Changes in flowing drainage network and stream chemistry during rainfall events for two pre-Alpine catchments

Izabela Bujak-Ozga[1,2], Jana von Freyberg[1,2], Margaret Zimmer[3], Andrea Rinaldo[1,4], Paolo Benettin[1,5], and Ilja van Meerveld[6]

[1]EPF Lausanne, School of Architecture, Civil and Environmental Engineering, Lausanne, Switzerland
[2]Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Mountain Hydrology and Mass Movements, Birmensdorf, Switzerland
[3]U.S. Geological Survey, Upper Midwest Water Science Center, Madison, Wisconsin, USA
[4]Università di Padova, Department of Civil, Environmental and Architectural Engineering (DICEA), Padova, Italy
[5]University of Lausanne, Department of Earth Surface Dynamics, Lausanne, Switzerland
[6]University of Zurich, Department of Geography, Zurich, Switzerland

Correspondence to: Izabela Bujak-Ozga (hydrology@izabelabujak.com)

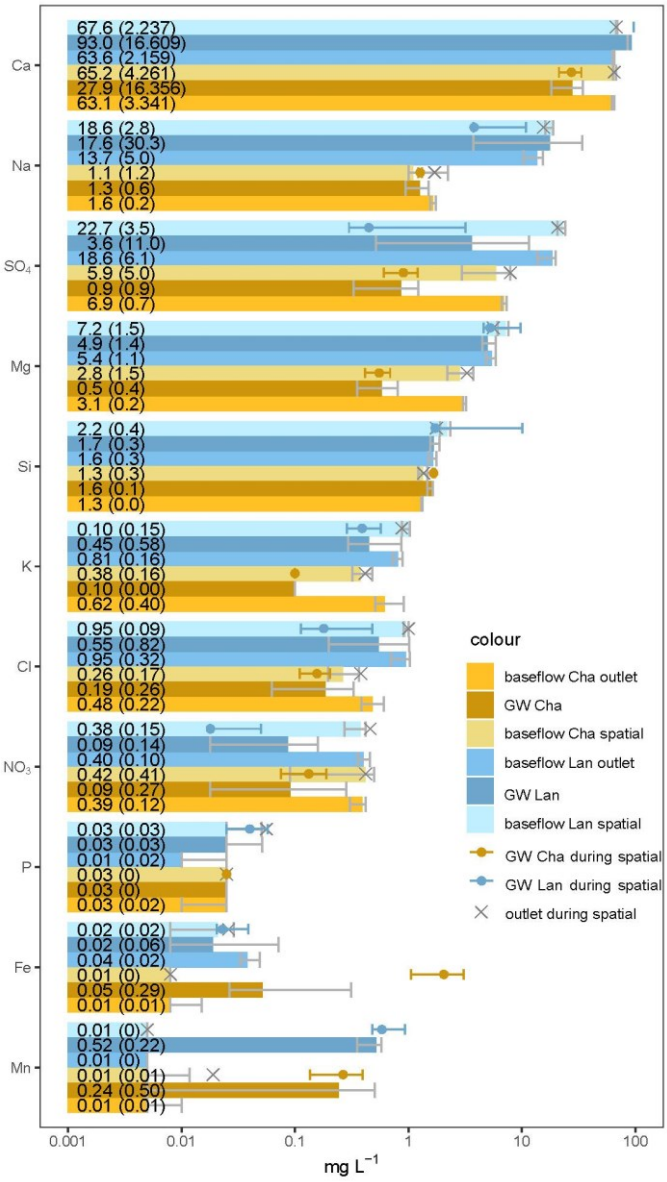

Fig. S1 Median (bars) and interquartile range (gray whiskers) of the concentrations of all groundwater samples collected in Cha (GW Cha; brown) and Lan (GW Lan; dark blue), all streamwater samples collected during baseflow conditions at the outlet of Cha (baseflow Cha outlet; orange) and Lan (baseflow Lan outlet; deep blue), and all surface water locations that had water during the spatial snapshot sampling campaign in Cha (baseflow Cha spatial; light yellow) and Lan (baseflow Lan spatial; light blue). All concentrations are in mg L^{-1}. Text indicates the median values and the interquartile range in parentheses.

