HR Wallingford
Working with water

HRPP 341

The Boscastle flood of 16 August 2004: Characteristics, causes and consequences

Dr CR Fenn, Dr R Bettess, Dr B Golding, FA Farquharson & T Wood

Reproduced from a paper published in:
Proceedings of the 40th Defra Flood and Coastal Management Conference
5th to 7th July 2005
University of York, UK

THE BOSCASTLE FLOOD OF 16 AUGUST 2004: CHARACTERISTICS, CAUSES AND CONSEQUENCES

Dr CR FENN[1], Dr R BETTESS[1], Dr B GOLDING[2], FA FARQUHARSON[3] & T WOOD[4]

[1] *HR Wallingford*
[2] *Met Office*
[3] *CEH Wallingford*
[4] *Environment Agency*

Abstract

On 16 August 2004, exceptionally intense and prolonged storm conditions centred over the North Cornwall coast and the headwaters of Bodmin Moor generated extreme flooding in and above the coastal villages of Boscastle and Crackington Haven. The event – which wreaked havoc and damage, but led to no direct loss of life – captured considerable media attention. *"What happened? Why there? How? How unusual was it? What's the risk of it happening again, there and elsewhere? What's being done?* [and yes] *Is climate change to blame?"* style questions peppered the press, and occupied the minds of many, at the time and after. This paper addresses the "what happened?" question. It reports on a flood forensics study carried out for the Environment Agency by HR Wallingford, with support from Halcrow, Royal Haskoning, The Met Office, CEH Wallingford and others. The event, from storm to runoff to flood to impact, has been reconstructed using best available evidence and applying best possible analyses (meteorological, hydrological and hydraulic). Propagation mechanisms – and features like the reported "walls of water" observed during the event - are investigated with a numerical model calibrated against evidence of peak water levels. Estimates are provided of the peak flow and peak water levels experienced, and their probabilities; these place the event amongst the most extreme ever to have occurred in the region and in the UK.

Key Words

Extreme rainfall, extreme floods, flood risk.

Introduction

Boscastle entered the UK's flood annals, in dramatic fashion, on 16th August 2004. Throughout most of the afternoon of that day - in peak summer holiday season - prolonged heavy rainfall centred over Otterham, on the edge of Bodmin Moor near the North Cornwall coast, led to severe flooding in a number of river catchments. Those most affected were the River Valency and the Crackington Stream, but flooding - and damage - also occurred on the River Ottery and the River Neet. Mercifully, no one was killed; but the event scarred the landscape, caused damage to buildings and infrastructure and has left an indelible mark on the local communities. As for the flooding of the small town of Boscastle itself, never has a flood of such ferocity been so widely witnessed and recorded, in the UK. So what happened?

The question – and derivatives like why there? and could it happen again? – requires review and analysis of the meteorology, hydrology, hydraulics and geomorphology of the event. Such studies were undertaken on behalf of the Environment Agency, by a consortium led by HR Wallingford, with a brief to report early findings within a few weeks and considered conclusions within a few months of the event. The work amounted to assembling forensic evidence, reconstructing the characteristics of the event and deducing its causes, on the basis of best available data and methods. The meteorology of the event was analysed by the Met Office; the hydrology by CEH Wallingford; the hydraulics and geomorphology by HR Wallingford. Halcrow and Royal Haskoning undertook post-flood surveys (in the Valency/Jordan and Crackington Stream catchments, respectively), and they and the Environment Agency assembled witness evidence from local interviews. The project team's final report (HR Wallingford, 2005) contains full details of the analyses undertaken and the conclusions reached. This paper provides a digest of issues and conclusions as to the causes, characteristics and consequences of the event; best estimates are provided, with necessary assumptions and unavoidable uncertainties declared openly. Whilst the full study deals with the event as it affected both the Valency/Jordan and Crackington catchments, for reasons of space this paper deals with the Valency/Jordan situation only.

The Catchment

Figure 1 below shows the geographical location of the Valency river and its tributaries above Boscastle; the locations shown refer to points at which inflow hydrographs were derived. The catchment is located on the north coast of Cornwall. The catchment area above Boscastle is approximately 20 km^2. The catchment rises to approximately 300m AOD and the main branch of the River Valency is approximately 7 km long. Thus the slope of the river is steep. There are a number of tributaries which are also steep, and some of them are incised as they approach the main channel. The soils are generally thin over impermeable bedrock. The catchment is predominantly rural with much of the land given over to grassland. There are significant areas of woodland adjacent to the main river and its tributaries.

