ALLUVIAL ANASTOMOSED CHANNELS: THE PREFERRED CHANNEL TYPE ON ACTIVE UK RIVERS

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Anastomosing rivers constitute an important category of multi-channel rivers and are characterised by multiple, interconnected, coexisting channels flowing over alluvial plains. They commonly form by avulsion processes, causing the formation of new channels on the floodplain; a process primarily driven by loss of channel capacity and flow breakout linked to local in-channel deposition. This style of channel is presently rare in the UK primarily due to historic channel and floodplain engineering and management. This study examines the character of developing anastomosed channels seen on a number of active gravel-bed channels in the north of England using aerial imagery and metre scale resolution aerial LIDAR data. Aerial imagery of the study sites indicate progressive development of a well-developed wooded valley floor associated with lateral bar extension and succession across stable isolated bar units. The LIDAR data are used to create detailed digital terrain models (DEMs) of the study reaches accurately representing sub-channel planform and morphology. Topographic metrics suggest well-developed underlying morphological features, dominated by an interlinked channel network split by variable length, generally low elevation interfluves and variograms created for each site suggest a common topographic pattern associated with the study sites. The gross morphology does not reflect the classic anastomosed features described by previous research, suggesting that different processes are operating to create these channel types. It is suggested that the anastomosing networks have developed across systems that were initially active meandering and wandering in nature, evolving in line with floodplain vegetative succession to stabilise these planform types. These modes of formation suggest a different origin of these anastomosed sites compared with those previously reported with floodplain management playing a key role in system development.

1 BACKGROUND

Anabranching is the prevailing river pattern found along alluvial tracts of the world's largest rivers [1]. Anastomosing rivers represent a major group of rivers that exhibit a multi-thread channel network divided by stable islands often reported as being low energy and composed of fine cohesive sediment, and colonized with vegetation and wetlands. Major controversies still exits about their definition [2], and the causes of their existence [3]. Nanson and Knighton [4] suggests several types of anastomosing channel exist ranging from cohesive sediment channels through sand-dominated, island forming reaches, mixed load, laterally active channels, sand-dominated, ridge forming channel networks, gravel dominated, laterally active channels through to stable gravel dominated channel complexes. Importantly they highlight that higher energy gravel anastomosing systems can also exist, contrasting to most of the other examples reported in the literature.

Anastomosing rivers are rare in the UK today due to channel and floodplain management practices. However they once were common in major wetlands and valley floodplains, possibly in partly fossilised form in medieval times [5]. Most lowland medieval rivers were either inactively meandering or anastomosing [5]. Cartographical evidence from Tudor times exists [6, 7], with Lewin [5] suggesting the channel form had survived from the late medieval period. Speed's (1611–12) county maps and town plans, also show many anabranching rivers and reaches that can be related to Leland's earlier descriptions, to later maps, and to relict channels still visible in contemporary remote sensing imagery [5].

Despite this loss, many rivers in the UK are showing local tendencies to recreate a wooded active floodplain anastomosing channels. This study examines the character of developing anastomosed channels on rivers across England and Wales using aerial photography and metre scale resolution aerial LIDAR data, contrasting the gross morphology with that of wandering systems.

2 STUDY SITE

Stable multi-thread channel networks are rare in the UK with the majority of watercourses classified as low activity and inactive single thread systems with an intensely altered and managed valley bottom. Occasionally, however, where valley bottom management has been abandoned the river and floodplain have developed a characteristically wooded form obscuring the channel and floodplain morphology and making them difficult to interpret from aerial imagery. Field investigation of a number of these sites has revealed a diverse channel and floodplain morphology with strong lateral connectivity achieved by stable multiple sub-channels. This study investigated a total of ten wooded anastomosed reaches across England and Wales and three wandering channels (Figure 1). Their general characteristics are illustrated in Figure 2 and summarised in Table 1. The sites occur on coarse bed rivers and exhibit a wide range of channel gradients in line with the wider river type in which the anastomosing sections occur.

Figure 1. Anastomosed and wandering channel sites investigated.

