Integral Pumping Tests

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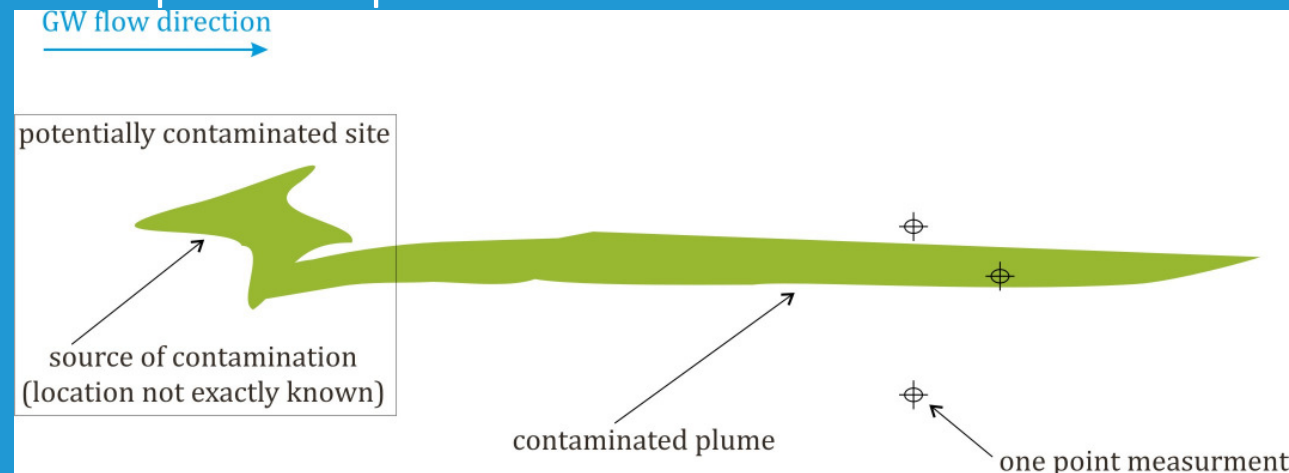3. Application
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1. Challenge

In the practice, localization of a source of contamination is in many cases hardly feasible.

- there are two main approaches for assessment of GW pollution:

    1. one point measurement leads to difficulties to reliable locate and capture the plume

GW flow direction

potentially contaminated site

source of contamination
(location not exactly known)

contaminated plume

one point measurment

    2. integral measurement considers the temporal and spatial influence from one or more pumped wells (spatial integral GW investigation)

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Spatial integral GW investigation allows the assessment of key contaminants in the entire area of consideration.
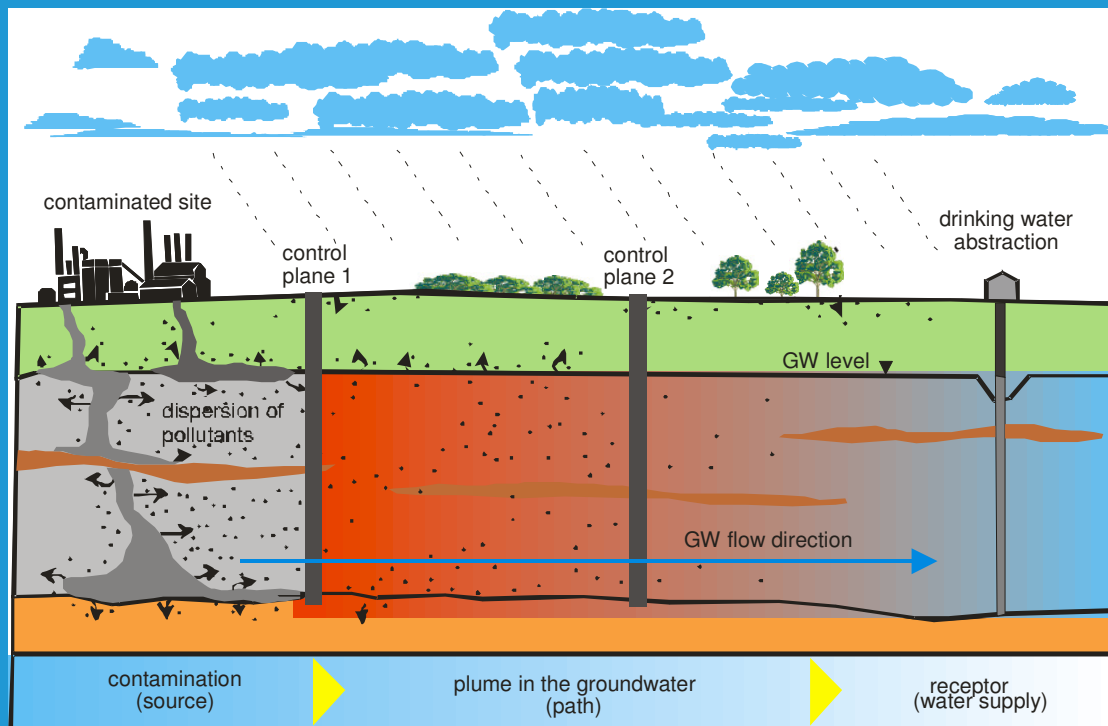
- pollution originates from several sources
- goal is to trace the pollution plume along the transport pathways back to the sources of pollution

