



Dept. of Hydrology  
University of Bayreuth



Lawrence  
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# ***Modeling the effects of geologic heterogeneity on river-aquifer exchange - dynamics and patterns in rivers with deep water table***

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*GW-SW Workshop, University of Sheffield, March 12<sup>th</sup>, 2008*

# Hypotheses

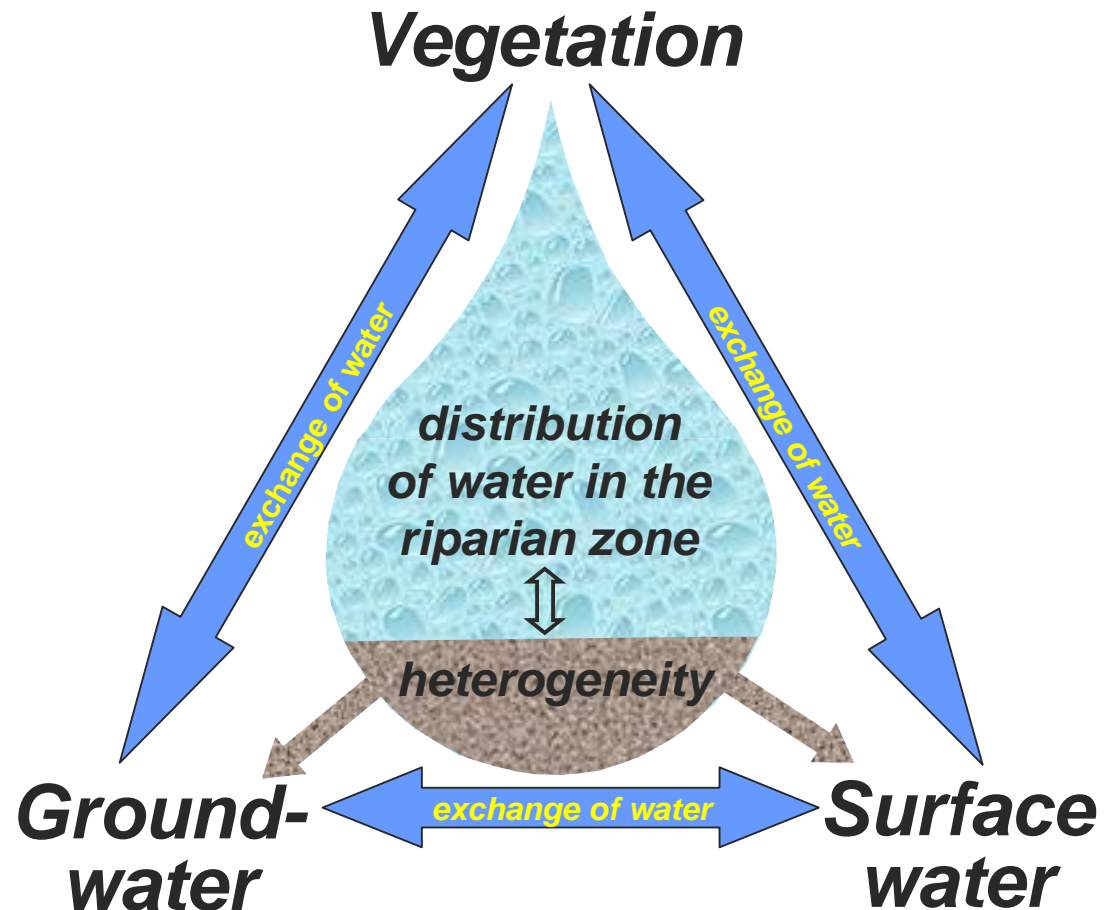
## Heterogeneity



- spatial variability of seepage
- perched aquifers
- riparian water distribution

