Slowing the Flow Partnership Briefing: Boxing Day 2015 Flood Event

Background

Pickering was much in the news over the Christmas 2015 period with various reports about how well or not the Slowing the Flow project measures (www.forestry.gov.uk/fr/slowingtheflow) had protected the town from flooding. Some claimed that they had prevented major flooding as experienced in York, while others suggested that the measures had not been properly tested because whilst rainfall was significant it was less than elsewhere. This led to a discussion about the merits of the new approach to flood management being evaluated at Pickering, based on working with natural processes. The project had implemented a range of natural flood management measures (including tree planting, woody dams and moorland drain blocking) in the Pickering Beck catchment between 2010 and 2012, followed by the construction of a large flood storage area in 2014/15. This note reports the results of an analysis of the Boxing Day event to determine whether the rainfall was sufficient to generate a potential flood and, if so, how the project measures contributed to protecting the properties that would have otherwise flooded.

Event details

The first step was to quantify the volume of rain that fell during the Boxing Day event by analysing the records from local rain gauges. There are two gauges in the general locality, one sited at Brown Howe in the upper part of the Pickering Beck catchment, and a second at Keld Head in the neighbouring Costa Beck catchment. Unusually, the lower elevation, Keld Head gauge recorded a higher rainfall total than Brown Howe but its location is considered to be less representative of the Pickering Beck catchment. Consequently, the record for Brown Howe was selected for this analysis. This gauge recorded a total of 50mm of rain fall over a 36 hour period from Christmas Day, representing a marked albeit not an extreme rainfall event.

Next, the event was examined to determine if the amount of rainfall was sufficient to generate a flood. The propensity of rainfall to produce a flood depends not only on the overall volume of rain but also on its intensity and on how wet or dry the catchment is in advance of it starting (referred to as antecedent wetness). Unfortunately, no two rainfall events are the same but an assessment can be made of the likelihood of flooding by comparing the Boxing Day event with previous floods.

Event Date	Flow Peak (m^3/s)	Event Type (Peaks)	Rainfall Totals (mm)						Antecedent Conditions
			6 hr	12 hr	18 hr	24 hr	36 hr	48 hr	
Nov 00	16.9	Multi	20.4	30.4	39.6	42.6	48.8	66.8	Wet
Aug 02	13.5	Single	53.4	72.8	78.8	98.0	98.2	98.4	Dry
Jun 07	27.9	Single	41.2	68.0	78.0	81.4	98.0	99.8	Wet
Sep 08	12.0	Single	23.0	36.8	49.2	51.4			Average
Nov 09	12.1	Single	18.2	25.6	38.8	47.2	50.4	52.6	Average
Nov 12	11.8	Multi	17.4	28.6	33.6	33.8	44.0	59.6	Wet
Dec 15	9.9	Single	14.2	23.2	33.4	44.6	50.0	50.0	Wet

Table 1 – Comparison of rainfall totals recorded at Brown Howe and peak flows measured at the Ropery Bridge gauge in Pickering for all high flow events since 2000

Table 1 compares rainfall totals and resulting peak flows through Pickering, for all high flow events recorded since 2000. The two standout events were in August 2002 and June 2007 when between 80 mm and 100 mm of rain fell within a 24 hour period.

Despite the similarity of the rainfall totals, the 2007 event generated more than double the peak flow of that experienced in the 2002 storm, at nearly 28m^3/s, which led to a major flood in the town. The much lower flood peak in 2002 resulted from the drier condition of the catchment prior to the rainfall, allowing soils to absorb and retain more rain water.

The remaining five events displayed relatively similar rainfall totals, although they also differed in terms of peak flows. The second highest peak flow and notable flood was in November 2000, which accorded with the second highest 48 hour rainfall total of nearly 67 mm. It was also notable by following a prolonged period of wet weather, with almost 180 mm of rain falling over a period of 10 days, meaning that catchment soils were very wet.

The 2008 and 2009 events closely resembled each other and were the next highest in terms of 24 hour rainfall totals (~50 mm) and peak flows (~12 m^3/s). While the 24 hour totals were higher than in the 2000 event, the lower 48 hour totals and drier catchment conditions explained the lower peak flows.

