Numerical Simulations of Radionuclide Transport through Clay and Confining Units in a Geological Repository using COMSOL

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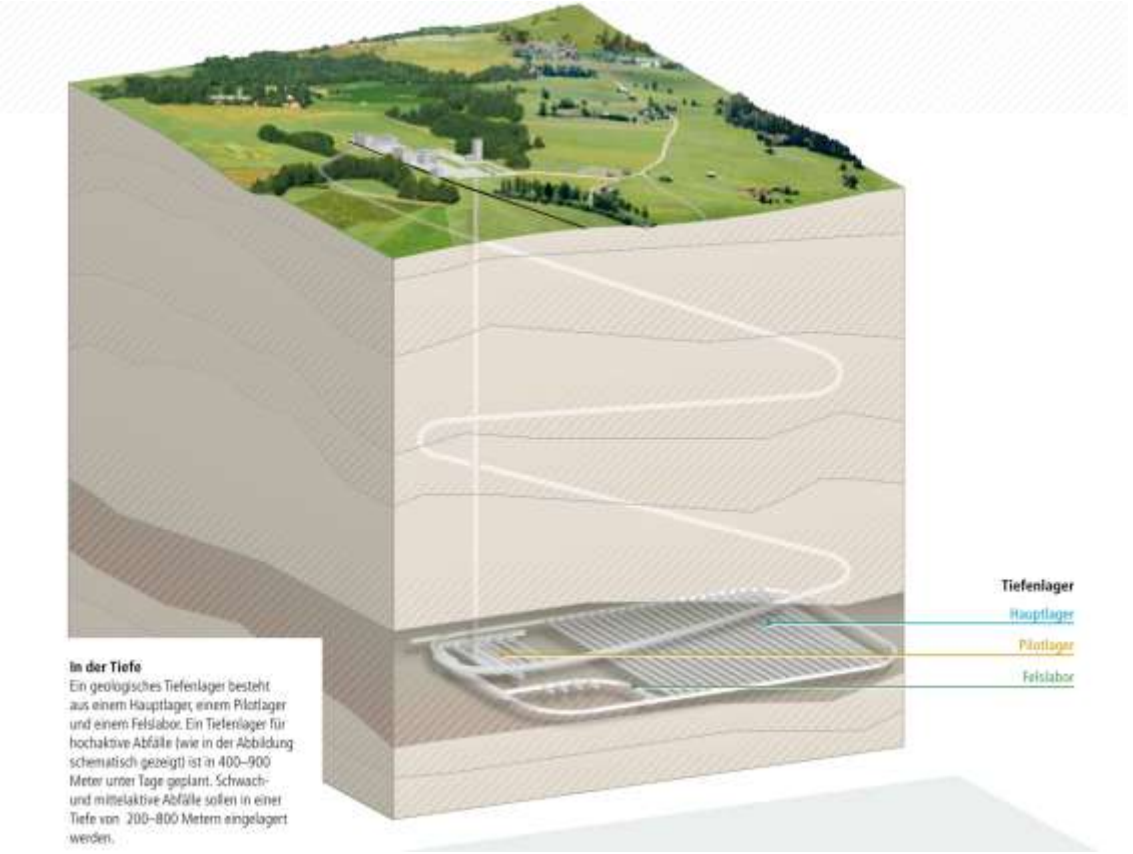
Outline

- Introduction
- Conceptual model
- Results
- Model issues
- Conclusions



Introduction

The Sectoral Plan for Deep Geological Repositories

Three stages of the general licensing procedure:

Stage 1 — 30. Nov 2011

Selection of geological siting areas (HLW and L/ILW repositories)

Stage 2 — 2014/15

Selection of at least two potential sites (per repository type)

Stage 3 — 2019/20

Site selection and start of general licensing procedure

Introduction

Swiss Federal Nuclear Safety Inspectorate ENSI

- National regulatory body with responsibility for the nuclear safety and security of Swiss nuclear facilities

- Some important tasks of ENSI with respect to site selection procedure for deep geological repoitories:

  - has general responsibility for safety related review

  - reviews proposed geologic site areas (stage 1) and sites (stages 2 and 3) with respect to safety and technical feasibility

  - provides scientific and technical knowledge to authorities, stakeholders and the public

  - performs independent calculations of radionuclide transport to check compliance with the regulatory dose limit (<0.1 mSv/year)

