Application of Different Tracers to Evaluate the Flow Regime at Riverbank Filtration Sites in Berlin (Germany)

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A. Knappe

Alfred Wegener Institute Potsdam

KOMPETENZZENTRUM WasserBerlin

Talk outline

- Introduction
  - Nasri
  - Berlin situation
- Methods/Tracer
- Results
  - Surface water
  - Bank filtrate
  - *Microcystin Experiments (Gesche Grützmacher, UBA Berlin)*
- Summary/Conclusions

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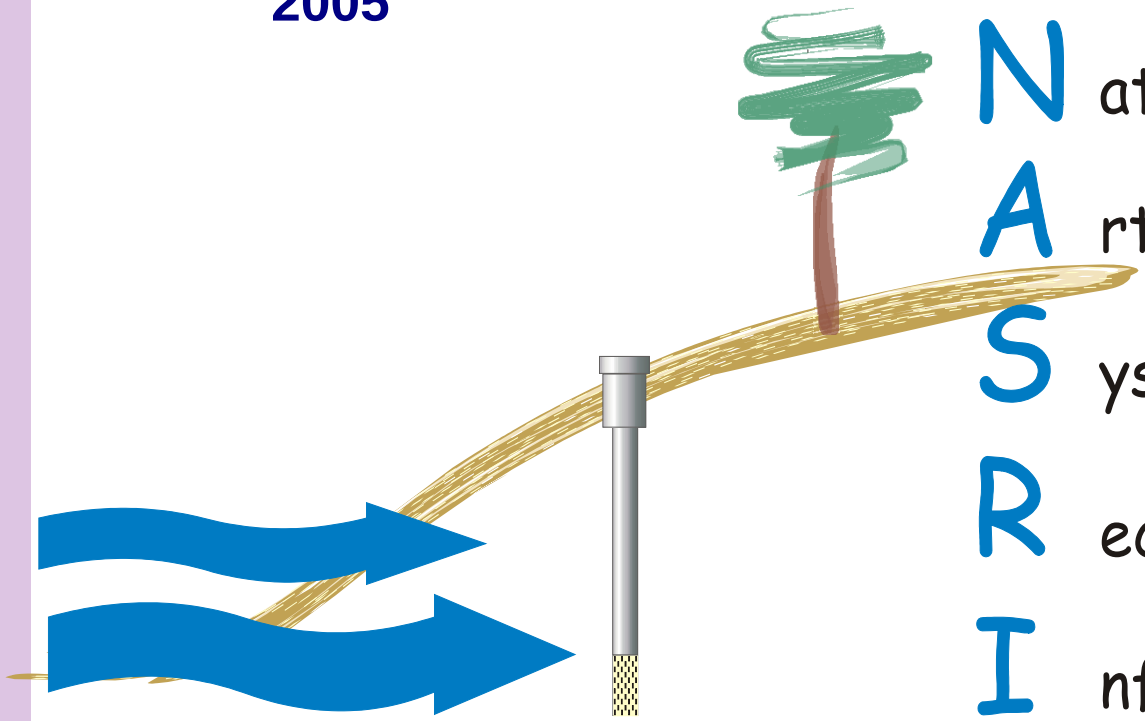
Research program in Berlin to study the fate of pathogens and organics, geochemical processes and hydraulics in bankfiltration and artificial recharge systems at laboratory, semi-technical and field scale.

May 2002 – May 2005



Natural and
Artificial
Systems for
Recharge and
Infiltration

KOMPETENZZENTRUM Wasser Berlin · Berliner Wasserbetriebe · VEOLIA Water · veritas iustitia libertas · IGB · TU berlin · Umwelt Bundes Amt – Für Mensch und Umwelt

Nasri: 7 Teams

Algae: Retention and elimination of cyanobacterial toxins (microcystins) (Dr. Chorus/Dr. Bartel, German Environmental Acency).

Bacteria: Using bacteriophages, indicator bacteria and viral pathogens for assessing the health risk (Dr. Lopez-Pila, Dr. Szewzyk, German Environmental Acency).

Drugs: Occurrence and fate of drug residues and related polar contaminants (Dr. Heberer, Technical University, Dr. Dünnbier, Berlin Water Company).

Hydrogeo: Hydrogeological-hydrogeochemical processes using a multi tracer approach (Prof. Pekdeger, Free University)

Models: Integrated modelling concepts: coupled groundwater transport and biochemical reactions (Prof. Nuetzmann,Institute for Freshwater Ecology)

Organics: Organic substances– process studies (Prof. Jekel, Technical University)

BWB: Data management, water sampling, analyses

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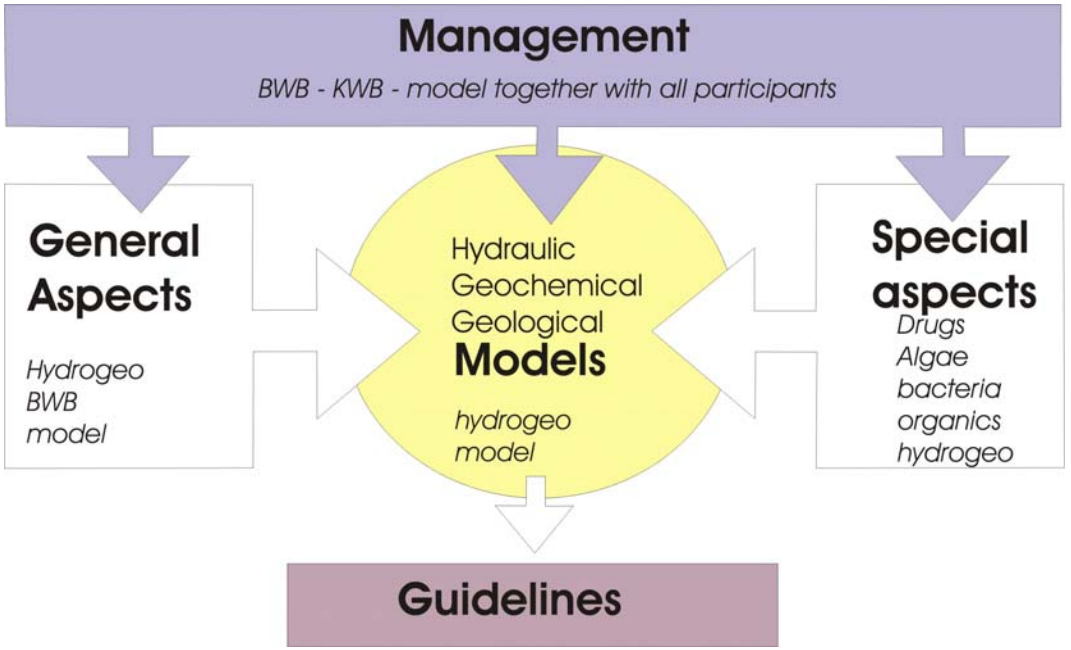
Objectives of Nasri



- **To ensure the long term sustainability of the groundwater resource and drinking water quality through the bankfiltration and the groundwater recharge process**
- **To expand the Know-How and quantify the relevant processes**
- **To obtain quantitative and qualitative guidelines for proper design and optimised operation of existing sites and for transfer of the integrated knowledge to other locations (use of models etc..)**

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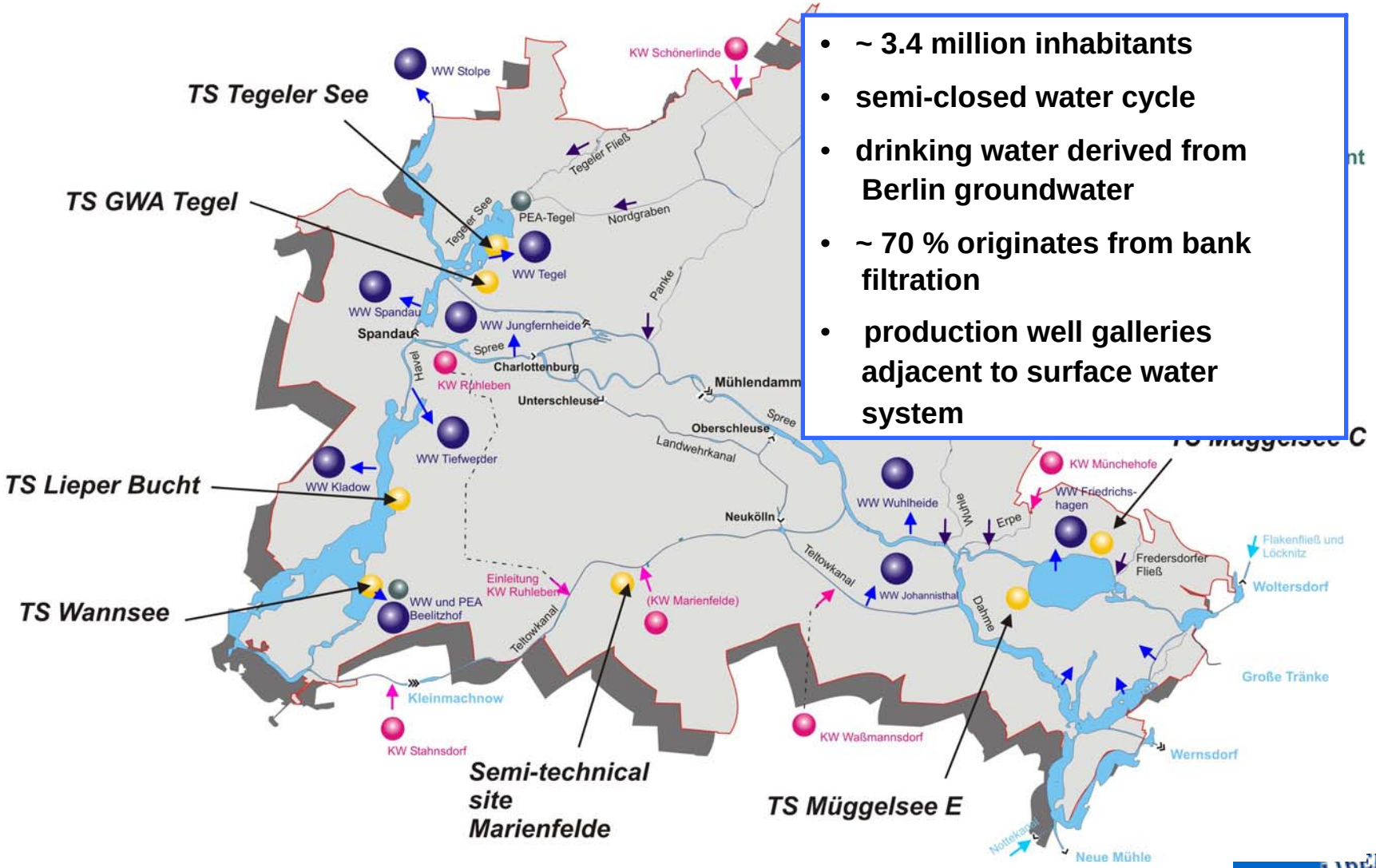
Berlin characteristics



- ~ 3.4 million inhabitants
- semi-closed water cycle
- drinking water derived from Berlin groundwater
- ~ 70 % originates from bank filtration
- production well galleries adjacent to surface water system