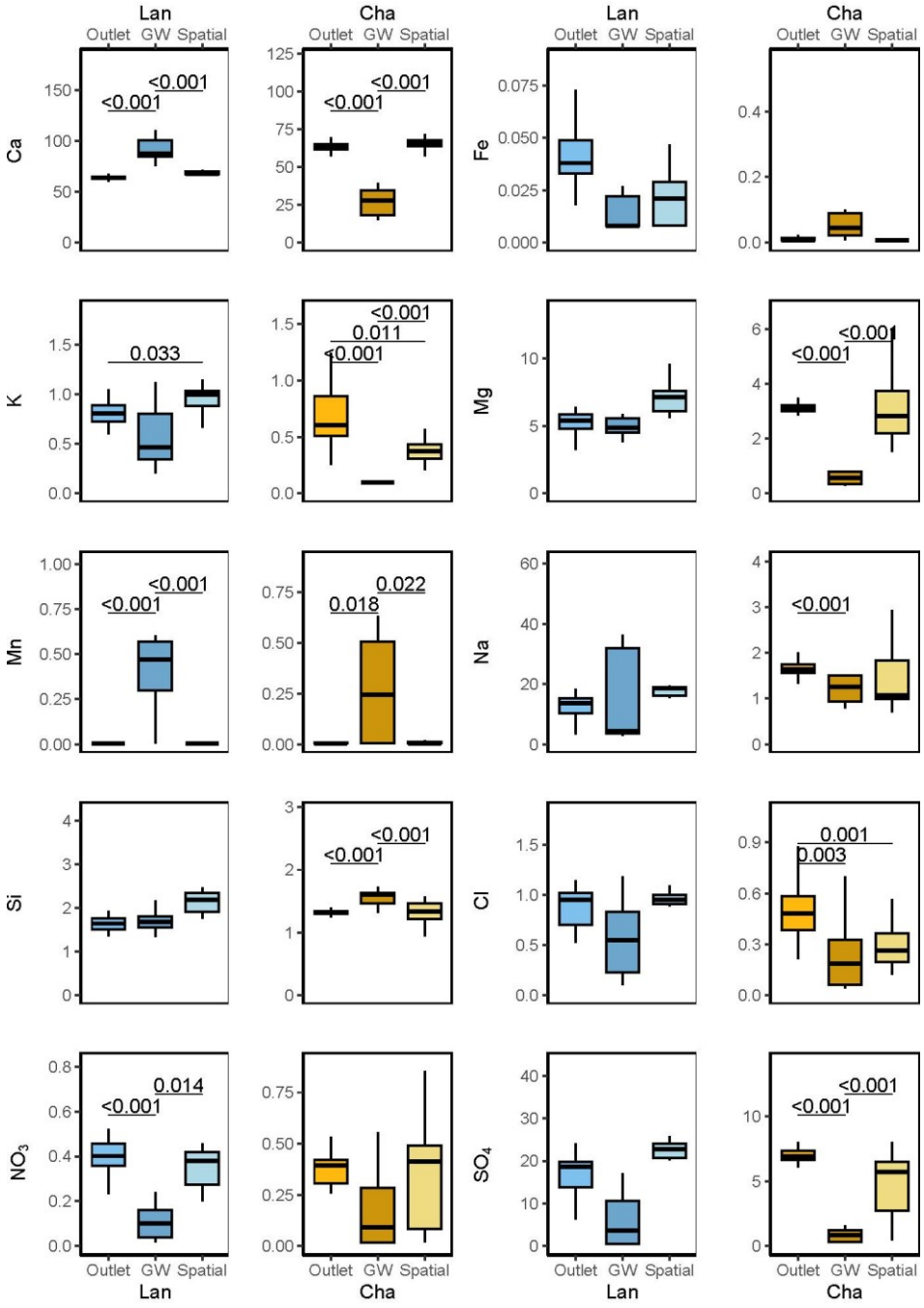

Fig. S2 Boxplots showing the solute concentrations of baseflow groundwater samples collected in Cha (GW Cha; brown) and Lan (GW Lan; dark blue), all streamwater samples collected during baseflow conditions at the outlet of Cha (baseflow Cha outlet; orange) and Lan (baseflow Lan outlet; deep blue), and all surface water locations that had water during the spatial snapshot sampling campaign in Cha (baseflow Cha spatial; light yellow) and Lan (baseflow Lan spatial; light blue). All concentrations are in mg L^{-1}. The line indicates the median concentration and the whiskers the interquartile range. Where the differences between groups were statistically significant according to the Dunn test, this is indicated with a horizontal line and the p-values are printed above the line.

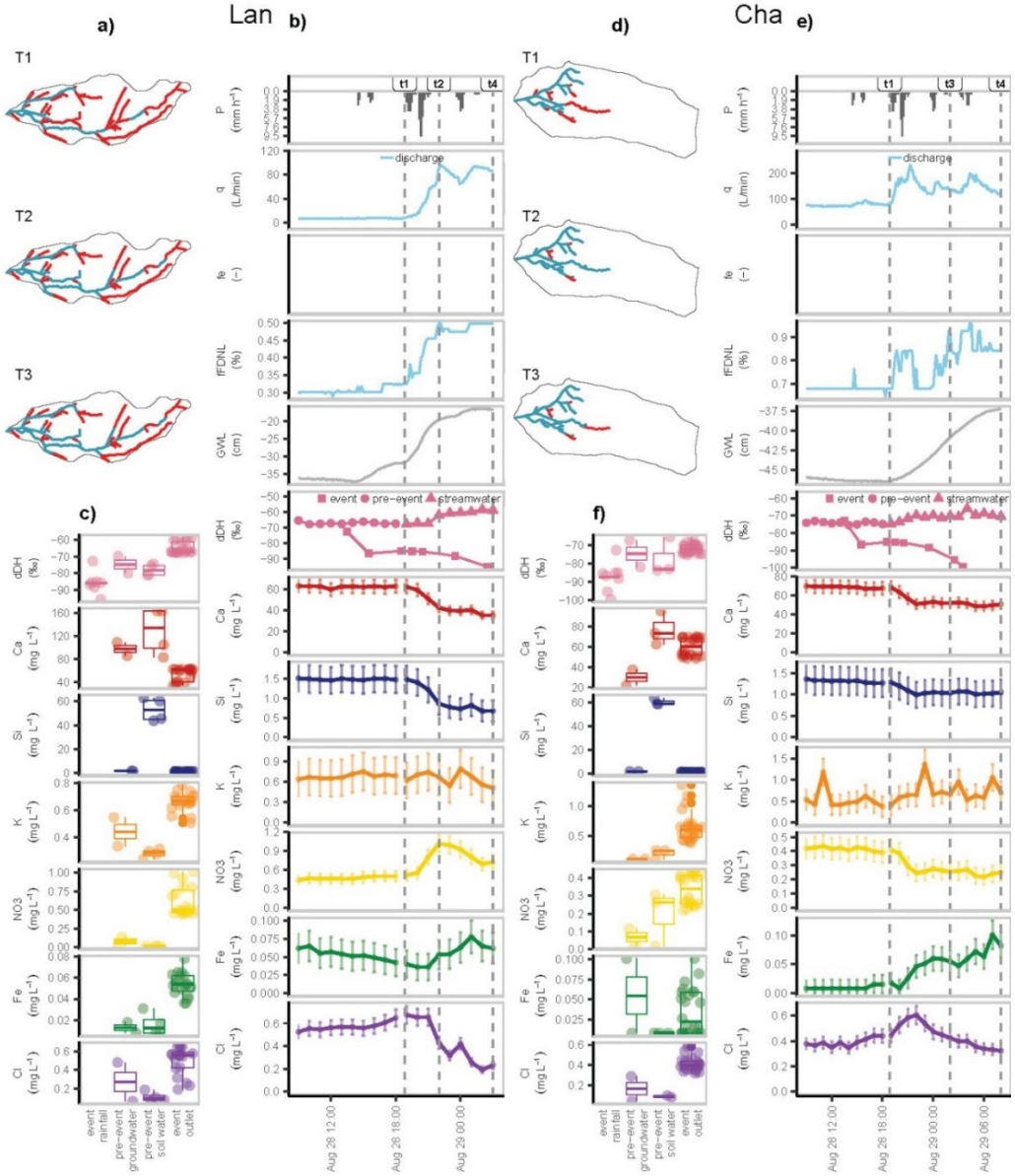

Figure S3: Maps of the flowing (blue) and not flowing (red) reaches of the channel network during three selected times during the 2021-08-2 event (a, d); time-series of hydrologic variables, δ^2H and solute concentrations, and the results of the hydrograph separation (b, c); box plots of the concentrations of the samples collected at the catchment outlet during the event, the weighted mean of the rainfall sampled during the event, pre-event groundwater samples, and pre-event soil water (lysimeter) samples (c, e) for the Lan (left) and Cha (right) catchments. In panels a, b, d and e, t_1 represents the start of the event, t_2, and t_3 mark the time of the maximum extension of the flowing drainage network (i.e. the largest f_{FDNL}), and t_4 marks the time when the last sample was collected during the event. Boxes in panels c and f show the 1st, 2nd, and 3rd quartiles and whiskers extend to the minimum and maximum values. GWL in panels b and e stands for groundwater level and shows data from locations LGW1 (Lan) and CBGW2 (Cha). The error bars in panels b and e represent the uncertainty of the laboratory measurements (solutes) or the calculated standard error (f_e), the dashed line represents the expected concentration based on the hydrograph separation and the shaded areas the upper and lower bound of the expected concentrations based on the standard error of f_e.

