Ingo Kock – Martin Navarro – Gerd Frieling

3D Fluid Flow in a complex ILW/LLW repository

Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH

EUROSAFE 2017

Outline

- Goals & Basics
- Methods & Models
- Results
- Conclusions

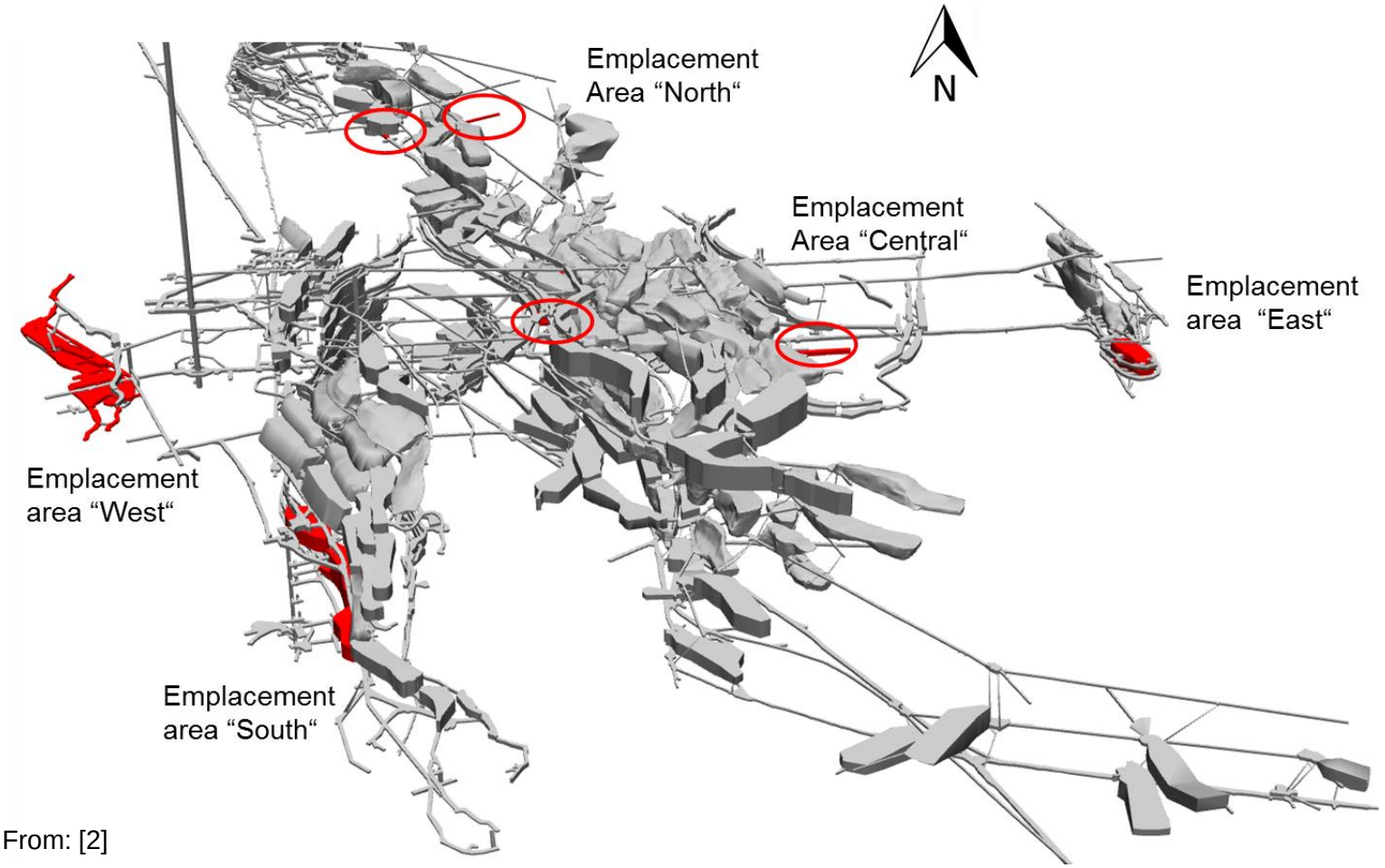
Goals

- Asses how the choice of the geometrical model (simple vs. complex) influences simulation results of the repository system regarding
  - fluid flow (e. g. gas and liquid fluxes)
  - fluid and radionuclide mixing (e. g. dilution)
  - radionuclide transport inside and potential leakage from the repository
- 3D – Multiphase Flow calculations for an existing repository
- Choice of repository: “Endlager für radioaktive Abfälle Morsleben” (ERAM)

Basics: Why choose the ERAM?

