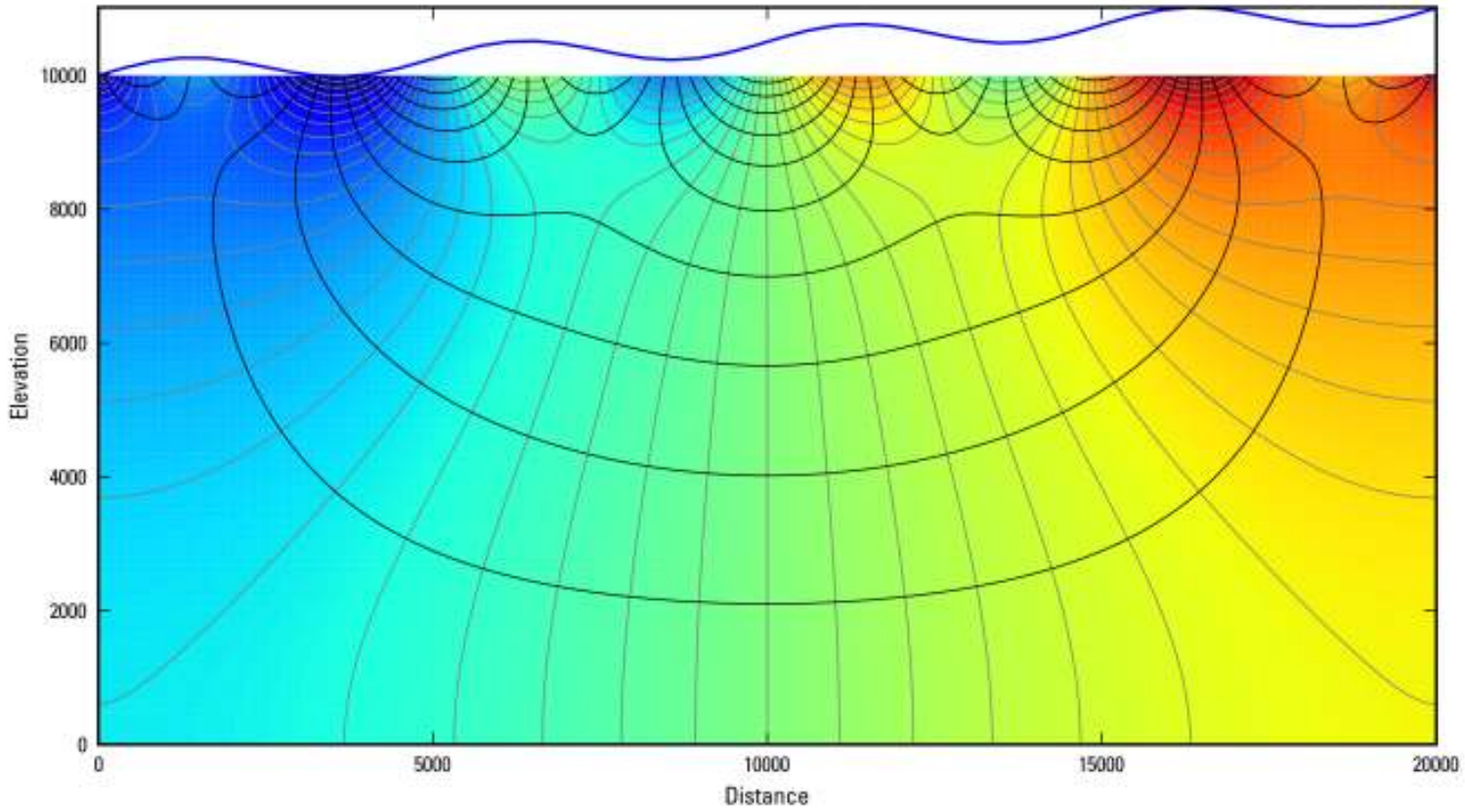
International Conference and Field Seminar
Karst Without Boundaries

11-15 June 2014
Trebinje (Bosnia & Herzegovina)
Dubrovnik (Croatia)

