UIT GmbH Dresden • Germany

Dynamical Models for Uranium Leaching

H. Kalka

More Info:

H. Kalka, H. Märten, R. Kahnt: Dynamical Models for Uranium Leaching – Production and Remediation Cases

in Uranium in the Environment, B.J. Merkel, A. Hasche-Berger (Editors), Springer Berlin Heidelberg New York, 2006
p. 235-245

Uranium Mining
and Hydrogeology 2005

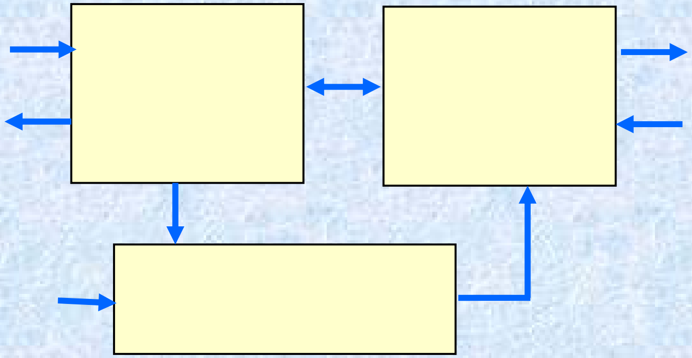
Dynamical Models for Uranium Leaching - Production and Remediation Cases -

Dynamical Models for Uranium Leaching

1	Model Concept
2	Production Case
	In-situ Leach at Beverley Mine
3	Remediation Case
	Flooding of Königstein Mine

Dynamical Compartment

Models



local conditions

available data

spatial-time structure

Transport

Kinetics

Thermodynamics

high time resolution

$\Delta t \geq 1$ h

mass and charge conservation

PHREEQC

modular design with C^{++}

Basic Equations (site-specific)

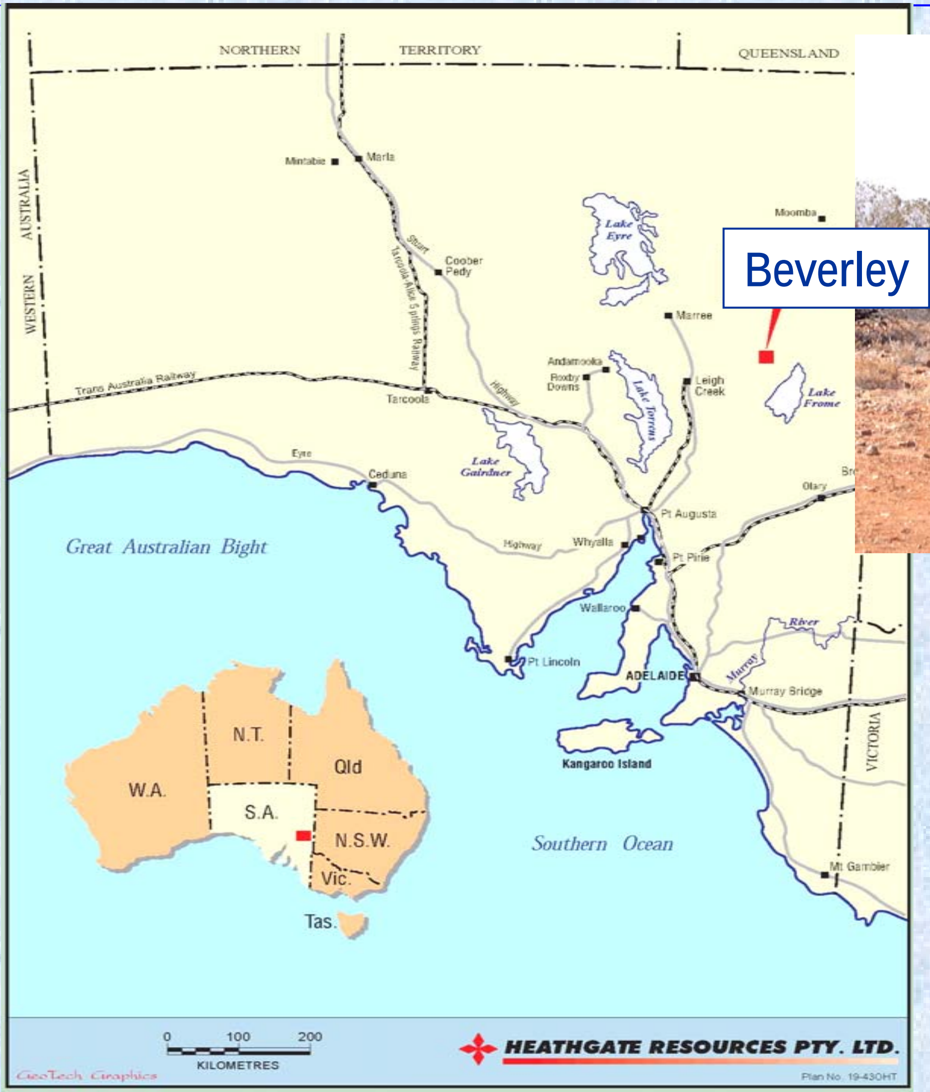
$$\frac{dm_i}{dt} = \left(\frac{dm_i}{dt}\right)_{adv} + \left(\frac{dm_i}{dt}\right)^{nat} + \left(\frac{dm_i}{dt}\right)^{techn}$$

natural processes

technological processes

advection $$\left(\frac{dm_i}{dt}\right)_{adv} = \sum_{j=1}^{N} \left[Q_{j\rightarrow i} c_j - Q_{i\rightarrow j} c_i \right] + Q_i^{in} c_{in} - Q_i^{out} c_i$$