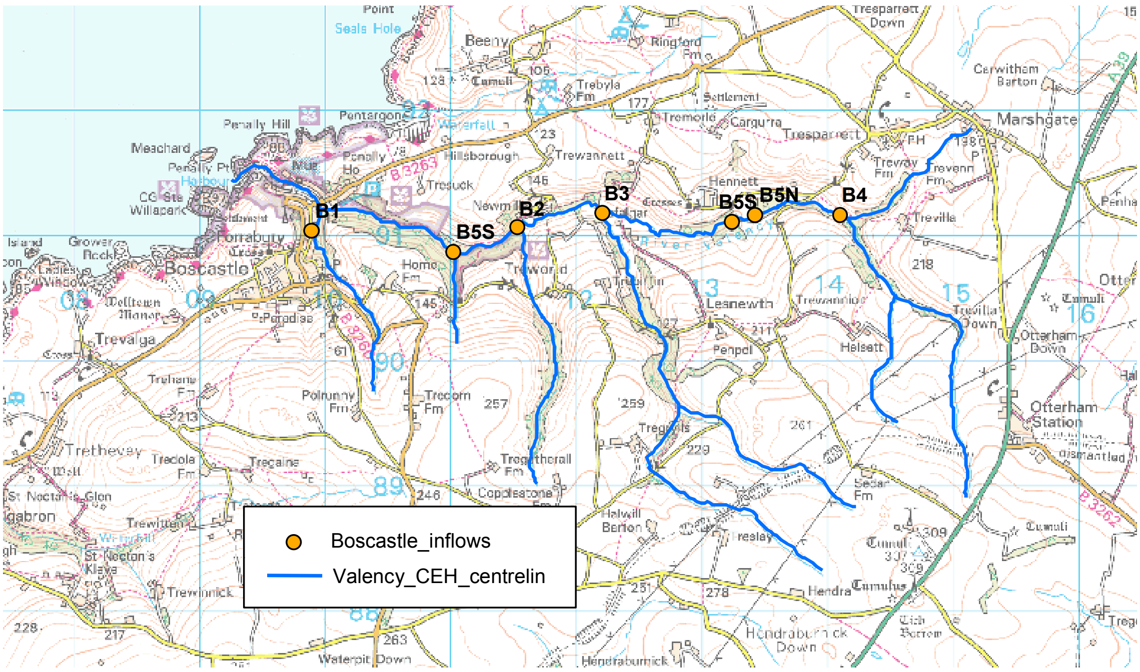

Figure 1 The Valency catchment above Boscastle, showing the river and main tributaries, and points at which inflow hydrographs for hydraulic modelling were calculated.

The flood event of 16th August 2004, as witnessed

The flooding of Boscastle on 16th August 2004 must be one of the best-recorded extreme flood events in the UK. Since the flood occurred during the day in the presence of many people, there is a good photographic record of the event. The prompt action by the Environment Agency in having the trash marks surveyed and in collecting eyewitness accounts following the event has added important qualitative and quantitative data. Inevitably there are gaps and inconsistencies in the accounts but for the most part we have extremely good information of the flood. The key features of the flood in Boscastle itself, from eye-witness accounts, may be summarised thus:

15:30 BST (1430 GMT): Flow begins to spill out of bank in the centre of Boscastle
15:45 BST (1445 GMT): The car park in Boscastle starts to flood.
16:00 BST (1500 GMT): Cars begin to be carried out of the car park by floodwater. Floodwaters are reported as flowing down a number of streets in Boscastle with depth and velocities sufficient to trap residents in their homes.
17:00 BST (1600 GMT): Floodwater depth and velocities are reported to be at/around their peak.
20:30 BST (1930 GMT): Floodwaters are reported to be back in bank.

The evidence indicates that the flood was out of bank for around 5 hours, rising to a peak (from the bankfull stage) in 1.5 hours. As the flood rose, some individuals reported very rapid, short-term rises in water level of 1 to 1.5 metres ("walls of water") in periods of a minute or less.

Post-flood surveys

Within two weeks of the event, HR Wallingford had made initial estimates of flood extent and hydraulic roughness at key locations around the catchment from walkover surveys, and Halcrow had surveyed cross-sections of the river and floodplain at key locations, and wrack-mark levels along the main rivers. Halcrow also made estimates of damage to property and infrastructure in Boscastle within days of the event. From such initial data, first estimates of the peak flow of the flood in Boscastle were placed at in excess of 150 m^3/s.

Reconstruction of the rainfall event

The area around Boscastle experienced extreme rainfall accumulations resulting from prolonged intense rain over a four hour period from 13:00 to 17:00 BST (1200-1600GMT) on 16th August 2004. The exact track of the rainfall cells varied slightly during this period, but between the Camel Estuary and Bude the variation was sufficiently small to ensure that the heaviest rain fell into the same coast-facing catchments throughout the period. The intensity of the precipitation was probably enhanced by large-scale uplift associated with larger scale weather troughs.

The synoptic situation at the time of the event was dominated by a large depression, with a complex structure of active development areas around it, in the eastern Atlantic. This structure reflected a history of successive pulses of tropical air being absorbed into the circulation, including former hurricane Alex. The effect of these larger scale processes on storm development would have been to create an environment of weak uplift and high moisture content, favouring extremely heavy rainfall. The extreme rainfall on 16th August 2004 resulted from a sequence of convective storms that were channelled along the north Cornish coast over several hours. Simulations carried out using 1km and 4km grid configurations of the Met Office NWP model all show a strong convergence line along the north Cornish coast. Satellite imagery indicates that convection developed upstream of Boscastle in the vicinity of the Fal estuary, but remained largely non-precipitating until it reached the convergence zone in the vicinity of the Camel estuary. Each storm cloud then developed rapidly to the equilibrium level, at 6.5km elevation. As they developed in the convergence zone, each of the storms spread out into a line of successive events spaced at intervals of about 5km, making the intense rain appear continuous, and apparently geo-stationary.

The recording rain gauge at Lesnewth confirmed the presence of variations in rain rate associated with these storms. The extreme precipitation in the vicinity of Boscastle appears to have been related to the fact that while convection was strong enough to generate heavy precipitation, it was shallow enough to permit development of closely packed storm cells with downdraughts weak enough not to distort the coastal convergence line.