The November 2012 event occurred shortly after most of the land management measures had been introduced, but before the flood storage area was built in 2014/15. Although the 24 hour rainfall total was the lowest, the 48 hour total and overall distribution of the rainfall were very similar to that of the November 2000 flood. Antecedent conditions were also very wet but base flows were lower prior to the start of the event. This suggests that the recorded peak flow of 11.8 m^3/s was not as high as might have been expected for the conditions, indicating that the measures may have had an effect on reducing flood runoff. However, a previous modelling analysis of the flow data was unable to demonstrate a reduction in the peak flow, partly due to the multiple peaked nature of the event.

The Boxing Day 2015 event was closest to those in 2008 and 2009 in terms of rainfall amount, with similar 24-36 hour totals of around 50 mm. However, antecedent conditions were much wetter owing to repeated heavy rainfall throughout December 2015, meaning that catchment soils were already very wet and probably close to saturation, reflected by the fact that base-flow was elevated at the start of the event. It is therefore notable that the recorded peak flow was much lower than during the other two events, reaching a maximum of 9.9 m^3/s. This suggests that the catchment measures reduced the expected peak flow by between 15-20%.

Analysis of Boxing Day peak flow and response of measures

Figure 1 shows the response of water levels recorded in the Pickering flood storage area in Newtondale, just upstream of Park Gate, during the Boxing Day 2015 event. The water level in the storage basin peaked at 22:15 on 26th December at 38.53 mAOD, which is approximately the same height as the top of the concrete inlet headwall visible in the photograph below (Plate 1). The photograph was taken at approximately 13:30 when the water level was at 37.9 mAOD, which is some 63 cm or two feet below the recorded peak level. Levels immediately downstream peaked at 37.27 mAOD, meaning a differential water level of 1.26 m across the control structure.

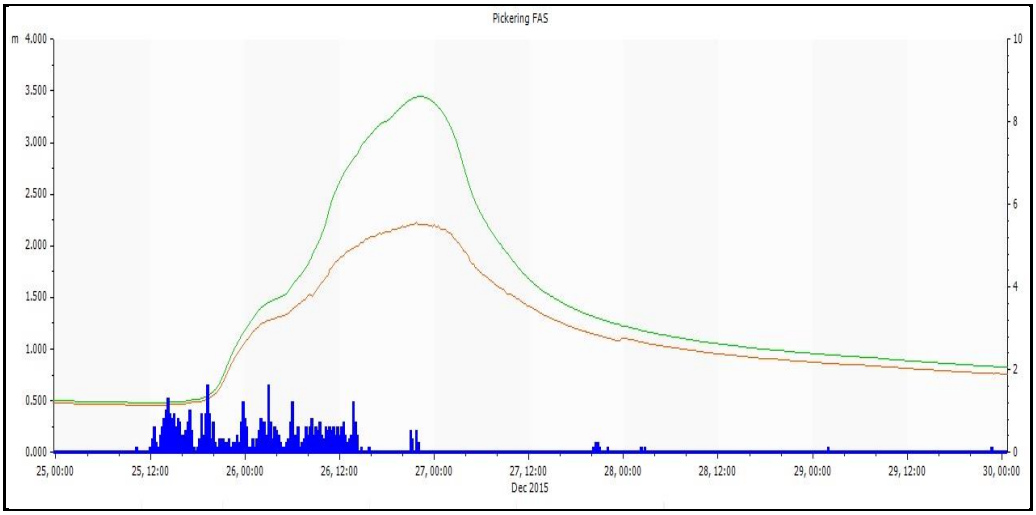

Figure 1 – Recorded water levels at the Pickering flood storage area (upstream (green) and downstream (red) of the flow control structure) in response to the Boxing Day rainfall event (rain (blue) measured at Brown Howe)

At the highest rate of rise, the flood storage area was filling at ~1.0 m^3/s. From analysis of this rate and evaluation of the known topography within the storage basin, it has been estimated that the maximum volume stored would have been in excess of 20,000 m^3, or 17% of the total capacity.

Plate 1 – View of flood storage area at Newtondale during the Boxing Day 2015 flood event.

Plates 2 & 3 – Views of water levels on Beck Isle during Boxing Day 2015 event

No properties were flooded in the town, although flood waters came close. Plates 2 and 3 were taken at approximately 14:30 on Boxing Day and show flood waters below the threshold of properties on Beck Isle (notice no flood doors were installed).