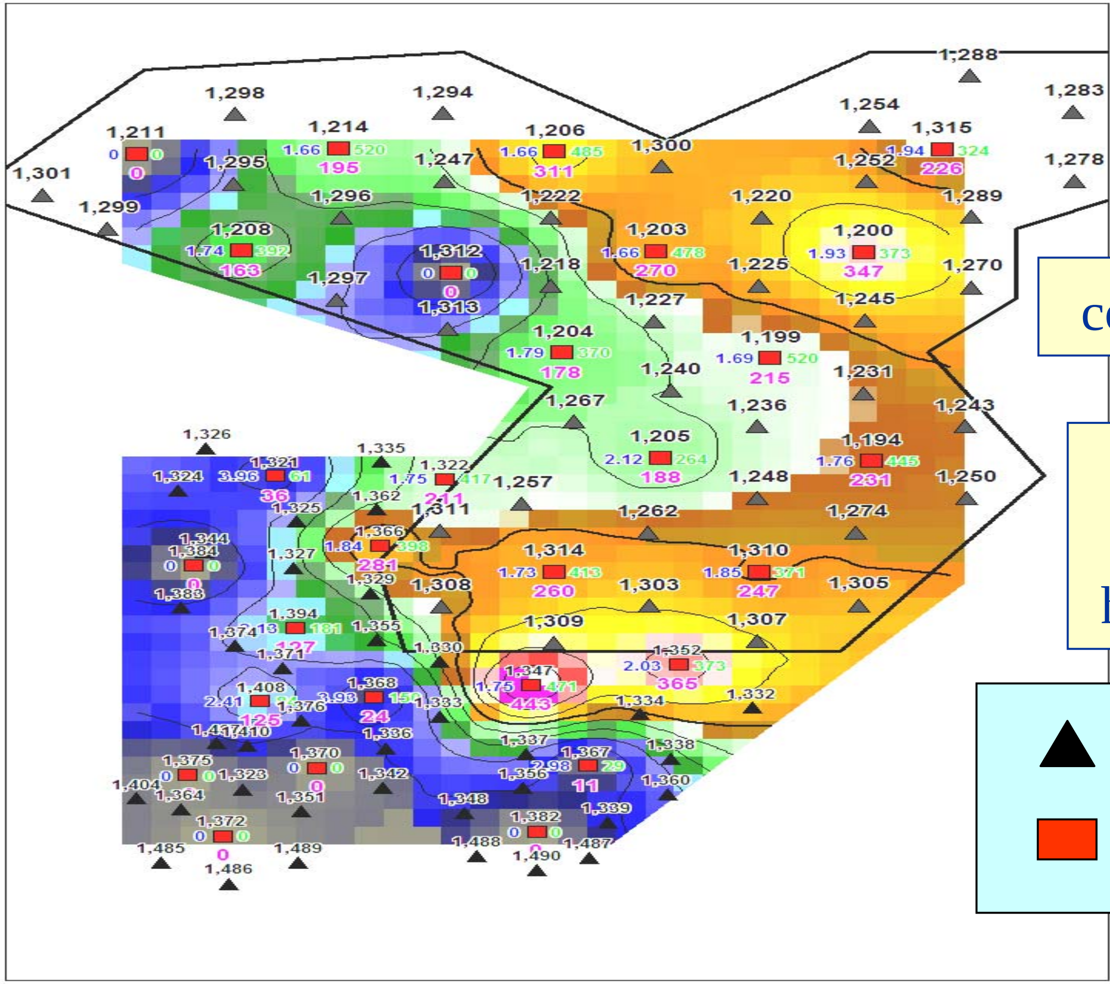
ISL Beverley Mine



Australia's first commercial acid ISL mine

since 2000

Wellfield / Wellhouse



complex flow pattern

averaging over
ore grades,
hydraulic parameters

▲ **injection**

■ **extraction**

First: Analytical Approach

mass transfer

$\frac{dm^{ore}}{dt} = -\lambda m^{ore}$	$m^{ore}(0) = m_0$
$\frac{dm}{dt} = \lambda m^{ore} - qm$	$m(0) = 0$

$= c_0 V_P$

initial mass

dissolution

flushing

$$c(t) = c_0 \frac{\lambda}{\lambda - q} \left\{ e^{-qt} - e^{-\lambda t} \right\}$$

Three Parameters

$$c_0 = m_0 / V_P$$

initial concentration

$$c(t) = c_0 \frac{\lambda}{\lambda - q} \left\{ e^{-qt} - e^{-\lambda t} \right\}$$