- Existing repository system in a salt formation with complex mine layout/geometry
- Detailed information is available[1]:
  - Decommissioning concept and plan
  - Radionuclide inventory
  - Gas generation
  - Mine layout
  - Scenarios
  - Calculations for long-term safety
- We can focus on numerical calculations

Basics: ERAM (Southern part Bartensleben)



From: [2]

Basics: ERAM

- Salt mine from 1897/1910 which is divided into two parts: “Marie” & “Bartensleben”
- Extraction of salt stopped 1969
- Emplacement of waste started in 1971 and (with interruptions) finished in 1998
- About 37,000 m^3 LLW und ILW
- Activity: about $6x10^{14}$ Bq (as of 30.06.2005)

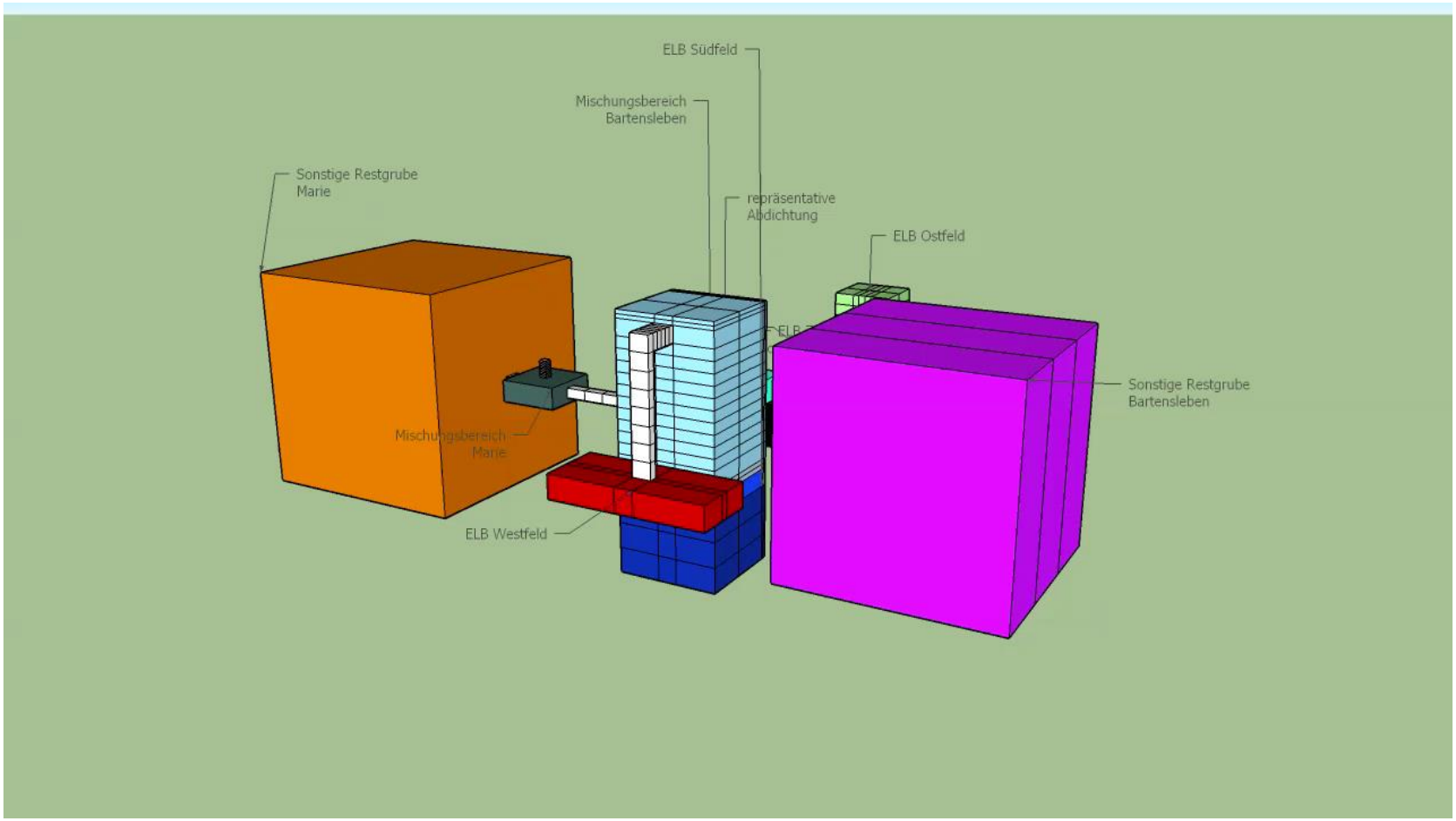
Methods and Models (1):

- Assumptions (based on existing long-term safety analysis[1]):
  - Most of the mine is considered to be accessible for fluids (liquid & gas)
  - This concerns two emplacement areas with radioactive waste: “North“ & “Central“
  - Other emplacement areas are isolated with 16 engineered barriers with a permeability of $1x10^{-18}$ m²: “South”, “West” & “East”
  - 2 scenarios: “dry” and “significant brine inflow”
  - The inflowing brine can corrode barriers, permeability increases to $1x10^{-14}$ m²

