Hessisches Landesamt für
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Analysis of Low Flow Measurements in River Basins, Hesse, Germany – Master‘s Thesis at TU Darmstadt, based on data provided by HLNUG

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Introduction and Methods

Low flow measurements reflect the behaviour of streams during periods of dryness and can help to assess the economic and ecologic impact of dry spells. Low flow values can be directly associated with groundwater recharge and have important implications on sustainable (ground-) water extraction for water supply or agriculture.
Climate-induced alterations in the amount and timing of river flows can intensify competition for municipal water use, irrigation, and hydropower generation. Changes in climate are predicted to cause an increase in number and severity of hydrological droughts with implications on water quantity and water quality due to decreases in water volume. Low flow values and low water levels deliver information on compliance of threshold values for the volume-dependent concentration of contaminants in water during drought events.
During the exceptionally hot and dry summer of 2003, the Hessian Agency for Nature Conservation, Environment and Geology (HLNUG) carried out a state-wide low flow measurement programme in over 750 gauges. After long times without precipitation, the dry weather discharge in streams equals approximately the baseflow which is a rough estimation of groundwater recharge.
The data from 2003 was used for a graphical representation of low flows for the corresponding river drainage basins. In total, 725 drainage basins were delineated. The measured discharge was normalised to the drainage basin size to allow a comparison (Figure 1).