Integral pumping test (IPT) is one example of spatial integral GW investigations.

- IPT is long-term pumping test with systematic analysis of contaminant concentration in the pumped water

- basic concept is to capture the whole contaminated plume by one or several measurement points lined in the control plane

- control plane shall:

    1. be downstream of the investigated site,

    2. cover a total width of GW stream, and

    3. be perpendicular to GW flow direction

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1. Challenge

The total pollutant plume emitted from a potentially contaminated site is captured.
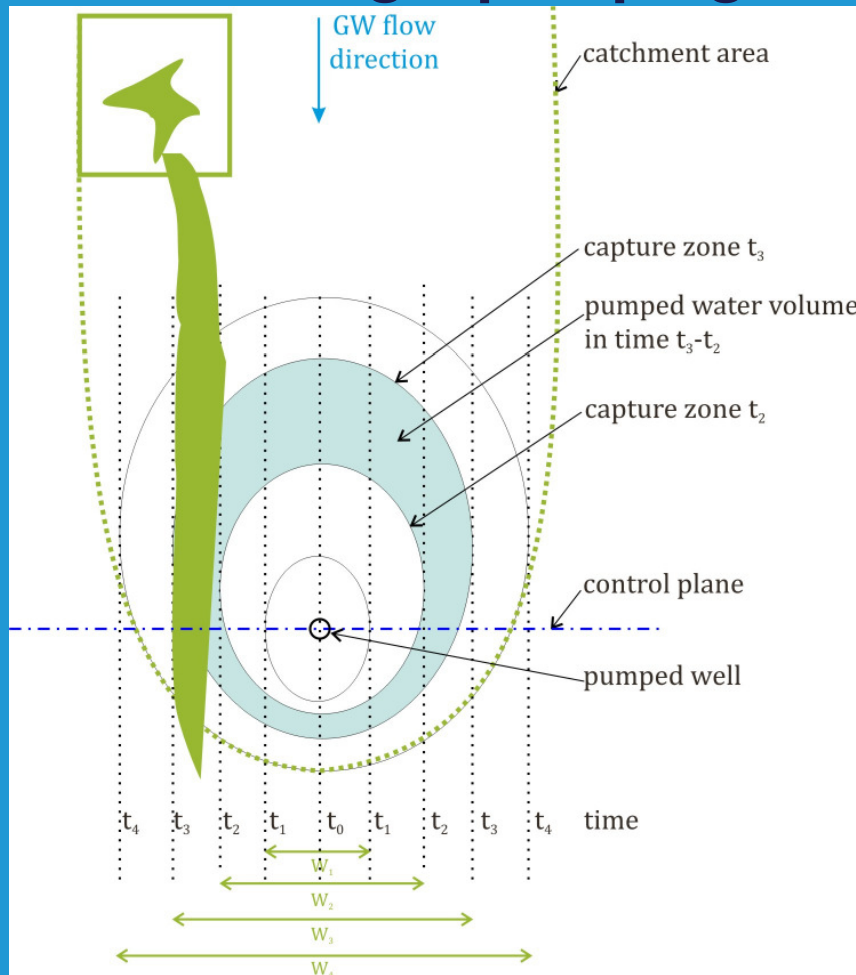

