

Challenges in the flooding of coal mines

- case study 'Ruhr area'

Further development of the 'box model' simulation concept
for the German hard coal mines

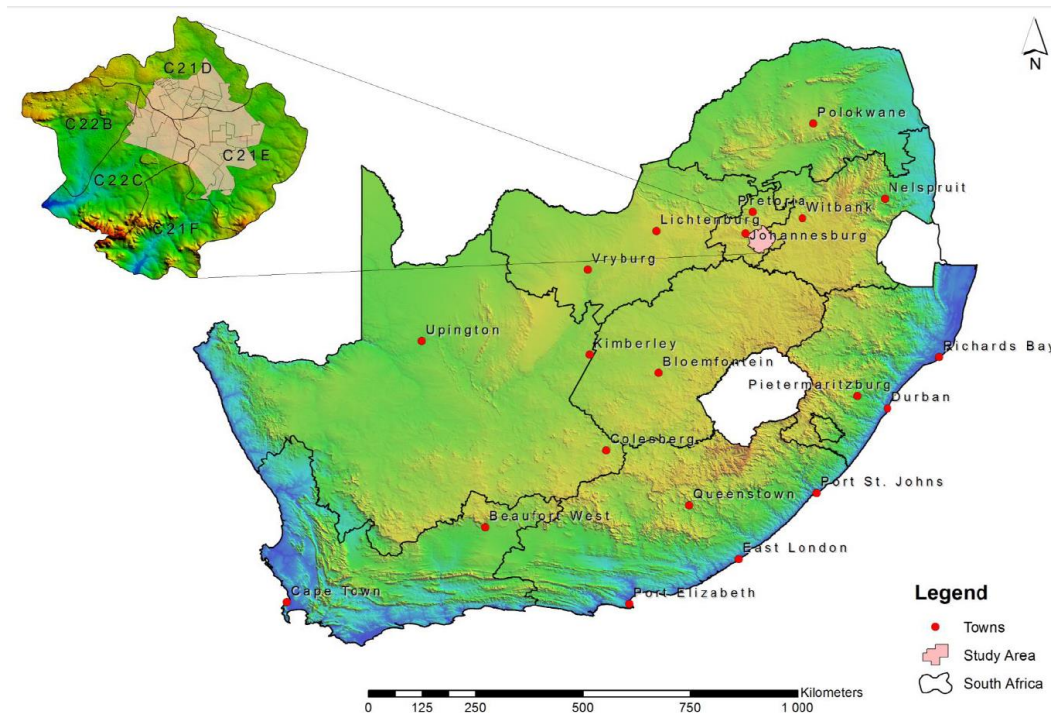
DMT GmbH & Co. KG

Hydrogeology & Water Management

Dr. Michael Eckart, Dr. Boris Dombrowski

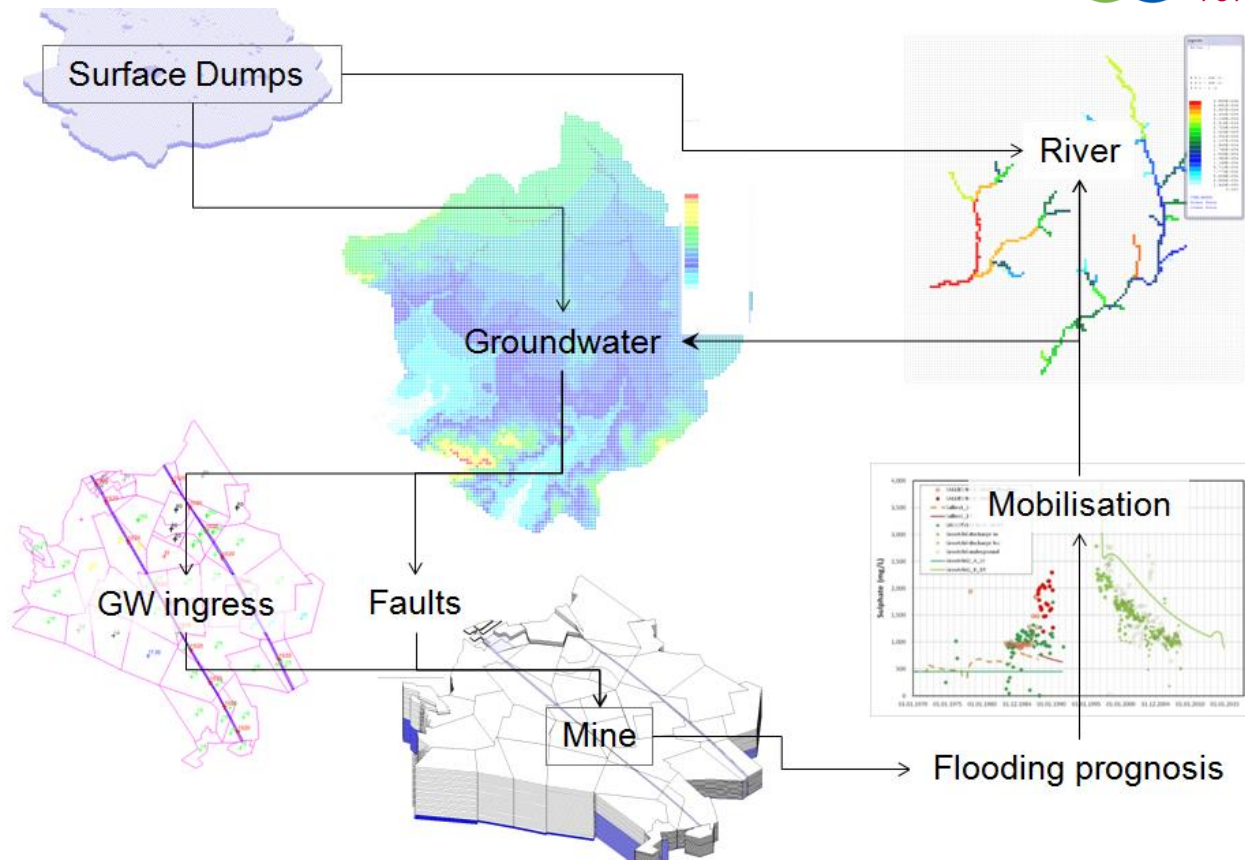
- **Companies DMT (TÜV-NORD GROUP) and RAG/DSK**
- **Development of the hard coal mining industry in Germany**
- **Challenges in the hard coal mine closure / future tasks**
- **Special tasks**
 - Forecasting mine water rise
 - Substance loads in the receiving waters - pollutant prognosis
 - Narrowing or closure of mine water pathways
 - Subsidence / uplift
- **Development of forecasting tools**

Coupled reactive mass transport for the East Rand Basin of SA (East Rand Basin Source Apportionment Study)



Holistic approach example: East Rand

Reactive mass transport: coupling of groundwater – mine water – rivers



TÜV NORD GROUP Overview

TÜV NORD GROUP

Headquarters in Hannover, Germany



Industrial Service,
Mobility, Education



Natural Resources



Aerospace



Information Technology

DMT - Hydrogeology & Water Management in the TÜV NORD GROUP

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Department: Hydrogeology & Water Management

DMT at a Glance

The international engineering & consulting service provider DMT serves the four markets **Mining, Infrastructure & Civil Engineering, Oil & Gas, and Plant & Process Engineering.**



We provide independent services in engineering, consulting, exploration and geotechnics, as well as measuring and research.



DMT's **roots** dating back to **1864**



About **1.000 employees** mainly with academic background



DMT comprising **13 operational consulting and engineering companies**



DMT's attitude is dedicated to **excellence, responsibility & innovation**

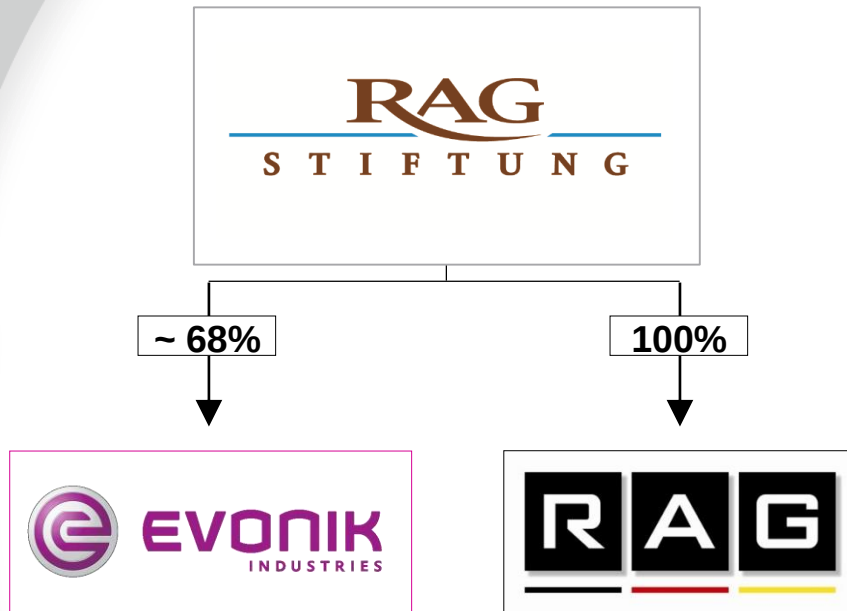


About **110 million € turnover**



Today **DMT** is a **core brand** of **TÜV NORD GROUP**

RAG-Stiftung at a Glance



Tasks of RAG-Stiftung

- Socially acceptable closure of the hard coal mining activities until end 2018
- Launching of EVONIK Industries on the capital market. Building up the foundation's asset portfolio.
- Financing perpetual mine management obligations (as from 2019)
- Supporting education, science, and culture in the mining regions