$$\lambda = a \cdot e^{b\,(2-pH)}$$

dissolution rate

$$q = Q / V_P$$

flushing rate

Example

$$m_0 = 200 \text{ t } U_3O_8$$

$$V_P = 30\,000 \text{ m}^3$$

$$Q = 200 \text{ m}^3 / \text{h}$$

$USiO_4$

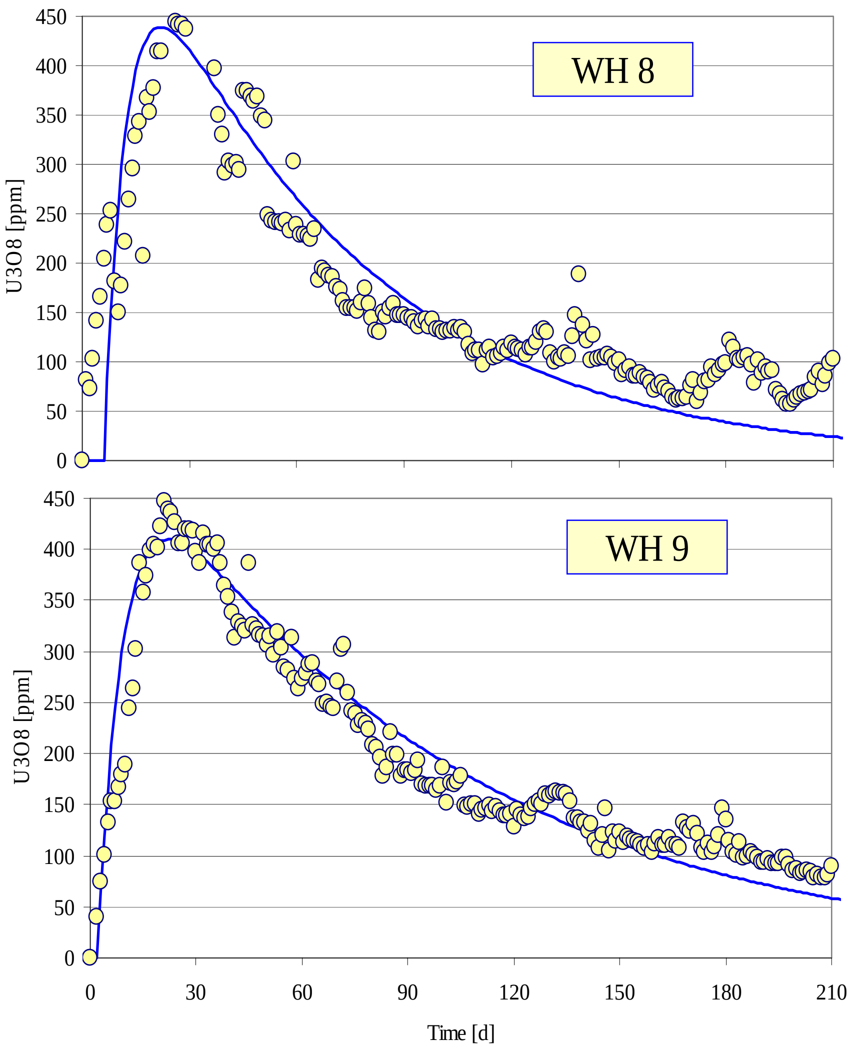
$$a = 0.5 \cdot 10^{-7} \text{ s}^{-1}$$

$$b = 3.2$$

Uranium in the Lixiviant

$$c_0 = 5.7\ \mathrm{g/L}$$
$$q = 0.160\ \mathrm{d}^{-1}$$
$$\lambda = 0.016\ \mathrm{d}^{-1}$$

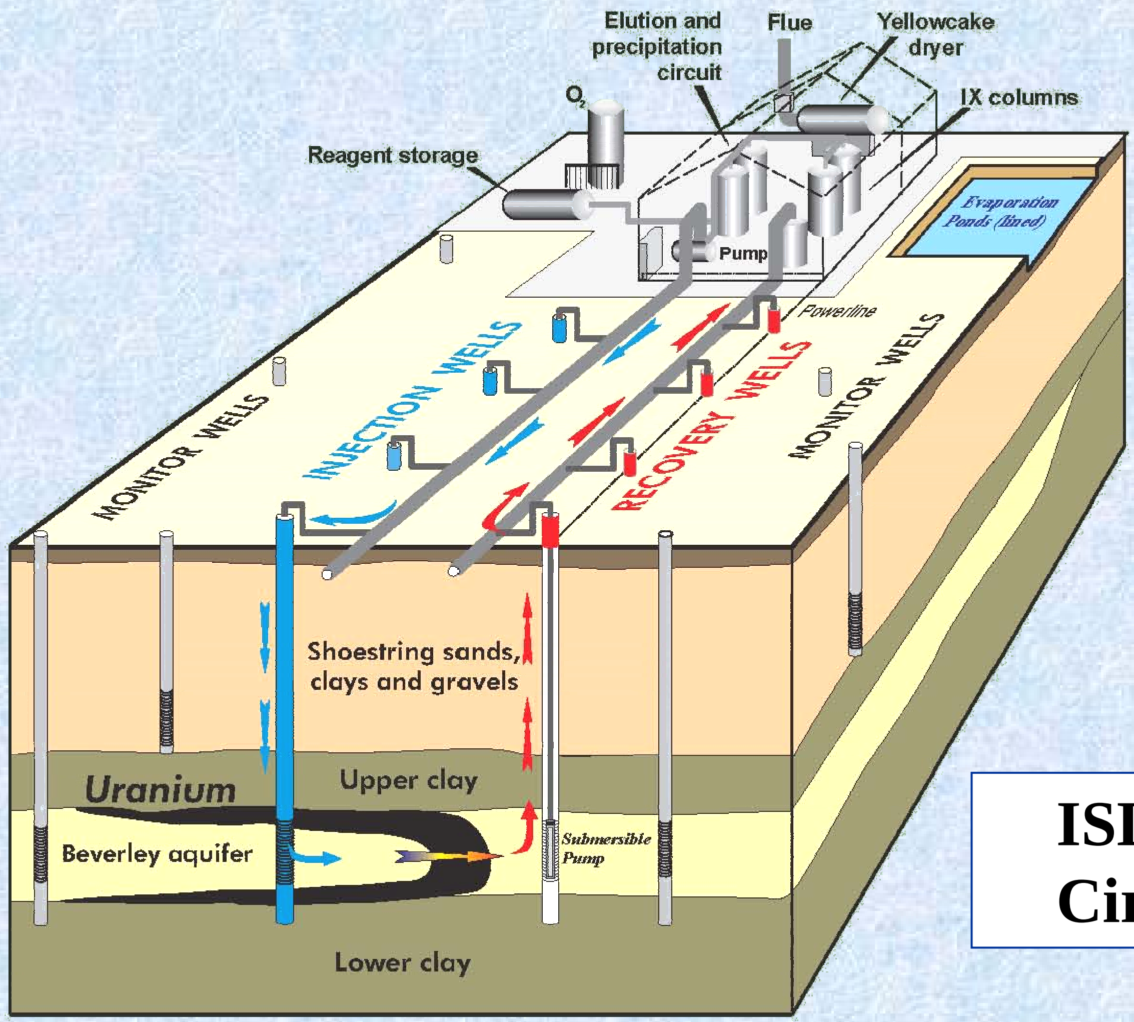
$$c_0 = 6.4\ \mathrm{g/L}$$
$$q = 0.136\ \mathrm{d}^{-1}$$
$$\lambda = 0.011\ \mathrm{d}^{-1}$$