- multiple concentration measurements are performed
- total flow rate at control plane is estimated
- the possible spatial distribution of contaminants is backward calculated
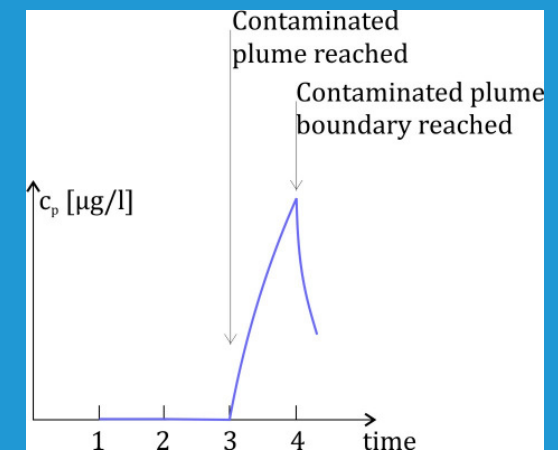- the method align the plume, but not the position (left or right)

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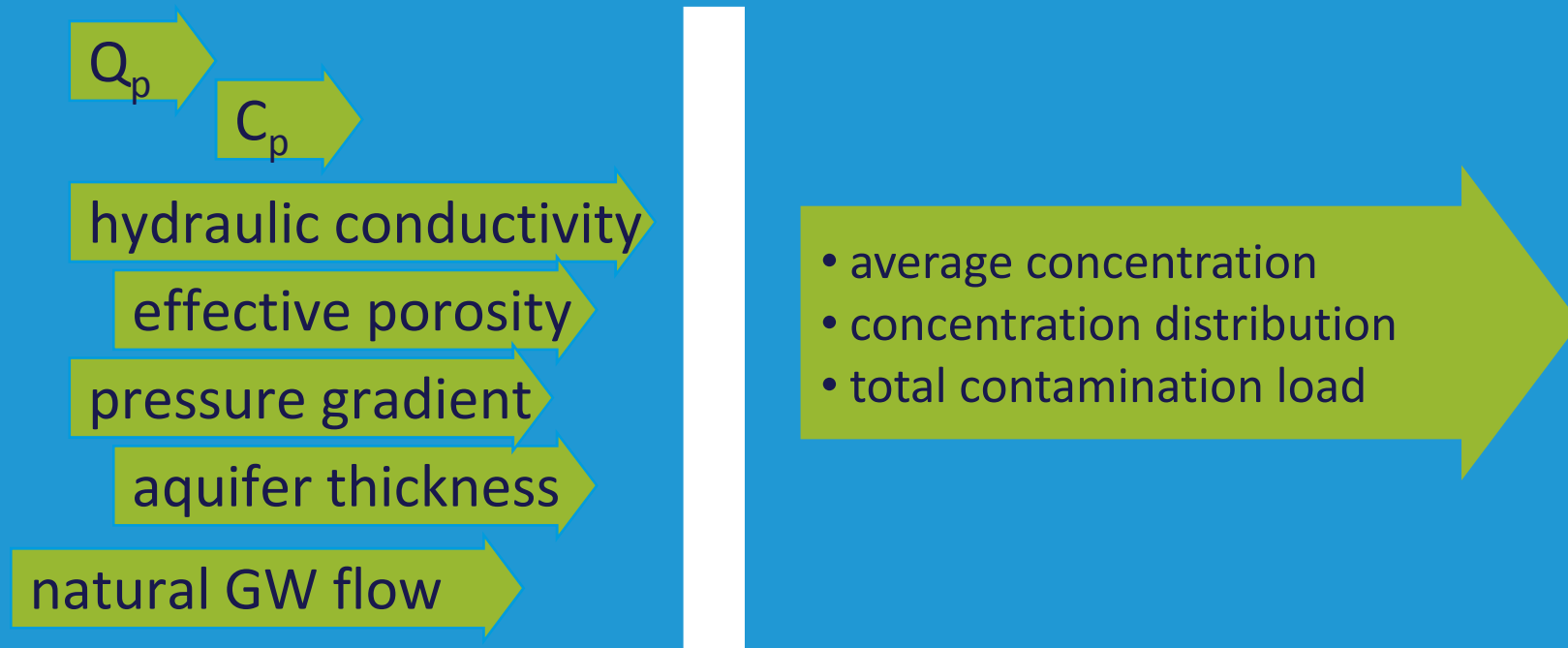**The IPT approach is based on the increase of the capture zone during a pumping test.**