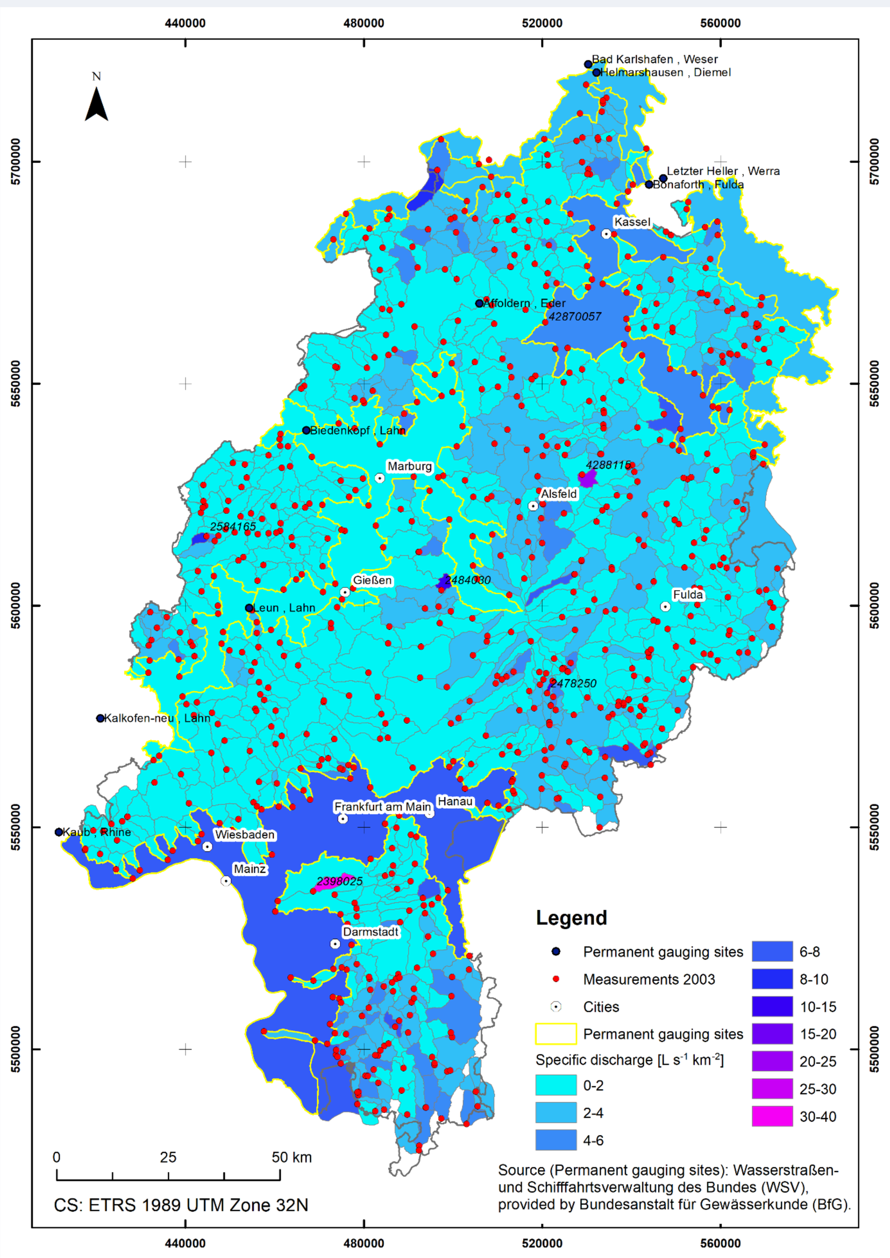

Figure 1: *Map of the drainage basins that were delineated using the results of the measurement programme 2003. The measurement sides with the highest measured values, including the gauge at the Edersee barrage, are labelled in italics.*

Results

For drainage basins where an outflow and at least one inflow were measured, the volume of the inflows and outflows was compared to determine whether the volume increased or decreased in the drainage basin. A balance of the discharge could be calculated for 316 of the 725 drainage basins. In total, 256 positive balanced discharge values were found; 52 drainage basins had a negative balanced discharge, and for 8 drainage basins, the balance of inflowing and outflowing discharge was equal to zero (Figur 2).
The results were normalised to the drainage basin area and are depicted in Figure 3.

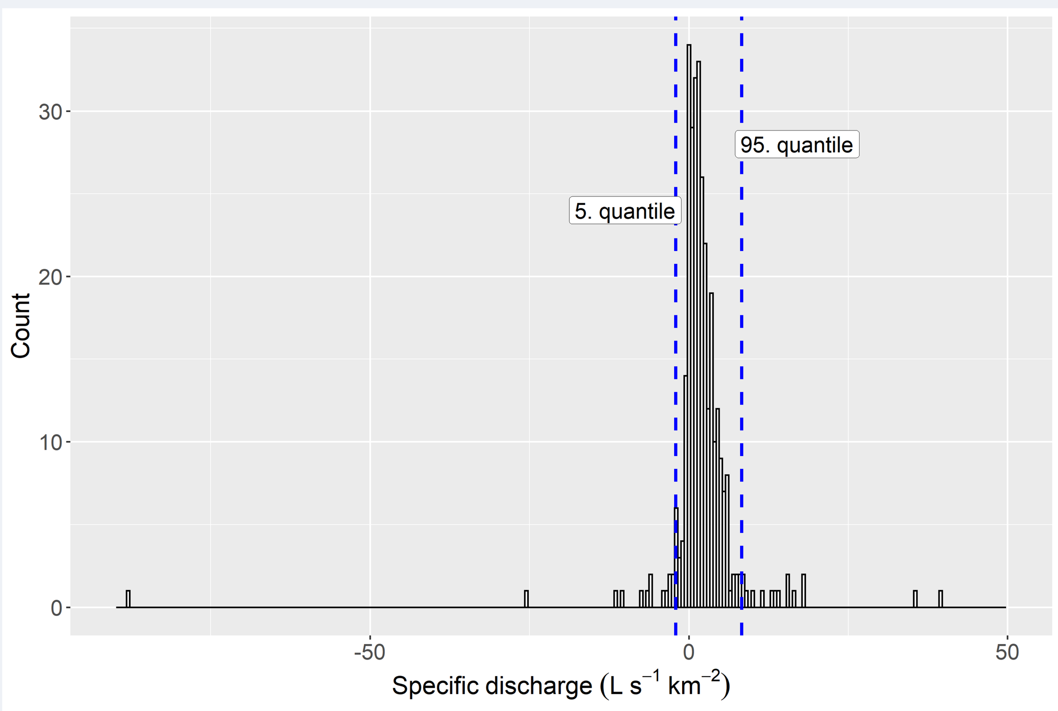

Figure 2: *Frequency distribution of the specific discharge values (n=316), calculated for drainage basins with at least one inletpoint.*