The Tipping Bucket Rain gauge (TBR) at Lesnewth recorded maximum short period accumulations of 68mm in 1 hour, 123mm in 3 hours, and 152mm in 5 hours. Comparison with the quality controlled check gauge indicates that these should be increased by 20% to 82mm, 148mm & 183mm, respectively, to allow for under-reading by the TBR. The Lesnewth TBR also recorded a peak rain rate of nearly 300mm/hr at about 16:35 BST (1535 GMT). At Slaughterbridge and Crowford, the storm peaked shortly after 14:00 BST (1300 GMT), whereas at Lesnewth the heaviest rain was around 16:30 BST (1530GMT) and at Woolstone and Tamarstone the peak was not until 17:30 BST (1630 GMT). These differences resulted from slight changes in the position of the rain band.

Observations of the spatial and temporal pattern of precipitation were well captured by the Cobbacombe and Predannack radars. Maximum values over 4km^2 pixels differed from those observed by the TBRs due to sampling differences, but the overall pattern was consistent. The highly localised character of the event can be seen clearly in the sharp spatial gradients of the Cobbacombe Cross radar data, in Figure 2 below. Note the high values around the SW-NE track through Lesnewth and Otterham, and the sharp reductions in rainfall totals away from it.

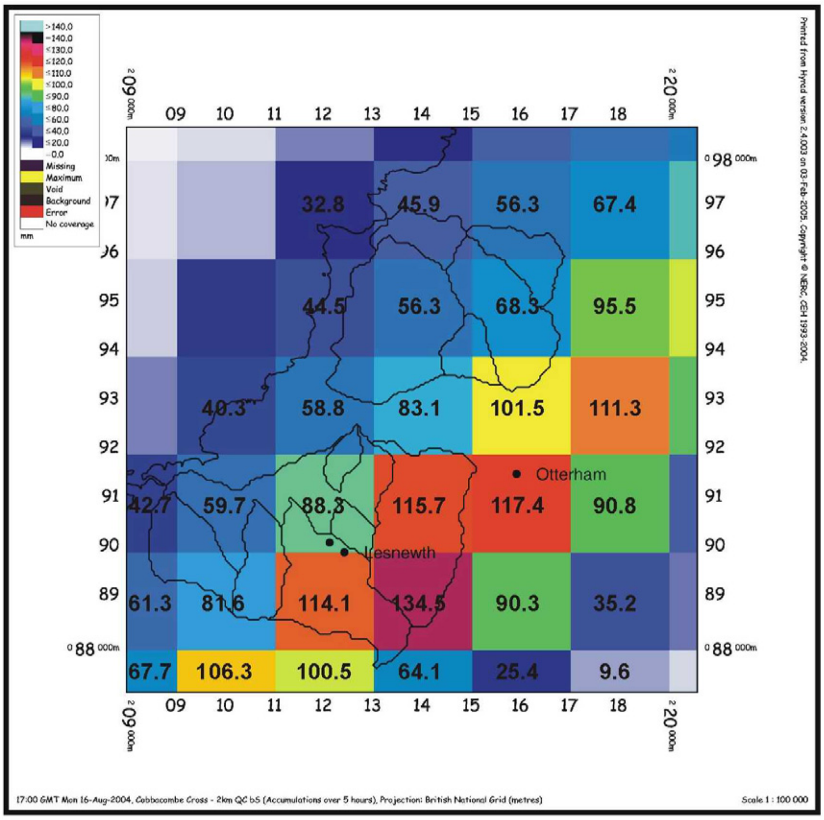

Figure 1 2 km gridded rainfall estimates based on data from the Cobbacombe Cross radar

The FORGEX method, as documented in the Flood Estimation Handbook (NERC, 1999), was used to assess the probability of occurrence of the observed rainfall. The adjusted, observed maximum one-hour fall at the Lesnewth TBR of 82 mm has an annual probability of occurrence of around 0.13%. This reflects a very high precipitation efficiency, associated with large scale synoptic forcing and the close packing of small individual storms. The three-hour total, again at Lesnewth, is comparable with the Camelford flood in 1957, and with several events in other parts of the country, most of which were accompanied by large hailstorms. The annual probability of occurrence is about 0.08%. The overall storm has an annual probability of occurrence less than 0.05%, which is larger, that is, less extreme, than that of the 1953 Lynmouth event and the 1955 Martinstown event. It is notable that all three events covered very small areas.

The South West peninsula has been subjected to six extreme rainfall events in the last century, of which three occurred in the decade 1951-60. The point ($1km^2$) probability deduced from an examination of these events indicates a similar annual probability to that derived using the FEH method. Allowing for the sparse observational network, the evidence indicates that an extreme rainfall event will occur somewhere in the South West region once every 20 years, on average.

Hydrological & hydraulic modelling of the flood event

Modelling strategy

Integrated hydrological and hydraulic modelling was undertaken to simulate, and thereby understand, the rainfall-runoff transformation and the development and passage of the resultant flood through the catchment. Using the available rainfall radar data as input, hydrological modelling was used to generate discharge hydrographs for selected sub-catchments of the Valency system. These flows were then routed down the catchment using a hydraulic model to generate discharge and stage hydrographs in Boscastle. Modelled stage hydrographs were compared with wrack mark and eye-witness accounts of flood levels, with the parameters of both the hydrological and hydraulic models being calibrated in reasonable fashion so as to achieve best-possible representation of the characteristics of the flood event by the hydraulic model.