Numeric Modeling of Well Capture Zones in Karst Aquifers

Alex Mikszewski, Neven Kresic, AMEC

Porous Media Models – Well Established



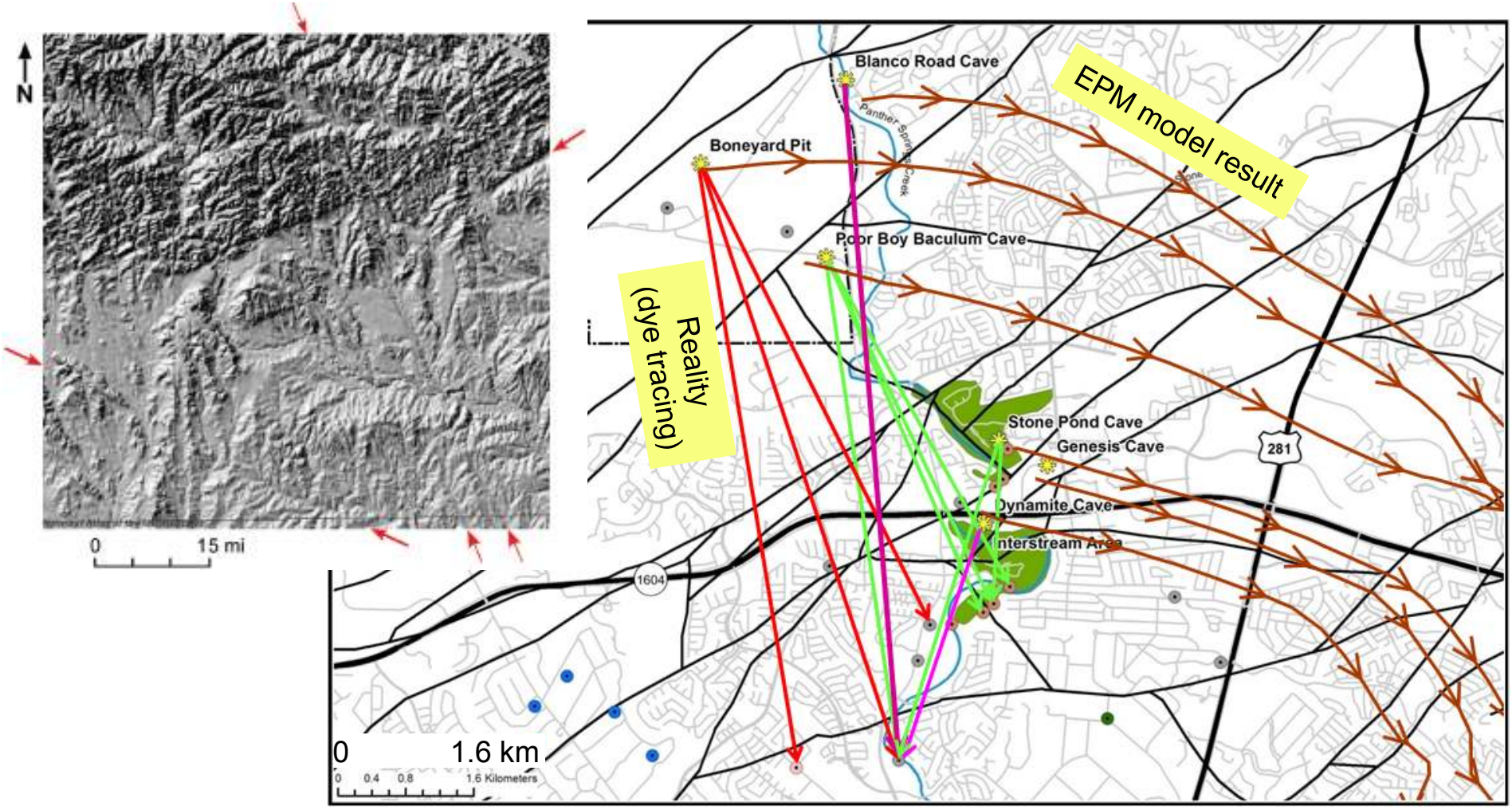
Main limitations

- Continuous layers
- Computationally intensive
- EPM approach

Positive developments

- Conduit Flow Process (CFP)
- MODFLOW USG

Regional **EPM** Model of Edwards Aquifer, Texas, USA

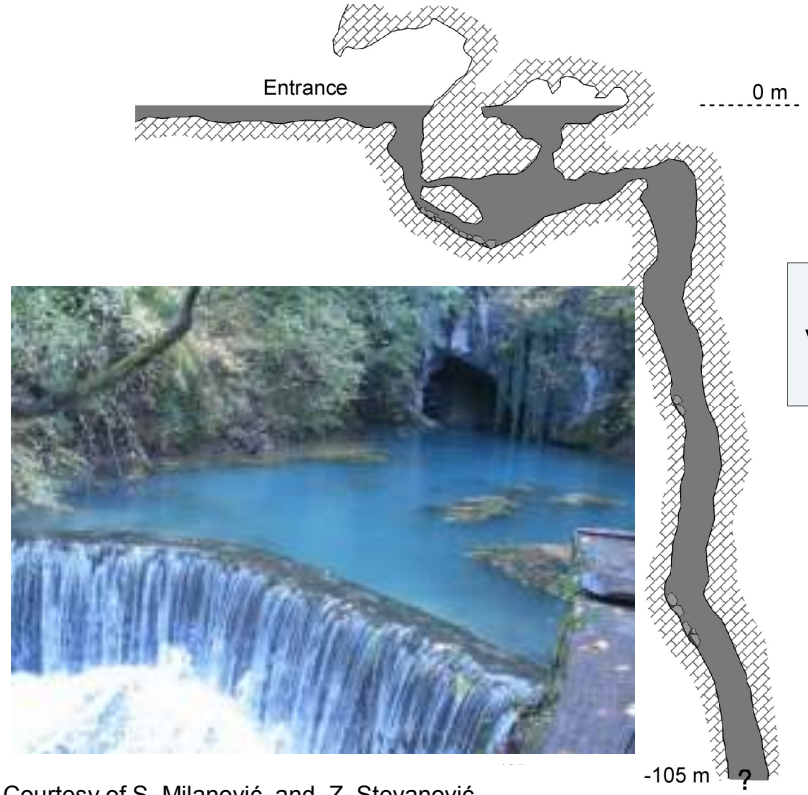


Courtesy of Geary Schindel, Edwards Aquifer Authority, San Antonio, Texas

EPM model velocity: ~ 1.5 km/year

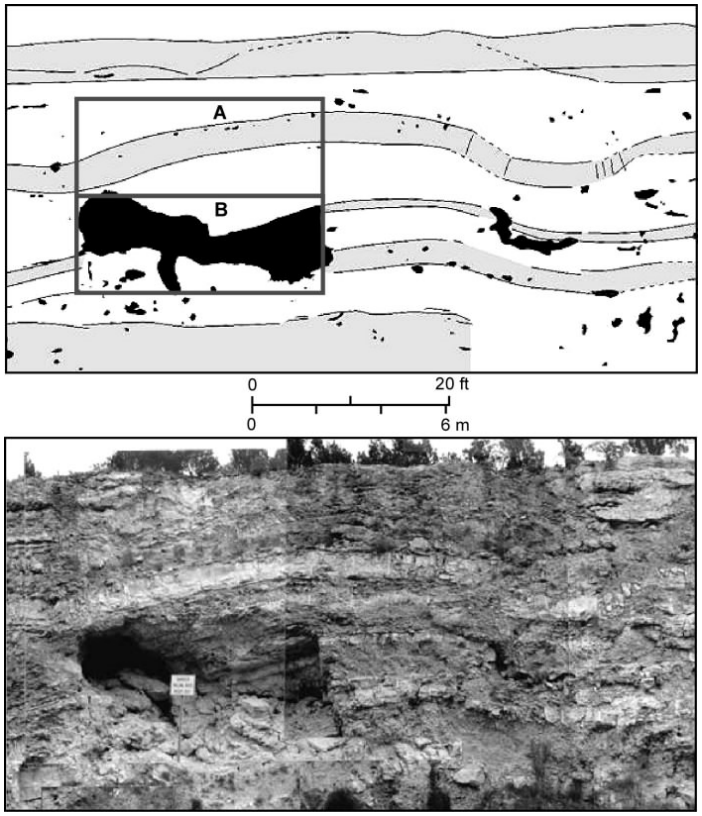
Reality: 25 m/day to 3.7 km/day

EPM models often defeat common sense
Can effective porosity of empty space be 0.00025?



Courtesy of S. Milanović and Z. Stevanović

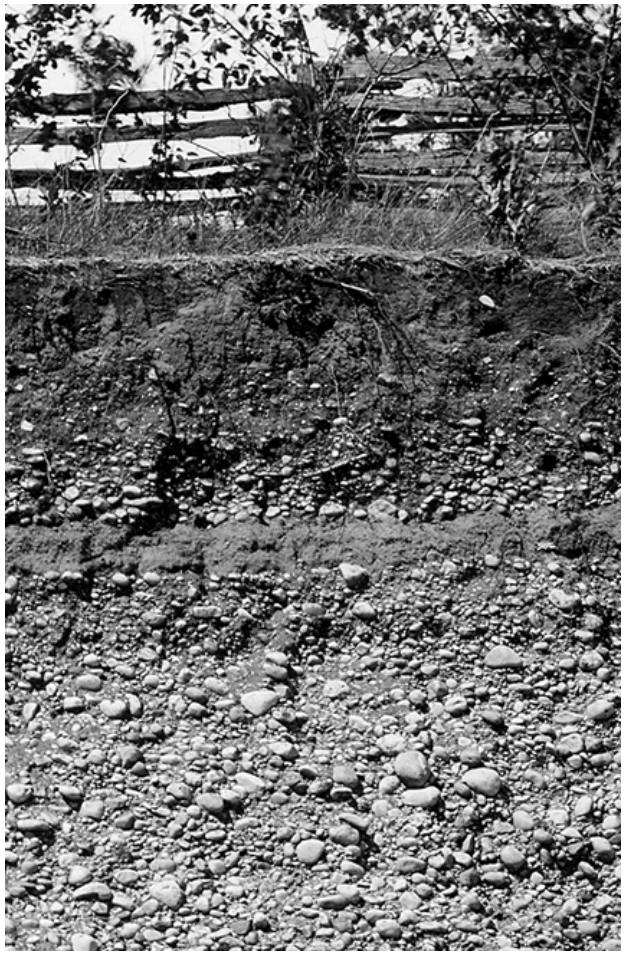
$$v = \frac{K \times i}{n_{eff}}$$



Modified from Hovorka, 2009

High flow velocities in EPM models are often simulated using extremely small effective porosity (n_{eff}) in cells representing preferential flow paths (conduits)