Dry weather discharge depends on a variety of geographic and anthropogenic factors that may interact with each other. The influence of drainage basin size, number of fault zones, and lithological unit on the measured low flow values were investigated. The quantitative influence of anthropogenic activities such as groundwater extraction from wells and gravel pits, or water discharge in streams from water treatment plants were not examined because of insufficient data.

A weak positive correlation (Spearman’s ρ = 0.217, p value = 3.8E-09) was found for the size of the drainage basins and the corresponding low flow. It can be concluded that larger catchments tend to generate higher discharge by providing more groundwater-fed baseflow during times with little or no precipitation.

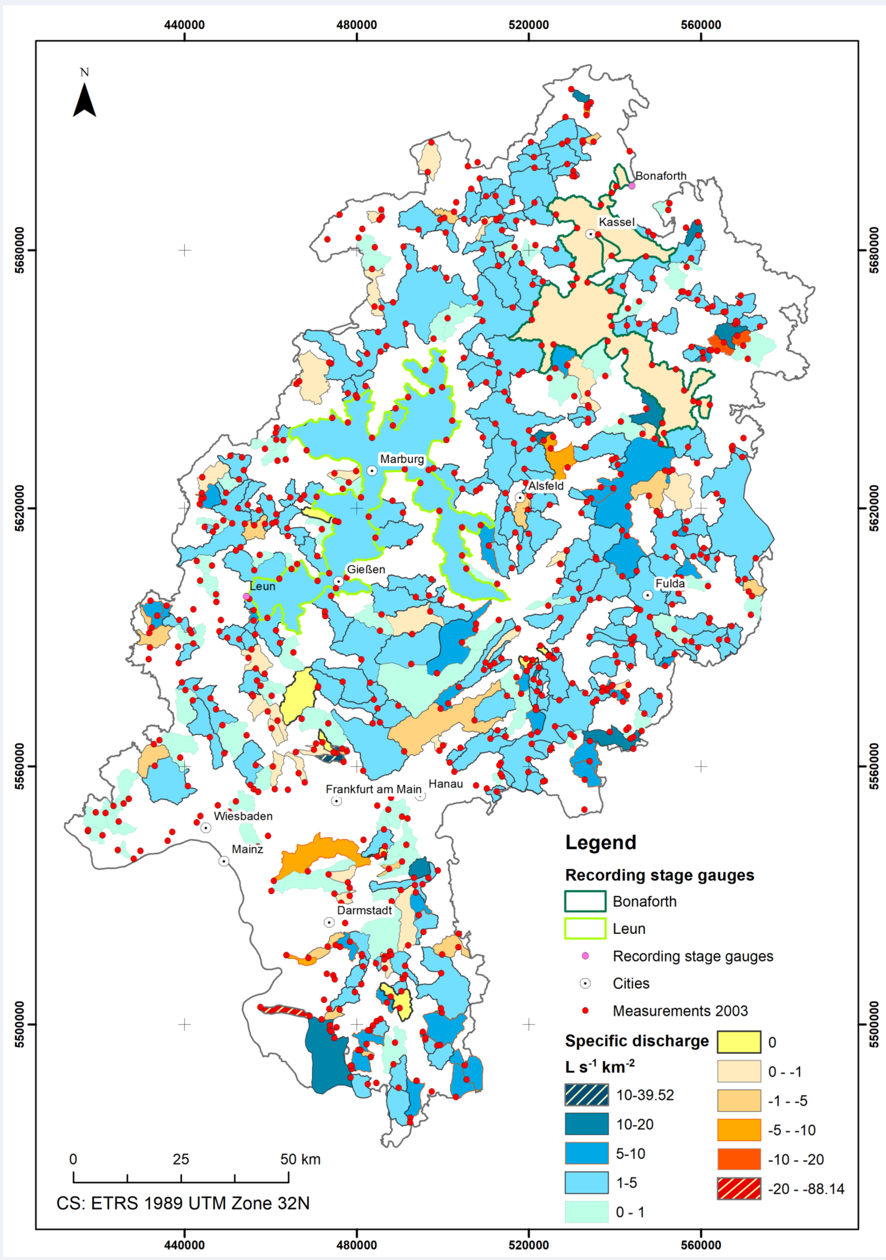

Figure 3: *Map of the drainage basins for which a balance of the in- and out - flowing water volume could be calculated. Positive balances, demonstrating an increase of the water volume in the drainage basin, are depicted in blue, while drainage basins with negative balances, indicating a loss of water volume, are shown in red.*

For the balanced discharge per drainage basin and the corresponding drainage basin area, a weak positive correlation (Spearman’s ρ = 0.115, p = 0.0411) was found. All drainage basins with an area larger than 1,000 km² had a positive specific discharge, indicating that larger drainage basins are less susceptible to influences which decrease the discharge, such as groundwater extraction.