Hydrological modelling

The currently accepted 'best UK methodology' for flood flow estimation is provided in the Flood Estimation Handbook (FEH; Institute of Hydrology 1999). Its focus and methods are geared towards more commonplace floods than those that affected the North Cornwall coast in August 2004, but it remains the only practical tool for modelling flood events on small ungauged catchments in the UK. The flooding at Boscastle from the Valency and Jordan catchments was very severe, and in consequence, difficult to reproduce reliably using FEH methods, as will be clear from what follows.

In the absence of flow records, the required parameters for rainfall-runoff estimation were determined using the standard FEH procedures for ungauged catchments. The required (spatially complete) rainfall data for the Valency catchment were derived from rainfall radar data, normalised to agree broadly with the adjusted rain gauge data. To obtain agreement with the best indications of water levels at given times and places (as obtained from eyewitness accounts and from wrack mark levels), it proved necessary to make a number of adjustments to parameters in the FEH method. To obtain reasonable agreement with best evidence flood levels, the time to peak had to be reduced by 50%, and the percentage runoff had to be adjusted, iteratively. The FEH constant percentage runoff (PR) was replaced by a time varying PR related to antecedent and developing conditions. PR at the start of the event was calculated using the FEH methodology, but was then increased as the storm proceeded, according to the formula given below, to reflect the progressive wetting of soils and the expansion of the variable contributing area of the catchment:

$PR_t = PR_{urb} * (1 + 0.8(\sum P_t/P_{TOTAL})$

where PR_t is the percentage runoff at time t during the storm, PR_{urb} is the FEH design percentage runoff derived from soil and storm rainfall total, $\sum P_t$ is cumulative rainfall from the start of the storm to time t, and P_{TOTAL} is the rainfall total for the entire storm.

The factor of 0.8 was determined empirically, as that needed to generate the necessary gearing factor to increase PR_{urb} from the FEH initial condition to the 85 to 95% values that probably prevailed towards the end of the storm. The high percentage runoff towards the end of the event, coupled with the steep slopes of the catchment, undoubtedly led to high volumes of fast flow running off from increasing areas of the catchment. The destruction of field walls, the under-mining of roads and tracks, and the washing away of fords in the upper parts of the catchment testify to the occurrence of significant, fast-flowing torrents running overland. The departures required from the standard FEH methodology were, in the circumstances, deemed reasonable and understandable.

Hydraulic modelling

Floodwater flows and levels were simulated with an INFOWORKS-RS model of the Valency river system. The model was constructed using post-flood cross sections and structure survey data. No pre-flood data was available. The observed pattern of flow through the streets of Boscastle was represented as a multiple channel arrangement, with flows through and between the various channels being controlled by appropriate spill structure placements and parameters. The downstream boundary of the model was set well upstream of the harbour, above tide and surge penetration levels. In the event, the flood peak occurred approximately 2h before high tide, but with a storm surge of 0.3m. Blockage of the two bridges in Boscastle was simulated by treating them as sluice structures, with partial and full blockage states being modelled to represent observed conditions.. The model was calibrated, on water level and timing, by reference to observed wrack marks, photographs, video and eye-witness accounts. Due account was taken of the possibility that early wrack marks may have become stranded above subsequent high water mark as bed levels and/or channel margins eroded as the flood progressed. As noted earlier, the available degrees of freedom in the hydrological and hydraulic phases of flood modelling were co-varied, iteratively, to achieve the net best possible (and believable) end result. In the event, it proved necessary both to vary the standard FEH parameters to produce flows of sufficient magnitude, and to model significant blockage of the bridges in order to match water level predictions from the model to the observed profile of peak water levels.

Figure 3 below shows the peak level calibration of the final model in the reach above its downstream boundary. The water level effects of the B3263 road bridge at chainage 350m and the smaller bridge at chainage 170m show clearly.

Figure 4 below shows the predicted discharge hydrograph at a number of locations in the catchment. The predicted peak discharge in the centre of Boscastle is around 180 m^3/s. This compares with FEH estimates of the Q_{med} (the median annual flow) at Boscastle of 4 m^3/s and of the 1% annual probability flow from FEH statistical modelling and rainfall-runoff modelling of, respectively, 10.4 m^3/s and of 34.8 m^3/s. The 2004 event was evidently exceptional in magnitude, and hence rare in occurrence, as well as unusual in origin.