Table 1. General characteristics of the anastomosed and wandering study sites

Site	Channel type	Elevation (m a.s.l.)	Reach slope	Bed material grade
River Severn at Welshpool	Anastomosed	61.28	0.0002	Cobble/gravel
River Wye at Whitney		65.46	0.0005	Gravel
River Lugg at Mordiford		41.54	0.0040	Gravel
Afon Vyrnwy at Llanymellych		61.03	0.001	Cobble/gravel
North Tyne at Tarset		232.77	0.0238	Cobble/gravel
River Wear at Wolsingham		141.11	0.0053	Gravel/cobble
South Tyne at Bellingham		108.19	0.0026	Cobble/gravel
River Irthing at Brampton		37.64	0.0027	Gravel/cobble
River Wye at Winforton		61.28	0.0002	Gravel
Lilburn Burn, Northumberland		61.74	0.0082	Gravel/cobble
River Seven at Refaill	Wandering	74.75	0.0022	Gravel/cobble
River Coquet at Rothbury		91.86	0.0028	Gravel/cobble
River Glen at Hedgeley		68.95	0.0028	Cobble/gravel

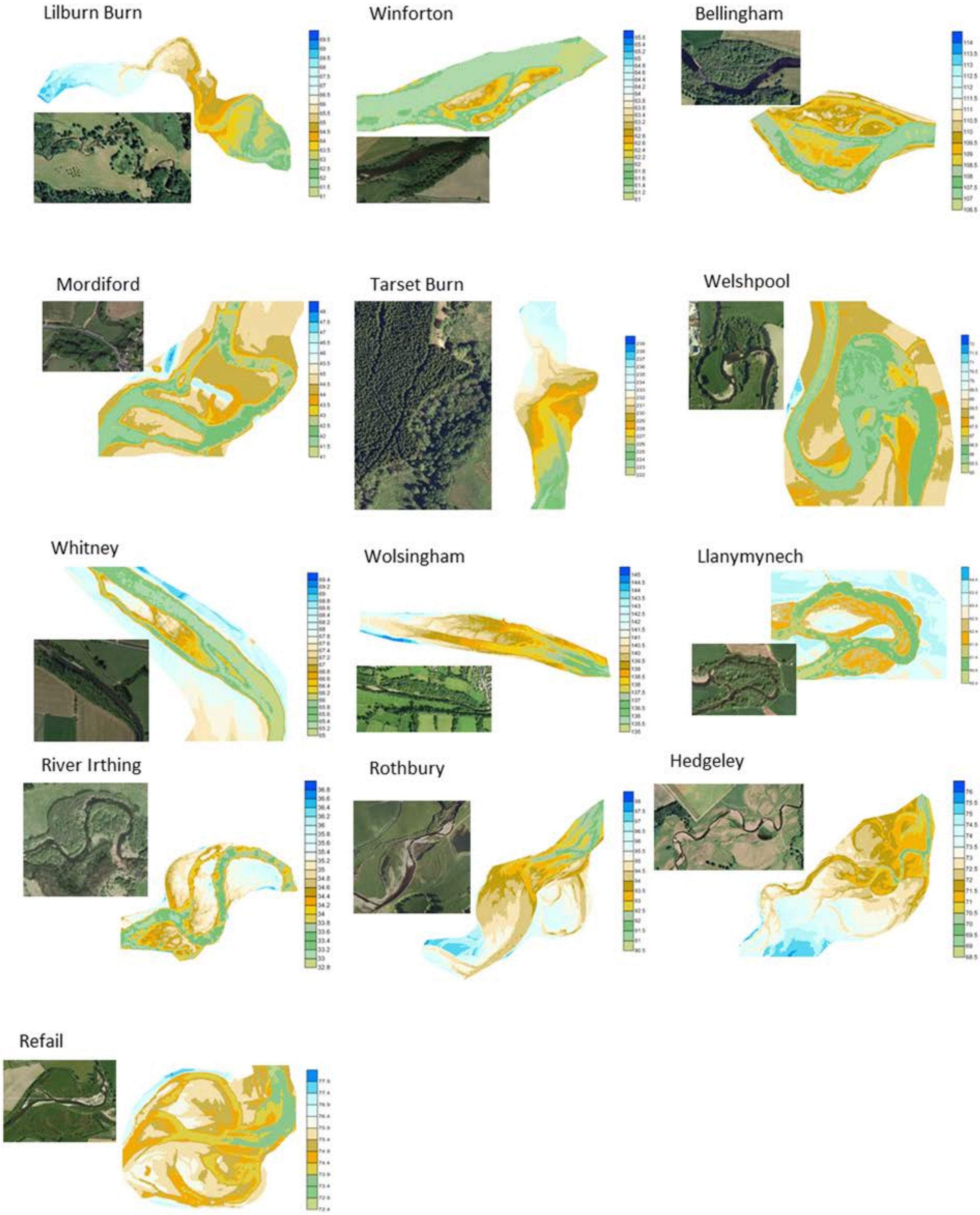

Figure 2. Anastomosed and wandering channel sites investigated (Aerial Image copyright GoogleEarth 2015).

2.1 Reach Scale Topographic Comparison

Bare earth aerial LIDAR data were obtained for each of the 13 study reaches from the UK Environment Agency open data archive. These data were meshed to create 1 m spatial resolution DEMs for each site. The data accurately records sub-channel planform and morphology allowing topographic metrics to be derived across the sites in the form of variograms characterising the variation in spatial roughness. Topographic variation is commonly due to processes operating at differing spatial scales in different directions (e.g. Webster and Oliver, [8]) and this may be represented in a variogram derived from topographic data contains a statistically-based, quantitative, description of a surface's roughness, characterising the spatial continuity or autocorrelation of the surface in space. Autocorrelation between two points suggest that there is an underlying spatial structure that links the locations suggesting coherent features across the landscape at the scale defined by the distance between the points. The degree of spatial autocorrelation is defined on the variogram as the point where the curve flattens off with the semi-variance value at this point representing the sill and the lag distance representing the range. Points on the surface separated by distances greater than the range are no longer autocorrelated [9]. The semi-variance at zero separation distance (the nugget) is a measure of unmeasured surface roughness at scales less than the sampling distance of the data.

Drift is common in elevation data [10, 11] especially along watercourses which exhibit a strong downstream gradient and this was removed from the data sets through linear detrending prior to variogram generation. The form of the variogram computed for the study sites and reflects the range and degree of auto-correlated topographic variabilities seen across each site (Figure 3). Valued for the range, sill and nugget for each site were computed by fitting a spherical model to each semi-variogram and these statistics are summarised in Table 2).