Conceptual Model

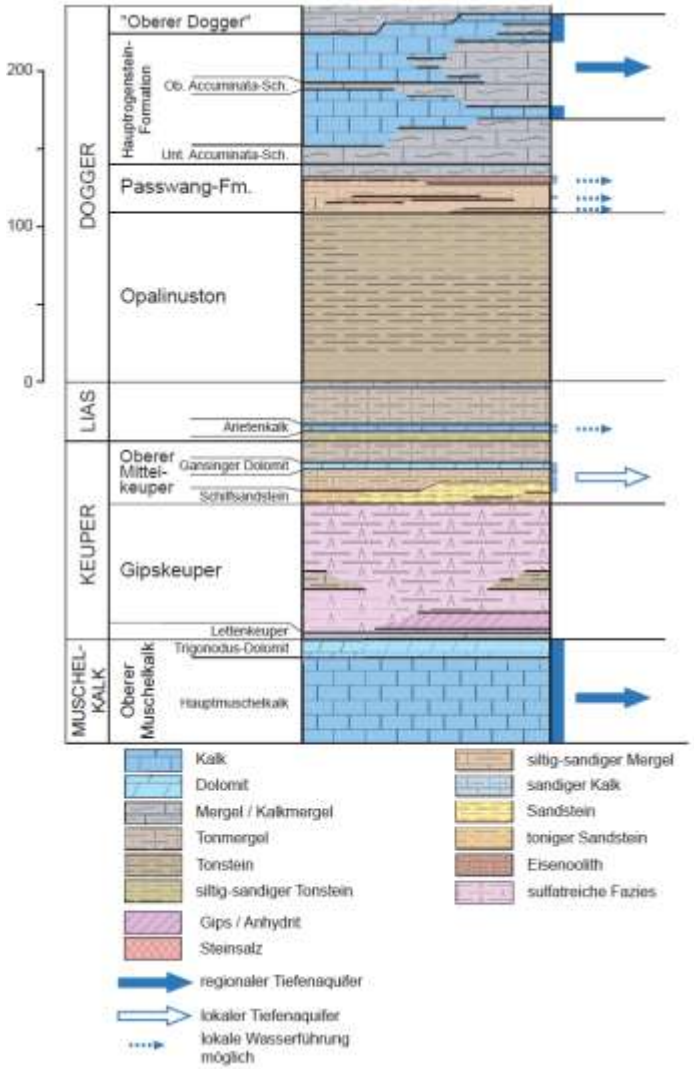


Figure from NTB 10-01
(Nagra, 2010)

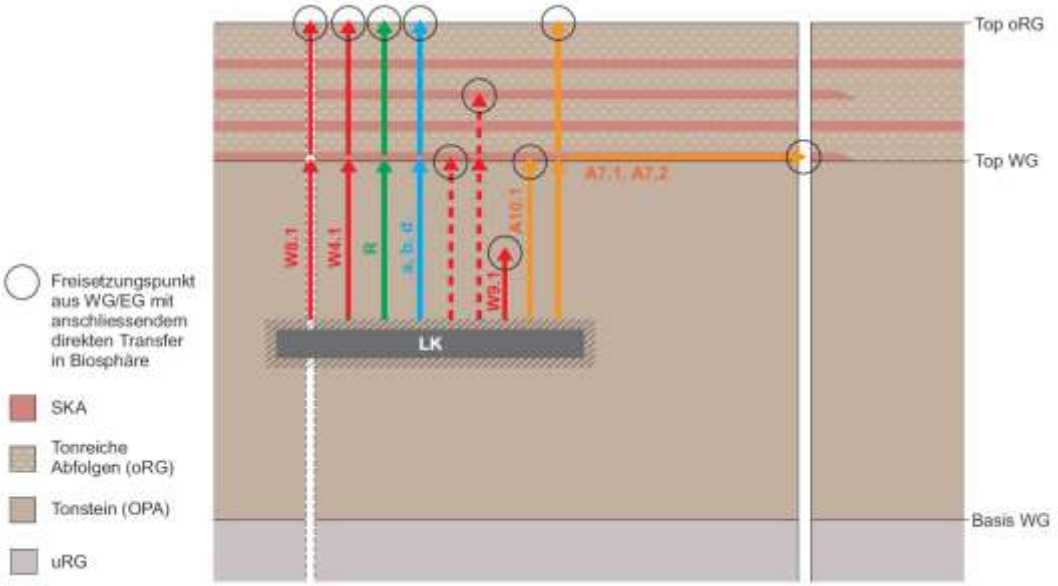


Figure from NTB 10-01
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Conceptual Model

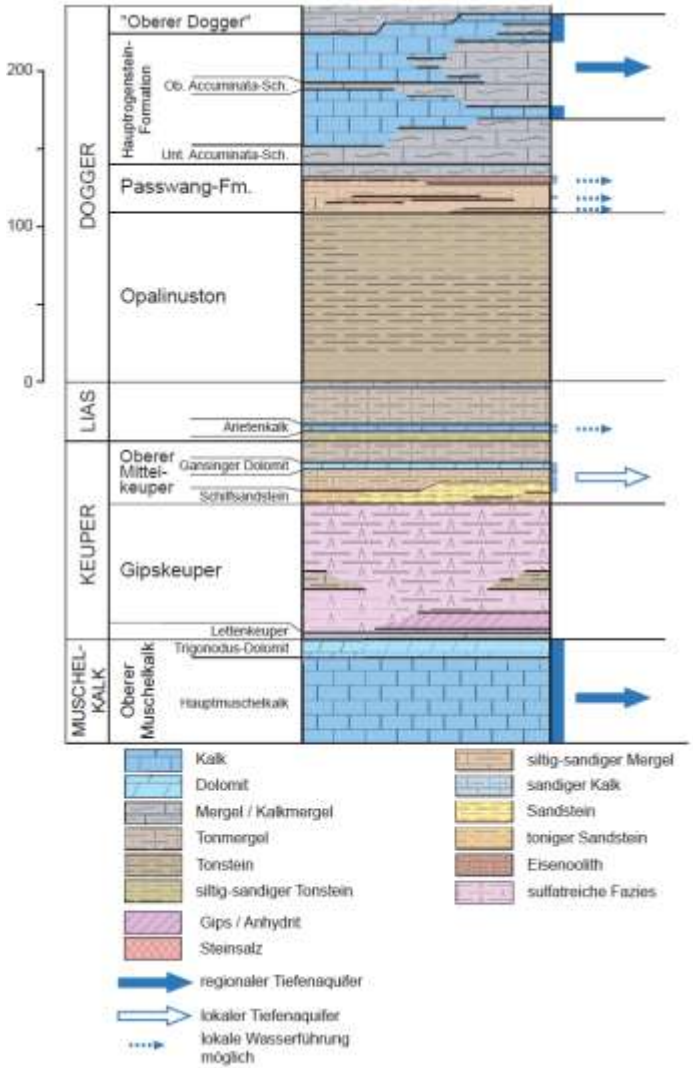
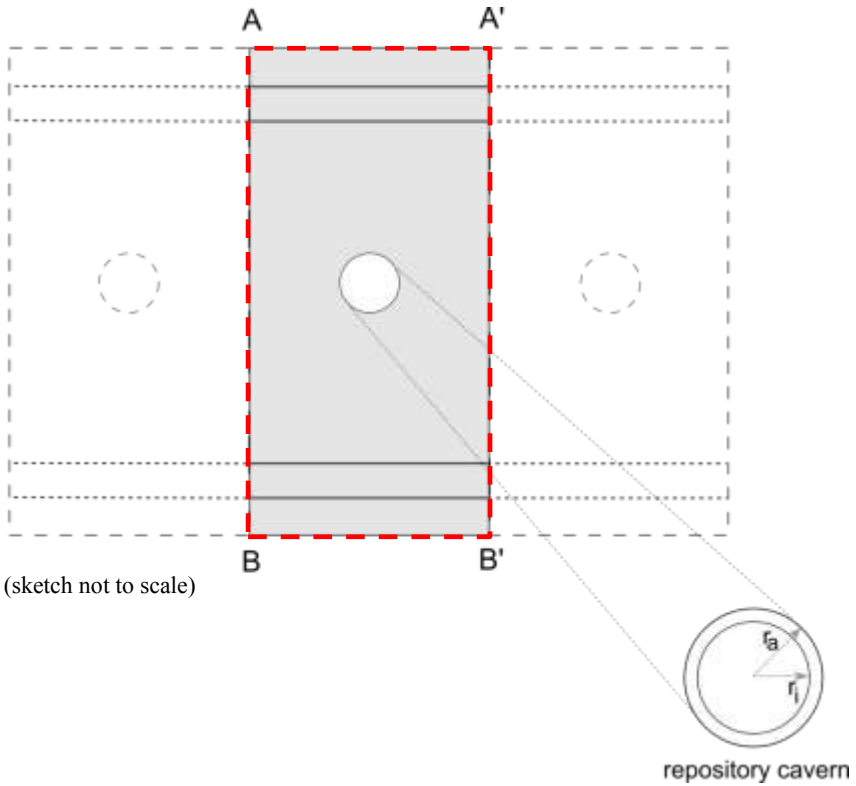


