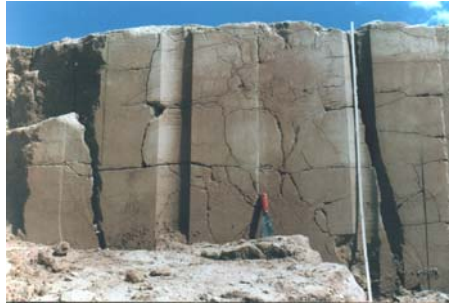


Vulnerability Assessment for Fractured-Matrix-Systems

by Dipl.-Ing. Rainer Enzenhoefer



(Pliezhausen, Dietrich 2005)

„Drinking water is essential for life and can't be substituted“
(DIN 2000)



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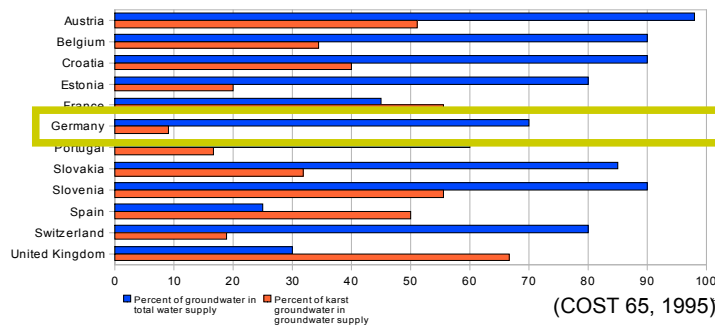
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Motivation

- Groundwater use for water supply
- Carbonate rock outcrops



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Introduction to Karstic Systems



- Storativity
- Flow velocities
- Scale dependency
- Huge catchment areas



Source: www.geopanorama.mcan.gc.ca



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Motivation

- Potential sources of contamination
 - ➔ Groundwater Protection
 - WFD: Groundwater Quality the biggest problem
 - ➔ Multi-barrier concept – Risk Assessment
 - Source, Pathway, Receptor
 - ➔ Water Safety Plan
- Challenges within a karstic system
 - ➔ reduced surface protection cover
 - ➔ fast fracture flow
 - ➔ high matrix storage



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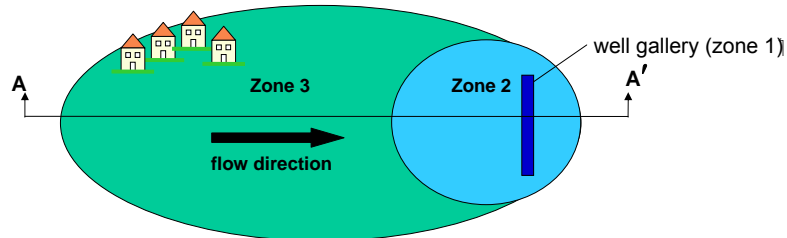
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Model concept

Model sketch for the possible investigation site:



- 1) How long does it take, that a contaminant reaches the well?
- 2) How long does it take, that a concentration limit is reached?
- 3) How long will the concentration be above the limit?
- 4) Where are the most sensitive zones within the catchment area?
- 5) How sure can be a supplier to pump „clean“ drinking water?



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Aim

- Develop an approach to assess the risk towards a well within a karstic aquifer system by identifying vulnerable sites on catchment scale.
 - Quantify actual threats
 - Prioritize vulnerable areas in protection strategies
 - Easy in application - overview over the catchment area
- Accounts for uncertainty
- Application for a real case scenario



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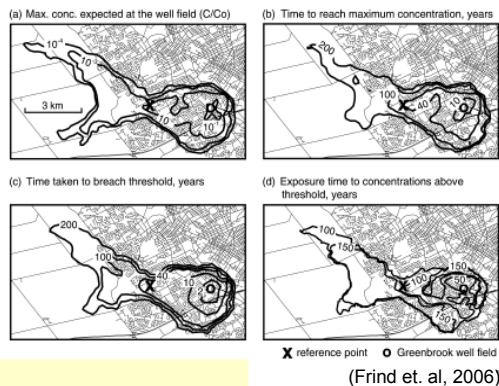
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Example in Porous Media

Well vulnerability measures:

1. Expected maximum concentration
2. Average travel time
3. Time until threshold is breached
4. Exposure time



Example ($c/c_0 = 1.0$):

- Max. concentration in ~ 40 yrs (2.)
- Expected maximum concentration 10^{-2} (1.)
- Threshold level 10^{-4} in ~ 35 yrs. (3.)
- Prevails for ~100yrs. (4.)



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Test site

Zweckverband Landeswasserversorgung

- Baden-Wuerttemberg, Germany
- Zweckverband Landeswasserversorgung
- $Q = \sim 100 \text{ Mio m}^3/\text{a}$
- Population: 3Mio
- GW-Anteil ~ 65%