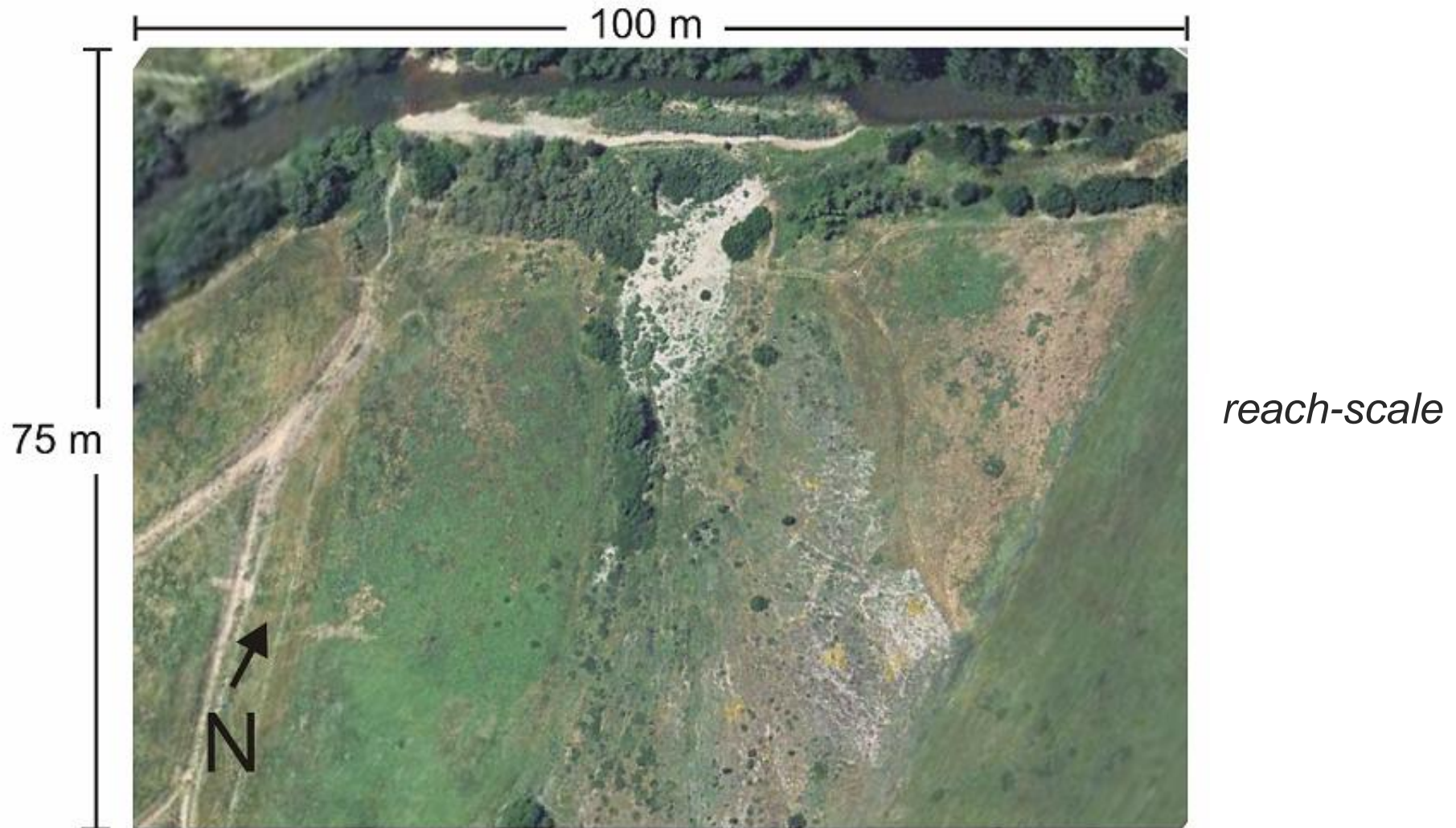


- groundwater recharge
- water availability for plants
- low river flows



*water & ecological management*

**Example: Cosumnes River, California**



# **Cosumnes River at Highway 99 - intermittent**



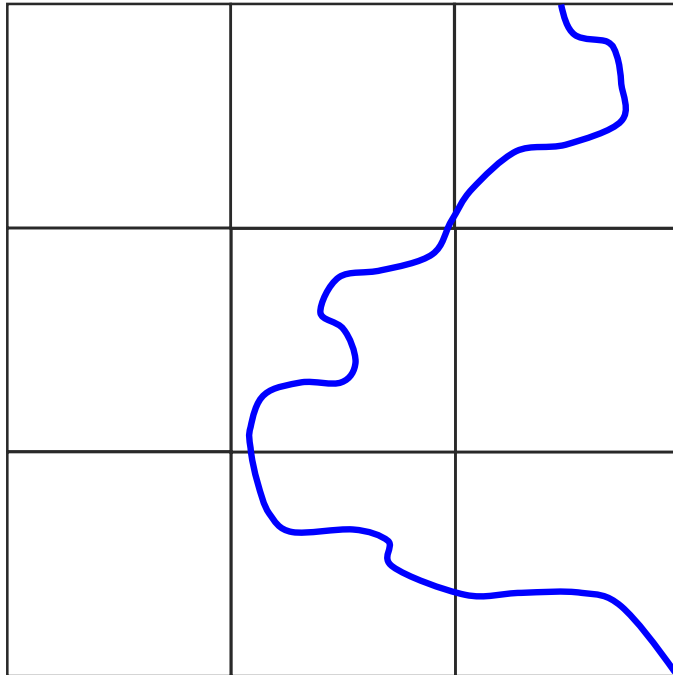
*September 2001*



*June 2002*

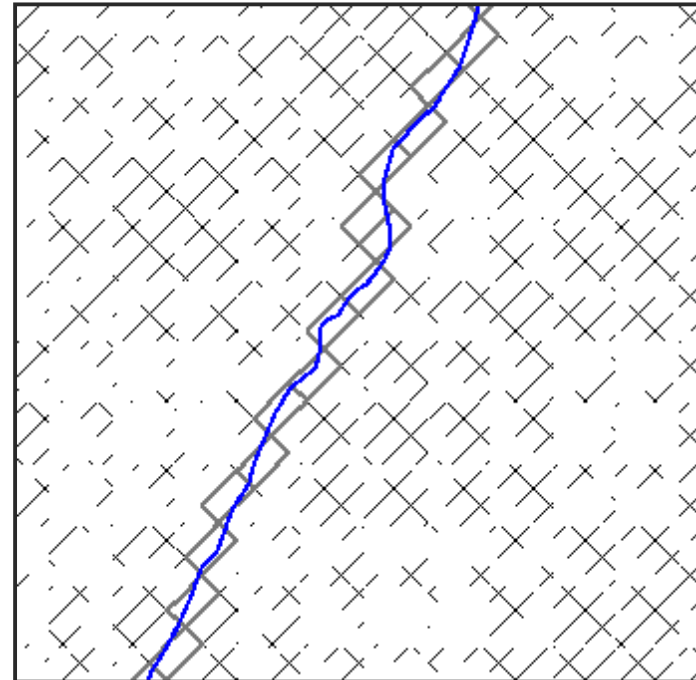
# Modeling river-aquifer exchange – scales

*regional-scale*