Post-mining activities

Technical Activities of the RAG AG after 2018



- Old mine shafts, shallow mine workings



- Surface subsidence, subsidence damages

Historical damages & consequences

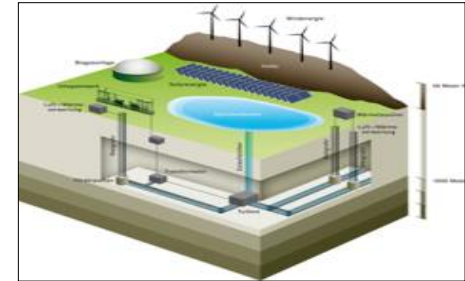


- Perpetual obligations, mine flooding



- Water issues, permissions, geospatial data management

Today's obligations & tasks



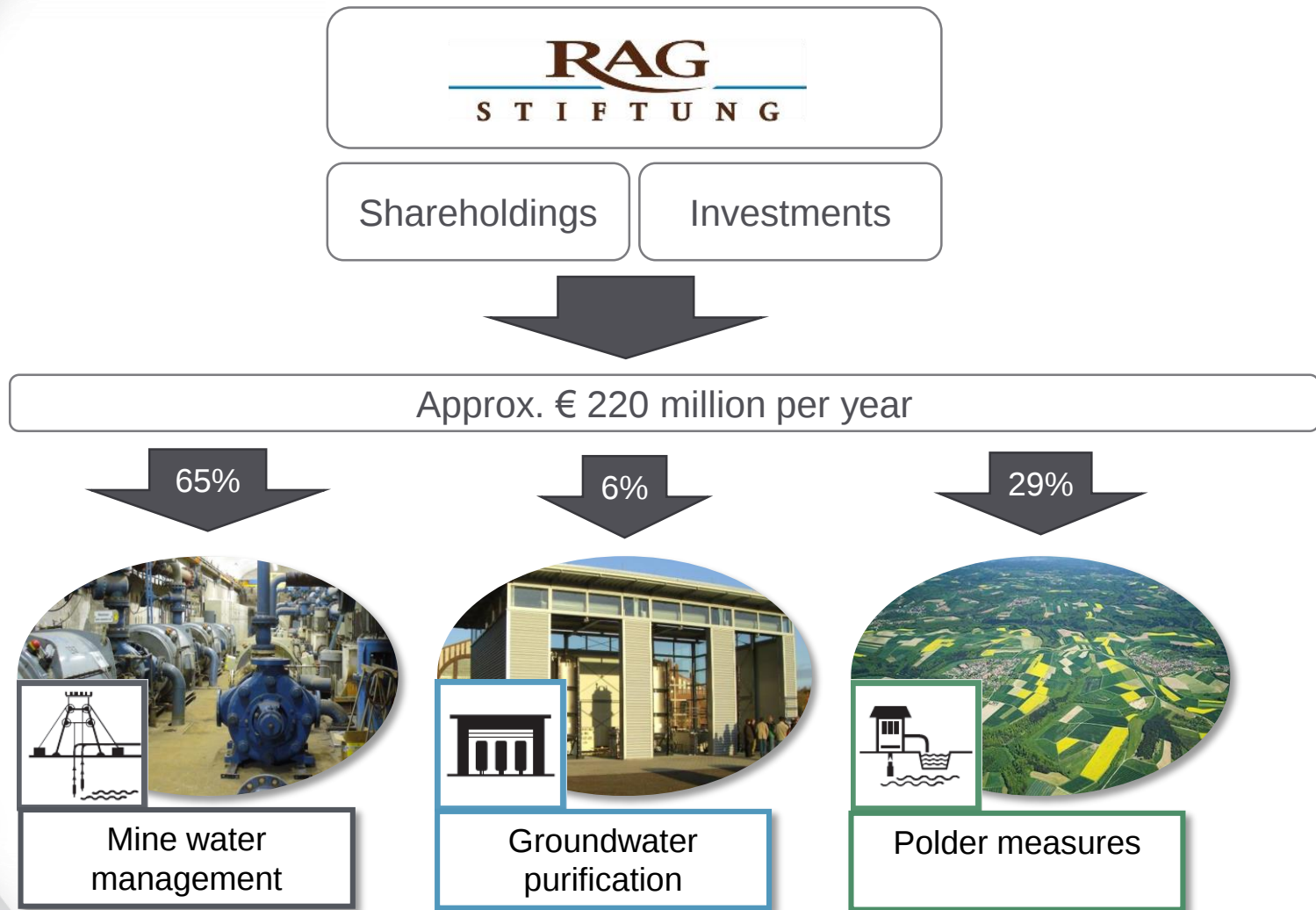
- Renewable energy



- Real estate, property

Future possibilities & chances

Financing perpetual mine management obligations



The future mine water management concept for the Ruhr area has 4 major targets

- **Conversion to well operation**

The underground pumping stations shall be replaced by submersible pumps operated from above ground

- **Reduction of pumping stations**

The number of pumping stations shall be reduced by using existing underground water pathways (interconnectivities)

- **Mine water level -680 Meter**

The regional mine water level shall rise but shall not reach the drinking water resources

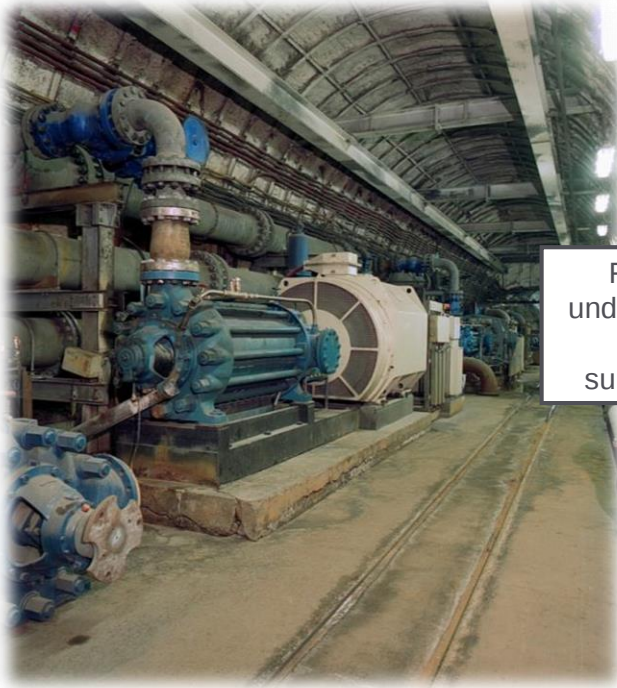
- **Reduce environmental impact**



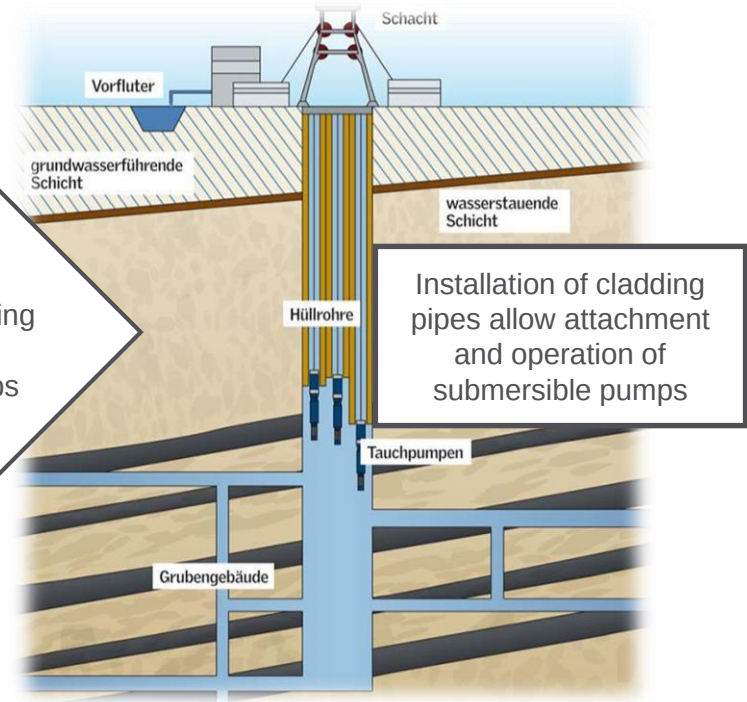
Modeling of mine water flow & reactive mass transport

