River channel instability in East Anglia as a result of increasing water demand

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BACKGROUND

In East Anglia, climate change is causing two extremes: floods and droughts. Adaptation is absolutely crucial or the region will face serious water shortages.

East Anglia is already the driest region in the UK with only half of the national average annual rainfall in a normal year. Most catchments, including a studied River Stour, are over-abstracted. Water has to be transferred from neighbouring catchments via pipelines and rivers, adding a lot of extra water to the natural river flows. Increased water transfers are due to start in 2013 and the River Stour will be the most affected.

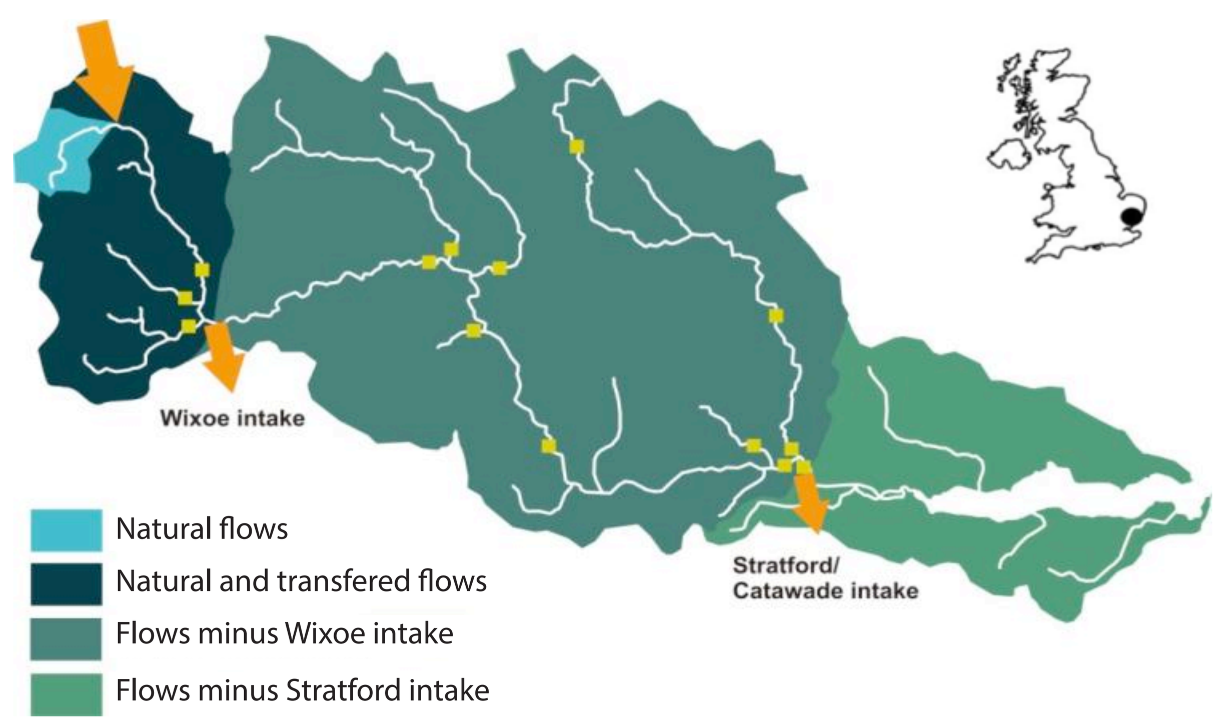

Figure 1 The River Stour catchment divided into four stretches depending on the amount of water transfer. Yellow squares are the gauging stations and orange arrows indicate the intake and off-take points for the transfer scheme.

PROJECT AIMS

(1) To measure the magnitude of river bank retreat on a modified river that is used as part of a water transfer scheme and to assess the effectiveness of the methods used for identifying the river bank retreat.
(2) To compare river bank erosion rates measured in the field between 2006 and 2010 with those derived from historical maps since the 1880s and to evaluate this using field data from other field studies on similar rivers in the UK.
(3) To assess the relative influence of river bank and channel properties such as bank material textures, shear strengths, bank heights and angles, water surface slopes or channel planform on river bank erosion rates on the field sites between 2006 and 2010.
(4) To assess whether, and to what extent, transferred flows (that increase discharge artificially) are increasing river bank erosion rates at the research sites.

