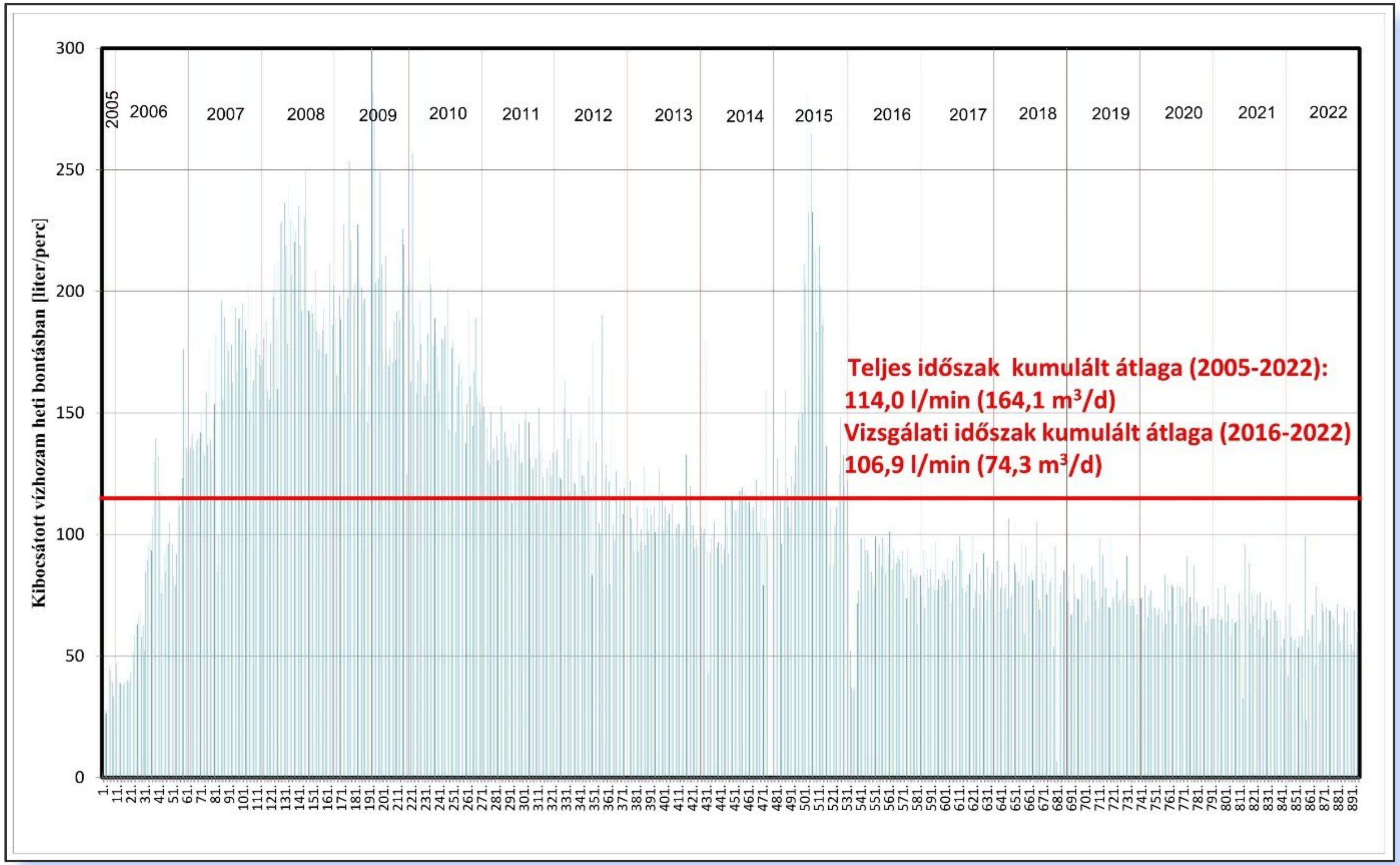
major chemical components, trace elements and natural radioisotopes ($\delta^{18}O$, $\delta^{2}H$, $\delta^{13}C$, ^{14}C, ^{3}H, $^{3}He/^{4}He$, $^{87}Sr/^{86}Sr$, $\delta^{234}U$, ^{81}Kr and ^{222}Rn) were analysed

→ calibration of numerical flow models against changing groundwater chemistry and age

Long-term hydrogeological monitoring (3)

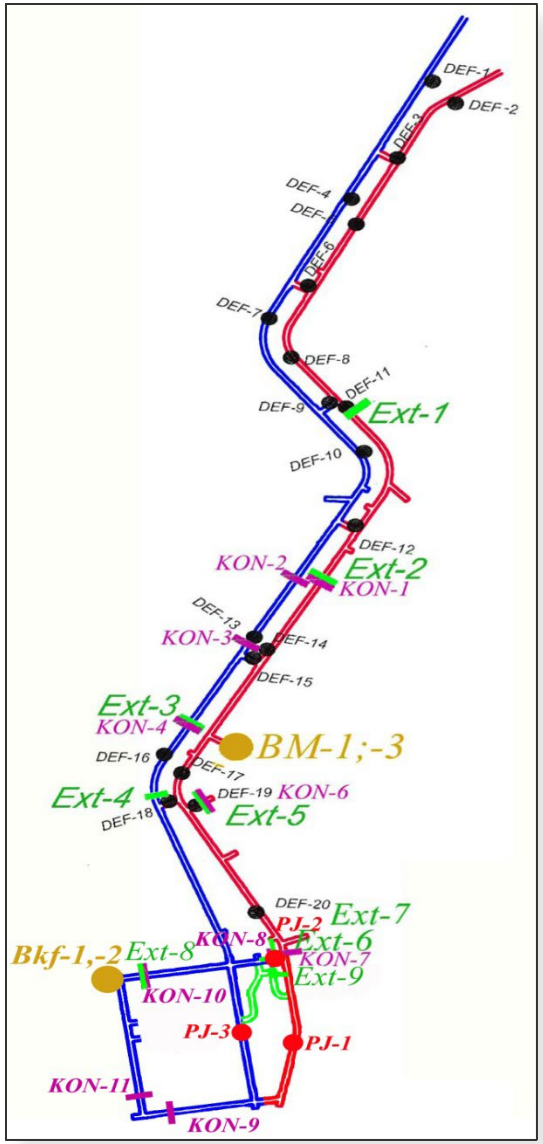


monitoring of **inflow rates** and **water release rates** from the underground facility