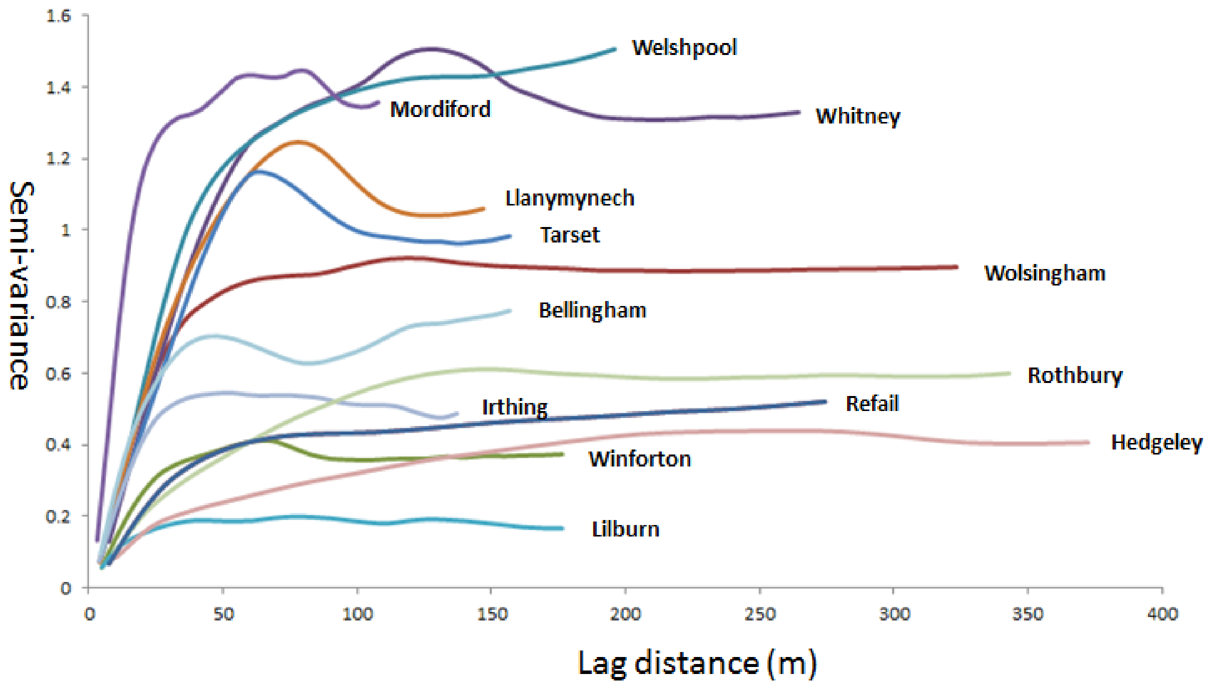

Figure 3. Variogram plots of the study sites.

Table 2. Semi-variogram range, sill and nugget parameters of the study sites

Site	Range	Sill	Nugget	Sill/Range
River Severn at Welshpool	0.054	45	1.250	0.028
River Wye at Whitney	0.114	80	1.400	0.018
River Lugg at Mordiford	0.010	40	1.400	0.035
Afon Vyrnwy at Llanymellych	0.830	80	1.200	0.015
North Tyne at Tarset	0.010	45	1.100	0.024
River Wear at Wolsingham	0.782	110	0.900	0.008
South Tyne at Bellingham	0.119	100	0.700	0.007
River Irthing at Brampton	0.010	20	0.130	0.007
River Wye at Winforton	0.003	100	0.380	0.004
Lilburn Burn, Northumberland	0.054	40	0.190	0.005
River Seven at Refaill	0.021	50	0.440	0.009
River Coquet at Rothbury	0.087	140	0.600	0.004
River Glen at Hedgeley	0.310	200	0.450	0.002

3 RESULTS AND DISCUSSION

The anastomosed reaches reviewed in this study range from low gradient low activity systems to upland gravel/cobble channels. Aerial LiDAR reveals a network of stable channels beneath the dense valley bottom woodland that has developed across the sites. Field visits further confirm