Spatiotemporal changes of three hydrological states in the temporary streams of a pre-Alpine headwater catchment

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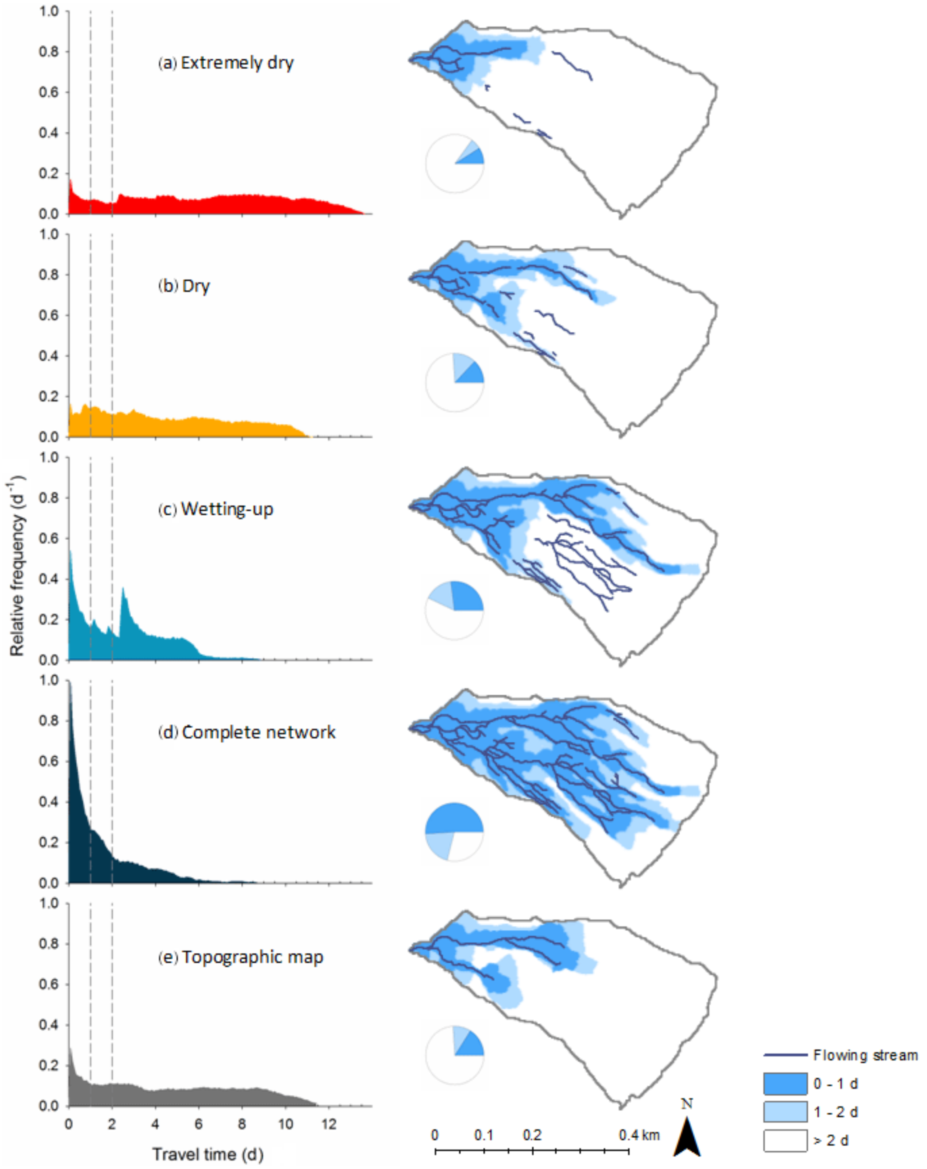
Temporary streams experience hydrological state changes

Relevance

Hydrological state changes cause expansion and contraction of the stream network.
This influences flow path ways and travel times, and therefore downstream perennial water quality and quantity.

