Low Lorton Gravel shoal and downstream embankment modelling report

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Objectives

1) Determine the impact of removing the downstream flood embankment on levels at Low Lorton Bridge and village.
2) Analyse under bridge scour following recent high flows and the impact on conveyance.
3) Analyse future shoal growth to look at how shoal will impact flood risk.
4) Suggest long tem impact of shoal on flood level and future gravel management scenario's.

Model

JBA were commissioned by the Agency in 2007 to produce hydraulic models for a number of flood risk area in North area, of which Low Lorton was one. JBA produced a 2D Tuflow model for Low Lorton in 2008, based on survey obtained in 2007. The EA does not have the 2D Tuflow software in house. JBA thus provided a version of their model with just the river channel (the ISIS component) included. This could then be run from the standard EA ISIS platform. The model was supplied by Kevin Frodsham, JBA, file name 'Final_All_0.035_trimmed_v2.DAT', dated 21/11/08, to be run using event file 'Q100_1SD_6.25.IED'.

Scenarios

Various scenarios were analysed by JBA. The main scenario used survey data from a survey in 2007. In the model the bridge has been surveyed explicitly with upstream and downstream cross-sections. The next cross-section in the model (CKER03_0008) is some 6 m downstream of the bridge. The next section is some 86 m downstream, on the bend, downstream of the houses (figure 1).

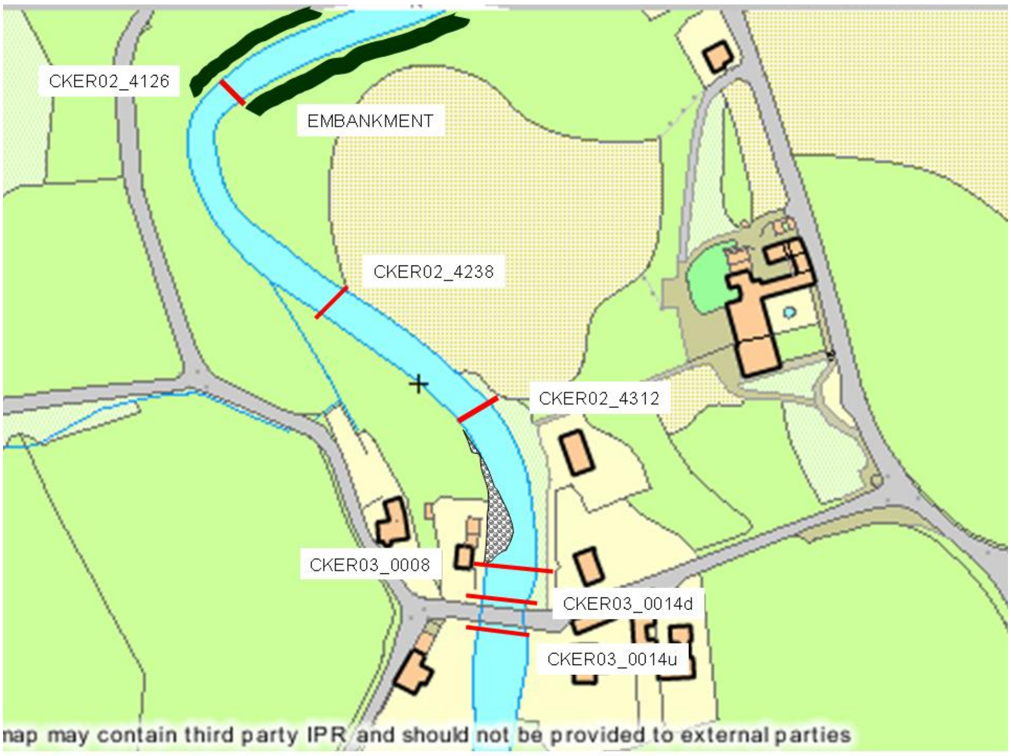

Figure 1) Cross –section layout showing shoal below bridge and embankments.

Objective 1 – the effect of the embankments

JBA modelled Low Lorton using detailed 2D floodplain modelling. At the 20% AEP (5 yr return), this gives a flood outline as displayed in figure 2. What is apparent from this is that out of bank flows are already occurring below Low Lorton. The impacts of the embankments then are to hold water up upstream on the right bank, and force flows off down a narrow section of the left bank (at the corner) towards the road. This restricts the floodplain area available to convey flows which in turn increases the water level upstream.

To model the effect of removing the embankments directly, it would have been simple to take the 2D model and modify the bank heights (i.e. embankment top) and observe the impact on floodplain flows. However, the Tuflow software is not available in-house. A useful approximation can be made by taking the 1-D channel model supplied by JBA. In this model, the cross-section is of the river channel only and stops either at bank embankment top or bank top (if there is no embankment). If the water level in the model run rises above banktop it is allowed to 'glass wall', i.e. water level continues to rise as if there was an invisible vertical embankment in place. This is not a reflection of a true embankment then, which would overtop and act as a spill. If modelled explicitly, the head losses in such an overtopping situation are quite complex and can result in model instability. The 'glass wall' approximation thus gives slightly higher river levels than would be expected in reality, but the simplicity in approach and robustness probably outweighs this simplification. At best it serves as a rough guide to the effect.