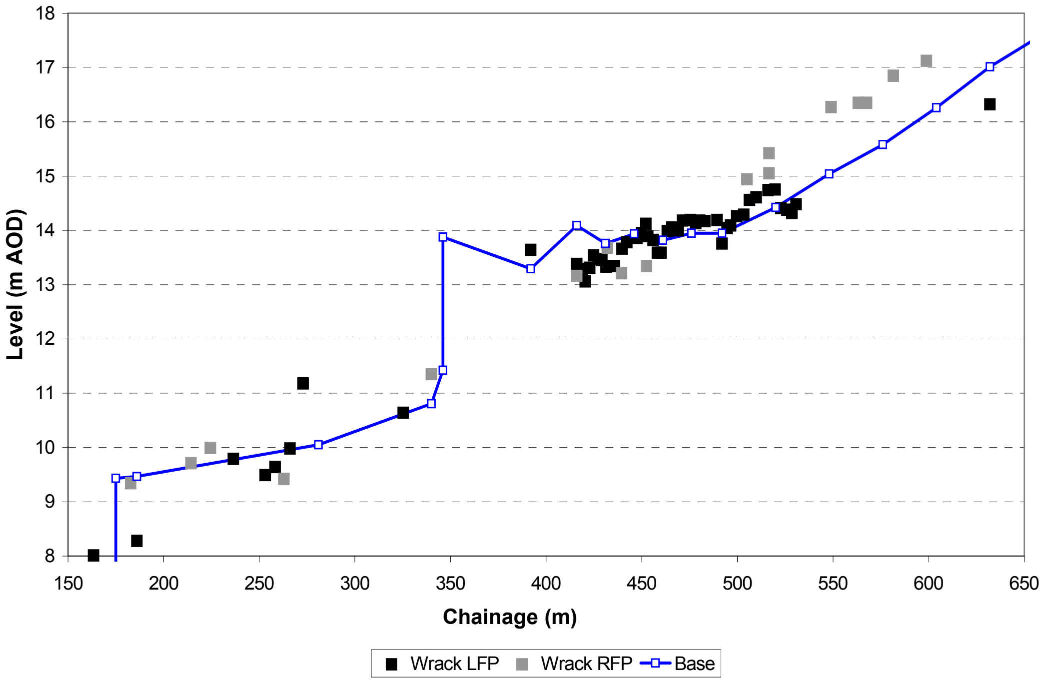

Figure 3 **Predicted water levels and observed wrack mark levels in Boscastle. LFP denotes a Left-bank Flood Plain wrack mark. RFP denotes a Right-bank Flood Plain wrack mark**

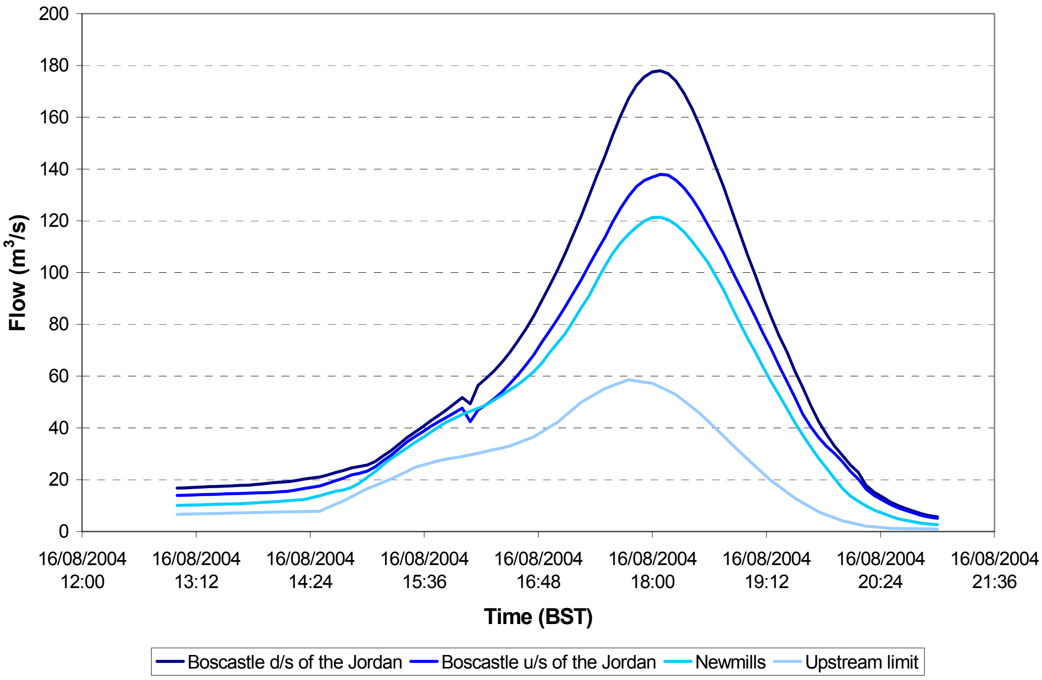

Figure 4 **Predicted discharge hydrographs at a number of locations in the catchment. New Mills is approximately 2 km upstream of Boscastle. The Upstream limit of the model is approximately 4.5 km upstream of Boscastle**

The exceedance probability of the 2004 flood

The history of flooding in Boscastle and elsewhere in the Valency catchment includes evidence of notable events as long ago as 1824. More recent floods occurred in 1950, 1958 and 1963. Using such photographic and witness account evidence as exists for these events, best estimates of peak discharge, based on reported water levels, are 90 m^3/s, 45 m^3/s and 40 m^3/s, respectively. Whilst these estimates must be treated with extreme caution, they suffice to indicate that the 2004 event, having an estimated peak flow of 180 m^3/s, was exceptionally large, and correspondingly rare.

A best possible representation of the flood frequency curve of the Valency/Jordan at Boscastle, derived from a combination of FEH statistical and rainfall-runoff methods, supported by historical evidence and considerable judgement, is given in Figure 5 below. A GEV Type II probability distribution appears to fit the Boscastle data and estimates best. It is clear that the 2004 flood event was a very extreme event. Its estimated annual exceedance probability was 0.30%, the equivalent of a 1 in 350 years return period. The GEV Type II curve indicates that the return period of an event of that magnitude might be as extreme as 1 in 450 years – an annual probability of 0.22%. On the basis of the available data, and recognising the uncertainties involved, it seems reasonable to conclude that the annual probability of a Boscastle-scale flood is around 0.0025. In other words, the 2004 flood had a return period of around 400 years, or a chance of recurring in any one year of 0.25%.