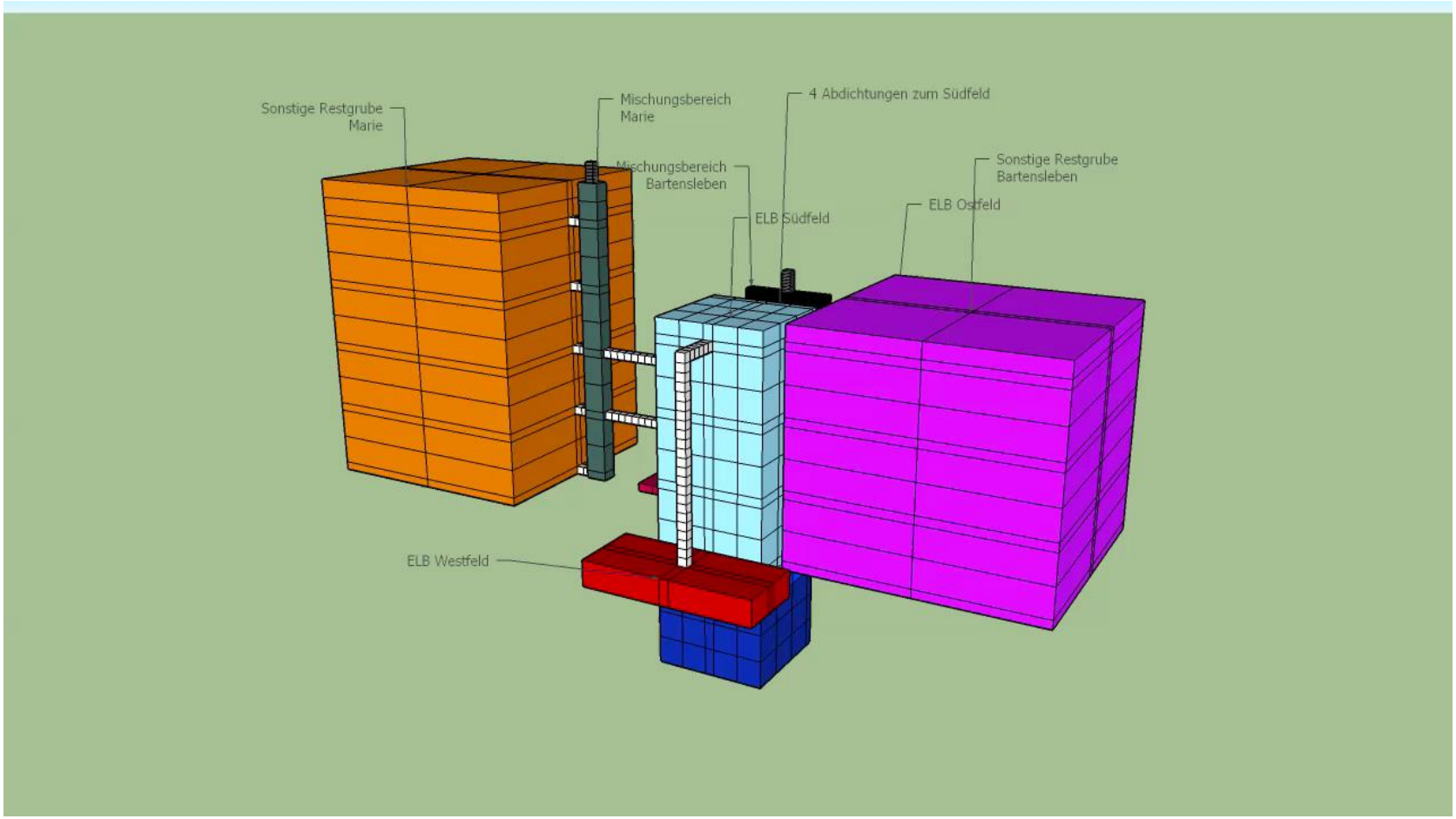
Methods & Models (2)

- 3D two phase flow calculations with TOUGH2-GRS[3,4]
- 3 different meshes:
  - Basic (based on existing concept from the long-term safety calculations): incorporates the mines' volume
  - Enhanced (based on existing concept from the long-term safety calculations): incorporates the mines' volume & depth
  - Complex: incorporates the mine's volume, depth, length, and level and room structure
- ^{14}C in CO_2/CH_4 as gaseous nuclide
- 34 other nuclides with a half-life > 500 a are considered.
- 700 deterministic & 400 probabilistic model runs