- pumped discharge (Q_p) is constant

- quasi steady state is assumed

- mixed concentrations (C_p) are measured

**By applying IPT the total contamination load through defined control plane is determined.**

- determination of concentration distribution and total load:

Q_p

C_p

hydraulic conductivity

effective porosity

pressure gradient

aquifer thickness

natural GW flow

- average concentration
- concentration distribution
- total contamination load

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The four typical concentration curves can be recognized based on their plume geometry and location.
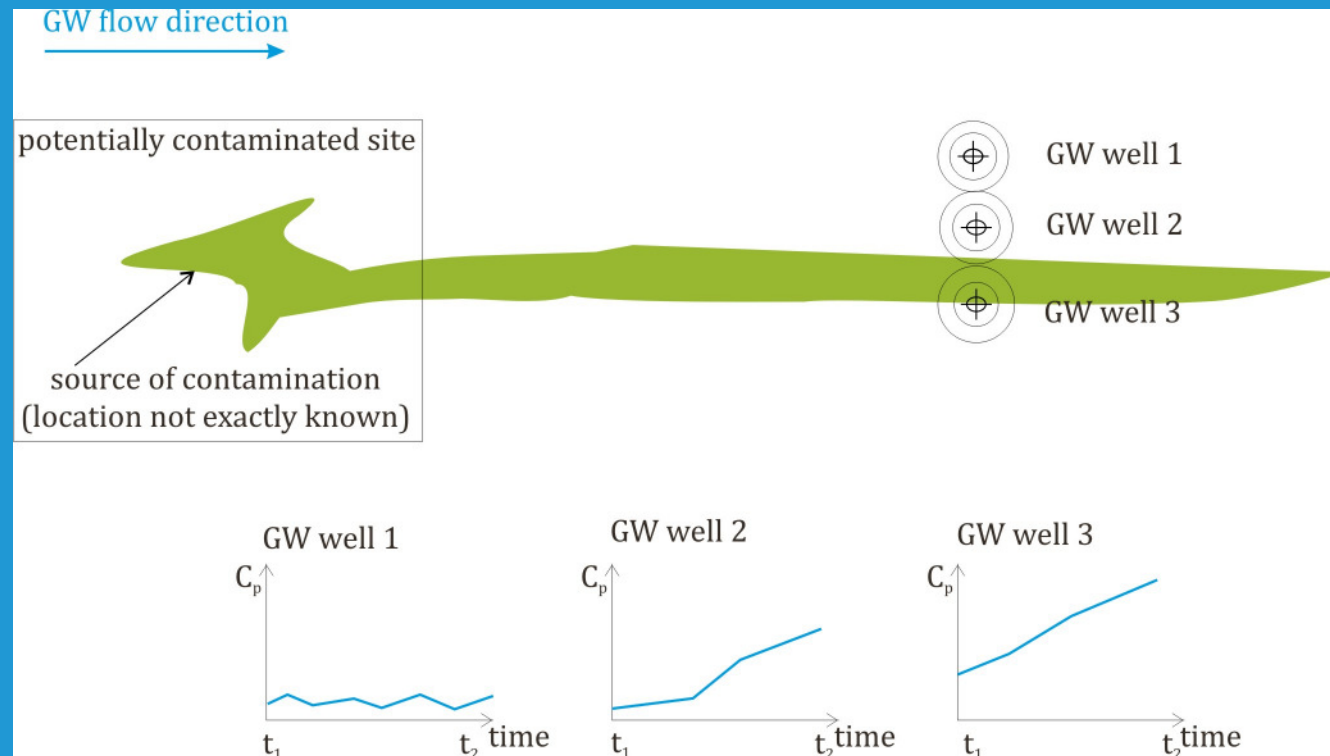
- examples of concentration curves
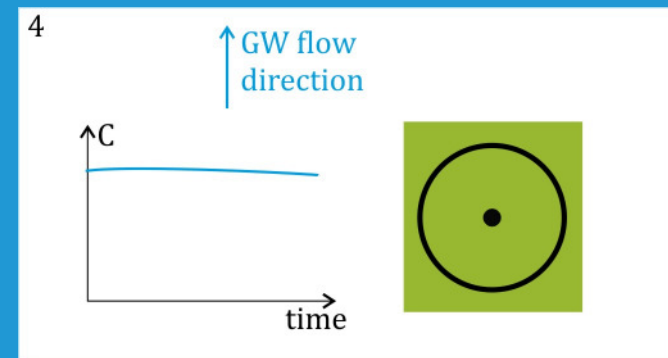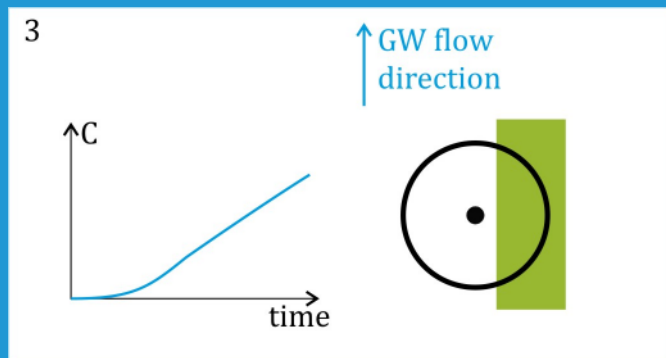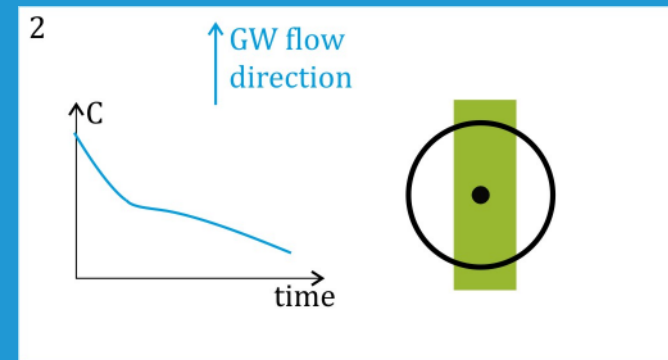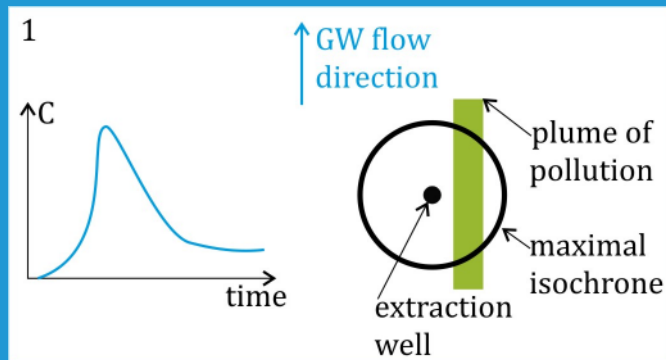
- IPT with only one measurement point can lead to difficulties

