Karlsruhe Institute of Technology

Early Career Hydrogeologists' Network

43rd IAH CONGRESS
25-29th September, 2016
le Corum , Montpellier, France

Numerical simulation of managed aquifer recharge into a karst groundwater system at the Wala reservoir, Jordan

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Division of Hydrogeology

(photo: Xanke, 2013)

Demographic growth and semi-arid climate challenge Jordan‘s water management

population and …

< 1 million people (1960)
6.5 million people (2013)
~ 9.5 million people (2015)

(photo: Xanke, 2012)

… economic growth

Water use 2014	(%)
Domestic	51
Agriculture	45
Industry	4

(photo: Xanke, 2016)

high variability …

(photo: Ali, 2012)

… in water availability

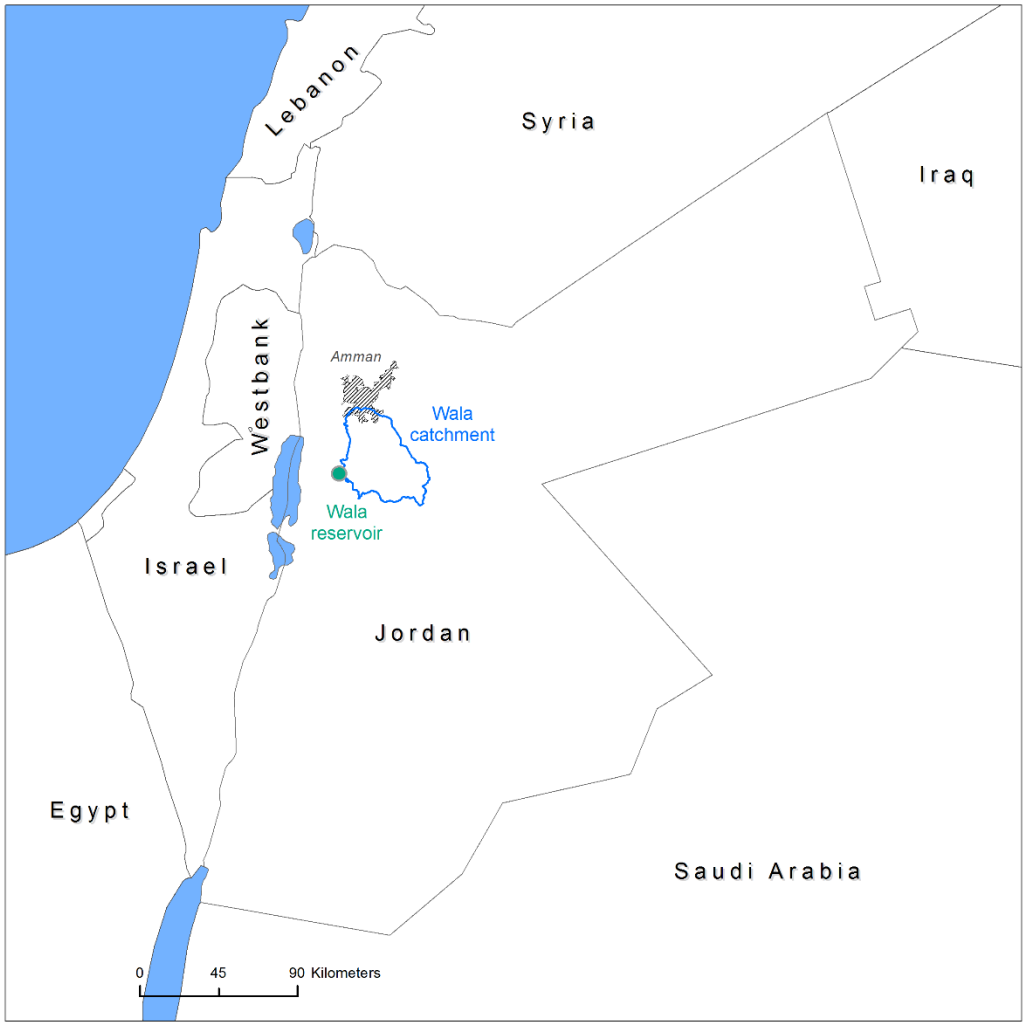
(photo, Al-hesa, 2010)