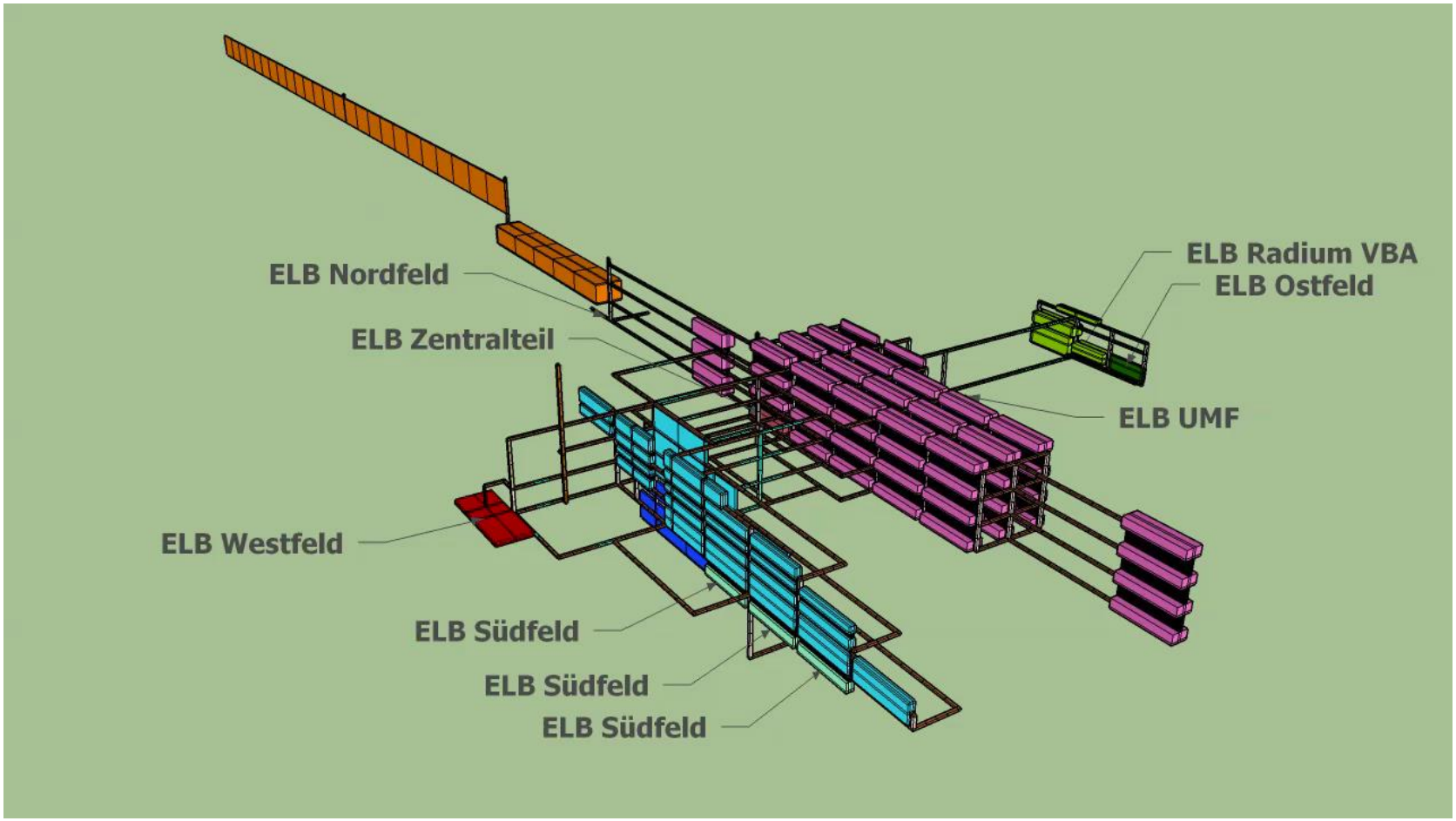
Basic model mesh



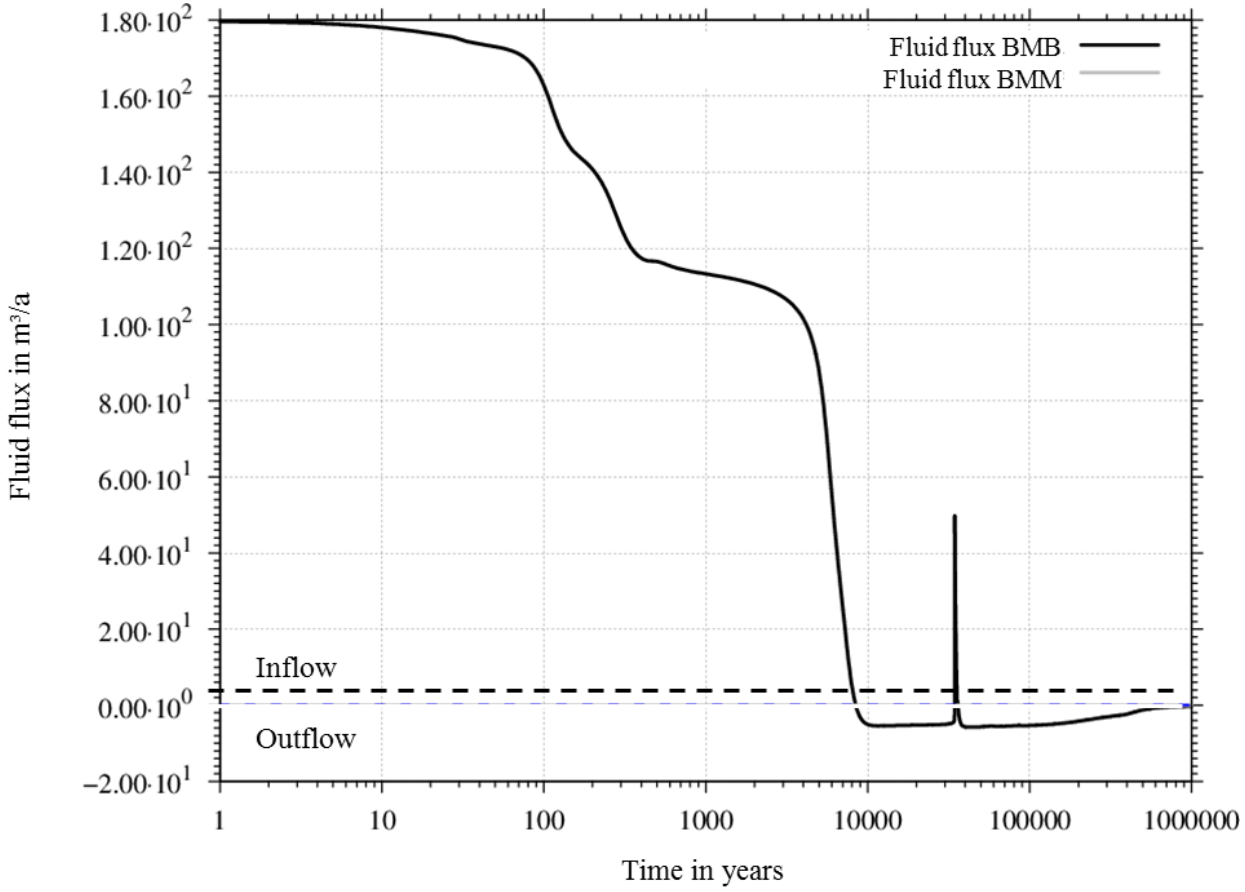
Enhanced model mesh



Complex model mesh

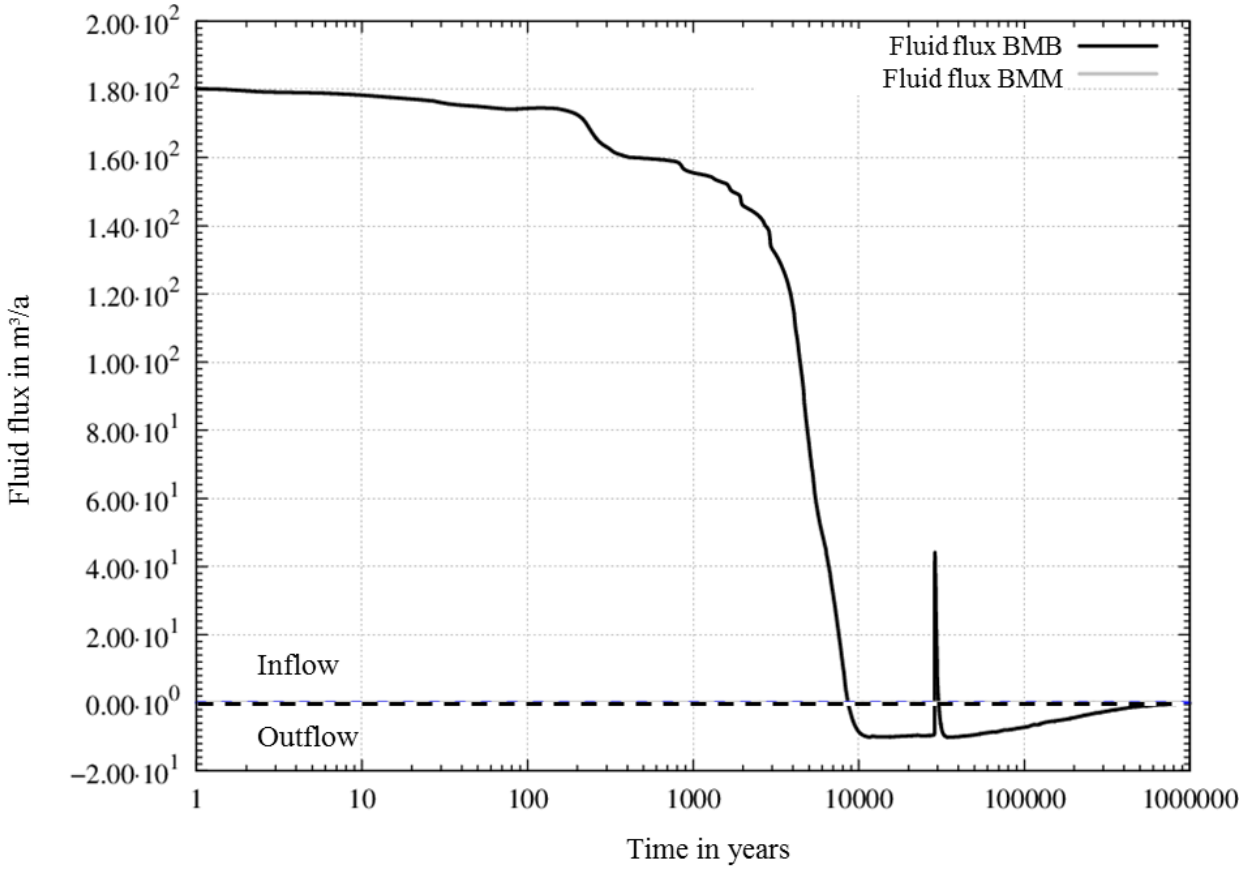