*50-100s of km river length  
grid cells  $\gg$  river channel dimensions  
purpose of modeling:  
river-recharge to aquifers  
regional water balance (e.g. conjunctive use)*

*river-scale*



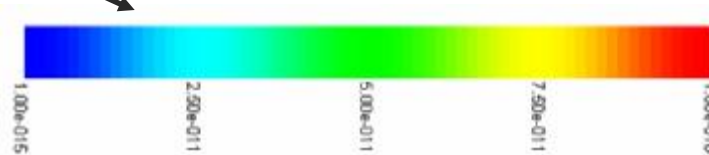
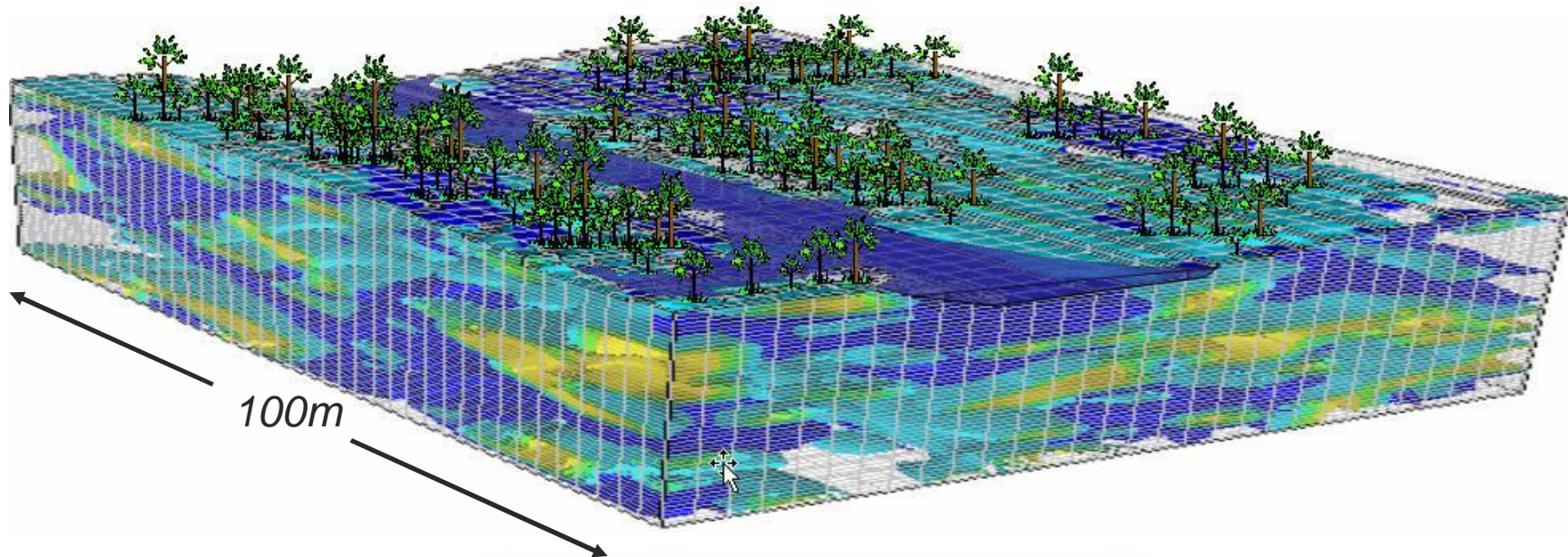
*5-50 km river length  
grid cells  $\approx$  river channel dimensions  
purpose of modeling:  
exchange patterns (e.g. loss v. gain)  
river flows (e.g. base flows)*