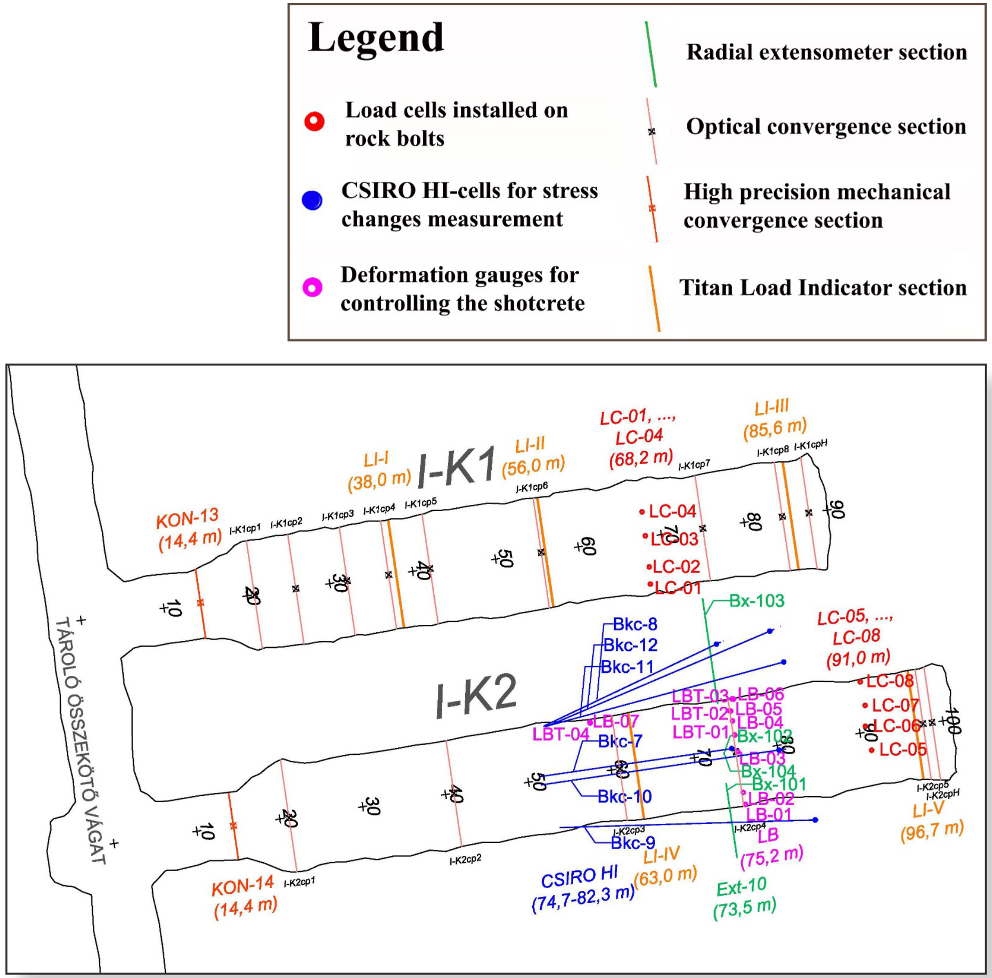


→ **calibration of numerical flow models against flow rates**

Long-term geotechnical monitoring (1)