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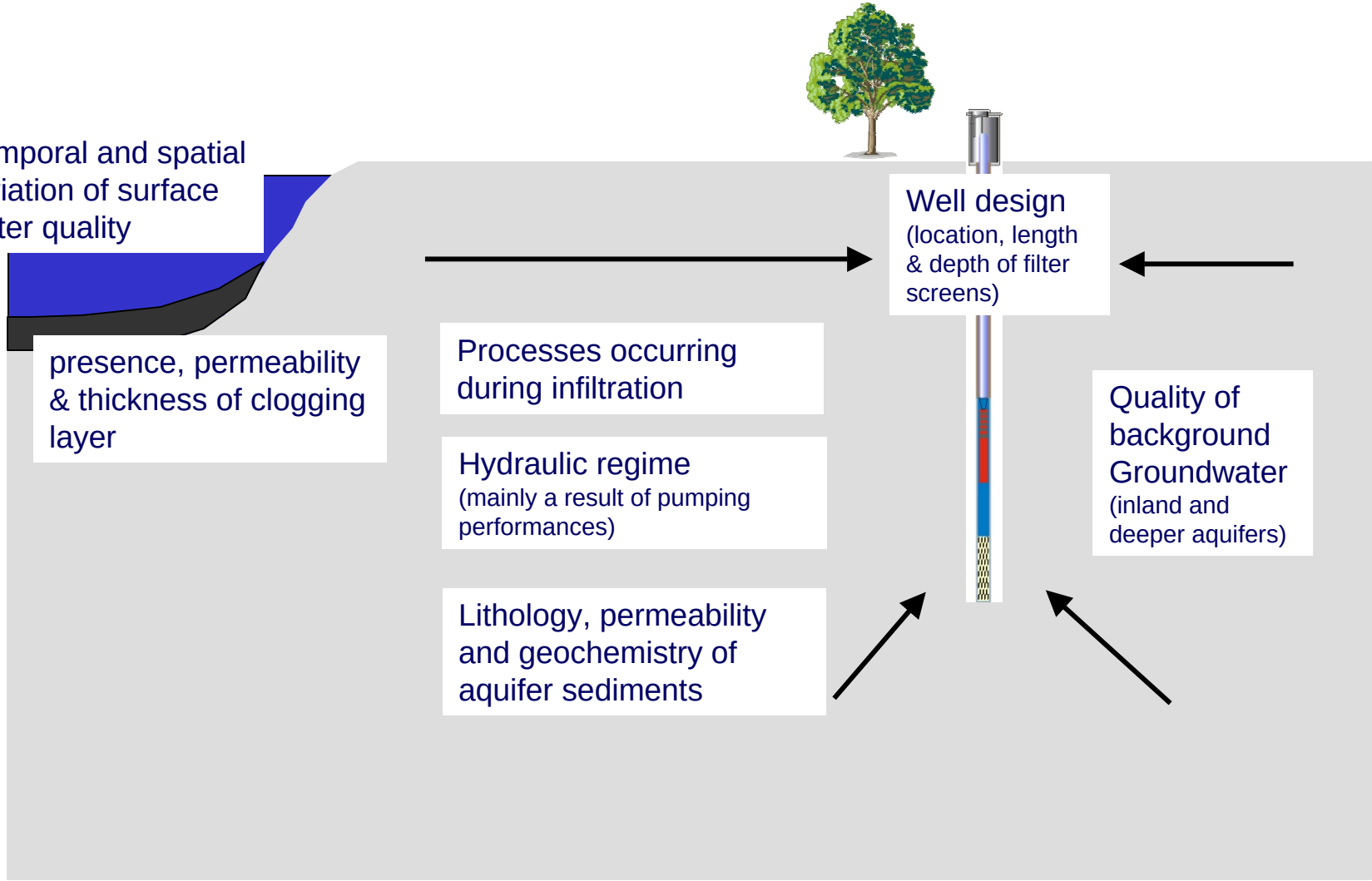
Factors influencing the raw water quality



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Objectives

Objectives

to use a variety of tracers at several field-sites in order to:

- estimate the proportion of treated wastewater in the surface water system
- estimate the proportion of bank-filtrate (and likewise deeper and landside groundwater) in the production wells
- derive travel times from the surface water to the production wells
- understand flow regime

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T/He age dating

Methods

^3H oder T $\xrightarrow{12.32y}$ ^3He

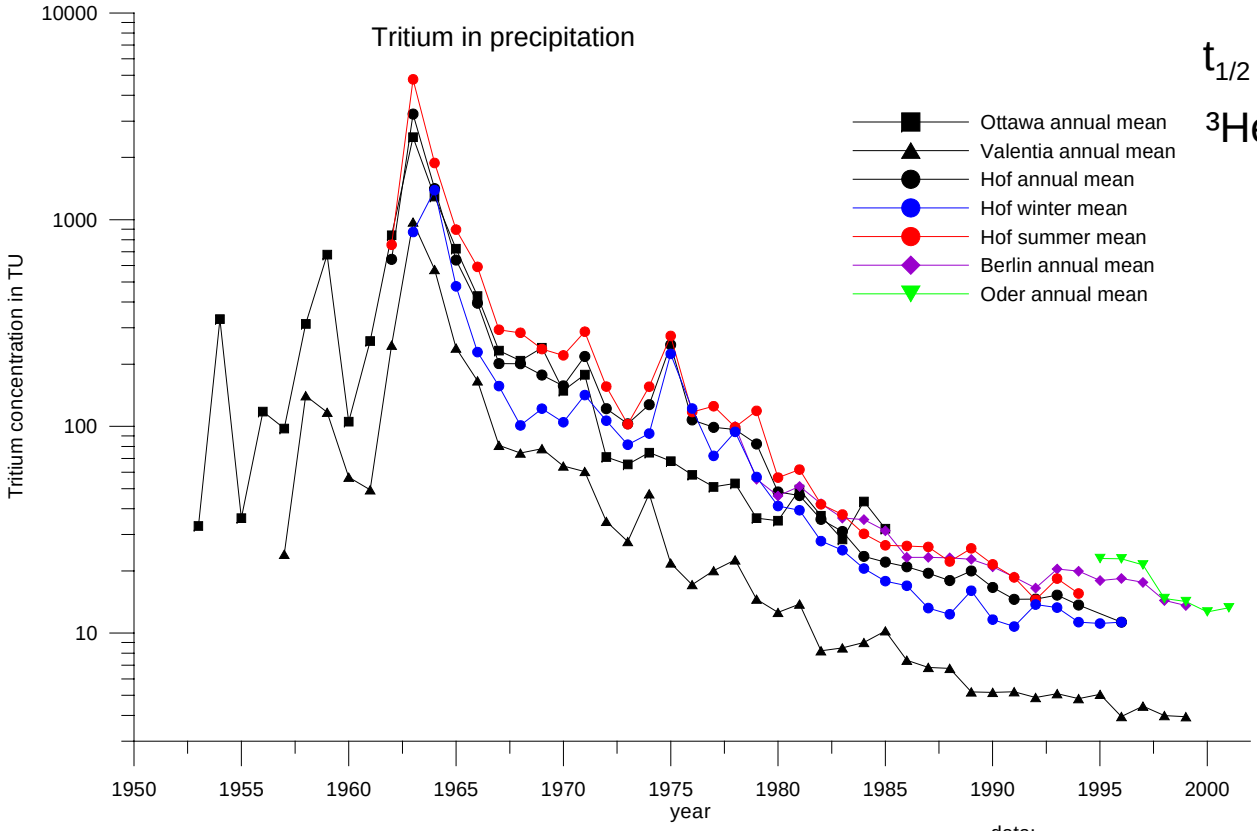
in water: 1TU 1T / 10^{18} H 0.118Bq/kg

Groundwater „age“:

$$\tau = {}^{t_{1/2}}/_{\ln 2} \cdot \ln\left(1 + {}^{^3He^*}/_{T}\right)$$

$t_{1/2}$ = 12.32y

$^3He^*$ = tritiogenic He



data: **Data: IAEA, BfG**

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Overview on applicable tracers in Berlin

Methods

Tracer:	Origin:	Useful for the interpretation of:	Difficulties:
δD, $\delta^{18}O$	surface water with seasonal variations	water movement	none, conservative tracer
Temperature	surface water with seasonal variations	water movement	retarding
Cl^-	surface water with seasonal variations	water movement	only if influence of saline groundwater can be excluded
Cl^-, Na^+, B	saline deeper groundwater	proportion of deeper saline groundwater	may vary strongly locally
SO_4^{2-}	dissolution of gypsum derived from building rubble in the shallow aquifer	proportion of shallow "native" groundwater	may vary strongly locally
B	surface water, effluent	water movement, proportion of bank filtrate in raw water	only if influence of saline groundwater can be excluded
Gd	surface water, effluent	water movement, proportion of bank filtrate in raw water	possibly degradable
EDTA	surface water, effluent	water movement, proportion of bank filtrate in raw water	sometimes the background groundwater has also got very high concentrations
Sr	surface water, very few seasonal variations	proportion of bank filtrate in raw water	not always applicable
T/He	Surface water, through atmospheric input	groundwater "age"	minimum age required is 2 months

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Mixing calculation

$$X = [C_w - C_{GW})/(C_{SW} - C_{GW})]*100\ [\%]$$

X = Percentage of bank-filtrate in the production well

C_w= Tracer concentration in the production well

C_{SW}= Tracer concentration in the surface water

C_{gw}= Tracer concentration in the groundwater

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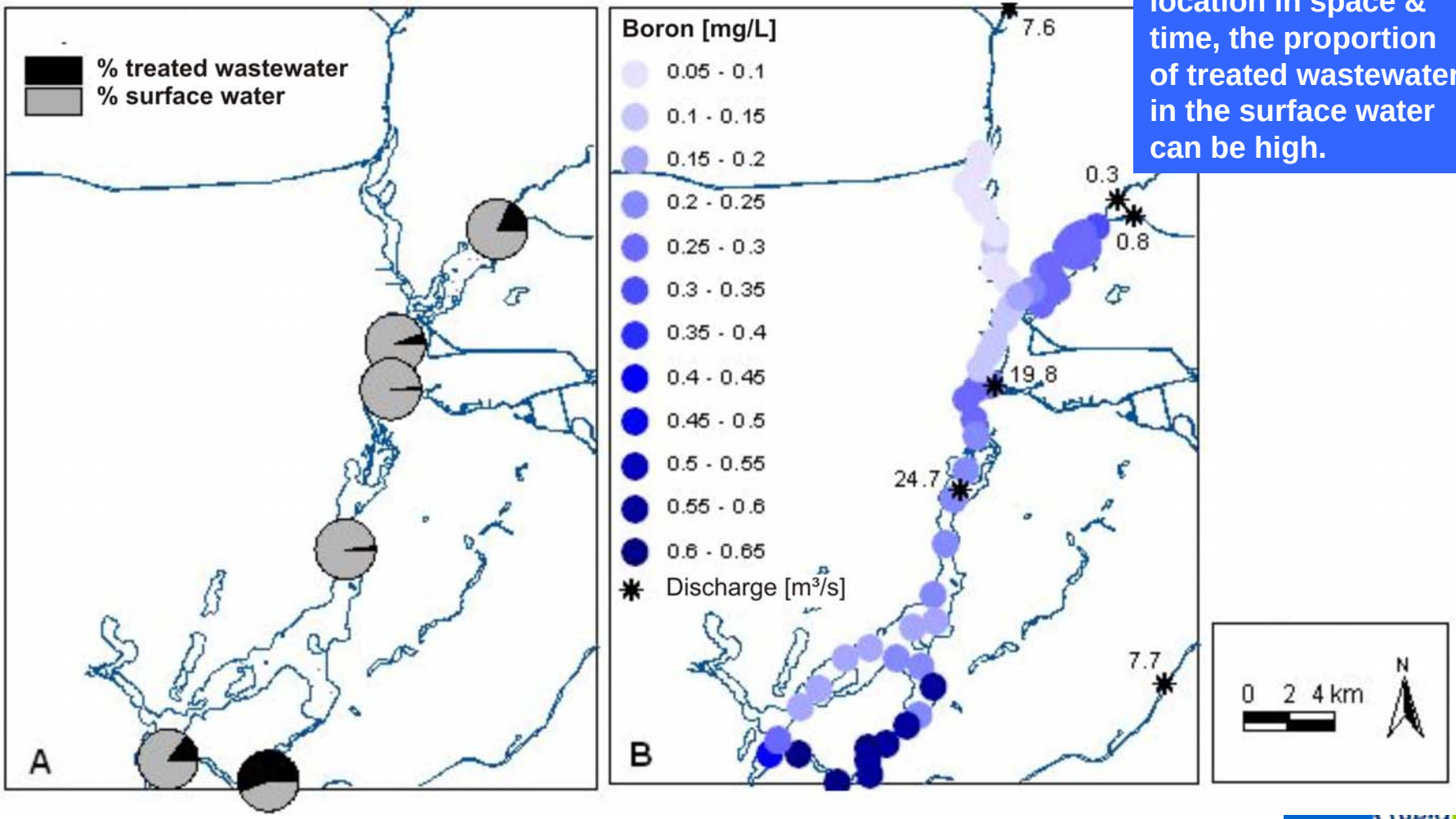
Surface water

Results

Spatial variations of B and percentage of treated wastewater in the surface water

Depending on location in space & time, the proportion of treated wastewater in the surface water can be high.