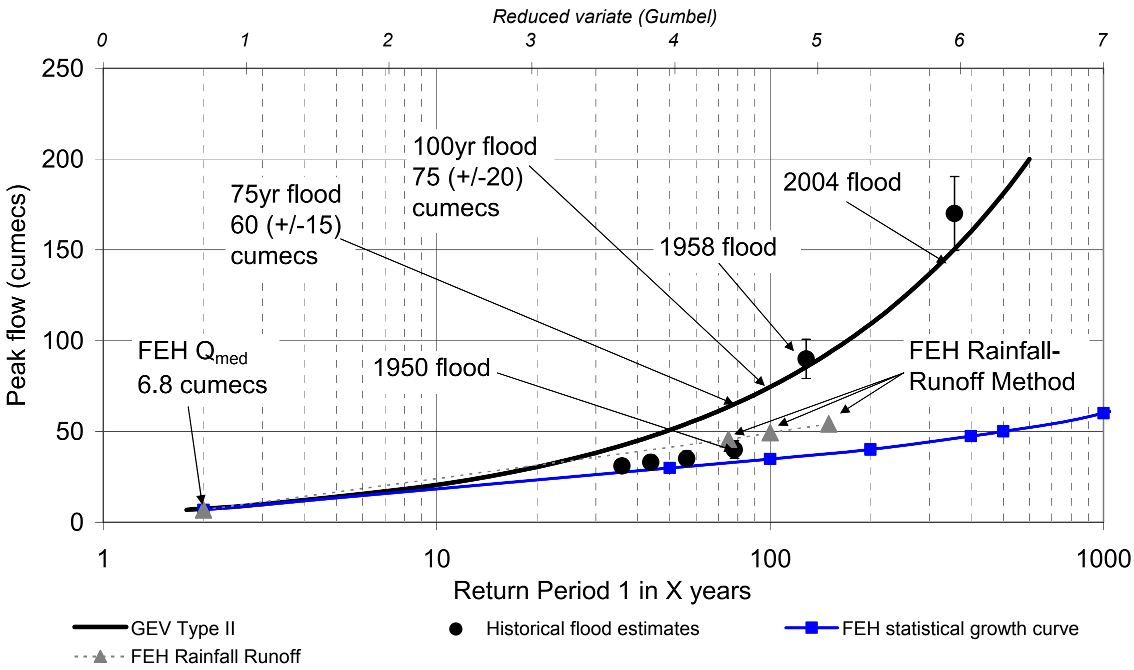

Figure 5 Estimated flood frequency curve for the Valency/Jordan catchment at Boscastle

Limitations and uncertainties of data, models and estimates

It will be clear that the various models used and the various estimates produced with them are based on a set of assumptions and are subject to a range of uncertainties, in both the base data and in the representation of physical processes and conditions within the models. Such is the nature of post-hoc modelling of exceptionally extreme events with insufficient data; but it is as well to declare limitations openly, in such circumstances.

It is clear from the rainfall radar data that the area of the rainfall event was limited, and that the spatial gradients of rainfall were large. The spatial resolution of the radar is only 2 km, which is coarse in comparison with the spatial gradients of the rainfall. In addition the catchment is near the limit of the area covered by the rainfall radar, and the data from the two rainfall radar stations do not always agree.

Hydrological and hydraulic modelling of such an extreme event is more uncertain still. The FEH method places proper reliance on available hydrological data, but there are little data available from similar catchments within the South West region, and for storms with the rainfall experienced in August 2004. Standard FEH methods had to be varied to simulate the extreme character of the rainfall-runoff processes experienced in the August 2004 event. Thereafter, the hydraulic model had to be constructed using post-event survey data, in the knowledge that wrack marks could not necessarily be relied on as peak water levels in a channel subject to such change as occurred during the flood. The division of flow down the various streets of Boscastle depends upon local features which are difficult to reproduce within a numerical model. The Froude number of the flows through the centre of Boscastle was relatively high, and this introduces numerical uncertainty into the hydrodynamic modelling. A further complication is added by the changes that took place during the event. The blockage of the bridges in Boscastle has already been discussed above. In addition walls and buildings were destroyed during the event. This means that a description of the topography of the floodplain at the start of the event is not appropriate for the end of the event. All these effects add to the uncertainty in the modelling.

As indicated above, there are many uncertainties associated with the modelling, but the results are deemed to be sufficiently robust to provide valuable information relating to the magnitude of the event and the probability of its occurrence. It is hoped that the problems experienced in reproducing such an extreme event will guide future model development and research.

Explanation of local hydraulic phenomena

Eyewitnesses testified to the occurrence of a number of transient, but significant, rises in water level at various places and times, during the flood. The most likely explanations for such local hydraulic phenomena would seem to be blockage of a flow route, with subsequent diversion or failure. To shed light on these observations, the hydraulic model was configured to test the impact of blockages of various types at various locations.

It will be recalled that to match observed peak water levels, the main B3263 road bridge had to be modelled as substantially blocked by flood-borne debris. Scenario testing with the hydraulic model indicated that rapid blockage of the bridge led to rapid increases in water level upstream of the bridge, and a significant re-distribution of flow into the streets of Boscastle. It seems reasonable to conclude that rapid blockage of the bridge could have led to sudden changes in flow route, and to rapid rises in water level.

