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Working rivers: the geomorphological legacy of English freshwater mills

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Freshwater mills historically were found throughout England serving a wide variety of uses. The decline in the need for water power over the last 100 years saw a reduction in the number of operational mills. Despite this decline, the associated river structures were rarely removed and many of these have exceeded their design life and have failed or are now starting to fail, with important geomorphological implications for the river. This paper investigates the geomorphological impacts of mills and their structures on English rivers, and considers their legacy for the contemporary management of these systems.

Key words: *England, mills, geomorphology, water power, river, sediment*

Introduction

Mills have been a feature of many English rivers for over 1000 years, but in the last century the original function of these mills has all but disappeared with the demise of the demand for water power. While most mills are no longer operational, many of the associated river modifications to England's 'working rivers' such as the weirs, sluices, mill channels (leats) and mill ponds remain, and continue to influence the river's stability and morphology. This is because the milling modifications introduce artificial conditions that regulate flow discharges and sediment transfers and so influence river processes. As a result, the morphology of many English rivers has been altered significantly over several centuries of human control. In some cases (such as urban environments), subsequent engineering works (e.g. flood defence works) can obscure earlier milling modifications, but for many rural English rivers the legacy remains and continues to influence the river's development.

Understanding the impact of milling on the geomorphological behaviour of rivers is critical to adopting appropriate management strategies for the remaining structures. In the early twenty-first century this is important because many of these old mill structures have either fallen, or are falling, into disrepair. As most mills have closed, basic maintenance of milling structures may no longer be undertaken and the consequences of allowing them to fall into disrepair needs to be carefully evaluated. The most pressing problem is the resultant morphological response of the channel to the failure of mill structures. In the past, the miller would manage the mill: the sluices would be maintained and the mill pond routinely dredged of accumulating sediment. Failure will have consequences beyond the immediate site: downstream is the potential for the release of a significant quantity of sediment that had previously been deposited in the mill pond (and this sediment could also be contaminated). Upstream the channel is likely to respond to new base level changes through channel incision and knickpoint propagation that could lead to serious upstream instability problems as this evolves (for channel stability models see Simon and Hupp 1986; Simon 1989).

Associated with the uncertainty of possible morphological responses to site deterioration is the question

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of ownership and liability. Renovation of mill structures into dwellings and offices is now common practice in England. However, ownership of the mill buildings could also include legal responsibilities for the continued upkeep of the associated structures. This would be particularly important if the structure had heritage value which would require liaison with English Heritage. If a mill structure fails and the morphological response is significant, then ultimately the owner of the structure could be liable for the effects of the failure. Redevelopment of any former mill site would also need to be balanced against the mill channel's environmental value (Wood and Barker 2000). Wood *et al.* (2001) note that sedimentation and vegetation encroachment of mill ponds since the closure of the mill may have particular aesthetic, recreational, archaeological and biological attributes worthy of conservation. In such instances, the Environment Agency and English Nature would need to be consulted on any impending management action.

These issues raise important questions for the contemporary management of the mill sites:

1 Should they be allowed to fail and/or fall into disrepair and promote a possible return to pre-disturbance conditions (a condition we know very little about)?
2 Should we allow managed failure to occur and mitigate against the worst effects of any anticipated morphological adjustment?
3 Should we maintain, or modify, the channel structures at cost, even though the structures no longer serve their original function?

Currently, guidance on such decisions is largely absent. This paper will investigate the various issues of mill management with reference to case examples of mill modifications, with emphasis on three contrasting English rivers, the River Tillingbourne (Surrey), the Upper River Cherwell (Oxfordshire) and the Hawkcombe Stream (Somerset). The conclusions will seek to address answers to the three questions outlined.

History of mills on English rivers

The earliest water mills consisted of a horizontal mill wheel and vertical shaft. These primitive mills are thought to have originated in Asia, spreading through central Europe and northwards to Ireland and Scotland but, interestingly, have never been discovered in England and Wales (Curwen 1944). Later-developed water mills comprised a vertical mill wheel and horizontal shaft. The original design of these water