Other catchment observations also show that the Boxing Day rainfall generated a marked high flow event. Plates 4 and 5 were taken from a camera installed to monitor water levels at one of the two timber bunds on Sutherland Beck in the neighbouring catchment of the River Seven. The top image, taken at 14:03 on Boxing Day, demonstrates that water flows were sufficient to exceed channel capacity and partly fill the timber bund storage area. Flows remained out of bank for around 9 hours and the volume of water stored at peak flow was estimated by modelling at 120 m^3, approaching 10% of the total storage capacity of the bund.

The response of the timber bund conforms with related observations that the network of 167 large woody dams (LWD) in both the Pickering Beck and River Seven catchments worked as expected by impeding water flows so that the backwaters were forced out of bank. In fact, flows were sufficiently strong to structurally weaken two of the dams and shift material in another eleven. It is important to note that those affected were among the first sets of dams installed in 2010-11, when less attention was paid to securing logs in place. These results are helping to inform LWD design and maintenance needs.

Plates 4 & 5 – View looking immediately upstream of the lower timber bund on Sutherland Beck during the Boxing Day flood event (above) and after the event on 31st December 2015 (below).

Analysis of peak water levels in Pickering using hydraulic modelling

Details of the recorded peak flows and associated water levels at Ropery Bridge in Pickering for the four high flow events since 2008 are provided in Table 2. Property flooding in the town starts in the lower lying Beck Isle area when the water level at the Ropery gauge passes 30.87 mAOD. This critical flood level is achieved when flows approach 12 m^3/s.

Event	Flow (m^3/s)	Peak Level (mAOD)
Nov 09	12.1	30.91
Sep 08	12.0	30.90
Nov 12	11.8	30.87
Dec 15	9.9	30.72

Table 2 – Peak flows and corresponding water levels recorded at Ropery Bridge in Pickering for the last four high flow events.

Plates 6 and 7 were taken during the November 2012 event and show flood waters surrounding the Beck Isle properties; the flood doors have been installed and there is noticeably more water present than in the photographs of the Boxing Day 2015 event (see plates 2 and 3 above). This confirms the above understanding of the threshold for flooding in Pickering.

Plates 6 & 7 - Views of water levels on Beck Isle during November 2012 event

In order to further understand the Boxing Day 2015 event, the 'pre' and 'post' project scenarios were hydraulically modelled.

This was essentially a run of the current Pickering town (ISIS-TUFLOW) model, with two different inflows to produce modelled peak flows at Ropery Bridge of:

- 9.9 m^3/s – This being the observed peak flow at the gauge on 26th December 2015.
- 12 m^3/s – This being the flow expected to be observed for this event (based on rainfall intensity and antecedent conditions associated with the 2008 and 2009 events – see above).

An iterative process was undertaken, amending the main inflow into the top of the model and examining the flow hydrograph at Ropery Bridge, until peak flows here matched the 9.9 m^3/s and 12m^3/s peak flows.

Required flow at Ropery Bridge (m^3/s)	**Inflow into model (m^3/s)**	**Modelled flow at Ropery Bridge (m^3/s)**
	7	8.93
9.9	8	9.97
	9	11.09
12.0	10	11.89

Table 3 – Comparison of model fit with required/observed peak flows

The derived modelled flows of 9.97 m^3/s and 11.89 m^3/s for the two scenarios were considered a near enough fit to the observed/required flows of 9.9 m^3/s and 12 m^3/s, respectively and so deemed as suitable for the purposes of this assessment. However, it should be noted that the small discrepancy for the 9.9 m^3/s run will potentially overestimate the actual flood outline, while the reverse will be the case for the 12 m^3/s run.

With both model runs complete, the maximum flood depth outlines were extracted and mapped as shown in Figure 2.