Physically-based modeling

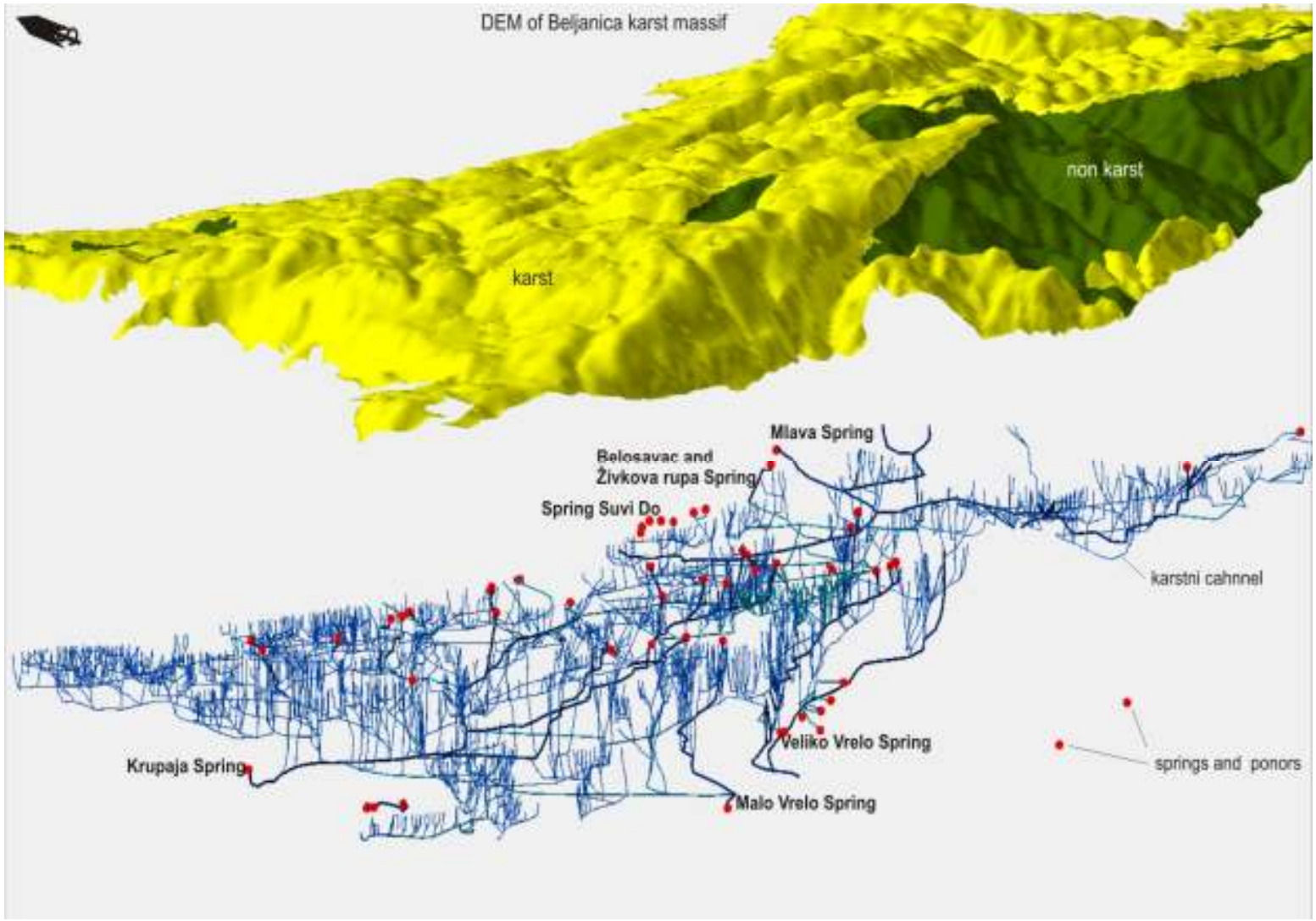


Courtesy of Geary Schindel

Valdina Farm sinkhole, Texas

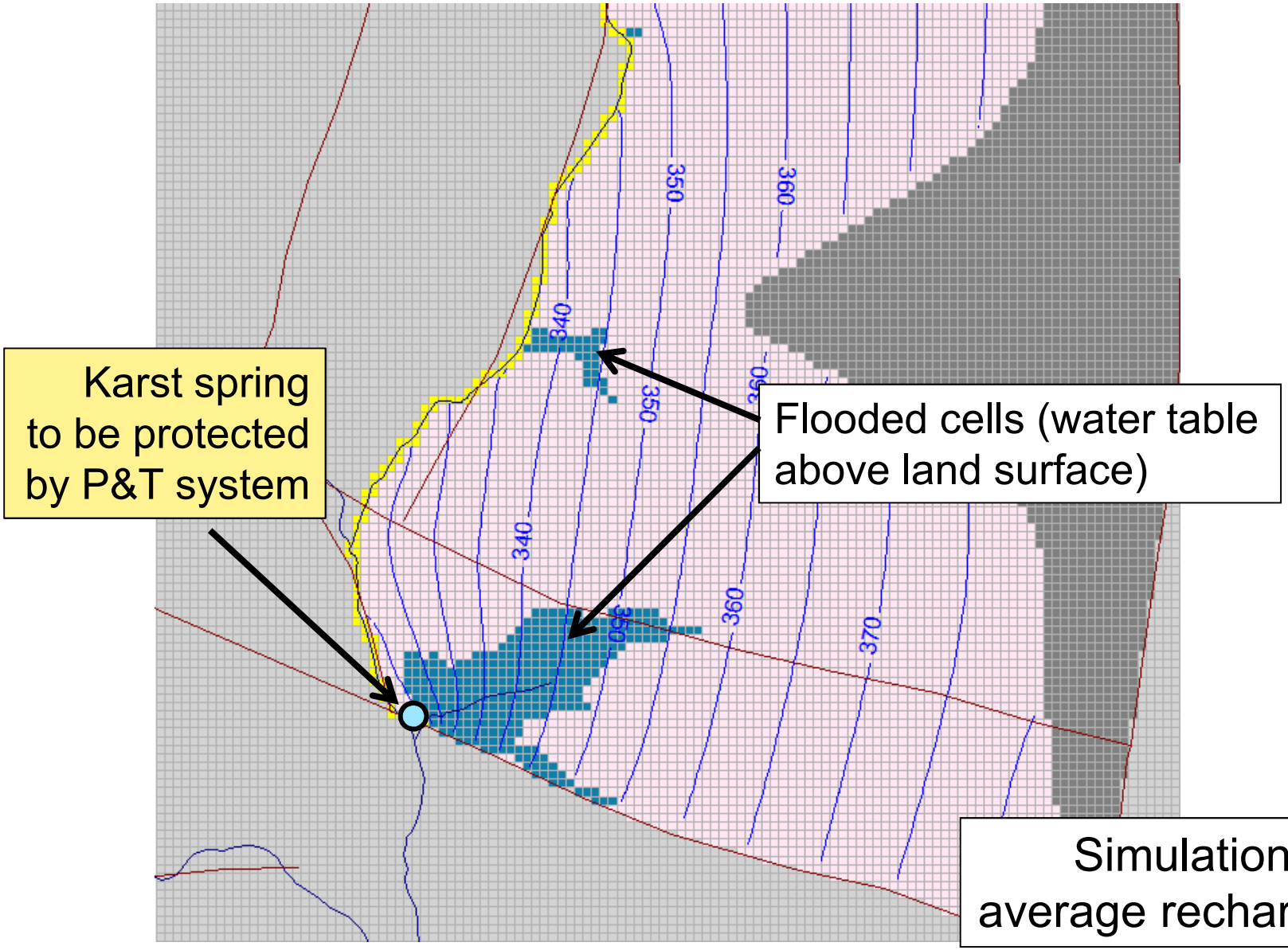
Courtesy of Dave Bunnell