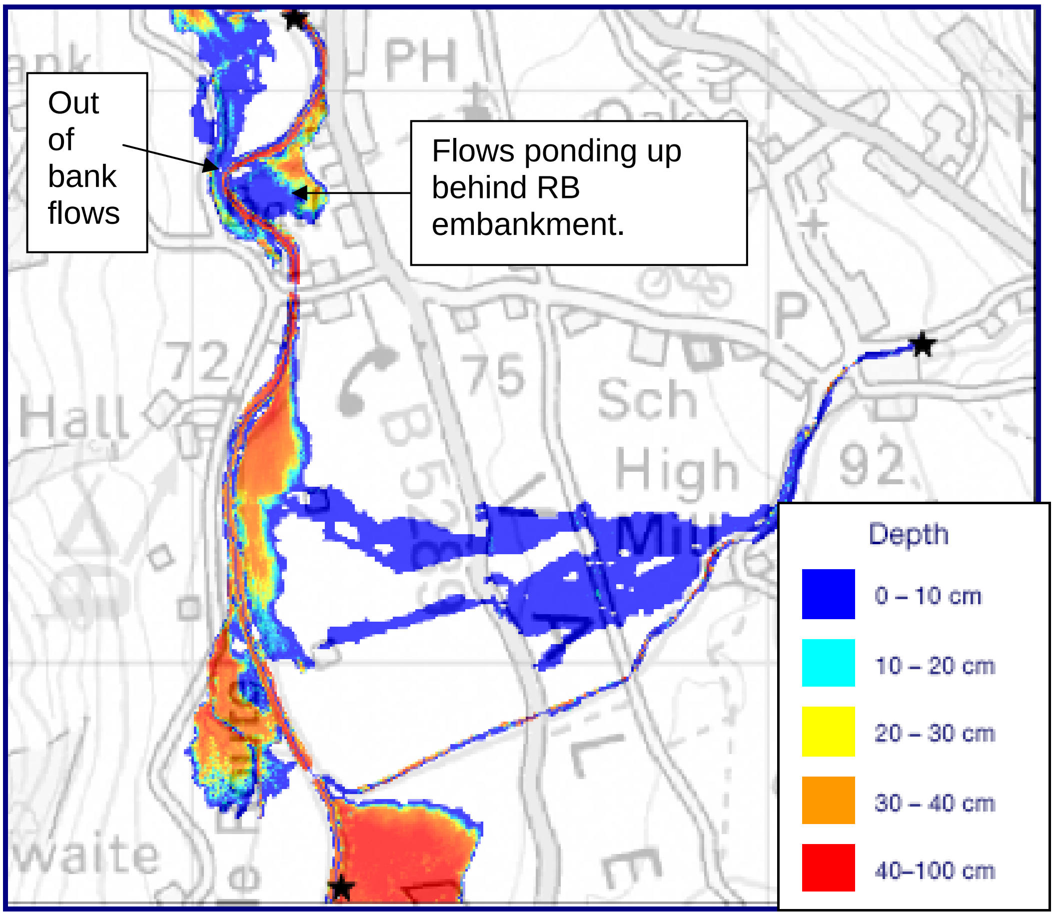

Figure 2) 2D flood outline Low Lorton. Reproduced from Low Lorton report (2008).

The scenario of embankment removal was then analysed and modelled. This involved taking spot heights of the floodplain from Agency LIDAR data and constructing long sections showing how water would be conveyed along the floodplain, in the absence of any embankments. Extended cross-sections (into the floodplain) were undertaken for cross-sections CKER03_0008 to CKER02_3289.

The two scenarios were then compared. Again, the unrealistic nature of the 'embankments' scenario must be stressed. The results (figure 3) show that removing the embankments does have an impact on levels, showing for the 1% AEP flows, approximately a 500 mm reduction in water level at the sections upstream of the embankment (in the vicinity of the Low Lorton Bridge properties).

The water levels for the embankment case were compared to the 2D model outflows. The results correlated quite well, with the current approach giving higher levels (but consistently higher) by 150 to 200 mm higher than the 2D model. Further work in refining the floodplain conveyance (set uniformly at 0.06) would probably help narrow this gap. The JBA approach models the effect of flow around and over the embankments specifically so should be considered as more accurate. In reality, the embankments will cause flow to back up (giving higher upstream levels) and then overtop or be bypassed. The JBA report highlights that the embankments will be overtopped by flows greater than 20% AEP (5 yr. return).

