Supplementary information for:

Localised geomorphic response to channel-spanning leaky wooden dams

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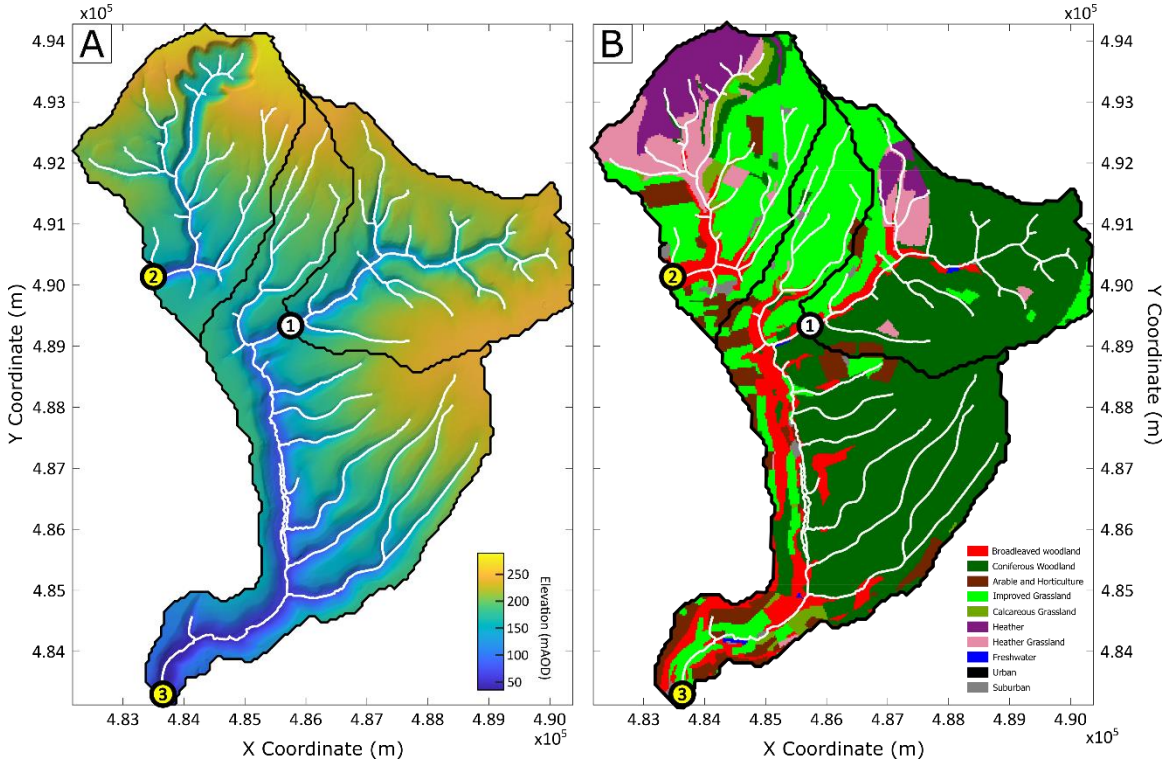
Flow frequency analysis

In lieu of long term flow data available for Staindale Beck, analysis was performed on the annual maximum series of two Environment Agency gauges, L2725 of Thornton le Dale, of which Staindale Beck is a tributary, and F25110 of an adjacent catchment to the study area. Both gauges have 15-minute resolution level measurements, and F25110 has discharge available, however there is low confidence when stage is >0.4 m due to the unconstrained channel (Hydrology NE Environment Agency, 2024). Flow frequency analysis was performed by 1) fitting the General Extreme Value Distribution to the annual maximum series to L2725 and F25110; 2) comparing the median normalised percentage exceedance curves for the study time period; and 3) performing cross-correlation comparisons between recorded level data at the most upstream logger (herein L590).