Jordan‘s water facts

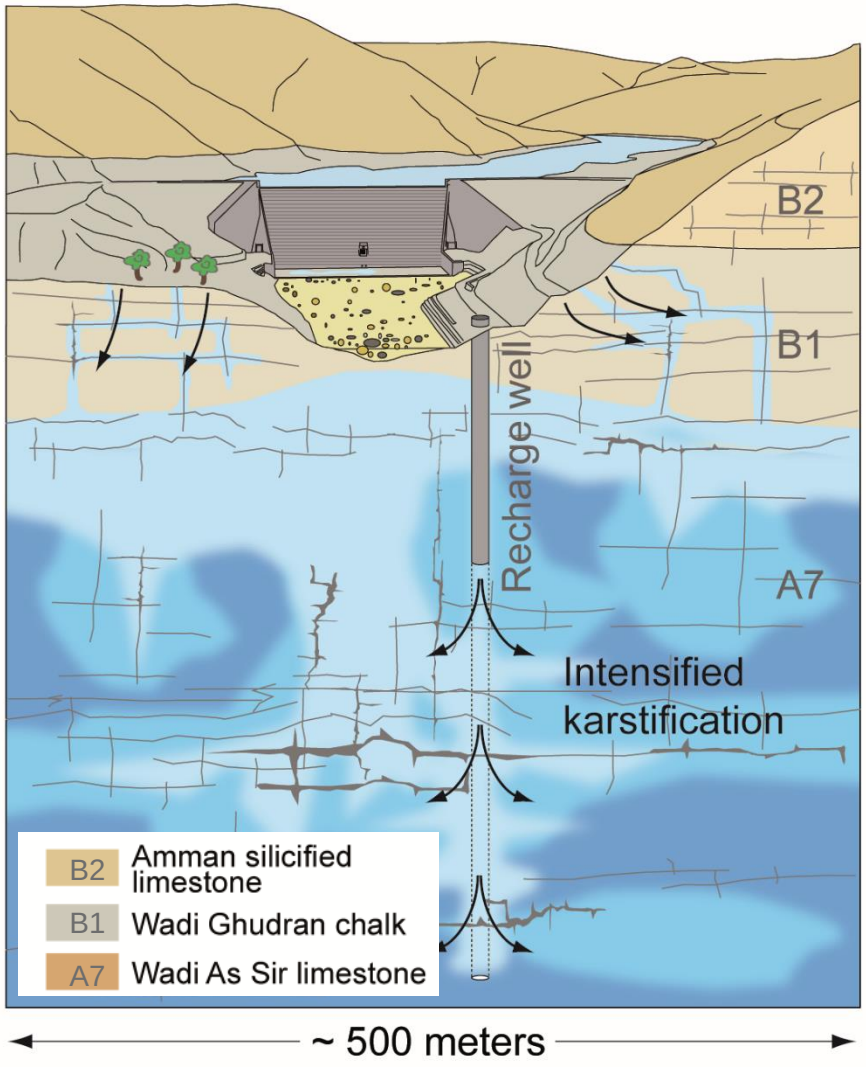
2014	(MCM)
Water demand	~1,400
Water supply	**973**
Surface water	259
Treated wastewater	125
Groundwater (~70% from karst aquifers)	589
Water deficit	**427**

Jordan‘s water strategy promotes the application **of managed aquifer recharge**

increase **groundwater availability** in summer

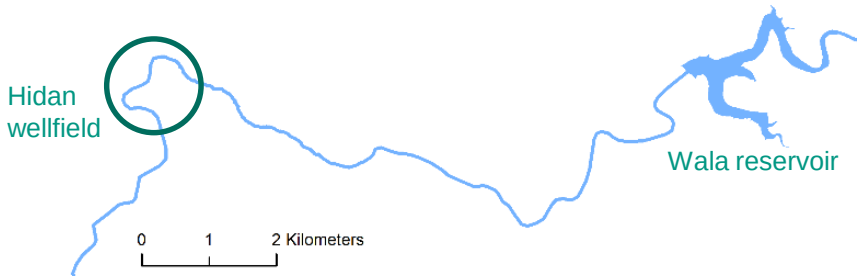


Wala reservoir stores flood water and recharges it to the underlying karst aquifer