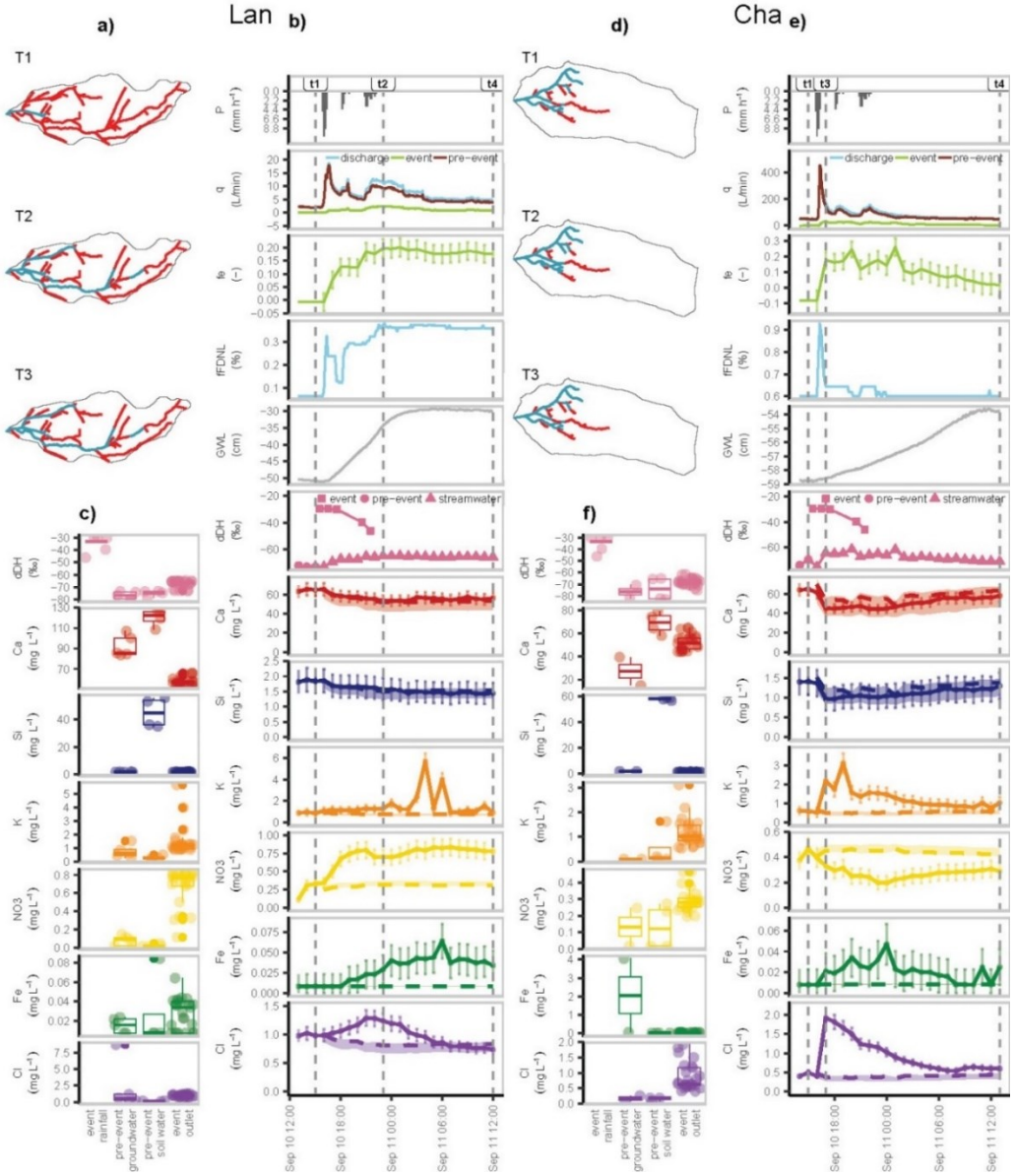

Figure S4: Maps of the flowing (blue) and not flowing (red) reaches of the channel network during three selected times during the 2021-09-10 event (a, d); time-series of hydrologic variables, δ^2H and solute concentrations, and the results of the hydrograph separation (b, c); box plots of the concentrations of the samples collected at the catchment outlet during the event, the weighted mean of the rainfall sampled during the event, pre-event groundwater samples, and pre-event soil water (lysimeter) samples (c, e) for the Lan (left) and Cha (right) catchments. In panels a, b, d and e, t_1 represents the start of the event, t_2, and t_3 mark the time of the maximum extension of the flowing drainage network (i.e. the largest f_{FDNL}), and t_4 marks the time when the last sample was collected during the event. Boxes in panels c and f show the 1st, 2nd, and 3rd quartiles and whiskers extend to the minimum and maximum values. GWL in panels b and e stands for groundwater level and shows data from locations LGW1 (Lan) and CBGW2 (Cha). The error bars in panels b and e represent the uncertainty of the laboratory measurements (solutes) or the calculated standard error (fe), the dashed line represents the expected concentration based on the hydrograph separation and the shaded areas the upper and lower bound of the expected concentrations based on the standard error of f_e.

