Closing down the mining in the Saar Region, Germany: Are we creating a transboundary “great man-made aquifer”? 

Thomas Walter
LUA Saarland
A small German state in the middle of Europe...

Surface: 2565 km²
1.036.000 inhabitants
Adhesion to FRG in 1957
Language: german!
with hundreds of years of industrial history

5 large Foundries and steel mills since 15th century, thereof 3 still working with a total of 15,000 employed

Mining since pre-roman times, Systemstically since 18th century, Number of know shafts > 900
Coal mining in the Saar Region

- Increasing mechanisation
- First vertical shaft
- June 2012: end of mining activity

Coal extraction vs. labour
Overview over Mined Region

- 900 shafts,
- 10s of 1000s of km of galleries, adits and gateroads
Overview over Mined Region

Surface > 600 km²

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- 10s of 1000s of km of galleries, adits and gateroads
Overview over Mined Region

- Surface > 600 km$^2$
- 900 shafts, 10s of 1000s of km of galleries, adits and gateroads
Overview over Mined Region

Surface > 600 km²

- 900 shafts,
- 10s of 1000s of km of galleries, adits and gateroads
3D-Model of the Deposit

KVB-Model: calculation of coal resources in Germany as a cooperation project of the Geological Surveys of Northrine-Westphalia and Saarland and the German coal industry
Total amount mined until 2012: 2 bill. t, (1.5 % of total volume)

Estimated remaining void volume: 1.5 billion m³

JUCH et. al, 1994; JUCH, 1997
Problems:

- Continuing pumping causes long term costs: ~ 20 Mio. €/a

Mine flooding seems to be unavoidable and therefore a flooding strategy is essential

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<th>first phase: flooding process</th>
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<td>• Rising groundwater levels in densely populated regions</td>
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<td>• Complex hydraulic structure makes mine rebound difficult to predict</td>
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<td>• Additional damages to expect at the surface, due to buoyancy of the rock pile</td>
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<th>second phase: long term problems</th>
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<td>• Flooding will change the hydrogeochemical environment</td>
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<td>• Long term behaviour of void system?</td>
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<td>• Long time stability of conduits?</td>
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Pastor & al. (2007): Optimisation of mine water discharge by monitoring and modelling of geochemical processes and development of measures to protect aquifers and active mining areas from mine water contamination
Hydraulic System
Longwall Mining

Diagram showing subsidence profile with max. convex curvature, max. concave curvature, max. tensile strain, and max. compressive strain indicated. Also shows max. tilt and max. horizontal movement with respect to the ground level. The diagram includes elements such as seam, goaf area, panel width Wpa, and depth of cover H.
Fig. 1.7 Development of a Subsidence Trough (to an exaggerated vertical scale)
Hydraulic Concept

Unmined rock

**strata above mined coal seams:** increased permeability through mechanical stress

**Mined coal seams:**
large flat draining areas with high porosity (~20%)

**Shafts and adits:**
system of regionally communicating conduits

Natural porosity

Technically induced porosity

- tertiary technical porosity
- secondary technical porosity
- primary technical porosity

1 E+00 1 E-02 1 E-04 1 E-06 1 E-08 1 E-10
Hydrogeological Model

- Increased permeability
- Panel/goaf
- Regional drainage level
- Open cast mine
- Natural GW level
- Technical drainage level
- Unmined rock
- Shaft
- Adits

Increased permeability
Groundwater Recharge

Mine dewatering:
\[ \pm 2.5 \text{ l/s/km}^2 \]

\[ \Delta h = 180 \text{ m} \]

Natural GW Recharge:
\[ 2.5 \text{ l/s/km}^2 \]

1. Signal after heavy rainfalls after 2 weeks,
Time lag between peaks \[ \pm 6 \text{ weeks} \]

1000 m b. s.
Mining systems could be considered and modeled as a „Technical Karst System“ , Forming an Artificial Groundwater System
Overview:

• Large hydraulic system with relevant pore volume
• Densely interconnected conduits with large diameters
• Goaf zones act as internal drainage zones with a very high internal surface
• Rock up to 1000 m depth unsaturated since more than 100 years

→ Long and at least partially very fast flow paths
→ Enormous mineralisation potential
Prediction of Flooding Process
Box Model of the Saar Region (DMT)

single homogeneous boxes representing available void volume
gydraulic connections by geometrically correct representations of mine workings
Transboundary System of Boxes

Barrage Sarrois 110 bar

Total des venues d'eau 63.3 m³/min

mis à jour : 03/11/11
Flooding Process of the Lorrainian Mines

**Permo - trias**

- **Slow rebound:** high pore volume
- **Fast rebound:** low pore volume

*Courbes d'ennoyage des secteurs Merlebach et Forbach*
Linking Box and Groundwater Model

- Technical abstraction/recharge
- Inflow from underground drainage
- Inflow from groundwater
- Mine drainage
- Outflow into groundwater

Boxmodell

Grundwassermodell
But what about long term behaviour?

The Karst analogon seems to be a reasonable approach, but even if a 3D-model of the deposit already exists and geometrical information is available with a very high degree of reliability, it most probably will turn out as not practicable due to information overflow.

Solution:

Finding the right balance between detailed view and overly simplification!
Conclusion

- It is fairly large
- It is obviously man-made
- It crosses an international boundary
- And it is capable to transport water over large distances

-> so it is a large transboundary man-made aquifer!

.... especially having in mind future mine closures (Germany, Poland, Ukraine etc.)