Water balance (2002-2012)	Total [MCM]	Annual average [MCM]
Inflow	136	129
Overflow	52	4.7
Recharge	**74**	**6.7**
Evaporation	7.8	0.7
Abstraction	**129**	**11.7**

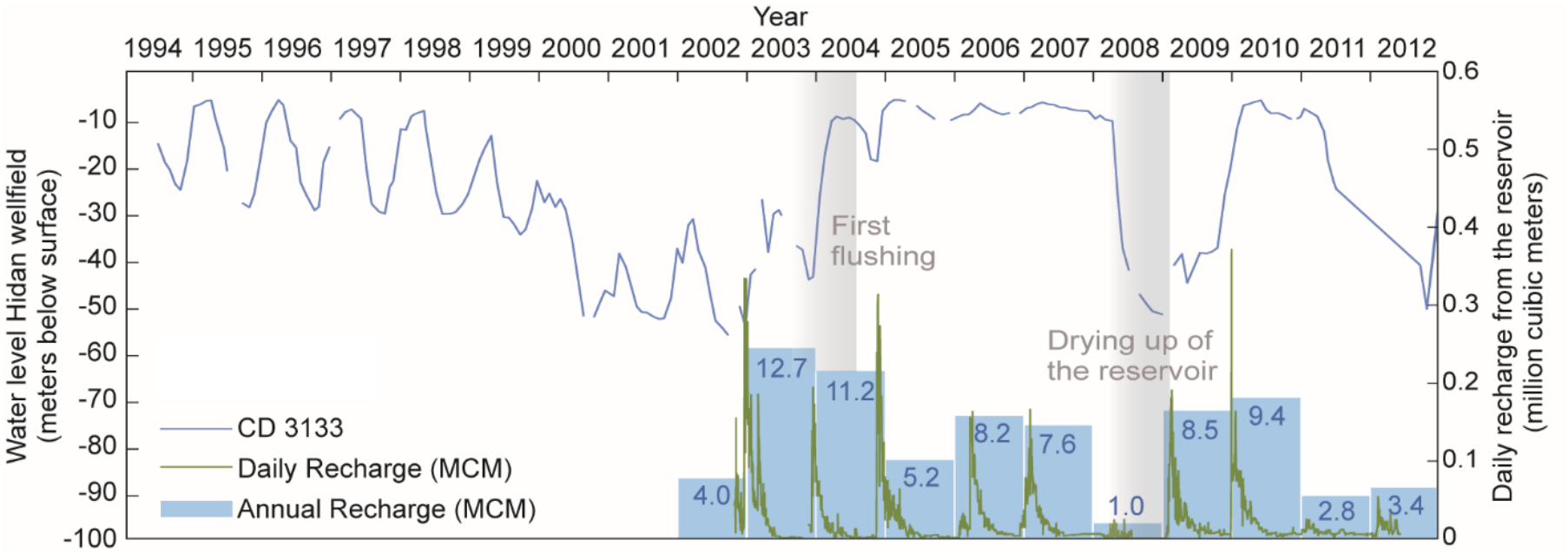
Proportion of recharge on abstraction = 56%



Source: Xanke et al. (2016) Numerical long-term assessment of managed aquifer recharge from a reservoir into a karst aquifer in Jordan. In: *Journal of hydrology*

Water level at the downstream Hidan wellfield is increased

- Drinking water supply to the capital Amman, Madaba city and adjacent communities



Source: Xanke et al. (2015) Impact of managed aquifer recharge on the chemical and isotopic composition of a karst aquifer, Wala reservoir, Jordan. In: *Hydrogeology Journal*

The model is used to better understand the characteristic aquifer hydraulics

Obtained by Calibration

- Reproduce water level fluctuations in the aquifer
- Identify the driving factors of water level fluctuations at the wellfield