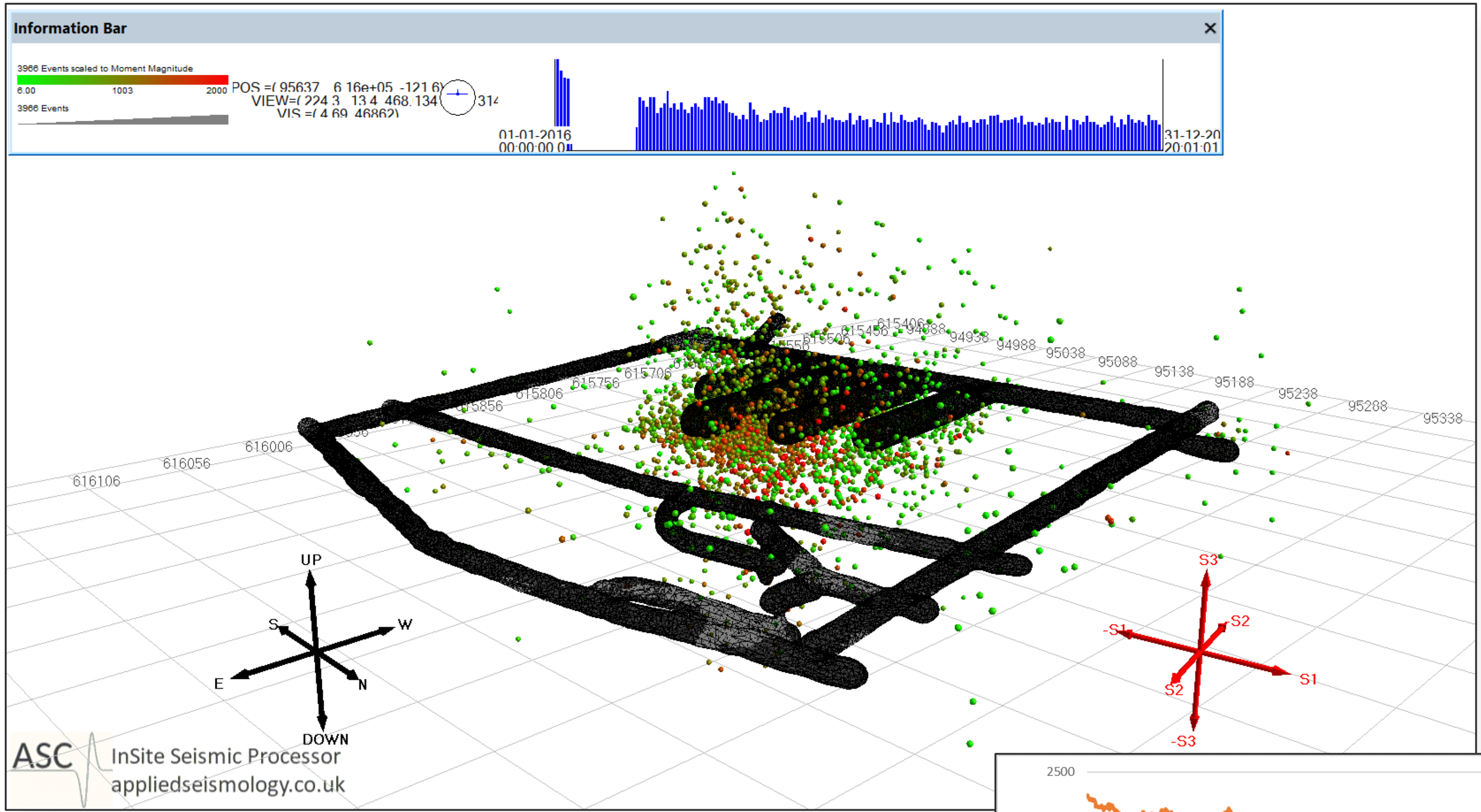


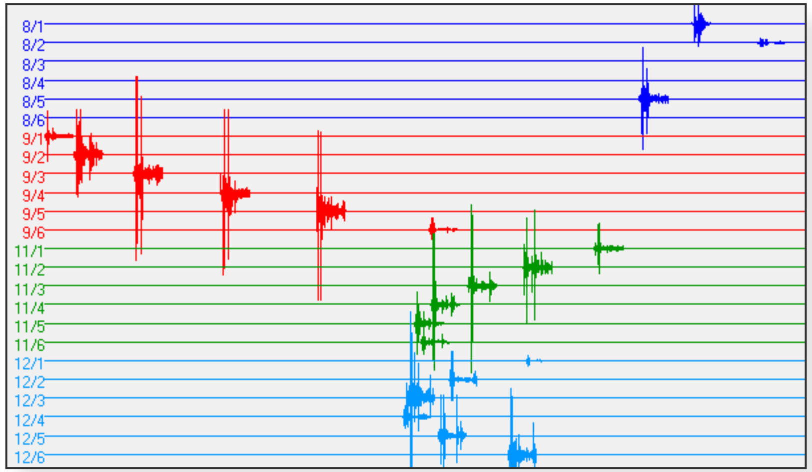
- Inclinometers – on the surface, at the entrances
- Radial extensometer sections and mine-by extensometer arrays (Ext)
- High resolution (±0,02 mm) mechanical convergence sections and optical convergence sections with resolution ±1 mm (KON)
- Automatic triangular deformation monitoring devices (DEF)
- In situ rock stress measurements using upgraded Doorstopper-method (BM) and 3D CSIRO HI-cells (Bkf)
- Stress change measurements (Bkc)



→ **calibration of numerical static models against strains and movements for further repository design**

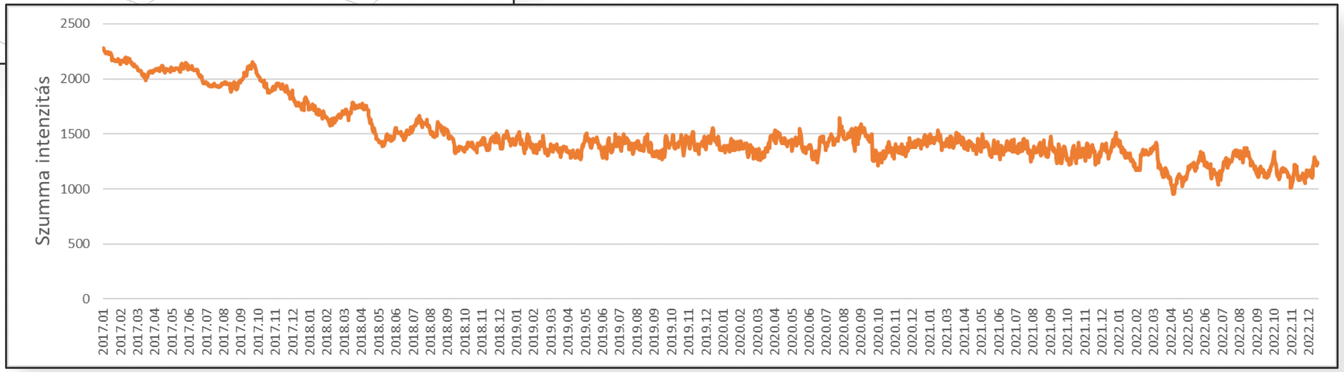
Long-term geotechnical monitoring (2)