# Modeling river-aquifer exchange - scales

*reach-scale*

*100-1000 m river length  
several grid cells make up river channel*

*purpose of modeling  
hyporheic exchange  
riparian moisture (e.g. phreatophytes)*



*Permeability [m<sup>2</sup>]*

# Methods

## Representation of geologic heterogeneity

- geostatistical simulation – SIS (hydrofacies)
- multiple realizations → Monte Carlo analysis

## Numerical modeling

### river-scale

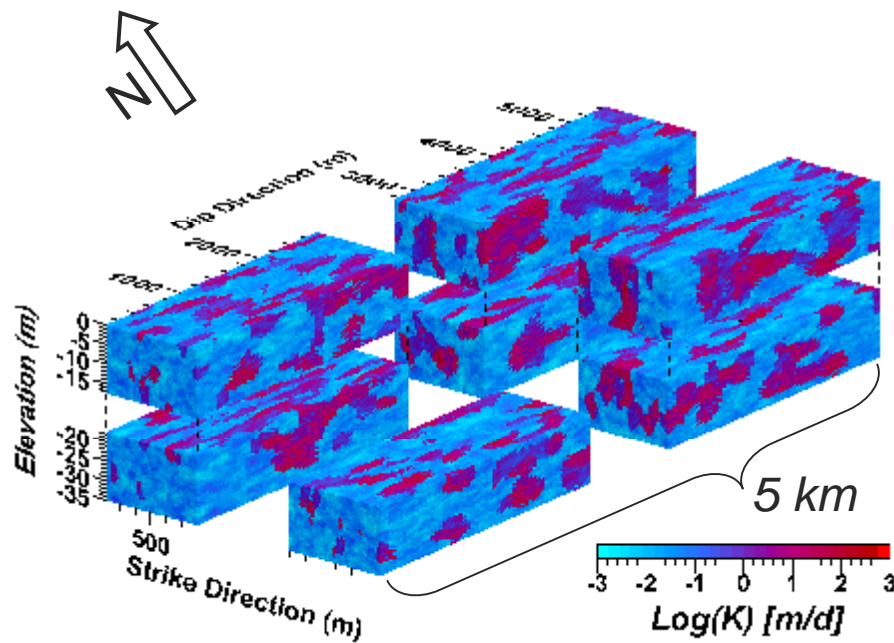
- variably saturated flow (Richard's eq.), van Genuchten retention model
- river flow: kinematic wave
- code: PARFLOW, run in parallel mode on linux-cluster, (*Kollet and Maxwell 2006*)

### reach-scale

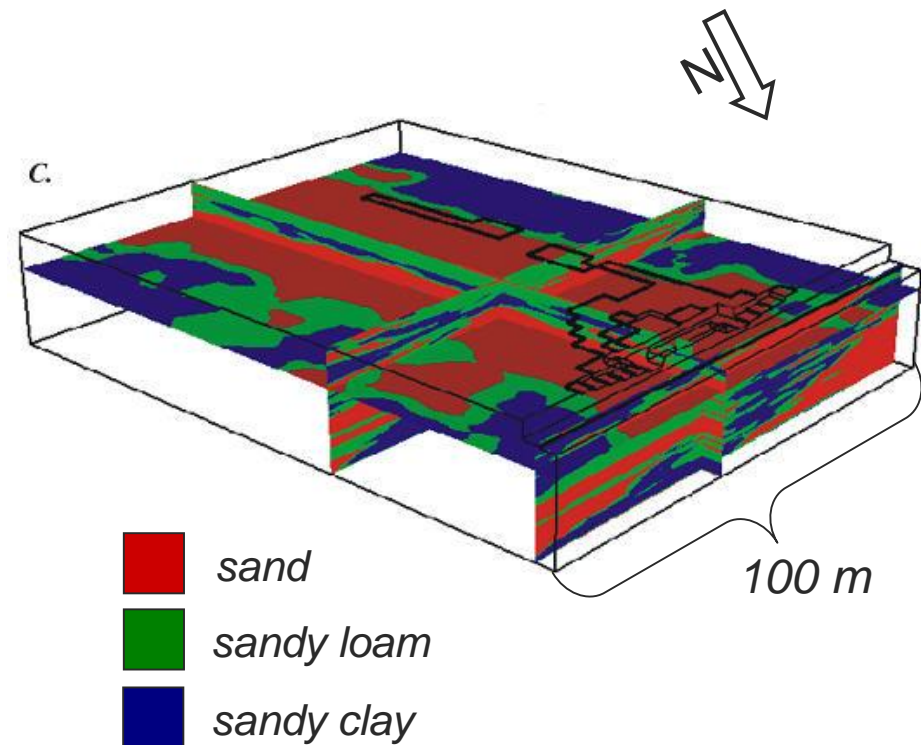
- variably saturated flow (Richard's eq.) heat flow, van Genuchten retention model
- river flow: pressure boundary condition
- code: TOUGH2 (*Pruess et al. 1999*)