Conversion to well operations

Installation of cladding tubes: Mine water level regulation as required



Replacement of underground pumping stations by submersible pumps

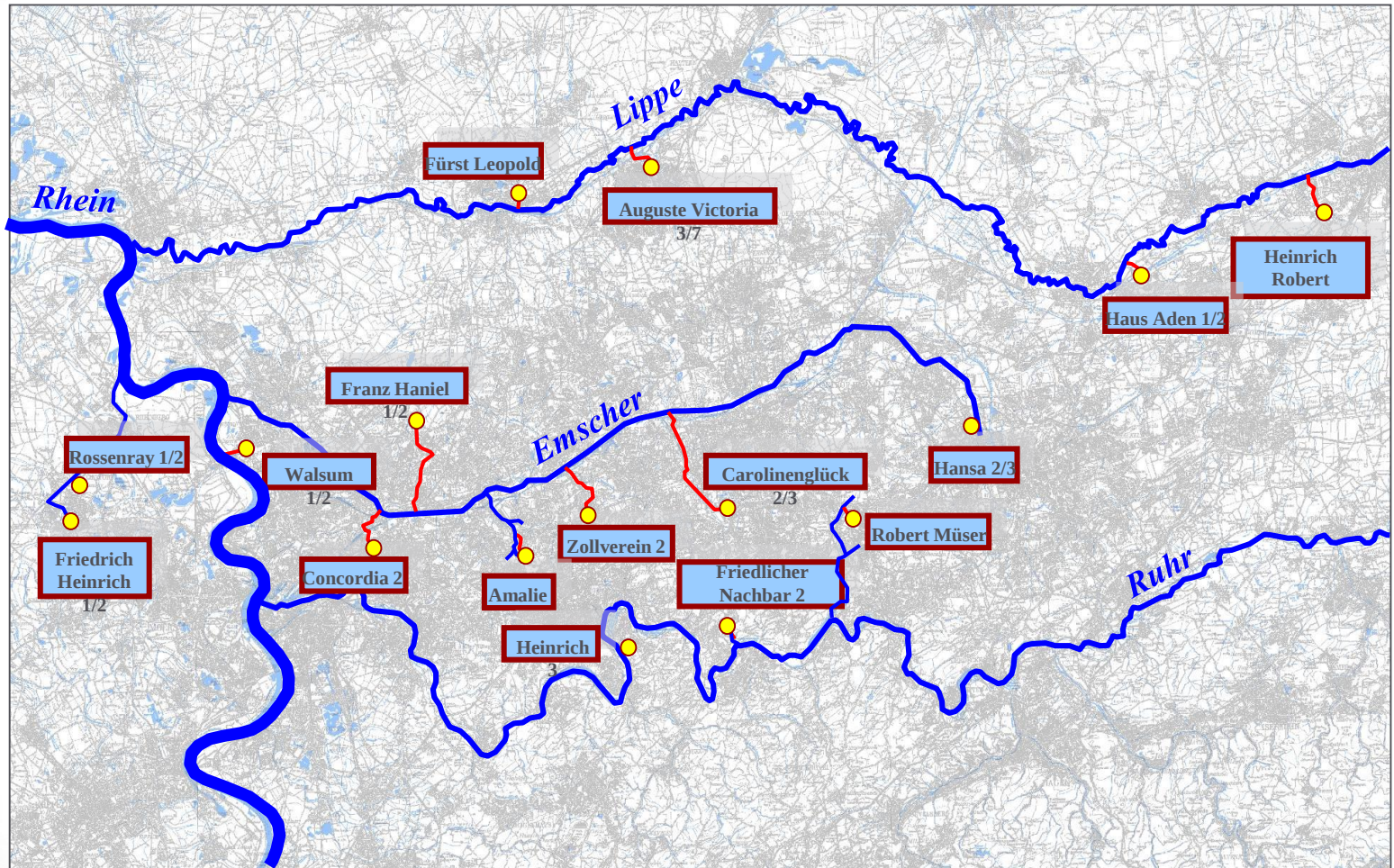


Today: Conventional pumping stations

Tomorrow: Submersible pumps

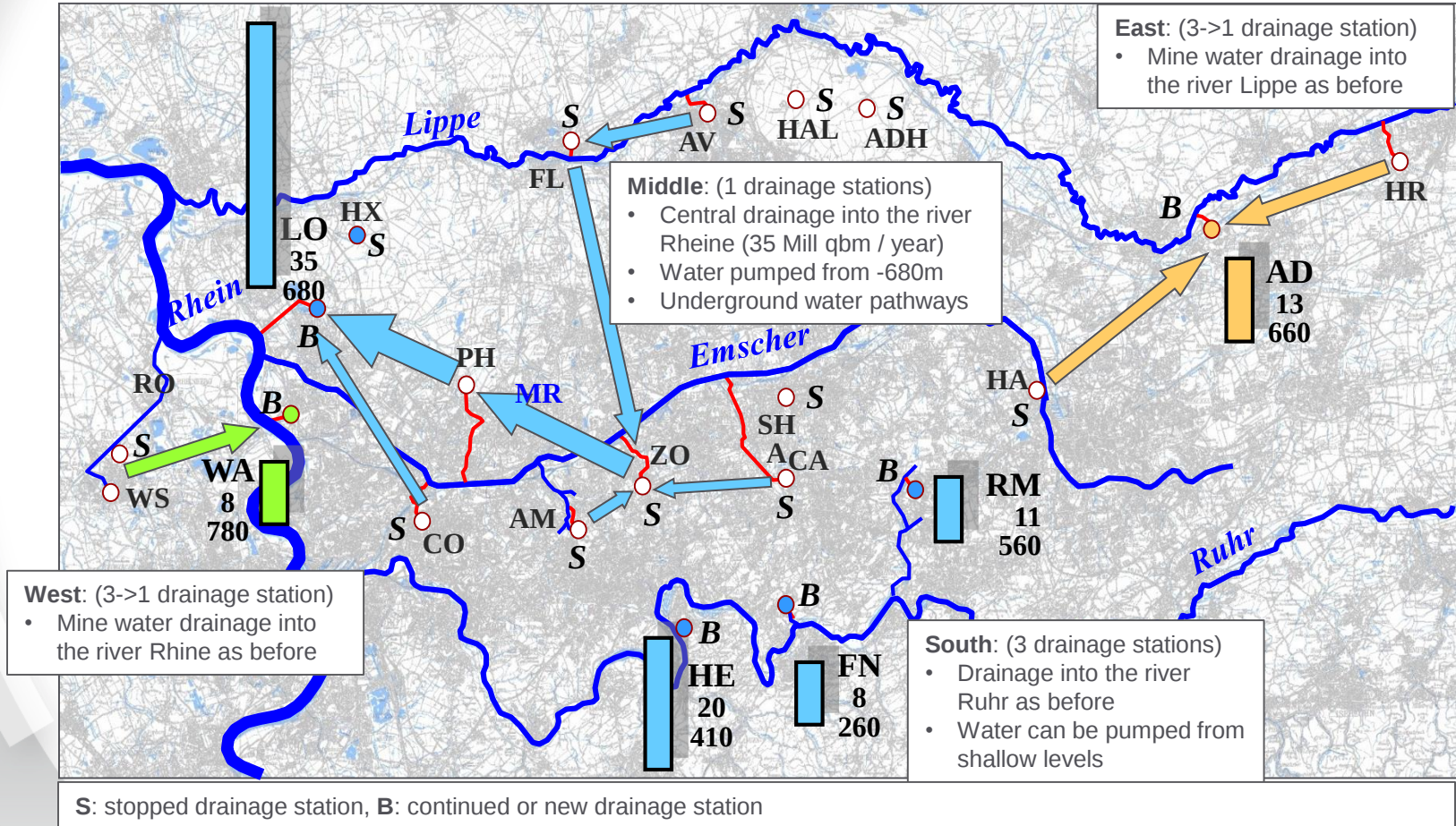
Reduction of pumping stations

Today: Mine water discharge system is decentralized



Reduction of pumping stations

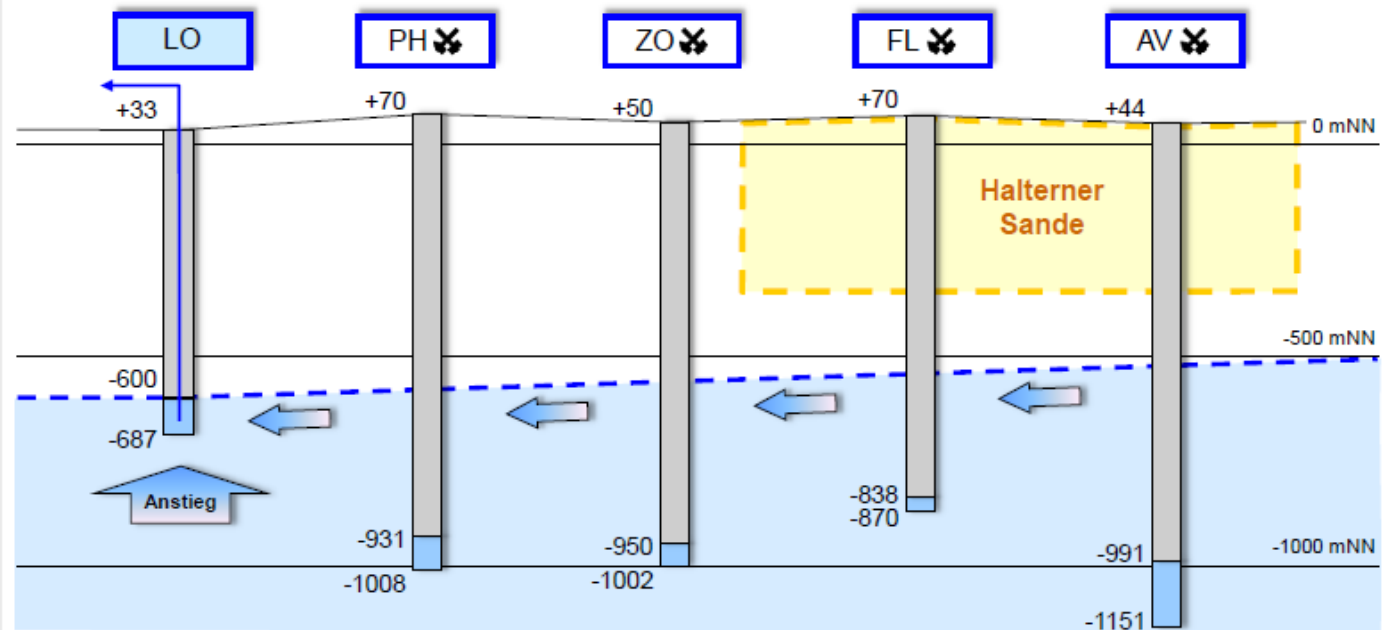
Tomorrow: Use of underground water pathways, centralized drainage



Mine water management concept of RAG



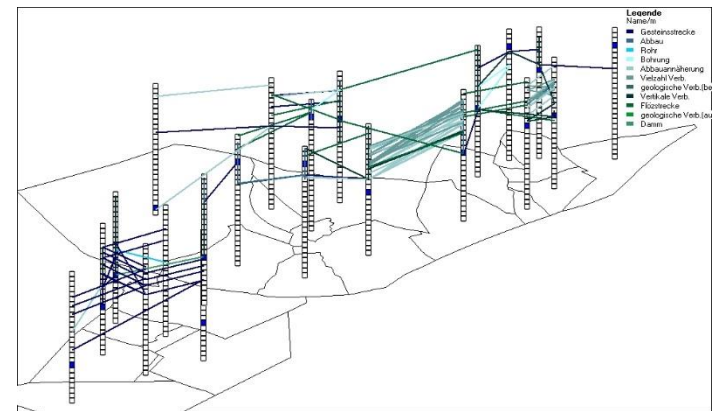
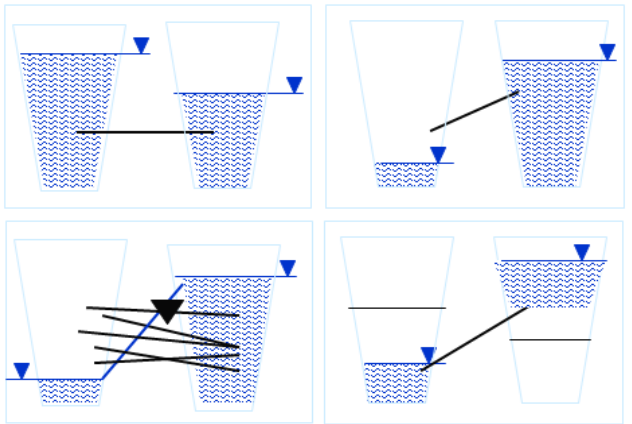
Aligning / adjusting of the pumping levels