Figure 2 Instances of erosion around pin, slumped bank, cantilever and shallow failure after high flow events on the River Stour in 2007 and 2009.

METHODS

The field study employed a unique combination of four geomorphologic field methods for detailed continuous bank research: (1) erosion pins (105 pins were installed), (2) repeated cross-sectional and bank profile surveys, (3) bank edge surveys and (4) Photo-Electronic Erosion Pins (PEEPs). This mixture of techniques was used to increase spatial and temporal accuracy and to capture a bigger picture about the changes to the river bank sites. The field study commenced in 2006 and lasted four years.

The magnitude of erosion recorded on pins and the retreat calculated from vertical bank profiles was found to correlate. Exceptions did occur, for example when significant erosion took place below or above the nearest pin, as illustrated by the toe scour (GB3-2).

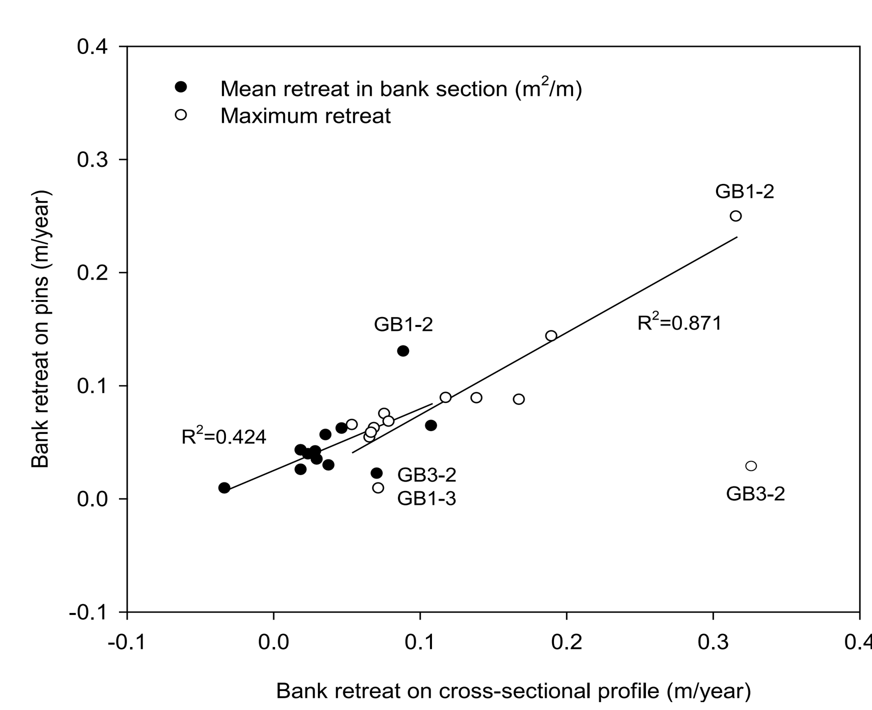

Figure 3 Relationship between the retreat calculated from vertical bank profiles and retreat recorded on erosion pins for selected sections. The mean retreat in the bank section is in m^2/m/year, other units are in m/year.

HISTORICAL AND SPATIAL CONTEXT

Historical GIS analysis was undertaken to supplement the field data. In seven out of nine field sites, field work revealed much higher annual retreat than the old maps. Exceptions were two sites (LB2 and C1) where field rates were similar to the historical data (1886-2004), and the maximum rates at these sites were relatively small.

