Natural Sediment Management (NSM): the most important component of Natural Flood Management (NFM)

Gestion des sédiments naturels (NSM) : la composante la plus importante de la gestion des inondations naturelles (NFM)

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RÉSUMÉ

Le transport et les dépôts de charriage provoqués par les crues peuvent avoir un impact sévère sur le risque d'inondation et des études ont montré que la sédimentation provoquée par les crues peut influencer les inondations locales dans une plus grande mesure que le changement climatique. Ce type de sédimentation a été exacerbé par l'ingénierie fluviale historique et contemporaine. Le matériau du lit mobilisé passe généralement le long de sections canalisées s'accumulant dans des zones à plus faible énergie en aval, augmentant potentiellement le risque local d'inondation dans les zones urbaines. Cet article résume l'étendue du problème en Cumbria au Royaume-Uni et illustre, à l'aide de Lidar répétés, comment la perte de stockage de sédiments fonctionnels dans le bassin versant supérieur exacerbe la livraison de sédiments grossiers vers les zones urbaines en aval. La perte des magasins de fans affluents et des réseaux de canaux errants est particulièrement importante à cet égard. Les résultats généralisés suggèrent que la naturalisation des systèmes canalisés au-dessus des zones urbaines vulnérables aux inondations peut avoir un impact très important sur l'atténuation des inondations en plus d'améliorer l'intégrité écologique et la biodiversité du fond des vallées.

ABSTRACT

Flood driven bedload transport and deposition can have a severe impact on flood risk and studies have shown that flood driven sedimentation can influence local flooding to a greater extent than climate change. This type of sedimentation has been exacerbated by historic and contemporary river engineering. Mobilised bed material generally passes along channelised sections accumulating in lower energy reaches downstream potentially increasing local flood risk in urban areas. This paper summarises the extent of the issue in Cumbria in the UK and illustrates, using repeat Lidar, how the loss of functional sediment stores in the upper catchment is exacerbating coarse sediment delivery to urban areas downstream. The loss of tributary fan stores and wandering channel networks is particularly important in this respect. The generalised findings suggest that naturalisation of channelised systems above flood vulnerable urban areas can have a very significant impact on flood mitigation in addition to enhancing valley bottom ecological integrity and biodiversity.

KEYWORDS

Natural Sediment Management, Natural Flood Management, Flooding, Dredging, Lidar.

1. CONTENT

Flood driven bedload transport and deposition can have a severe impact on infrastructure and flood risk following extreme events, especially in upland settings and studies have shown that flood driven sedimentation can potentially influence local flooding locally to a greater extent than climate change. This type of sedimentation has been exacerbated by channelisation which has been shown to increase water velocity and flood conveyance locally, increasing stream power and promoting incision and bed armouring. Mobilized bed material generally passes along channelised sections accumulating in lower energy reaches downstream increasing local flood risk. The result of this is that coarse sediment is routinely removed from urban channels following flooding to re-establish channel capacity and flood protection levels, and to mitigate against local erosion.

Although knowledge of sediment transport has improved over the last 25 years, our understanding of bedload transfer and sediment delivery is still based on a limited set of observations or on models that make assumptions on hydraulic and sediment transport processes. Repeat aerial Lidar survey data of the watercourses of the Cumbrian Lake District, UK have shown that the sediment storage dynamics have been altered significantly from natural. Coarse sediment delivery processes remain relatively unaffected and continue to operate at a low level consistent with a temperate upland flow regime and this material is delivered through to larger watercourses downstream. Many of these systems flow across flatter valley floor areas formed principally by glacial and fluvio-glacial deposition with large upland floodplain sediment stores associated with areas upstream from valley constrictions and moraine deposits. Under natural conditions tributary systems would have formed extensive valley margin fans splaying mixed sediment across the valley bottom and these features remain as significant geomorphic units in many valleys. However, historic engineering and management has denatured these systems with tributaries rationalised into straightened and often embanked single thread channels across the valley bottom. Some are also culverted and others are further rationalised into a single artificial channel flowing along the valley margin capturing inputs from several tributaries in order to better manage the valley bottom for agriculture. Quantification of the degree of alteration reveals that these practices are ubiquitous and the impact on the volumes of sediment delivered to receiving channels is severe with almost no functional valley fans observed across the whole of Cumbria.

The form and function of the main channel systems in Cumbria has also been significantly altered over time with widespread channel straightening, dredging, embanking and revetting creating simple conduits for flow. The impact on coarse sediment dynamics is significant, with an audit of a number of main channels revealing a paucity of sedimentary features with the channels exhibiting a plane bed configuration most often with armouring. This has occurred due to the altered flood hydraulics along these channels with steepened, over-deep, narrow fixed channels retaining flood water that would naturally dissipate across the valley floor. The resultant enhanced flood energy generally moves all supplied sediment downstream restricting dynamic sediment accumulation to occasional often ephemeral waning flood bars. Overbank deposition is also almost completely absent with embankments cutting off another key coarse sediment store in the upper catchment.

These changes to the coarse sediment regime are clearly illustrated on the River Caldew above the City of Carlisle where the balance of erosion and deposition is clearly influenced by channelization with very restricted overbank sedimentation and only limited local and transient in-channel bar deposition recorded over an 11-year study period encompassing four events greater than bankfull. This contrasts with the behaviour of a long naturalising reach just above Carlisle where a developing wandering channel system is acting to store coarse sediment in-stream as large bar complexes and the overbank as splay deposits associated with a well-connected floodplain. Such behaviour is significant with regard to reducing downstream flood risk with less coarse sediment flux occurring through to vulnerable reaches in Carlisle and suggests that naturalisation of channelised systems above flood vulnerable urban areas can have a very significant impact on flood mitigation.

Overall the impact of the loss of multiple sediment storage areas in catchments in Cumbria is leading to an over-supply of material through to urban areas downstream and current management practices persist in maintaining this status-quo protecting low grade pastoral farmland to the detriment of urban areas downstream. It is essential that this approach to management ceases and river and valley bottom functionality is restored. In this way natural processes can be used to increase flood resilience downstream with natural sediment storage zones acting to mitigate against excessive coarse sediment fluxes downstream. Naturalisation will also result in self-sustaining fluvial systems exhibiting a dynamism currently not seen in the managed and constrained systems currently present with obvious

consequent benefits to biodiversity. Recent innovative approaches involving targeted low impact approaches to river naturalisation on systems including Grisedale Beck and Goldrill Beck above Patterdale, Trout Beck at Flakebridge and Swindale Beck above Shap, (all within Cumbria, UK) are all demonstrating the positive economic, social and environmental benefits of restoring natural river and valley bottom system functioning and these exemplar projects should form the basis of a new approach to river restoration and associated land management into the future.