SO_4, Cl, Fe, Ca, Si ?

geochemical model

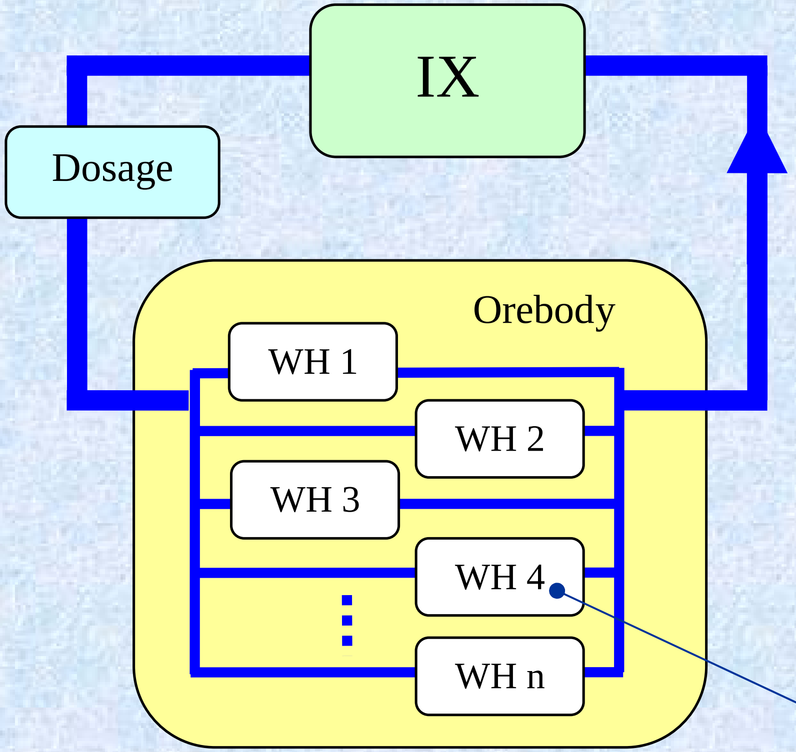
Beverley Mine

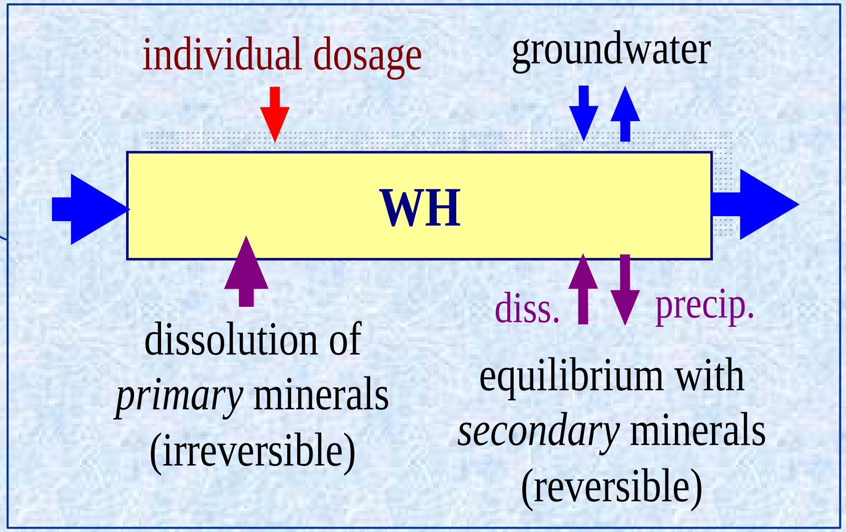


ISL Production Circuit

ISL Cycle

Compartment Structure





ISL - Numerical Model

leaching + IX

time behavior of

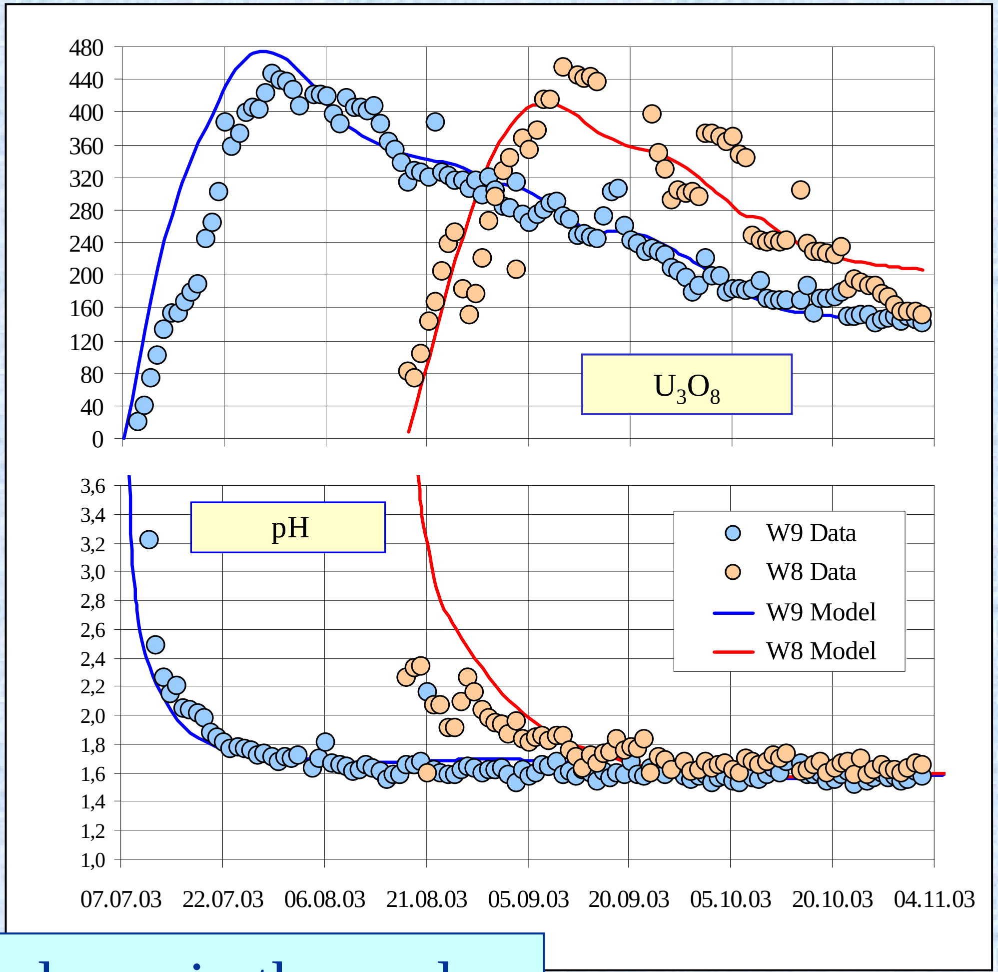