Figure from NTB 10-01
(Nagra, 2010)

model geometry
(2D models)



(sketch not to scale)

Conceptual Model

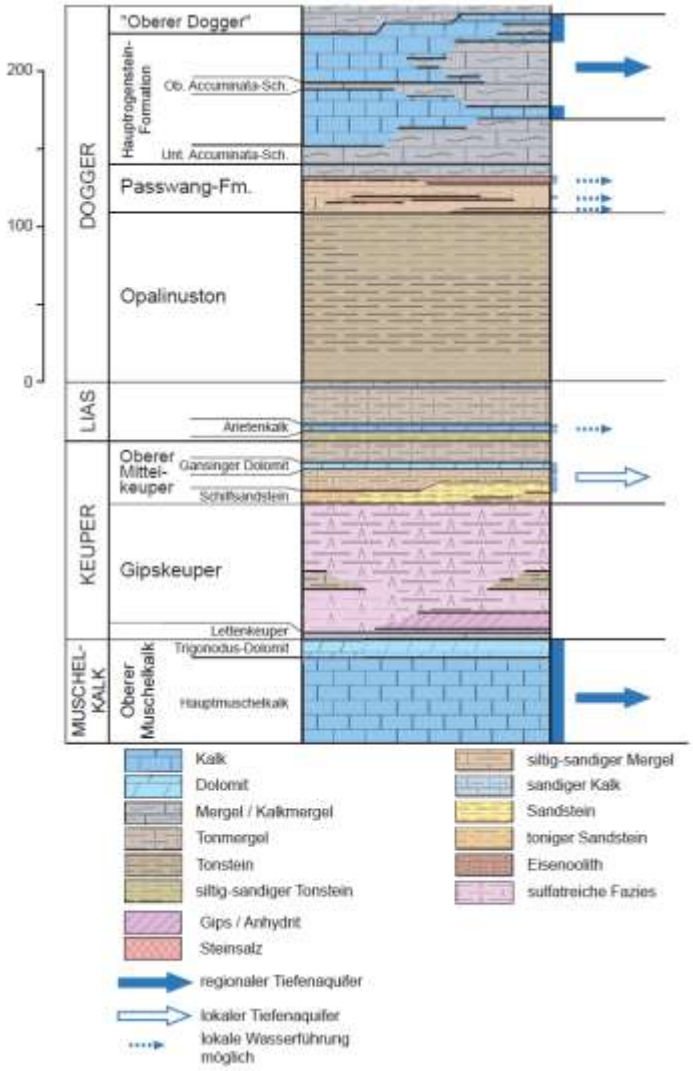
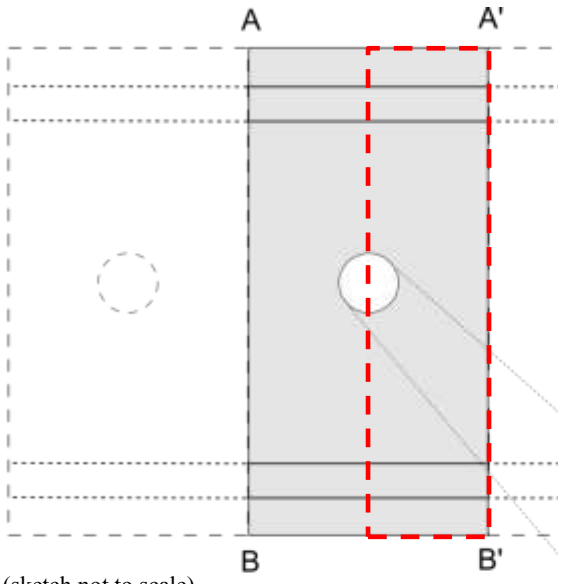


Figure from NTB 10-01
(Nagra, 2010)

model geometry
(3D models)