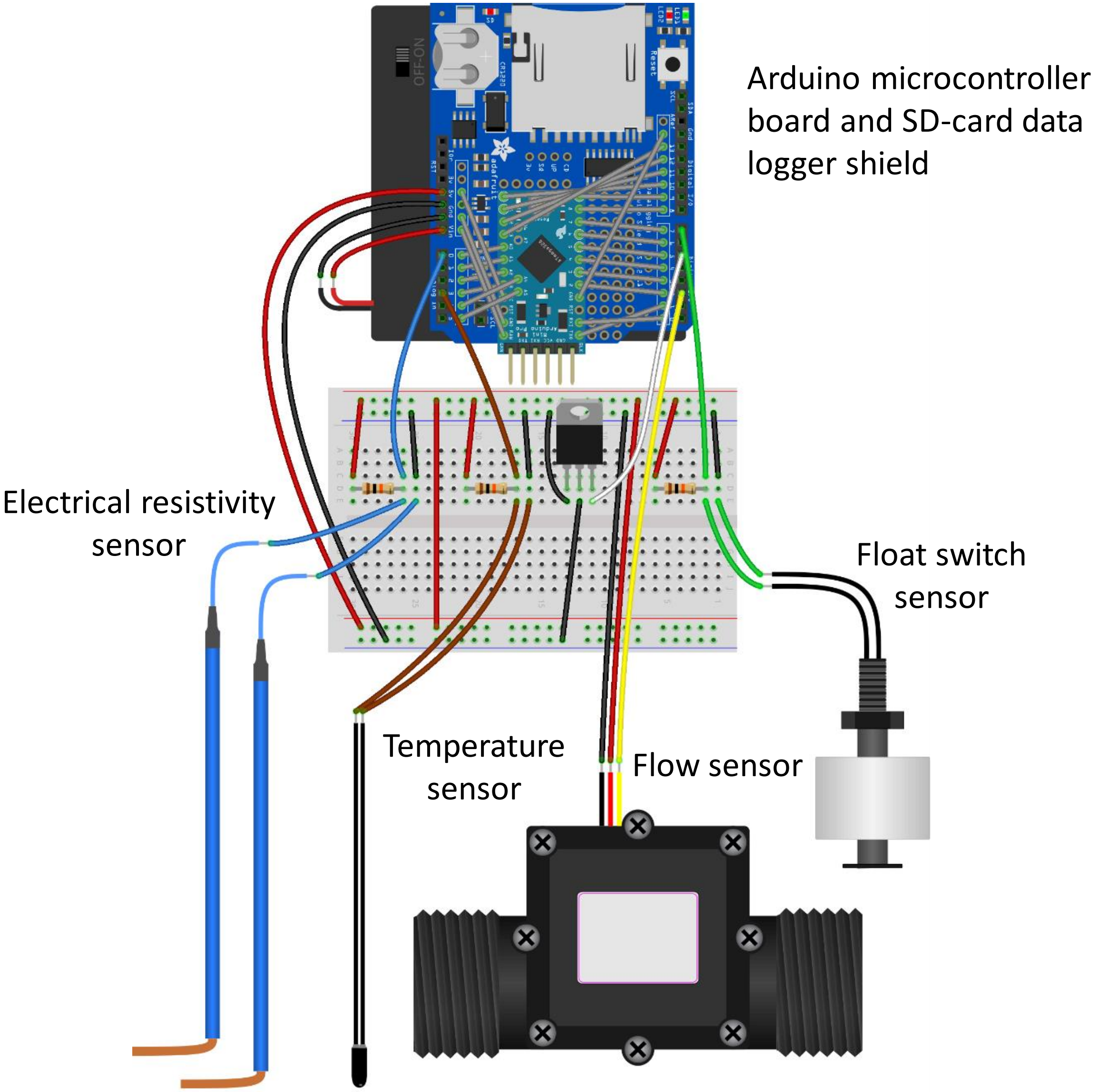
<u>Research gaps:</u>

- High spatiotemporal resolution state data is limited
- Only a few studies describe state changes during rainfall events
- These studies do not differentiate between the standing water and flowing water states



van Meerveld et al. (2019), *HESS*

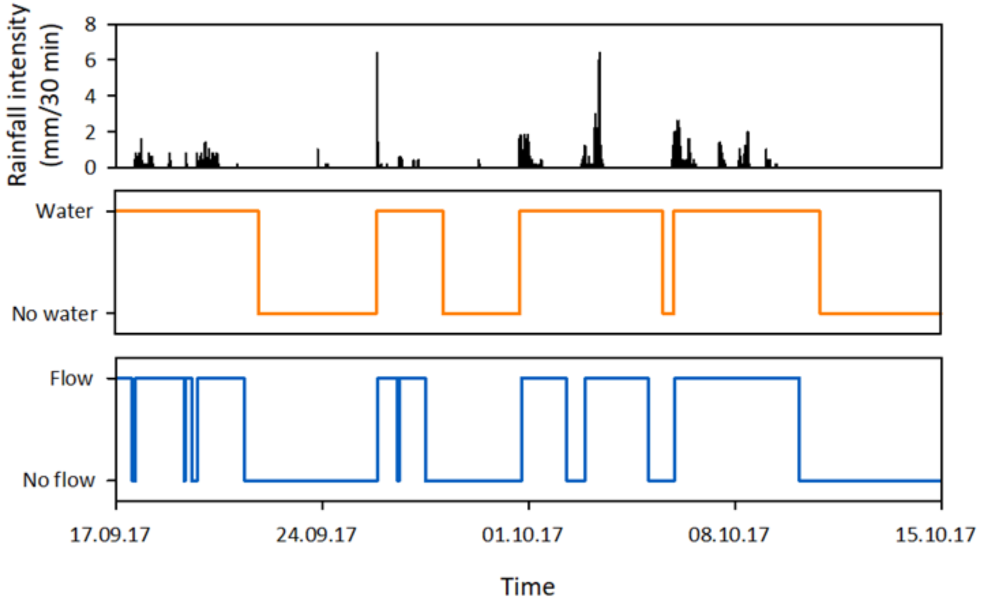
Multi-sensor monitoring system



We developed a monitoring system that provides high spatiotemporal resolution data on the three main hydrological states in temporary streams:

- Dry streambed
- Standing water
- Flowing water

Processed sensor data and rainfall



Assendelft and van Meerveld (2019), *Sensors*

Multi-sensor monitoring system

Field setup

Assendelft and van Meerveld (2019), *Sensors*

Our paper on the design and field testing of the monitoring system
https://doi.org/10.3390/s19214645

sensors MDPI

Article

A Low-Cost, Multi-Sensor System to Monitor Temporary Stream Dynamics in Mountainous Headwater Catchments

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Abstract: While temporary streams account for more than half of the global discharge, high spatiotemporal resolution data on the three main hydrological states (dry streambed, standing water, and flowing water) of temporary stream remains sparse. This study presents a low-cost, multi-sensor system to monitor the hydrological state of temporary streams in mountainous headwaters. The monitoring system consists of an Arduino microcontroller board combined with an SD-card data logger shield, and four sensors: an electrical resistance (ER) sensor, temperature sensor, float switch sensor, and flow sensor. The monitoring system was tested in a small mountainous headwater catchment, where it was installed on multiple locations in the stream network, during two field seasons (2016 and 2017).