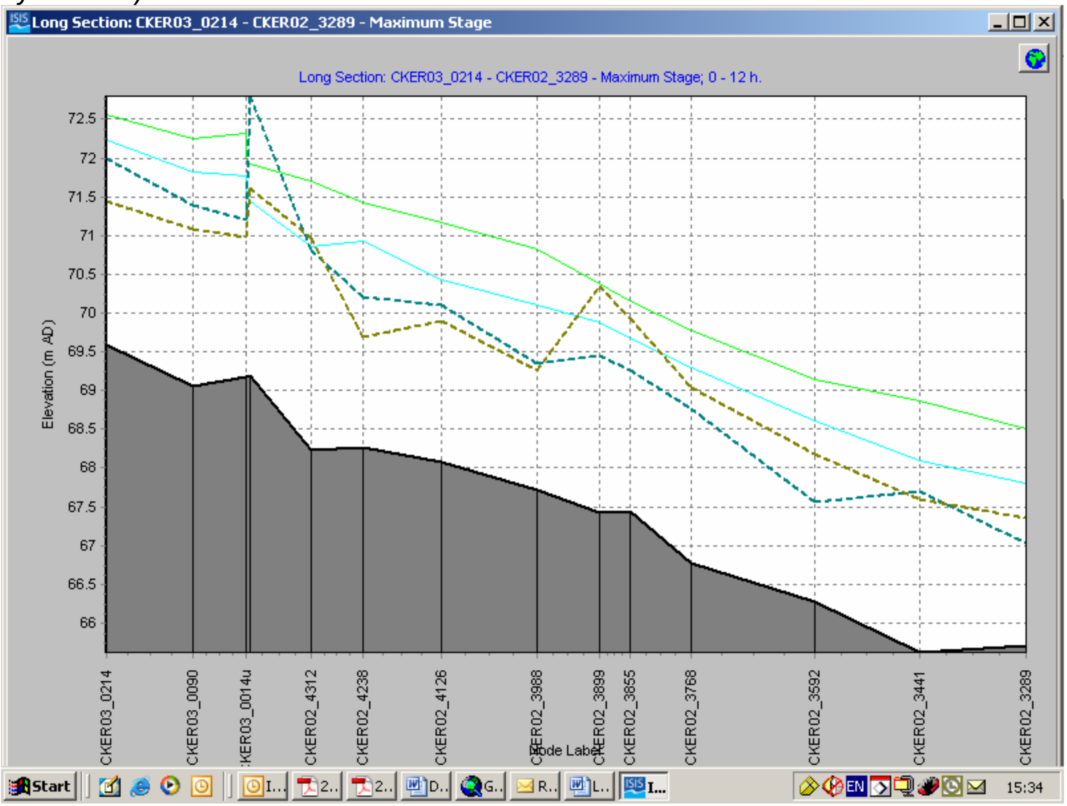

Figure 3) 1% AEP, maximum levels at Low Lorton, Green = Full embankment scenario, Blue = no embankments. (Cocker03_0014u is the bridge)

As discussed, the scenario for embankment removal is a little artificial, as the 'with embankments case' assumes no overtopping. Despite this, the 'no embankment' model indicates that there will be some benefit in water levels at the properties at Low Lorton upstream. The model results suggests up to a 500 mm reduction in water level, but given the unrealistic nature of the embankment scenario, a conservative estimate would be more sensibly in the region of 100 to 200 mm. The JBA report shows that a 100 mm reduction in level would reduce the 1% AEP (100 yr flow), to be equivalent to the 2 % AEP (50 year flow). Furthermore, opening up the embankments will prevent flood flows being concentrated onto the LB of the floodplain which appears to direct flows towards the Low Lorton road. Removing the embankment will increase the width of available floodplain flow from 50 m to 180 m. A wider cross-sectional area, will clearly improve conveyance and reduce levels upstream.

Downstream at Low Lorton village there are further properties. The properties in this location are on the RB, set on higher land and have property thresholds above the 1 %AEP. It should be noted that for the properties with river frontage (Home cottage and its northern neighbour) – the 1 % AEP flow route goes through the garden, but does not impact the property. The embankment removal would not have an impact on flood levels in this location.

As the embankment provides a low level of flood protection, it is unlikely that the frequency of flooding to the field will be changed significantly, however the area that commonly floods may change – with potentially more frequent flooding of the land downstream of the bend on the left bank.

The conclusion from this study is that the embankments marked on figure 4, should be removed. This will improve conveyance in this critical area and should benefit the properties at Low Lorton Bridge and should not increase the flood levels downstream at Low Lorton village, all other factors (i.e. channel blockages etc) remaining constant.

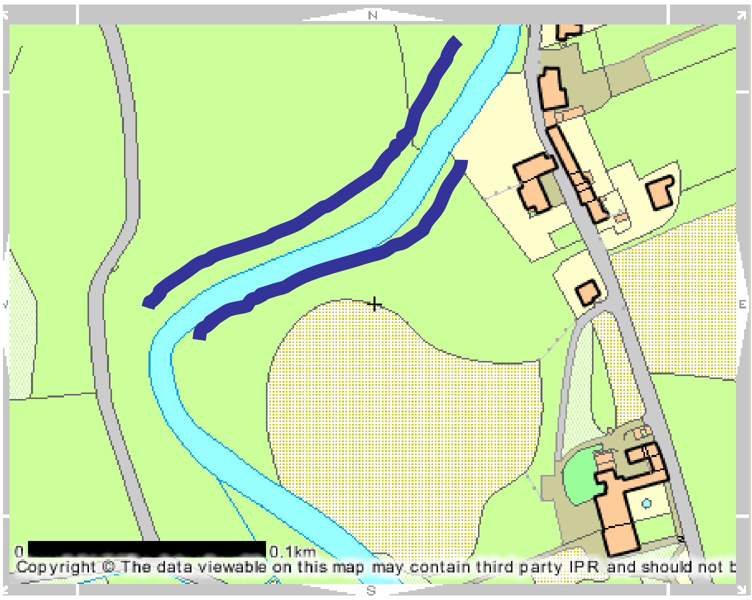

Figure 4) Embankments to be removed.

