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An underutilized resource: historical flood chronologies a valuable resource in determining periods of hydro-geomorphic change

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Abstract Floods are recognized as important geomorphic drivers within the hydrological system, but short hydrological records can inhibit the application of hydrological data in determining periods of hydrologically driven geomorphic change. This paper details the construction of a series of historical flood chronologies, based on some of the largest catchments within the UK. Flood chronologies have been constructed for eight large UK rivers; the selected sites provide a network covering many of the largest river catchments in the UK centred on cities and towns with long detailed documentary flood histories. These chronologies offer an opportunity to assess the long-term patterns of flooding, indirectly determining likely periods of increased geomorphic activity. This research represents the first coherent large-scale analysis undertaken of historical multi-catchment flood chronologies, providing an unparalleled network of sites across the country, permitting analysis of the spatial and temporal distribution of historical flood patterns on a national scale.

Key words catchments; flood chronology; frequency; historical; national; UK

INTRODUCTION

Historical flood chronologies are increasingly recognized as a valuable source of information relating to high magnitude flood events, which are inherently poorly reflected in current instrumental records. The collection and application of historical flood records has increased dramatically in recent years, reflecting the acceptance and even expectance of historical flood records within high magnitude flood frequency analysis (NERC, 1999; Black & Burns, 2002; Williams & Archer, 2002; Macdonald *et al*., 2003). The rise in historical flood record application has uncovered large amounts of additional material documenting historical floods. Much of this material has been transferred onto the British Hydrological Society's *Chronology of British Hydrological Events* (Black & Law, 2004), a database now containing an extensive list of source materials and references to historical floods in UK river catchments, improving the speed and effectiveness of historical flood chronology construction.

This paper represents the first step in an ongoing project to construct a national record of historical flooding in the UK. The current distribution of historical flood chronologies reflects areas of severe recent flooding (since 1990), with much of the current work focussing on central and northern England (Fig. 1). Continuing research is currently expanding this database to include additional catchments in areas currently underrepresented.

Fig. 1 National map identifying the catchments for which historical flood chronologies have been constructed and are considered within this paper.

HISTORICAL FLOOD RECORDS

Historical flood records represent an opportunity for the extension of river flow records, a valuable opportunity considering average gauging station record length is ~25 years (Marsh & Lees, 2003), with only a handful of stations extending back to the 19th century. Documentary accounts of flooding can be found in numerous forms, either directly or indirectly chronicling historic floods. Often the largest floods had dramatic consequences to the local indigenous populations (Mudelsee *et al.*, 2004a). This is often reflected in the oldest documented floods as they caused damage to towns or city defences, such as the flood of 1210 in Perth, which caused the partial collapse of the castle and subsequent death of the King's son (Macdonald *et al.*, 2006). The records considered in this paper focus on documentary sources, including epigraphic (level) markings and flood stones. The identification of source materials is an important consideration when constructing historical flood chronologies. They are by their very nature often reflective of the presence of literate individuals, and hence most sites with long records are urban centres, reflecting the presence of monastic or governmental centres. The selection of sites therefore inevitably focuses on historic urban cities and towns, but this must be tempered with an understanding of past anthropogenically influenced hydrological system changes within the catchment. Recent accounts (1750–) include greater detail, providing levels or even estimated discharges of river flow. The historical floods have been estimated based on the levels or descriptions present within the records; the exact estimate of flow is indicative, with greater confidence being placed on the ranking within the flood record. The instrumental (gauged or stageboard) records are also included to provide a complete ranking of the largest events. The use of indicative discharges at high flows is appropriate, as often gauging of contemporary high flows is still inexact due to a variety of factors (Macdonald, 2004). The ranking of the historical floods will permit the analysis of the flood frequency in later stages of this research.

Site selection

Site selection was based initially on areas that have suffered severe recent flooding and which contain detailed historical flood information coupled with reasonable instrumental records. The location of the sites in many cases reflects the areas with the greatest quantity of available historical hydrological information. Each site has had some anthropogenic interference to the natural hydrological regime of the catchment over the assessed period. As a result, a brief review of each of the sites analysed is undertaken within the paper to clearly indicate some of the factors that require consideration prior to historical flood analysis and augmentation.