  ⇨ more measurement points

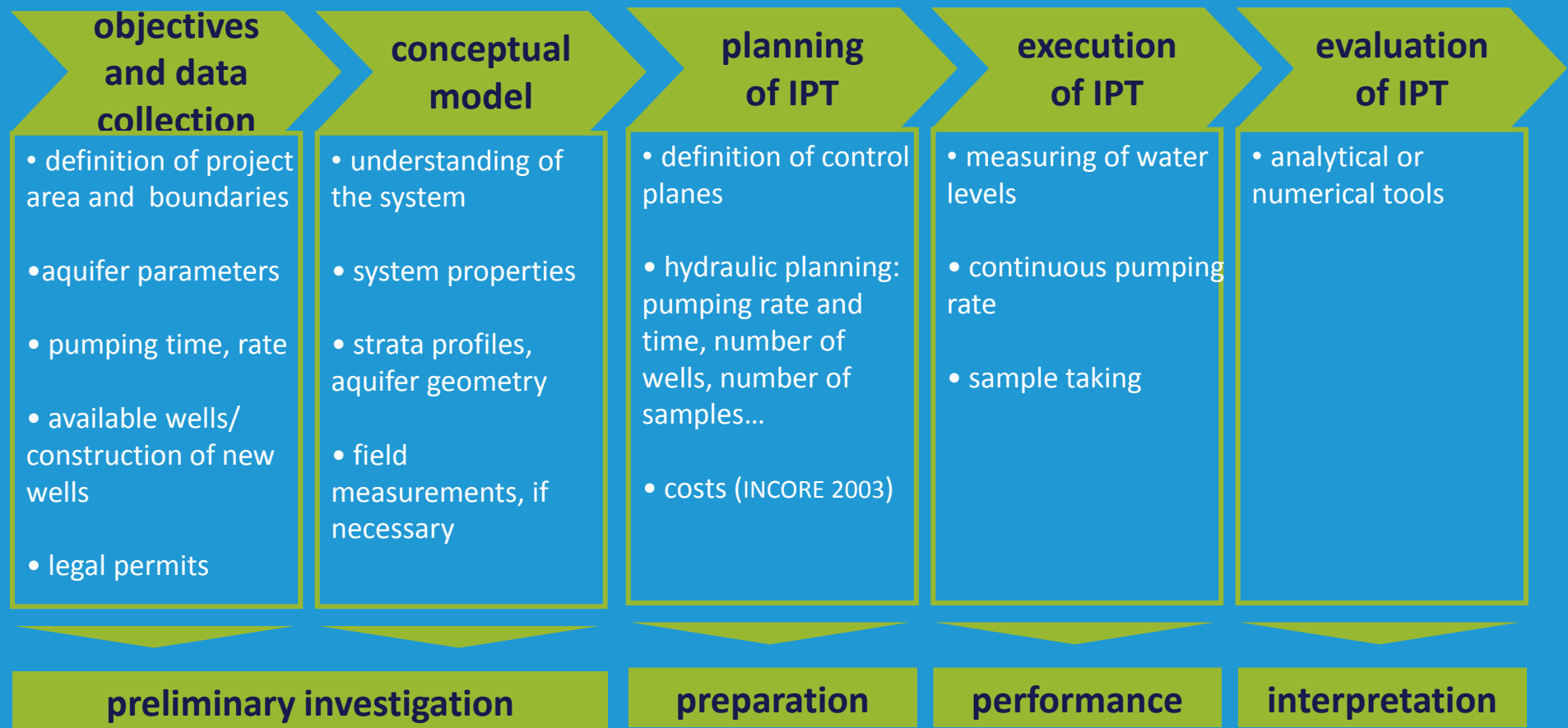**More pumping wells are necessary to capture the plume.**

- GW well 1 → out of the plume

- GW well 2 → reaches the plume after some time, C_p are lower than in reality

- GW well 3 → at the beginning pumping of contaminated water

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IPTs require detailed planning, collection of data and a comprehensive conceptual model.

- planning and performance of IPTs

objectives and data collection	conceptual model	planning of IPT	execution of IPT	evaluation of IPT
• definition of project area and boundaries • aquifer parameters • pumping time, rate • available wells/ construction of new wells • legal permits	• understanding of the system • system properties • strata profiles, aquifer geometry • field measurements, if necessary	• definition of control planes • hydraulic planning: pumping rate and time, number of wells, number of samples… • costs (INCORE 2003)	• measuring of water levels • continuous pumping rate • sample taking	• analytical or numerical tools
preliminary investigation		**preparation**	**performance**	**interpretation**

3. Application

Many tools are available to calculate a spatial distribution of contamination and total load.