Objective 2 – recent scour impacts
As part of their study, JBA modelled in very simple terms the impacts of the gravel shoal at Low Lorton Bridge by adding 0.5 m to the river bed levels under the bridge to simulate gravel accumulation, and removing 0.5 m to the bed under the bridge to simulate gravel extraction on the shoal downstream. Removing 0.5 m bed, had the impact of reducing peak 1% AEP levels by 0.2 m, adding 0.5 m to the bed had the impact of increasing the 1% AEP level by 0.2 m.

During the recent high flow event (October 2008), the flows under the bridge resulted in significant scour of both the bed below the bridge arch, and of the shoal that forms in the wider part of the channel downstream of the bridge. Locals in the property 'Lorton Low Mill' reported noticeable bed scour under the bridge. A subsequent survey revealed considerable scour : complete removal of the central bar, and scour of up to 600 mm of the bed. This data is displayed in figure 5. The yellow line (Dec 2008 survey), compares with the dark blue line (2007 survey).

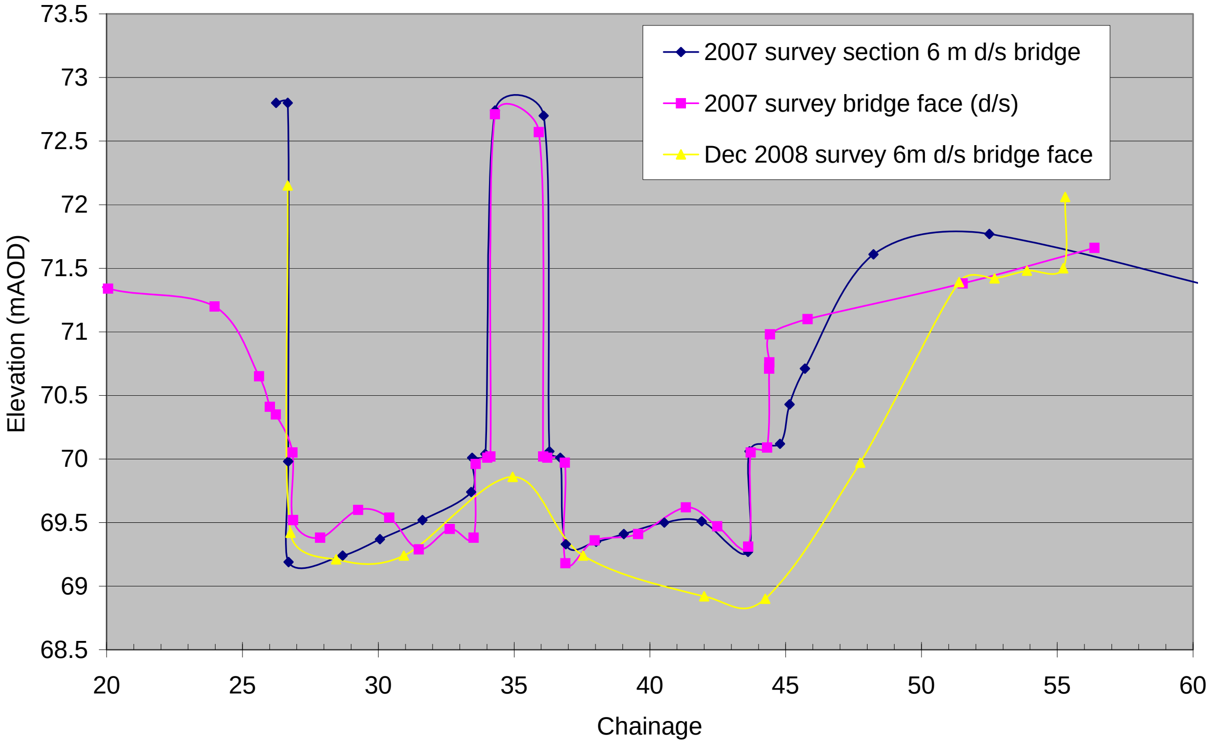

Figure 5) Cross-section survey below the bridge –blue and pink are 2007, yellow is the Dec 2008 survey.

The shoal has now currently been eroded and has reformed down at the corner, and has deposited where the river flows out onto the floodplain (where the channel velocity decreases). The current impact of the scour is to decrease the 1% AEP by 0.2 m.