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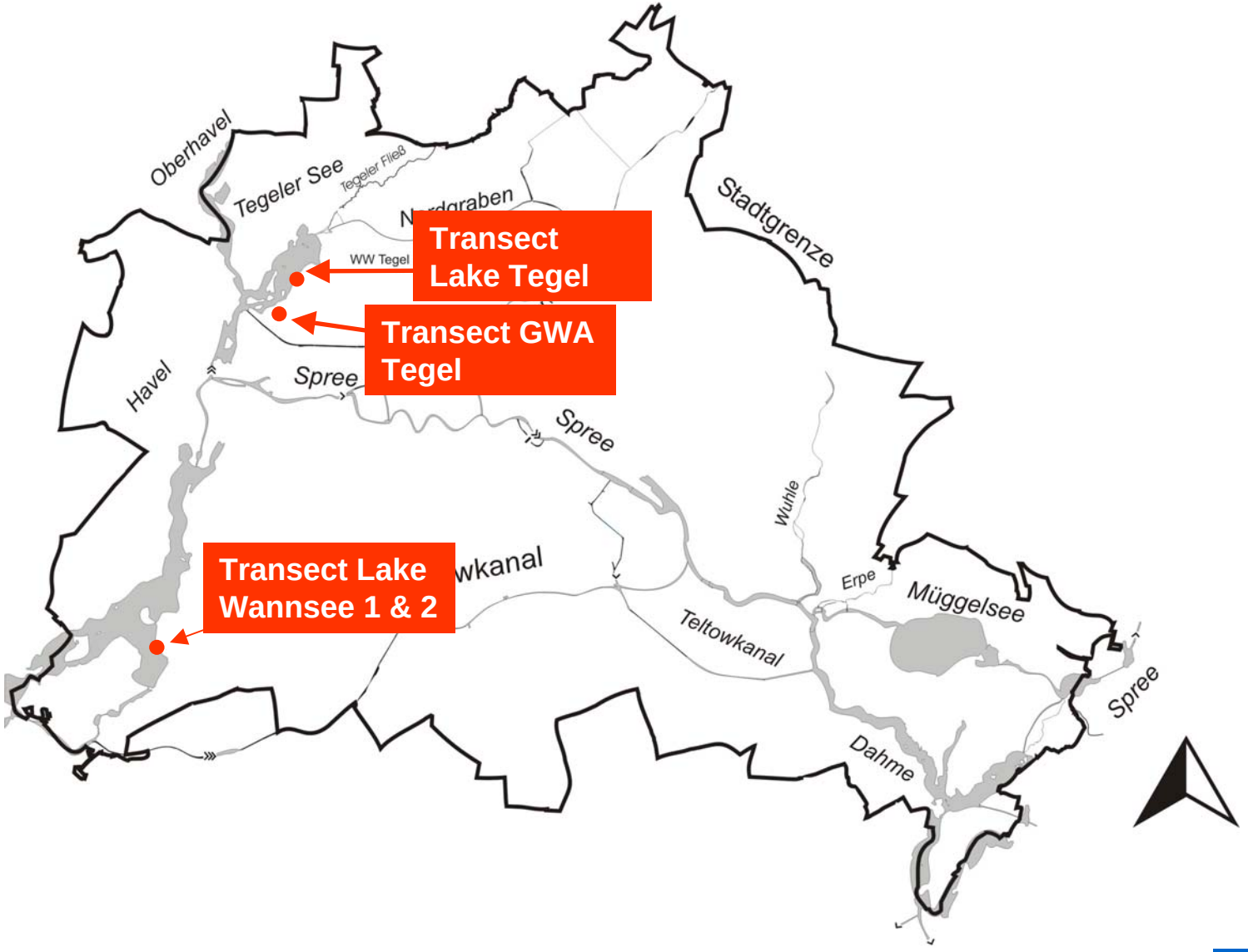
Location of field sites



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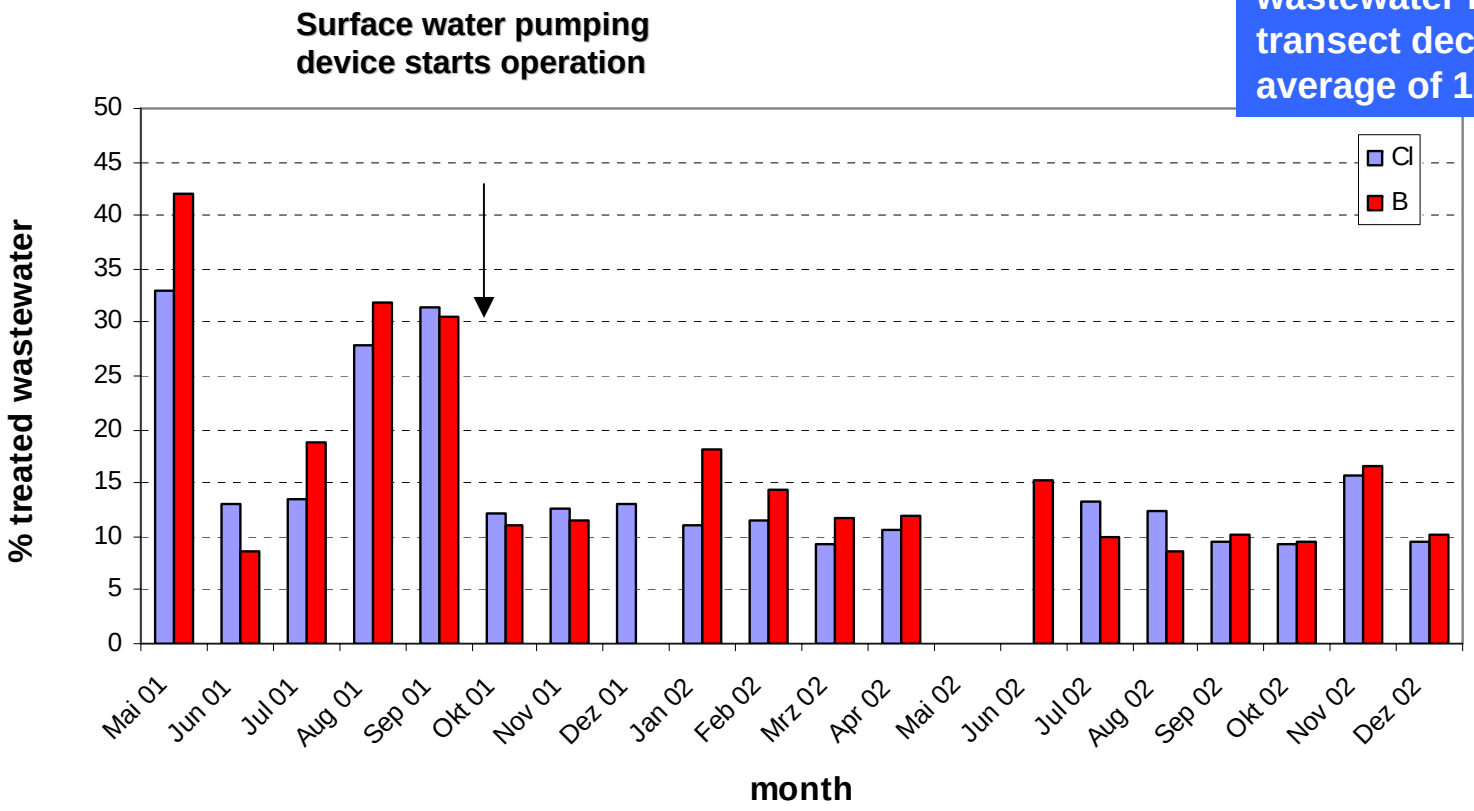
Surface water

Percentage of treated wastewater in Lake Tegel near the transect

Results

Since operation of pumping device started, the proportion of treated wastewater in SW near transect declined to an average of 12 %



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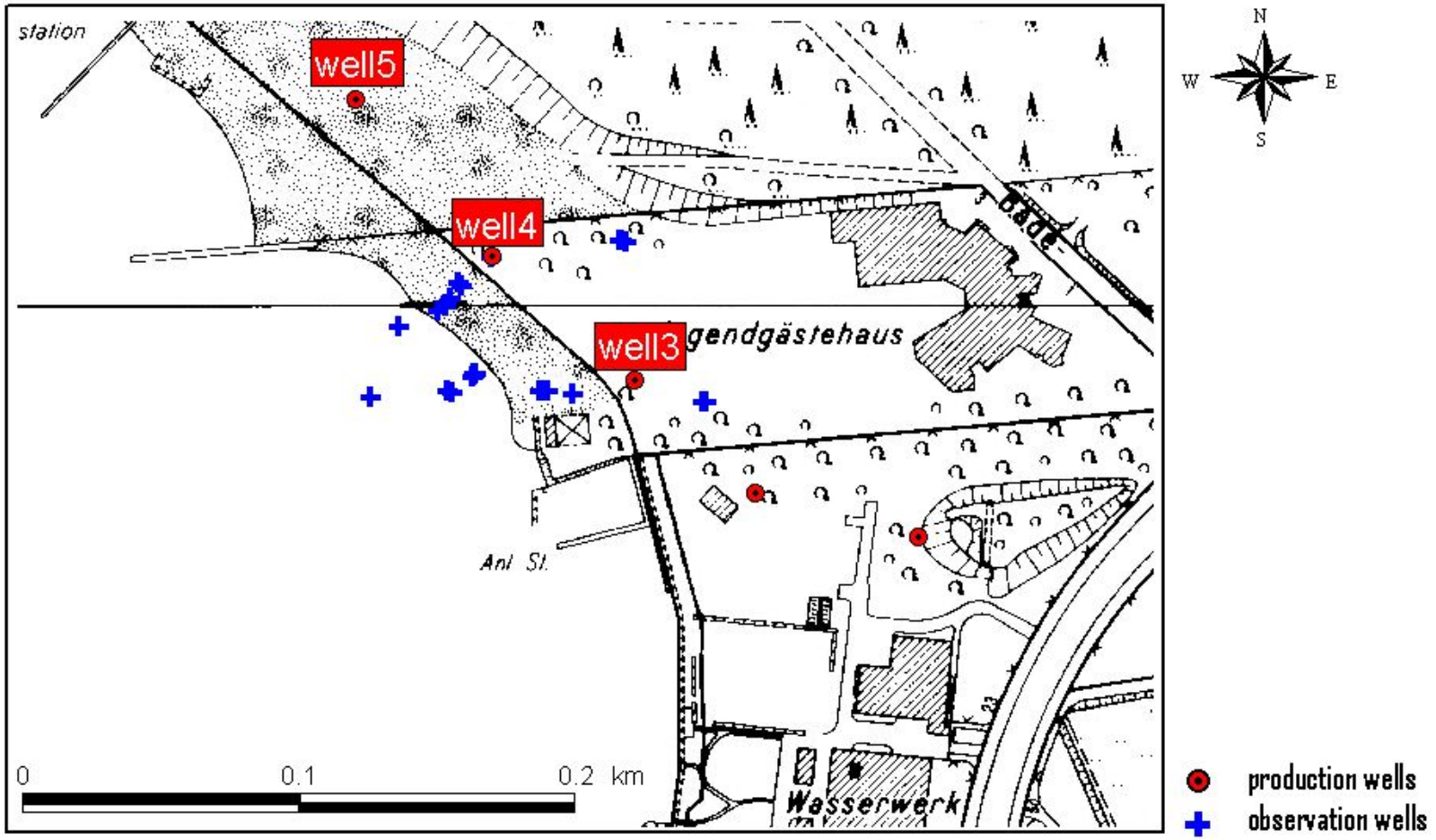
Field-site Lake Wannsee

Results



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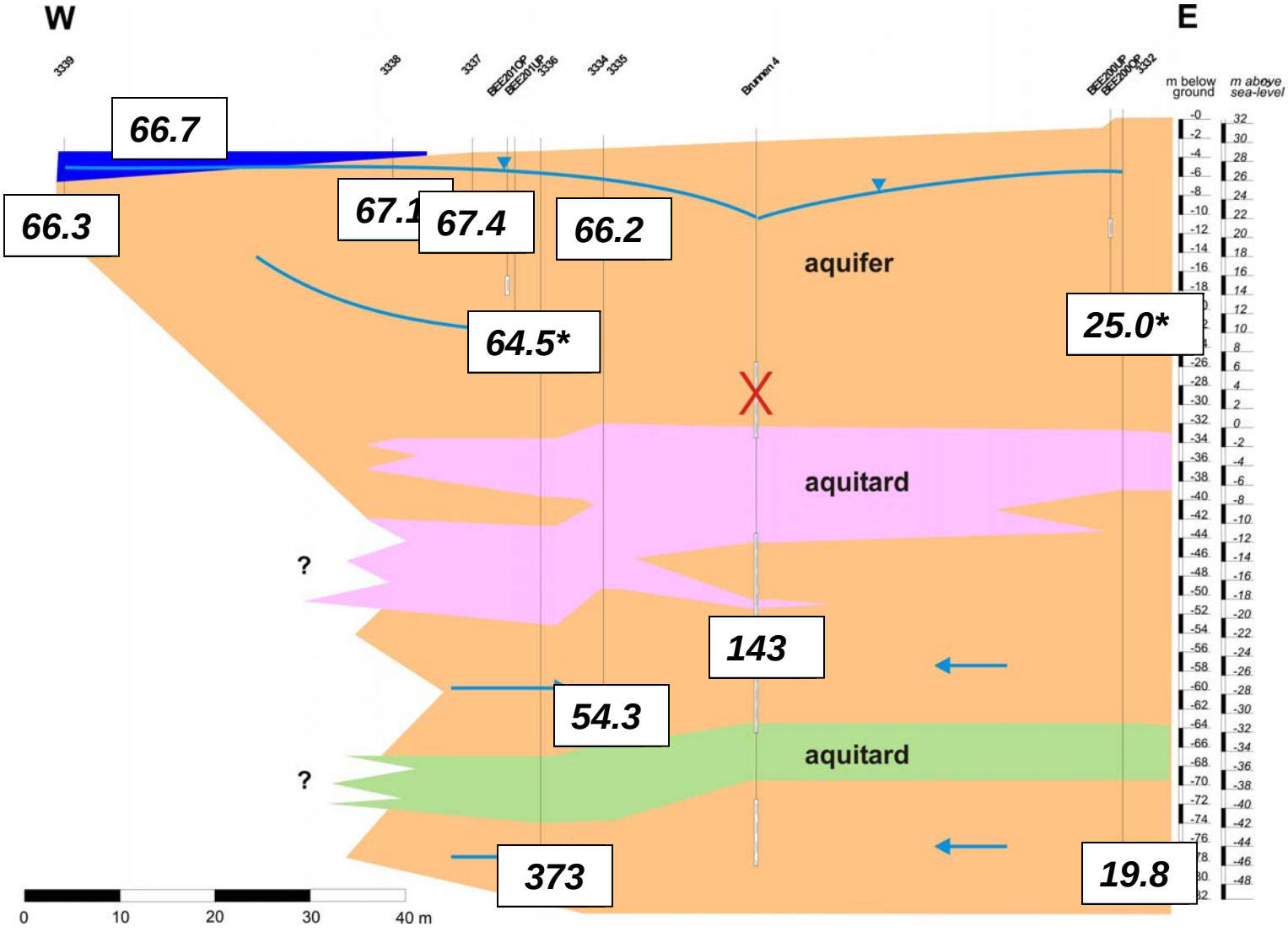
Transect Lake Wannsee 1, hydrochemistry