Results: Basic model mesh



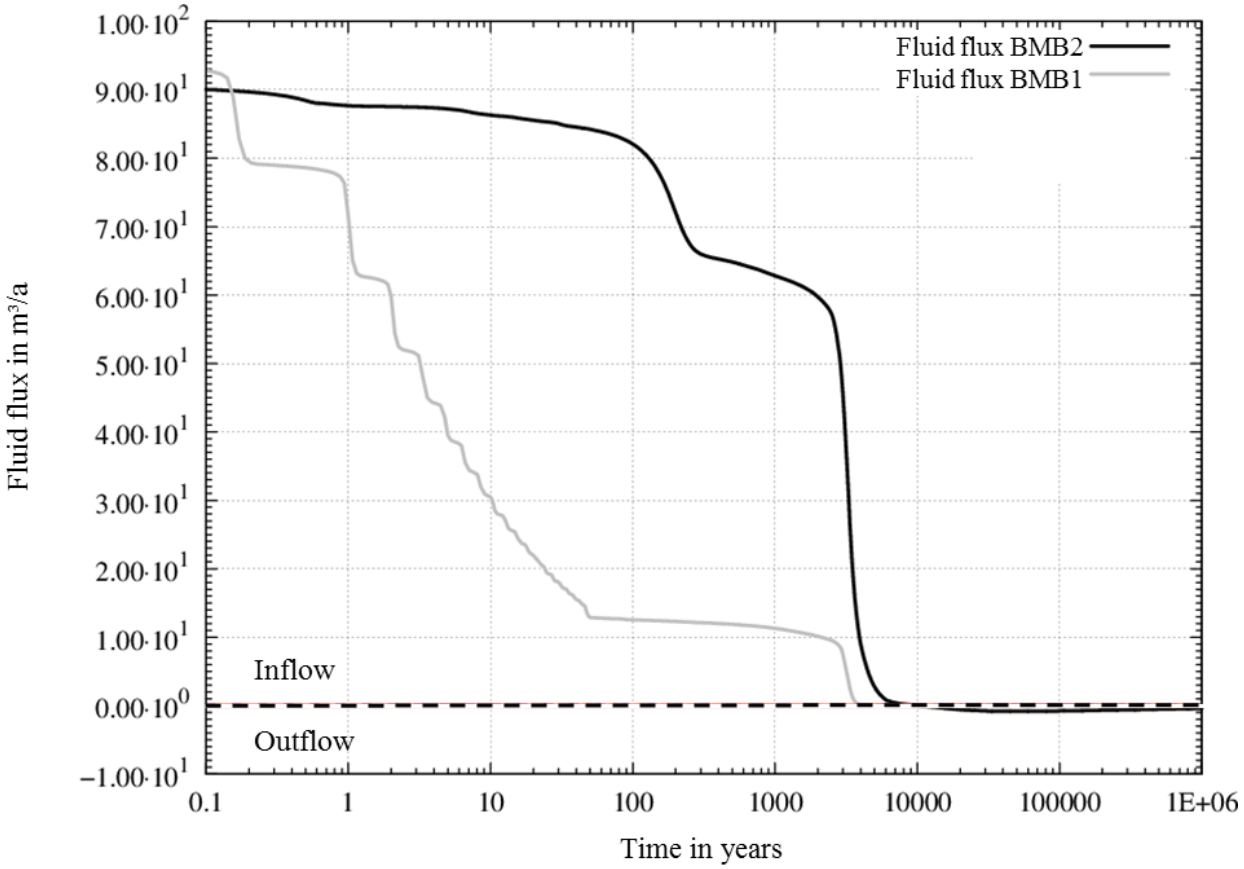
- Only inflow for “Bartensleben” part active
- In less than 10.000 ys the open mine areas are filled with brine.
- After ~34.000 ys barrier to repository area „South“ is corroded ➔ short but strong inflow event.
- After ~45.000 ys radionuclides are transported out of „South“