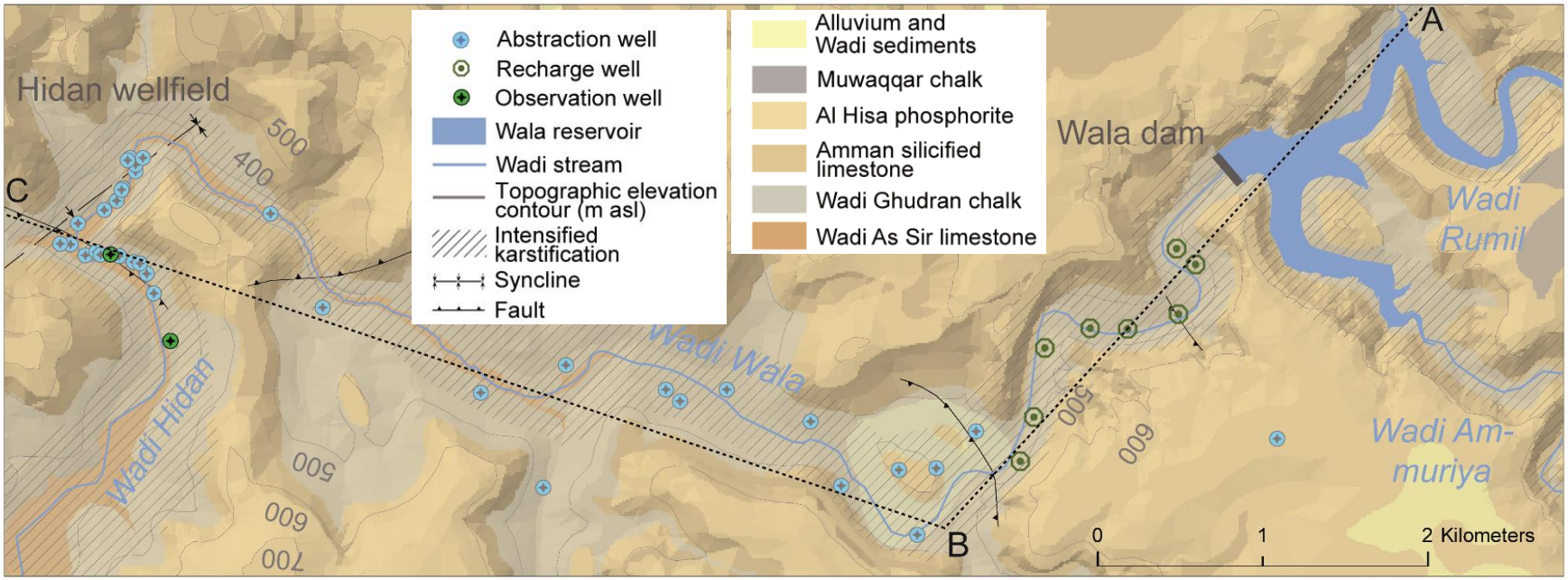
Obtained by scenarios

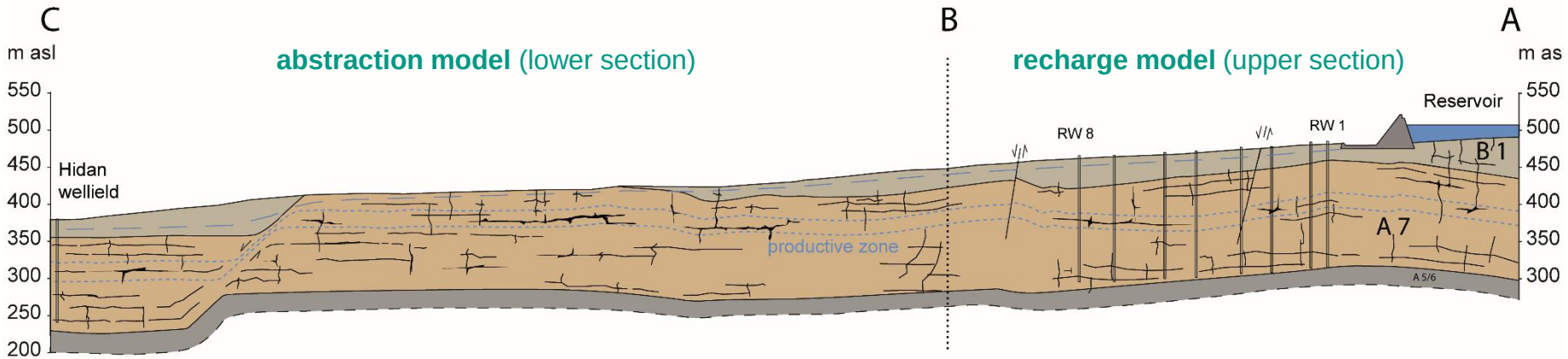
- Predicted infiltration decrease caused by reservoir sedimentation
- Provide a basis for optimized water resources management