Results



Cl [mg/l]

Data: Ilat average 10/2000 –11/2001
***BWB 01/2003 – 04/2003**

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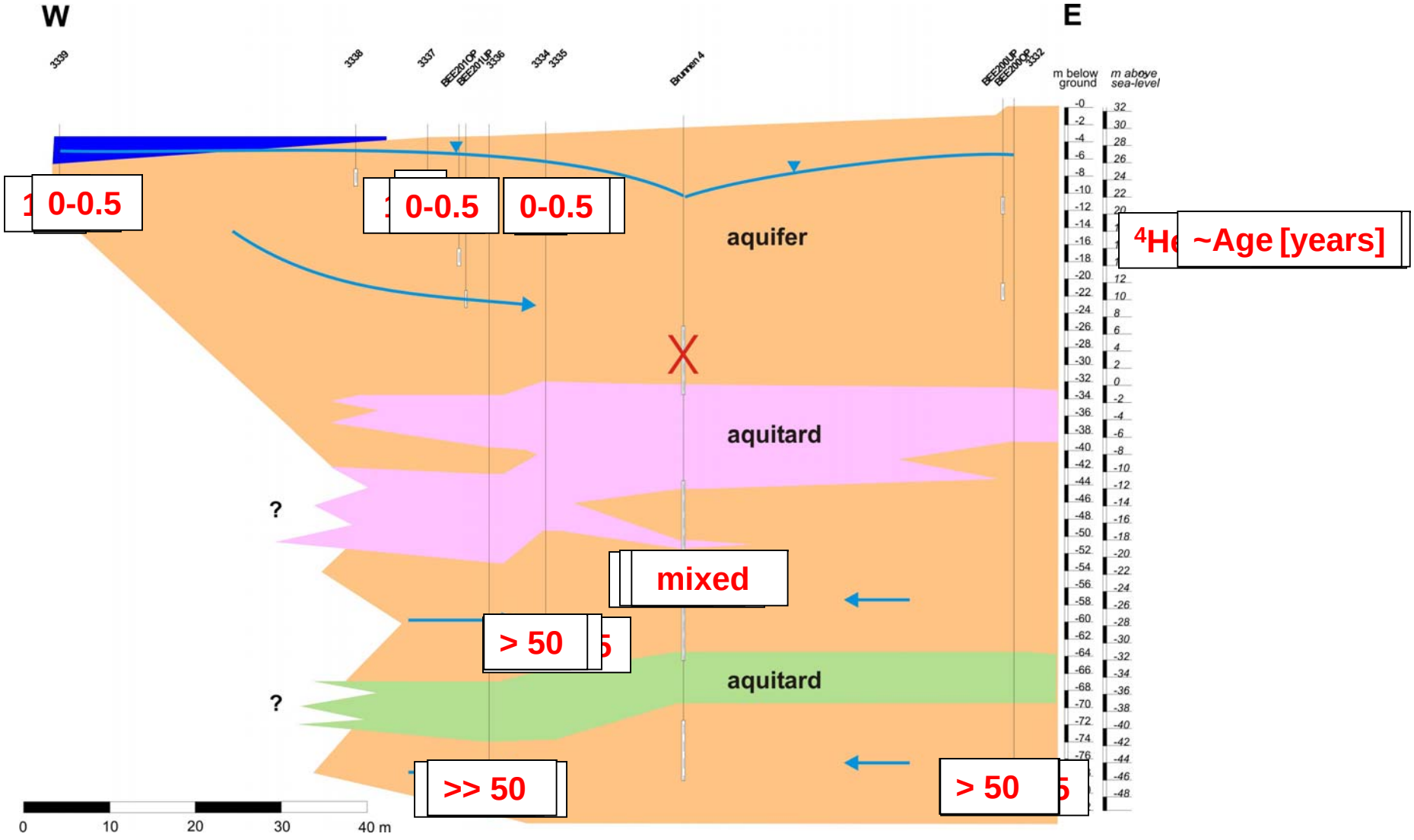
Transect Lake Wannsee 1, age dating

Results



Data: Helis Laboratory, University of Bremen

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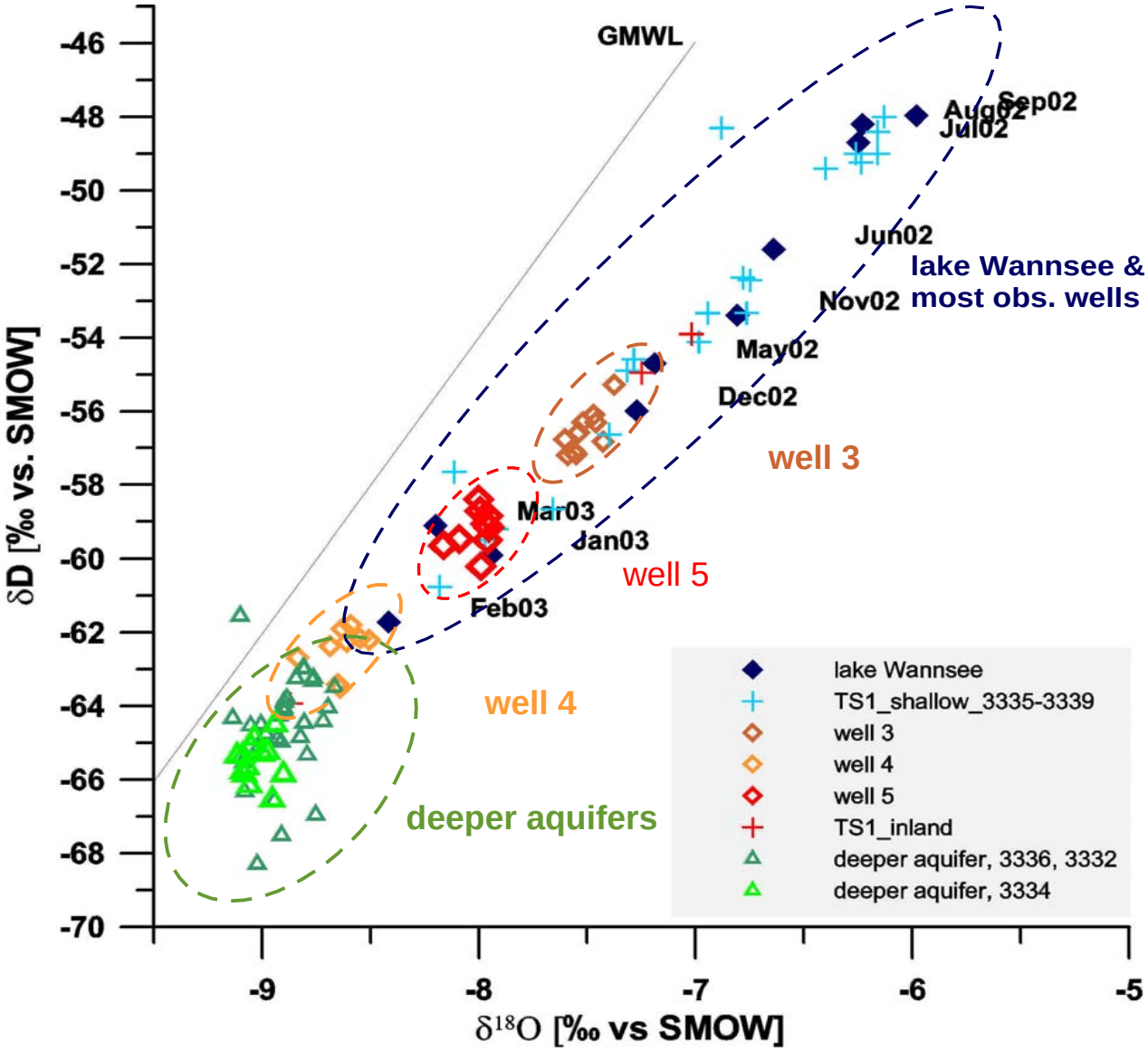
Transect Lake Wannsee 1, dD versus d18O

Results



well 3 (new transect) has a much higher proportion of bank-filtrate!

Data: Alfred-Wegener Institute Potsdam

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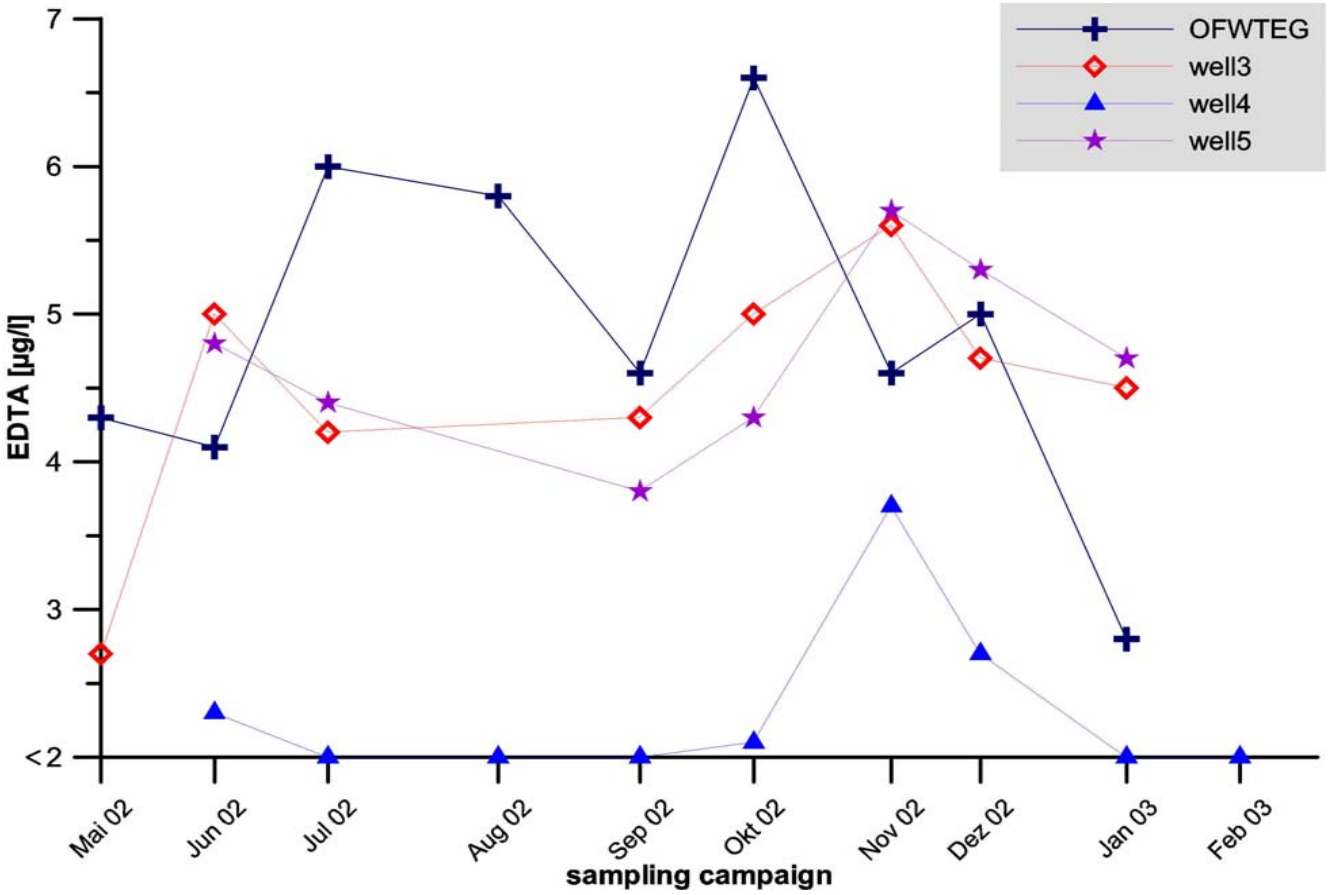
Field-site Lake Wannsee