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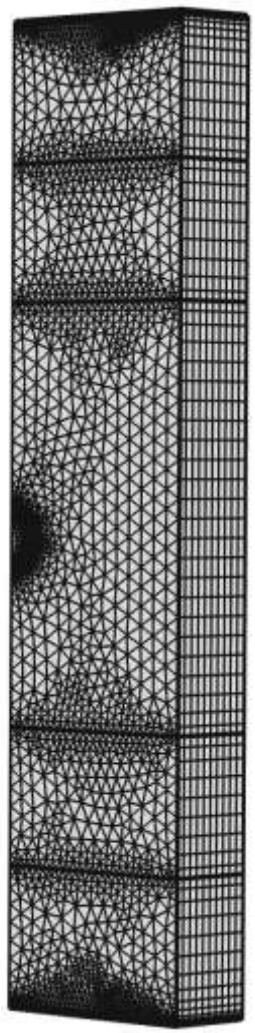
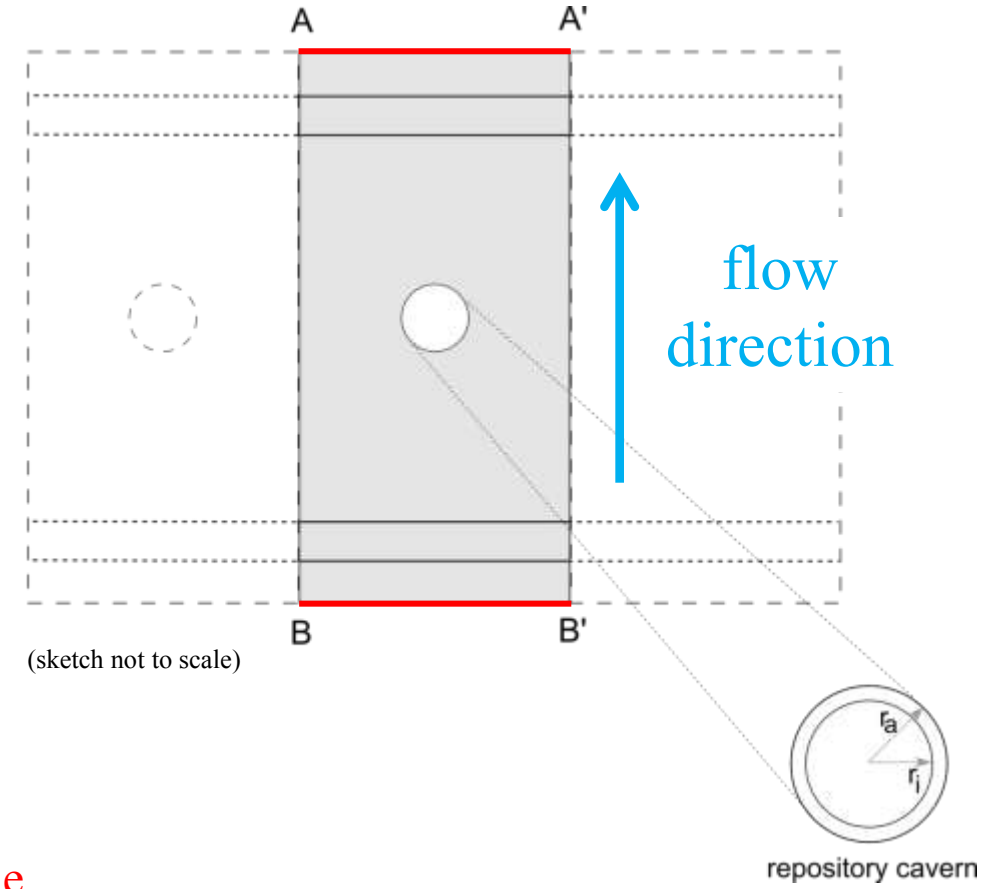


Conceptual Model

Initial and Boundary Conditions

zero concentration/
const. head (so that
gradient is 1m/m)