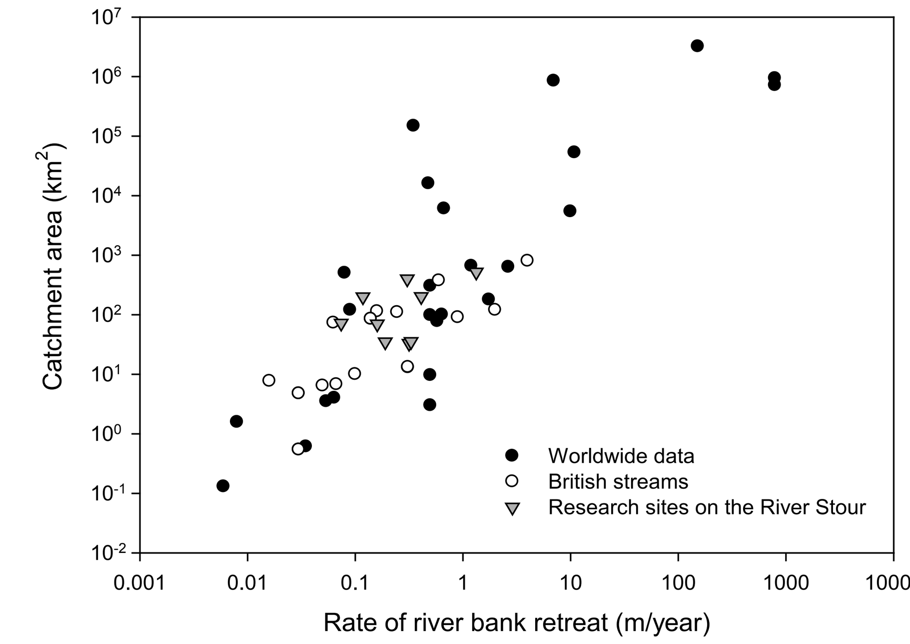

Figure 4 Maximum erosion rates and the catchment area on a logarithmic scale from worldwide and British rivers (data from reviews by Hooke 1980 and Lawler 1993), and from this research on the River Stour.

Despite the fact that the field sites in this research could be regarded as extreme in their nature, the bank retreat rates on the River Stour correspond to the maximum rates reported by other authors elsewhere in Britain.

BANK PROPERTIES AND EROSION RATES

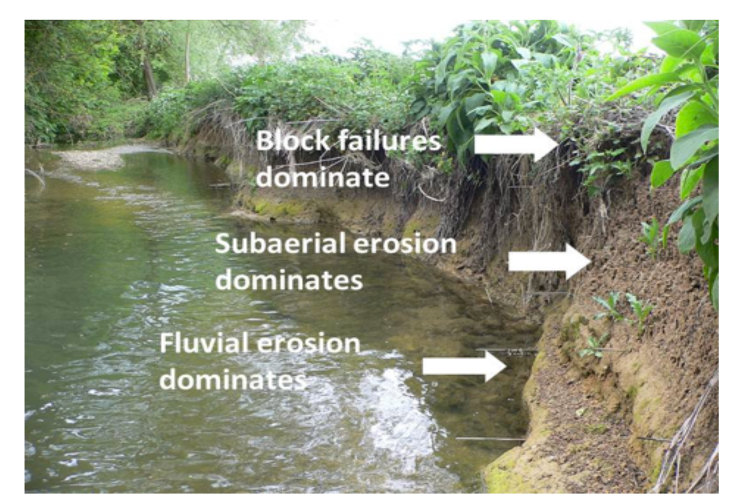

Figure 5 Vertical process dominance zones applied to the study sites with the formation of a flat surface on the boundary between zones 2 and 3.

Three vertical process dominance zones have been identified: (1) top zone, where overhangs develop due to the added soil strength from roots; (2) middle zone, where subaerial processes dominate with no added root strength; and (3) toe zone most prone to fluvial erosion.