pH, ORP

U, SO_4, Cl, Fe, Ca

Na, Al, Mg, K, Si

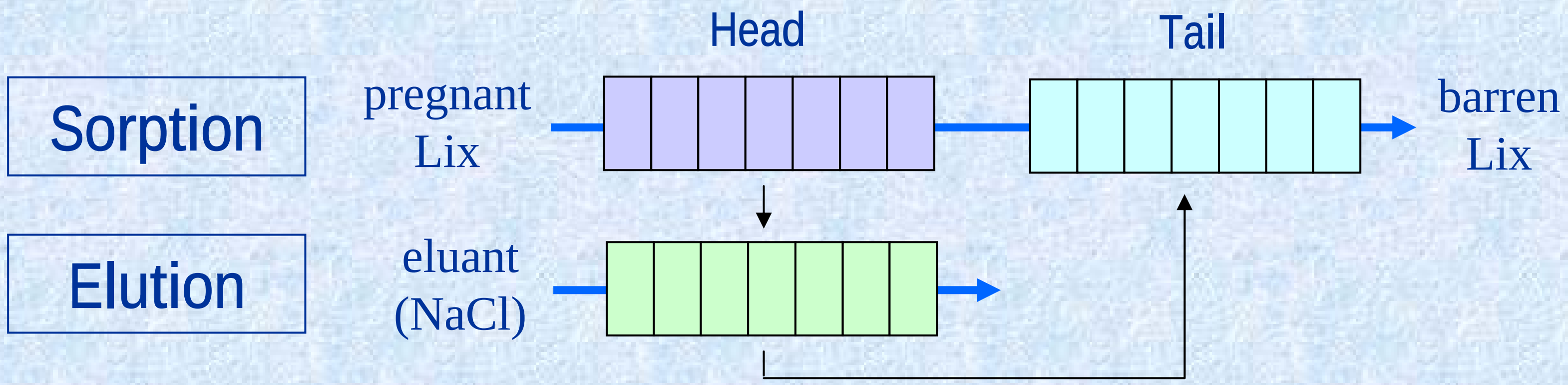
interfering leaching

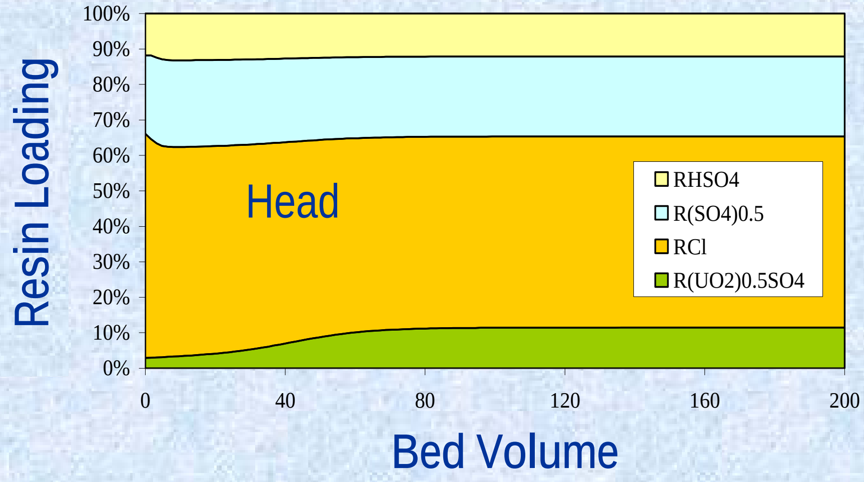
silicate minerals

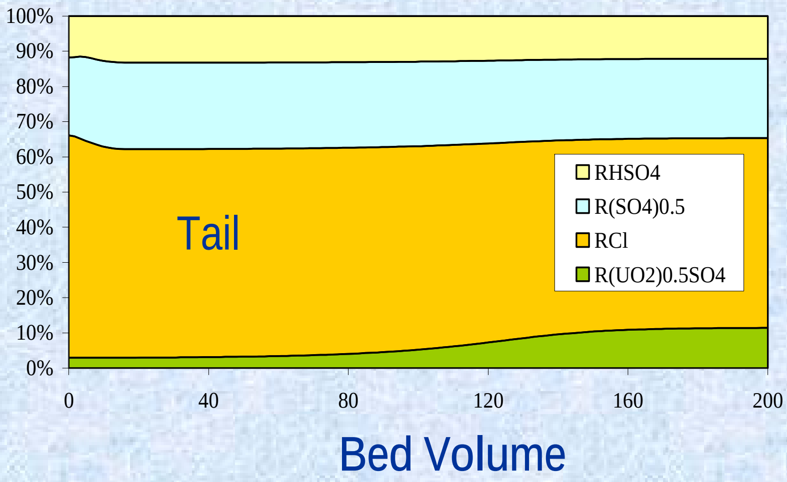


... and material balance in the cycle

IX colums (Uranium Recovery)