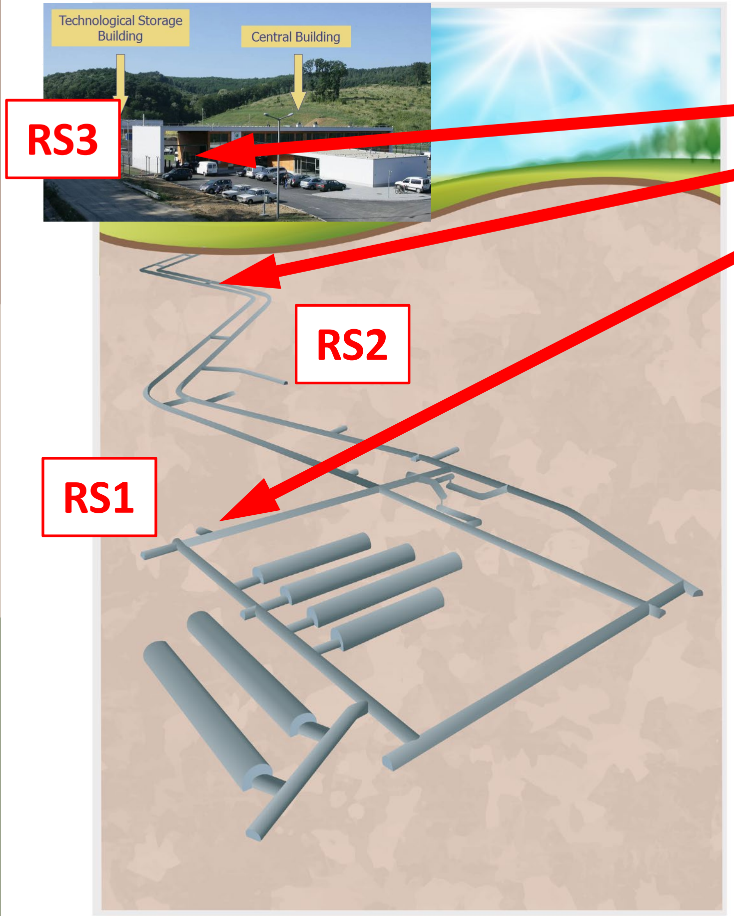


→ **calibration of numerical static models against shear strength**

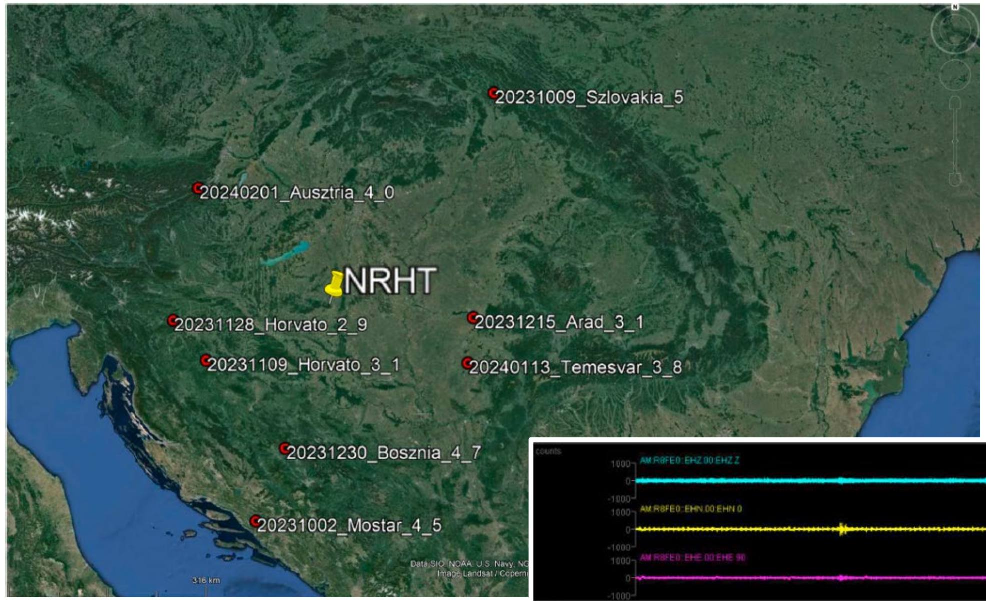
Seismo-acoustic monitoring allows to follow changes in rock stress distribution both in space and time, to understand the behaviour of the rock mass



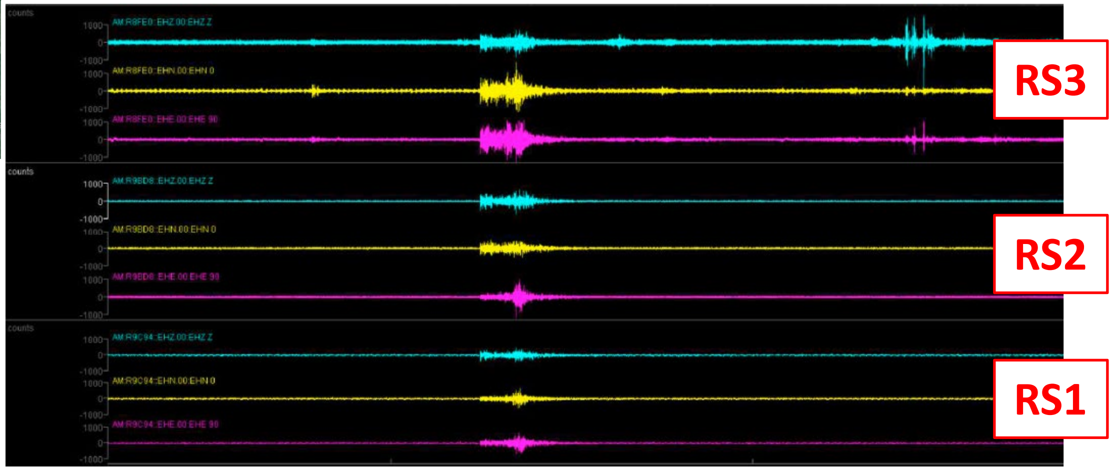
Verify and increase accuracy of site-specific data



3 seismographs were installed in the surface technological building **(RS3)**, at shallow depth in the first cross-tunnel **(RS2)** and at 250m depth at the disposal level **(RS1)**



Comparison of earthquake seismograms registered on the surface and at different depths