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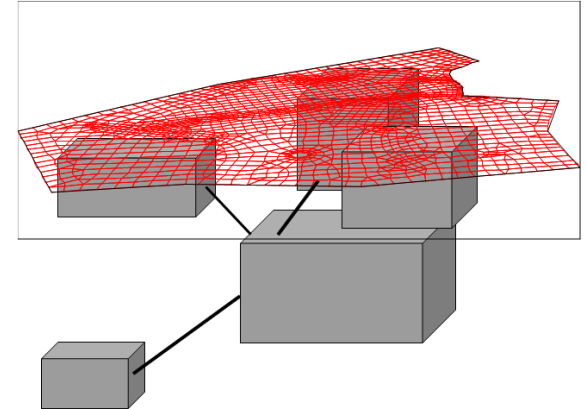
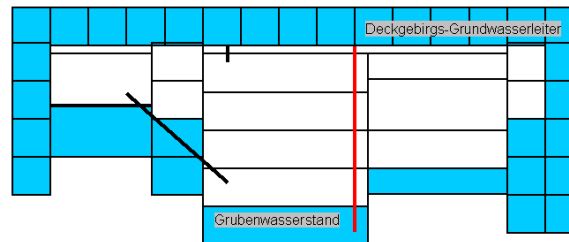
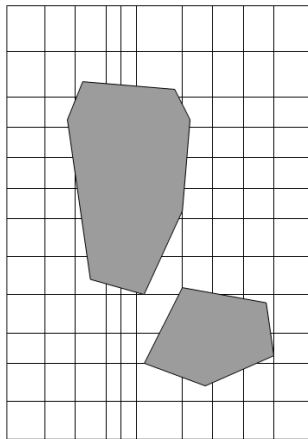
Special features of water flow in mining districts

- Defined points of overflow
 - Partially turbulent flow (pipes, drives, shafts, drill holes)
 - Interconnections between minefields (roadways, drill holes, shafts, nearby production lines, etc.)
 - Time-varying flow properties (settlement, convergence, roadway collapse)
 - Density-dependent flow (high salt content)
- Uncertainties about the temporal behavior of underground water pathways



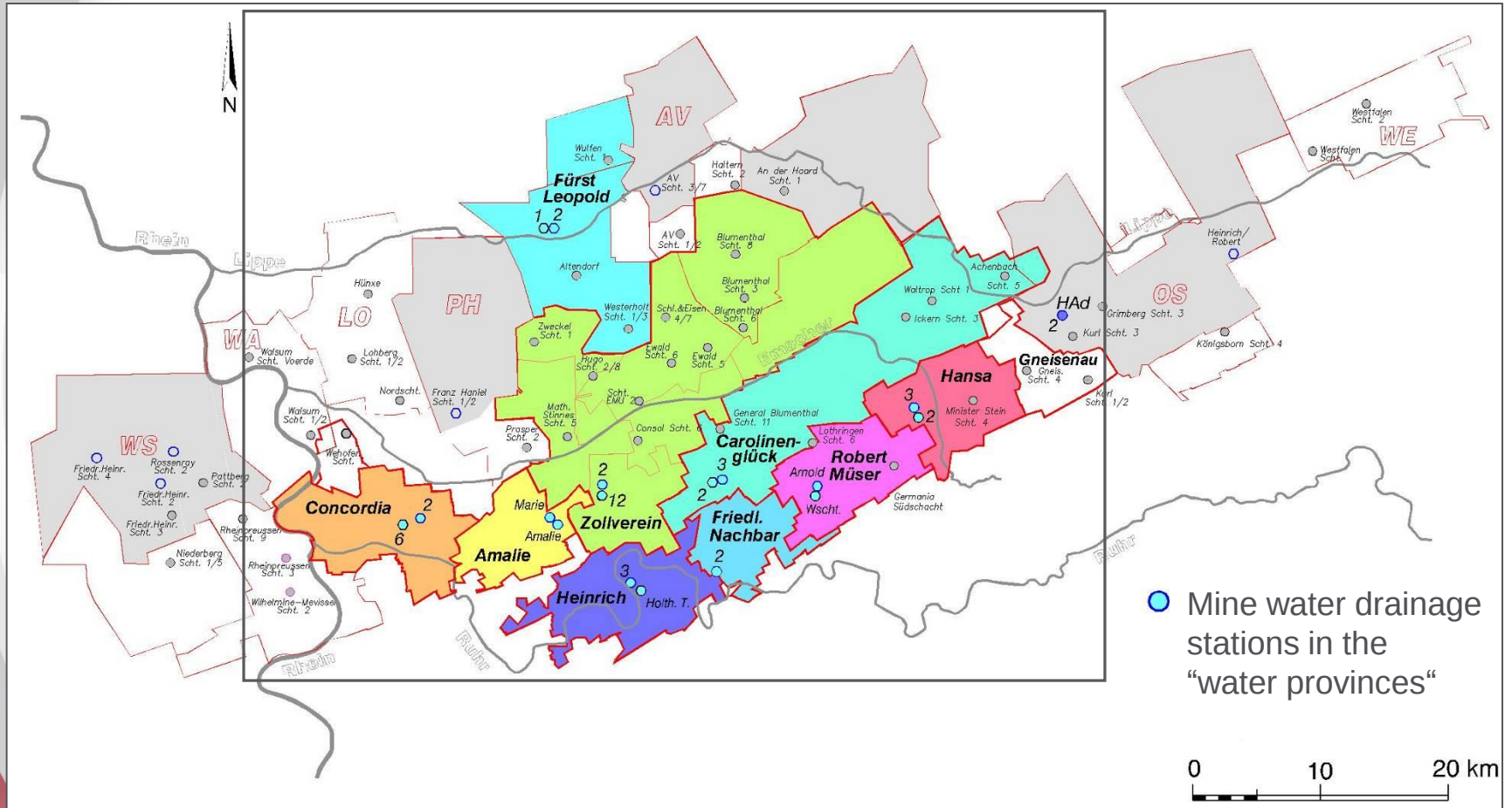
Box model - mine water management simulation software considers special aspects of water flow in mine areas