➡ **Two climate scenarios** for a dry and a wet period, each 10 years

➡ **Two well management scenarios** for each climate scenario

The model domain is projected onto a 2-dimensional profile along the wadi

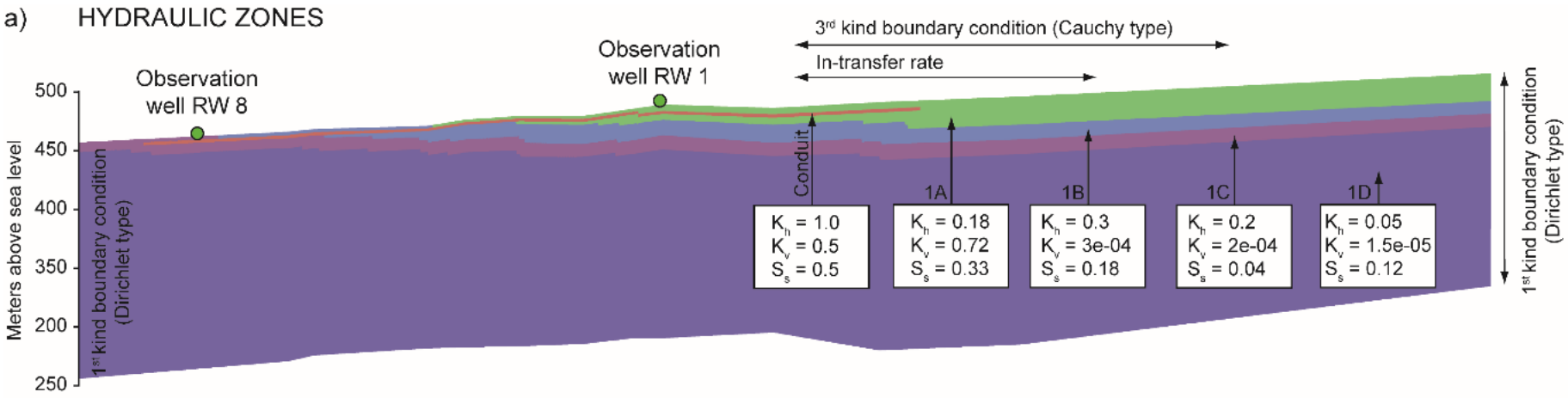




(Source: Xanke et al. 2016)

Recharge model: subdivision into hydraulic zones simplifies the calibration procedure

- Approach: finite element method (FEFLOW) – saturated flow conditions - confined setting (cross sectional model)