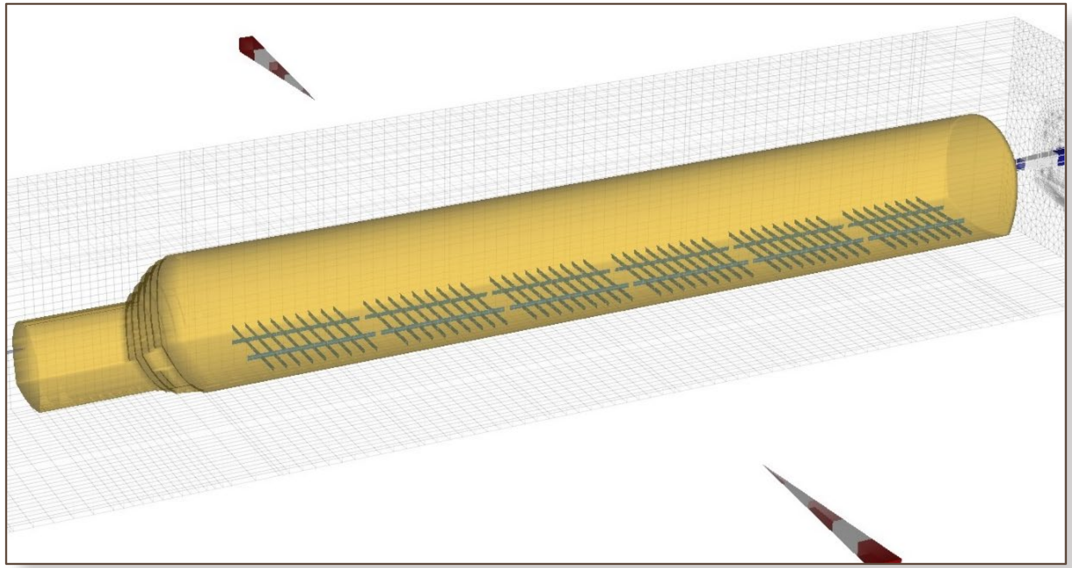


→ **define site-specific data for seismic attenuation with depth and amplification due to the surface layers**

Investigation of deviations from the designed state (1)

Fractures have appeared on the base plate of the concrete vault in the K3 disposal gallery, after 6 months of the construction

Regulatory authority has stopped the construction work and required to assess safety consequences of the fractures



Additional flow modelling and performance assessment was carried out and negligible effect on the post-closure safety was demonstrated

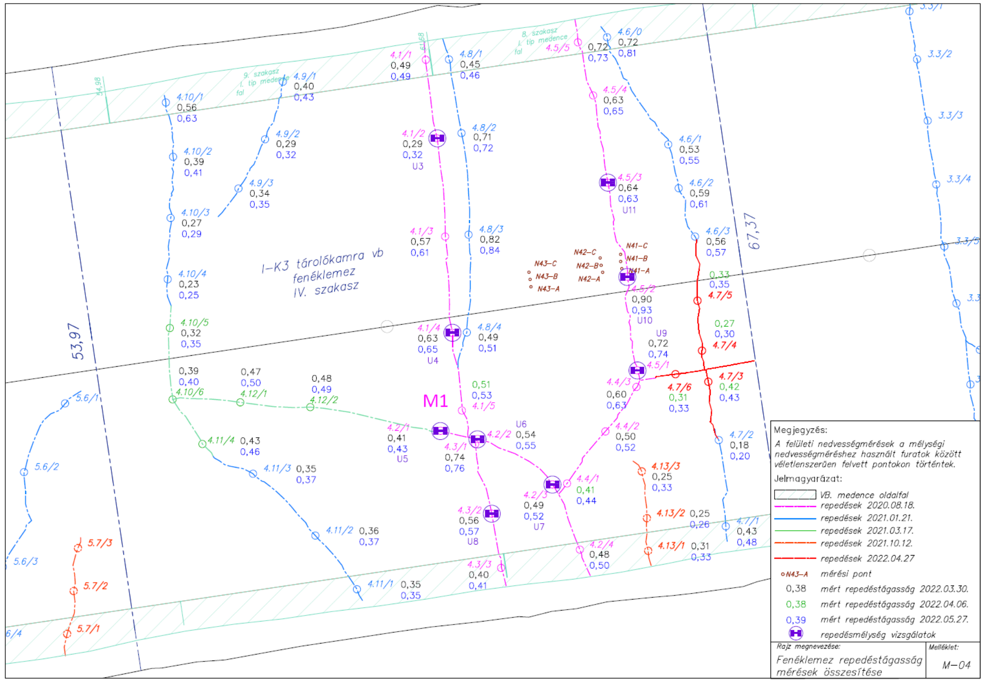
Questions inside PURAM from the construction department:

- **Why unnecessary stringent design targets and acceptance criteria were set?**
- **Why corrective actions (injection, grouting) has to be taken?**

Role of the multi-barrier system, application of BAT and ALARA principles were explained and clarified

Investigation of deviations from the designed state (2)

External factors, like seismic event or convergence of the walls **were excluded** from the possible reasons based on monitoring data

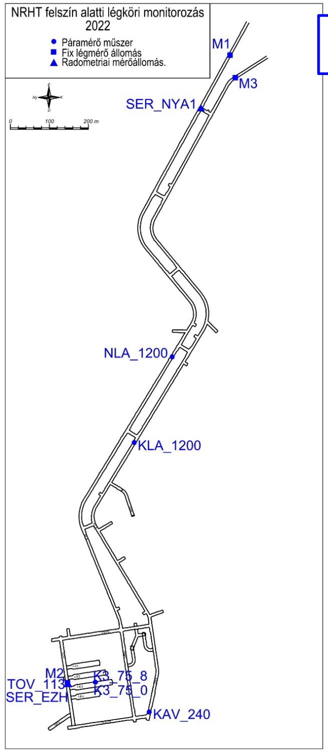


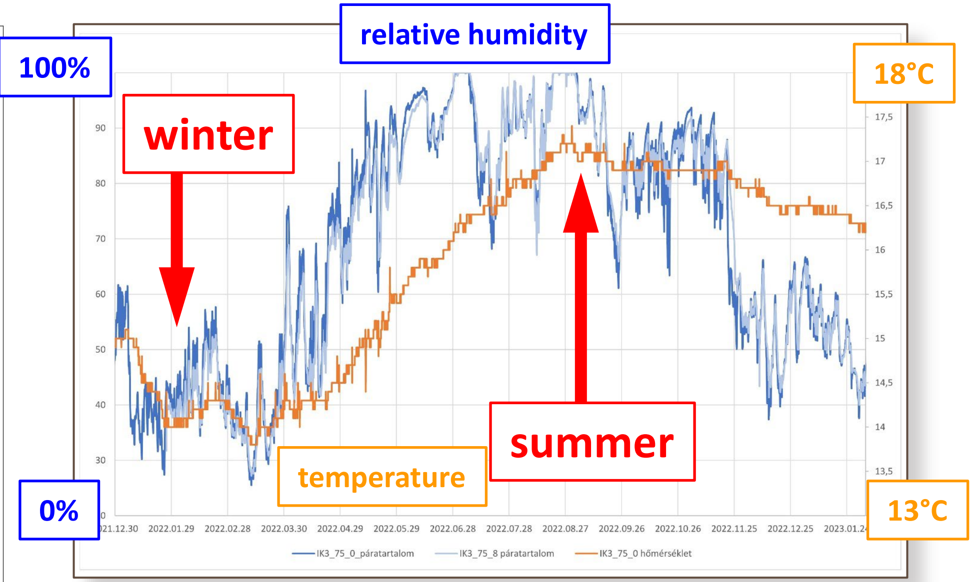
The fracture system was **mapped** and investigated with **in situ measurements and drilled holes**