# Distribution of hydrofacies - geostatistics

river-scale



reach-scale

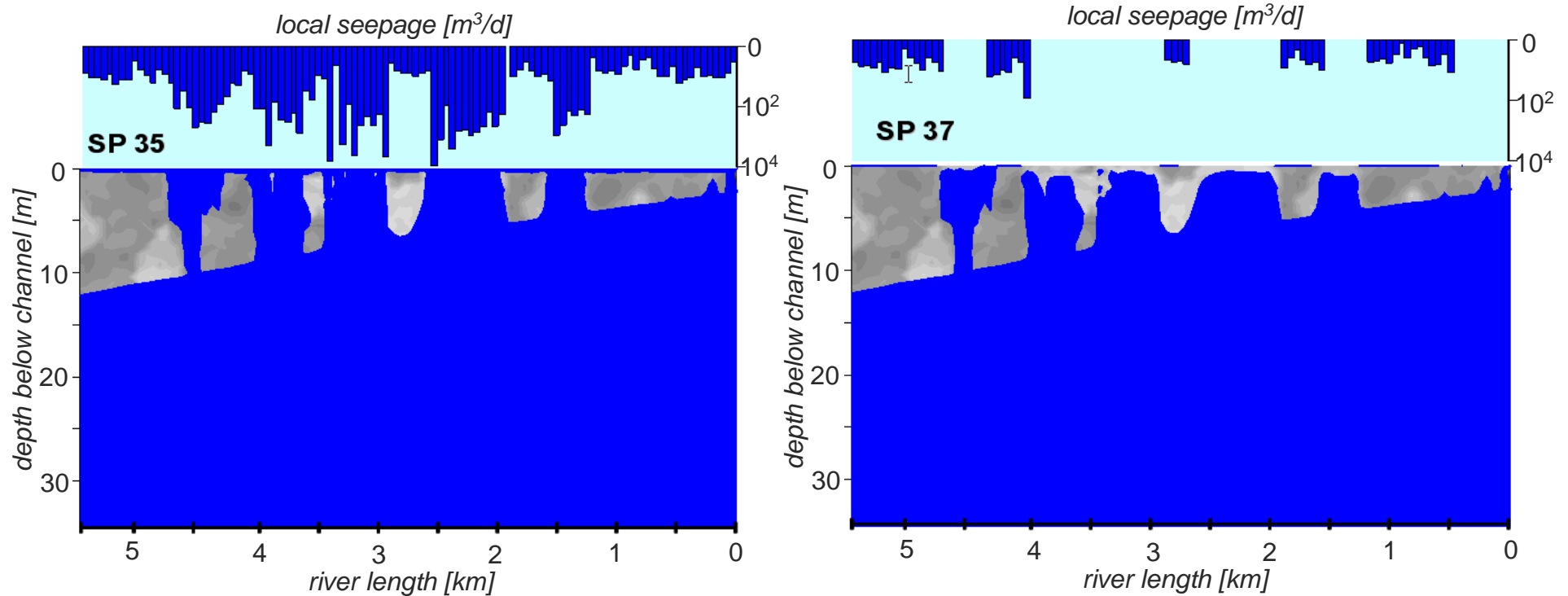


# Simulated saturation – river-scale

## longitudinal profiles

continuous flow phase

drying phase



formation of preferential flow areas and perched zones

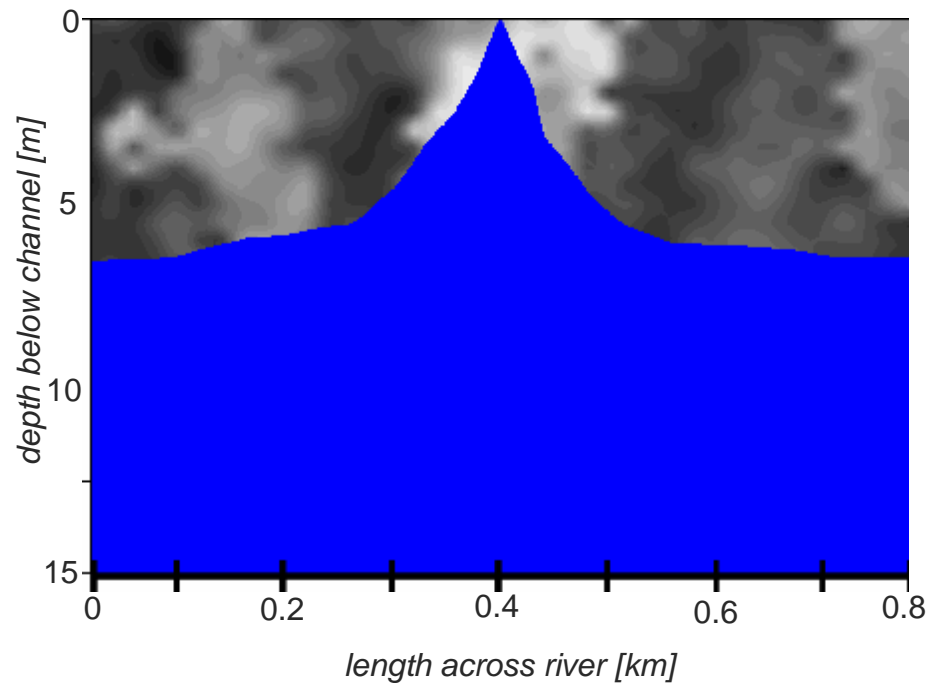
grey colors indicate hydraulic K: dark grey = low, light grey = high