The shoal has reformed further down around the corner, because : this is the inside of the bend, where secondary flow effects occur, which leads to deposition of material on the inside of the bend; and because the confinement on the RB is eased, and flow can spill onto the RB floodplain. Flow onto the floodplain gives a wide cross-section for water to spill out onto, which means that the shoal will not significantly elevate water level at this location and upstream – because of the wider cross-sectional flow area downstream (flow across the floodplain).

Concern has been raised that the new location for the deposited material will have a back-up effect upstream, having an impact on flood risk. To model this effect, the current shoal (figure 6) was modelled explicitly.

In the model, cross section CKER02_4312 represents this location (see figure 1). The new shoal levels were included in the model and the model run with this new cross-section. The difference in elevation between the new and old shoal is given in figure 7. The impact on water level is given in figure 8. Whilst levels are difficult to discern on figure 8, the original 100 yr level at the bridge is 71.98 mAOD, and the level including the shoal on the corner is 72.03 mAOD. The increase in water level is thus 0.05 m or 5 cm. Given at the 100 year flow, the river level is nearly 3 m, this does not represent a significant increase in water level. We would not recommend shoal removal for such a small increase in water level, but will monitor the shoal and ensure vegetation build-up does not occur. Also, the spill out onto the RB floodplain will mean that actual water level increase in this location is likely to be less then 5 cm, as it spreads over a wider area.

Figure 6) the shoal at the corner at cross-section CKER02_4312.

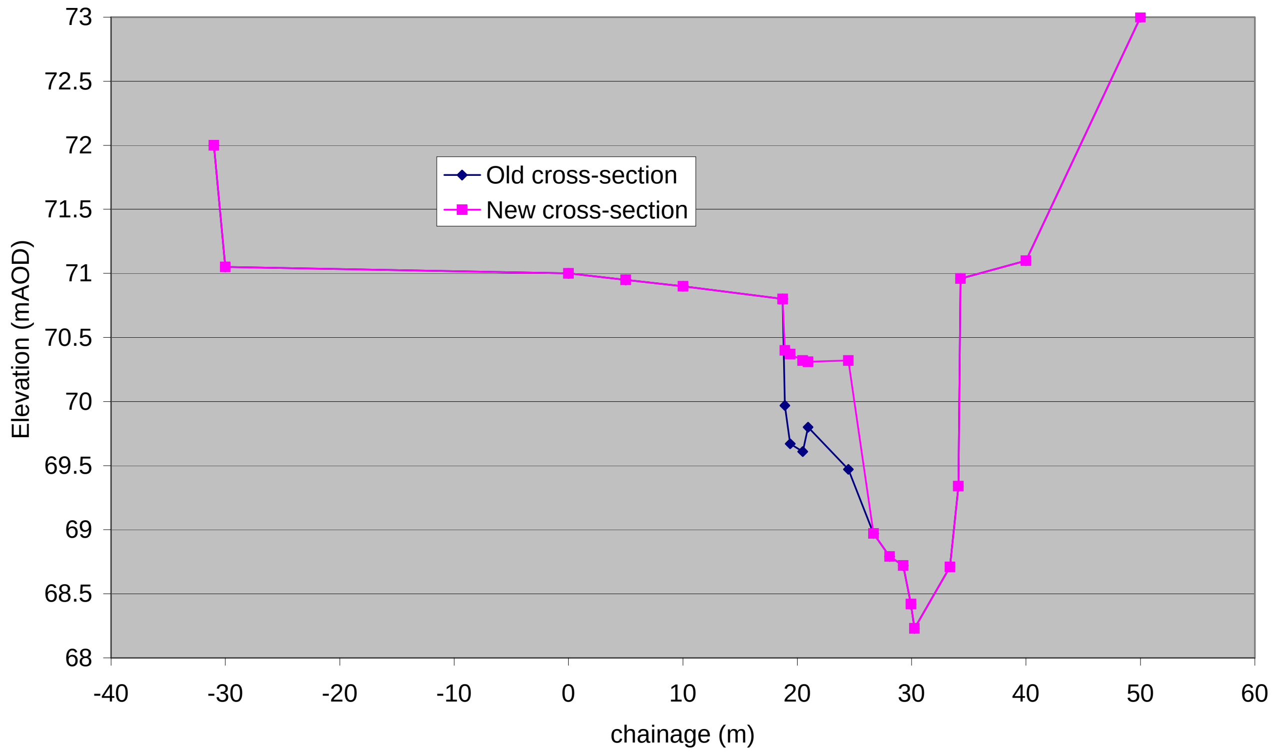

Figure 7) Revised cross-section profile showing gravel shoal.