Within the River Tay catchment urban development has been minimal. Land use has changed considerably with much of the catchment now under pastoral or rough grazing. The construction of hydroelectric dams in the mid-20th century has resulted in approx. 11% of the upper catchment receiving river flow regulation, which has reduced peak river flows during flood events. The River Tyne also has approx. 11% of its upper catchment managed by the hydroelectric system at Kielder water; significant gravel extraction in the mid-twentieth century has dropped the river bed level by up to 3 m. This has had a significant impact on attempting to assess the magnitude of the older floods on the Tyne, but fortunately detailed records exist, coupled with an extensive series of flood marks and contemporaneous estimates of river flow for some historical floods. The River Ouse at York has one of the longest river level records in the UK dating from 1877. The record is from a relatively stable section of the channel through the city centre, where little extra development has been undertaken within the channel since the record began. Upstream of York relatively little urban development has occurred. Changes in farming practices and mining in the upper tributaries may have modified the hydrology of the catchment, although the extent of this is uncertain (Longfield & Macklin, 1999). Numerous changes have occurred within the River Trent over the period considered, with gravel extraction, flood management, channelization and urban development all occurring; these will have influenced the catchment hydrology, particularly during smaller floods, but their impact during rare high magnitude events is less certain. The River Dee at Chester has undergone dredging and gravel extraction, the strongest control on the river flow is the management of Lake Bala (upper catchment) where the lake outflow has long been managed for both power and as a source of drinking water (mid-18th century); there has been relatively little urban expansion within the upper catchment. The River Severn has received extensive river management in the past. As a result the assessed section is based in the upper to middle reach of the catchment where development has been less extensive than further downstream. River resource management (reservoirs) within the upper catchment has led to greater modification of low flows than during high magnitude events. The River Ouse (Sussex, Lewes) is the smallest of the catchments considered, but has experienced the most extensive urban development and hydrological management.

RESULTS AND DISCUSSION

A visual inspection of the flood records from the different sites identifies no single discernible period of flooding for all the catchments (Fig. 2). This may suggest that changes in flood frequency/magnitude are more subtle, reflecting gradual changes in climate. The discernment of a single generating mechanism is difficult, as principal flood generating mechanisms may change over time in response to climatic or land use variations. Within this paper, catchment stationarity is assumed (except where knowledge of considerable catchment change permits amelioration of the data inclusion). The assumption permits the analysis of the data over the complete period, though as Parent & Bernier (2003) recognized, greater certainty can be placed in contemporaneous data, which they defined as post-1770 for the Garrone catchment, France. It is unlikely that small changes within the catchments will have considerable implications for the largest floods (Macdonald, 2004). The lack of flood records for a given year does not necessarily signify that a flood did not occur, but that it was simply not recorded. However, it is likely that the largest events have been recorded, particularly since approx. 1750, as record density improves and becomes more systematic.

Although not reflected in the records presented, there are noticeable variations in flood seasonality. Older records contain a higher density of snowmelt driven floods for many of the catchments, particularly in the 18th century; not all of these events can be attributed estimated magnitudes and therefore are not included within the analysis. The increase in high magnitude floods in central and southern Europe around 1700, which has been linked to the cold and dry climate of the Late Maunder Minimum (1675–1720) (Mundelsee *et al*., 2004b) are not represented within the UK rivers. Abrupt changes in the historical flood record may reflect wider climatic variability permitting an abstract assessment of regional palaeoclimatic change (Mundelsee *et al*., 2004a; Macklin *et al*., 2005).

A visual assessment of the flood chronologies suggests no single period of increased flooding across all catchments. Within the different catchments there are periods of increased flood frequency. The period 1570–1625 on the River Tay consists of several high magnitude events. No known explanation can be given that could attribute this to anthropogenic influences, suggesting a change in the regional climate and subsequent flood generating mechanisms. The notable difference in relative