■ = full saturation

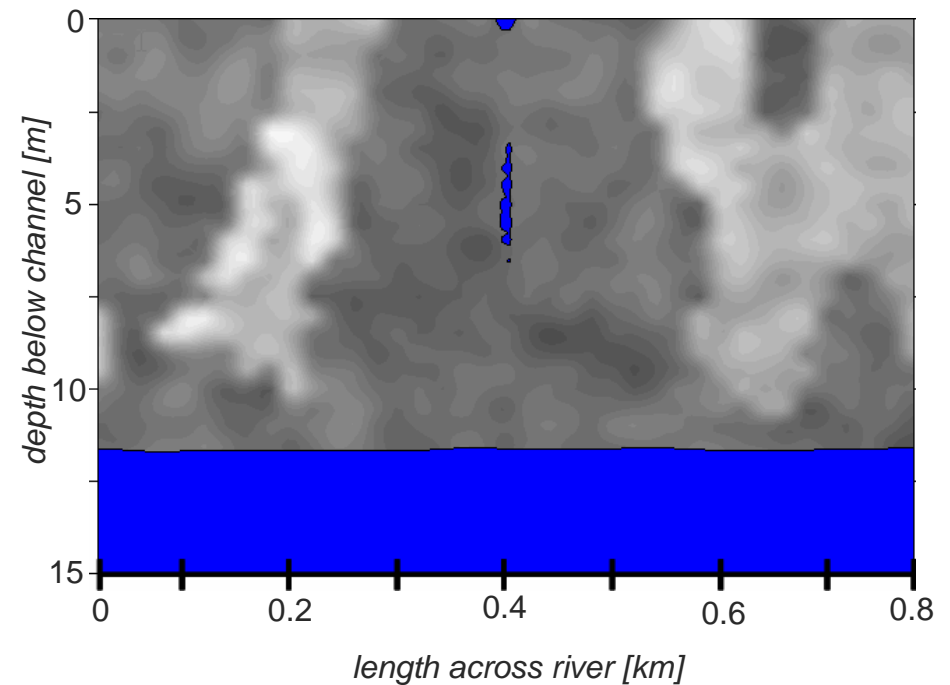
# Simulated saturation – river-scale

## cross-sections

*preferential flow area*



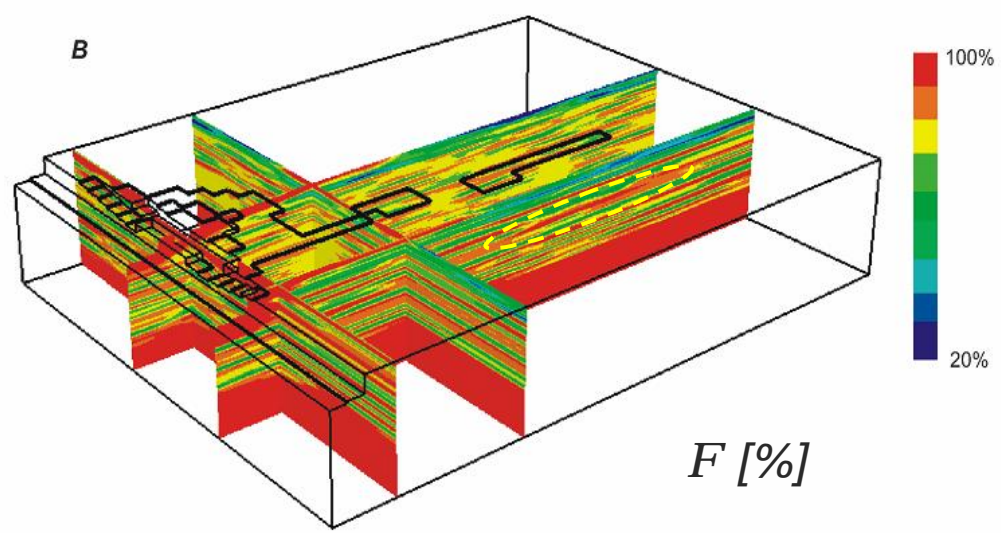