- Most of the water flows through open systems such as roadways and shafts
- Within these systems, there is mainly hydraulic short circuit
- Nearly identical mine water levels within interconnected mine districts (3-dimensional definition of volume elements / cells)
- Mine water qualities are considered with discretization, possibly refinement necessary



Mine water management in the Ruhr area

Today: Decentralized mine water pumping in the “water provinces”



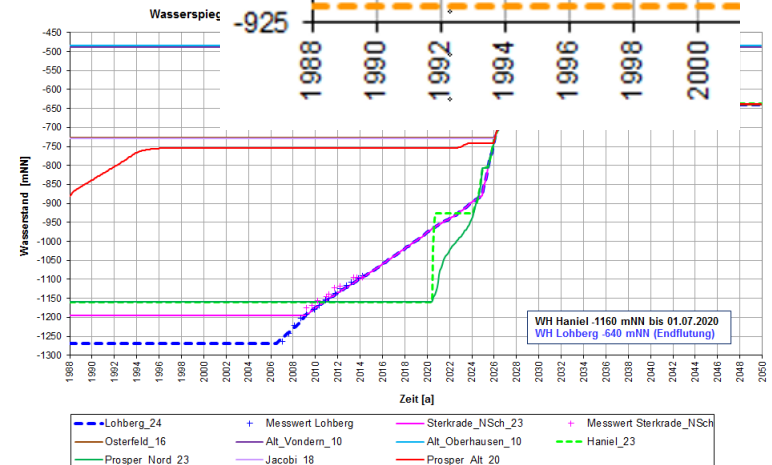
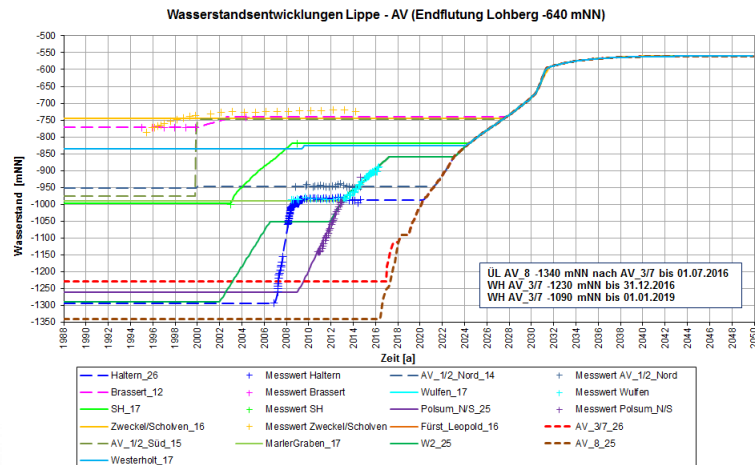
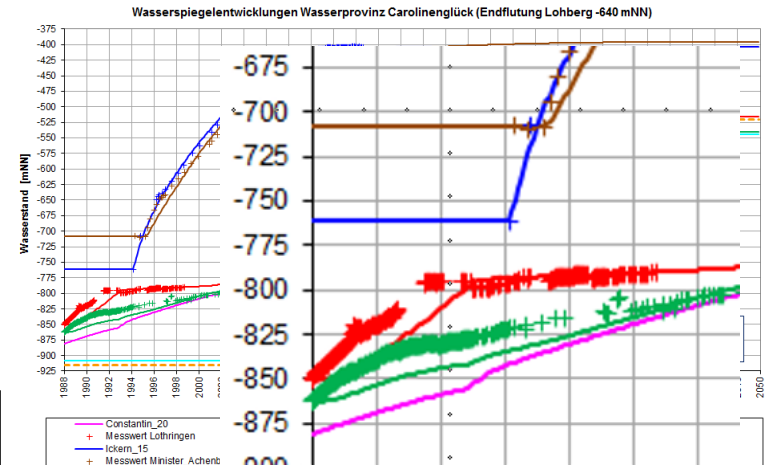
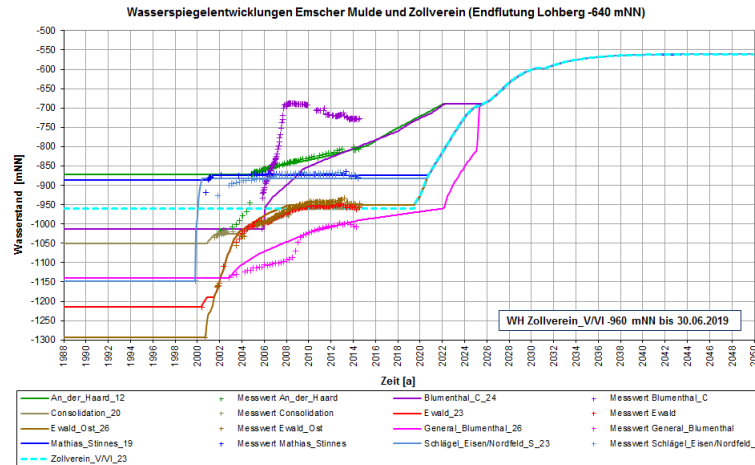
Ruhr area: Box Model parameters

- East-West dimension: app. 120 km
- North-South dimension: app. 80 km
- Pumped amount of mine water per year: app. 75 Mill. m²
- 139 boxes, 26 slices = 3614 volume balance elements
- Hundreds of shafts
- Floodable void space > 2 Billion m³
- Extracted coal > 10 Billion m³

Ruhr area: Major tasks of the modeling

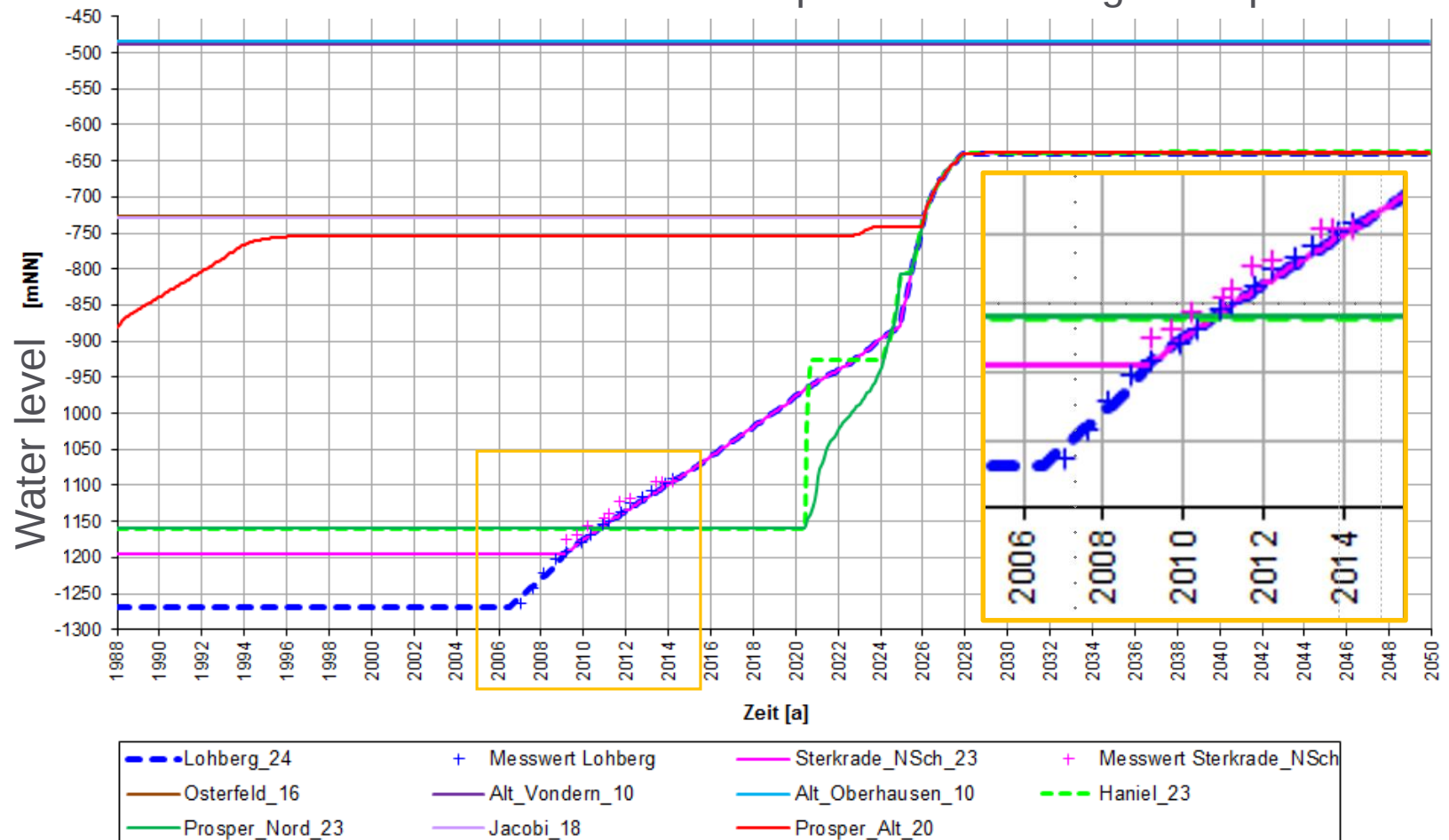
- **Prediction of rising mine water levels**
- **Geochemical forecast of flooding water quality**
 - Including pollutants such as Sulphate, Iron, Chloride, PCB, turbidity
- **Uncertainty considerations / sensitivity analyzes**
- **Safety assessments: Standing water levels next to active mining operations**