that many of these channels are active during elevated flows (Figure 4). Despite the multi-thread nature of the channel network the sites do not conform with the general anastomosing group of rivers discussed in most of the literature (e.g. Makaske, [12]), that exhibit a multi-thread channel network divided by stable islands composed of fine cohesive sediment, characteristic of a low energy system.

Figure 4. Example valley floor morphology at the study sites.

Visual inspection of the morphology as defined by the LIDAR would suggest that many of these multi-channel networks share similarities with wandering and, active meandering channels with distinct patterns in the secondary channels reflecting the lateral channel dynamics of these systems. A sub-group is also present displaying secondary channel networks associated with lateral extensions of the main channel to form features similar to the meandering sites (Figure 5).

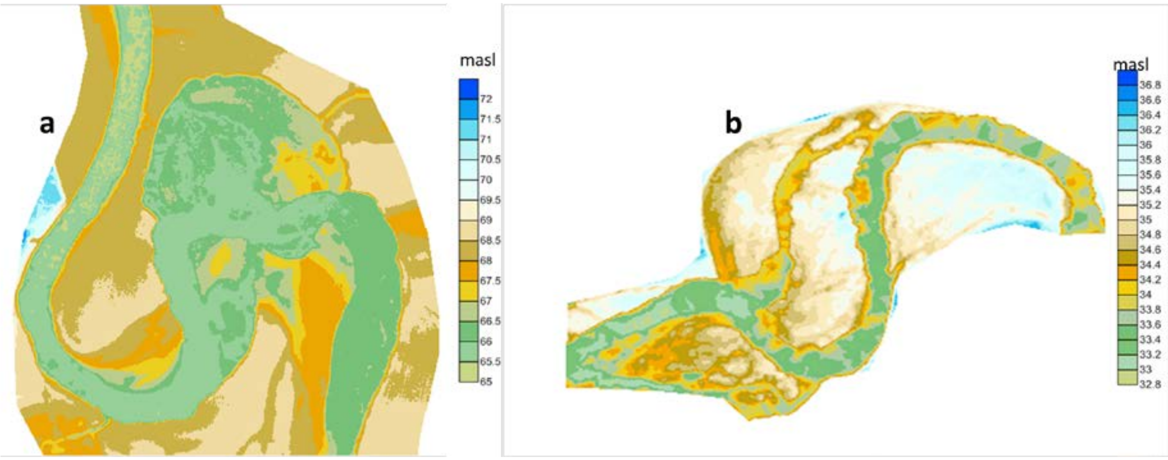

Figure 5. Example stable wooded anastomosed reaches displaying an (a) wandering and (b) active meandering underlying morphology