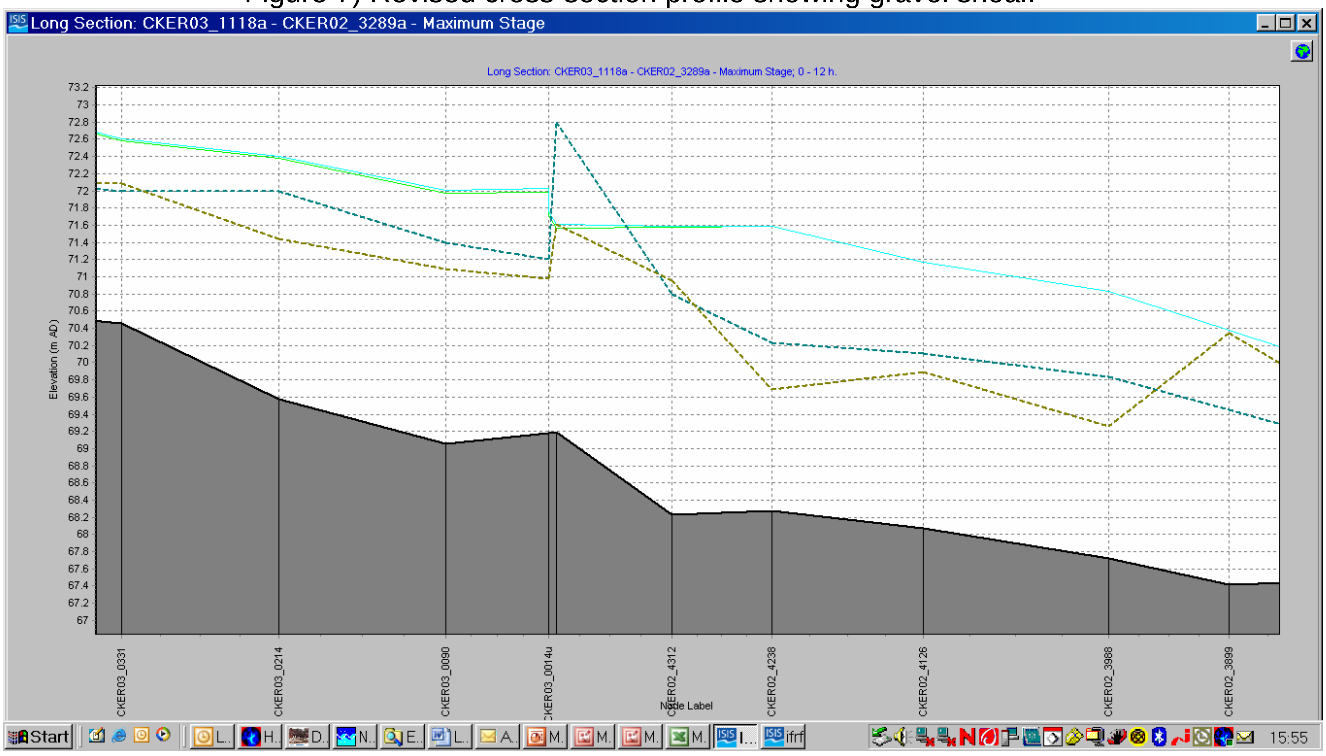

Figure 8) Long-section 100 year water levels. Green line = original cross-section, blue line = new shoal.

This means that the current shoal on the corner should be monitored to ensure it remains vegetation free, but should not be removed routinely.

Following a site meeting on the 09th June 2009, concern was raised regarding flooding of Low Bridge Cottage via the garden of River Mead cottage. Residents expressed concern that the shoal would cause out of bank flows to occur more quickly, and that the out of bank flows would then overtop the left bank, flow along the low garden (floodplain area) and flood Rivermead. However, It is thought (see page 6, para 4) that the low right bank would cause flows to go out over the right bank floodplain, and to this end, a further cross-section was taken directly through the shoal section to verify the levels (figure 10). It should be noted that this location (figure 11) is some 5 m downstream of the cross-section indicated in figure 7 of this report. This survey shows the right bank top to be at 70.96 mAOD and the left bank top to be 71.05 mAOD. Thus flows will break out over the right bank floodplain before they will break out over the left bank.