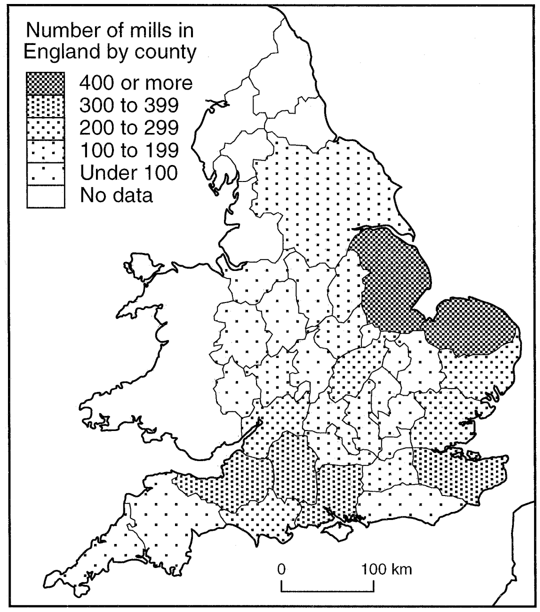


Figure 1 Distribution of freshwater mills in England recorded in the 1086 Domesday Survey (after Hodgen 1939)

mills has been attributed to the Roman engineer Vitruvius (between 20 and 11 BC) and they are believed to have been first constructed in Britain by the Romans (Curwen 1944; Vince 1984). One thousand years ago, water mills were widespread in England and the Domesday Survey of 1086 documents 5624 mills in England (Hodgen 1939) (Figure 1). These were constructed for a variety of purposes, such as printing, grinding flour, snuff, blacksmiths, paper, dyeing and skinning, and several mills could be concentrated on a particular river if appropriate conditions existed. For example, Skilton describes the River Wandle as 'the hardest working river of its size in the world' (1947, 41), and by 1610 there were 24 mills sited on just 15 kilometres of river. The same mill site may have been used many times for different milling purposes and it is not uncommon for the original mill buildings and channel structures to have been modified and/or replaced several times to date.

This documented history challenges our perceptions of the nature of human intervention on English rivers because we are more readily alerted to changes that are discernible from documented historical sources of the last 200 years (such as rapid urbanization and channelization). Our understanding of the morphology of English rivers over the last millennium tends to be limited, and our conceptual geography of natural pre-industrialized rivers and the identification of the pre-disturbance condition remain unclear if we consider the relative abundance of mills recorded in the Domesday survey.

The nature of the channel modifications for milling varies, but freshwater mills usually require that the river is impounded by constructing a dam across the main channel, raising the water level upstream to create a mill pond (Giles and Goodall 1992). The regulation of the head of water in the mill pond is controlled by varying the outflow from a sluice. The released water then flows down the mill race (alternatively referred to as a mill leat) to the mill wheel, where it is used to generate mechanical power (Jansen *et al.* 1979). The kinetic energy at the mill wheel is dependent on the discharge at the mill race, the head of the water with respect to the mill wheel and the mechanics of mill construction. Mill wheels are classified as overshot or undershot, depending on whether the water passes over or under the wheel, respectively. Overshot wheels are further defined as high breast or low breast, depending on whether the water passes above or below the wheel's rotational axis (Vince 1984). Overshot wheels were generally more effective than the undershot type (Priestley 2001). From the mill wheel, water is then channelled in the tail race (or tail leat, the channel downstream of the mill wheel) and returned to the river.

Impacts of mill structures on river systems

As with other forms of river regulation, such as channelization (Brookes 1988), mill structures have had significant impacts on river systems. Milling modifications directly influence the geomorphological behaviour of a river by regulating gradient and stream power and influencing the river's flow and sediment load carrying capacity (Thoms and Walker 1992). The geomorphological effects of mill impoundment are similar to those associated with dams (Shuman 1995) (Figure 2). Upstream of the weir and/or control sluice regulating water stage, the reduced slope of the mill pond flows promotes a reduction in stream power and an associated reduction in the river's sediment load carrying capacity. The mill pond acts as a sediment sink, encouraging the deposition of fines in the backwater channel and reducing the downstream transfer of sediment. There are also potential problems of bank erosion through fluctuating water levels upstream. Immediately downstream of the weir and sluice, stream power is increased and, in combination with the reduction in sediment load, promotes localized clear-water erosion. Localized scour may be controlled by hard defences to prevent adverse channel change at the mill site itself, such as the channelization of the tail race or the creation of a scour pool.