Results: Enhanced model mesh



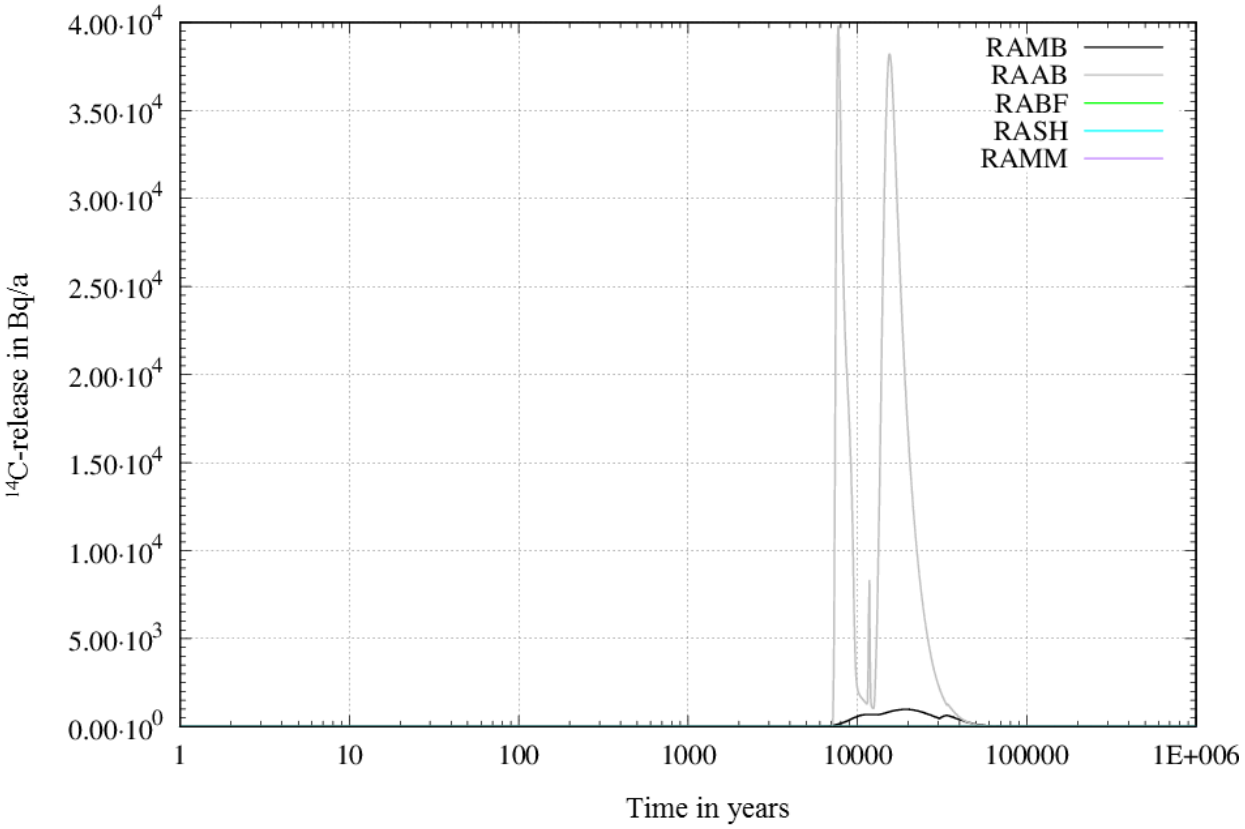
- Almost identical results compared to basic model
- Barrier corrosions finishes a bit earlier after ~30.000 ys
- Short but strong inflow event therefore occurs earlier (compared to basic model)