This differentiation is supported by a review of the variogram analysis which suggests that two broad groupings may be distinguished based on the degree of elevation variation present at the sites (Figure 6). The first group includes active channel widening and meandering morphology sites with the second group dominated by wooded zones associated with channel wandering. This broad division is also supported by a scale independent analysis of the variogram properties (Figure 7) looking at the ratio between auto correlated topographic variance (sill) and auto correlated distance (range). This again suggests that the Welshpool Mordiford and Tarset sites are topographically similar along with the Wye at Whitney, all of which have developed through lateral extension, with the remainder developing across a wandering topography.

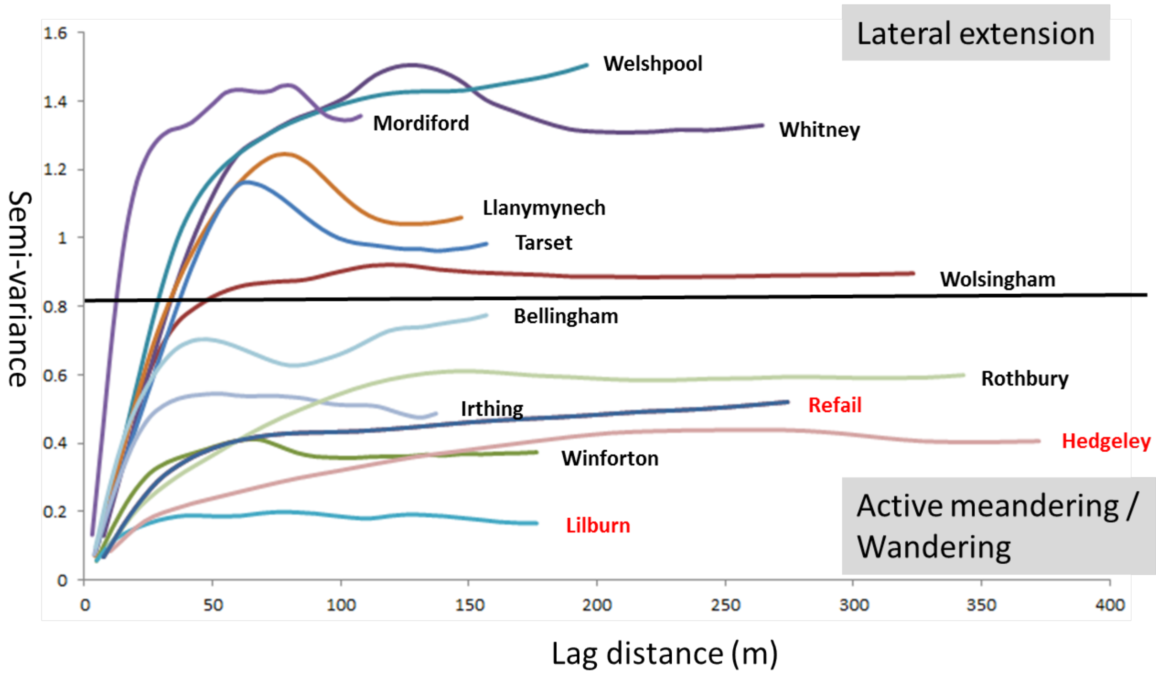

Figure 6. Process based differentiation of wooded anastomosed sites based on morphological similarity (red text represents contemporary wandering and active meandering channels).