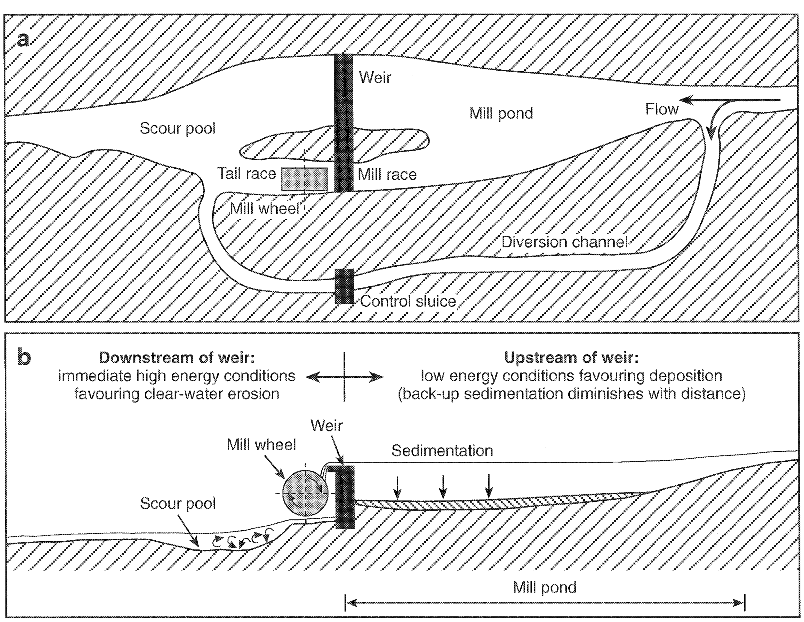


Figure 2 Geomorphological control at the mill site: (a) planform, (b) cross-section

Individual mills are seldom found in isolation along a watercourse and the net geomorphological impact of a flight of mills is to change the natural longitudinal profile of the river channel. The mill ponds provide a series of storage reservoirs that regulate flows (dependent on their storage capacity) to the downstream channel and create backwaters upstream. As with other examples of river impoundment (e.g. Petts 1984; Shuman 1995), the regulatory impacts decay downstream with distance from the mill as the natural river gradient is re-established. This is dependent on the overall valley gradient. Where mills are closely spaced the channel is effectively stepped and the localized slope artificially determined.

Given the considerable age of many English mills, many rivers have long since adjusted to the imposed condition and sought geomorphological stability. Gradual sedimentation of the mill ponds (and possibly the diversion channels) will reduce their effectiveness to provide a head for the mill wheel. The rate of mill pond sedimentation is dependent on sediment delivery, but for lowland English rivers rates are typically low. When the mills were active it was common practice for the millers to periodically dredge or flush the mill ponds to maintain their operational performance. It is quite possible that the mill ponds might be maintained long after the mills function has ceased, and may continue to regulate downstream flows. Where the river reaches downstream of the mill have been encroached by development, the continued regulation of flow from the mill pond may provide an effective means of flood control, but the maintenance of these conditions may require a commitment to maintain and/or improve the impounding weirs and sluices.

Where these channel structures are falling into disrepair, the geomorphological implications for their removal and/or modification or upkeep needs careful consideration. Their failure could promote a destabilizing morphological reaction as the channel seeks to establish a new equilibrium condition with changing gradient. The failure of an existing structure, through natural deterioration, can have rapid and widespread implications for channel adjustment. This may include the incision of the bed and upstream knickpoint propagation, leading to a rapid release of sediment. Adjustment through any one given reach will exert an influence on adjacent reaches, therefore the removal or modification of mill structures at any one site cannot be viewed in isolation from adjacent reaches.

Case studies

Three case studies are used to illustrate the legacy of mills, the variety of impacts and the potential management operations that could now be undertaken on the remnant mill structures (Figure 3). Their choice reflects a variety of geomorphological responses to the river's post-milling histories. The case studies are: the River Tillingbourne (Surrey), where routine maintenance of the mill sites has maintained river channel stability; the upper River Cherwell (Oxfordshire), where progressive deterioration of the mill sites and gradual adjustment of the river has had knock-on environmental impacts; and the Hawkcombe Stream (Somerset), which demonstrates that mill structure failure can be potentially hazardous.

The River Tillingbourne (Surrey)

The River Tillingbourne is a westward-flowing tributary of the River Wey; the confluence with the River Wey lies just south of Guildford, Surrey. The river occupies a valley on the North Downs on the northern limb of the Wealden anticline confined by the chalk scarp ridge of the North Downs. Local head deposits, derived from the solifluction of the scarp, supply clays and produce a moderately cohesive channel substrate of sandy clays locally armoured with chert (Downward 1996).