Time-series of EDTA in production wells

Results



Data: Berlin Water Company

Proportion of bank-filtrate calc. with EDTA:
Well3 = 61-97 %
Well4 = 10-47 %
Well5 = 88-96 %

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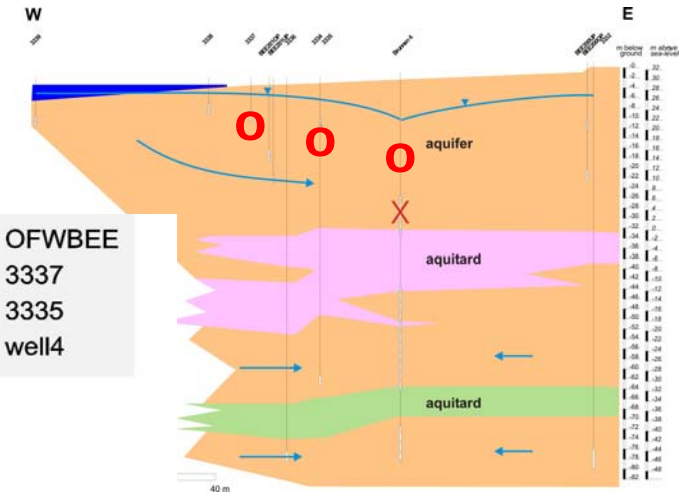
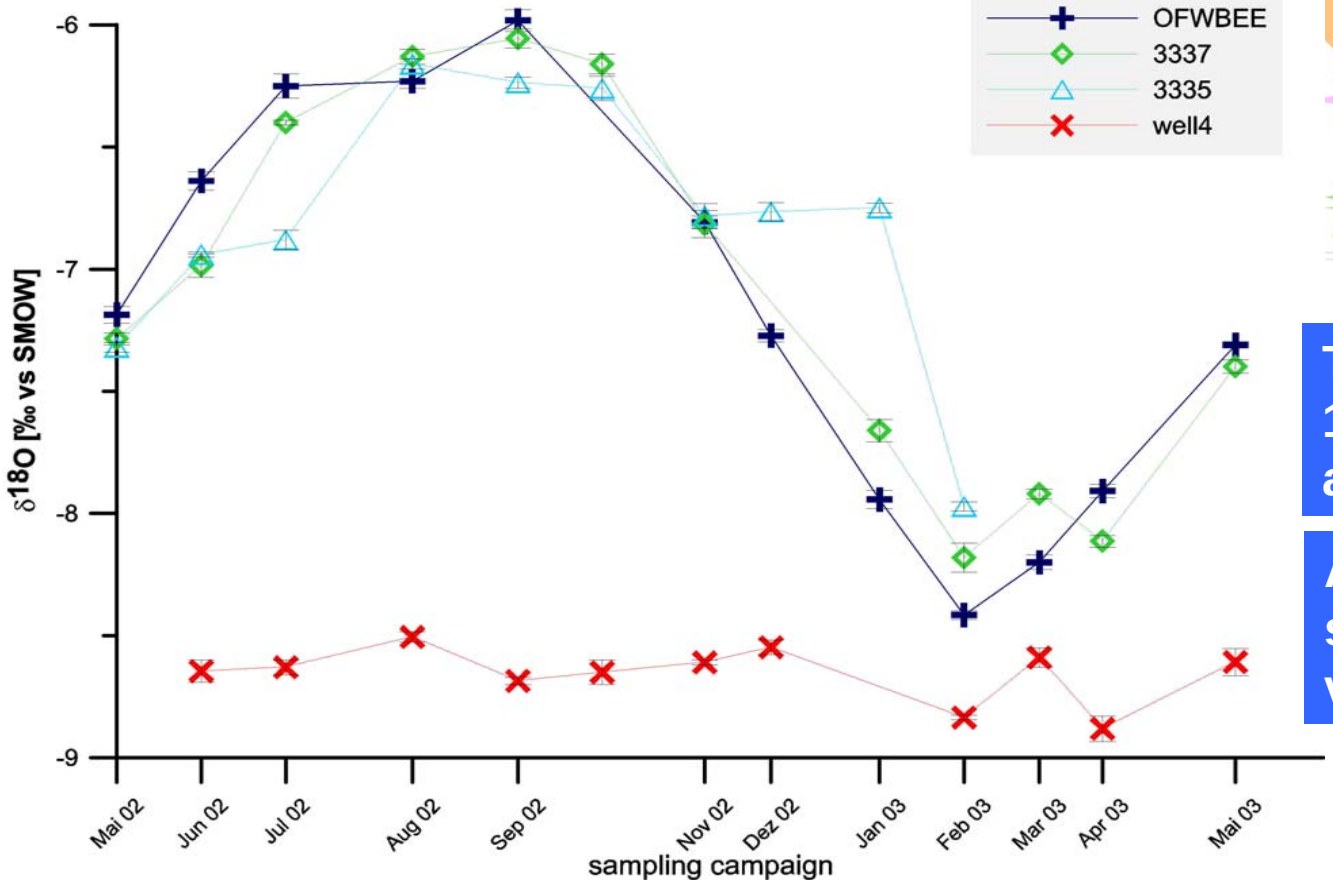
Transect Lake Wannsee 1

Time-series of d18O in shallow observation wells

Results





Travel time Lake-well4 1-2 months in shallow aquifer

All production wells show no seasonal variation

Data: Alfred-Wegener Institute Potsdam

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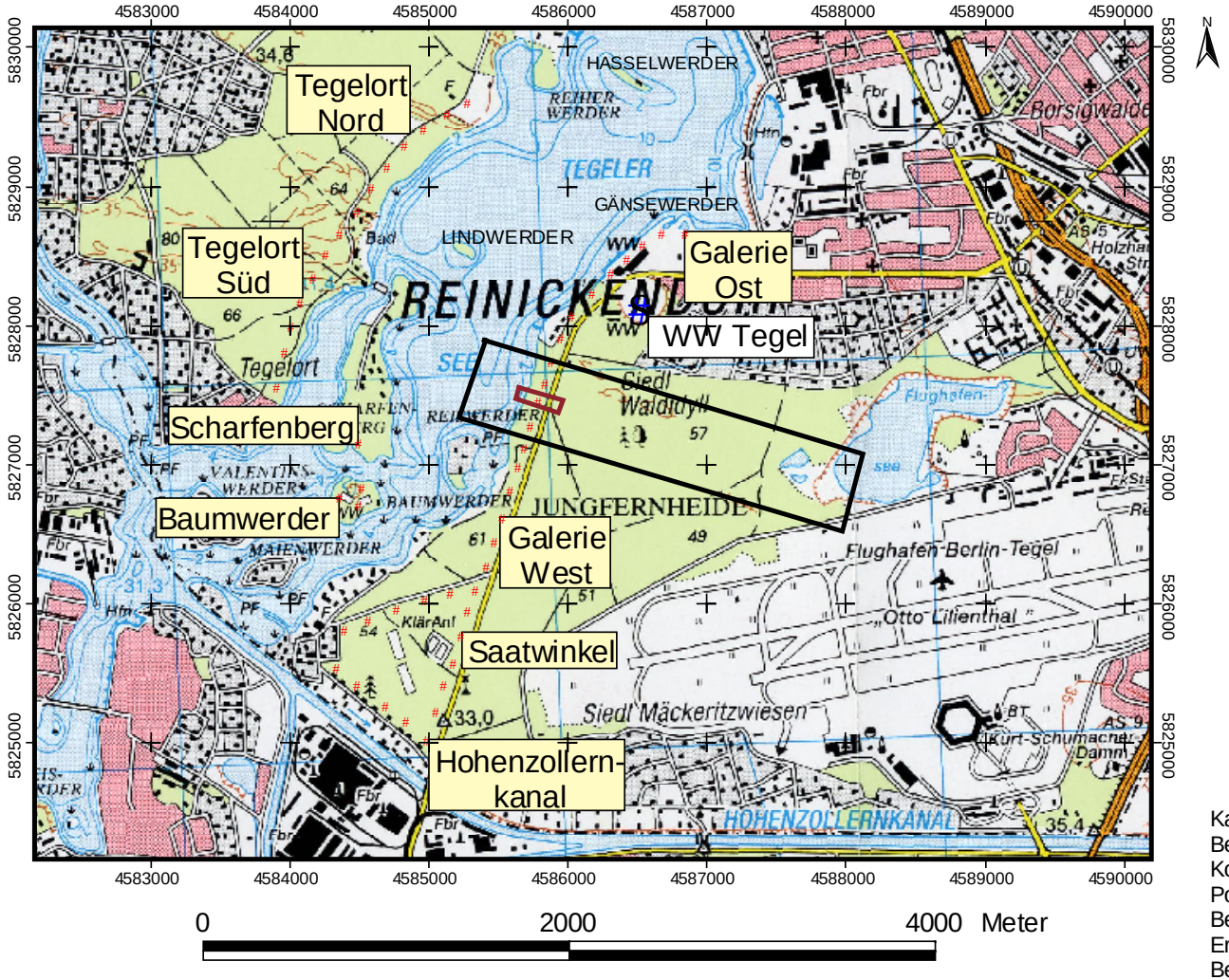
Flow model Lake Tegel

Results



Legend

- # well
- # # # well gallery
- Tegelort Süd — name of well gallery
- transect Tegel
- model region

Kartengrund: TK 50 Blatt L3544
Berlin-Spandau, 1998
Koordinaten: Gauß-Krüger
Potsdam-Datum (Zentralpunkt Rauenberg)
Besselellipsoid
Erstellungsdatum: 12/2002
Bearbeiter: Jeannette Rümmler

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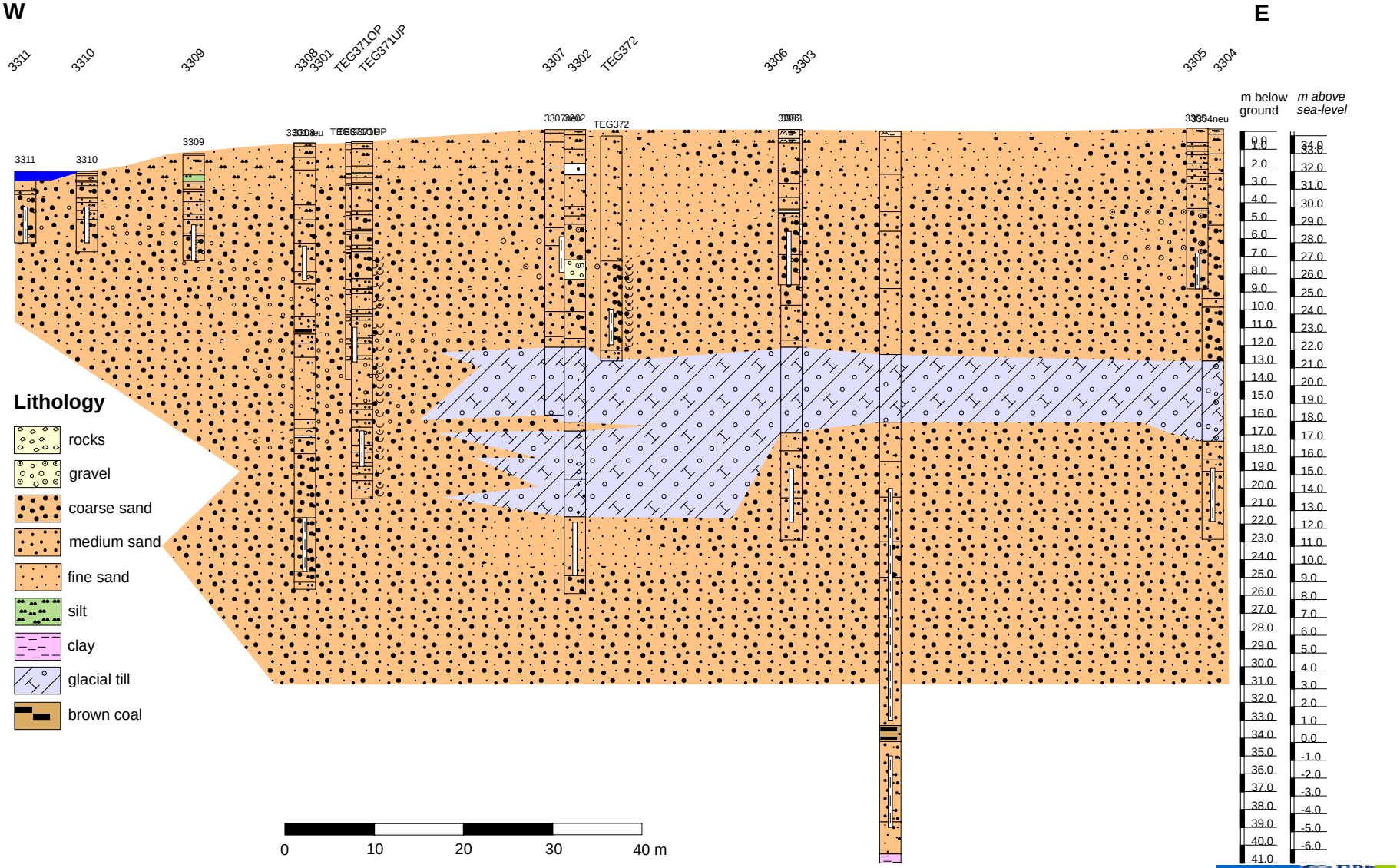
Transect Lake Tegel