Reality of convoluted 3D conduit networks

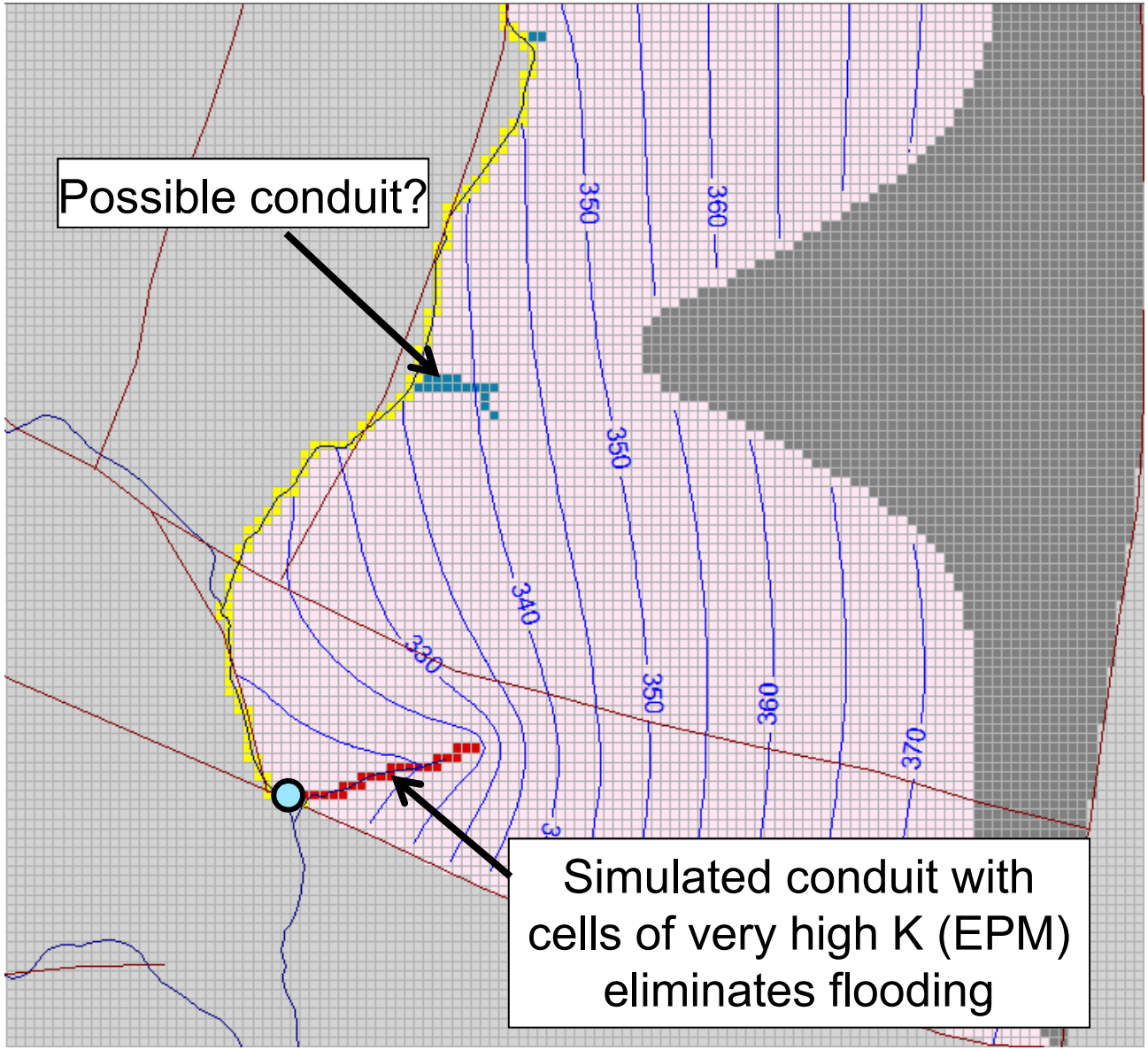


Courtesy of Dr. Sasa Milanovic, Centre for Karst Hydrogeology, University of Belgrade