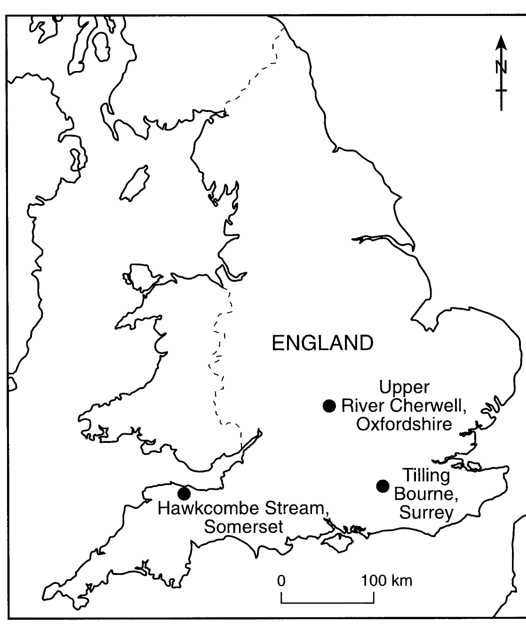
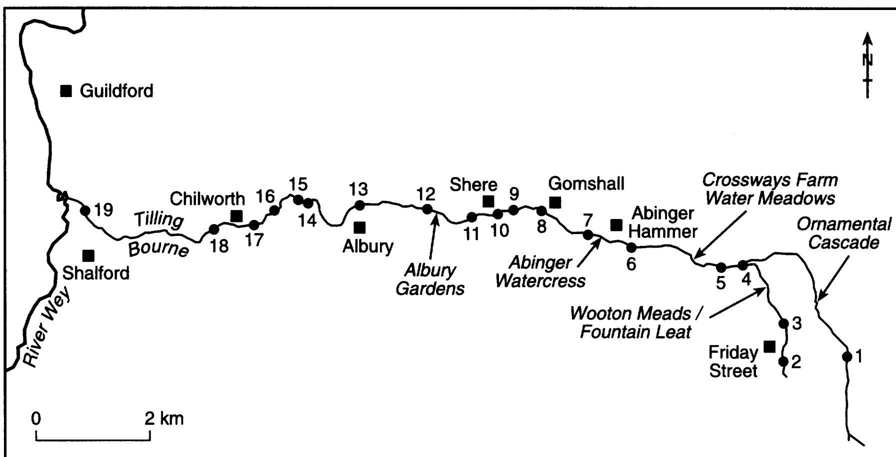


Figure 3 Case studies

Historical changes in the Tillingbourne Valley have been well documented, with evidence of human settlement pre-dating the Domesday survey of 1086. The watercourse of the River Tillingbourne has been utilized as a source of power, water supply and ornamentation, and the geography of settlement and industrial development of the valley is inextricably linked to the river. The density of mills was high, with over 22 mills recorded in total for the 19 kilometre length of main channel in its documented history (Figure 4). Land management in the river valley owes much to the continued role of estate ownership, and the function of any one individual mill was carefully integrated with adjacent mills to optimize the river's resource. It is this closely governed and integrated structure that allowed such diversity and density of river use to develop and flourish.

The River Tillingbourne mills served a variety of uses and water power was used for milling corn, paper making, fulling, metal working, tanning and gunpowder production. The history of the individual mills has been well documented and evidence indicates that many of the mills continued to be used into the early twentieth century. Maps and historical photographic records from 1935 suggest that channel conditions have changed little in the last 70 years. The pre-1935 channel was one that was dominated by the mills and, while the twentieth century saw the dereliction of the majority of the mills on the



1	Brookmill	16th century mill. Only pond remains.
2	Pond Bay	Gunpowder mill. No mill remains.
3	Friday Street	Late 16th century corn mill. Closed 1736. Mill house and weir remain.
4	Wooton Wire Works	1627. Moved from house 1675 and river landscaped. Abandoned remains.
5	Abinger Mill	Pre-1086 to 1890. Multiple uses. Mill demolished early 20th century. Landscaped.
6	Paddington Mill	Pre-1086. Multiple uses. Mill pond used for angling to 1965. Now completely silted.
7	Abinger Forge Mill	Iron working pre-1788. Converted (paper making, corn). Factory on old site.
8	Gomshall Mill	Pre-1086. Multiple uses. Recent renovation to restaurant and shops.
9	Netley Mill	Pre-1233 to 1907. Multiple uses. Pump house 1903 to 1952. Reclamation of mill pond 1970.
10	Shere Lower Mill	Pre-1086. No mill remains.
11	Shere West Mill	Corn mill pre-1638. Pond restoration (aesthetic and flood storage) early 1990s.
12	Albury Park Mill	Pre-1727. Rebuilt, operational until 1820s. No mill remains.
13	Albury Mill	Pre-1255. Mill remains – inoperative. Now site of laboratories.
14	Postford Upper Mill	Paper mill early 1800s, closed 1830s. Waterloo pond remains
15	Postford Lower Mill	Pre-1693. Multiple uses. 1996 housing development.
16–18	Chilworth Gunpowder Mills	Pre-1086 corn milling. Gunpowder works to 1920. Abandonment. Ponds maintained as fisheries.
19	Shalford Mill	Pre-1086 to 1914. Mill pond siltation. Mill restored 1930s. Now managed by National Trust.