Investigation of deviations from the designed state (3)

It was concluded that fractures on the base plate of the vault have been developed due to **inhibited shrinkage** of the steel reinforced concrete structure. The main **reasons** were:

Unexpectedly large variations in relative air humidity

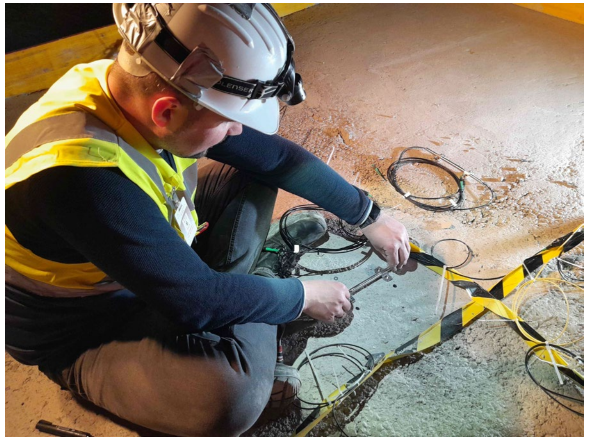


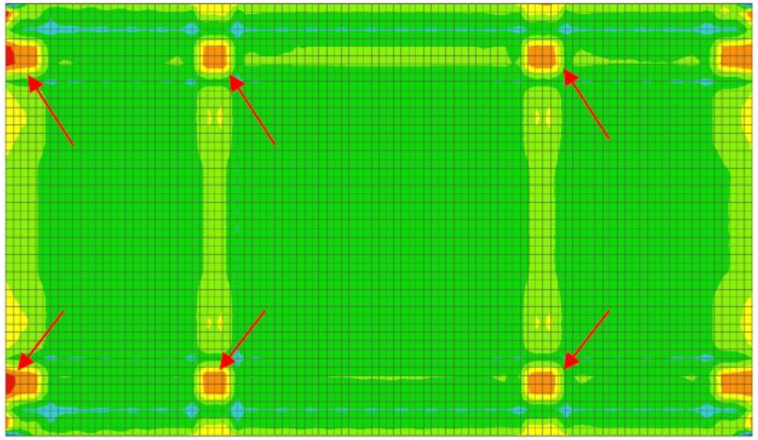


A detailed meteorological monitoring campaign was conducted in the underground facility

Increased ability for fracking at shrinkage due to larger strength of the concrete than designed

In situ experiments and laboratory tests with the concrete slab





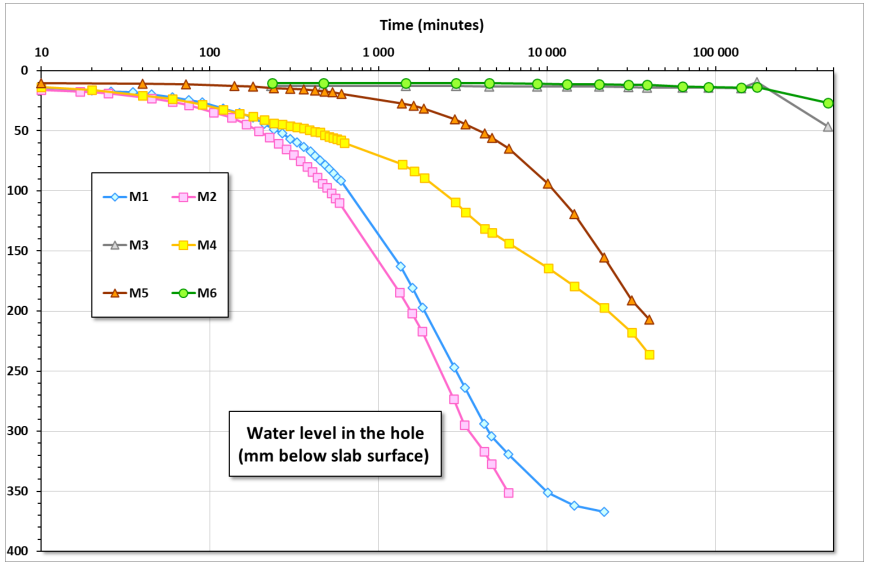
Modelling of strain distribution within the concrete slab

→ revised input data were used for re-designing the steel reinforced concrete structures

Investigation of deviations from the designed state (4)

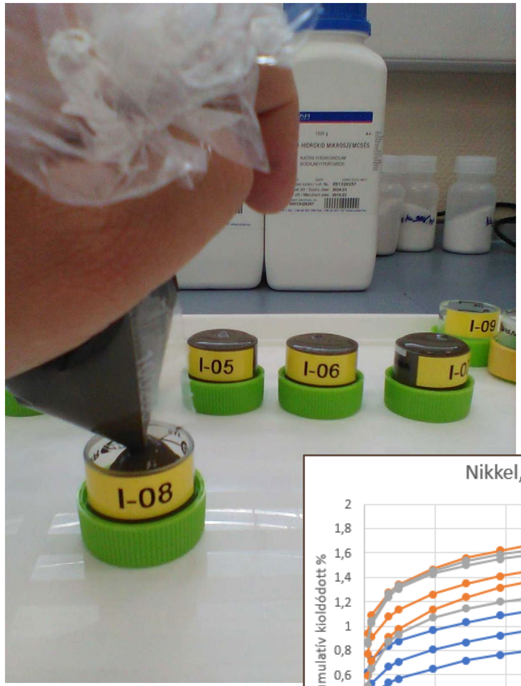
Different treatment and grouting technologies were **tested** to seal the fractures (microcement, silica gel)