No correlation was found between the number of fault zones per drainage basin (which tended to increase with the basin size) and the measured low flow and discharge.

Drainage basins situated in the lithological unit of the Triassic Buntsandstein showed higher low flow (Figure 4) and discharge values than drainage basins covered by Paleozoic and Tertiary volcanic rocks or Devonian marine sedimentary rocks.

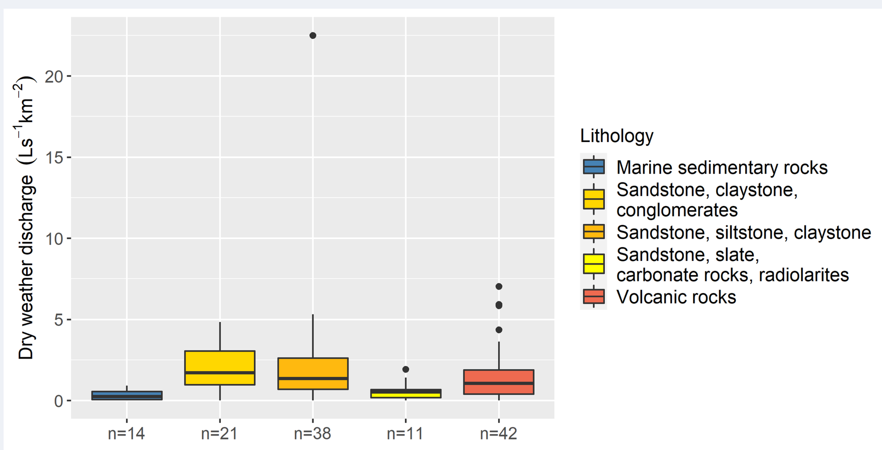

Figure 4: *Comparison of low flow values in 2003 at drainage basins that were covered to at least 70% by rocks of the same lithological unit. The unit of the "Marine sedimentary rocks" includes sandstone as well as metamorphosed sedimentary rocks (slate and quarzite). The fourth unit "Volcanic rocks" comprises alkali basalt, basanite, tephrite, nephelinite, tholeiitic basalt, olivine basalt, and andesite.*

Conclusion and Outlook

The results of the 2003 low flow measurement campaign were used to delineate the drainage basins of each measurement point, and to identify drainage basins with exceptionally high or low dry weather discharge values. A balance of in- and out-flows was calculated for the drainage basins to determine whether the total volume of water increased or decreased in the drainage basin.
In 2018, a second low flow measurement campaign was carried out, which is currently analysed as part of a master’s thesis project at the University of Marburg.

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