Estimation of Key Parameters for Shallow Geothermal Assessment in Multi-Layered Aquifers Using 3-D Geological Modeling: Case Study in Augsburg, Germany

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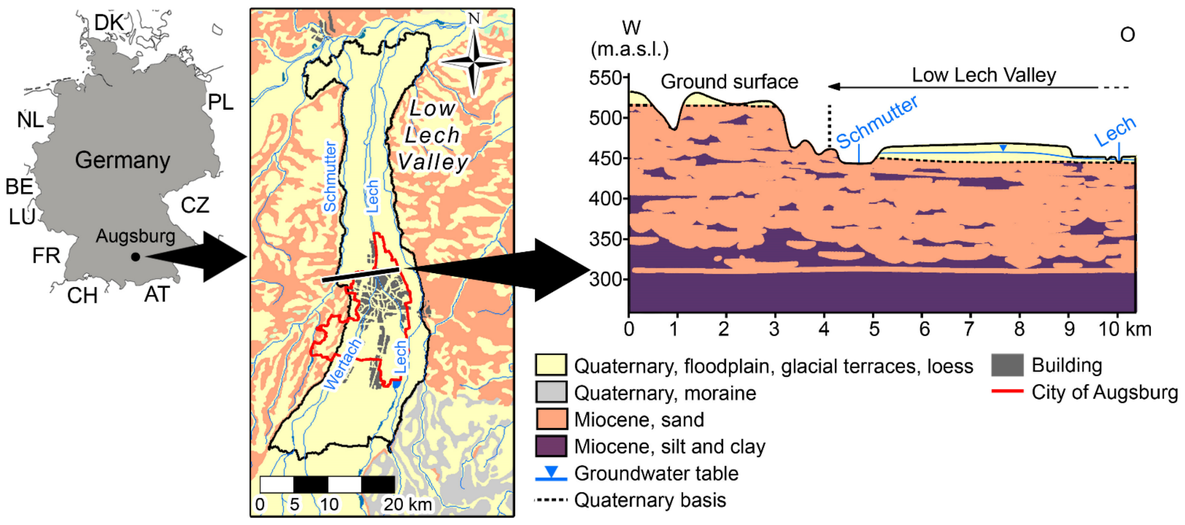
Geological Setting: The Augsburg Area

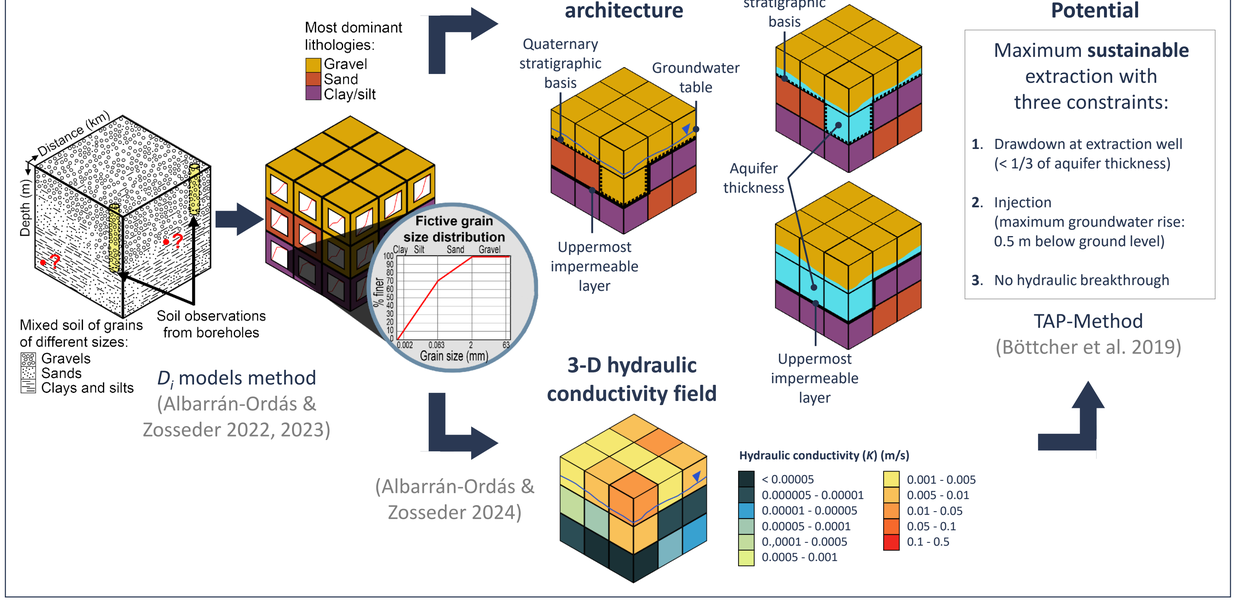


Goals

1. **Characterization** of the **multi-layer aquifer system**: composition & boundaries
2. Determination of **key spatial parameters** for open-loop geothermal heat pumps (GHP)
3. Assessing & managing **potential** for **open-loop GHP**

Methodology

Geological reality → Stochastic 3-D modeling of sediments → Estimation of 3-D aquifer geometries & properties distribution → Potential assessment