Study site and monitoring setup

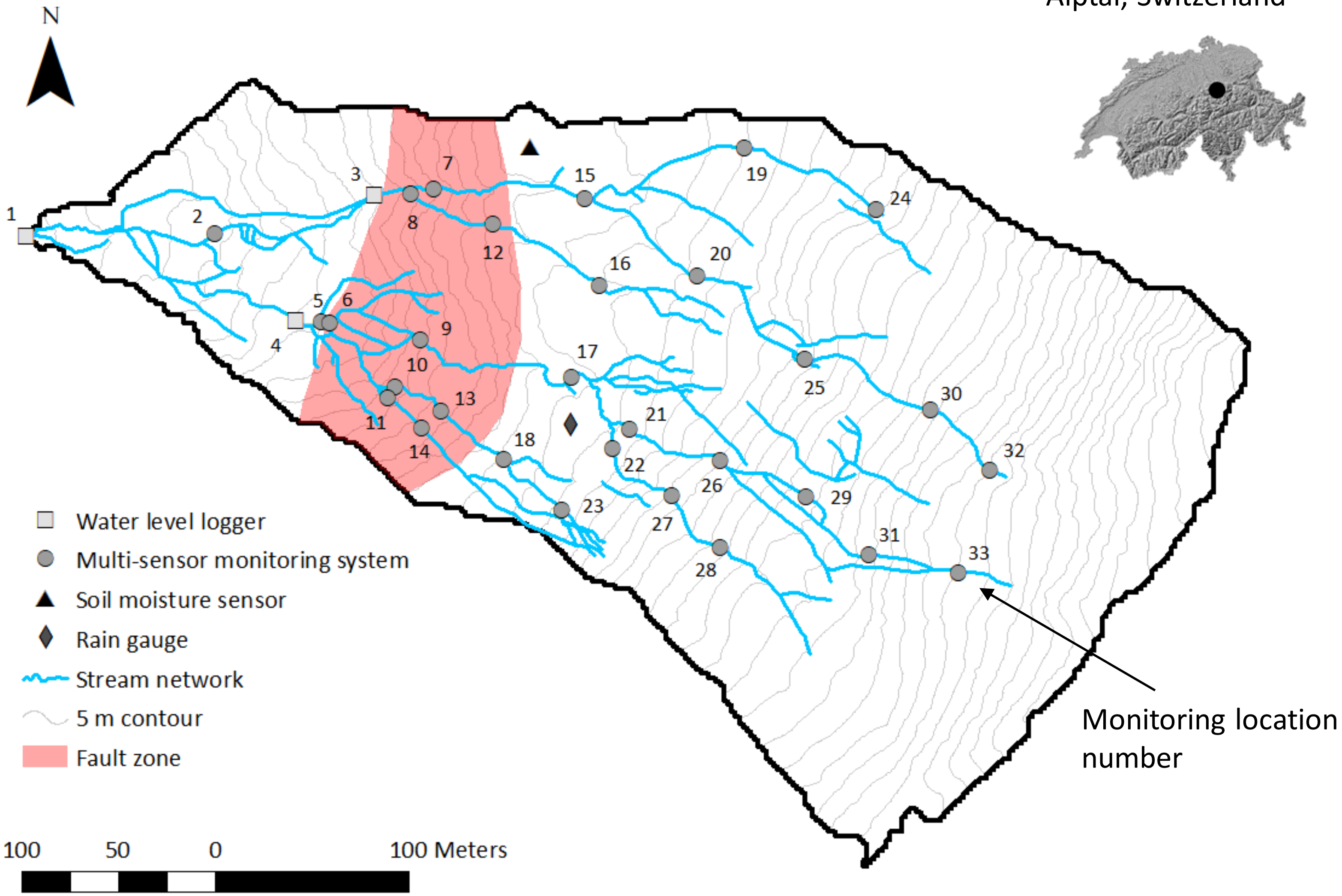
Study site

- Headwater catchment of the Studibach, Alptal, Switzerland
- Size: 0.12 km²
- Elevation: 1421 -1656 m.a.s.l.
- Average slope: ~20°
- Rainfall: 2300 mm/yr

Monitoring setup

- 30 multi-sensor monitoring systems
- 3 water level loggers
- Soil moisture sensor (0-25 cm)
- Rain gauge
- Monitoring period: Summer-Fall 2017