Results



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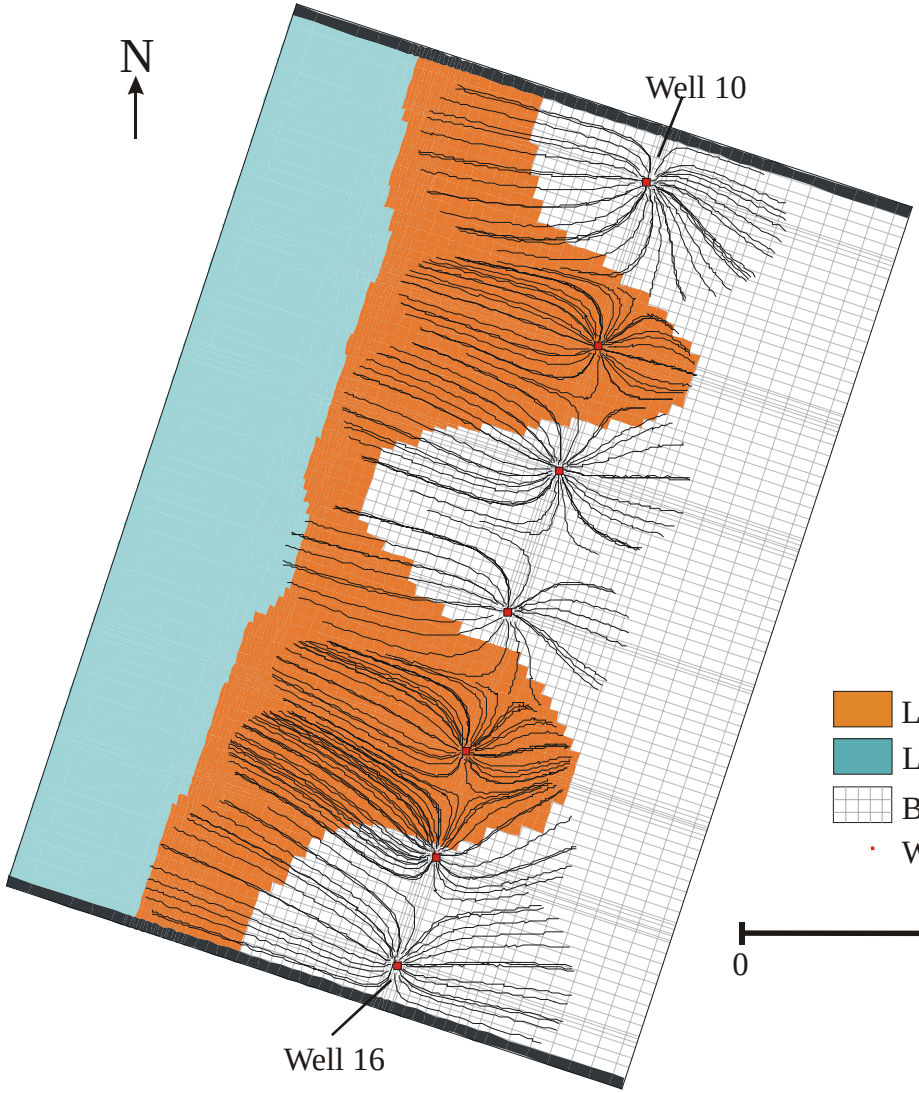
Flow model Lake Tegel

Results

steady state model



Shortest travel time between single wells and position shoreline* in weeks/days

well 10 = 31/217
well 11 = 32/224
well 12 = 29/203
well 13 = 26/182
well 14 = 34/238
well 15 = 32/224
well 16 = 28/196

*Flow field after 190 days

Leakage aquifer 1
Leakage lake sediment
Boulder clay above aquifer 2
Well

0 — 200 Meter

Bearbeiter: J. Rümmler, 7/2003

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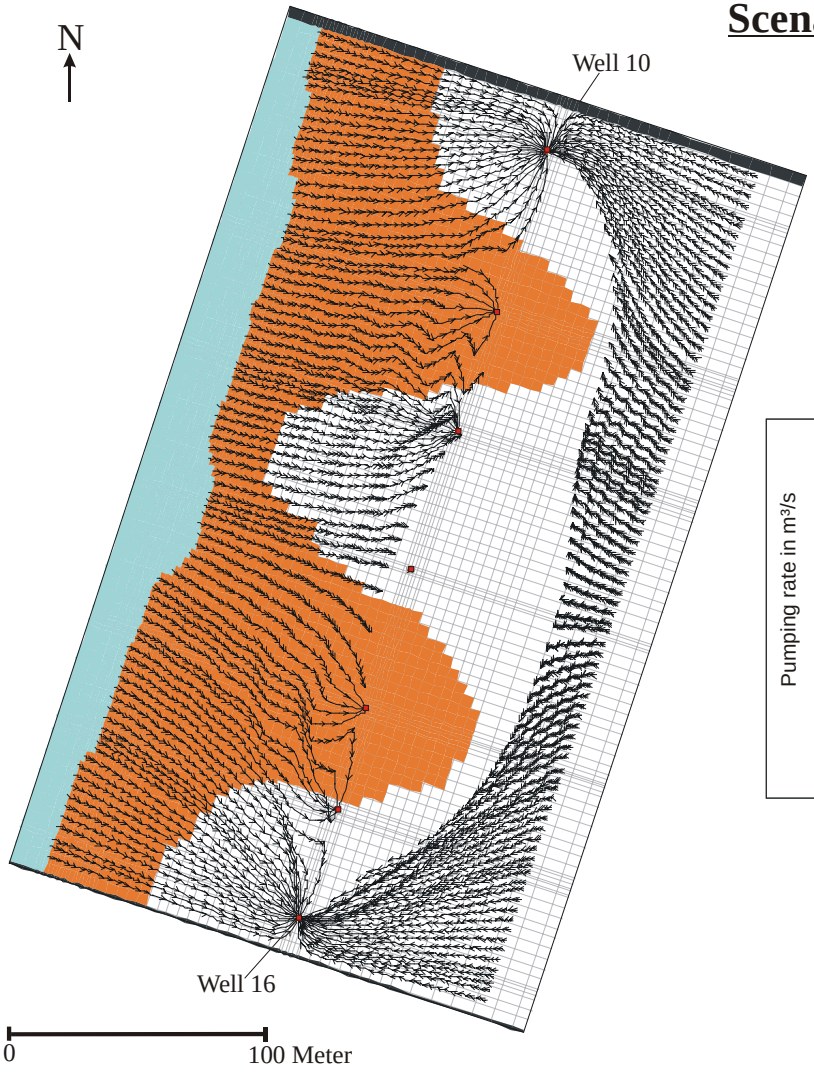
Flow model Lake Tegel

Results

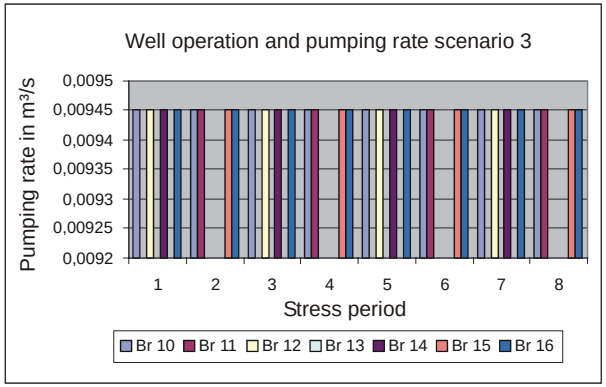
Scenario 3



Shortest travel time between single wells and position shoreline in weeks

Br 10 = 23
Br 11 = 29/30
Br 12 = 29
Br 13 = -
Br 14 = 30/31
Br 15 = 32
Br 16 = 22/23

Pumping regime is very complicated – Flow models help to understand the influence of different pumping scenarios on groundwater flow paths!



Leakage aquifer 1
Leakage lake sediment
Boulder clay above aquifer 2
Well
Intervall <——< = 1 Week

Bearbeiter: J. Rümmler, 7/2003

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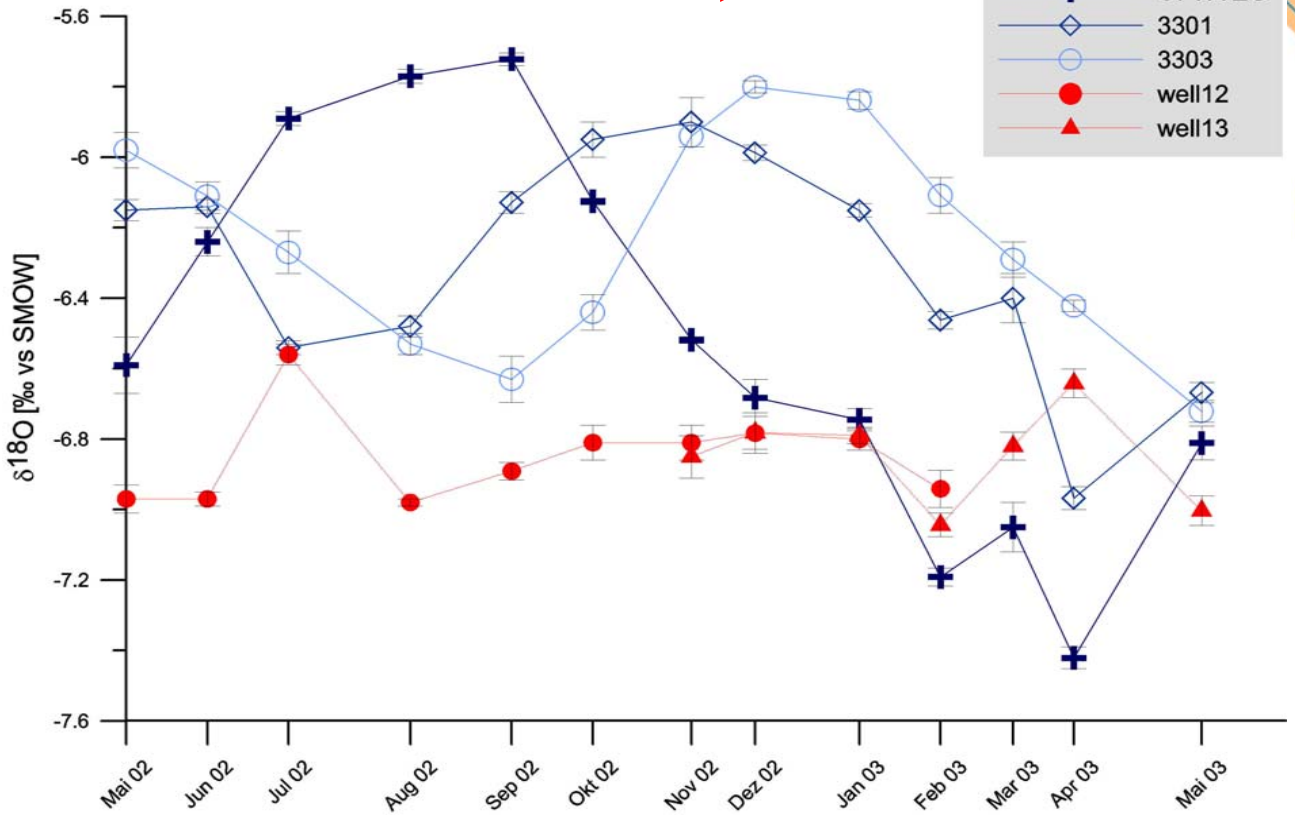
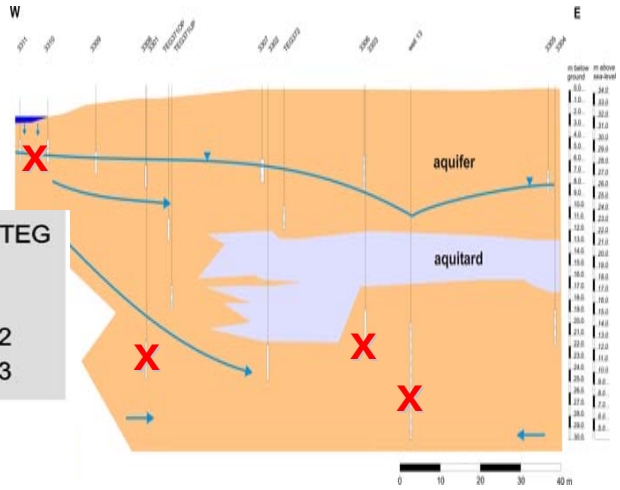
Lake Tegel, age dating and hydrochemistry