Results: Complex model mesh



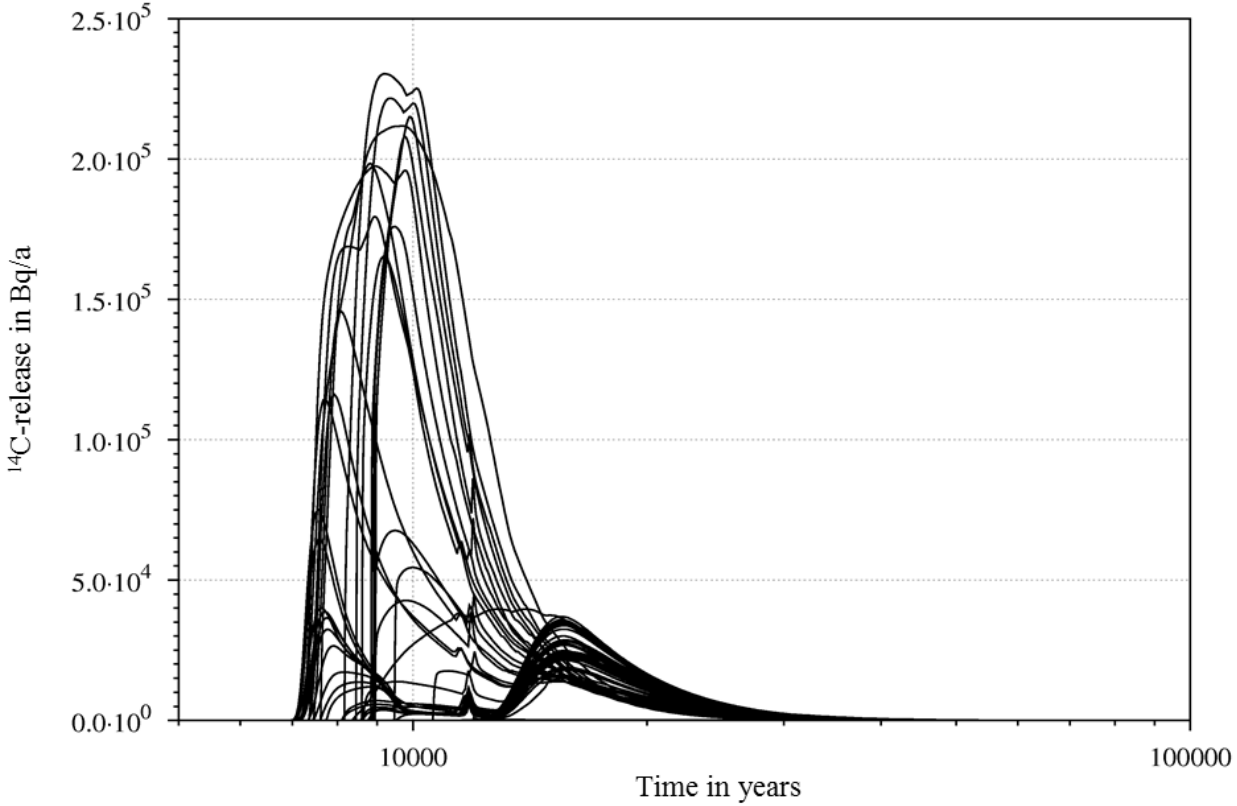
- Only inflow for “Bartensleben” part active, but for two postulated locations
- In about 10.000 ys the open mine areas are filled with brine.
- No occurance of a strong inflow event.
- Corrosion of barriers takes considerably longer

Results: Complex model mesh



- Release occurs at postulated inflow locations of “Bartensleben”
- Location roughly equivalent to single inflow of basic and enhanced model
- Release differs strongly between these two locations
- Reason is that “RAAB” is directly located 4 floors above emplacement area “North”

Results: Complex model



- Probabilistic parameter variations for 2-phase-flow parameters
- 100 model runs
- Release at “Bartensleben RAAB”
- Significant parameters:
  - Gas entry pressure of salt concrete backfill
  - Residual gas saturation

Conclusions

- Increasing the complexity does not necessarily lead to complex flow or transport paths
- However
  - locally such complex processes can be observed.
  - simplified models show only aspects of internal transport
  - complex models can help to deepen the understanding of the repository system's behaviour.
- Simple models vs. complex models (single-phase vs. multi-phase; simple geometry vs. complex meshes):
  Not competing but complementing for safety cases.

Thank you for your attention!

- Many Thanks to
  - BMUB (For financial support; No: UM13A03400)
  - BfS and its subcontractors for helpful assistance with many questions regarding the ERAM

References

[1] Resele G, Ranft M, Wollrath J (2009) Endlager Morsleben - Nachweis der radiologischen Langzeitsicherheit für das verschlossene und verfüllte Endlager: eine Übersicht, Salzgitter
http://www.bfs.de/SharedDocs/Downloads/Morsleben/DE/planfeststellungsverfahren/905-00-V02.pdf

[2] Kock I, Frieling G, Navarro M (2016) Fluidströmung und Radionuklidtransport in komplexen Endlagerbergwerken: Synthesebericht Teil 1/2. Zweiphasenfluss in einem salinaren Endlager am Beispiel des ERAM, GRS-399. Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH, Köln

[3] Pruess K (1990) TOUGH2: A general purpose numerical simulator for multiphase fluid flow, Berkeley, California, USA

[4] Navarro M, Eckel J (2016) TOUGH2-GRS: Version 1. User Manual, GRS-403. Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) gGmbH, Köln