Alptal, Switzerland



Photos of the streams

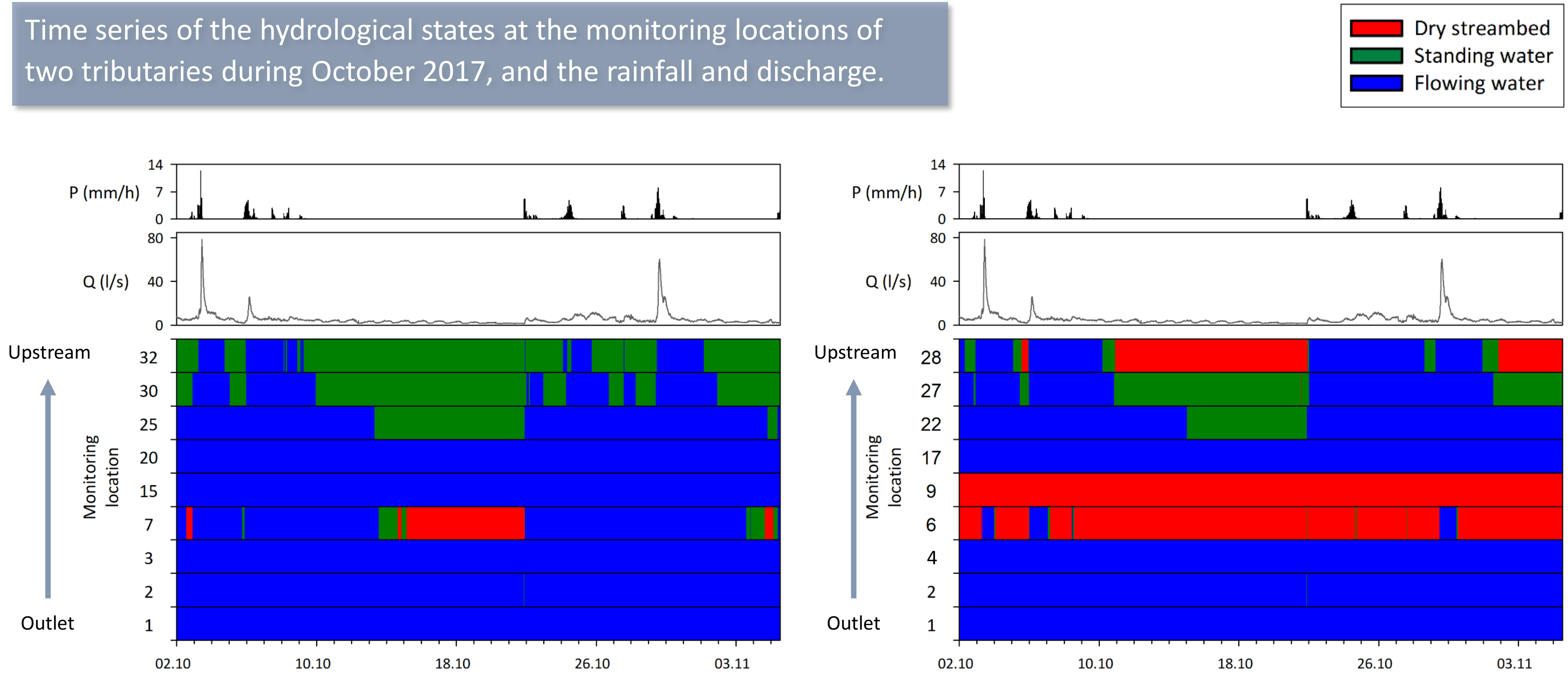
Perennial section at outlet

Ephemeral section in fault zone

Intermittent section near ridge

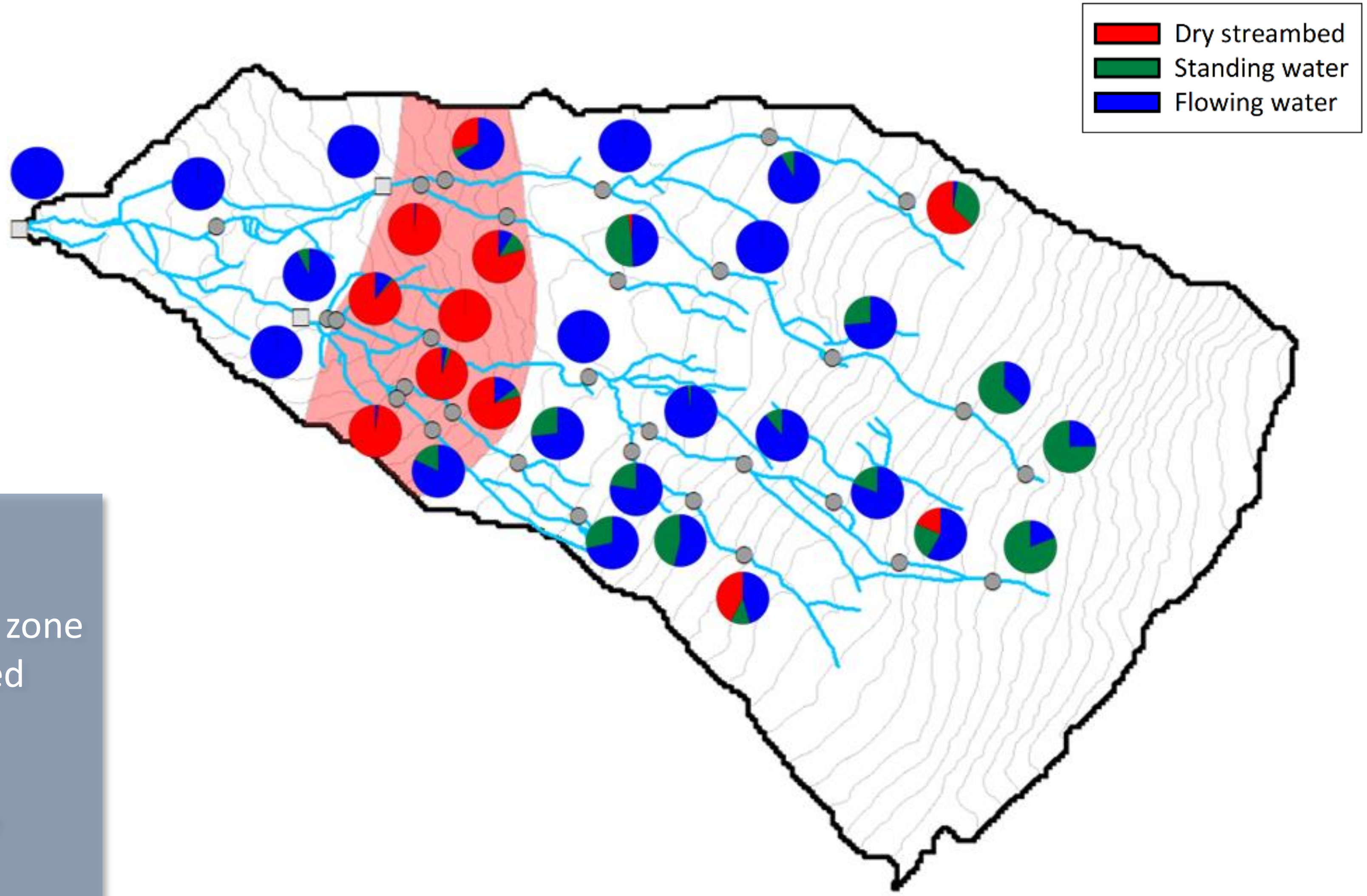
Results – Hydrological state changes

Time series of the hydrological states at the monitoring locations of two tributaries during October 2017, and the rainfall and discharge.



Results – Hydrological state permanence

Pie charts with the fraction of time for the three hydrological states during the monitoring period



When following the different tributaries upstream:

- Mostly flowing water below the fault zone
- In the fault zone mostly dry streambed
- Directly above the fault zone mostly flowing water
- Gradually more standing water in the upstream areas