Calibration and Prognosis: Flooding Ruhr-Area Predicted and measured mine water levels

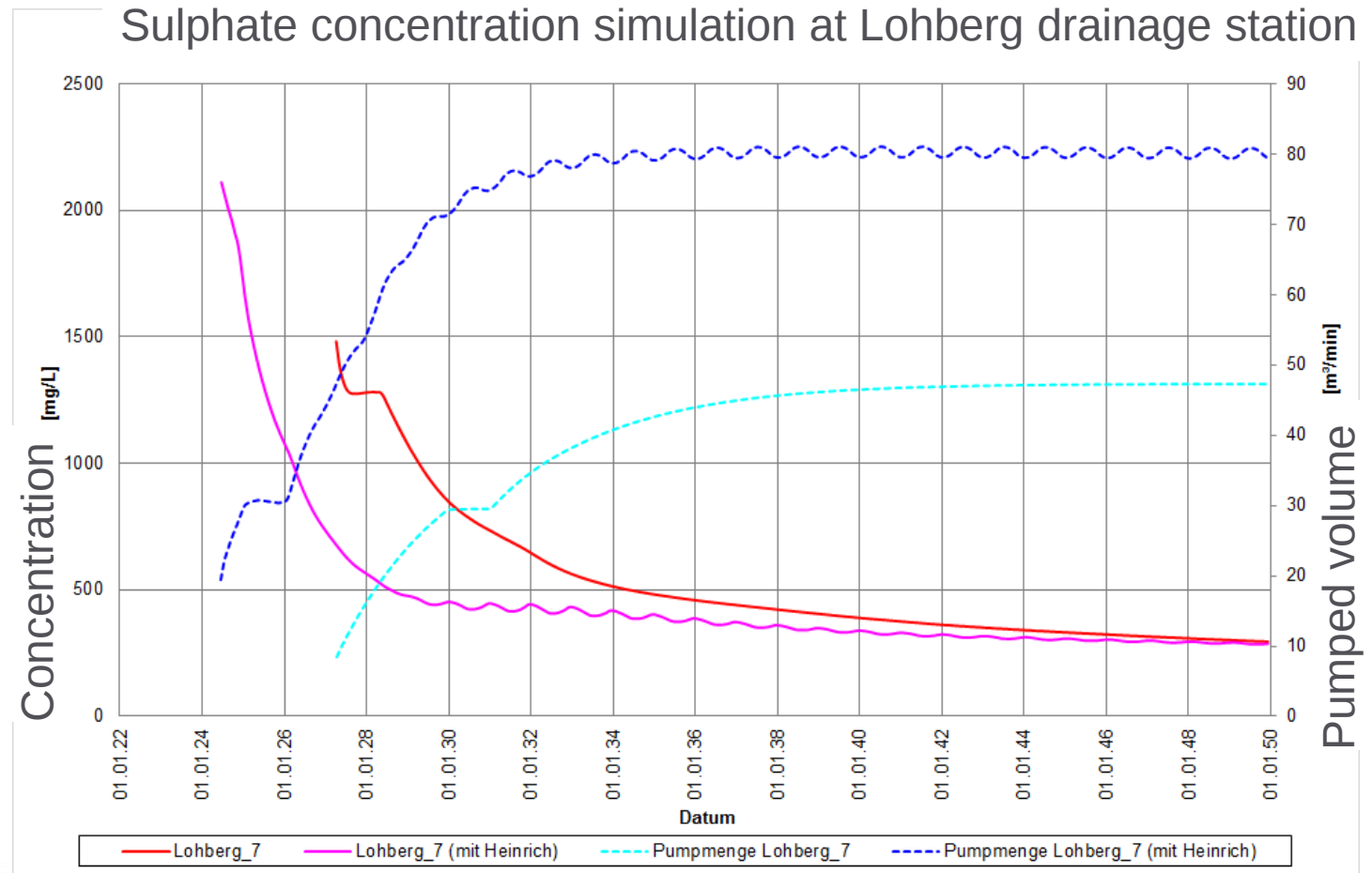


Calibration and Prognosis: Flooding Ruhr-Area Predicted and measured mine water levels

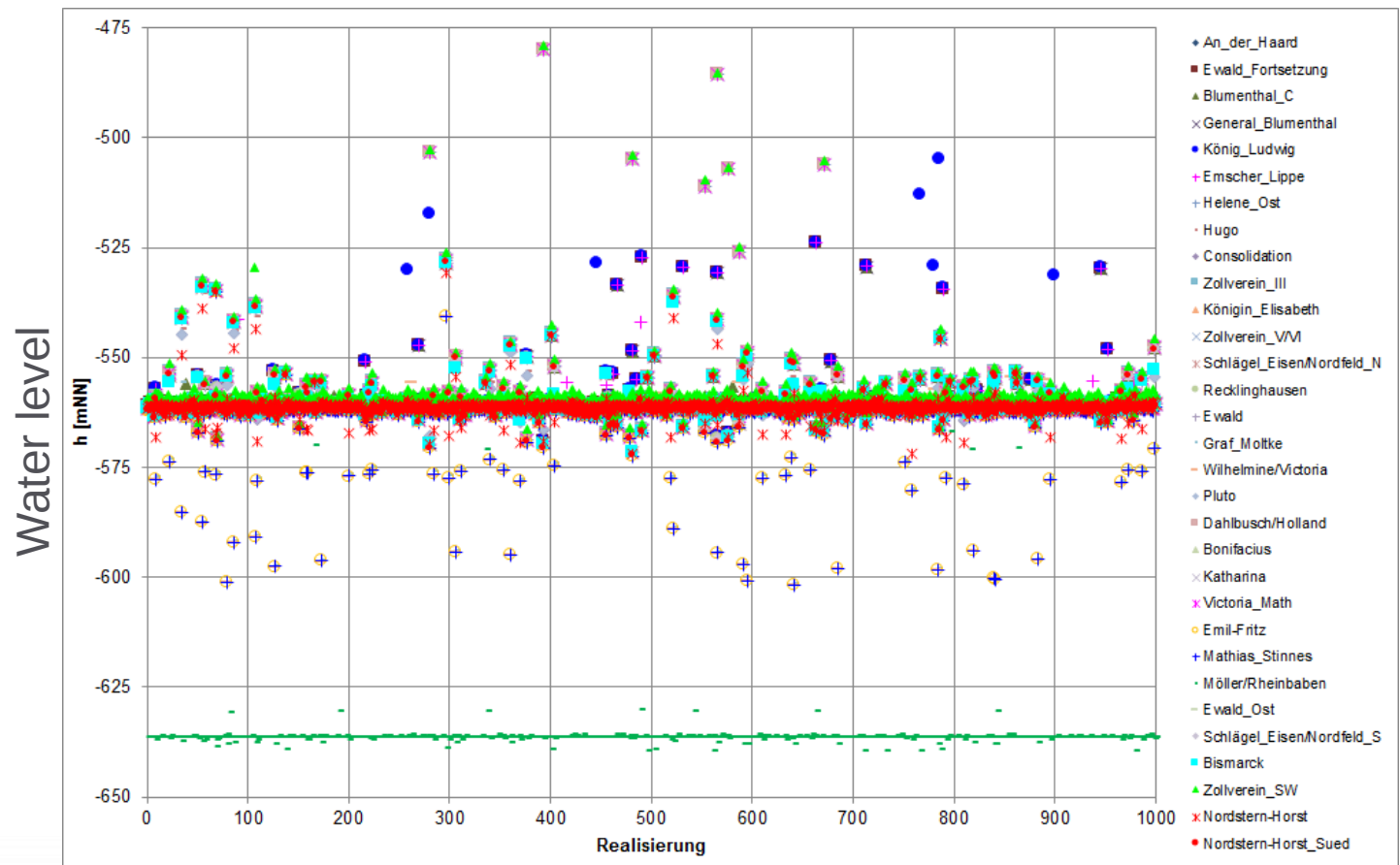
Water level simulation in the water province Lohberg / Prosper-Haniel



Development of Sulphate in Lohberg



Sensitivity Analysis: possible flooding levels in case of water pathway collapse (number per 1000 model runs)