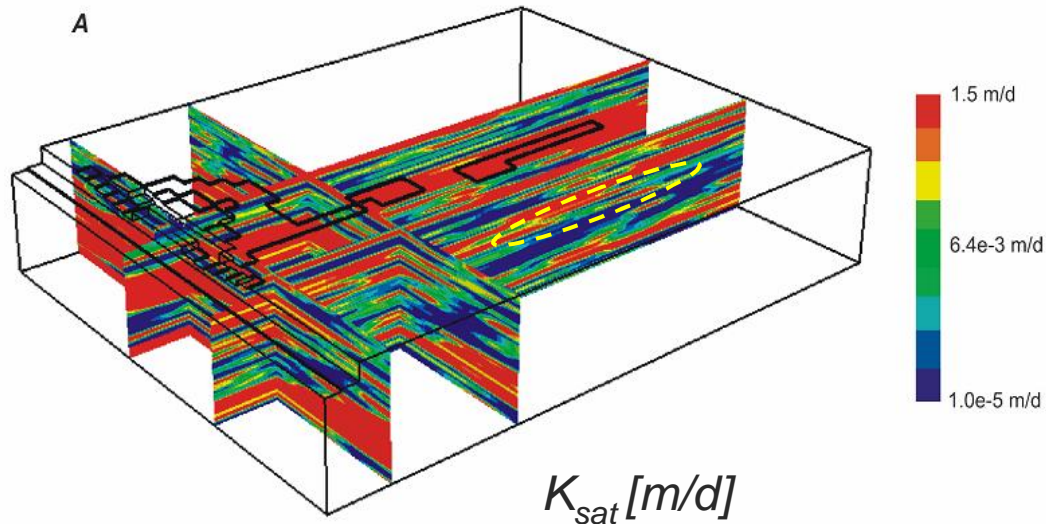
*perched area*



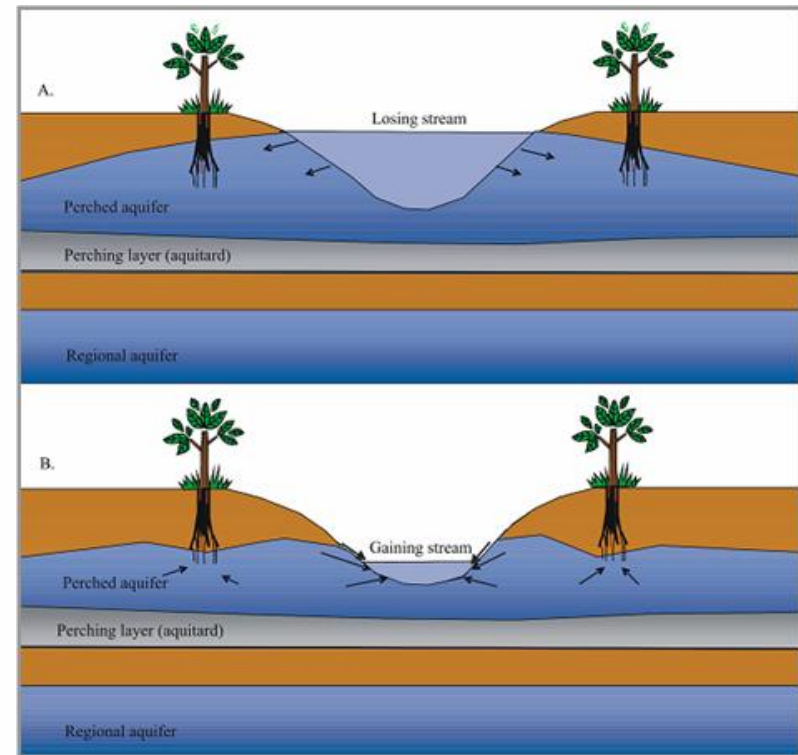
grey colors indicate hydraulic K: dark grey = low, light grey = high

