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Effective and sustainable river restoration: 4D monitoring of a large upland gravel-bed river

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Naturally functioning gravel-bed rivers are dynamic, highly biodiverse, well connected to their floodplains. They provide valued services to mitigate downstream flood wave propagation and storage of supplied sediment. Human-altered environments, whether urban, agricultural or otherwise, have severely degraded channel form and function and have all but destroyed natural fluvial processes. They have been trained, straightened and dredged, with embankments further restricting flood waters, and management maintains the status-quo. These interventions have often resulted in an armoured plain river bed devoid of physical complexity to support stream metabolism, ecosystem productivity and biochemical function. Effective and sustainable river restoration; primarily through the structural alteration of channel form, requires an advanced mechanistic understanding of how flow and sediment transport regimes affect biota and ecosystem processes. Here we critically examine the 2021 restoration of Goldrill Beck, Cumbria, UK, using repeat drone based orthophotography and DTM outputs to quantify system response. Coupled with HEC-RAS 2D modelling we provide an insight into different river controls on the composition, structure, and dynamics of flow, sediment dynamics, habitat; and system resilience to a geomorphologically effective flood events. The recorded changes are used to critically assess current approaches to river restoration and we suggest that a process-based approach to river restoration utilising improved scientific understanding of natural flood functioning and sediment dynamics is needed to address the challenges for ecosystem management that lie ahead.