- available tools for IPTs evaluation

    - IPV- Tool [Rothschink, 2007]

        → www.lubw.baden-wuerttemberg.de

    - MAGIC software tool [Ertel *et al.*, 2008]

        → www.magic-cadses.com

    - C-SET [Huss, 2012]

        → www.lubw.baden-wuerttemberg.de

    - CSTREAM analytic [Bayer-Raich *et al.*, 2003]

        → www.ufz.de/task

    simple methods

    - CSTREAM numerical [Bayer-Raich *et al.*, 2003]

        → www.ufz.de/task

    - different numerical models

    numerical methods

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Generally, IPTs are applicable without technical limitations, but the range of the parameters shall be verified.

- Parameter range of applications
  - hydraulic conductivity [m/s] 10^{-6} 10^{-2}

  - water head in pumping well high enough to enable a sufficient drawdown

  - GW flow direction cannot be determined in the case of smooth hydraulic gradients

  - plume lengths [Teutsch *et al.,* 1997]

 | | |
    |---|---|
    | PAH | 300 m |
    | BTEX | 420 m |
    | CHC | 2150 m |

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City Chlor

## District Hohenlohe has successfully implemented IPT method.

- brownfield is former industrial company, metal working
- the contaminated site is located in quaternary, valley deposits

- after GW remediation measured CHC concentrations reached 6.000 µg/l
- it was decided to implement IPT for investigation:
  - control plane was defined along the property boundary
  - 96-hours pumping tests were performed in 3 GW wells
  - 6 samples were taken for each IPT

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Almost 100 % of the contaminated plume was covered, which allowed precise determination of complex plume geometry.
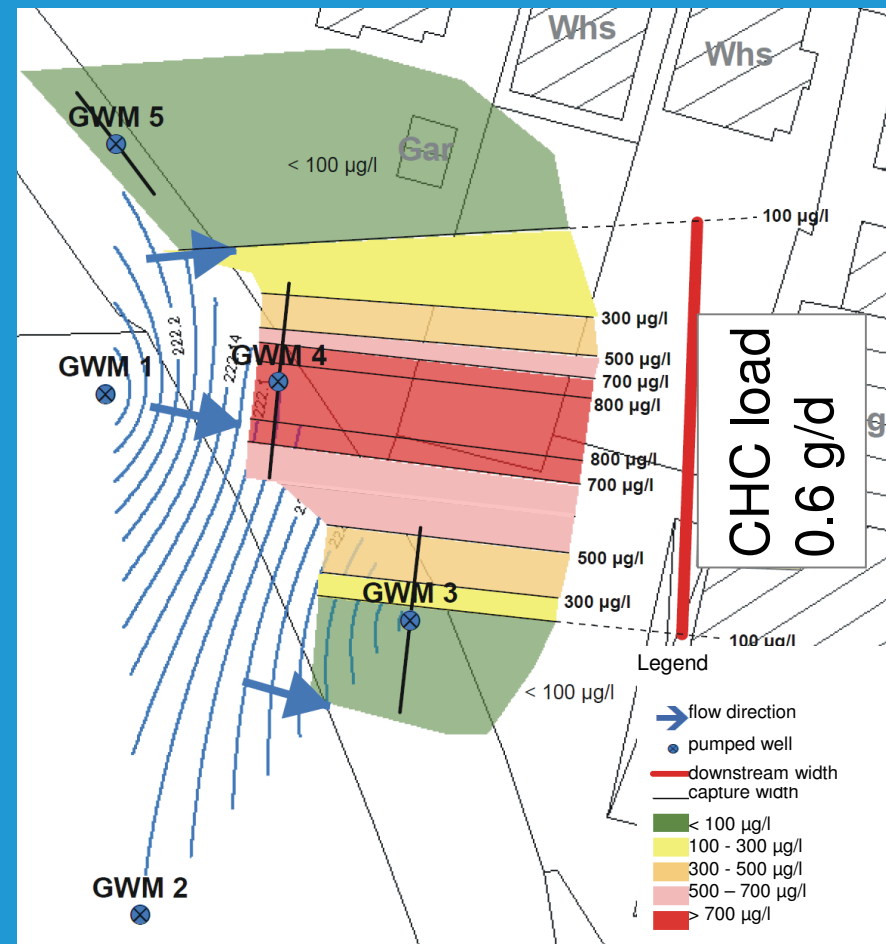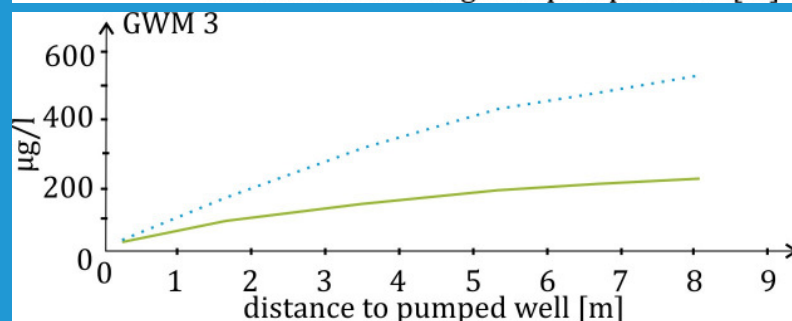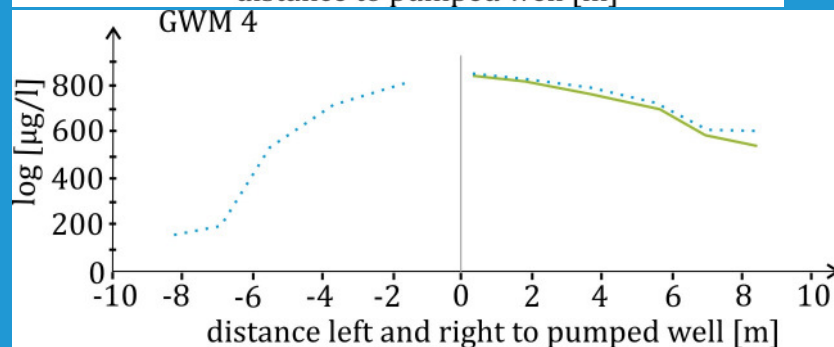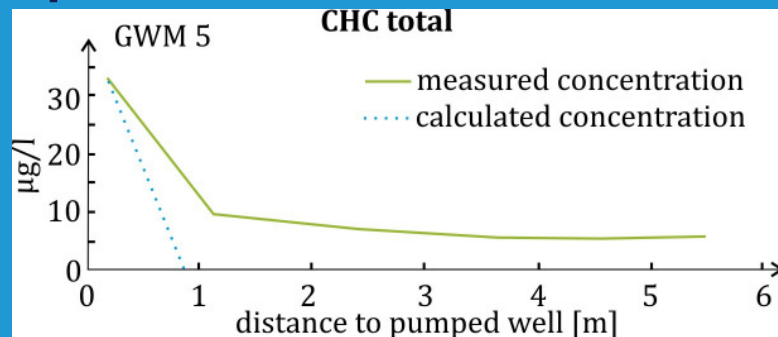
1. Challenge