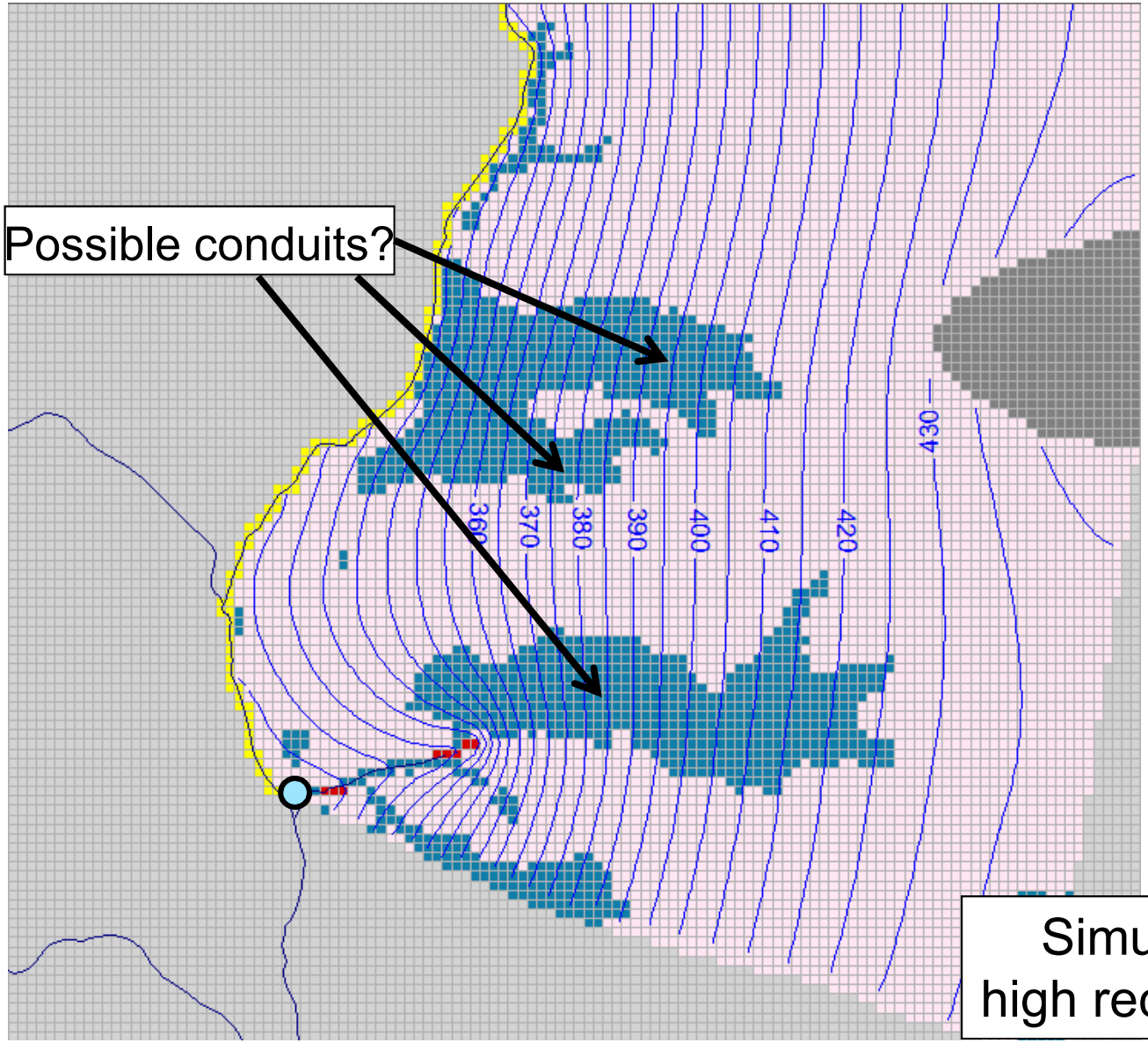
Useful Feedback from (EPM) Models



Useful Feedback from (EPM) Models



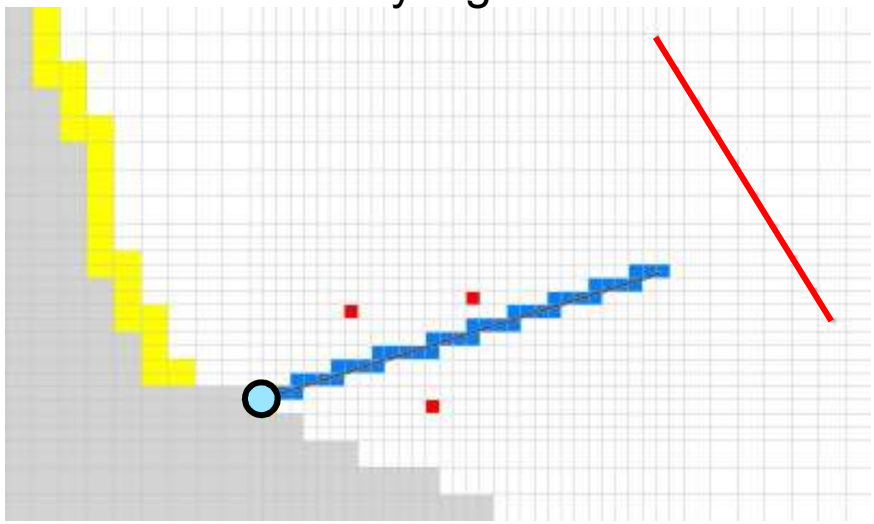
Useful Feedback from (EPM) Models



Simulation of high recharge rate

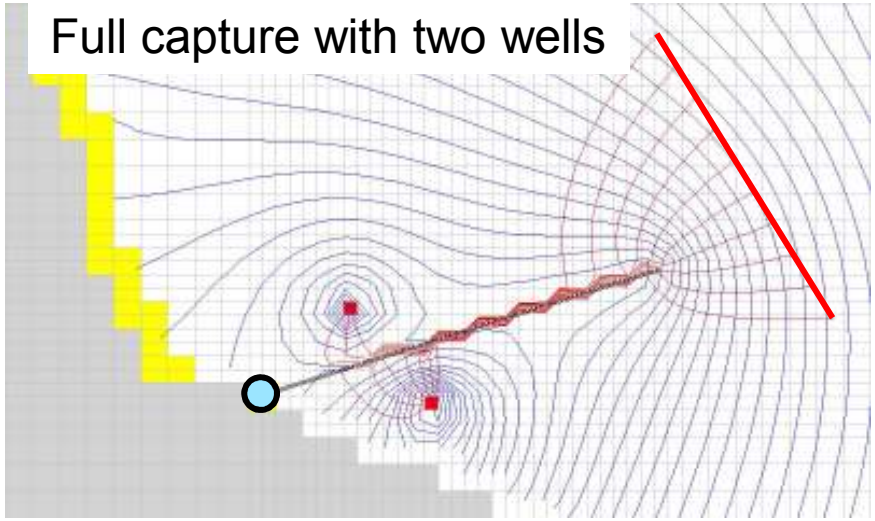
Limitations of EPM Models

Assumed conduit modeled with extremely high K cells



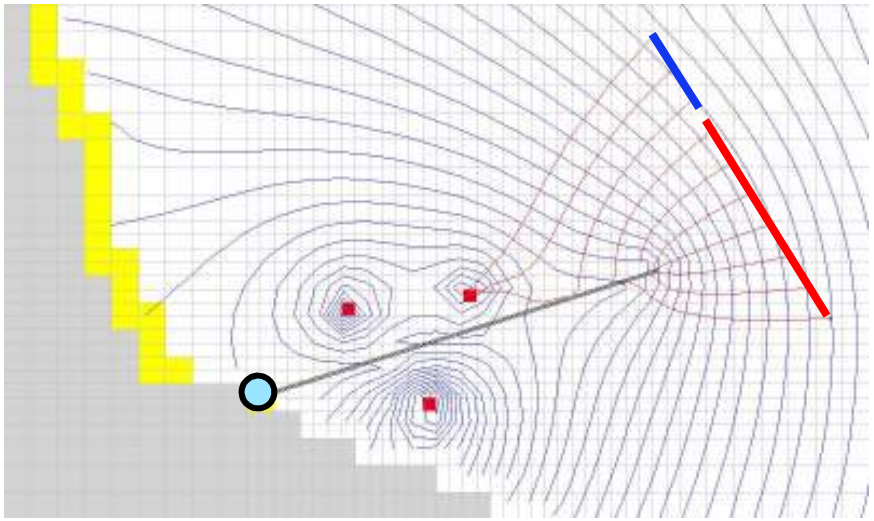
Full capture with one well

Full capture with two wells



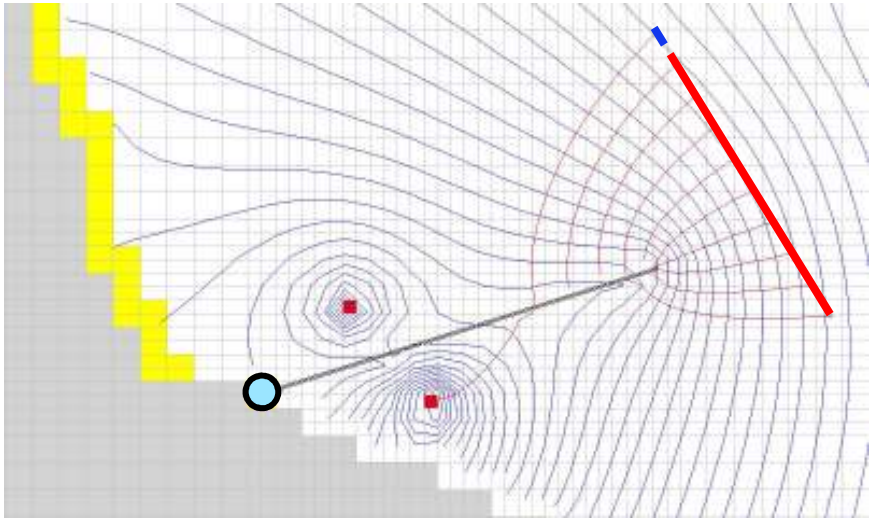
EPM conduit concentrates flow which is then all captured by P&T well(s)

