Comparing field methods to quantify surface-groundwater interaction

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MOTIVATION

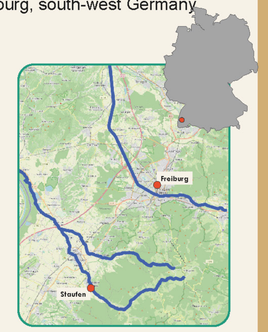
Surface streams feeding into the aquifer can contribute significantly to local groundwater recharge (loosing stream). Likewise streams can gain up to their full water quantity from shallow aquifers (gaining stream).

In the context of increasing drought stress on streams in southern Germany, this connection becomes also increasingly important for modelling groundwater recharge. Because its pathways can be obscure, groundwater-surface water interaction (GSI) is difficult to quantify.

Here we explore non-intrusive ways to observe this interaction.

AREA OF RESEARCH

- Three medium-sized streams (average local discharge: 2-10 m³/s)
- Streams fall dry in summer increasingly often (intermittence)
- Located near the city of Freiburg, south-west Germany (population: 230.000)
- Flow from Black Forest Mountains (hard rock) into the Upper Rhine Valley (alluvial sediments)
- Hydrogeological connection to aquifers supplying the area with drinking water
- Intensive agricultural land-use holds risk of pollution



1. EXPLORATION WITH THERMAL IMAGING

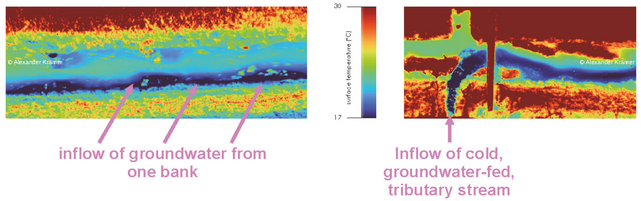
Identify areas with strong stream-aquifer-connectivity, based on openly observable phenomena e.g.:

→ low distance between surface and groundwater table

→ stream intermittence depending on season

→ streams running dry and reappearing further downstream

- Thermal images taken via UAV help to locate groundwater intrusion (left)
- Also useful when side streams show strong groundwater inflow (right)
- Works best in seasons of high temperature difference (summer & winter)
- To gain absolute values calibration to irradiance is always necessary



inflow of groundwater from one bank

Inflow of cold, groundwater-fed, tributary stream

3.a DISCHARGE FROM STAGE-DISCHARGE RELATION

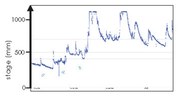
The most common method for obtaining discharge estimates is establishing a numerical relation between water level and discharge at each measuring station:

- Water level (H) is continuously measured at fixed stations (water capacitance or pressure logger)
- Discharge (Q) is measured regularly in field campaigns (electromagnetic induction meter or current meter)

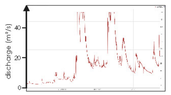
→ discharge rating curve

→ computation of continuous discharges

H

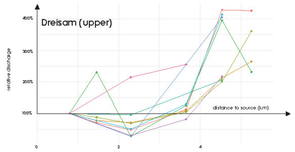


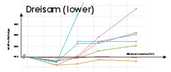
Q

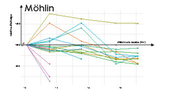


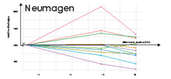
2. SEQUENTIAL DISCHARGE GAUGING

- Comparing discharges of sequential stream segments gives information about sections net water gain and loss
- Downstream discharge both increases of decreases depending on location, season and weather
- General behaviour can be observed, allowing classification of river sections into “gaining” and “loosing” stream sections







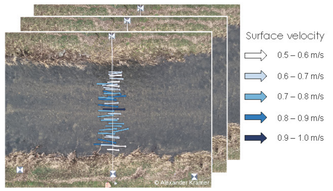


3.b PARTICLE TRACKING VELOCIMETRY (PTV)

Remote sensing of surface velocity

- Seeding of surface stream with floating particles (wood chips)
- Capturing sequential photos from a fixed position via UAV
- Tracking individual particle’s movement between frames

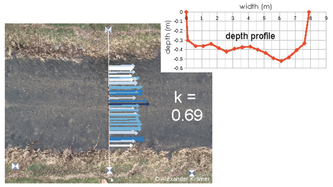
→ speed and direction of surface flow (v_i)



Computing discharge

- Determine fraction of individual vectors parallel to main stream flow
- Convert surface velocity v_i to mean velocity V_i via velocity index k ($V_i = kv_i$)
- Include depth profile

→ stream discharge



stress RES

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CONCLUSIONS

Exploration

- A strong surface-groundwater interaction can be visible including phenomena such as re-appearing streams
- Thermal drone footage is useful for identifying local hotspots

Discharge from stage-discharge relations

- Established method which is practiced widely
- Holds large uncertainties for extreme discharge (high & low)
- Requires high effort in manual labour
- Fixed stage gauge equipment is vulnerable

Particle tracking velocimetry

- Novel method which shows promising results
- Method is not yet fully established
- Depends on fair weather conditions

→ **we recommend a combination of methods**

FUTURE PLANS

- Improve properties of seeding material used for PTV
- Automate readout of PTV discharge sensing
- Explore multispectral channels for exploration and particle tracking
- Compute discharge via weighted average using water temperatures

Curious? Check my abstract for more!

LURCH Grundwasser nachhaltig bewirtschaften
FONA Forschung für Nachhaltigkeit
GEFÖRDERT VOM Bundesministerium für Bildung und Forschung

(1) Chair of Hydrology, University of Freiburg
(2) WWL Umweltplanung und Geoinformatik GbR

Images
1.: http://odysseydatarecording.com
2.: https://onsetcomp.com
3 & 4: https://www.ott.com/products/water-flow-127
5.: https://www.drone-sales.co.uk/dji-enterprise-drones

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