Many observers believe that the rapid increases in water level they observed during the flood event were caused by the rapid and progressive failure of blockage or trash dams in a downstream sequence. This mechanism was deemed to have been significant in the Lynmouth event (Dobbie, 1952). Field observations certainly indicated that sizeable debris-dams or trash-dams had formed in the upper parts of the catchment, during the flood event, and that these dams had led to diversion (avulsion) of channels around them. To test whether such trash-dams could generate significant dam-break waves, scenario testing of dams of 1m and 2m height at a point 200m upstream of the Boscastle car park were introduced into the hydraulic model. Full details of the test may be found in HR Wallingford (2005). The results are summarised in Table 1 below. They indicate that failure of a 1m high dam would increase water levels in Boscastle by 0.055 metres; whereas failure of a 2m high trash dam would create a wave of 0.159 metres additional height. To create a water level rise of 1m to 1.5m, a trash-dam would need to have been of the order of 5 to 10 m in height. Whilst the possibility that trash dam failures may have contributed to fluctuations in water level cannot be ruled out, it would seem more likely that observed rapid rises in water level were due to local changes in flow paths resulting from such events as the rapid blockage of the bridge.

Table 1 Effect of hypothetical trash dams on local flood levels

Cross-section	Location	Level (m AOD)			Level increase (m)	
		No dam	1m Dam	2m Dam	1m Dam	2m Dam
12	Upstream of car park	17.501	17.556	17.660	0.055	0.159
8	Between car park and B3263 road bridge	12.230	12.263	12.323	0.033	0.092

Consequences of the flood

Geomorphological impacts

The flood of 16th August 2004 caused widespread and significant changes to the channel and valley geomorphology of the Valency and its tributaries, more so than in the adjacent Crackington Stream catchment. Field mapping has identified numerous instances of channel avulsion and lateral movement, and has revealed evidence of numerous debris jams and headcuts. Incision and bank erosion were commonplace, and in places were extremely severe.

In terms of their geomorphological impact, debris jams played a significant role and were often the instigator for avulsions and exacerbated bank erosion and incision. Much of the floodplain is wooded, with steep valley sides, and the flood flow was evidently funnelled down the valley with high velocities and stream power, up-rooting large numbers of trees and shrubs on the floodplain. The debris carried by the flow was then deposited in the channel and on the floodplain, where there were obstructions to the large woody objects passing, or where the channel slope reduced and the energy of the water reduced. These debris jams then instigated local changes in the geomorphology; if they blocked the channel completely they often resulted in avulsions; if not, then they caused a decrease in velocity and associated sediment deposition upstream and erosion and scour pools downstream.

The overall effect of these changes in geomorphology is that the river channels are now greatly oversized with respect to their mean annual flow. It is expected that in the months and years to come, the rivers will tend towards the re-achievement of an equilibrium channel form. It is expected that there will be aggradation in reaches where the post-flood slope is over-steep and further erosion of new channels where the flow is cutting through deposits or forming new routes where avulsion has occurred.

Damage to property

During the event there was substantial damage to property and to highway, drainage and other infrastructure assets. This was not limited to the Boscastle area. There was significant morphological change to the river channels throughout the catchment which led to fords and bridge crossings being washed away. High velocity flow down some of the roads caused significant amounts of damage, see Plate 3.

Plate 1 Trash blocking the original channel with the new channel in the distance to the left

Plate 2 Trash covering and blocking the main channel, which now lies under trash accumulation

Plate 3 Flood damage to road in upper Valency catchment

Risks to people

There were a number of features about the flooding in Boscastle that contributed significantly to the flood risk to people. The rainfall was worst in the upper part of the catchment and was significantly less in the centre of Boscastle, as can be seen from the data shown in Figure 2,: the rainfall radar data shows that Boscastle received 42.7 mm of rainfall, in comparison with 134.5 mm in the upper catchment. Thus the people in Boscastle were not fully aware of the severity of the rainfall event. The rate of rise of the flood was rapid. The river first went out of bank at about 15:30 BST (1430 GMT), but by shortly after 16:00 BST (1500 GMT) a number of the streets were impassable. An additional contribution to the risk came from the nature of the flow on the floodplain. In many situations, the floodplain predominantly provides storage and flow velocities are low. By contrast, in Boscastle the flow velocities were high. This meant that even when the water depths were relatively shallow it was not possible to wade through the flow. These factors contributed to the number of people trapped in buildings, despite their being only a short distance from dry land. In the centre of Boscastle, those trapped by the flow were generally able to retreat to the upper floors of buildings as the flood level rose. The risk to those people trapped in buildings was significantly increased by the large quantities of trash, in the form of both trees and cars, that were being swept along by the flow at high velocity. Impact by trash appeared to cause or contribute to the demolition of some of the buildings. This meant that even those people who were sheltering in buildings were not necessarily safe. Under the circumstances, it is perhaps surprising that there was no loss of life. The success of the helicopter air-lift, from the nearby base, was notable.

The experiences at Boscastle demonstrate that the risk to people is likely to be greatest where:

a) there is a rapid rise in water levels,
b) there are significant flow velocities on the floodplain
c) there are changes in flow paths during the event, which lead to rapid rises in local water level,
d) the presence of large debris moving at high velocities threatens the structural stability of buildings

Conclusions

Evidence and analyses indicate that the Boscastle flood of 16th August 2004 was unusual in origin, highly localised in extent and extremely rare in occurrence.