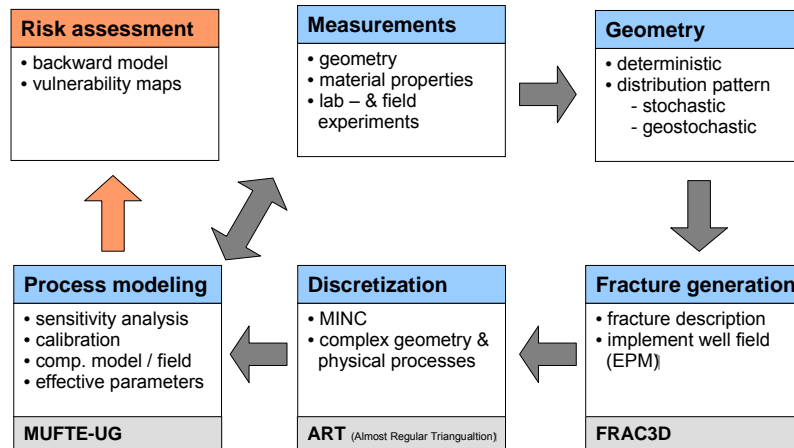
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Overview – Vulnerability assessment



(modified from: Silberhorn-Hemminger, 2002)



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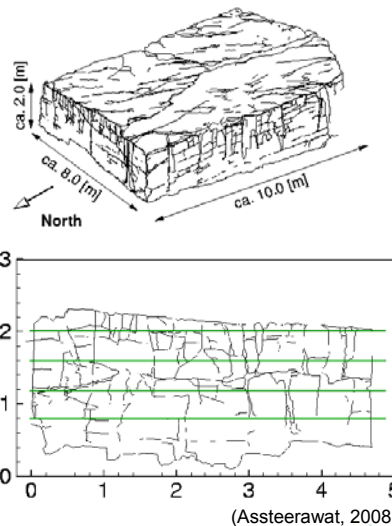
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Measurements – fracture characteristics

- fracture aperture
- fracture density
- fracture orientation:
 - strike (or azimuth) and dip
- fracture size: shape
- fracture trace: length
- fracture connectivity
-



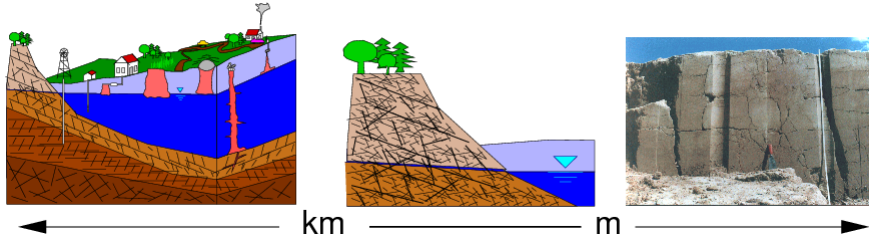
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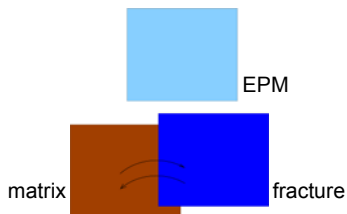
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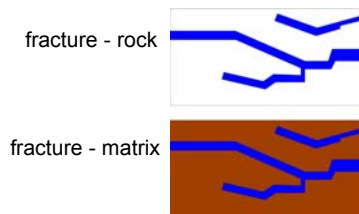
Scale Model approach



Continuum Model



Discrete Model



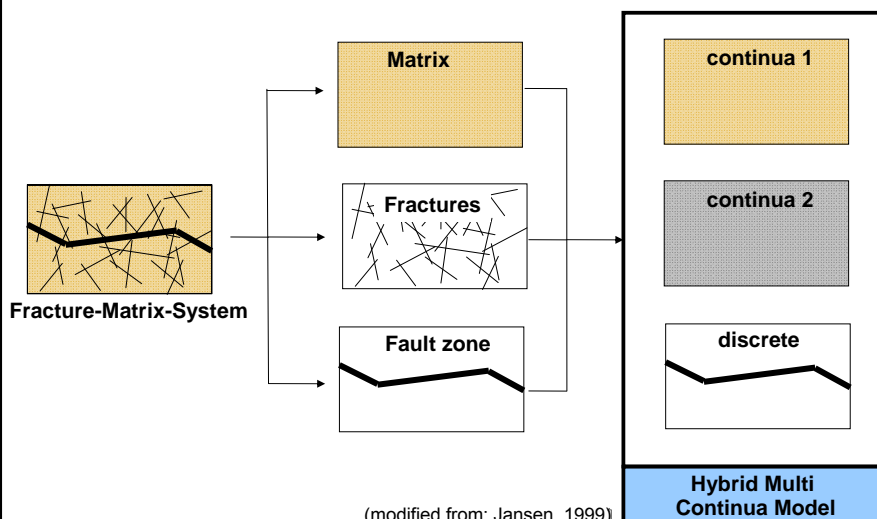
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Flow concept – Hybrid Multi Continuum Model



(modified from: Jansen, 1999)



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What to expect from the course?

- Learn to introduce risk into the field of karstic modeling and groundwater protection
 - Risk assessment on local and on catchment scale
- Risk assessment is fundamental to describe the 4 well vulnerabilities
- Enhance the concept of the actual risk assessment
 - Implement fate and attenuation processes
- Learn about the weaknesses and strength of the presented risk model concept



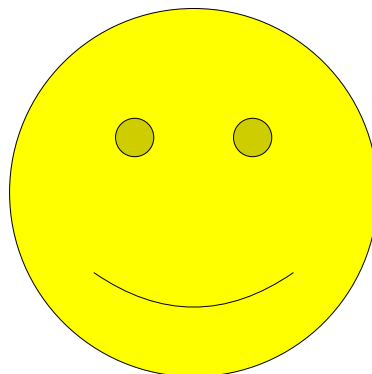
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Questions?



Thank you very much!!



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