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- There is extensive experience in practice for implementation of IPTs

- IPTs have no technical limitations and can be used for soils with wide range of parameters

- IPTs allow reliable and fast determination of a total contaminated load, average concentration and possible contamination distribution
    - analytical tools for simple cases and uniform aquifers
    - numerical tools for more complicated cases

- IPTs are at high stage of development and represent powerful tool to investigate source – plume interactions in the groundwater

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Thank you for your attention.

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References

(1) Ertel & Schollengerger [2008] MAGIC Handbook for Integral Groundwater Investigation, Polish Geological Institute, Warsaw, Poland

(2) Holder & Teutsch [1999] Bestimmung der Schadstoffimmission im Grundwasser – Verfahrensprinzip, Messung und Modellierung, in *Integrale Altlastenerkundung im Neckartal Stuttgart*, Amt für Umweltschutz- Heft 4/1999, Stuttgart, Germany

(3) Leschik, Musolff, Krieg, Martienssen, Bayer-Raich, Reinstorf, Strauch, Schirmer [2009] Application of integral pumping tests to investigate the influence of a losing stream on groundwater quality, Hydrology and Earth System Sciences Discussions, p. 4210-4232

(4) Ptak & Kirchholtes [not published] Grundwasserabstromerkundung mittels Immissionspumpversuchen, altlastenforum Baden-Württemberg e.V., Stuttgart, Germany

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