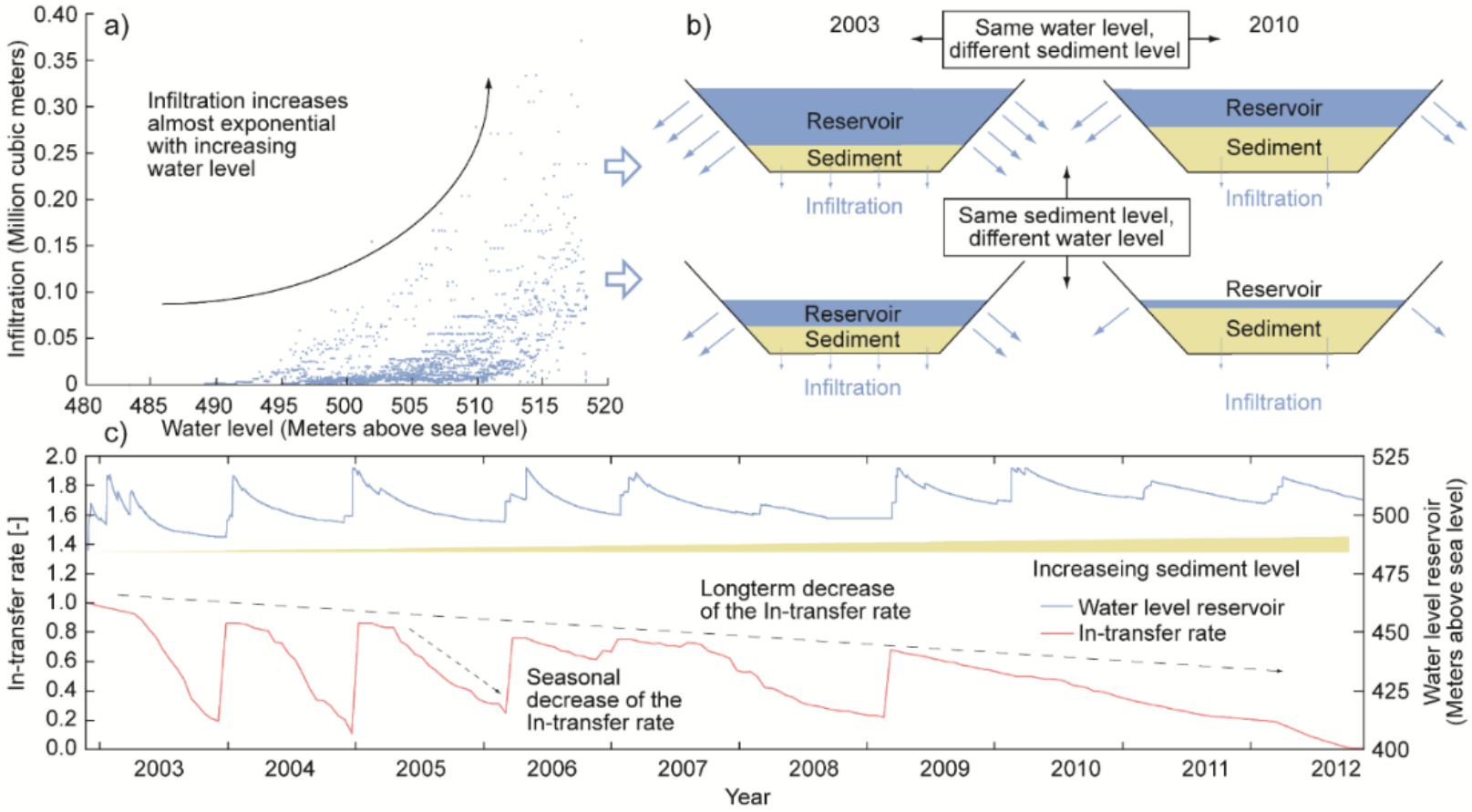


Superelevated presentation – K values are in m/s

(Source: Xanke et al. 2016)

Recharge model: in-transfer rate Φ regulates infiltration from Wala reservoir

- Infiltration increases exponential with water level
- In-transfer rate (Φ = K/d) was manually adapted

