

Investigating the hydrogeological controls of a reconnected ephemeral stream's flow regime on an alluvial fan in an ecologically important setting

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Background and introduction

- Ennerdale, NW England.
- High rainfall, temperate climate (2000 mm/y⁻¹, PET 450 mm/y⁻¹).
- River Ehen hosts largest remaining freshwater mussel (FWM) population in England.
- Population decline gave the emphasis for conservation measures.
- Upper River Ehen flows out of Ennerdale Water, a natural lake raised by a 1.3 m weir.
- An ephemeral tributary Ben Gill was reconnected across the alluvial fan to the River Ehen in 2014 after having being diverted into the lake in 1971 (Fig.1).
- This reconnected the sediment and water supply to the river (Fig.2) with the aim to break-up the armoured riverbed & improve habitat for FWM and Salmon.

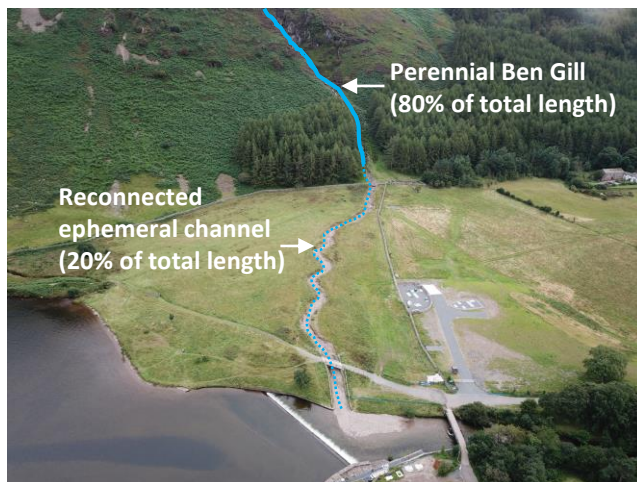


Fig. 1: Aerial view of Ben Gill channel cutting across the alluvial fan entering the River Ehen just downstream of Ennerdale Water.

Aim

- To understand the hydrological functioning of the reconnected tributary and its importance as a source of sediment and water for the upper River Ehen.

Objectives

- Understand the factors influencing the hydrological regime of Ben Gill and develop a predictive understanding on whether its flowing or not.
- Monitor geomorphic evolution of the reconnected Ben Gill (erosion, deposition, sediment yields etc).
- Assess the influence of sediment supplied by Ben Gill on the fluvial dynamics of the upper River Ehen.

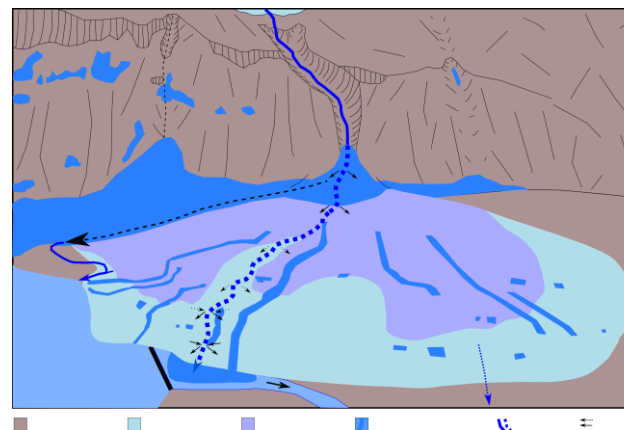


Fig. 2: Ben Gill-River Ehen confluence gravel bar in 2019. Arrows = flow directions.

Methods & data collection

- Geophysical investigations of alluvial fan sedimentology across which ephemeral Ben Gill flows: Used electrical resistivity tomography (2.14 km (Fig.3)), ground penetrating radar (4.11 km) sediment cores and outcrops.
- Hydrological monitoring of Ben Gill ephemeral flows, discharge and rainfall.
- Hydrogeological monitoring of the alluvial fan aquifer from five piezometers and slug tests.
- Developed a conceptual model of the alluvial fan aquifer (Fig.4).
- Drone flights, SfM photogrammetry, difference of DEMs: Assessed erosion and deposition in the ephemeral channel.
- Fine & coarse sediment sampling of the Ehen riverbed.
- Monitoring River Ehen suspended sediment concentrations.
- ADCP surveys of riverbed topography & flow velocities.

Fig.4: Conceptual hydrogeological model of the alluvial fan. Brown = aquitard, light blue = low productivity, purple = moderate productivity, blue = high productivity. Ben Gill channel also depicted.