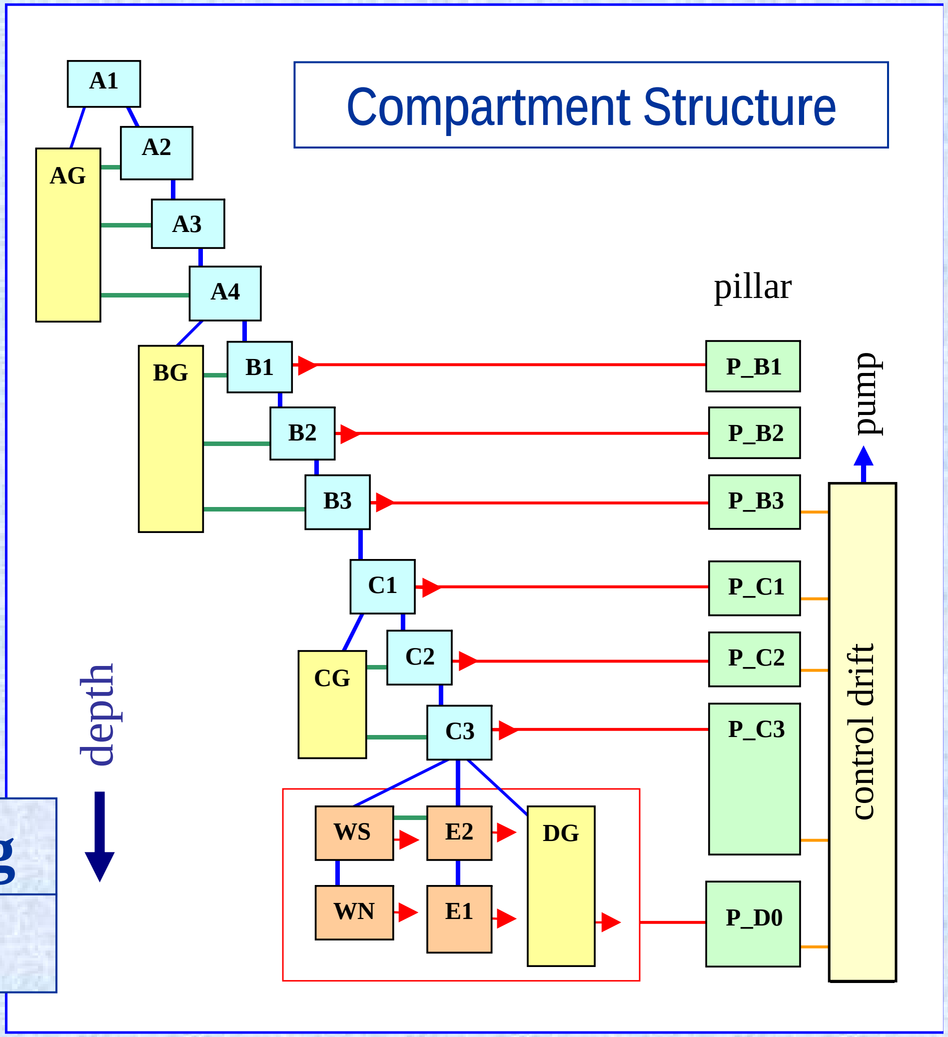


Königstein Uranium Mine

South-East Saxony
(near Dresden)