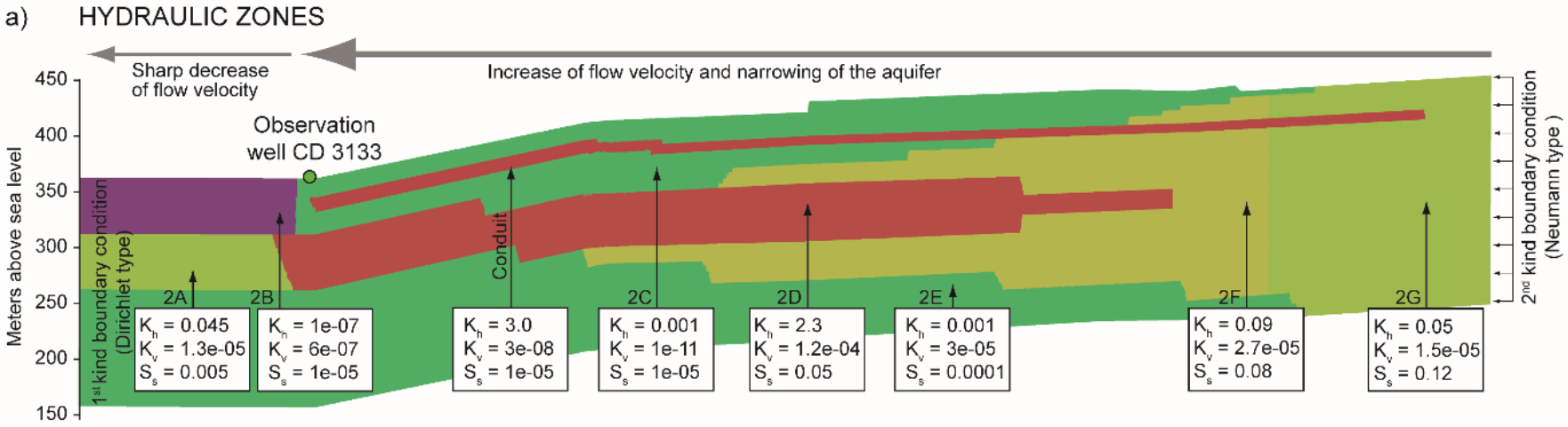


(Source: Xanke et al. 2016)

Abstraction model: strong water level fluctuations are controlled by changes in the mean pumping depth

- A fault at Hidan wellfield has a damming effect on groundwater flow
- Inherent problems in representing pumping rates in a 2D vertical model

→ statements about the magnitude of fluctuations have to be considered carefully

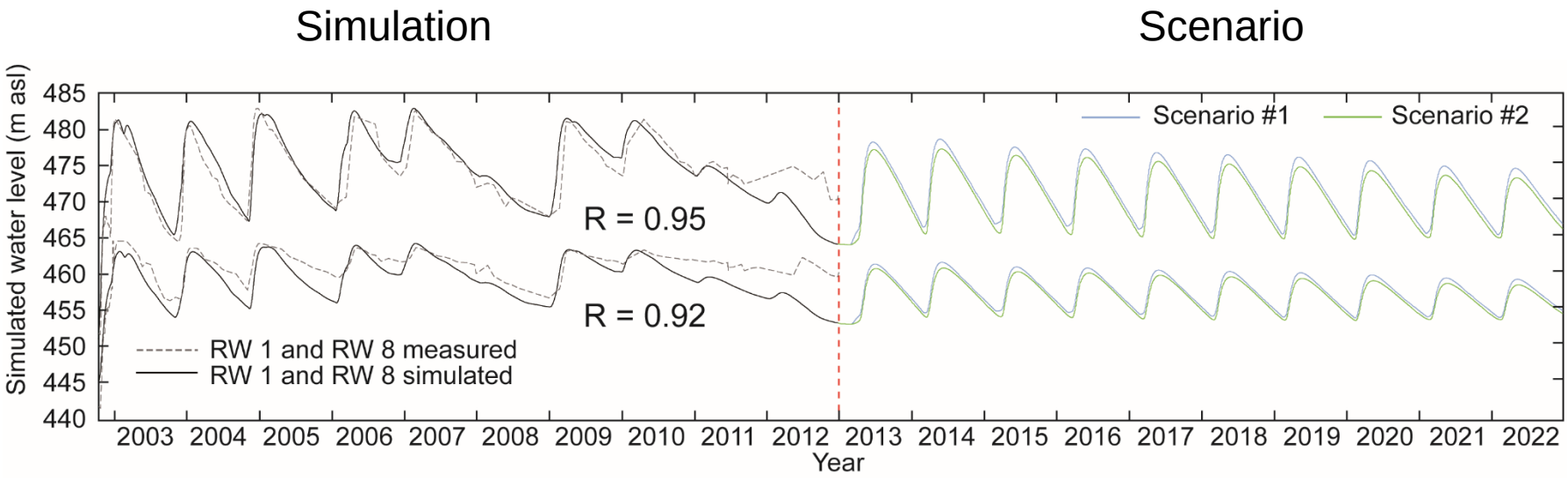


Superelevated presentation – K values are in m/s

(Source: Xanke et al. 2016)

Lowering of annual average groundwater level of about 2.7 meters at recharge wells …