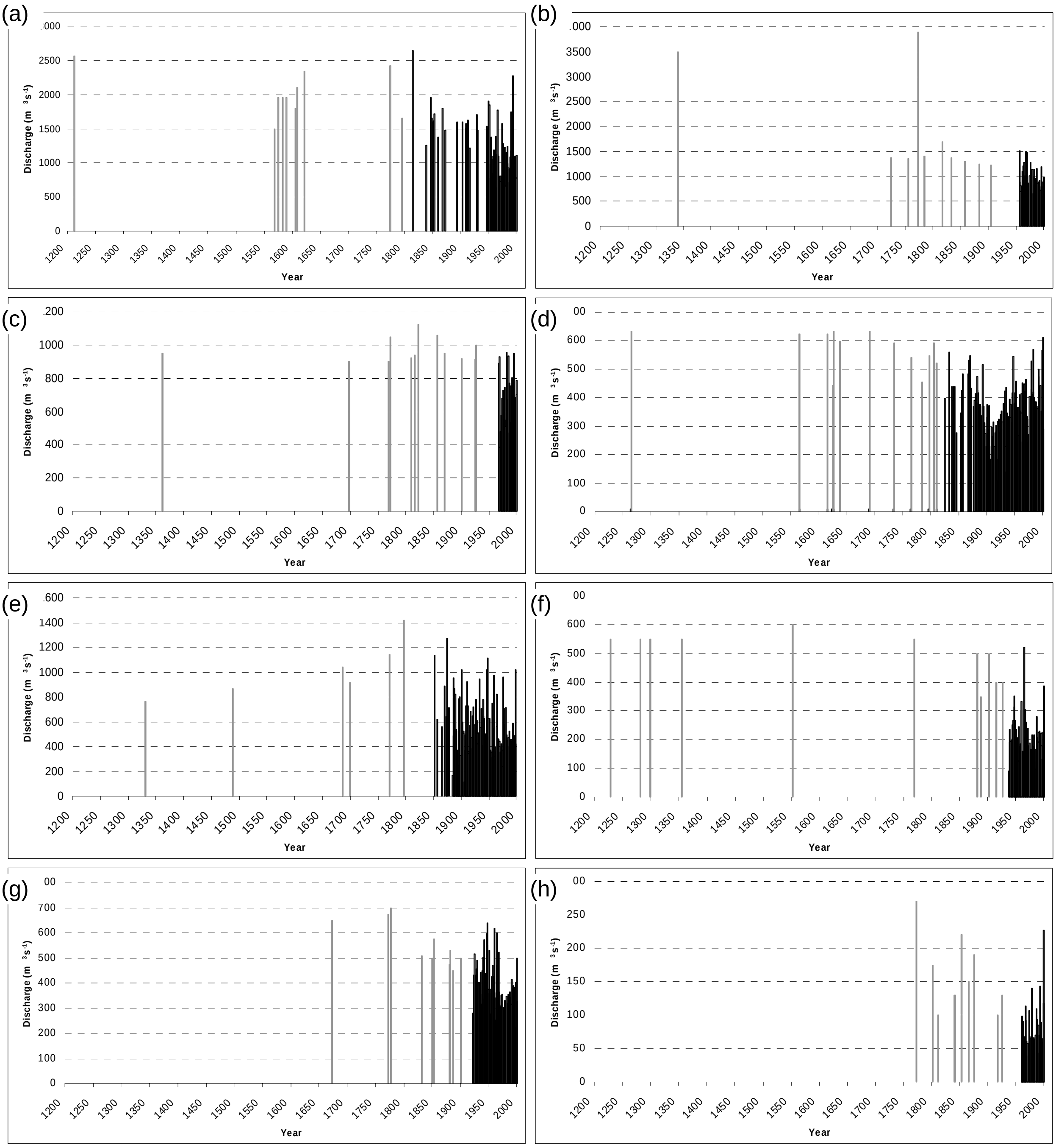

Fig. 2 (a)–(h), Historical flood chronologies for the Rivers Tay, Tyne, Eden, Ouse (Yorkshire), Trent, Dee (Cheshire), Severn and Ouse (Sussex), respectively. The solid black indicates instrumental (gauged or stageboard) records, whilst the grey represents estimated flood magnitudes based on historical accounts or/and markings (epigraphic and flood stones).

latitude and catchment relief (potential for snow-pack accumulation) compared to the other sites may support this theory. Within the River Ouse catchment (Yorkshire) a similar pattern of flooding occurs around 1625 but to a lesser degree, with four notable events occurring within several years. The periods of apparent increased flooding on the Rivers Tay and Yorkshire Ouse (Fig. 2(a),(d)) during the late 16th and early 17th century are also prevalent in southern and central Europe (Bradzil *et al.*, 1999). The absence of records from other catchments for this period may reflect a lack of flood recording rather than non-occurrence.

Most of the sites indicate that flood frequency increased in the early 19th century (Fig. 2(a)–(e), (h)), the strongest signals being from the Rivers Eden, Yorkshire Ouse and Severn. In the Rivers Ouse (Yorkshire) and Severn this appears to be centralized around 1750, a period climatically considered to include some of the sharpest phases of development in the "Little Ice Age" (Lamb, 1995).

The apparent increase in flooding witnessed since 2000 within the UK appears, on consideration of the long-term flood record, to be unexceptional, the period between 1960 and 2000 being considered as "flood poor". The apparent change in flood frequency since 2000 may reflect natural variability, as there appears to be no significant shift in long-term flood frequency, a view supported by Mundelsee *et al*. (2004b).

CONCLUSIONS

The results from the eight sites considered show no single pattern of historical flooding, though this study has shown that single, high magnitude floods transcend catchment boundaries, e.g. in 1771 on the Rivers Tyne and Eden and in 1795 on the Rivers Severn and Trent.

The apparent period of intense flooding in the River Tay around 1600 is not present in other records, though a period of flooding occurs on the River Ouse (Yorkshire) around 1625; this may reflect a period of increased flooding nationally with an absence of records at other sites, or it may be a reflection of different flood generating mechanisms within Scotland and northern England compared to other regions of the UK. Additional studies of Scottish rivers should clarify this. The flood frequency signals from sites (b)–(h) appear more diluted; in some catchments visual periods of greater activity can be determined, particularly around 1800–1880. Further analysis and data collection should improve current flood records. The chronologies permit additional understanding of the long term patterns of flood frequency/magnitude within these catchments, episodes that may also reflect periods of extensive hydro-geomorphic change.

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