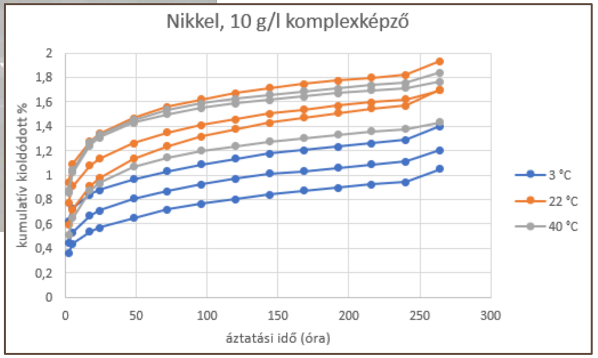
In situ hydraulic tests were carried out in the holes drilled on the fractures before and after the grouting



Based on the test data, **high pressure grouting with silica gel** was selected and **approved by the authority** as an appropriate treatment method

Long-term experiments under repository conditions



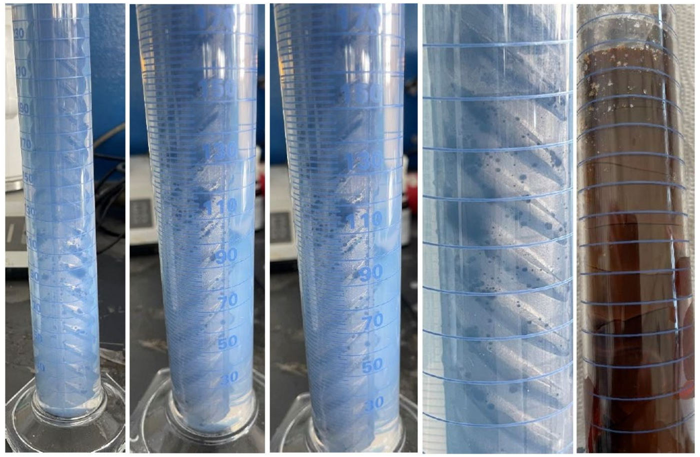


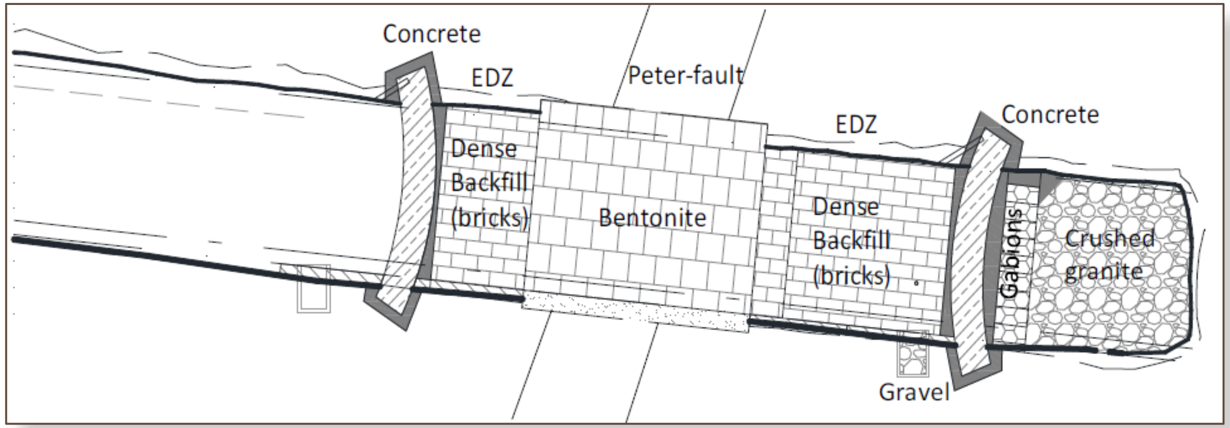
Leach tests to investigate **release of RNs** from the **cemented liquid waste form** in the presence of **complexing and chelating agents**

Laboratory scale experiment, provides input data for the safety assessment

Corrosion experiments with the **steel rods,** immersed into **silica gel** in the **presence of NaCl**