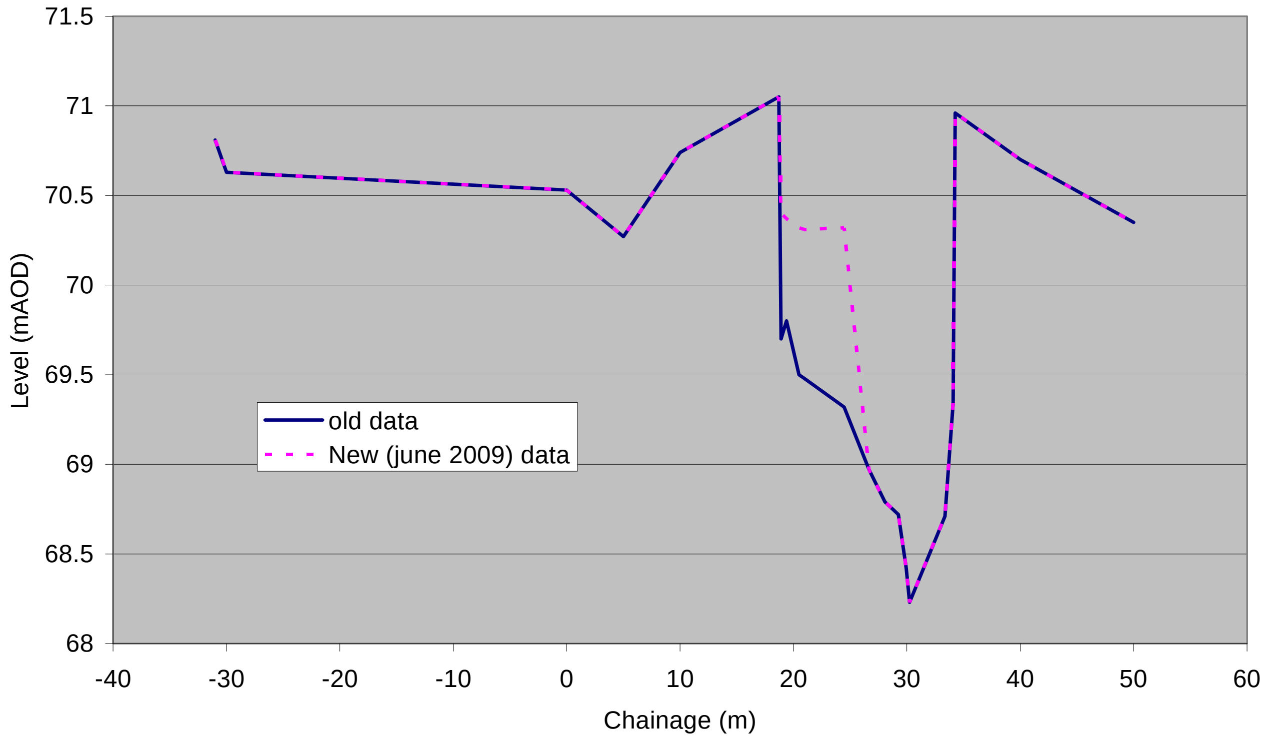

Figure 10) Cross-section taken in June 2009 through the shoal

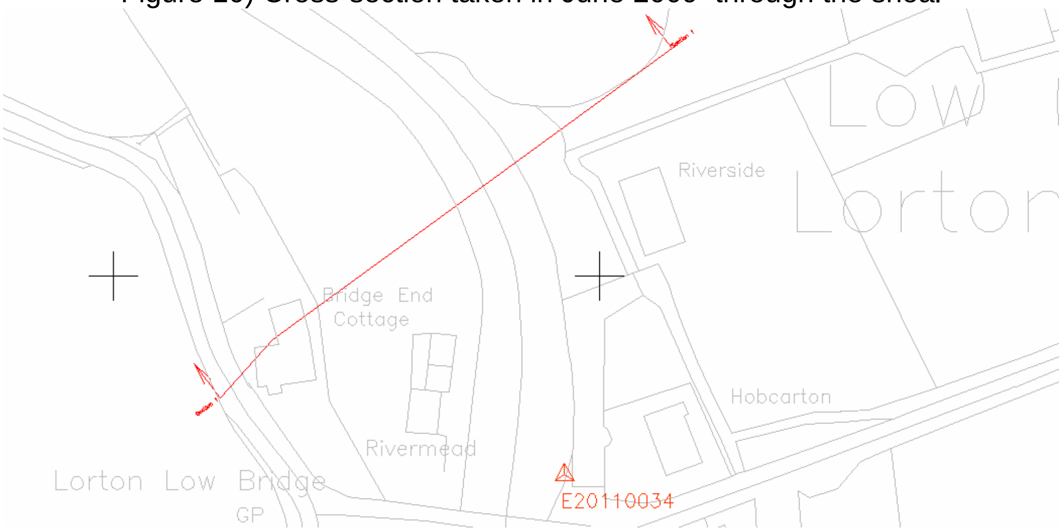

Figure 11) location of new cross-section.

<u>Objective 3) Future shoal growth</u>

The Accumulated shoal downstream of the bridge was scoured by the October 2008 event. However, this is a response to a significant magnitude flow event. Previously, there had been reports that the shoal was accumulating. However, the recent event shows that under high flow conditions the shoal scours and creates channel capacity (figure 12). This is due to the hydraulics of the bridge and downstream area. Under high flows, flow is confined by the bridge arches which increase velocity. This in turn increases scour force and on a large event is sufficient to entrain the material downstream. The reason why this works is due to the bridge and the stone covered banks and groynes on either bank just downstream of the bridge. These are fixed boundaries which deflect energy back into the river channel, and encourage entrainment and movement of the gravel in the mobile bed.

The shoal will undoubtedly accumulate over subsequent events. However, what has been shown is that the hydraulic conditions in this location are sufficient to encourage scour under high flow events. To this extent the shoal is self-cleansing.

The only concern is that the shoal might accumulate and subsequent events may not be of sufficient magnitude to entrain and convey gravel. The only real likelihood of this occurring may relate to an increase in sediment supply from upstream, or if vegetation forms on the shoal, preventing the shoal from being eroded.

Figure 12) From Low Lorton Bridge looking downstream (07/11/08)

Objective 4) Future management

As the shoal has been shown to be self-scouring under large magnitude flows due to the hydraulics (fixed bridge and hard wall boundaries downstream), it is recommended that gravel is not removed routinely at this location.