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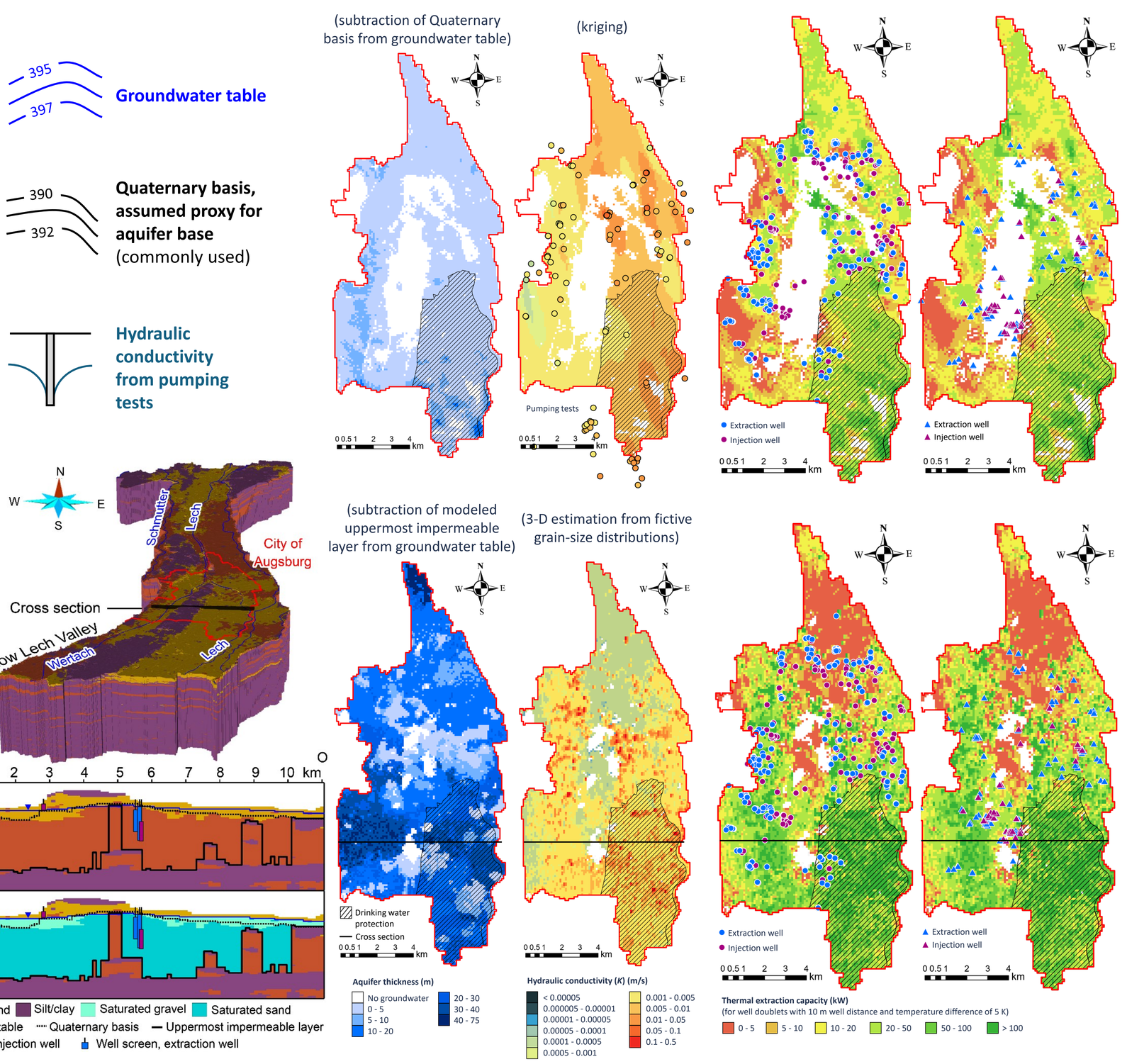
Results: Conventional vs. 3-D Geomodeling Approach

Approach	Aquifer definition data	Key parameters: Aquifer thickness	Key parameters: Hydraulic conductivity (K) within the aquifer	Open-loop GHP potential & installations: Potential and GHP wells in the Quaternary	Open-loop GHP potential & installations: Potential and GHP wells in the Miocene
Conventional with 2-D data from simplified datasets (common practice)	**Groundwater table**	(subtraction of Quaternary basis from groundwater table)	(kriging)		
	Quaternary basis, assumed proxy for aquifer base (commonly used)				
	Hydraulic conductivity from pumping tests				
Enhanced by 3-D geological modeling (proposed practice)		(subtraction of modeled uppermost impermeable layer from groundwater table)	(3-D estimation from fictive grain-size distributions)		



Conclusions

Current utilization of open-loop GHP wells

512 wells screened in the Quaternary (44%)
- 59% for injection
  - ► in dry Quaternary deposits only injection
- 41% for extraction

264 wells screened in the Miocene (22%)
- 25% for injection
- 75% for extraction

395 wells screened partially in both (34%)

Limitations of common practice

- **Poor alignment of GHP wells with potential**
  - ► Example: apparent high potential in the N
  - ► Reason: insufficient heterogeneity integration limited by the use of K from pumping tests
- **No compliance with the assumed proxy for the aquifer base (Quaternary basis)**
  - ► 56% of wells not screened in the Quaternary
  - ► Reason: Quaternary basis ≠ aquifer base

Obstacles to effective potential management

Key strengths of the proposed practice

- **Adequate match of GHP wells with potential**
  - ► Reason: improved integration of heterogeneity provided by the modeled grain-size patterns and location-dependent K
- **Correspondence with the modeled uppermost impermeable layer**
  - ► Reason: the delineation of aquifer geometries provides a realistic representation of the aquifer base

Improvement of geothermal potential estimation and management

Acknowledgements

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