*Table 1: Monitoring gauges used for analysis. †Environment Agency, *this study. Grid references shown are in British National Grid (EPSG:27700).*

Gauge ID	Location	Upstream area	Grid Reference	Start of record	Record length (years)
L2725†	Thornton Beck at Thornton le Dale	33.3 km^2	SE 83681 83418	19/02/08	16
F25110†	Levisham Beck at Levisham Mill	12.0 km^2	SE 83532 90119	01/07/03	21
L590	Staindale Beck	11.1 km^2	SE 85930 89451	18/02/20	2.5

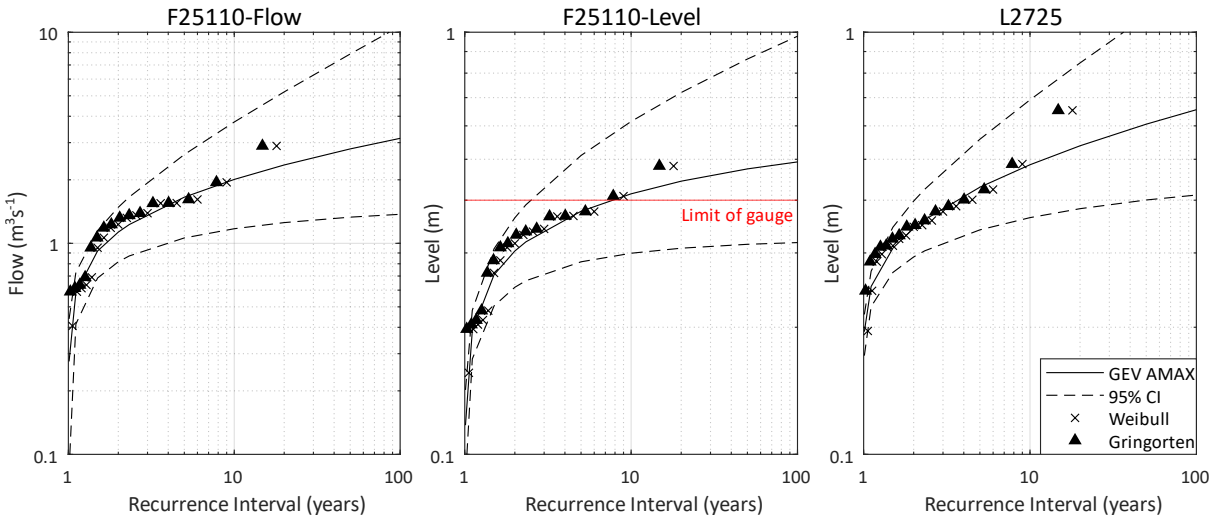
Catchments used for flow frequency analysis are shown in Supplementary Figure 1 and summarised here. The catchment draining L2725 has 62 km of river network, mostly comprised of first-order streams after the Strahler (1957) stream order notation and has an elevation range of 35–276 mAOD (metres Above Ordnance Datum). It is dominated by coniferous woodland (58%) and improved grassland (20%). The study catchment draining into L590 is a subset of L2725, with 20.3 km of river network, an elevation range of 105–276 mAOD, and is also dominated by coniferous woodland (69%) and improved grassland (15%). The adjacent catchment to the east, F25110, has 22.6 km of river network and is predominantly improved grassland (42%) and heathers (33%) with an elevation range of 73–289 mAOD.



Supplementary Figure 1: A) OS Terrain 5 elevation (Ordnance Survey, 2020) and stream network (white) of the study area delineated by catchments including the study area (1), the area upstream of F21550 (2) and upstream of L2725 (3). B) 25 m Land Cover Map for the area of interest (Morton et al., 2021).