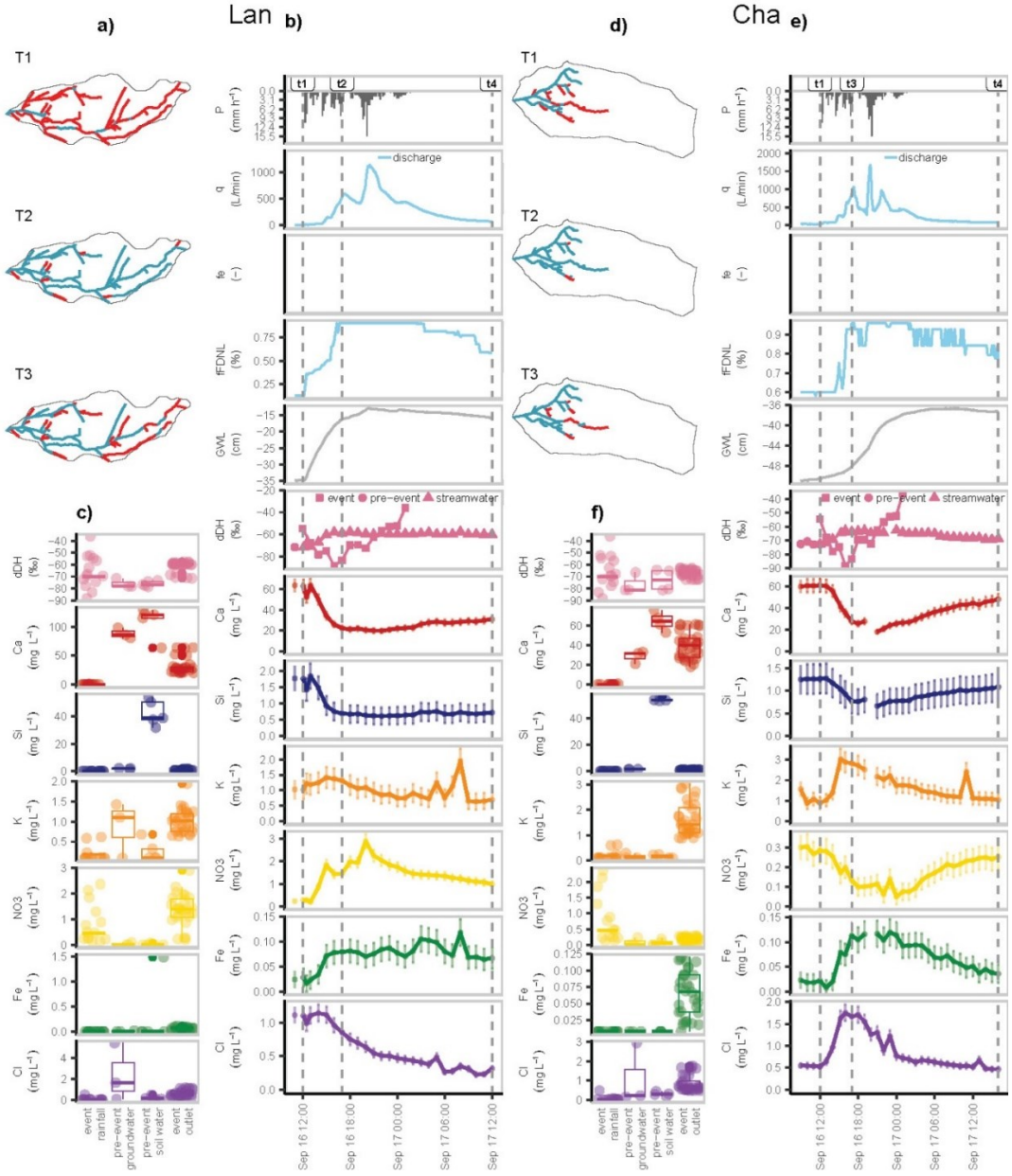

Fig. S5 Maps of the flowing (blue) and not flowing (red) reaches of the channel network during three selected times during the 2021-09-16 event (a, d); time-series of hydrologic variables, δ^2H and solute concentrations, and the results of the hydrograph separation (b, c); box plots of the concentrations of the samples collected at the catchment outlet during the event, the weighted mean of the rainfall sampled during the event, pre-event groundwater samples, and pre-event soil water (lysimeter) samples (c, e) for the Lan (left) and Cha (right) catchments. In panels a, b, d and e, t_1 represents the start of the event, t_2, and t_3 mark the time of the maximum extension of the flowing drainage network (i.e. the largest f_{FDNL}), and t_4 marks the time when the last sample was collected during the event. Boxes in panels c and f show the 1st, 2nd, and 3rd quartiles and whiskers extend to the minimum and maximum values. GWL in panels b and e stands for groundwater level and shows data from locations LGW1 (Lan) and CBGW2 (Cha). The error bars in panels b and e represent the uncertainty of the laboratory measurements (solutes) or the calculated standard error (f_e), the dashed line represents the expected concentration based on the hydrograph separation and the shaded areas the upper and lower bound of the expected concentrations based on the standard error of f_e.