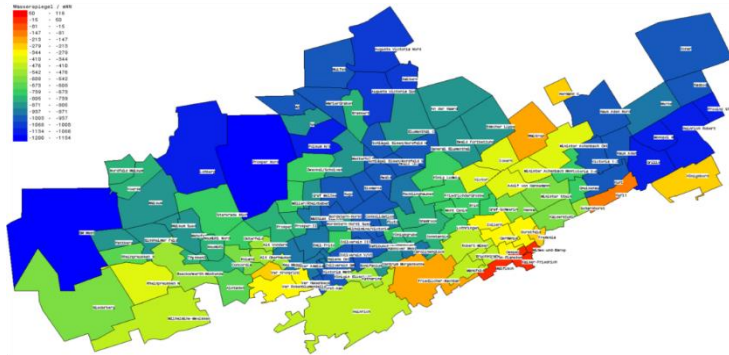
Conclusions and major results of the modeling

The 'box model concept' is a very powerful tool to simulate mine flooding even in very large coal mine regions with many individual mines involved

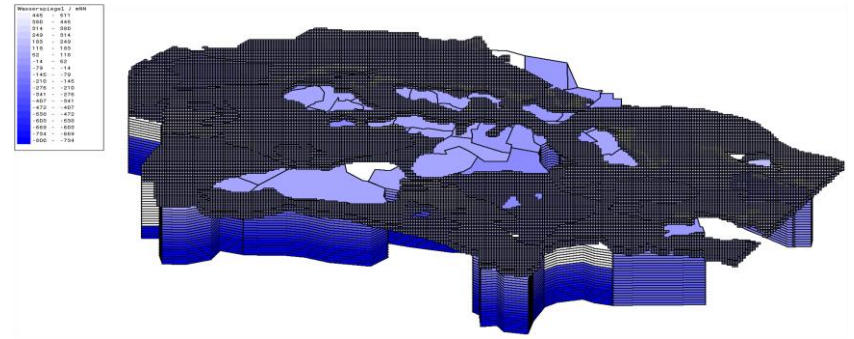
- Rising mine water levels for different flooding scenario
- Geochemical forecast of flooding water quality
 - Sulphate, Iron, Chloride,
 - special pollutants such as PCB, turbidity
- Uncertainty considerations / sensitivity analyzes
- Safety assessments: Standing water levels next to active mining operations

Thank you for Your attention

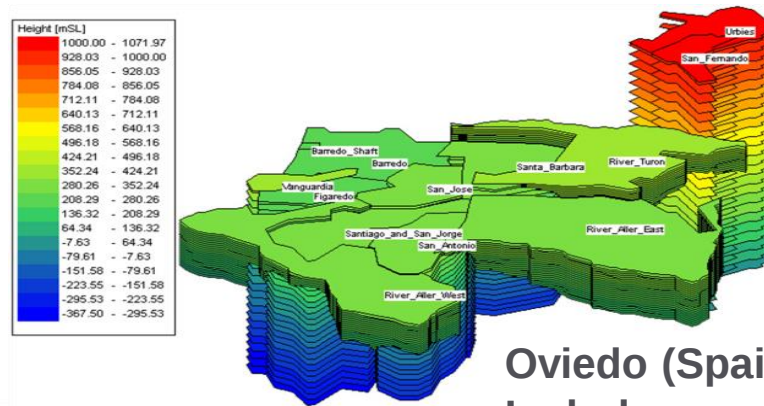
Examples of model discretization



Ruhr area (Germany)

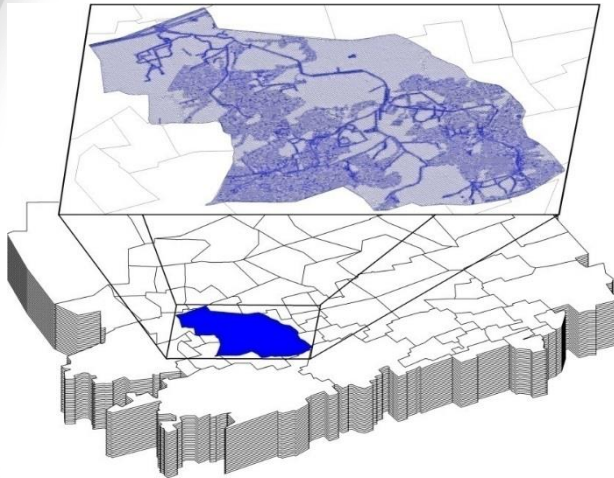


Upper Silesia (Poland):
3 GWL above coal mining

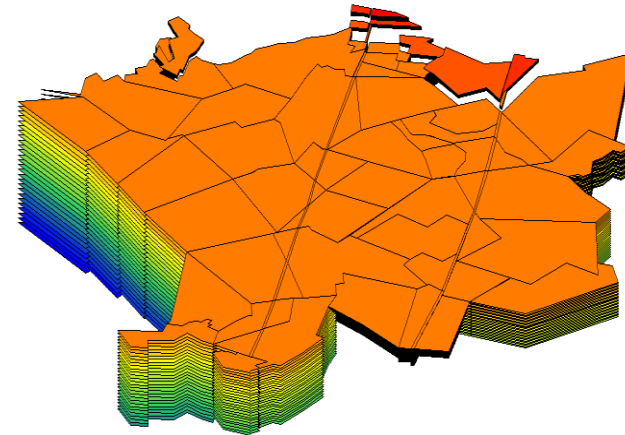


Oviedo (Spain):
Includes a mountain region

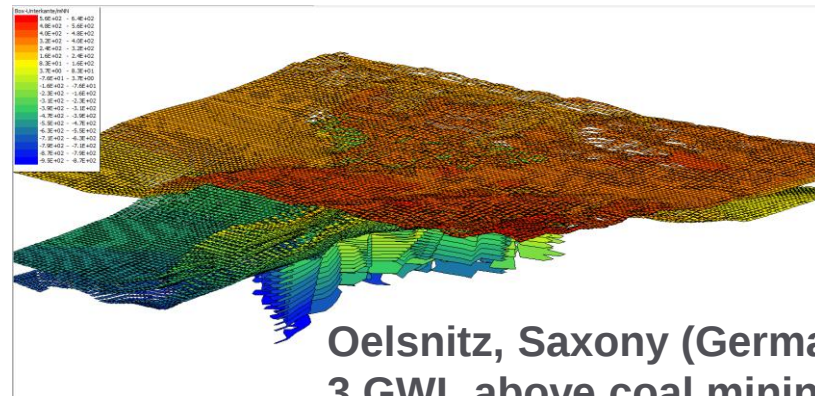
Examples of model discretization



Ruhr area (Germany):
Linked flow model
'Schwarzbach' (2 GWL
above coal mining)