Figure 4 Mills past and present on the Tillingbourne, Surrey. Mills continue to influence river channel morphology

River Tillingbourne, the overwhelming impression is that the channel 'infrastructure' remains and the form of the watercourse is still determined by the weirs and sluices serving the former mills.

Continued management and maintenance of the river's mills and mill sites has been important in sustaining the river's overall geomorphological stability. This is believed to result from an increased trend towards the preservation, restoration and renovation of the existing mills and associated structures toward the latter part of the twentieth century (e.g. Shalford Mill by the National Trust). Flood protection for rural housing (by the Environment Agency) has also been important in tackling localized incidences of channel instability (e.g. at the former gunpowder mills at Chilworth). In all cases, stability has been achieved through maintaining the channel form through periodic maintenance, so that while appearing 'naturalized', the channel macroform of the River Tillingbourne is not 'natural'. This trend is likely to continue, particularly as many of the mill ponds are now actively managed as game fisheries and the angling lobby, in close association with the estates, have sought to carefully preserve the character of the watercourse. For the immediate future at least, the continued stability of the river is assured.

Upper River Cherwell (Oxfordshire)

The upper River Cherwell catchment covers an area of around 906 square kilometres and is located in central England (Environment Agency 2000). The upper River Cherwell is located in the Cotswolds, northeast of Banbury (Figure 5), from where the channel flows in a predominantly north–south direction until it joins the River Thames in Oxford. In contrast to the River Tillingboune, there has been limited intervention in the management of the

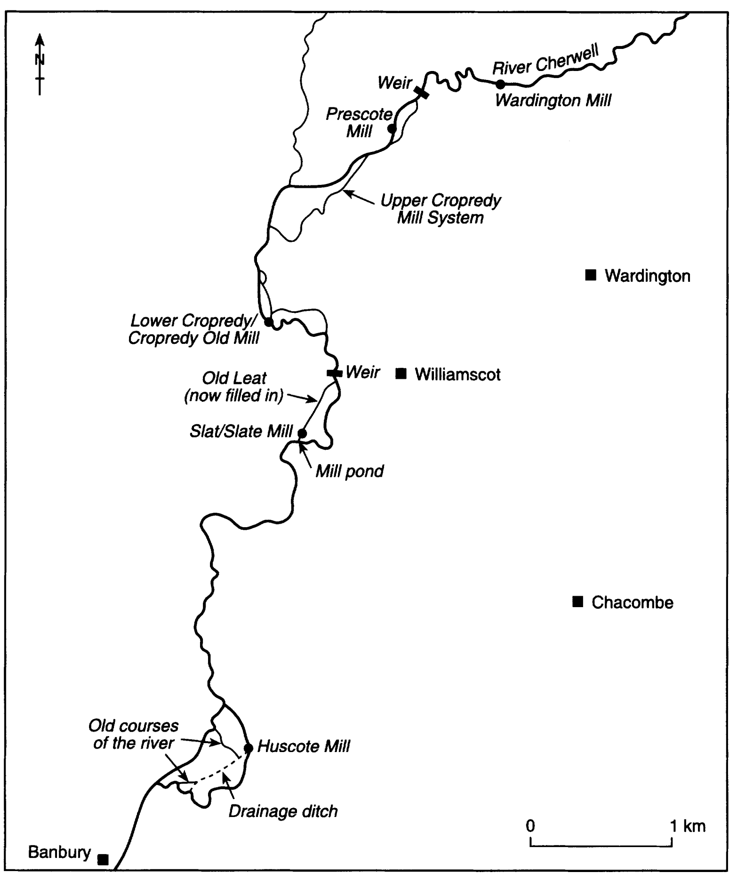


Figure 5 Mill locations and channel planform modifications on the upper River Cherwell, Oxfordshire (adapted from Thorne and Skinner 2003)

former mill sites on the upper River Cherwell, specifically in the more rural areas. The upper River Cherwell has had a long history of modification. The river water has been used extensively for agriculture and this has been crucial to the development of Banbury; the town is located in one of the most fertile farming regions in Europe (Crossley 1972). Mills were an important feature of the landscape both in the town of Banbury and in the surrounding rural areas. For example, evidence suggests that in 1695 three corn mills and one hemp mill were located within the grounds of the former Banbury Castle (Crossley 1972). In addition, documents suggest that one of the mill leases required the miller to keep enough water in the mill dam to flood the nearby pasture land and provide 14 days of water for cattle grazing in dry seasons (Crossley 1972). On the upper Cherwell, in the rural setting, upstream of where the M40 motorway now dissects the Cherwell valley, to Hay's Bridge on the A361, a further six mills were once present, five of which are thought to be the structures mentioned in the Domesday book of 1086 (Crossley 1972). These were all detailed on the Ordnance Survey map of 1882 and all except the mill at Prescote Manor Farm were indicated as being used for corn production.