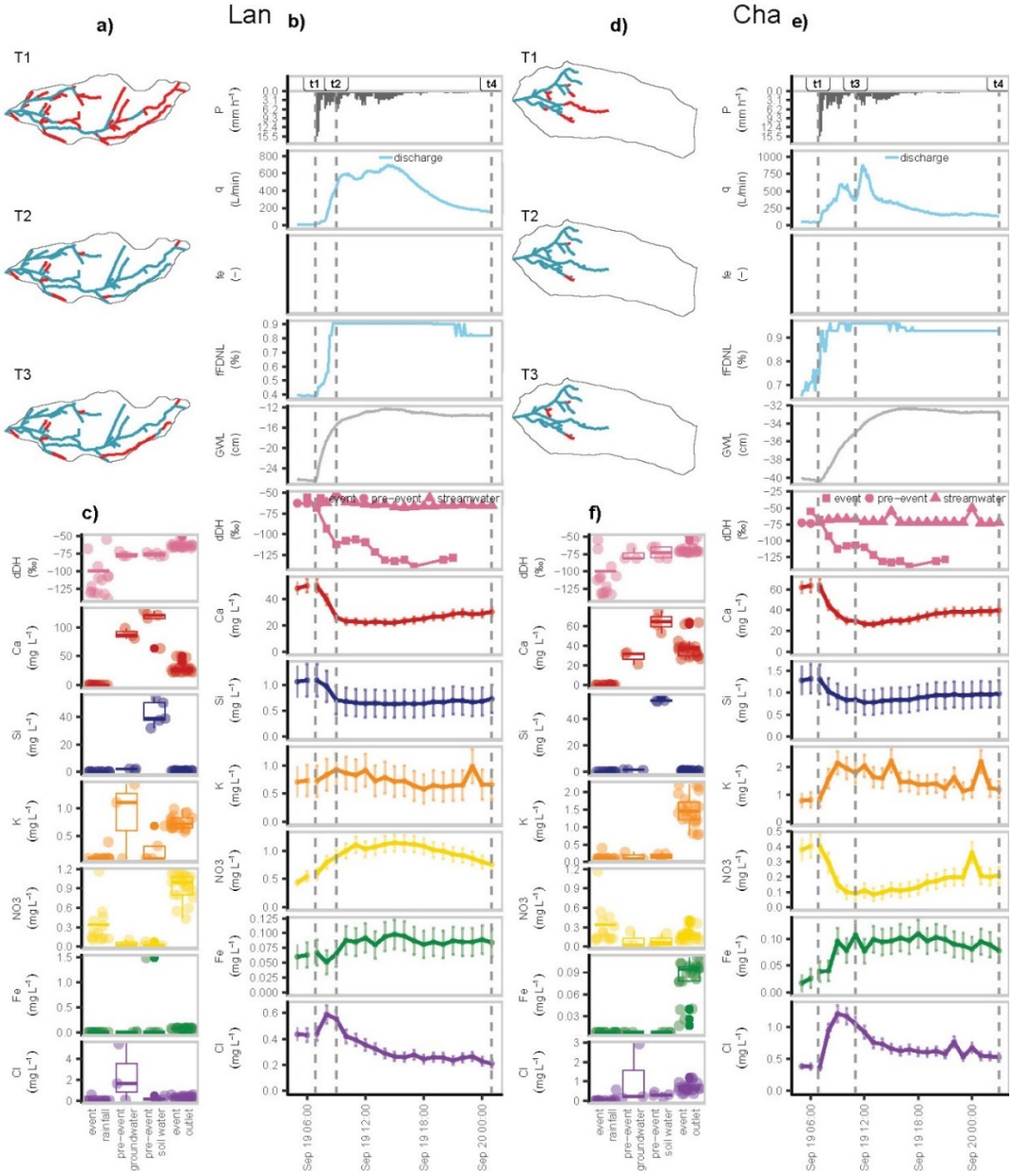

Figure S6 Maps of the flowing (blue) and not flowing (red) reaches of the channel network during three selected times during the 2021-09-19 event (a, d); time-series of hydrologic variables, δ^2H and solute concentrations, and the results of the hydrograph separation (b, c); box plots of the concentrations of the samples collected at the catchment outlet during the event, the weighted mean of the rainfall sampled during the event, pre-event groundwater samples, and pre-event soil water (lysimeter) samples (c, e) for the Lan (left) and Cha (right) catchments. In panels a, b, d and e, t_1 represents the start of the event, t_2, and t_3 mark the time of the maximum extension of the flowing drainage network (i.e. the largest f_{FDNL}), and t_4 marks the time when the last sample was collected during the event. Boxes in panels c and f show the 1st, 2nd, and 3rd quartiles and whiskers extend to the minimum and maximum values. GWL in panels b and e stands for groundwater level and shows data from locations LGW1 (Lan) and CBGW2 (Cha). The error bars in panels b and e represent the uncertainty of the laboratory measurements (solutes) or the calculated standard error (f_e), the dashed line represents the expected concentration based on the hydrograph separation and the shaded areas the upper and lower bound of the expected concentrations based on the standard error of f_e.

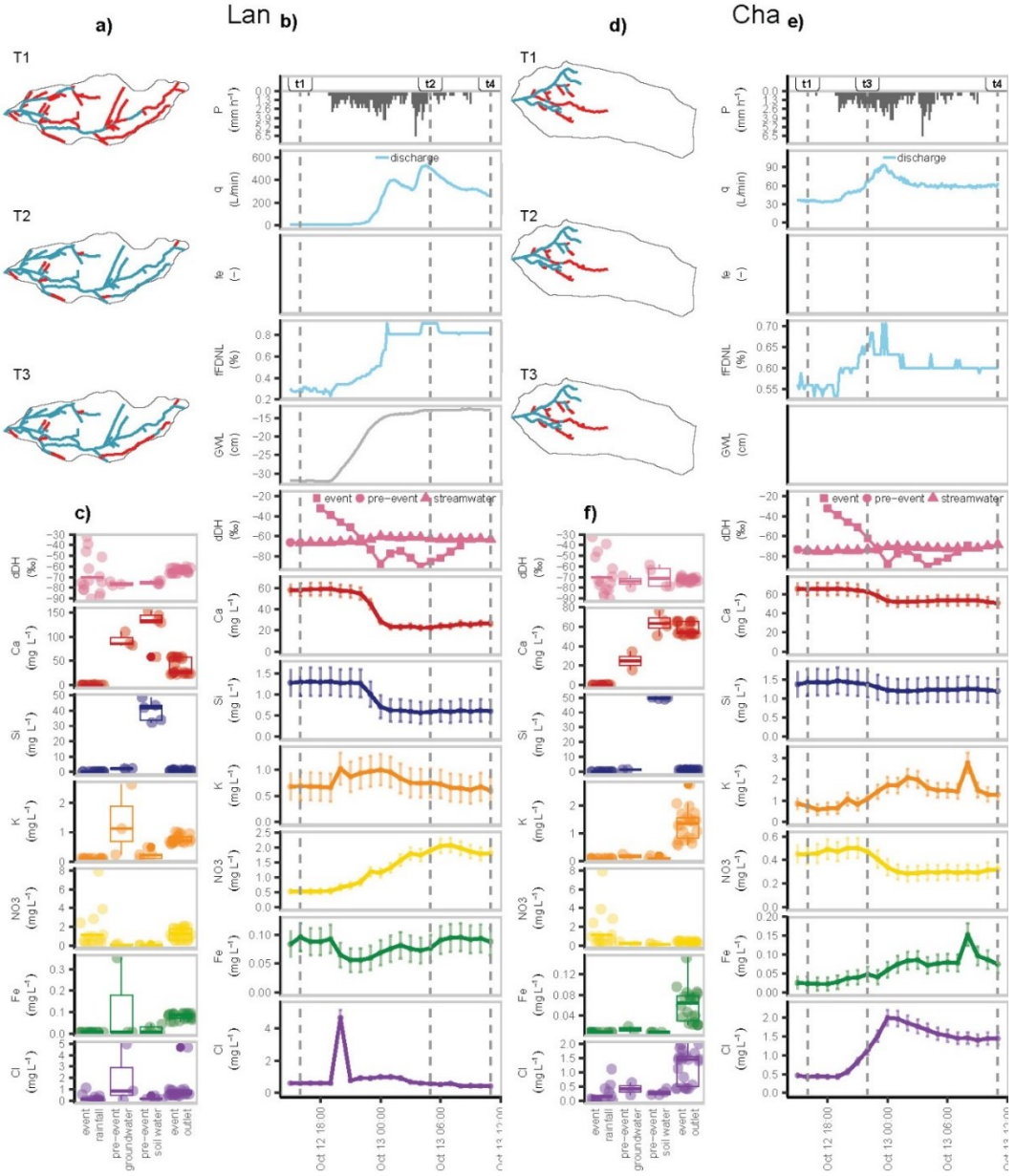

Fig. S7 Maps of the flowing (blue) and not flowing (red) reaches of the channel network during three selected times during the 2021-10-12 event (a, d); time-series of hydrologic variables, δ^2H and solute concentrations, and the results of the hydrograph separation (b, c); box plots of the concentrations of the samples collected at the catchment outlet during the event, the weighted mean of the rainfall sampled during the event, pre-event groundwater samples, and pre-event soil water (lysimeter) samples (c, e) for the Lan (left) and Cha (right) catchments. In panels a, b, d and e, t_1 represents the start of the event, t_2, and t_3 mark the time of the maximum extension of the flowing drainage network (i.e. the largest f_{FDNL}), and t_4 marks the time when the last sample was collected during the event. Boxes in panels c and f show the 1st, 2nd, and 3rd quartiles and whiskers extend to the minimum and maximum values. GWL in panels b and e stands for groundwater level and shows data from locations LGW1 (Lan) and CBGW2 (Cha). The error bars in panels b and e represent the uncertainty of the laboratory measurements (solutes) or the calculated standard error (f_e), the dashed line represents the expected concentration based on the hydrograph separation and the shaded areas the upper and lower bound of the expected concentrations based on the standard error of f_e.