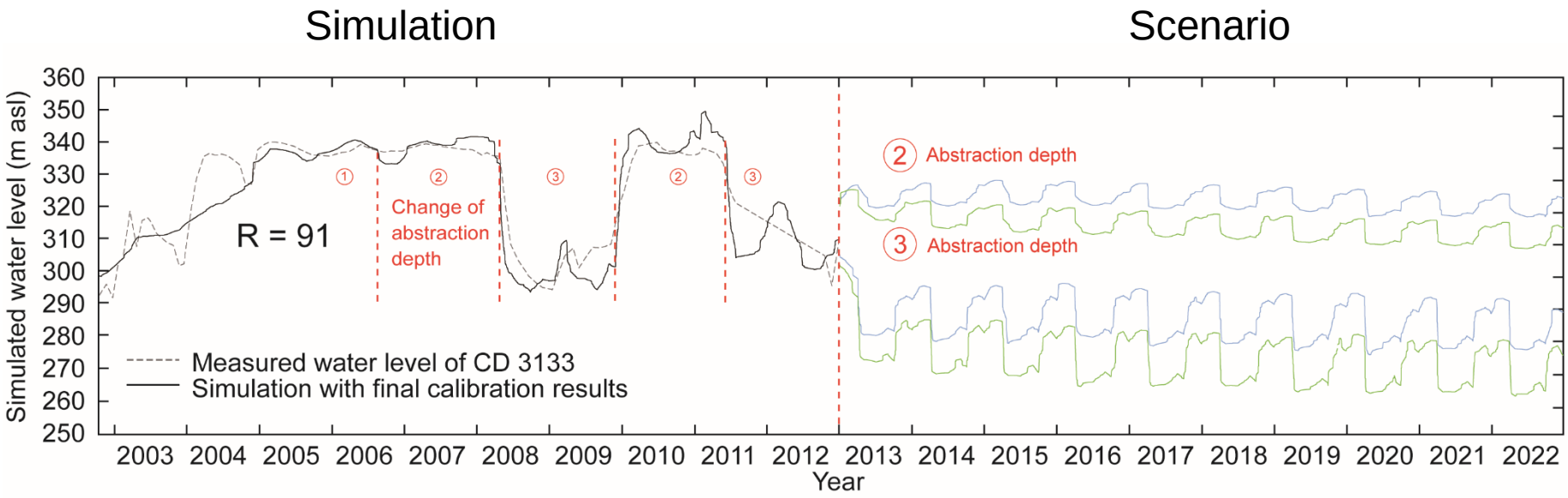
- satisfying accordance of measured and simulated groundwater level fluctuations at recharge wells



(Source: Xanke et al. 2016)

… and probably a greater depletion at the wellfield

- satisfying accordance of measured and simulated groundwater level fluctuations at Hidan wellfield



(Source: Xanke et al. 2016)

Conclusions

Numerical model

- **Reliable simulation results** were achieved with **2D vertical profile models**
- subdivision into **hydraulic zones** allows the simulation of the **karst characteristic flow pattern**

Management

- The Wala reservoir poses a **successful example** of **managed recharge into a karst aquifer**
- Technical measures are required to **reduce the sedimentation rates** and to remove sediments from the reservoir
- The **wellfield requires** an **improved management** in terms of monitoring and abstraction

Acknowledgements

- Co-authors: Hervé Jourde, Tanja Liesch and Nico Goldscheider
- BMBF – Federal Ministry of Education and Research, Germany
- The SMART II Project (FKZ 02WM1079-1086 and FKZ02WM1211-1212)
- The SMART Move Project (FKZ 02WM1335C)
- Ministry of Water and Irrigation (MWI), Amman - Jordan
- Water Authority Jordan (WAJ)
- Jordan Valley Authority (JVA)

Publications

- Xanke et al. (2015) Impact of managed aquifer recharge on the chemical and isotopic composition of a karst aquifer, Wala reservoir, Jordan. In: *Hydrogeology Journal*.
- Xanke et al. (2016) Numerical long-term assessment of managed aquifer recharge from a reservoir into a karst aquifer in Jordan. In: *Journal of hydrology*.
- Xanke et al. (2016) Contamination risk and drinking water protection for a large-scale managed aquifer recharge site in a semi-arid karst region, Jordan. (Submitted to: *Hydrogeology Journal, August 2016*).

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