Results

- Alluvial fan is composed of coarse, permeable debris flow and palaeochannel deposits forming a shallow, productive aquifer.
- Fan apex Infiltration rates and the discharge entering the fan apex strongly control the flow regime of the ephemeral channel.
- Flows typically occur when discharge entering the fan apex exceeds 60 l/s, typically following >9-11 mm rainfall events (Fig.5).
- See published paper (Blackburn *et.al.* 2021) for details (Fig.6).

- Ben Gill channel geomorphology is highly active (frequent erosion/scour, deposition) though it is gradually stabilising.
- Initially high volumes of fine sediment entering the River Ehen following the reconnection are now decreasing (Figs.7 & 8).
- Slight overall GSD coarsening with the development of gravel bars in the upper River Ehen (Fig.2).

Further work

- Numerical modelling of alluvial fan aquifer to predict the timing and magnitude of future ephemeral flows.
- Model future geomorphological changes within Ben Gill (erosion/deposition).
- Continue to monitor geomorphic adjustments in the River Ehen.

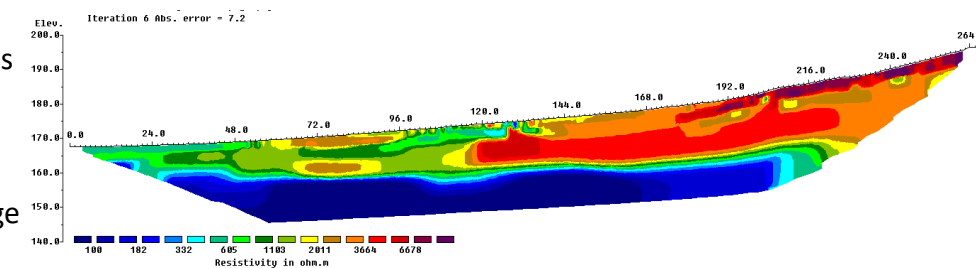


Fig. 3: Geophysical investigations: 260 m ERT profile from the alluvial fan edge (left), up to the fan apex (right). Fan sediments = green-red, underlying clay till = blue.

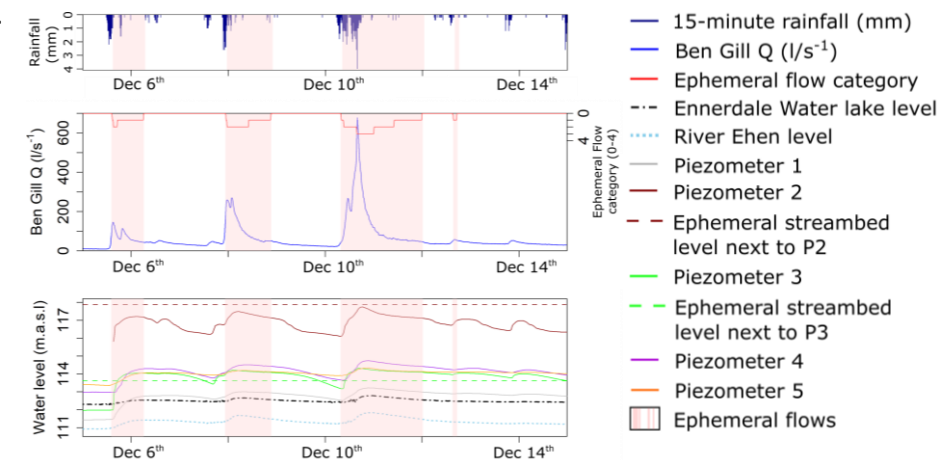


Fig. 5: Hydrological data incorporating a series of ephemeral flows in December 2019 showing piezometric, river and lake responses to rainfall.



Research papers

Hydrogeological controls on the flow regime of an ephemeral temperate stream flowing across an alluvial fan

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Fig. 6: Recently published article in the Journal Of Hydrology.



Fig. 7: Ephemeral flows of similar magnitudes in 2016 (left) and 2019 (right). Note the decrease in the suspended sediment load during the 2019 flow.

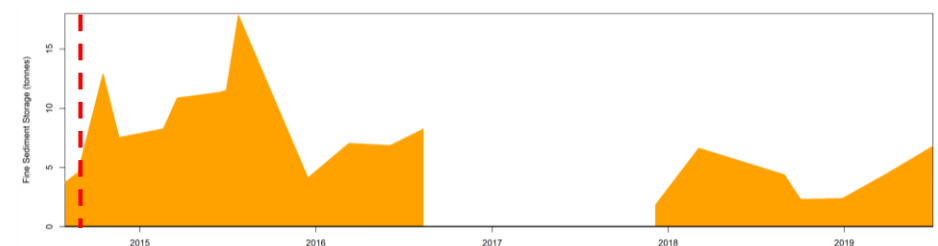


Fig. 8: River Ehen fine sediment bed storage 2014-2020. Red line = reconnection.