Results

Lake to 3303: 3 - 4 months

Lake to 3301: 2 - 3 months





Production well water shows no seasonal variation
Travel time Lake-well 13:
6-9 months (Fritz 2002)

Data: Alfred-Wegener Institute Potsdam

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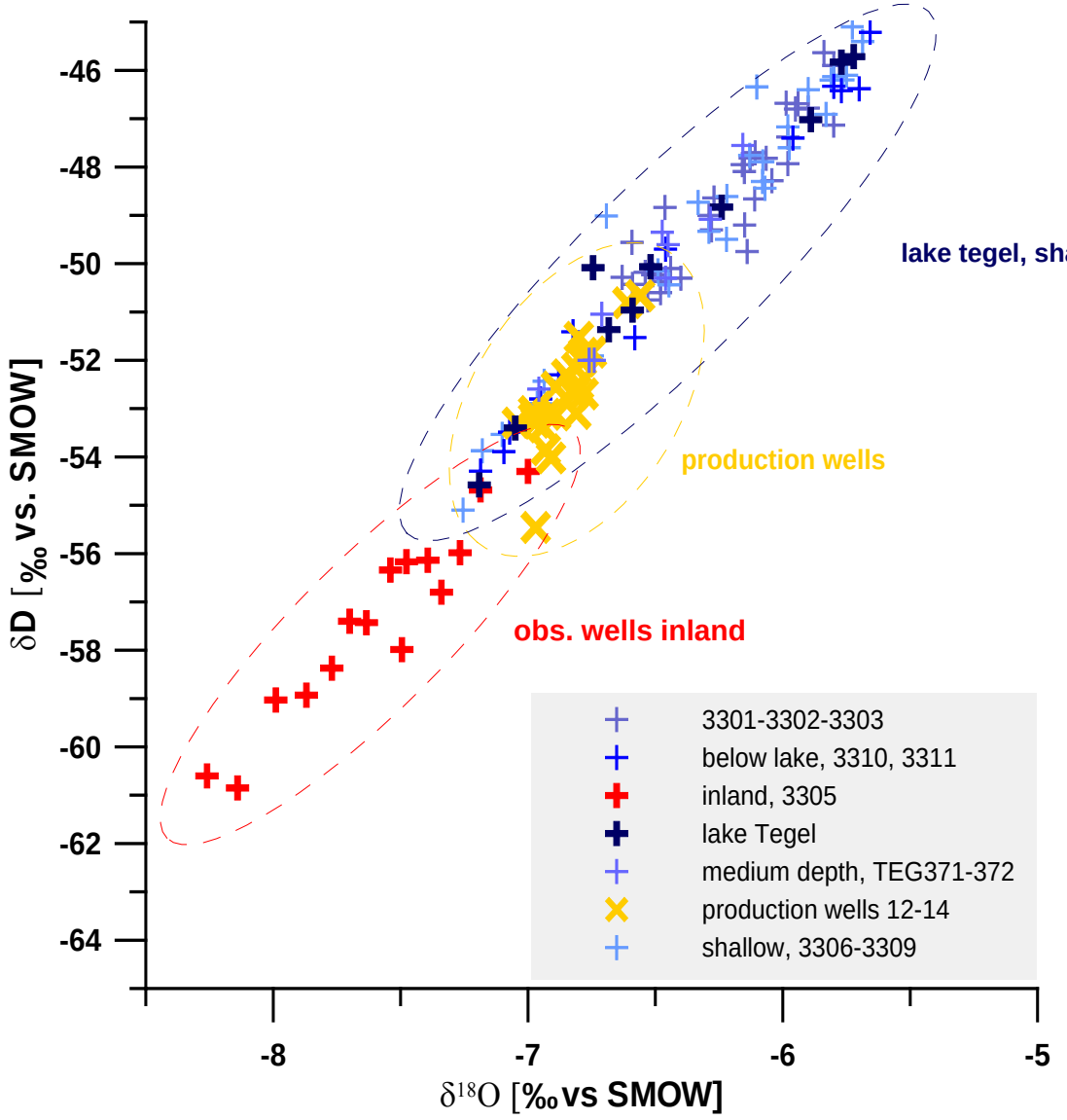
Transect Lake Tegel, dD versus d18O



Production well water is a mixture of background groundwater and bank-filtrate
Proportion of bank-filtrate: ~ 80 %

Data: Alfred-Wegener Institute Potsdam

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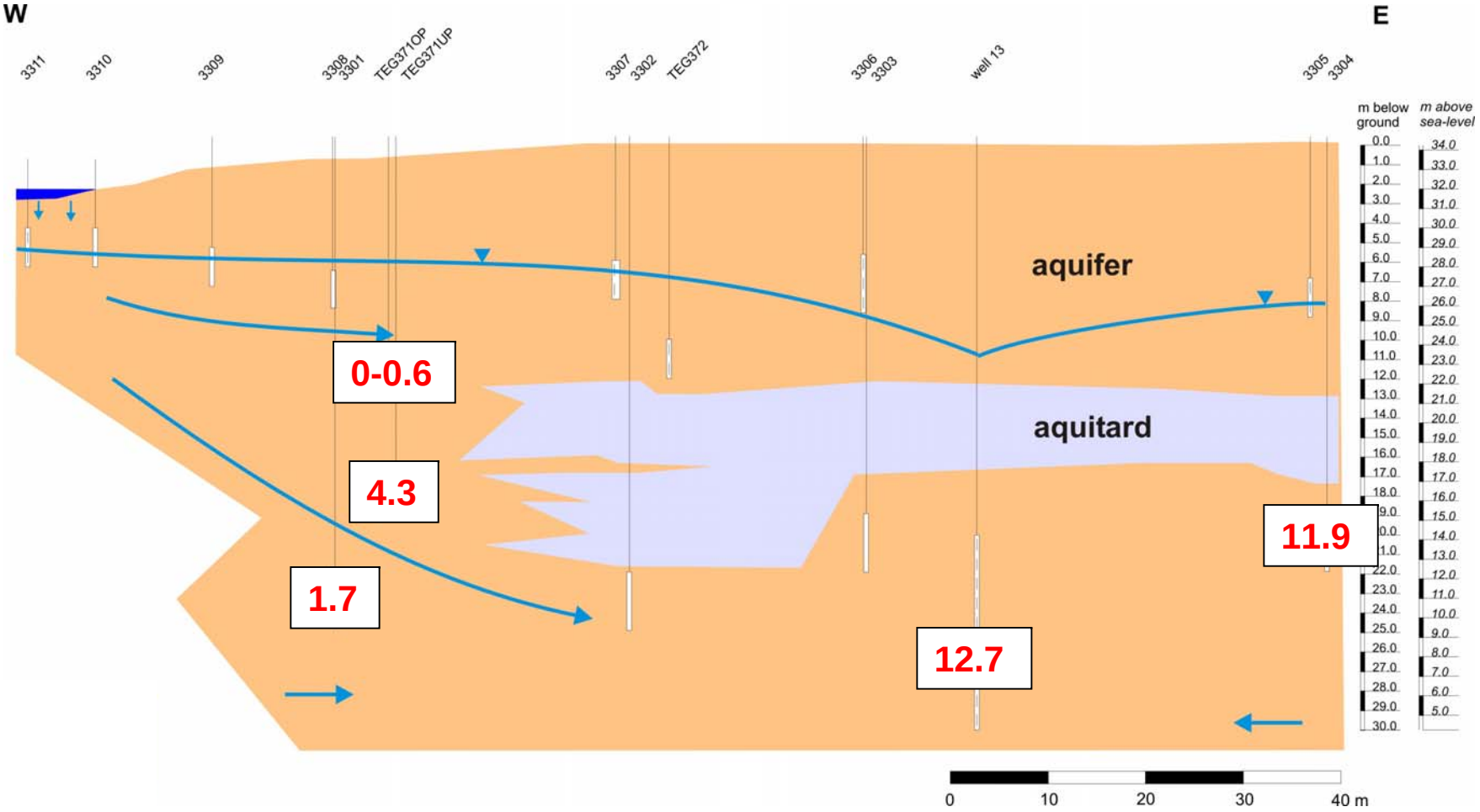
Lake Tegel, age dating

Results



~Age [years]

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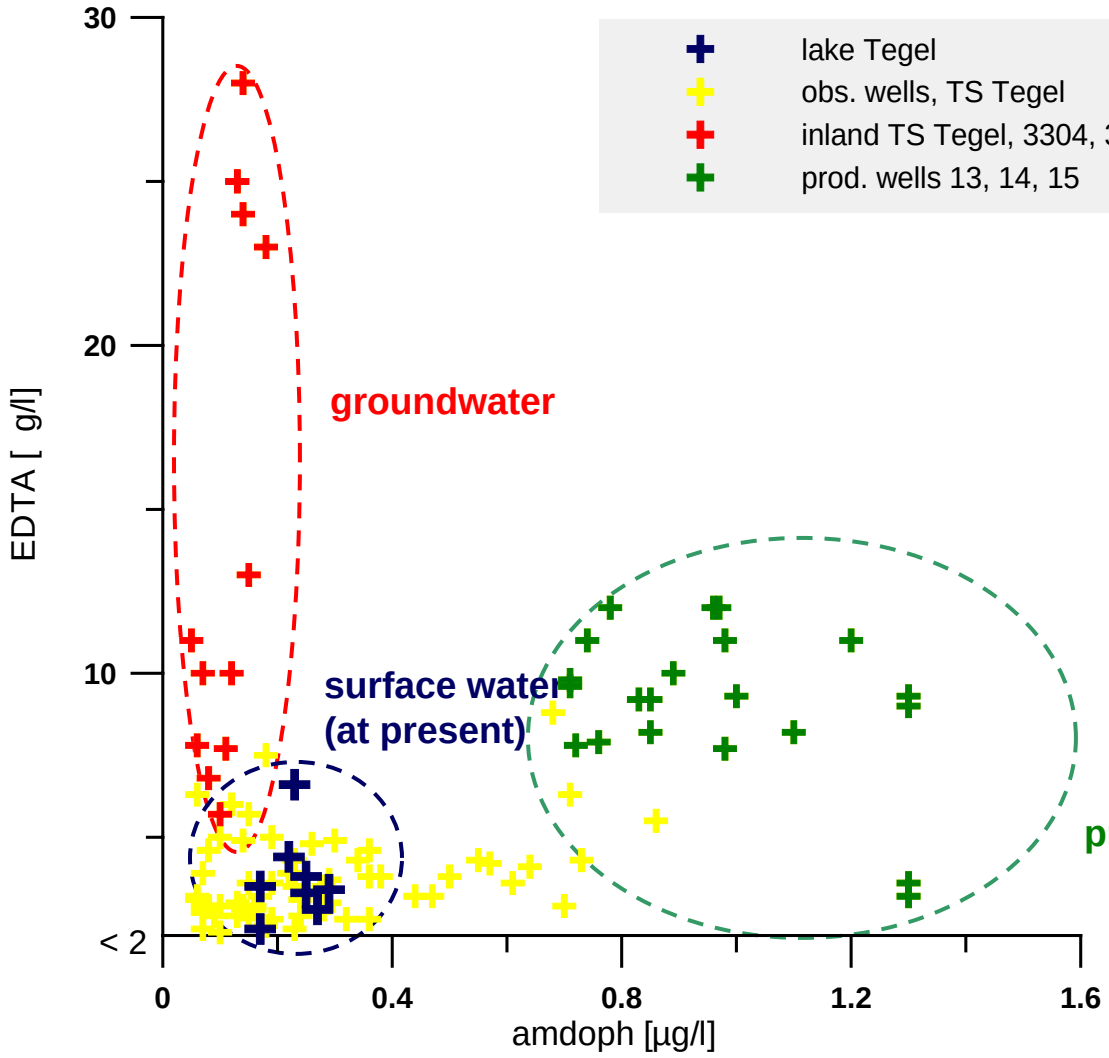
Lake Tegel, age dating

Results



Specific water constituents confirm that production wells may contain a considerable amount of older bank-filtrate!