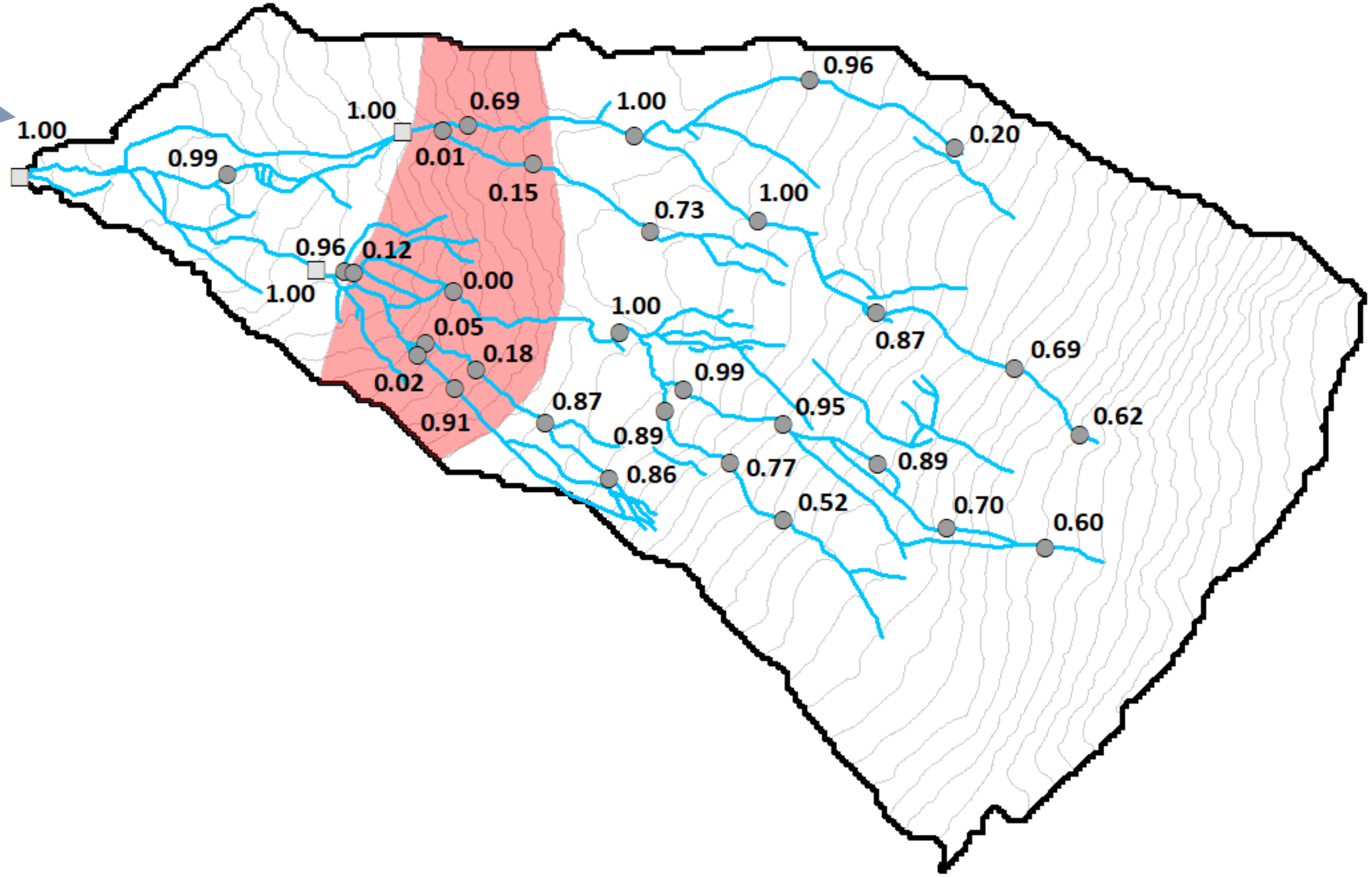
Results - Hydrological state permanence

- Weighted Permanence Number

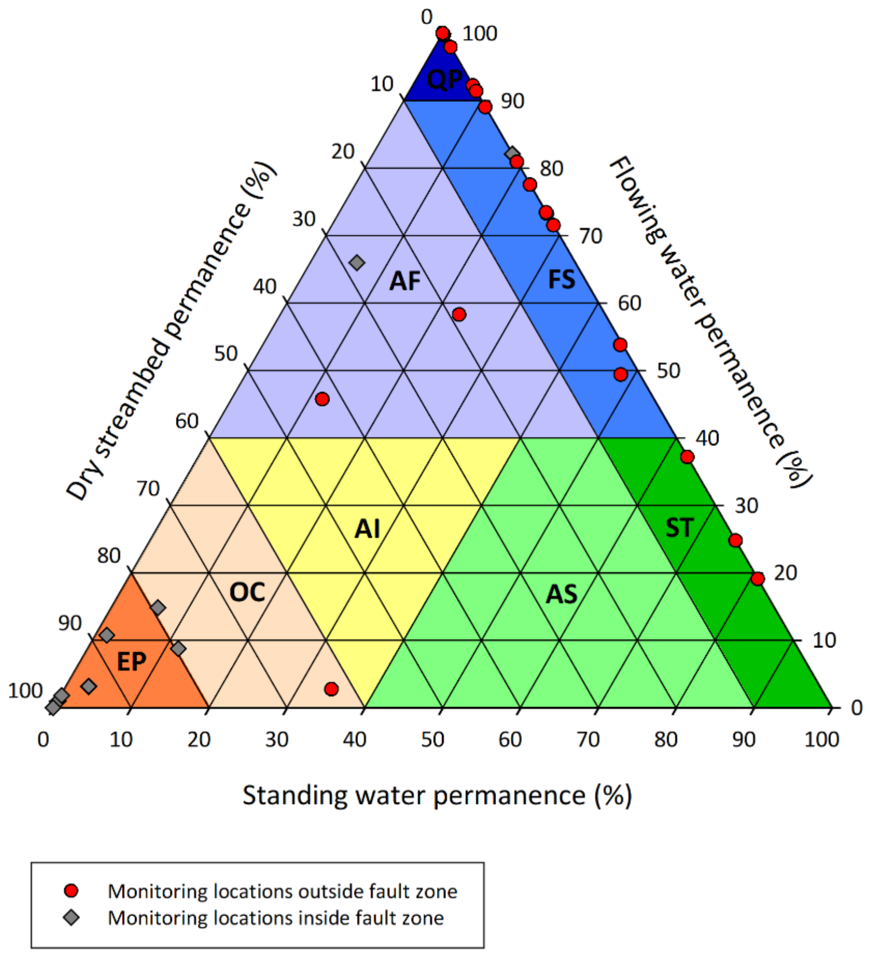
  $$WPN = f_d \bullet 0 + f_s \bullet 0.5 + f_f \bullet 1$$

- f_d = fraction of time with dry streambed state
- f_s = fraction of time with standing water state
- f_f = fraction of time with flowing water state