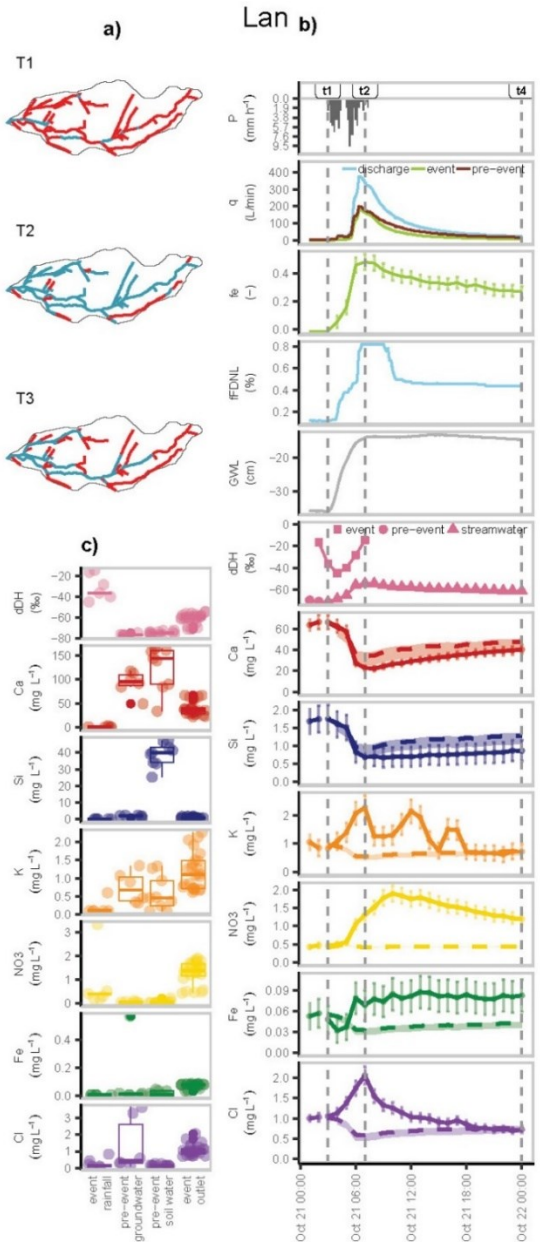

Fig. S8 Maps of the flowing (blue) and not flowing (red) reaches of the channel network during three selected times during the 2021-10-21 event (a); time-series of hydrologic variables, δ^2H and solute concentrations, and the results of the hydrograph separation (b); box plots of the concentrations of the samples collected at the catchment outlet during the event, the weighted mean of the rainfall sampled during the event, pre-event groundwater samples, and pre-event soil water (lysimeter) samples (c) for the Lan (left) catchment. In panels a, b, t_1 represents the start of the event, t_2, and t_3 mark the time of the maximum extension of the flowing drainage network (i.e. the largest f_{FDNL}), and t_4 marks the time when the last sample was collected during the event. Boxes in panel c show the 1st, 2nd, and 3rd quartiles and whiskers extend to the minimum and maximum values. GWL in panel b stands for groundwater level and shows data from locations LGW1 (Lan). The error bars in panels b represent the uncertainty of the laboratory measurements (solutes) or the calculated standard error (f_e), the dashed line represents the expected concentration based on the hydrograph separation and the shaded areas the upper and lower bound of the expected concentrations based on the standard error of f_e.

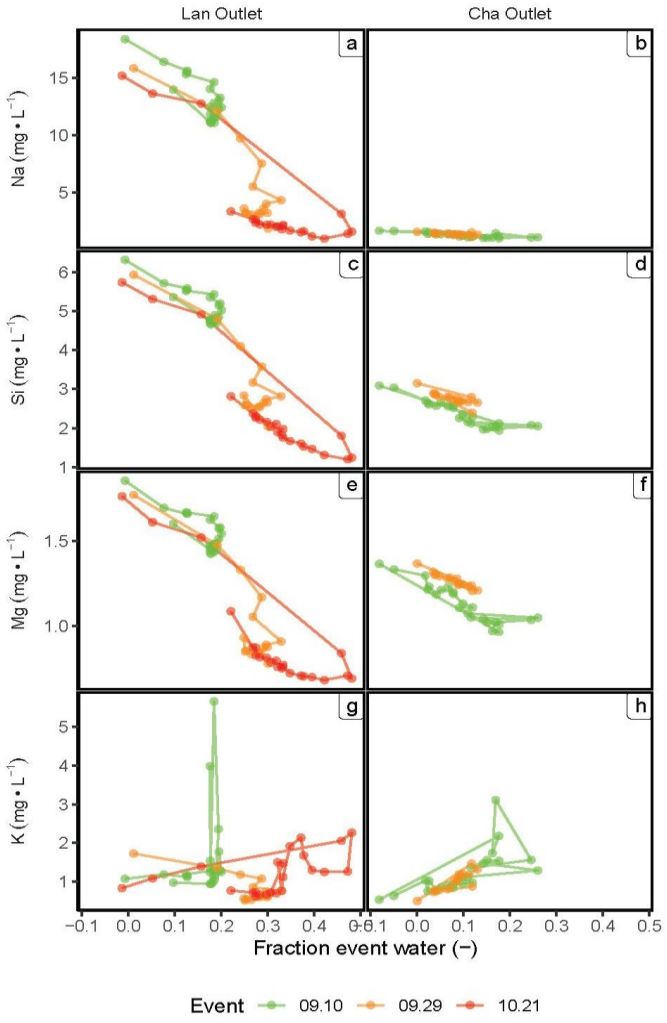

Fig. S10 Relation between the concentrations of selected solute and event water fractions (f_e) for three events in Lan (left) and two events in Cha (right).