It is suggested that wooded anastomosed channel types may form via two principal evolutionary pathways. The first is exhibited by the lateral development group of channels where sub-dominant channels are strongly associated with well-connected extensive lateral features associated with the main channel. The second route appears to be via chute and meander development and cut-off, with the gross morphology of the reaches displaying a clear sequence of channel movement and abandonment, similar to that seen across active meandering and wandering channel systems. These have developed on higher energy gravel dominated rivers and lower energy systems transporting finer sediment with the primary driver for stabilisation being floodplain management. Lateral activity remains high across wandering and active meandering channel types where woodland is prevented from developing due to intensive land use. Multi-channel planform stabilisation occurs where floodplains have been abandoned and woodland can evolve.

The results of this research are consistent with the findings of Carson [13] and Nanson and Knighton [4] who highlight that higher energy gravel anastomosing systems can exist. Similarly Church, [14], and Desloges and Church [15], describe relatively energetic wandering gravel-bed rivers transitional between meandering and braided systems. These often have a dominant channel much like the examples from the UK described in this paper and may alternate between multithread and single-thread reaches, again similar to the UK examples. Smith and Smith [16] have shown for three Canadian rivers that anastomosing reaches can grade into braided reaches, differentiated by more stable banks and finer sediments. We also show transition across sites between wooded anastomosed and higher activity unwooded wandering reaches.

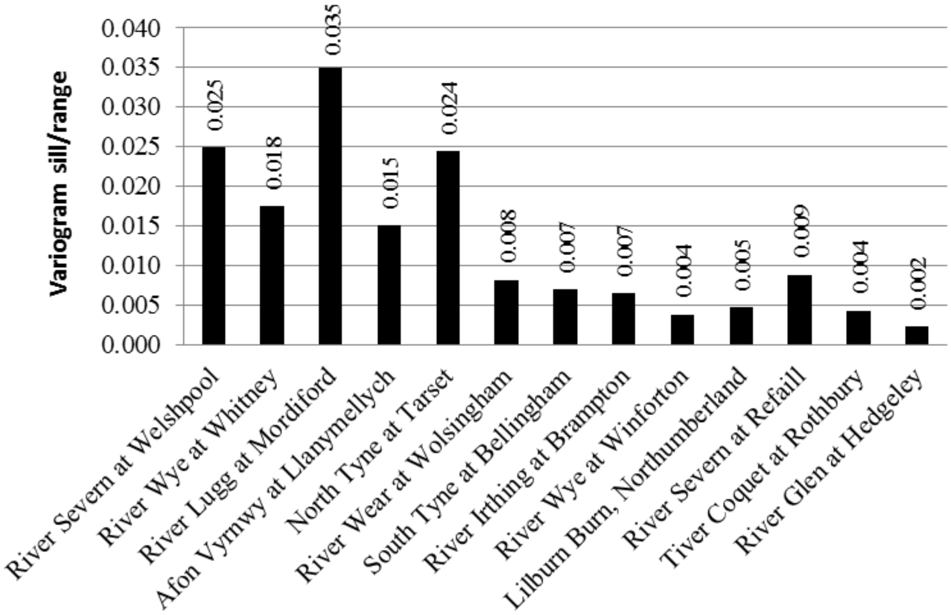

Figure 7. Spatially independent comparison of autoi-correleated sill and range values for the study sites.

In contrast to the sites reported here Harwood and Brown [17] present data from the Gearagh, wooded anastomosed system on the River Lee, Ireland. This site consisted of a dense interconnected network of channels divided by fragmented wooded islands and islets. Inter-channel flows were caused by variations in water surface elevations due to backing-up behind debris dams, with biotic components such as debris dams, tree root masses and tree-throw pits playing a key role in the partitioning of flow and development of the underlying bar and channel morphology. Whilst it is agreed that the overall mode of formation differs from the study sites reported here, the internal mechanisms for sub-channel development and maintenance appear remarkably similar with woody debris and leaf debris dams playing a major role in influencing flow patterns and sub-bar scale morphology (Figure 5).

4 CONCLUSIONS

This paper has investigated the origins of a number of developing anastomosed river channels in the UK. Analysis of the underlying topography as revealed from LIDAR data from the sites suggests that they have developed across former active meandering and wandering channel sites but now display typical stable multi-thread closely connected channels. It is suggested that both active meandering and wandering systems may develop into anastomosed systems where vegetative succession is allowed to proceed in line with channel development and that this is likely to be the dominant channel type that would develop on UK watercourses where floodplain use and management to reduce.

5 ACKNOWLEDGMENTS

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