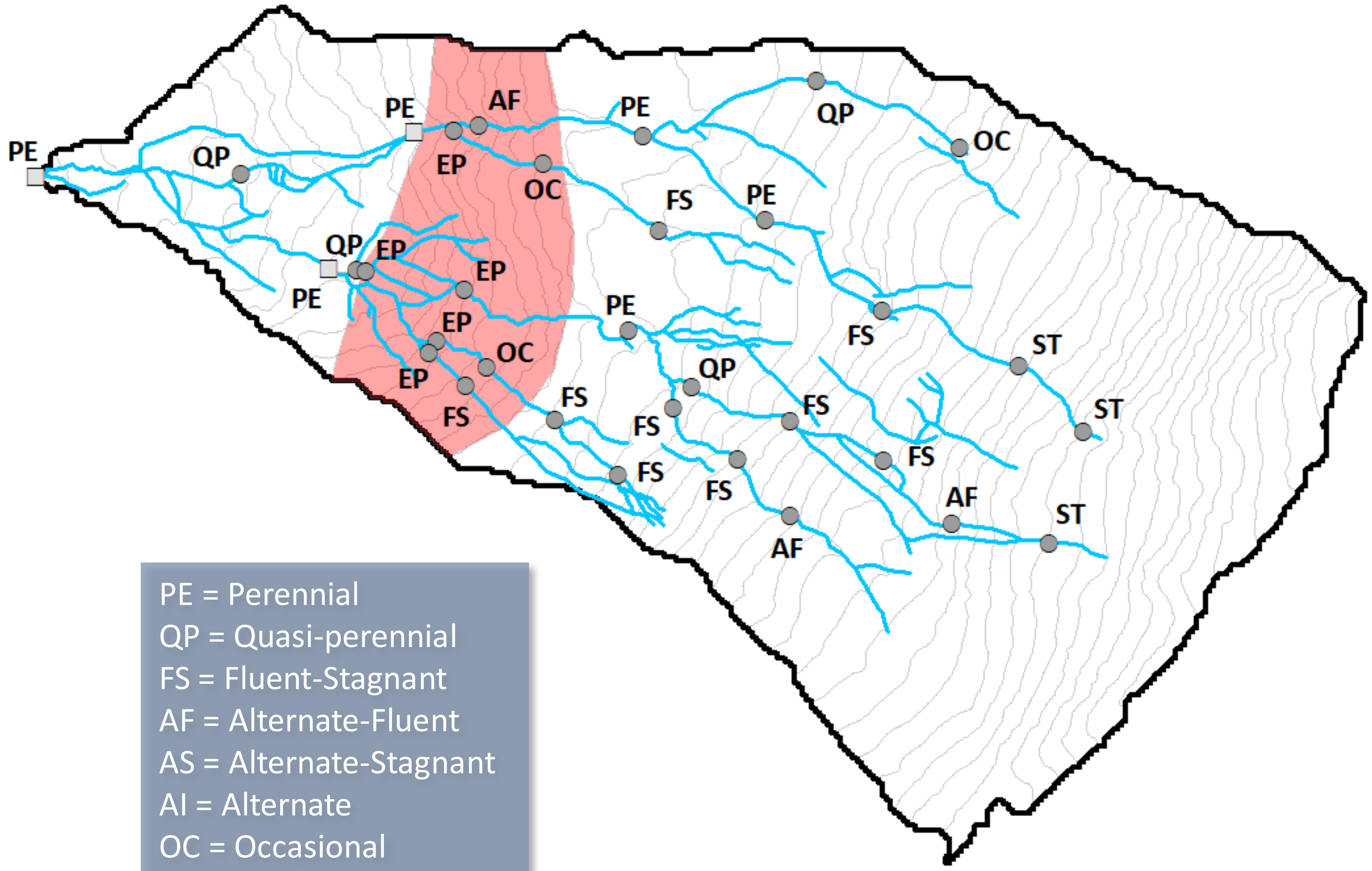
- Value close to 1 indicates mainly flowing conditions, value close to zero mainly dry



Results – Stream regime



Ternary plot after Gallart et al. (2017), *Science of the Total Environment*



PE = Perennial
QP = Quasi-perennial
FS = Fluent-Stagnant
AF = Alternate-Fluent