 = full saturation

# Simulated saturation – reach-scale



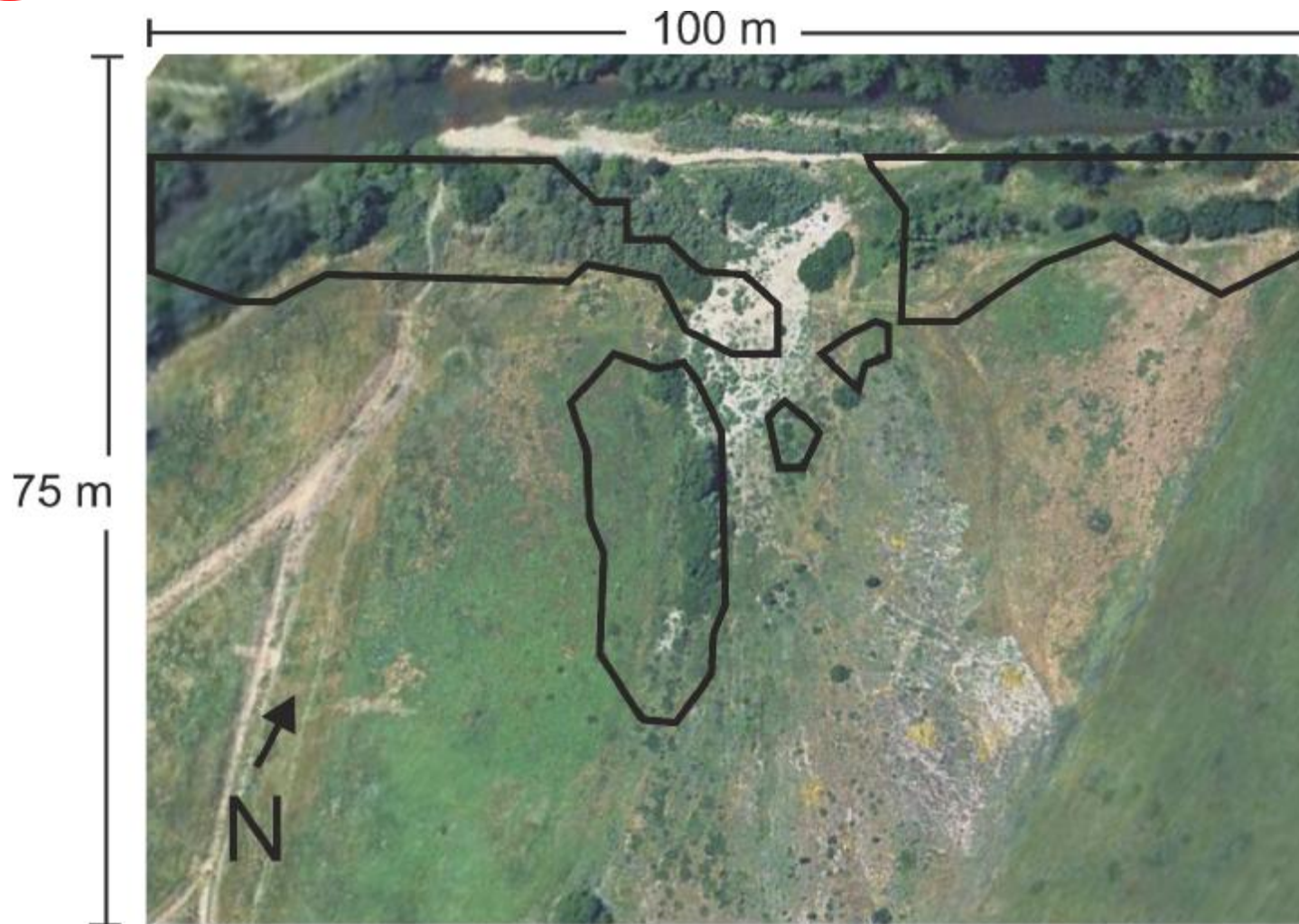
## perched aquifers



A = wet-season B = dry-season

Niswonger 2005

# Simulated moisture distribution – reach-scale



*polygons indicate zones with sufficient moisture to support phreatophytes*

## Conclusions

- hydrofacies heterogeneity is an important control of seepage
- focused seepage and perched aquifers
- distinct spatial and temporal patterns of connectivity
- distinct river flow patterns → duration of critical low flows
- connectivity controls riparian moisture → phreatophyte distribution
- significant buffering of the vadose zone → seepage ≠ GW recharge
- powerful integrated models exist to simulate patterns and dynamics at river- and reach scales
- models are computationally expensive but provide important insights

### Management implications

- feedbacks between deep water table and river via preferential flow paths
- perched areas can sustain riparian vegetation
- concept of „disconnection“ in rivers with deep water table is questionable

# Acknowledgements

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