Simulations with CFP

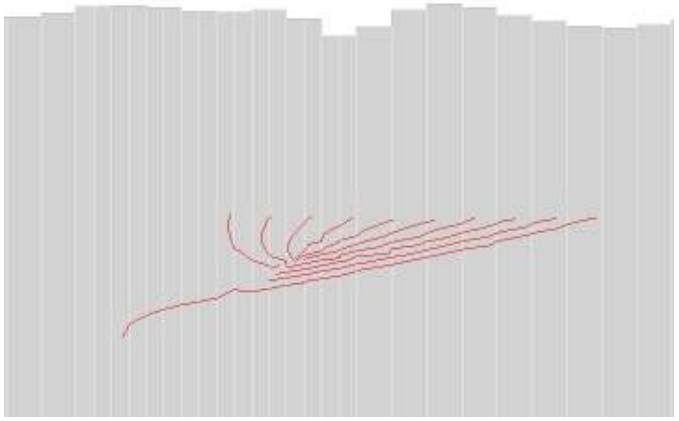


Some capture (blue plume portion)

Red plume portion enters the conduit and flows to the spring

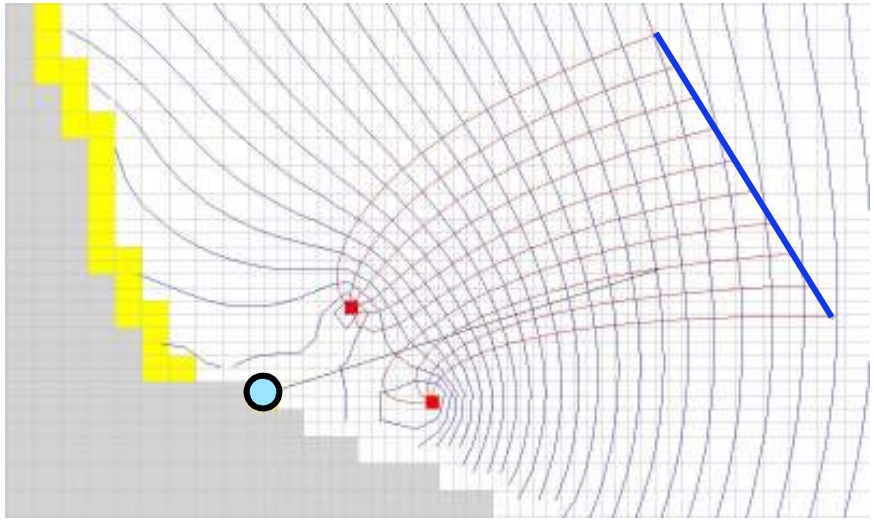


Very minor capture of particle(s) flowing under the conduit



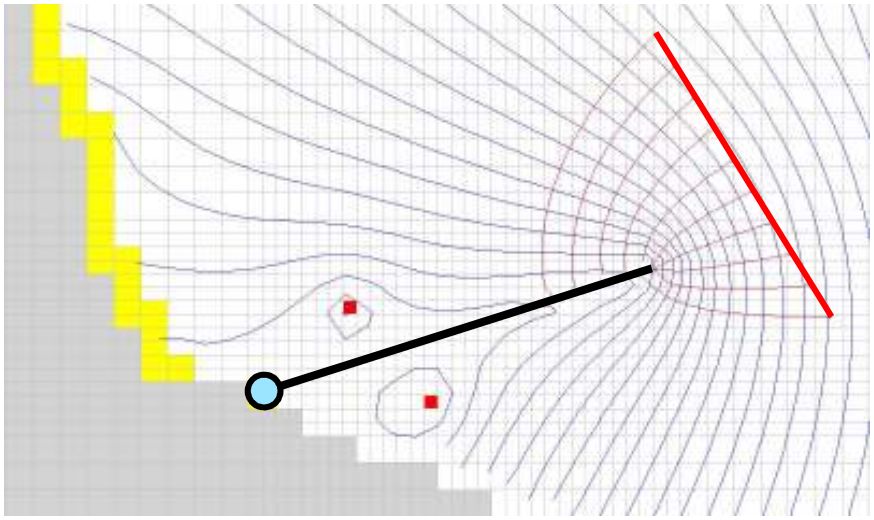
Comparison : EPM vs. CFP

EPM, no conduit of any kind



Full capture

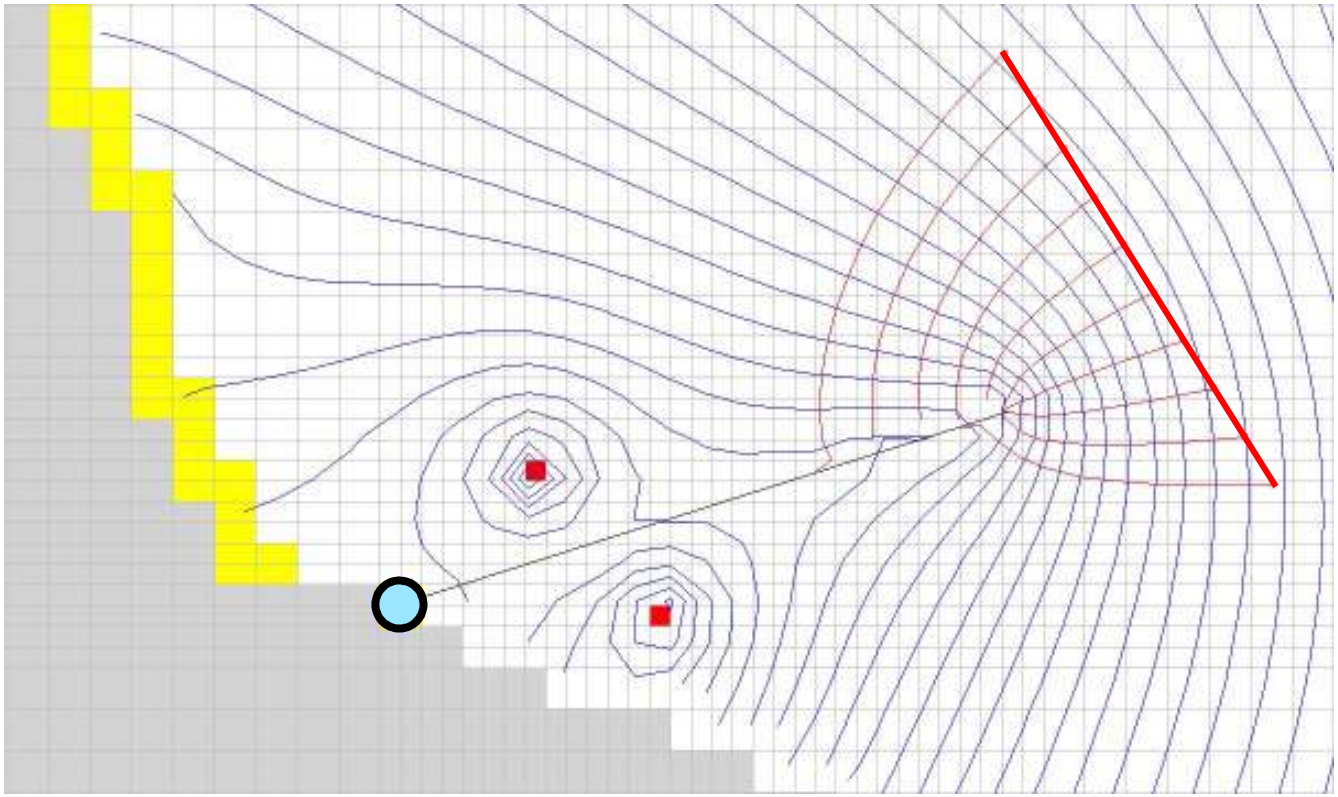
CFP conduit



No capture

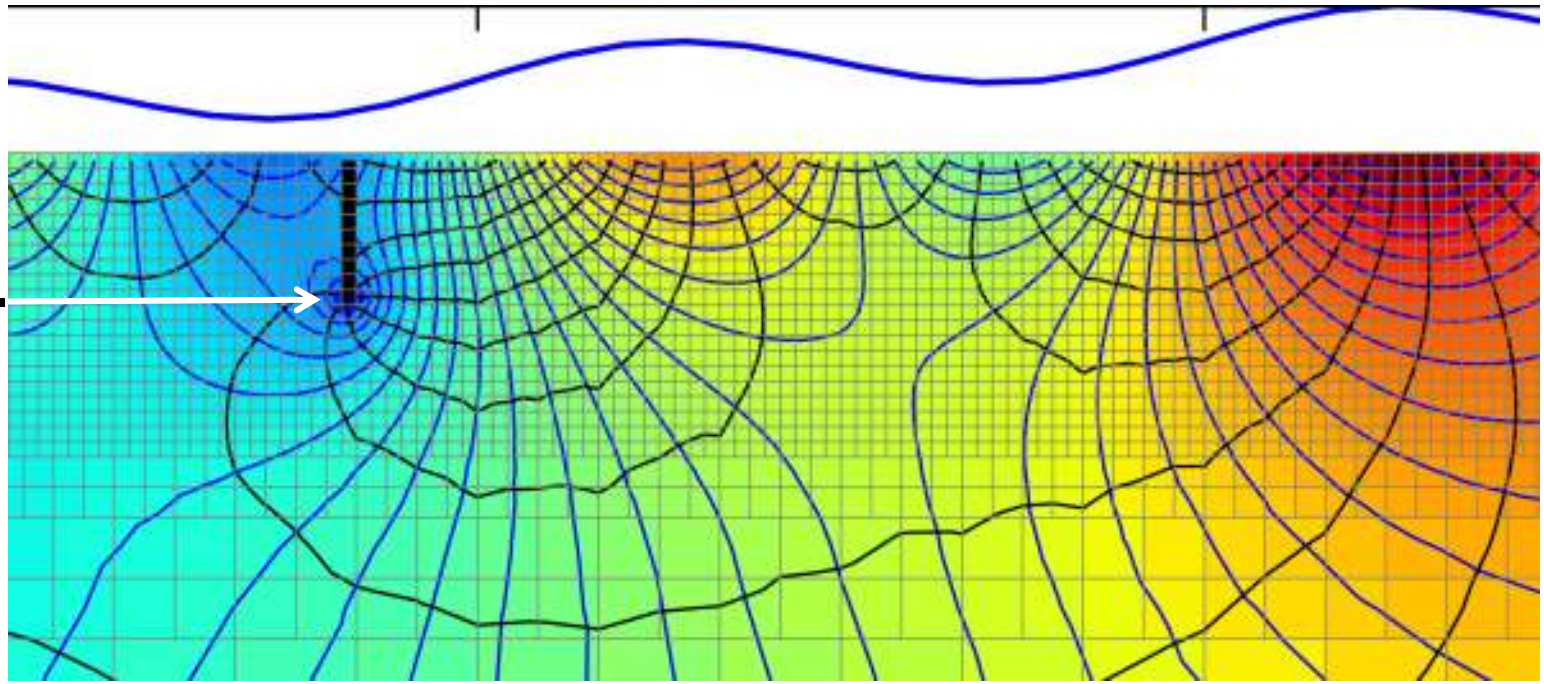
CFP vs. EPM: Conclusion

CFP conduit, tripled Q at wells