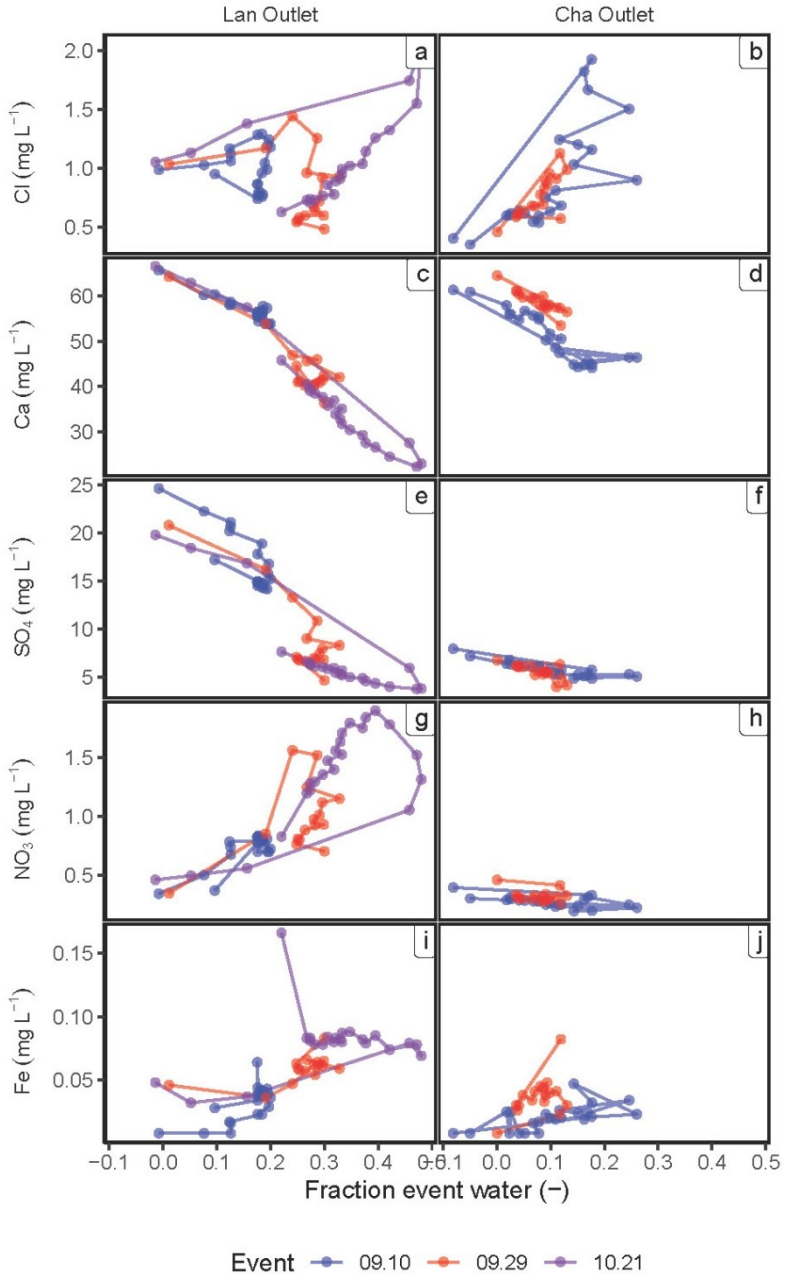

Fig. S11 Relation between the concentrations of selected solutes and the event water fractions (f_e) for three events in Lan (left) and two events in Cha (right). Results for the other solutes are shown in Figure S10.

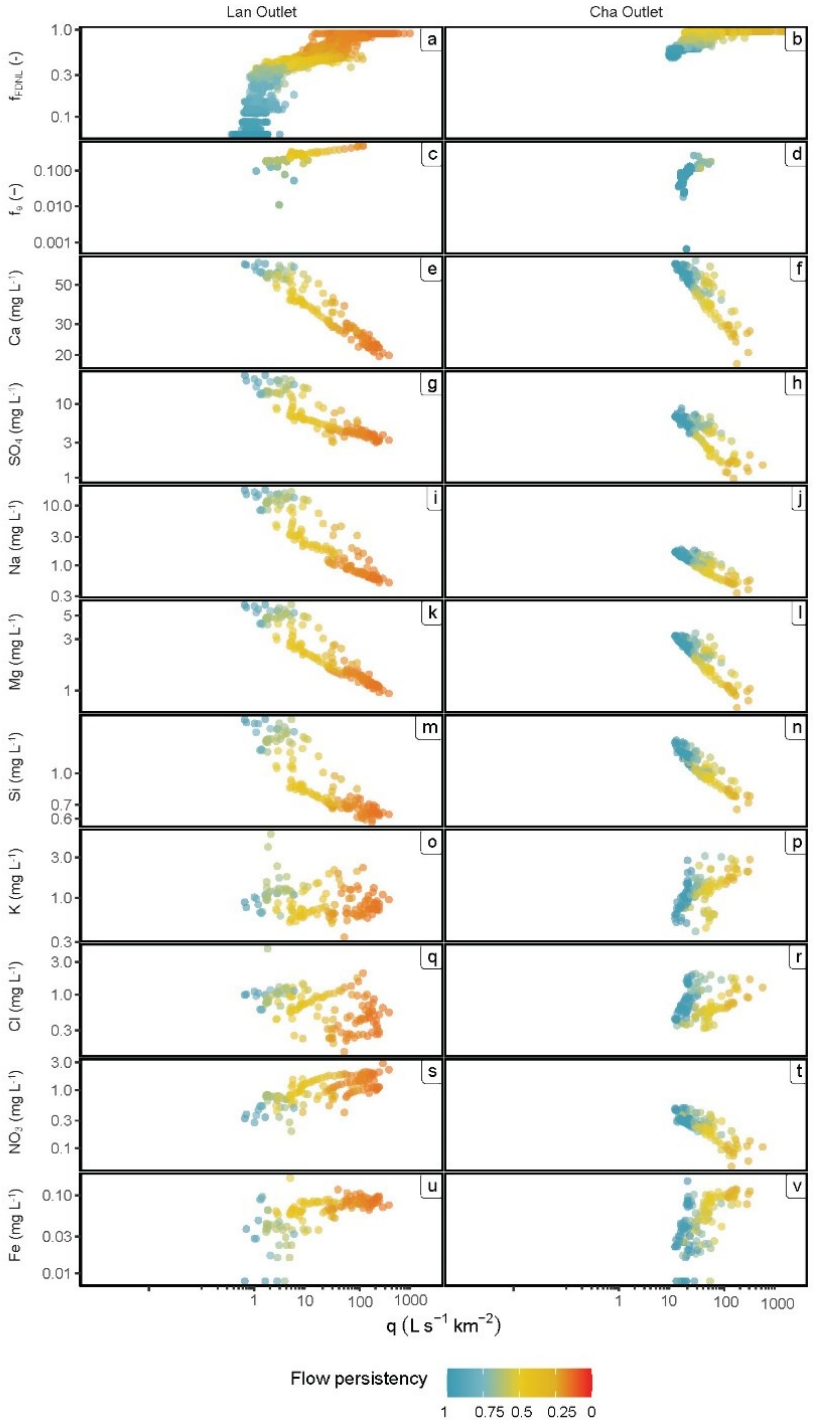

Fig. S12 Relation between the event water fraction (f_e) or solute concentrations and the discharge (q) at the outlet for Lan (L1; left) and Cha (CB1; right). Data points are color-coded by the persistency the channel reach with lowest persistency that was flowing at the time of sample collection. Event water fractions could only be calculated for three events in Lan and two events in Cha.

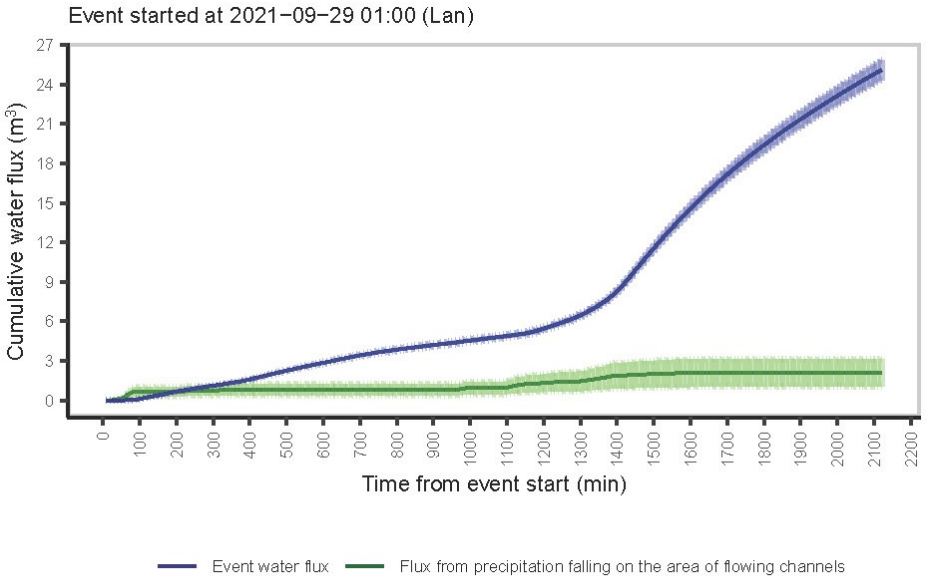

Fig. S13 Time series of the cumulative water flux from event water (blue) and from precipitation falling on the area of flowing channels (green) during the event 2021-09-29 in the Lan catchment. The area of flowing channels was calculated assuming the average width of flowing channels of 0.2 m (dark green line), 0.1 and 0.3 m (shaded light green). The event water flux was estimated using the calculated event water fractions (dark blue) and taking into account the standard error of the event water fractions (shaded light blue).