A review of historic maps suggests that the construction of these mills had significant impacts on the river's morphology. The first edition of the 1882 maps shows that each of the six mills between the present day M40 motorway and Hay Bridge had accompanying leats. Mill construction often involved building a 'lasher' across the main channel to force increased flow down the mill leat. Additional modifications to the channel have also occurred. On the main course of the Cherwell, around Huscote Mill, the river has been diverted in the form a straight cut alongside the disused railway embankment. This particularly straight section pre-dates the first edition of the Ordnance Survey maps of 1882. The original course of the channel, which initially rejoined the leat downstream of Huscote Mill, has now been reduced to a wet ditch. The historical evidence thus suggests that the anthropogenic influence in this largely rural area has been significant and much of it pre-dates the oldest available maps, making interpretation of the sequence of modification difficult.

In the contemporary rural landscape, many of the constructed leats still remain although some, such the one on Slat/Slate Mill, have since been filled. The long-term geomorphological impacts of the mill structures have been significant (Thorne and Skinner 2003). For example, upstream of the diffluence of the Huscote Mill leat from the main channel of the Cherwell, sedimentation has been extensive. Downstream of the 'lasher' structure there is a significant drop in elevation, indicating the effects of clear-water erosion and accompanying channel incision. This significant flow split has led to low flow problems in the main course of the Cherwell, since the dominant flow pathway is currently down the leat. Some of the former mill structures are still evident in the floodplain, such as Cropredy Old Mill, but all that is left of many of them, such as Huscote Mill, are their foundations. Future management of the river must carefully consider the status of these structures when deciding appropriate courses of action to ensure that the progressive deterioration of these former mill sites does not cause undue in stability and/or flood-related problems that may manifest elsewhere in the watercourse.

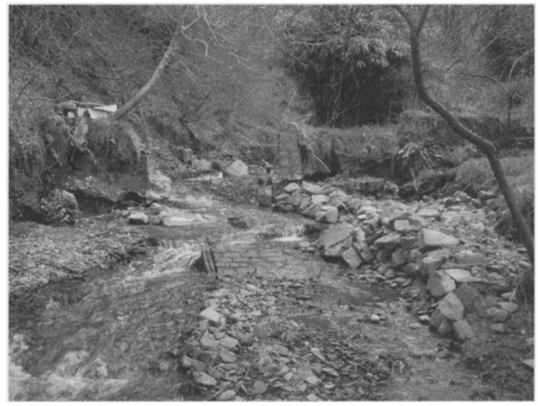


Plate 1 Failure of the mill structure on the Hawkcombe Stream promotes rapid river channel adjustment

Hawkcombe Stream (Somerset)

The Hawkcombe Steam catchment covers an area of approximately 7 square kilometres in northwest Somerset within Exmoor National Park. The headwaters of the stream are located on Exmoor. The stream flows generally in an easterly direction through a confined wooded valley, before flowing northwards to the Bristol Channel as it reaches the edge of Porlock village (Figure 6). The failure of individual mill sites on the Hawkcombe Stream has led to extensive instability (Plate 1). Failure in itself is not necessarily problematic so long as the associated geomorphological changes can be readily