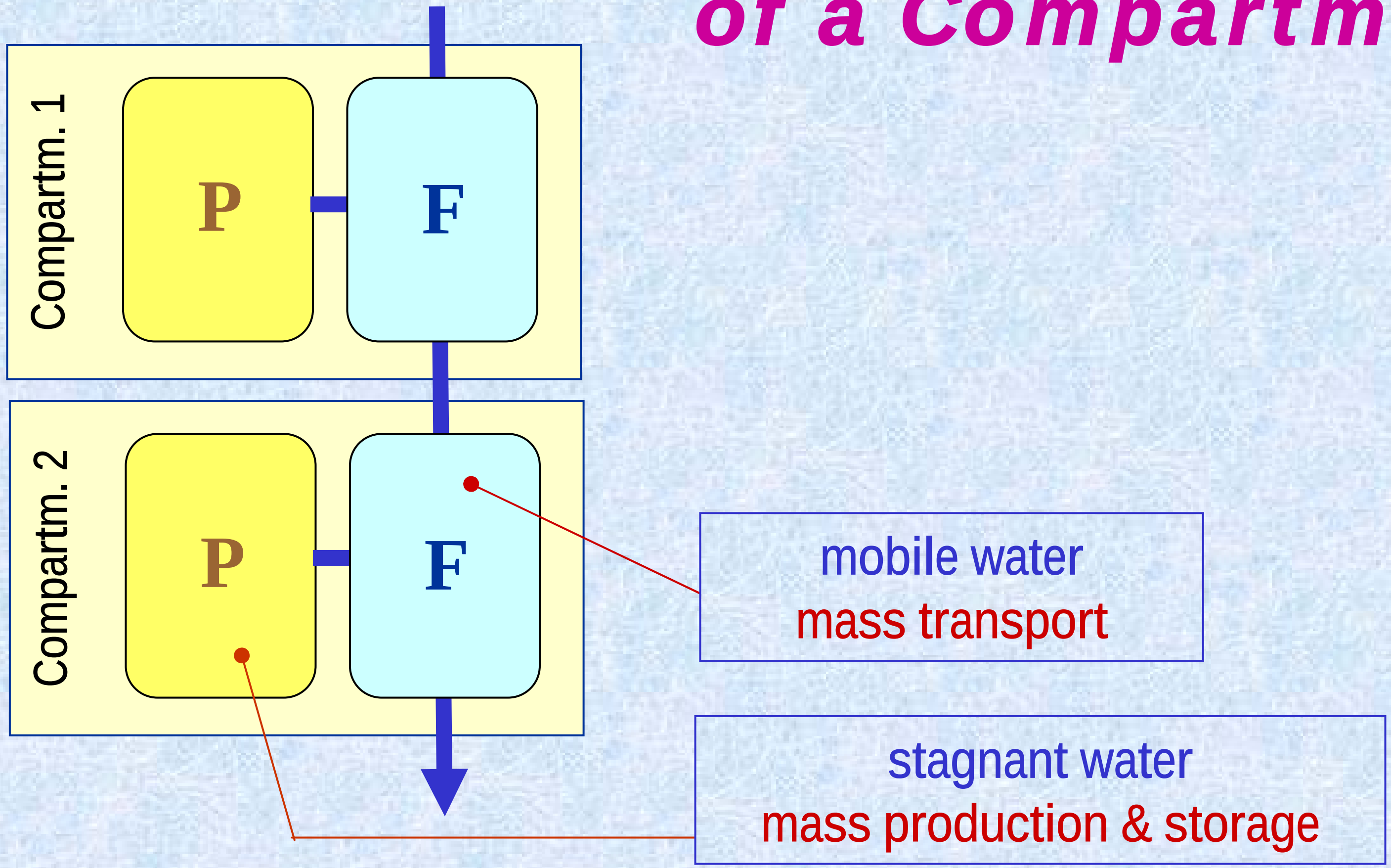
1967	mining
1984	acid ISL

1991	decommissioning
2001	start flooding



Internal Structure

of a Compartment



Mass Transfer (Leaching)

$$\frac{dm_i^F}{dt} = \left(\frac{dm_i}{dt}\right)_{trans} + \left|Q_i^{exch}\right|(c_i^P - c_i^F) + m_i^{sekm}\,\delta\,(t - t_i)$$

$$\frac{dm_i^P}{dt} = -\left|Q_i^{exch}\right|(c_i^P - c_i^F)$$

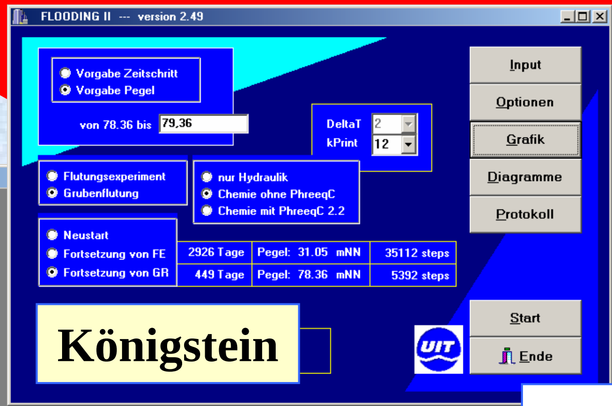
short-term source

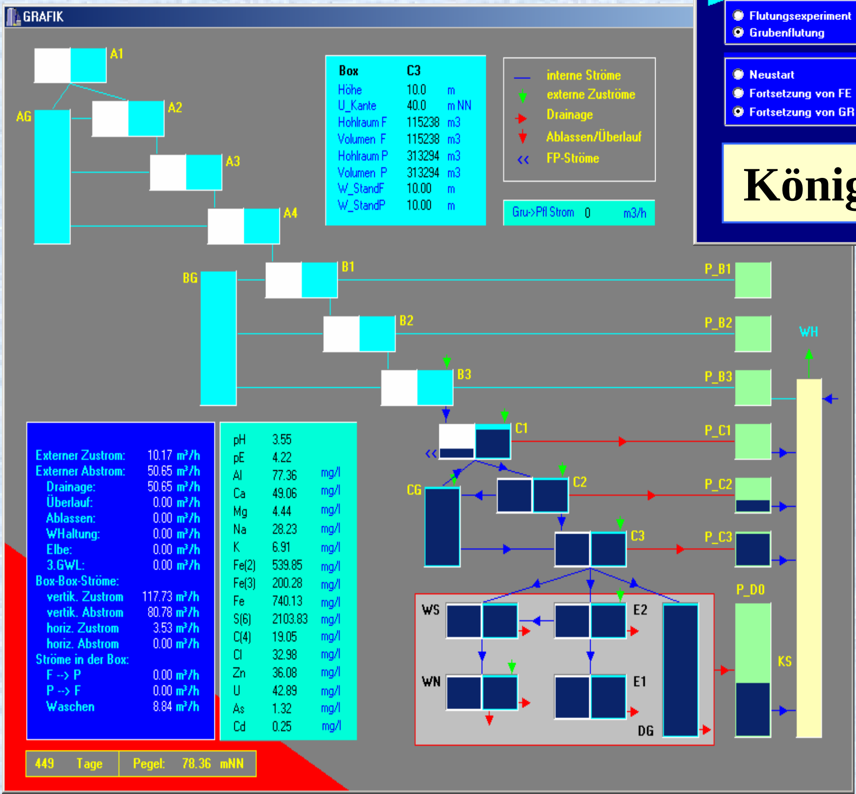
long-term source

density driven: $Q_i^{exch} = \Lambda\ (\rho_i^P - \rho_i^F)/\rho_0$

The Software “Flooding II”