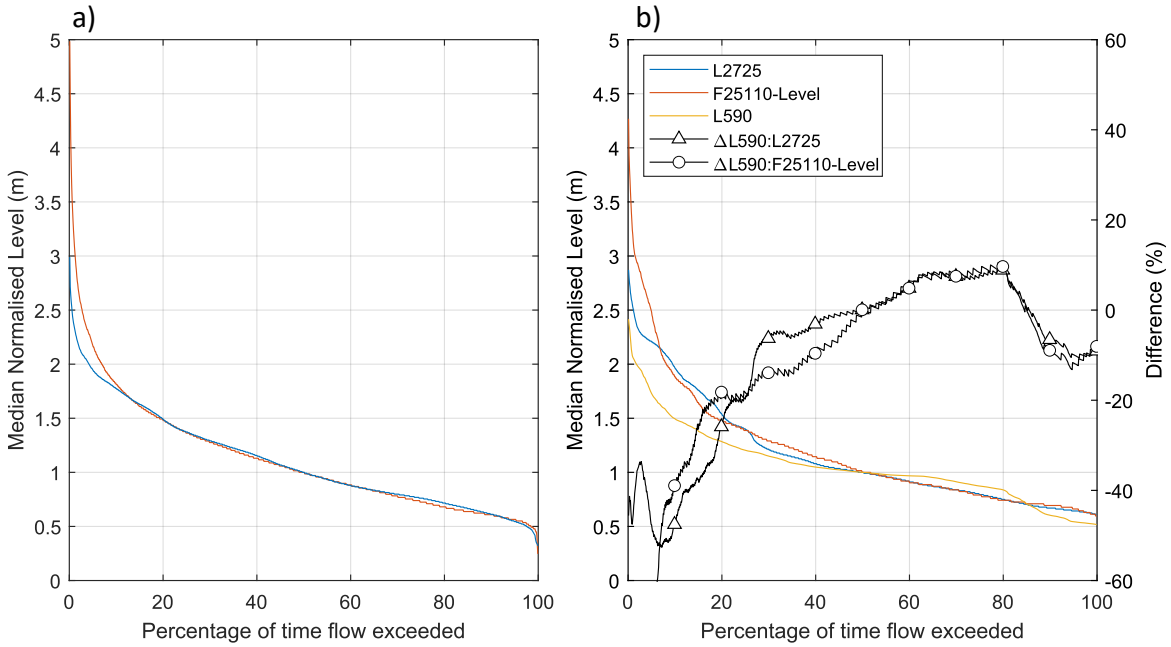
Results

Annual maximums for calendar years were extracted from the full time series for analysis. Extreme values for F25110 that were greater than the confidence limit for the site (0.4 m) were removed except for two readings (0.4820 m [2023] and 0.4090 m [2012]) to attempt to constrain substantial flow events. The data was fit to the Generalized Extreme Value Distribution in MATLAB with a 95% confidence interval to produce a rating curve (Supplementary Figure 2). The majority of annual maximum flows and levels—plotted using both Weibull (1939)and Gringorten (1963) plotting distribution methods—were within the 95% confidence limits.



Supplementary Figure 2: Graphical frequency analysis for Environment Agency data fit to the Generalized Extreme Value Distribution. Also shown are the Weibull and Gringorten plotting positions.

To directly compare the level gauge data the full dataset was median normalised (Supplementary Figure 3a). There is good agreement for 90% of the flow time, however F25110-level is elevated for the 0–10% of flows, suggesting a flashier response than L2725. For comparison to the most upstream levelogger installed at site 2, the full dataset was sampled to the monitoring period (18/02/2020–11/08/2022), and the logger retimed to match the gauges (15-minute resolution). The logger installed as part of this study most closely matches that of L2725, however shows a similar agreement to F25110-level also for 90% of flows (Supplementary Figure 3b). Elevated values for F25110-level and L2725 at exceedances > 0.85 suggest greater storage in the catchments, which was expected as it's a larger catchment fed by other streams, many of which are supported by a chalk aquifer. Elevated values for F25110-level and L2725 at exceedances <0.5 suggest that there are more frequent mid- to upper-range events, which is surprising given their proximity, however, may be explained by differences in dominant land cover (forest vs grassland) and basin morphometry. Elevated values at the 0-0.1 exceedances suggest that F25110-level and L2725 are flashier than the study site.



Supplementary Figure 3: Median normalised level (a) and a subset of covering the study period (b). The most upstream site levelogger (L590) is also shown, with the percentage difference when compared to L2725 and F25110-level.

The subsampled hydrographs were cross correlated to L590 whilst varying the lag period to assess quantify their agreement through time. L2725 had a maximum correlation of 0.942 with a lag range of –15–45 minutes whilst F25110-level had a slightly higher correlation with a maximum of 0.962 when the lag was 30–60 minutes.

Overall, there is a good agreement between the hydrographs for the different logger sites therefore, in lieu of any other flow data, the rating curve extrapolated from L2725 and F21150 was applied to L590 to estimate the rarity of events during the monitoring period as discussed in the main text of the manuscript.

References

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