No capture

Numeric Models of Karst Aquifers

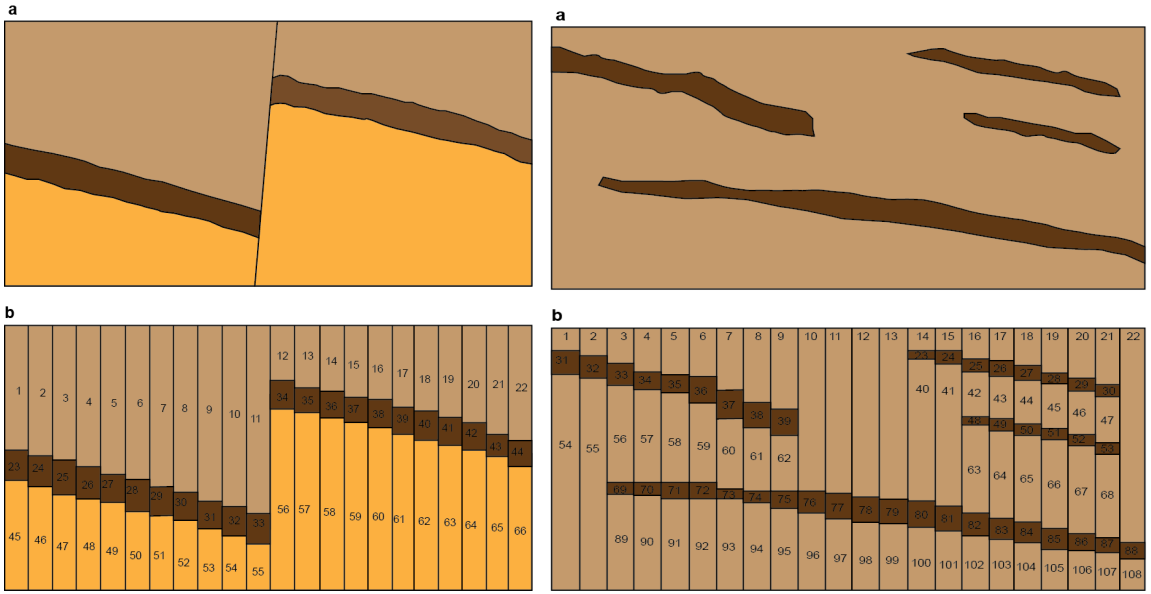


Courtesy of Dr. Christian Langevin
Modeled with MODFLOW USG

Main requirements of physically-based numeric models in karst at any scale

- Do not use inadequate tools and EPM approach
- Fully consider complexities of conduit flow
- Simulate interactions in the conduit-matrix system
- Represent the nature (hydrogeology/geology) as close as possible

MODFLOW-USG

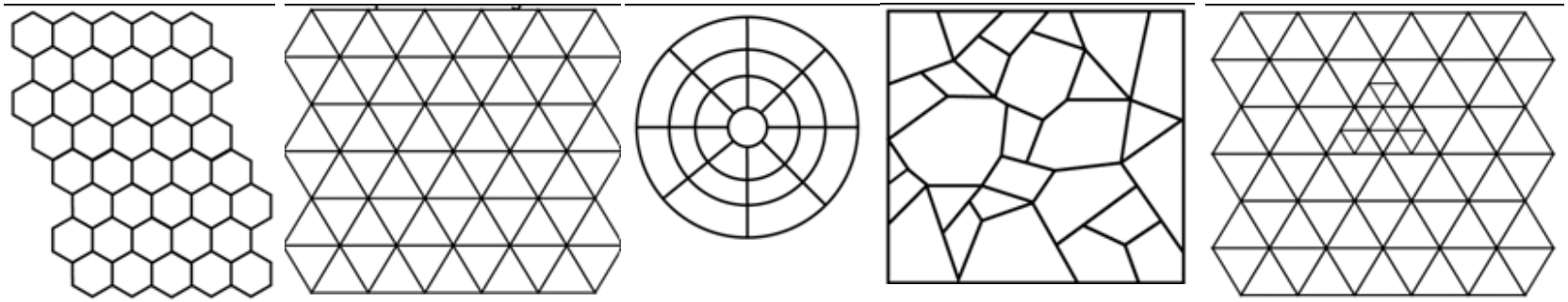


MODFLOW USG
(UnStructured Grids)