Laboratory scale experiment, provides input data for optimisation of the design

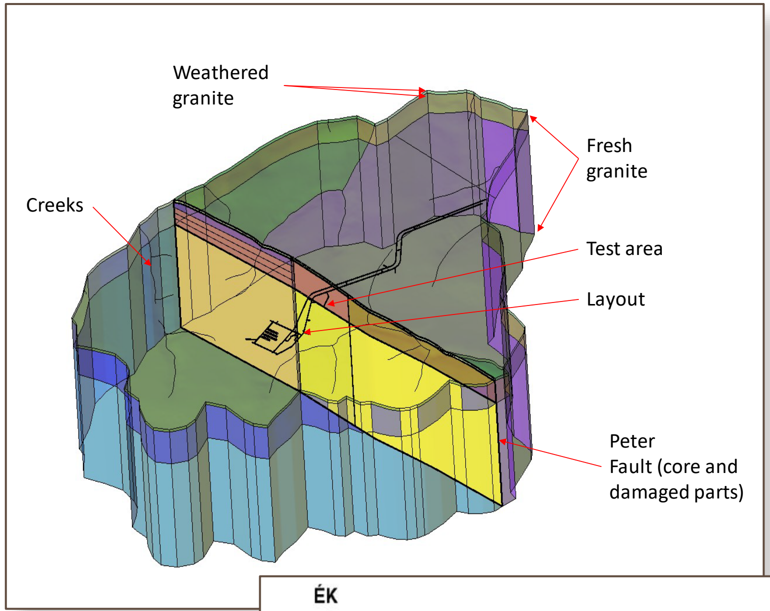


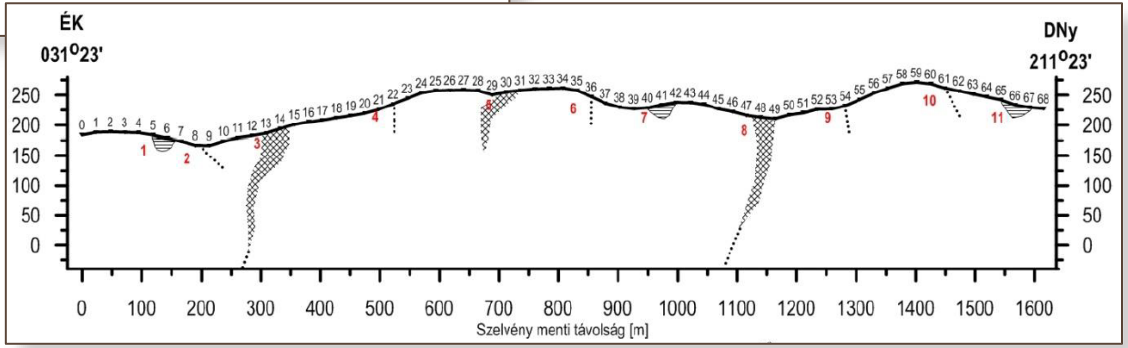


Design and **construction** of a **sealing structure** in the **access tunnels** (planned for 2027)

Full-scale demonstration experiment, provides input data for the final design

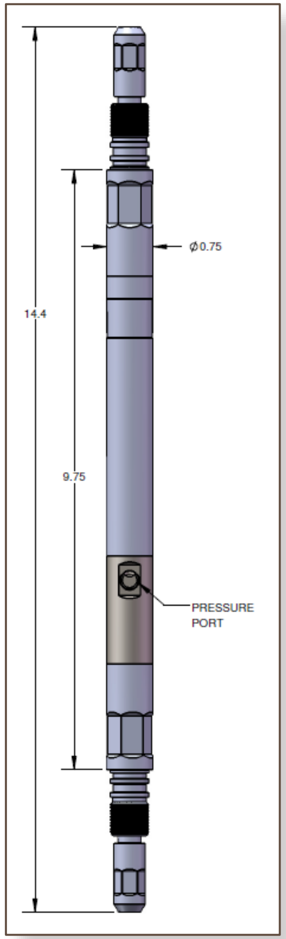
Development and testing of new methods and technologies



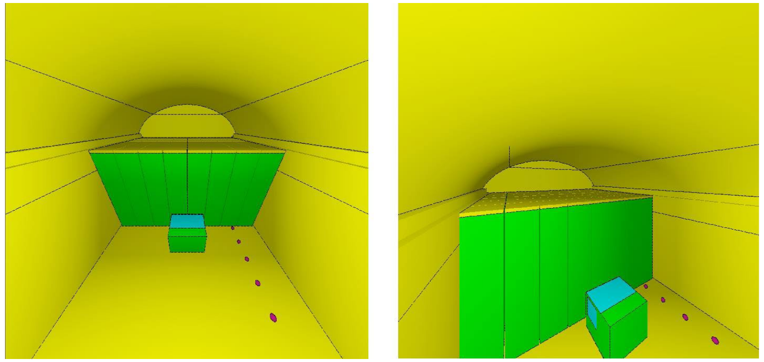


Testing of the **Horizontal Loop Electromagnetic (HLEM) Survey** to **detect sealing fault zones** from the surface

Testing and **application** of **new measuring devices** for the **multi-packer monitoring systems**



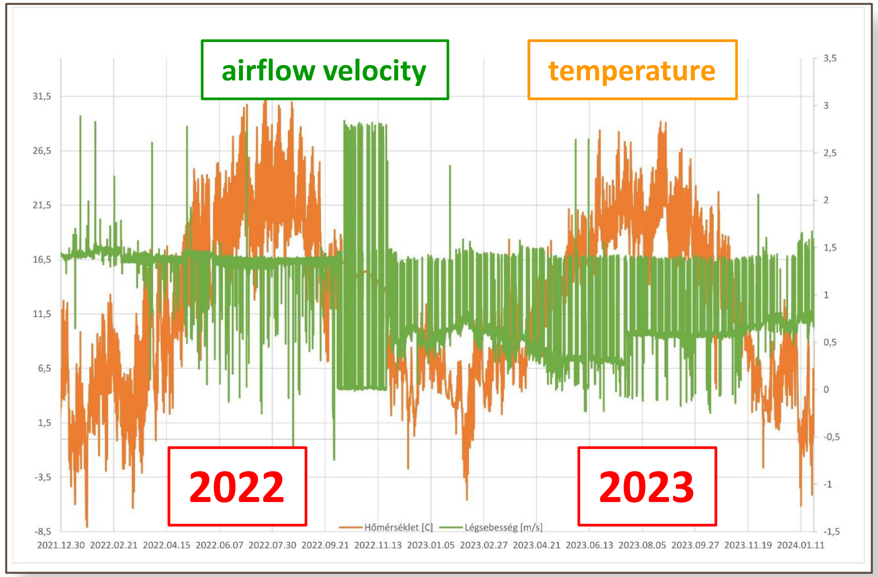
Reduce radiation exposure and operational costs



Based on **numerical modelling**, develop **optimisation measures** (shielding, distancing, time limitation) in order to **reduce radiation exposure** of the operating personnel

Measure the **actual dose rate distribution** around the waste packages

Reduce airflow velocity in order to **decrease ventilation costs,** but still maintain **suitable temperature** and **humidity conditions** for the **workers**, **engineering structures** and **measuring devices**



Final notes

- According to Hungarian legal regulations, **R&D activities must be planned, approved and reported** to the nuclear authority during **site selection** and **repository construction**. **No such requirement** formulated for the **operational period** of the facility.
- In Hungary, for each operating disposal and storage facility and for the DGR program, **general R&D objectives** and tasks are listed in the **National Program**, which prepared by PURAM (as the responsible WMO), published in a **governmental decree,** and **reviewed** in every 5 years.
- **RD&D support for a disposal facility should continue during its operation!**
- **Special considerations of radiological, organisational, permitting issues are required** if in situ RD&D activities conducted in an operating facility.
- During the operational phase, **major part** of the RD&D activities serves for the **technological development** and **engineering design**, nevertheless, **research to increase site-related knowledge** is also important for the **periodic safety review**. **Certain problems** to solve and **needs** may arise **at any time**, therefore **flexibility** is necessary in RD&D planning for the operational phase!

Thank you for your attention!