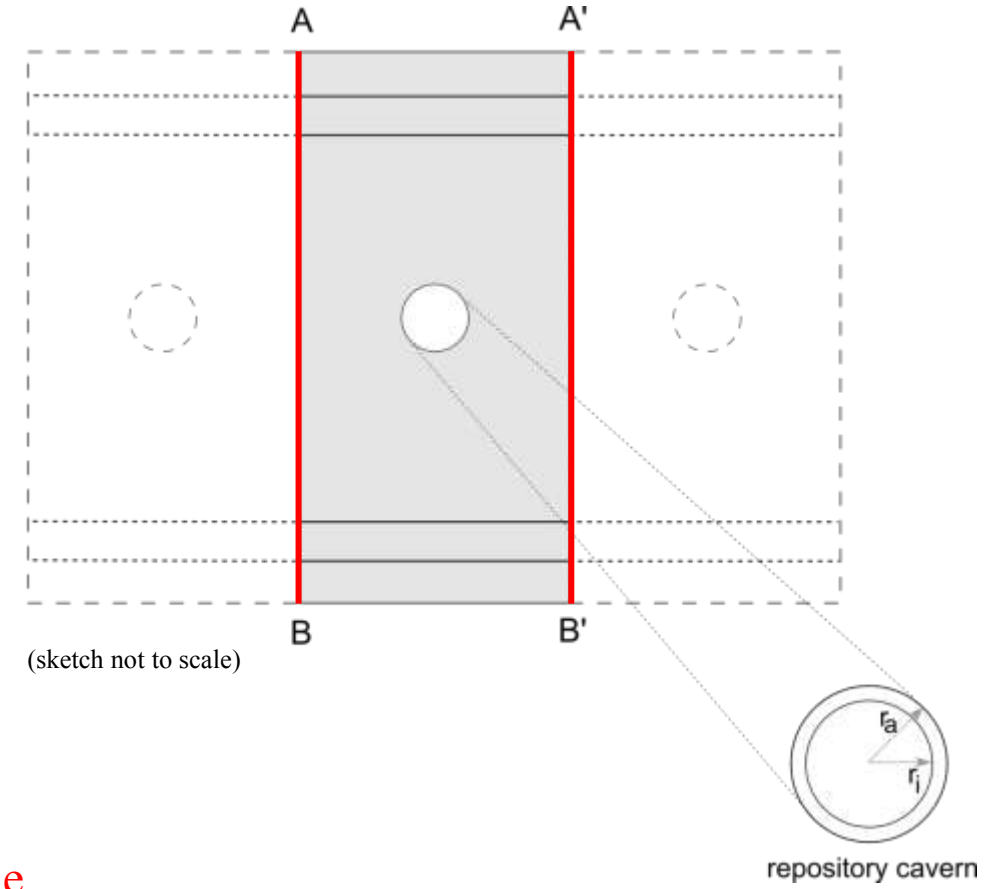
"Darcy's Law" module

"Solute Transport" module

Conceptual Model

Initial and Boundary Conditions

no flow / no flux
due to symmetry



"Darcy's Law" module

"Solute Transport" module

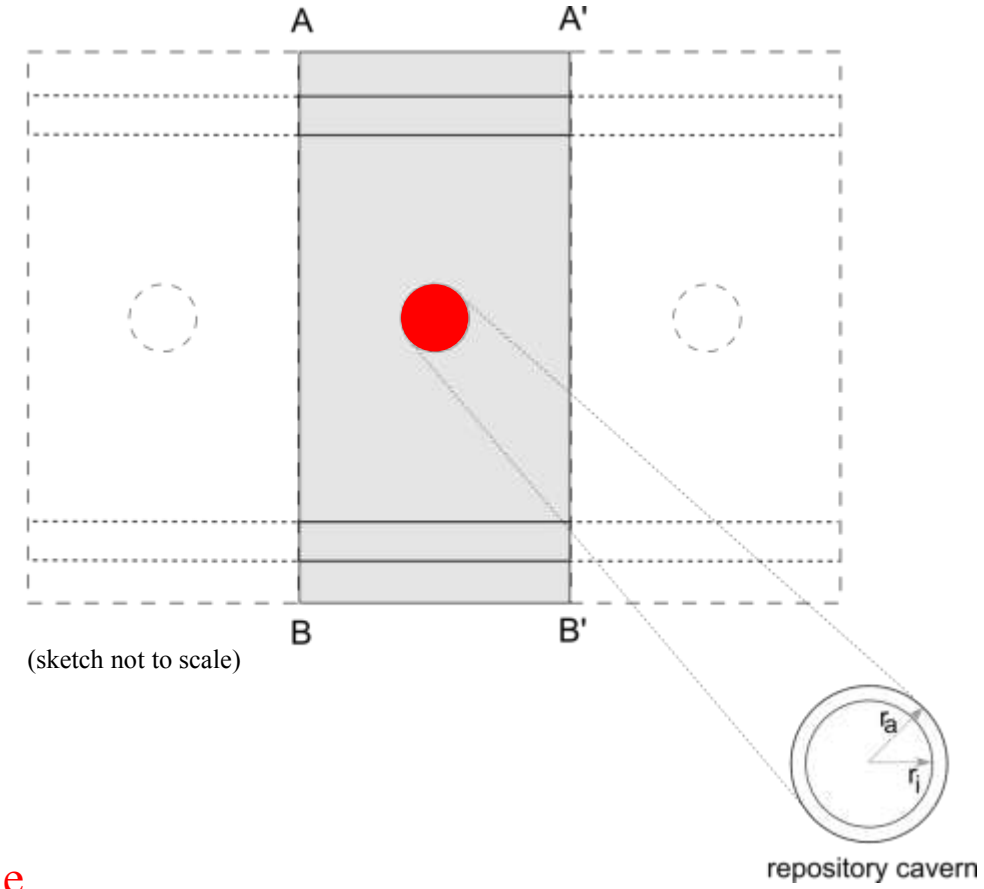
Conceptual Model

Initial and Boundary Conditions

Source term as an initial concentration

selected radionuclides in this case:
I-129, Se-79 and Cl-36

decay during transport



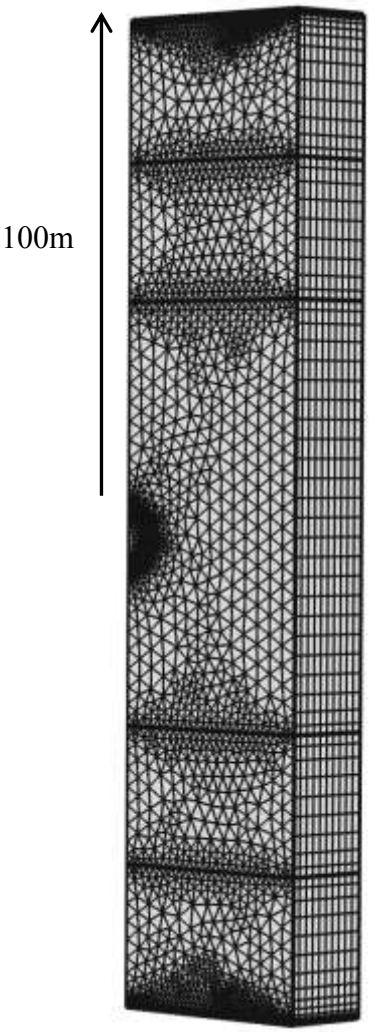
"Darcy's Law" module

"Solute Transport" module

Results

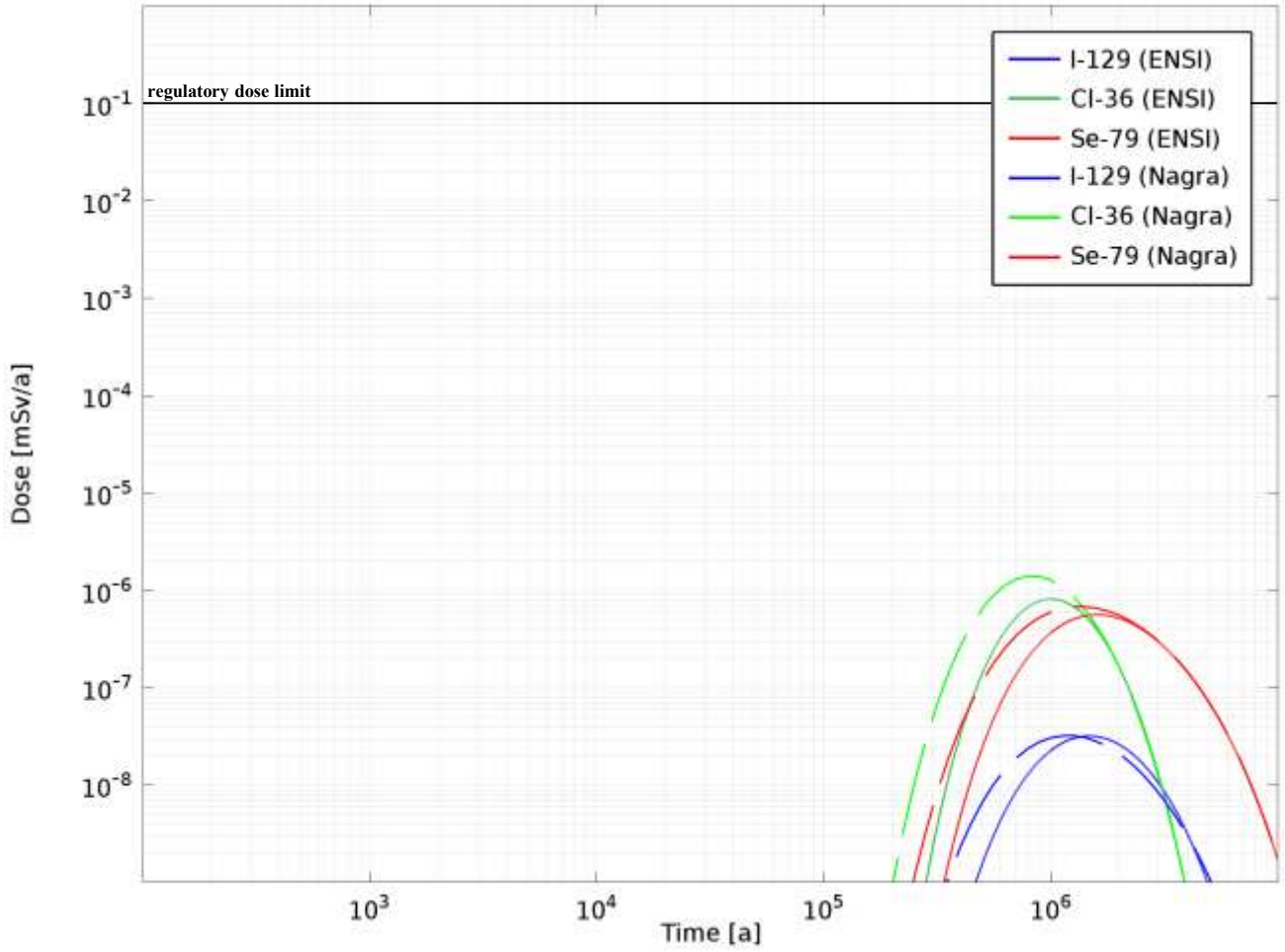
Model Case Study A

- Low and intermediate level waste
- Host rock “Opalinus Clay”
- Confining units
  (“Brauner Dogger”, claystone, marl and sandy limestones)
- Total length of transport path approx. 100m