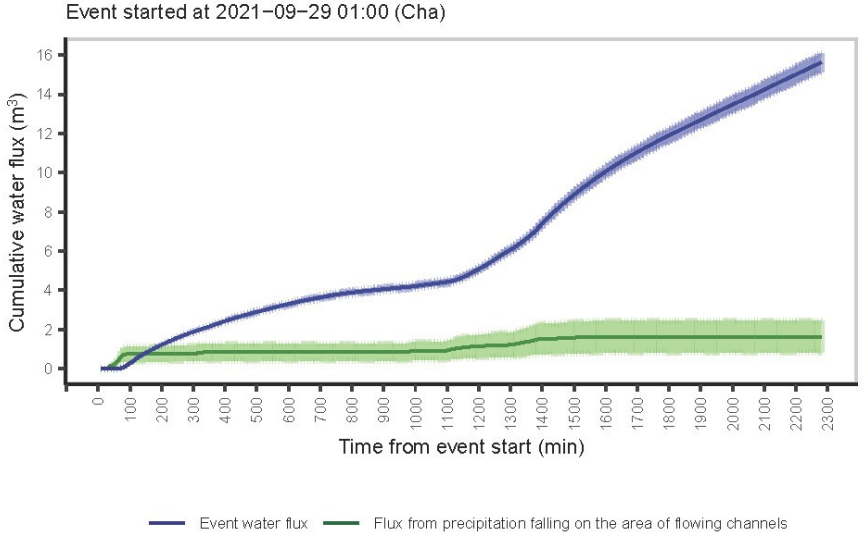

Fig. S14 Time series of the cumulative water flux from event water (blue) and from precipitation falling on the area of flowing channels (green) during the event 2021-09-29 in the Cha catchment. The area of flowing channels was calculated assuming the average width of flowing channels of 0.2 m (dark green line), 0.1 and 0.3 m (shaded light green). The event water flux was estimated using the calculated event water fractions (dark blue) and taking into account the standard error of the event water fractions (shaded light blue).

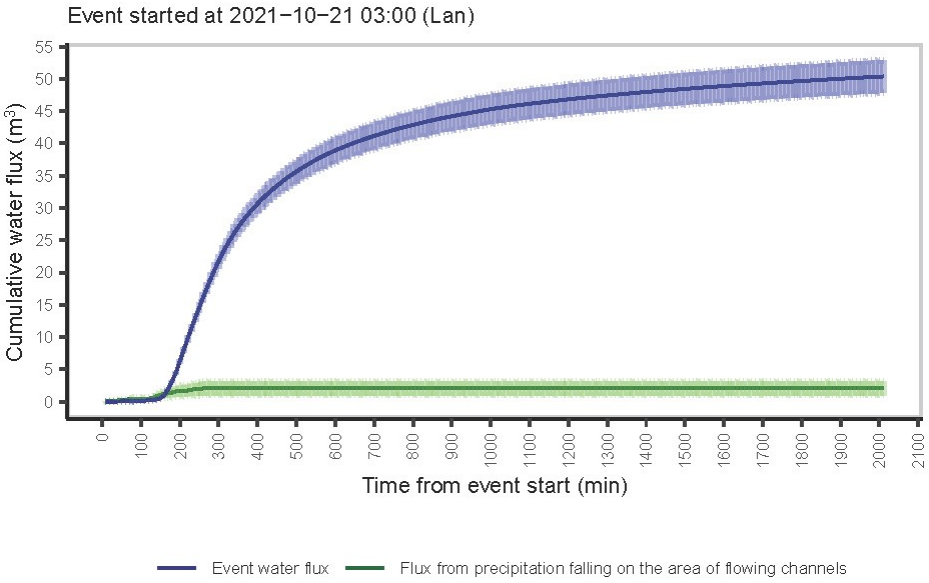

Fig. S15 Time series of the cumulative water flux from event water (blue) and from precipitation falling on the area of flowing channels (green) during the event 2021-10-21 in the Lan catchment. The area of flowing channels was calculated assuming the average width of flowing channels of 0.2 m (dark green line), 0.1 and 0.3 m (shaded light green). The event water flux was estimated using the calculated event water fractions (dark blue) and taking into account the standard error of the event water fractions (shaded light blue).

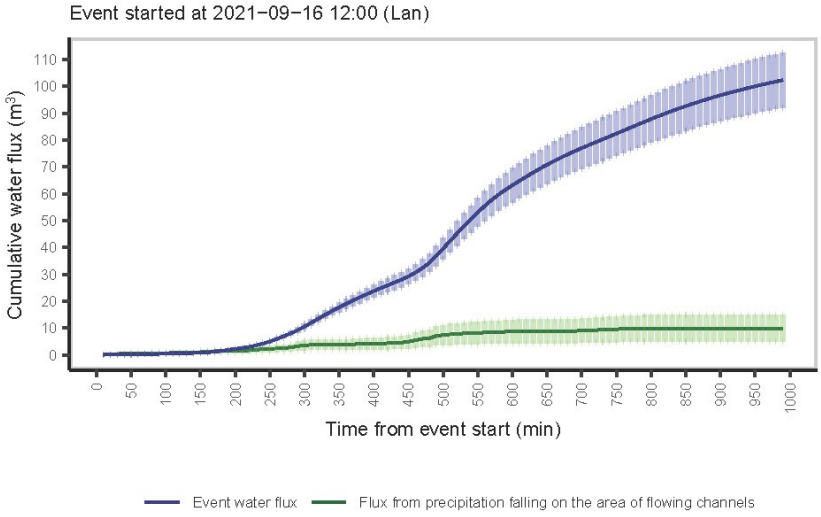

Fig. S16 Time series of the cumulative water flux from event water (blue) and from precipitation falling on the area of flowing channels (green) during the event 2021-09-16 in the Lan catchment. The area of flowing channels was calculated assuming the average width of flowing channels of 0.2 m (dark green line), 0.1 and 0.3 m (shaded light green). The event water fractions could not be calculated for this event. Therefore, to gain an understanding of the order of magnitude it could have reached, the event water flux was estimated using the assumed event water fraction of 0.25 (dark blue), and a relatively large standard error of 0.1 (shaded light blue).