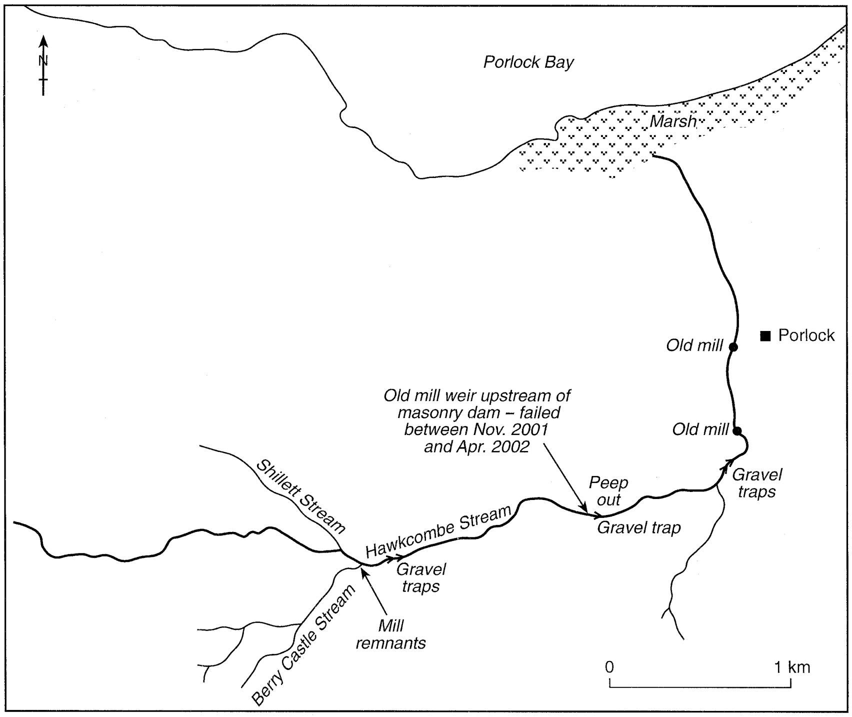


Figure 6 Mill and mill remnant locations of the Hawkcombe Stream, Somerset (adapted from Thorne and Skinner 2002)

accommodated within the watercourse without undue risk to individuals and property. However, the case study illustrates that unchecked, sudden mill structure failure could have important repercussions.

The development of Porlock has been linked integrally to the Hawkcombe Stream, and the system has a long history of modification. The water has been used extensively for industrial purposes since the thirteenth century (Atkinson 1997), including woollen mills, tanneries and hydroelectric power. The region as a whole has had a long history of milling, with the Domesday Book of 1086 documenting around 50 mills within the west Somerset area (Allen 1978). Woollen mills became the mainstay of the local economy around Exmoor following the development of water-powered fulling stocks in 1185 (Atkinson 1997). The Hawkcombe Stream was an ideal location for these mills as a consequence of the steep, confined catchment combined with the proximity to grazing sheep on the upland moorland. Water rights proved to be a contentious issue within Porlock, with documented court cases evident. In 1607 the miller of the Manor Mill (the former Rectory Mill in the centre of the village) accused another mill owner further upstream of illegally diverting flow from the stream to his mill (Chadwyck-Healey 1901). Cases such as this highlight the importance of the stream to the local economy at this time, as well as the pressures on the river system as a whole. The woollen mills declined in the region in the early 1700s (Atkinson 1997).

A review of the first edition of the Ordnance Survey maps intimates that the main course of the Hawkcombe has not changed significantly since 1889. The previously documented evidence suggests that much of the change to the planform of the Hawkcombe Stream pre-dates the earliest maps. This is relevant both for the upstream headwaters and the straightened section downstream of Porlock.

A geomorphological reconnaissance survey (Thorne and Skinner 2002) revealed that in the Hawkcombe Stream catchment a series of remnant mill structures with accompanying leats were present. As the Hawkcombe Stream is a relatively high energy system and the mills were constructed several hundred years ago, many of the structures have since failed with old walling and mill leats frequently being the only surviving structures. The significant adjustment, through knickpoint migration, observed in the headwaters, could reflect the response to recently failed structures. During the winter of 2002 a weir failed upstream of 'Peep-Out', releasing an estimated 200 cubic metres of sediment into the gravel trap immediately downstream (see Plate 1). Upstream, there was immediate knickpoint migration, causing bed degradation and channel widening. Failures like these present serious management problems. The question of what mitigation works are needed when old structures fail, and who should undertake them, is increasingly becoming a problem that needs to be addressed around the country.

Conclusions

The examples cited highlight a variety of challenges for the management of remnant mills in English river systems. If the structures have been maintained (e.g. the River Tillingbourne), geomorphological stability (albeit artificially constrained) can be sustained. In the cases where maintenance has not occurred (e.g. Hawkcombe Stream), failure of mill structures can lead to extensive channel instability. Whether this instability can be considered a risk to individuals and property is largely a function of location and riparian development, but the Hawkcombe Stream mill failure demonstrates that the effects (e.g. knickpoint erosion) are not necessarily confined to the mill site alone.

The question that needs to be addressed is how we should approach the management of mill structures that are currently not being maintained and could fail sometime in the near future. Successful management is dependent on balancing (a) the environmental gains or losses, (b) the risks of geomorphological change to riparian land (e.g. flooding and erosion) and (c) the cost of maintaining the mill site. Any management action is likely to require consultation with English Heritage, the Environment Agency and English Nature, depending on the conditions present at the site. The cost implications associated with continued maintenance or allowed failure is a major issue. The owner of the mill structure is likely to be liable for both maintenance and associated effects that could be attributed to failure. In cases where failure can bring environmental gains and anticipated river changes do not impact on the riparian corridor, there is a good case for allowing failure to occur. In cases where failure may promote environmental losses (e.g. ecological or heritage) and/or river changes that impact on the riparian corridor, the cost of maintaining the mill structure must be carefully evaluated against the risks. In all cases the applied geomorphologist can provide a suite of management support skills that can aid the careful evaluation of these risks.