AS = Alternate-Stagnant
AI = Alternate
OC = Occasional
EP = Episodic

Results – Wetness thresholds

Thresholds for state changes were determined for all monitoring locations:

- Precipitation (mm)
- Soil moisture in upper 25 cm of the soil (mm)
- Discharge (l/s)

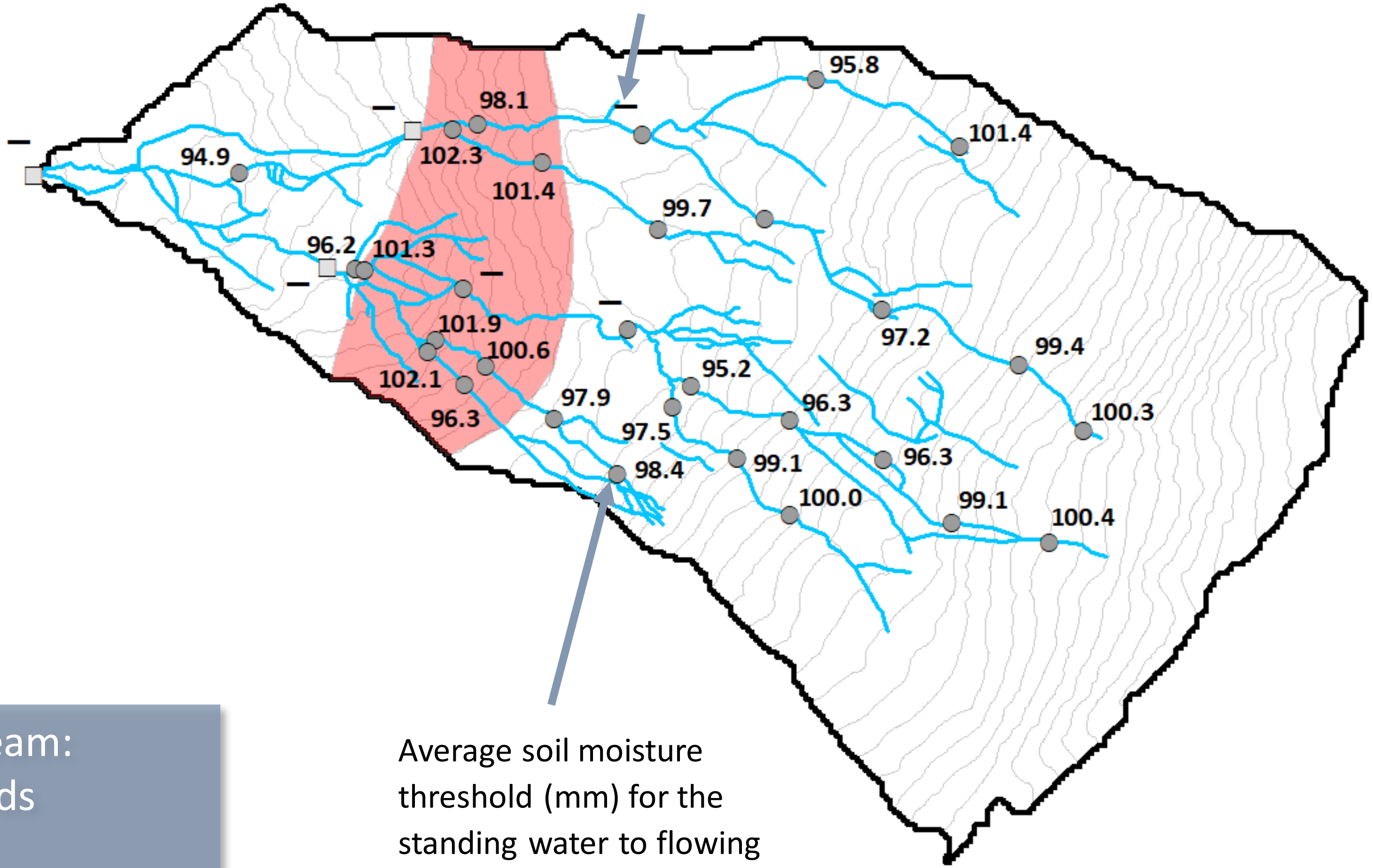
State changes:

- Dry streambed – Standing water
- Standing water – Flowing water
- Flowing water – Standing water
- Standing water – Dry streambed

When following the different tributaries upstream:

- Below the fault zone relatively low thresholds
- In the fault zone relatively high thresholds
- Directly above the fault zone relatively low thresholds
- Gradually higher thresholds in the upstream area

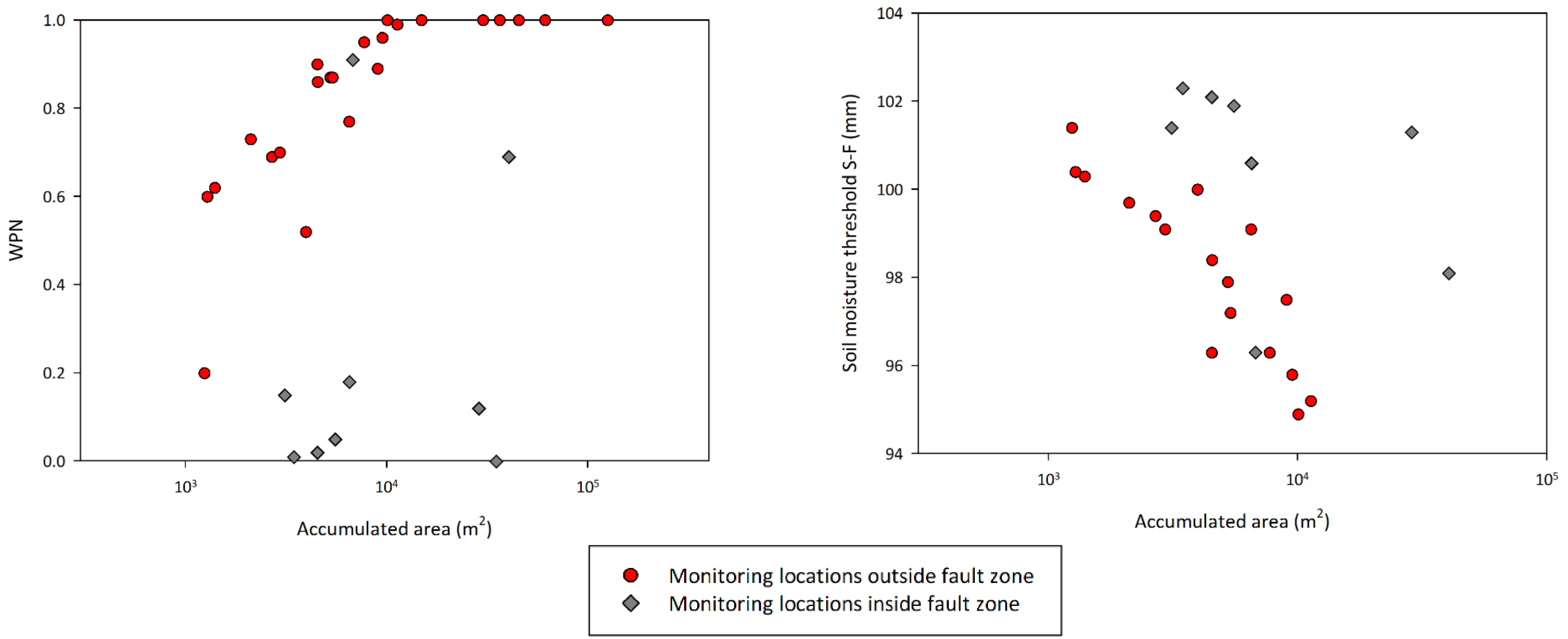
No state changes for locations with perennial flow



Average soil moisture threshold (mm) for the standing water to flowing water state change

Results – Spatial controls

The Weighted Permanence Number and the wetness thresholds for state changes were compared to topographic and local controls for all monitoring locations. The WPN and wetness thresholds for the monitoring locations outside the fault zone are highly correlated with the accumulated area.



Discussion/Conclusions

- The multi-sensor monitoring system can provide high spatiotemporal information on the three main hydrological states.
- The significant fraction of the standing water state highlights the need to differentiate between standing water and flowing water.
- The Weighted Permanence Number and wetness thresholds for state changes show a similar spatial pattern across the study catchment.
- Outside the fault zone the state permanence and wetness thresholds are related to the accumulated area.
- Inside the fault zone this relation does not hold, as the streams transition from gaining streams to losing streams

References

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