The rainfall event of the 16 August 2004 was brought about by an extremely unusual combination of circumstances: intense convective cells; an environment of high, low-level moisture content; quasi-stationary coastal convergence; large scale uplift caused by cyclogenesis in the area. Individually, none of these events is rare; but their combination is extremely so. Investigating the probability of the event in terms of analysing the likelihood of the same particular characteristics combining again is unlikely to be fruitful, as it is likely that any future extreme rainfall event will arise from a different combination of forcing mechanisms. Using FORGEX, it has been estimated that the annual probability of occurrence of the rainfall event is less than 0.05%. The South West peninsula has been subjected to six extreme rainfall events in the last century, of which three occurred in the decade 1951 to 1960. Allowing for the sparse observational network, the evidence indicates that an extreme rainfall event will occur somewhere in the South West region once every 20 years, on average. There is no apparent climatic variation that explains the predominance of extreme events in the 1950s, and it is concluded that this is due to natural variation. There is at present no clear-cut evidence to suggest that long-term climate change may be affecting the probability of such extreme events.

The flood event on the Valency was modelled using a combination of hydrological and hydraulic models. A number of changes had to be made to the standard FEH methodology in order to simulate the hydrological processes. The

Time to Peak had to be reduced to 50% of that predicted by using standard catchment descriptors. In addition a variable Percentage Runoff regime had to be used, which increased from an initial value determined through the standard soil and storm rainfall total calculated, but which then grew to 95% as the catchment wetted up and its effective contributing area expanded.

Observation that the bridges in Boscastle were substantially blocked by trash during the event was confirmed by the numerical modelling, to the extent that it had to be modelled with substantial blockage at peak flow, in order to fit model predictions to observed data. The modelling also suggested that the rapid blockage of the main bridge in the centre of Boscastle would have led to large and rapid increases in water level upstream as a result of changes to flow paths. This is a likely explanation of the reported rapid increases in water levels that occurred during the rise of the flood. The best estimate of the peak flow of the flood in Boscastle is 180 m^3/s.

Using a flood frequency curve derived from a combination of the FEH statistical and rainfall-runoff methods, supported by historical evidence and considerable judgement, the best estimate of the annual exceedance probability of the 2004 Boscastle flood has been assessed at around 0.0025; i.e. a flood of the assessed magnitude has a 0.25% chance of recurring in any year (equivalent to a return period of 400 years). It will be noted that, extreme as it is, the exceedance probability attached to the flood event is considerably greater than that attached to the rainfall event (which is deemed to have an annual exceedance probability of 0.05%). The different probabilities undoubtedly reflect the use of the different frequency estimation methods used for the rainfall and flood events. The rainfall event's recurrence probability was derived from application of the FORGEX method of the FEH, which results in a low probability estimate. As described above, the standard application of methods from FEH also provides a low estimate for the probability of the flood event (as can be verified by extrapolating the FEH statistical growth curve shown in Figure 5). The frequency estimate of the flood event was instead made by reference to the GEV Type II curve, which fitted the data much better.

The data and methods used to derive the estimates given are necessarily subject to caveats, as cannot but be the case when dealing with rare events. Notwithstanding, it is clear that the Boscastle flood was an extremely rare event. It could recur, but the probability of its recurrence is low.

Acknowledgements

The contents of this paper are based on a study carried for the Environment Agency by a team led by HR Wallingford. The meteorological work was undertaken by the Met Office; the hydrological work was undertaken by CEH Wallingford; the hydraulic and geomorphological studies were undertaken by HR Wallingford. Halcrow undertook the post-flood surveys in the Valency and Jordan valleys, and Royal Haskoning undertook those in the Crackington Stream catchment. The contributions of all parties and individuals involved, including those received from the people of Boscastle and Crackington Haven, are gratefully acknowledged.

References

Dobbie C H, 1952, Report on Lynmouth Floods, Devon River Board

HR Wallingford (2005) Flooding in Boscastle and North Cornwall, August 2004. Phase 2 Studies Report. HR Wallingford Report.

Institute of Hydrology (1999) The Flood Estimation Handbook.

NOTES

Fluid thinking...smart solutions

HR Wallingford provides world-leading analysis, advice and support in engineering and environmental hydraulics, and in the management of water and the water environment. Created as the Hydraulics Research Station of the UK Government in 1947, the Company became a private entity in 1982, and has since operated as a independent, non profit distributing firm committed to building knowledge and solving problems, expertly and appropriately.

Today, HR Wallingford has a 50 year track record of achievement in applied research and consultancy, and a unique mix of know-how, assets and facilities, including state of the art physical modelling laboratories, a full range of computational modelling tools, and above all, expert staff with world-renowned skills and experience.

The Company has a pedigree of excellence and a tradition of innovation, which it sustains by re-investing profits from operations into programmes of strategic research and development designed to keep it – and its clients and partners – at the leading edge.

Headquartered in the UK, HR Wallingford reaches clients and partners globally through a network of offices, agents and alliances around the world.

HR Wallingford
Working with water

HR Wallingford Ltd
Howbery Park
Wallingford
Oxfordshire OX10 8BA
UK

tel +44 (0)1491 835381
fax +44 (0)1491 832233
email info@hrwallingford.co.uk

www.hrwallingford.co.uk