- hydraulics
- geochemistry





1 000 000 × PhreeqC

1 hour on PC

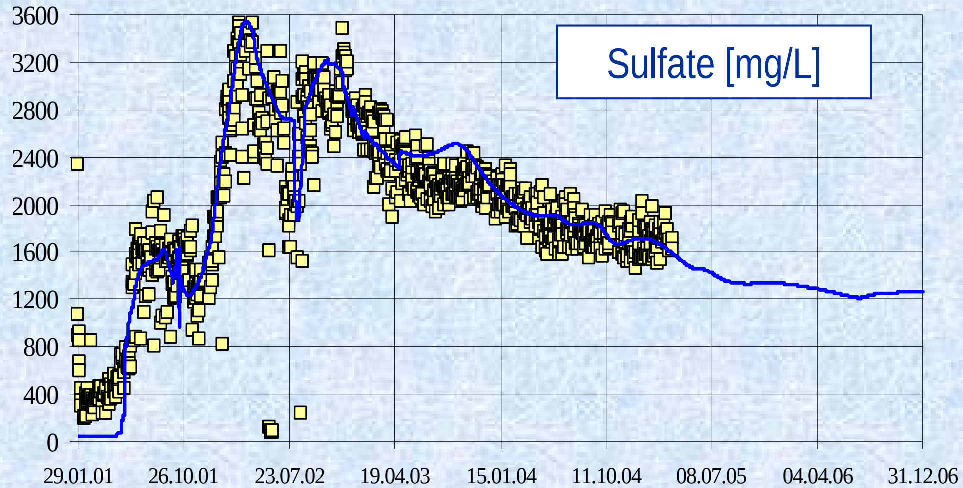
↕

2 year forecast

Step-by-Step Approach

First Flooding Experiment

Second Flooding Experiment



Model Calibration

1993

1997

2001

Fine Tuning

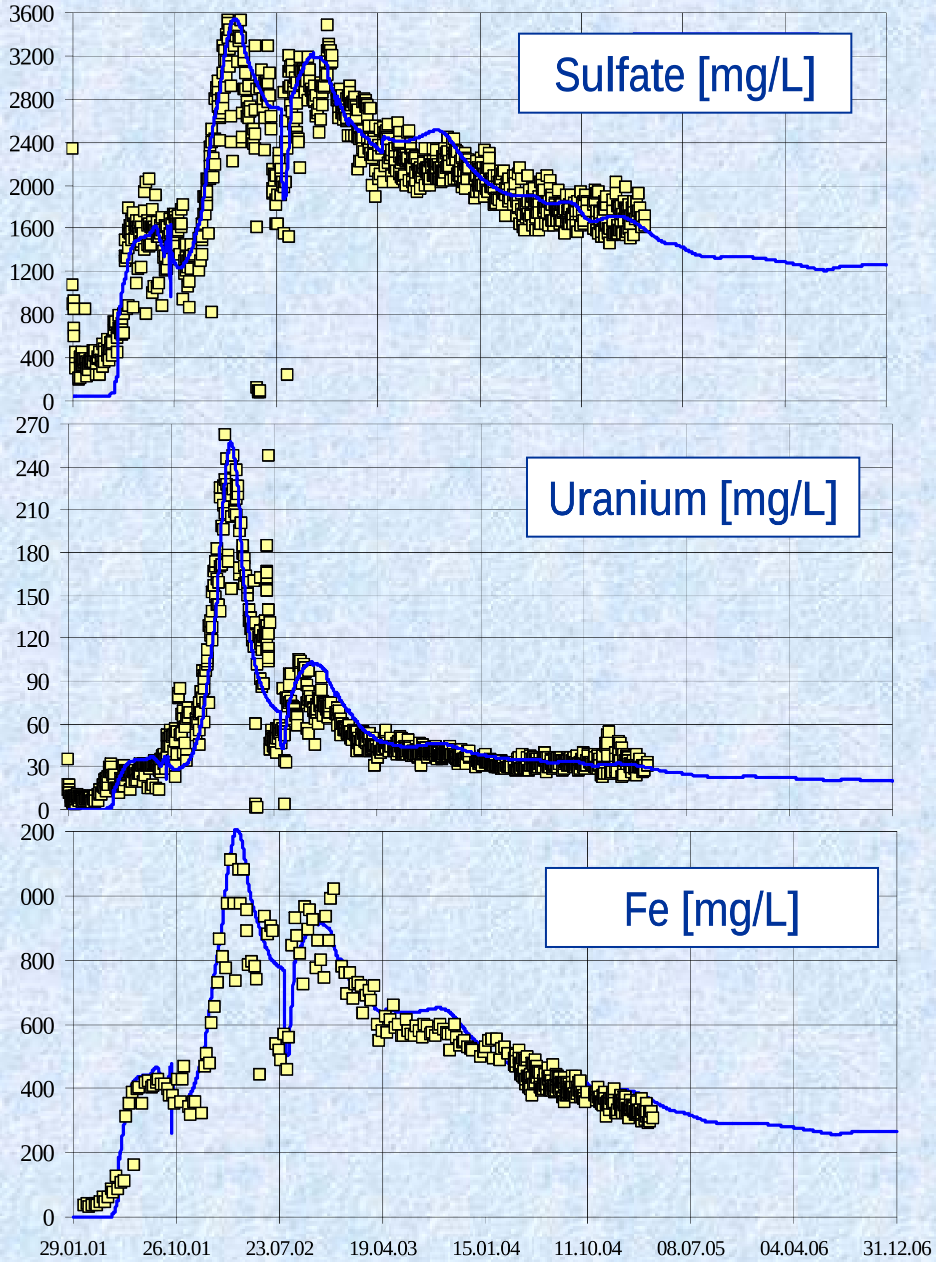
2005

Forecast

Time dependence

pH
15 elements

hydraulics



Königstein Mine - Forecast

Conclusions

The Models were used to

- Evaluate dynamics of mine/process water chemistry
- Select optimized strategies for leaching / remediation
- Interpret laboratory and pilot experiments
- Systemize chemical and hydraulic field data
- Derive a guidance for process monitoring