With reference to the questions asked in the Introduction, three management scenarios should be considered.

1 A 'do-nothing' approach would allow natural deterioration of the mill structures and promote self-regulation of the river over time. This may lead to environmental gains, such as the removal of major obstacles to fish migration. However, the river's geomorphological response is uncertain, particularly because the pre-disturbance conditions often pre-date our earliest documentary records.
2 A 'manage the failure' approach would allow controlled deterioration of the mill structures to assess and mitigate against the effects of morphological adjustment, particularly where the partial recovery of the site can be demonstrated. This may be a favoured management approach where there are clear environmental benefits of deterioration identified but where developments within the riparian corridor necessitate that some form of intervention is necessary.
3 A 'maintenance' approach may be prudent where the environmental costs (e.g. habitat loss from mill ponds) and riparian corridor risks of anticipated failure are deemed unacceptable. Mill heritage and conservation values might give added weight to these arguments.

No blanket solution to the management of English mills can be offered because of the inherent singularity and geomorphological sensitivities of the watercourses concerned. However, it is important to draw attention to these mill sites in view of their continuing deterioration and to highlight the need for the evaluation of the risks associated with deterioration. Recognition and assessment of their condition and risk sensitivity in advance of unexpected failure would seem a prudent management option.

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References

Allen N V 1978 *The waters of Exmoor* The Exmoor Press, Dulverton

Atkinson M ed 1997 *Exmoor's industrial archaeology* Exmoor Books, Tiverton

Brookes A 1988 *Channelised rivers, perspectives in environmental management* Wiley, Chichester

Chadwyck-Healey C E H 1901 *The history of part of West Somerset* Henry Sotheran and Company, London

Crossley A ed 1972 *A history of the county of Oxford* vol 10 Oxford University Press, Oxford

Curwen E C 1944 The problem of early watermills *Antiquity* 18 130–46

Downward S R 1996 *River Wey fluvial audit* Environment Agency (Thames Region), Reading

Environment Agency 2000 *Local environment agency plan Cherwell Valley: environmental overview* Environment Agency (Thames Region), Reading

Giles C and Goodall I H 1992 *Yorkshire textile mills 1770–1930* HMSO, London

Hodgen M T 1939 Domesday watermills *Antiquity* 3 261–79

Jansen P, Van Bendegom L, Van den Berg J, De Vries M and Zanen A eds 1979 *Principles of river engineering: the non tidal alluvial river* Pitman, London

Petts G E 1984 *Impounded rivers, perspectives for ecological management* Wiley, Chichester

Priestley G 2001 *The water mills of the Water of Leith* The Water of Leith Conservation Trust, Edinburgh

Shuman J R 1995 Environmental considerations for assessing dam removal alternatives for river restoration *Regulated Rivers: Research and Management* 11 249–61

Simon A 1989 A model of channel response in disturbed alluvial channels *Earth Surface Processes and Landforms* 14 11–26

Simon A and Hupp C R 1986 Channel evolution in modified Tennessee channels in *Proceedings of the 4th Federal Interagency Sedimentation Conference* Las Vegas, Nevada US Government Printing Office, Washington DC 5.71–5.82

Skilton C P 1947 *British windmills and watermills* Collins, London

Thoms M C and Walker K F 1992 Channel changes related to low-level weirs on the River Murray, South Australia in **Carling P A and Petts G E** eds *Lowland rivers: geomorphological perspectives* Wiley, Chichester 235–50

Thorne C R and Skinner K S 2002 Fluvial audit of the Hawkcombe Stream prepared for the Environment Agency South West Region Nottingham University Consultants Limited, Nottingham

Thorne C R and Skinner K S 2003 Fluvial audit of the upper River Cherwell prepared for Atkins Global Nottingham University Consultants Limited, Nottingham

Vince J 1984 *Discovering watermills* 4th edn Shire Publications Ltd, Tring

Wood P J and Barker S 2000 Old industrial mill ponds: a neglected ecological resource *Applied Geography* 20 65–81

Wood P J, Greenwood M T, Barker S A and Gunn J 2001 The effects of amenity management for angling on the conservation value of aquatic invertebrate communities in old industrial ponds *Biological Conservation* 102 17–29