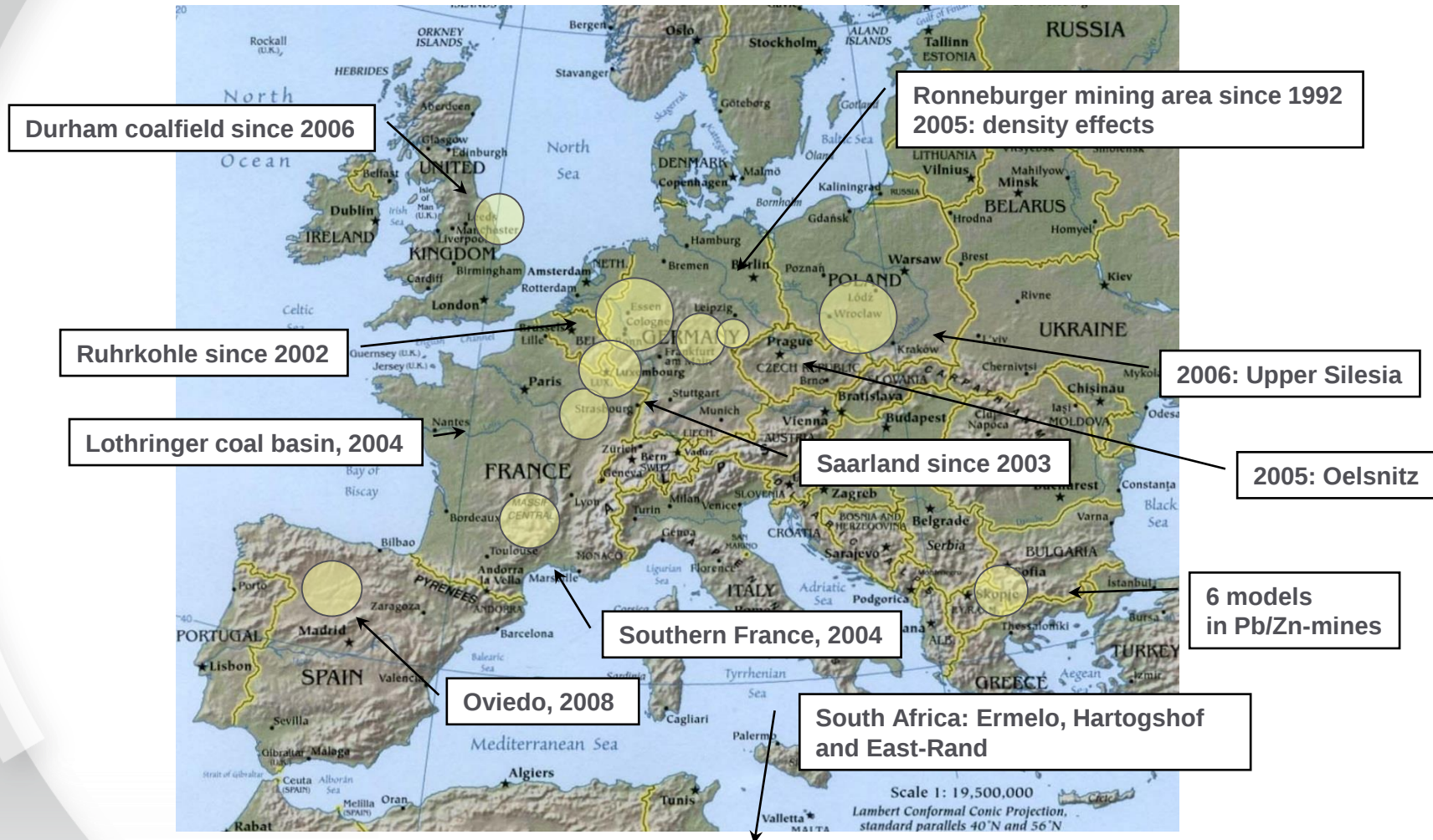


East-Rand (South Africa):
Including fault systems



Oelsnitz, Saxony (Germany):
3 GWL above coal mining

Further applications of the box model



Thank you for Your attention

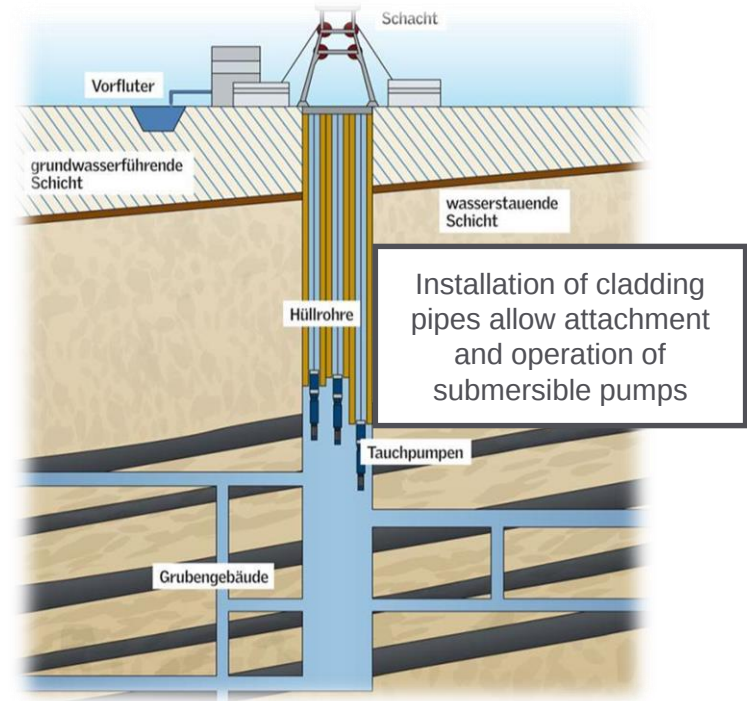
Historical development of the RAG



Installation of cladding tubes: Mine water level regulation as required Conversion to well operations



Cladding pipes in a shaft before shaft filling

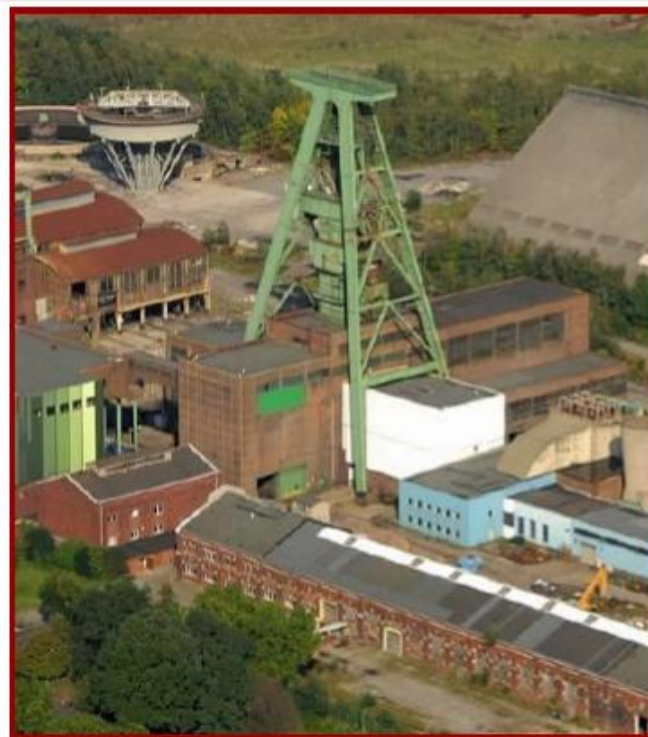


Tomorrow: Submersible pumps

Mine water management concept of RAG



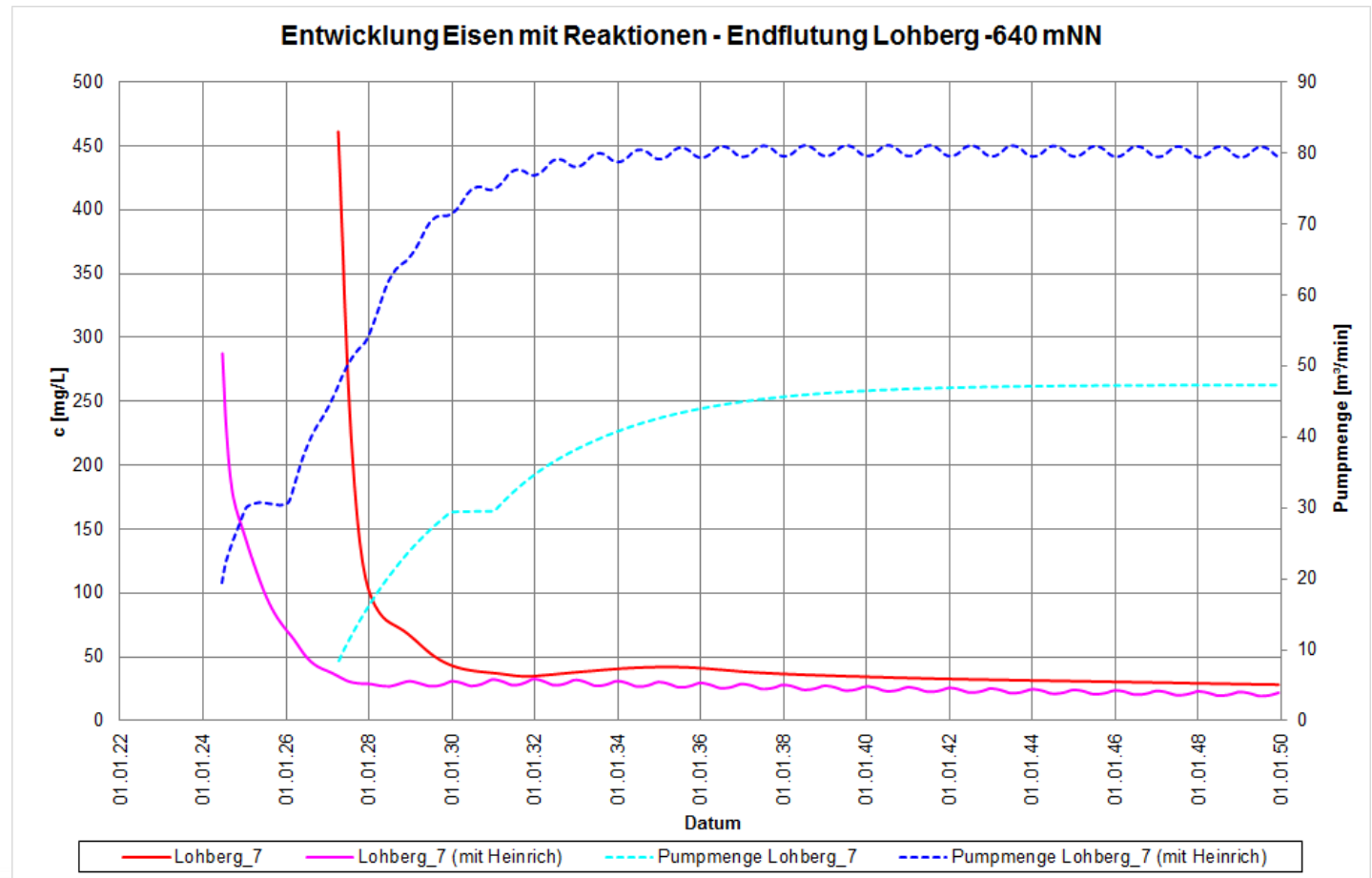
Ruhr region – Emscher area
Central mine drainage ‘Lohberg’



- Lohberg central dewatering system will pump the mine water from (today) seven dewatering points and discharge it directly into the river Rhine
- Planned start of operation is 2035

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Development of Iron in Lohberg



Development of Chloride in Lohberg