Results

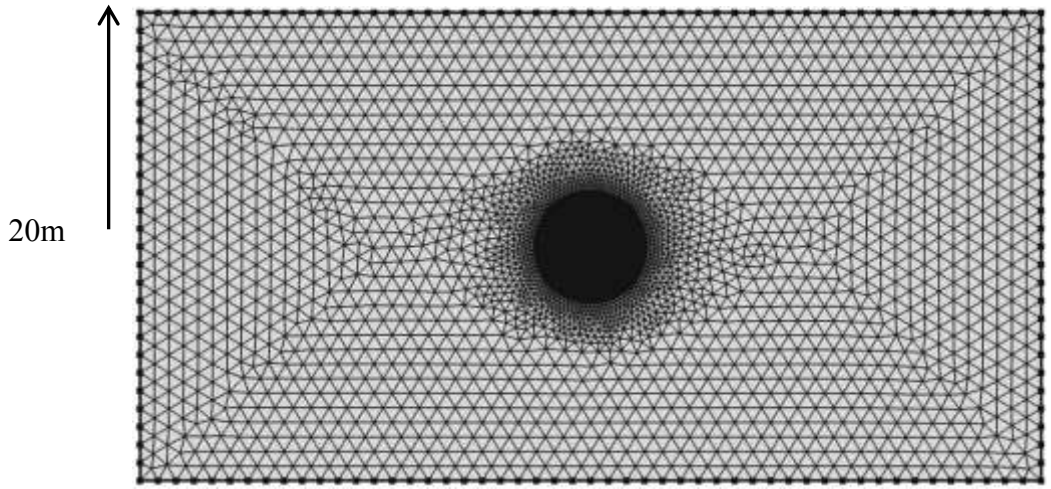
Model Case Study A



Results

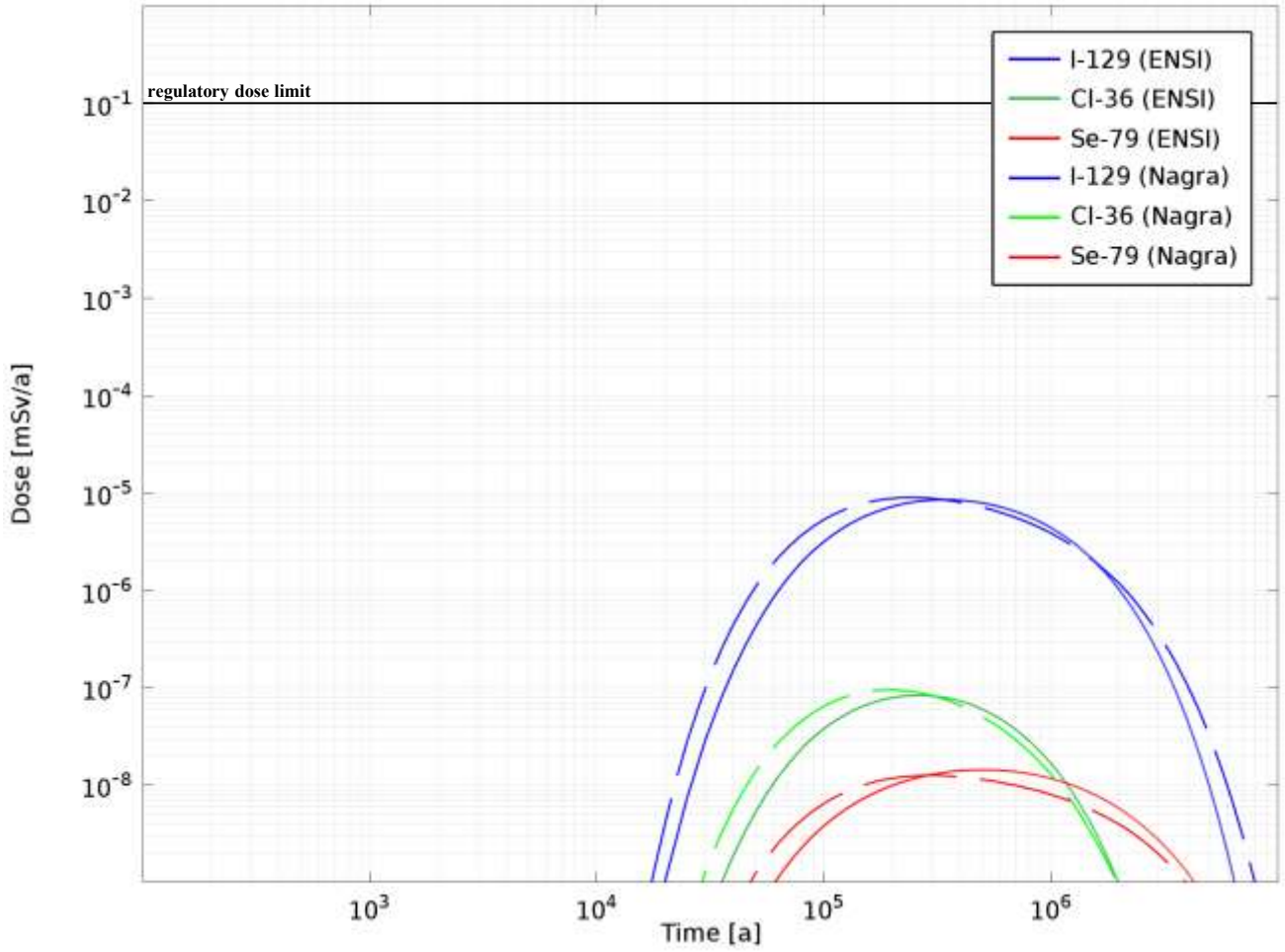
Model Case Study B

- Long-lived and intermediate level waste
- Host rock “Opalinus Clay”
- Confining units neglected
- Total length of transport path approx. 20m