Figure 5 shows the degree of change in shoal level over time. The data show that the build up level of the centre shoal was up to 72.8 mAOD for the maximum elevation of the central shoal. The bed also accumulated up to 0.5 m of gravel, to a level of 69.6 mAOD. Given that the nature of the deposition is uncertain, the gravel shoal should be monitored on an annual basis. These levels should be modelled and if a significant impact on level is observed consideration for a selected removal (top-scrape) should be considered.

Trigger levels

The residents at Low Lorton are concerned to know what trigger levels would cause an impact on flood risk and thence trigger removal of gravel. This is difficult to define with certainty, due to variations in shoal deposition and structure. For example the recent deposition has shown bed and shoal accumulation, whereas in the past there has simply been shoal accumulation. Thus setting a simple shoal threshold is not possible for the location downstream of the bridge.
It should also be noted that the cross-section below the bridge is about twice (21 m) the width of the cross-section downstream at the corner (13 m); gravel deposition will occur in the over wide section.

Various scenarios were run in the model. Broadly, downstream of the bridge, it would appear that a build up to a level of around 69.5 mAOD, extending half or two-thirds of the channel, starts to have an impact on upstream water levels. However, we will undertake to monitor and model the gravel level annually to verify this, as deposition will be non-uniform, and then take action as appropriate. Monitoring locations are indicated in figure 13 and indicative trigger thresholds in table 1 (NB see note about modelling specific shoal/bed change above)

Cross-section location	Bed level (mAOD)	Shoal level (mAOD)
CKER02_4389	68.55	69.95
CKER02_4375	68.5	69.5
CKER02_4315	68.5	69.5
CKER02_4264	68.9	none
CKER02_4215	68.8	none

Table 1) indicative trigger thresholds

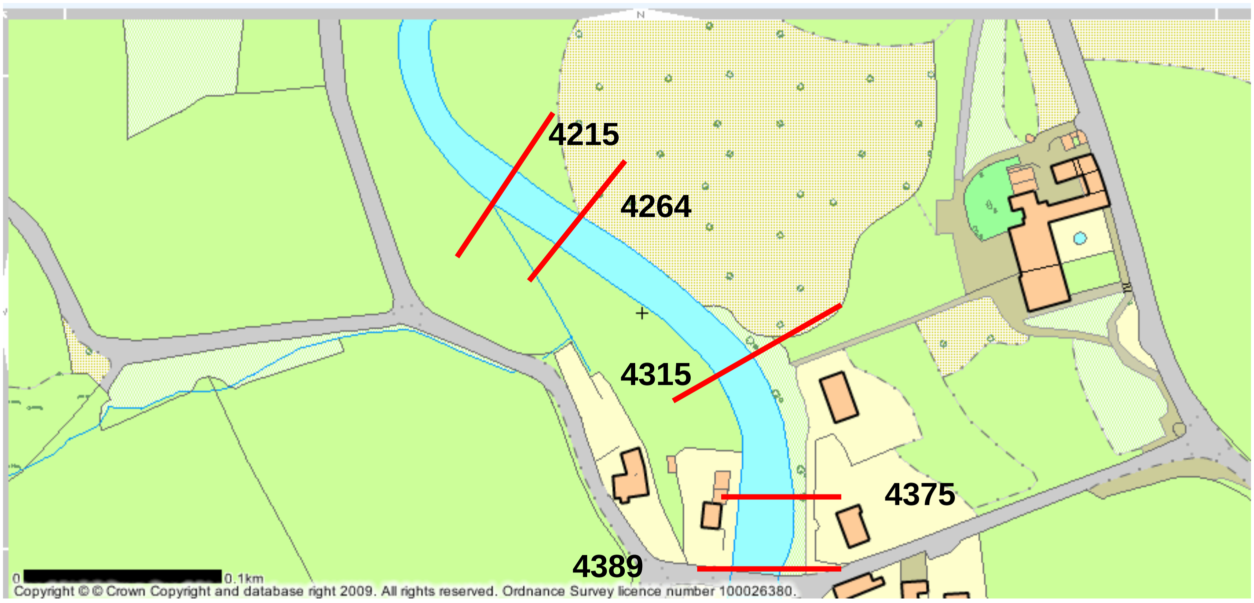

Figure 13) Location s for gravel shoal survey.

The shoal should be kept clear of vegetation, as vegetation build-up may decrease conveyance.

Glossary

AEP = Annual Exceedence percentage of occurrence. 1% AEP = 100 year flow. 50 % AEP = 2 year return.

JBA = Jeremy Benn Associates Consulting.

References

National Flood risk Mapping Framework : Derwent Villages Flood Mapping. Whit Beck at High Lorton, river cocker at Low Lorton. August 2008, JBA report for Environment Agency.

Kevin Frodsham, JBA, *pers. comm.* dated 21/11/08, file name 'Final_All_0.035_trimmed_v2.DAT' run using event file 'Q100_1SD_6.25.IED'.