Data: Berlin Water Company

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Summary & Conclusions

- Combining a number of tracer may help to understand the hydrogeology and hydraulics at a very complex bank-filtration system in Berlin.
- With the help of T/He, ages of groundwater from different aquifers can be estimated.
- Combining discharge measurements with the concentrations of wastewater indicators, proportions of wastewater in the surface water can be calculated. (Wannsee: ∅ 8.5 % in winter, 20.1 % in summer; Lake Tegel ∅ 12 % near respective transects).
- With tracers showing strong seasonal variations in the surface water, travel times can be estimated (Lake to wells: Wannsee: 1-2 months, Tegel: 5-8 months).
- Relatively “young” water constituents like EDTA are only present in the bank-filtrate and can be used to calculate proportions of bank-filtrate in the wells at Lake Wannsee. Large differences exist in the different wells (~ 10 % BF in well 4, ~ 90 % BF in well 5).
- At Lake Tegel, proportions of bank-filtrate in the wells are generally high (~ 80 % in average).
- Age dating, lack of seasonal variations in the wells as well as substances formerly present in the surface water in higher concentrations (e.g. amdoph) indicate that a proportion of the bank-filtrate is much older that predicated from observation wells.

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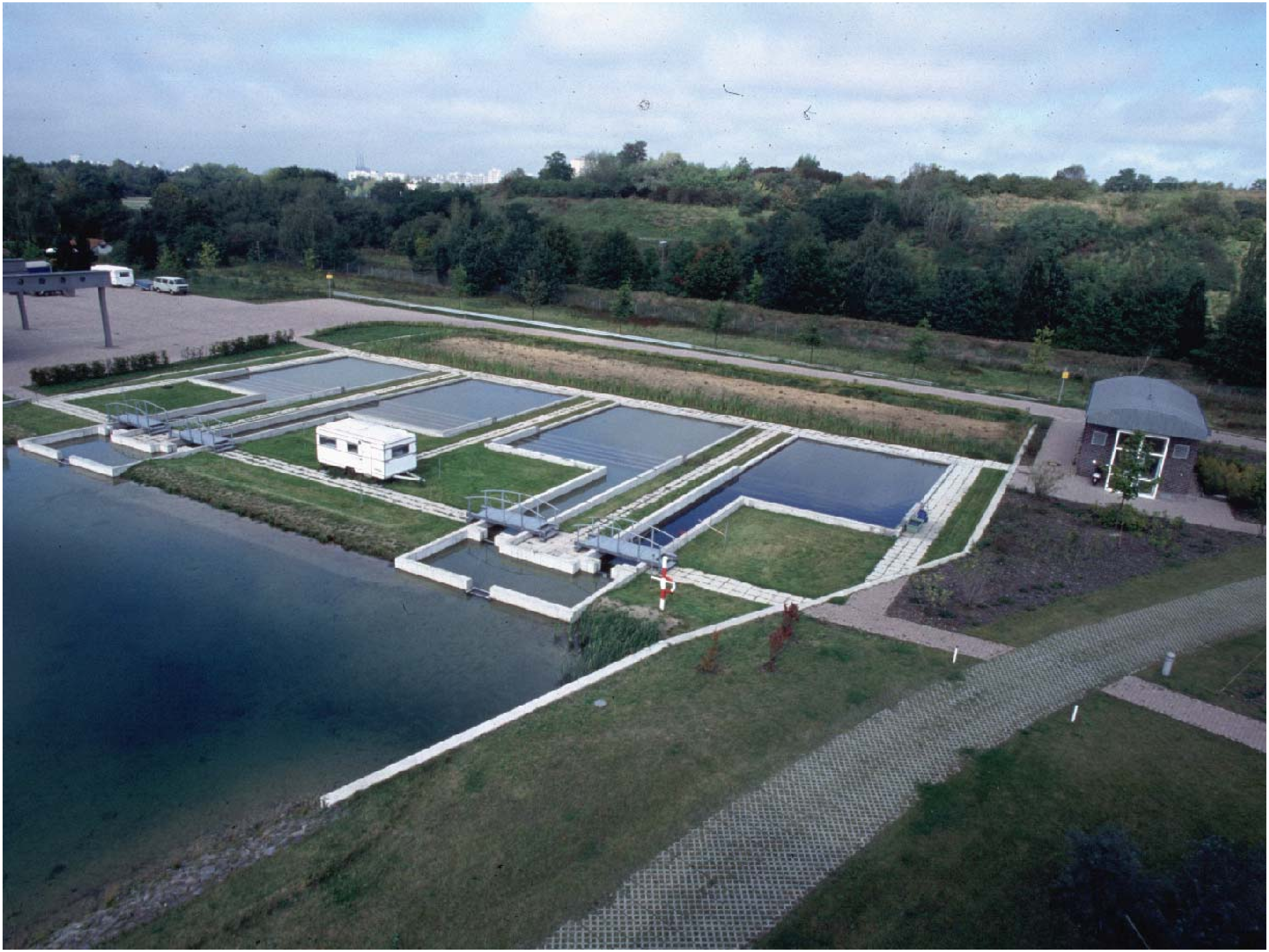
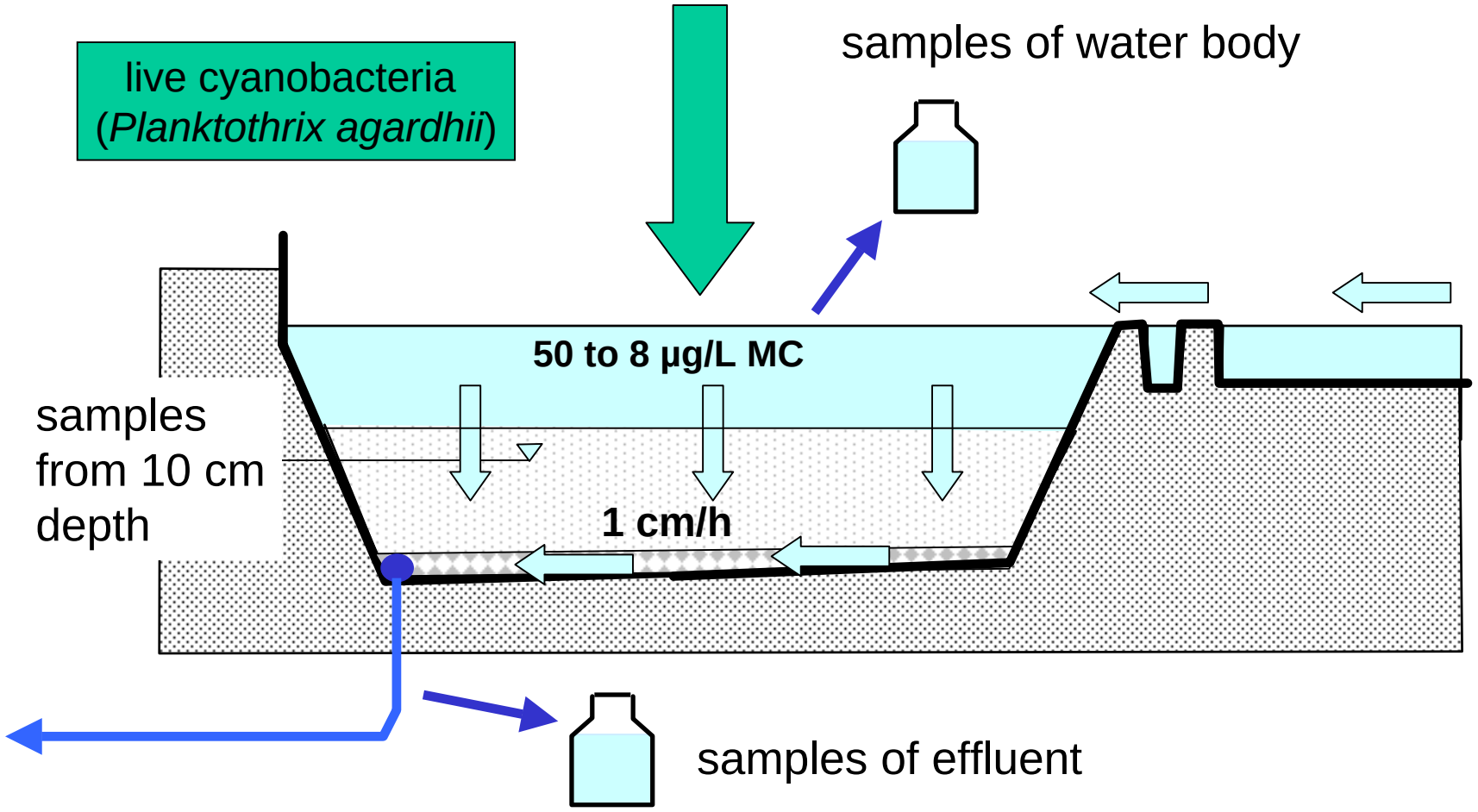
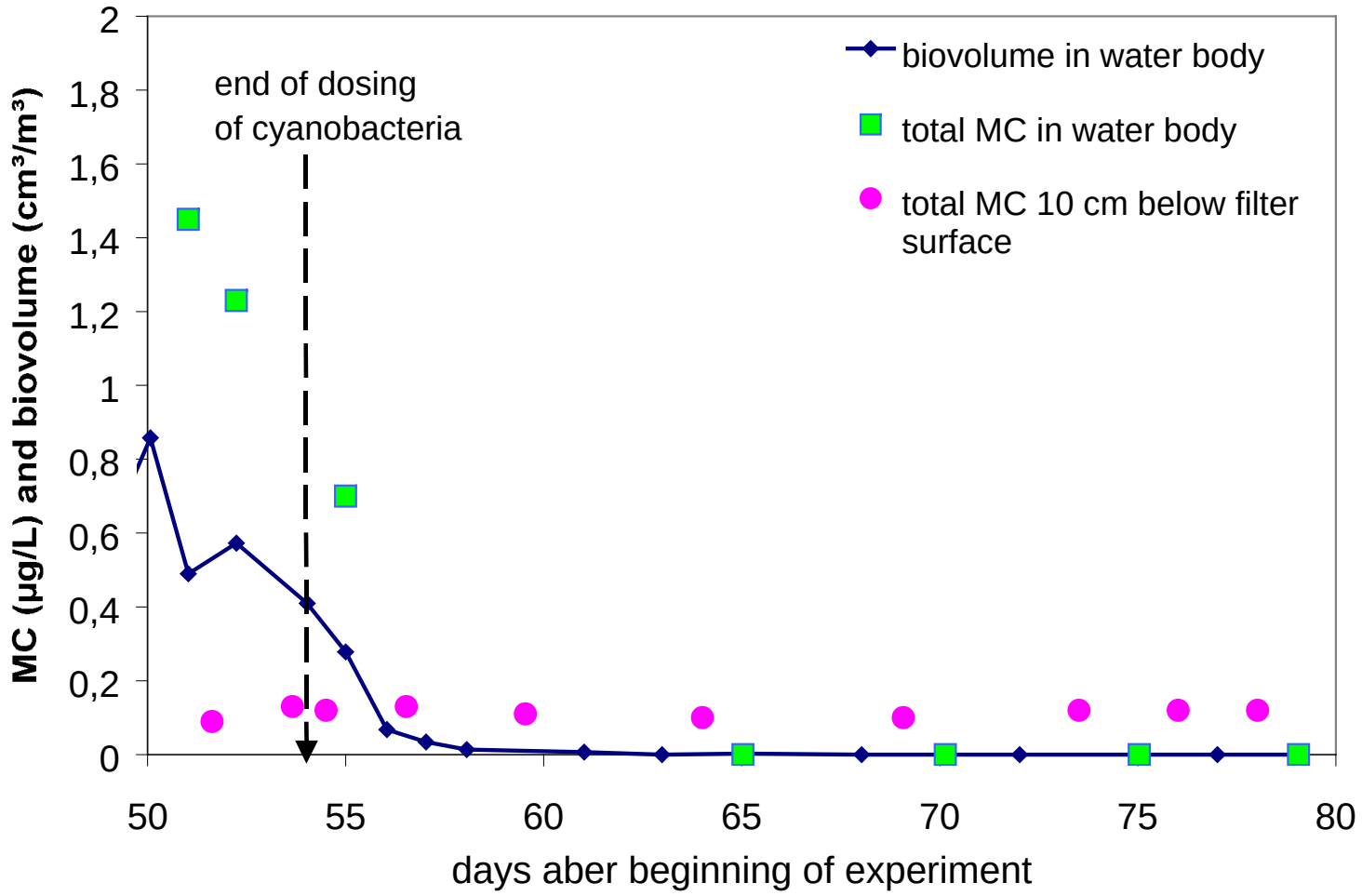


Slow Sand Filter Experiments



Results Grützmacher et al.

Cellbound / Extracellular Cyanotoxins (Microcystins)



➔ **Cells can act as long-term source for microcystins**