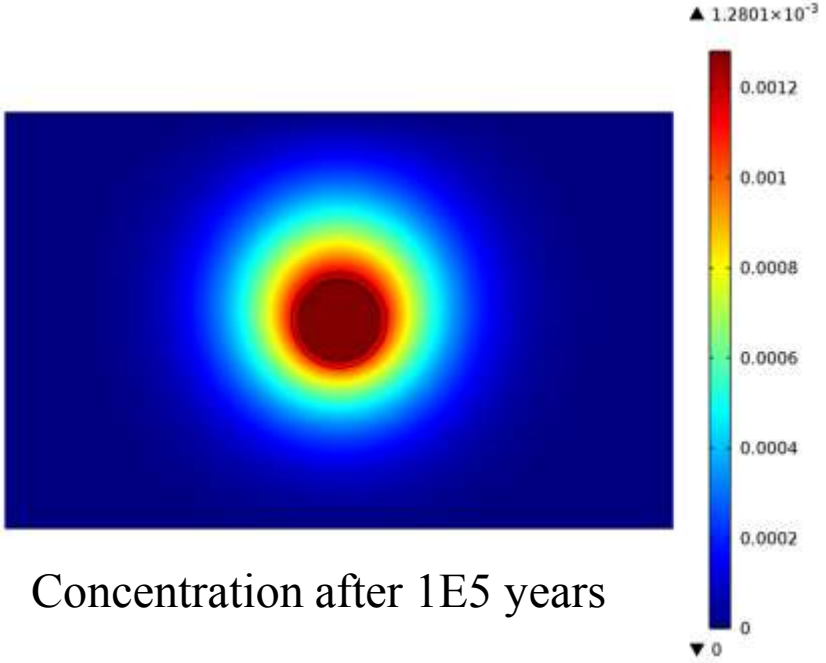
Results

Model Case Study B



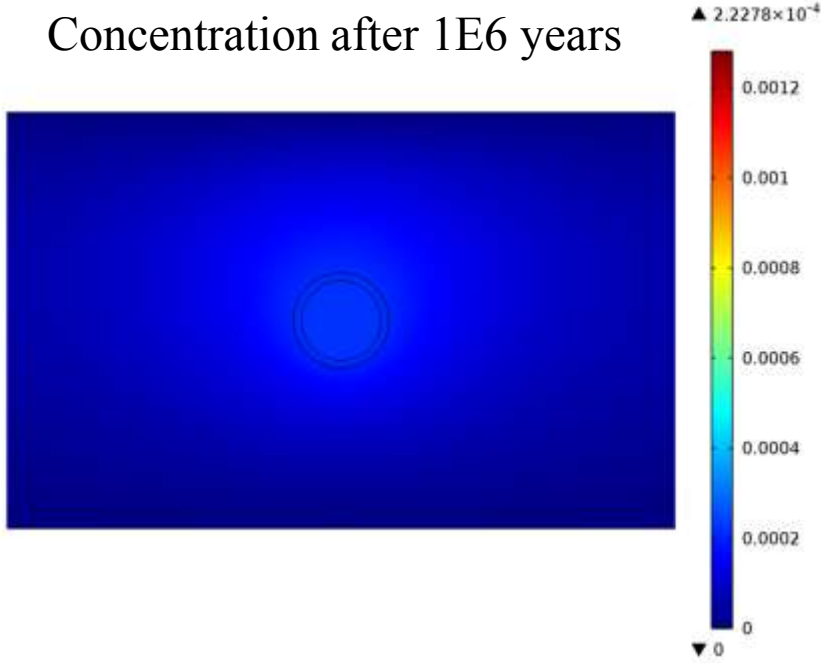
Results

Model Case Study B



Concentration after 1E5 years

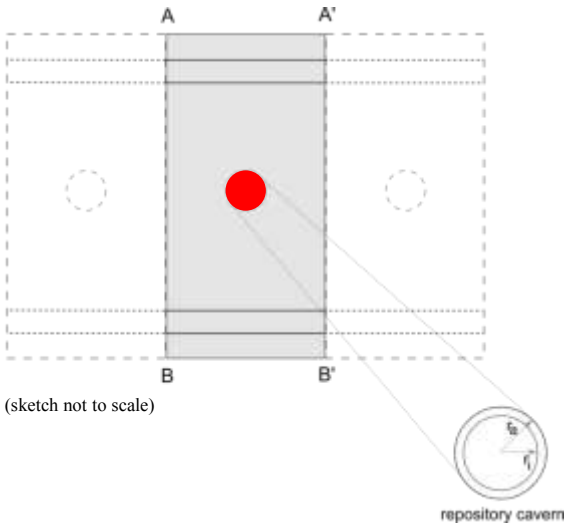
Concentration after 1E6 years



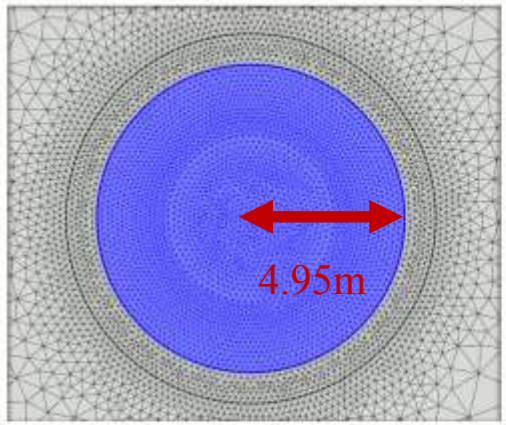
Model issues

- Fine mesh important for correct mass balance (initial concentration)!

Correct cross sectional area of cavern:
$4.95^2 m^2 * \pi \sim 76.98 m^2$

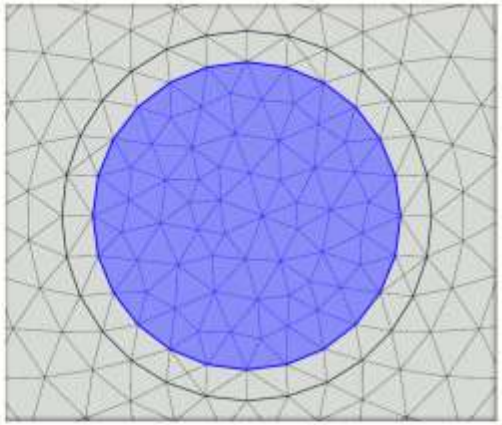


(sketch not to scale)



Element statistics

Minimum element quality:	0.8513
Average element quality:	0.9758
Element area ratio:	0.2157
Mesh area:	76.96 m^2

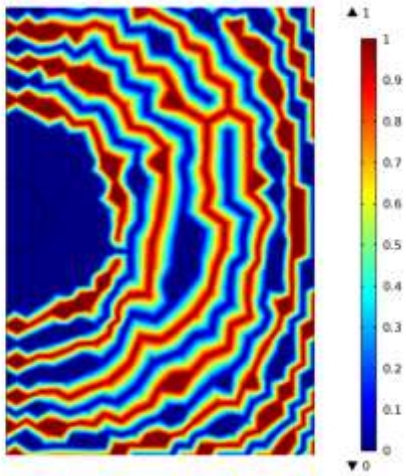


Element statistics

Minimum element quality:	0.8562
Average element quality:	0.9432
Element area ratio:	0.386
Mesh area:	76.1 m^2

Model issues

- Fine mesh important for correct mass balance (initial concentration)!
- „Negative“ concentrations can occur in the model, when the „real“ concentration is very low or at sharp concentration fronts



expression: c<0
(i.e. 1 means c<0)

Conclusion

- COMSOL is a robust tool, that (among other codes) has been and will be used by ENSI for radionuclide transport calculations.
- ENSI‘s calculations in the presented case studies yield similar results to Nagra. The minor differences are most likely due to different codes that were used.
- Some technical issues (degree of meshing detail, „negative“ concentration issues, …) have to be kept in mind.
- ENSI is working on the implementation of COMSOL for radionuclide transport calculations in fault zones and 2-phase flow.

Thank you very much for your attention!

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