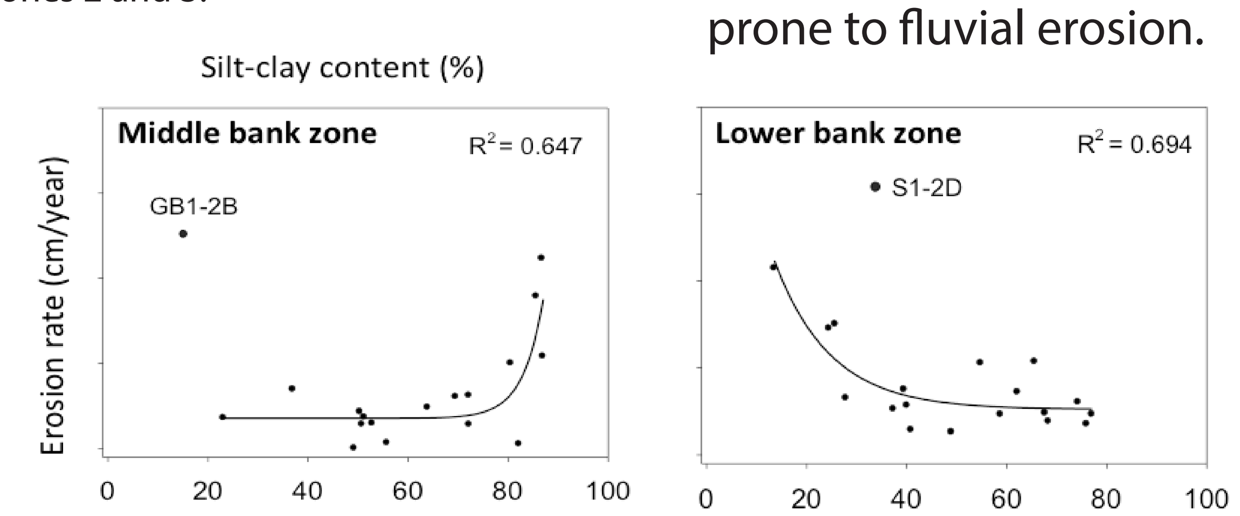

Figure 4 Silt-clay content (as volumetric %) versus annual erosion rate recorded on pins (cm of retreat/year) was found to correlate at two bank zones: middle (2) and bank foot (3).

TRANSFERRED RIVER FLOWS

There was no clear correlation of the field erosion rates and river flows, even when the transferred flows created nearly half of the discharges effective for particle entrainment. Only morphological evidence was found that shows that the transferred river flows have an effect on river channel form on the River Stour.

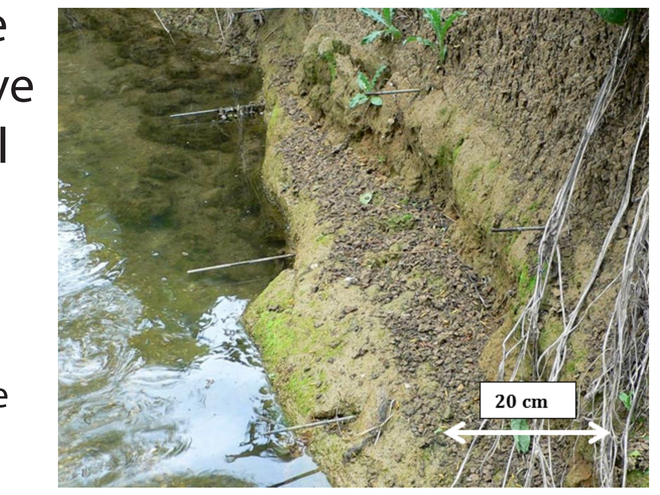

Figure 6 A piece of flat bank with monitoring pins indicating a level of prolonged water transfer on the LB1, River Stour.

CONCLUSIONS

A river bank retreat of up to 1.3 m/year was recorded, which is much higher than the maximum rate of 0.2 m/year interpreted from historical maps since 1886. The studied river channel was used to transport additional water to supply, which was found to create 40% of all effective flows in the upstream reaches during the study period. The impact of this transferred water decreased downstream. The frequency of effective flows due to the water transfer scheme was examined against the river bank erosion retreat data considering the complexity of the channel boundary processes. Clear morphological evidence has also been collected that proves the effect that the water transfer flows are having on the river channel.

It is expected that the amount of water transferred via the River Stour to reservoirs will increase in the future. This will have an influence on river bank stability in two ways: (1) directly – as a consequence of the banks being subjected to prolonged periods of transferred flows and (2) indirectly – through related channel engineering and maintenance.

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