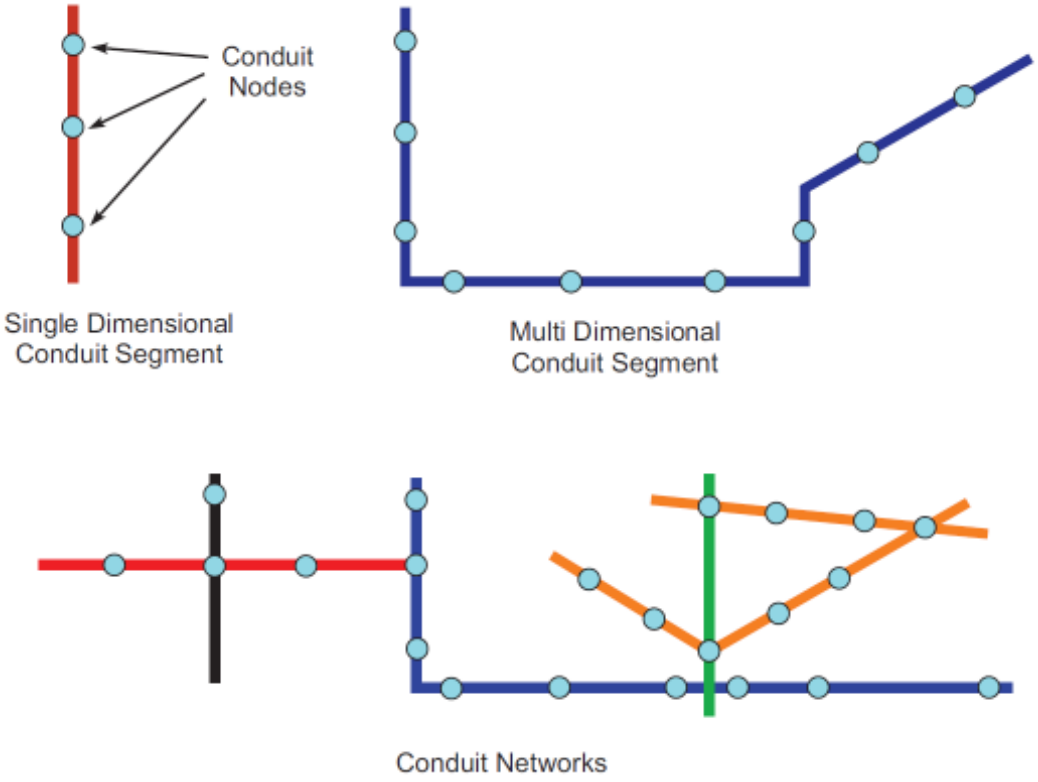
Released in 2013

No limitations

- any geometry
- any linear process
- computationally efficient
- volumes fully preserved

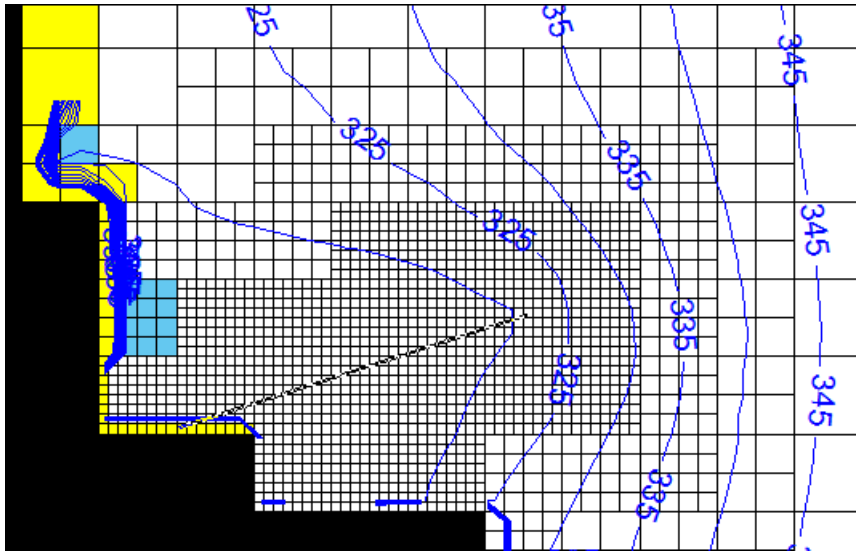


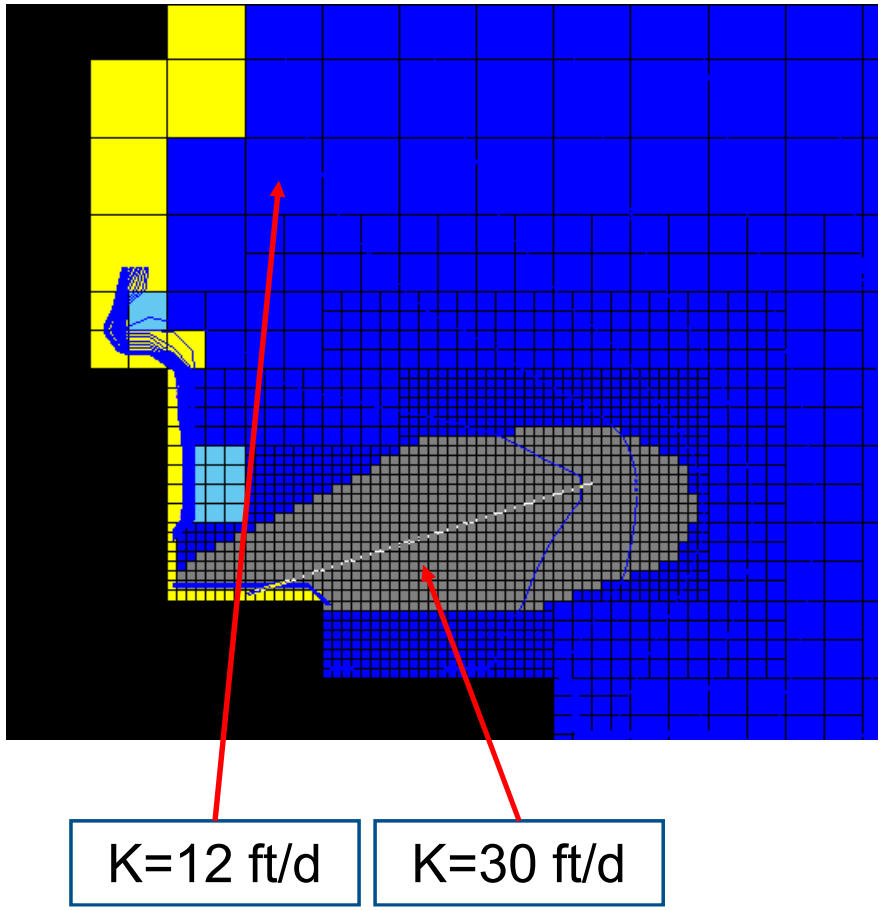
MODFLOW-USG



Any combination of 3D conduit networks, not constrained by matrix cells geometry

Model Refinement with USG





Any cell can be assigned different parameter, including anisotropy