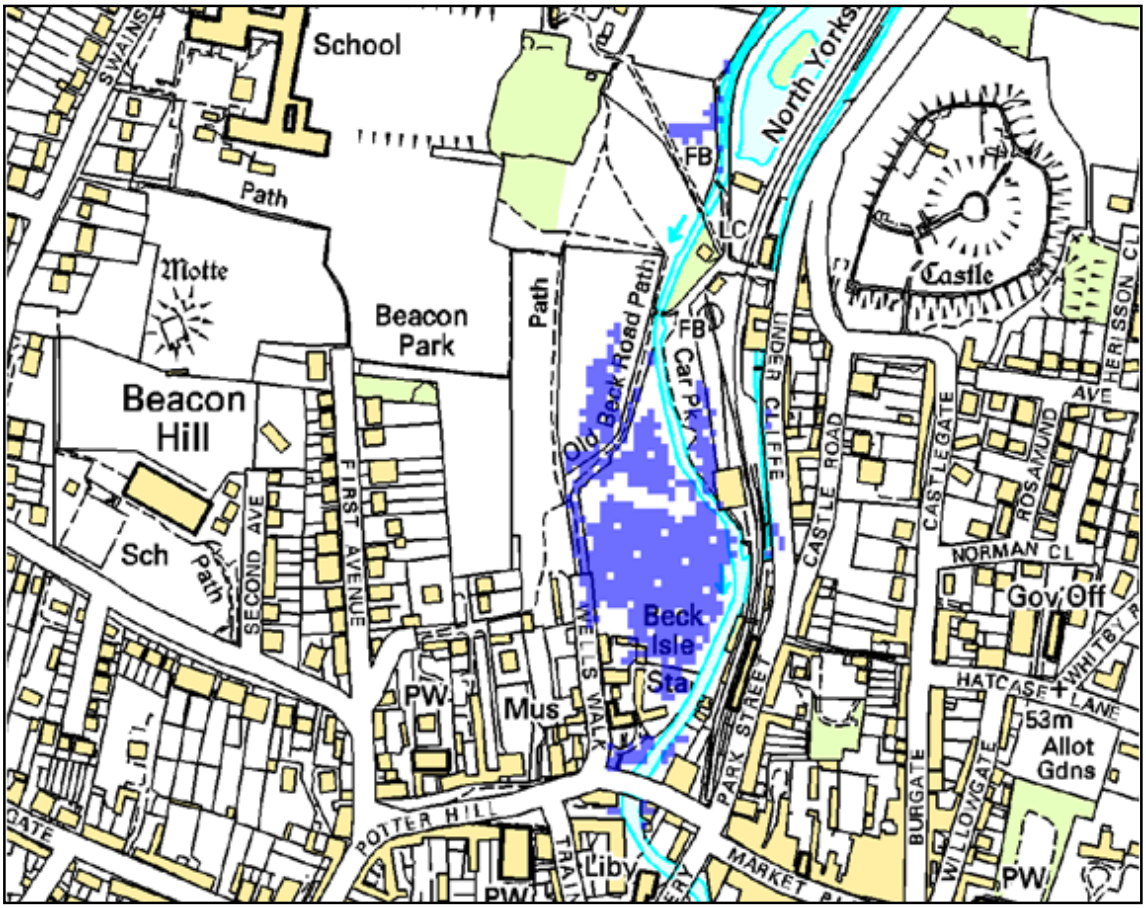

Figure 2a - Modelled flood outline for a peak flow of 9.9 m^3/s at Ropery Bridge

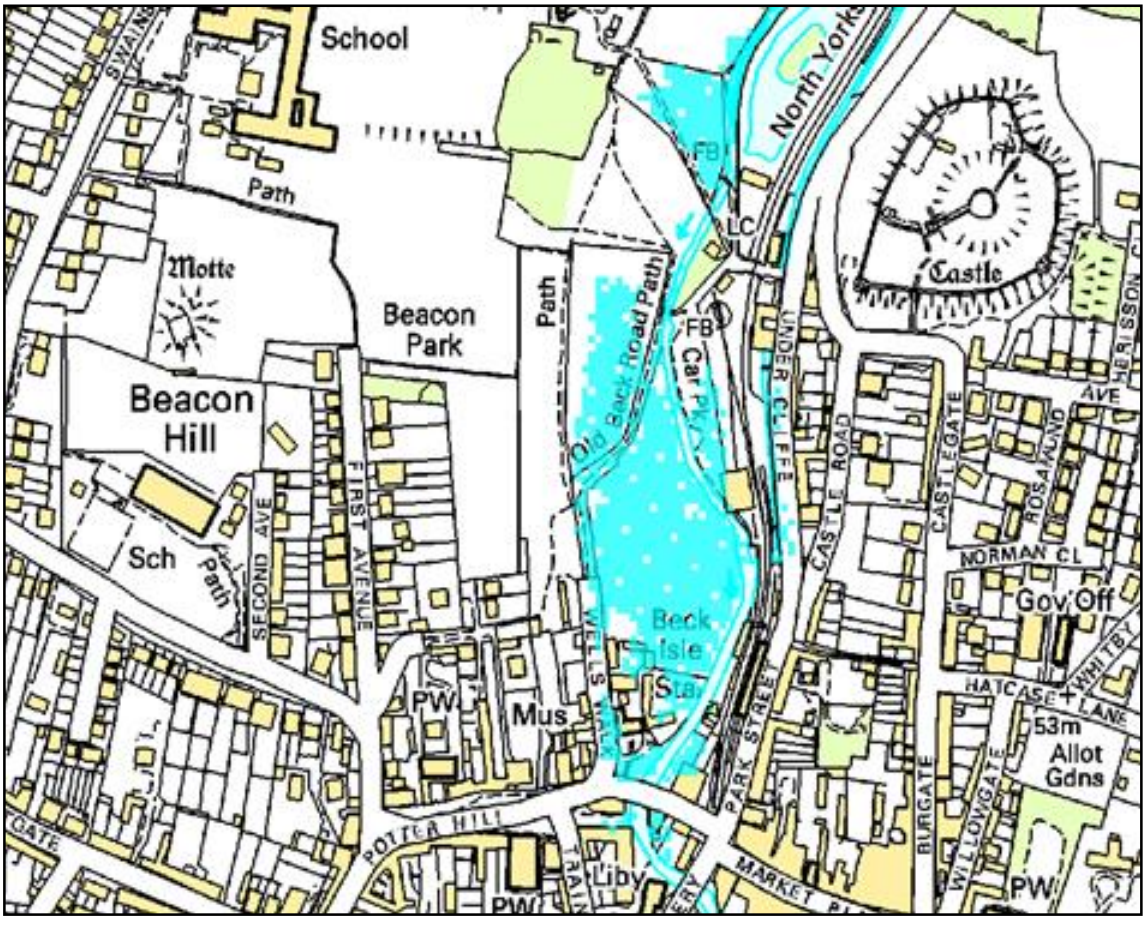

Figure 2b - Modelled flood outline for a peak flow of 12 m^3/s at Ropery Bridge

The maps show that the modelled 9.9 m^3/s flow gives a flood outline that is confined to open areas and largely away from buildings and properties. In contrast, the modelled 12 m^3/s flow outline indicates more extensive inundation, including around buildings and Wells Walk.

Conclusions

Based on a detailed analysis of the Boxing Day 2015 event in relation to previous peak flows, it can be concluded with a relatively high degree of certainty that the Slowing the Flow project measures prevented flooding that would otherwise have occurred to a small number of residential properties and the museum in the Beck Isle area of Pickering.

The results suggest that the measures reduced the peak flow by around 2 m^3/s or 15-20%. It is difficult to separate the contributions from the different measures but based on the extent of inflows to the flood storage area, it is estimated that around half of the reduction was due to the upstream land management measures and half due to the flood storage area.

If this reduction is sustained, properties on the Beck Isle may be better protected by the measures than expected. Originally, it was thought that Beck Isle would continue to flood with the same frequency as it has previously, due to the main effect of the flood storage area only becoming active once peak flows in the beck have reached 14.5 m^3/s. This is above the level of flow at which property flooding occurs on Beck Isle, and is the main reason why property level protection has been installed in this area. However, with the analysis of this event now complete it is understood that the controlling of pass-forward flows from the flood storage area and the wider measures noticeably affects flows through Pickering at a range well below what was expected, and one that corresponds with the threshold of flooding on Beck Isle. As a result, it is clear that peak flows and thus flood risk to properties on Beck Isle is being reduced by the presence of the Slowing the Flow measures, although it should be remembered that Beck Isle is not comprehensively protected by the flood storage area and as such properties here remain at a flood risk that is higher than that of the rest of the town.

Slowing the Flow Partnership
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