Briefing Note: an assessment of the rarity of the November 2009 Floods

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On the 19th and 20th November 2009, prolonged heavy rainfall brought extensive flooding to many parts of the western UK and Ireland, with the worst flooding concentrated in west Cumbria. The towns of Cockermouth and Workington experienced particularly severe flooding which inundated large numbers of properties and caused transport chaos. A police officer died in Workington after a road bridge collapsed.

CEH scientists have been working to assess the rarity of the event using the latest statistical techniques. This work is ongoing, and two journal papers are being prepared for submission early in 2011. This short article provides a brief synopsis of some of the key findings. Some of this work was presented at the British Hydrological Society Fourth International Conference at Newcastle University in July 2010[1].

Rainfall

The flooding followed several days of heavy rainfall. However, it was triggered by an extreme rainfall event during which a total of 316.4mm of rainfall was recorded at the Seathwaite Farm raingauge in Borrowdale over a 24-hour period. This is a new UK record, exceeding the previous 24-hour value observed during the Martinstown, Dorset storm of July 1955 (Eden & Burt, 2010[2]).

The spatial extent of the extreme rainfall is shown in Figure 1, which illustrates that the highest rainfall totals were mainly experienced within the river catchments denoted by gauging station numbers 73010 (River Leven), 75003 (River Derwent), and 75004 (River Cocker). Extreme rainfall, exceeding 350mm over the 24-hour period, was focused almost entirely within the Derwent catchment that feeds into Bassenthwaite Lake before outflow at the Ouse Bridge gauging station (75003). Analysis of rainfall over the longer 37-hour period shows significant totals in the upper reaches of the Derwent and catchments to the east.

Recent research led by CEH[3] and funded by Defra has developed a new model of UK rainfall frequency. This model can be used to assess the return period, or average interval between occurrences, of observed storm events. The Environment Agency provided hourly and daily rainfall depths recorded in Cumbria during November 2009, and these were used together with the new model to estimate return periods for the rainfall amounts recorded at the Seathwaite Farm and Honister Pass raingauges.

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[1] http://www.ceg.ncl.ac.uk/bhs2010/index.htm

[2] Eden, P. and Burt, S. 2010. Extreme rainfall in Cumbria, 18-20 November 2009. *Weather,* **65**, 1, 14.

[3] Stewart, E. J., Jones, D. A., Svensson, C., Morris, D. G.,Dempsey, P., Dent, J. E., Collier, C. G. and Anderson, C. W.2010. Reservoir Safety – Long return period rainfall (two volumes). R&D Technical Report WS 194/2/39/TR, Joint Defra/EA Flood and Coastal Erosion Risk Management R and D Programme.

The results show that the 24-hour rainfall recorded at Seathwaite Farm up to midnight on 19/20 November has an estimated return period of over 1800 years, making it a very rare event. In contrast, the lower 24-hour total of 301.4 mm at Honister Pass has a return period estimated by the new model of about 400 years. This reflects the fact that this gauge is situated at higher altitude and records high rainfall depths much more often than the gauge at Seathwaite Farm, which lies in the Borrowdale valley.

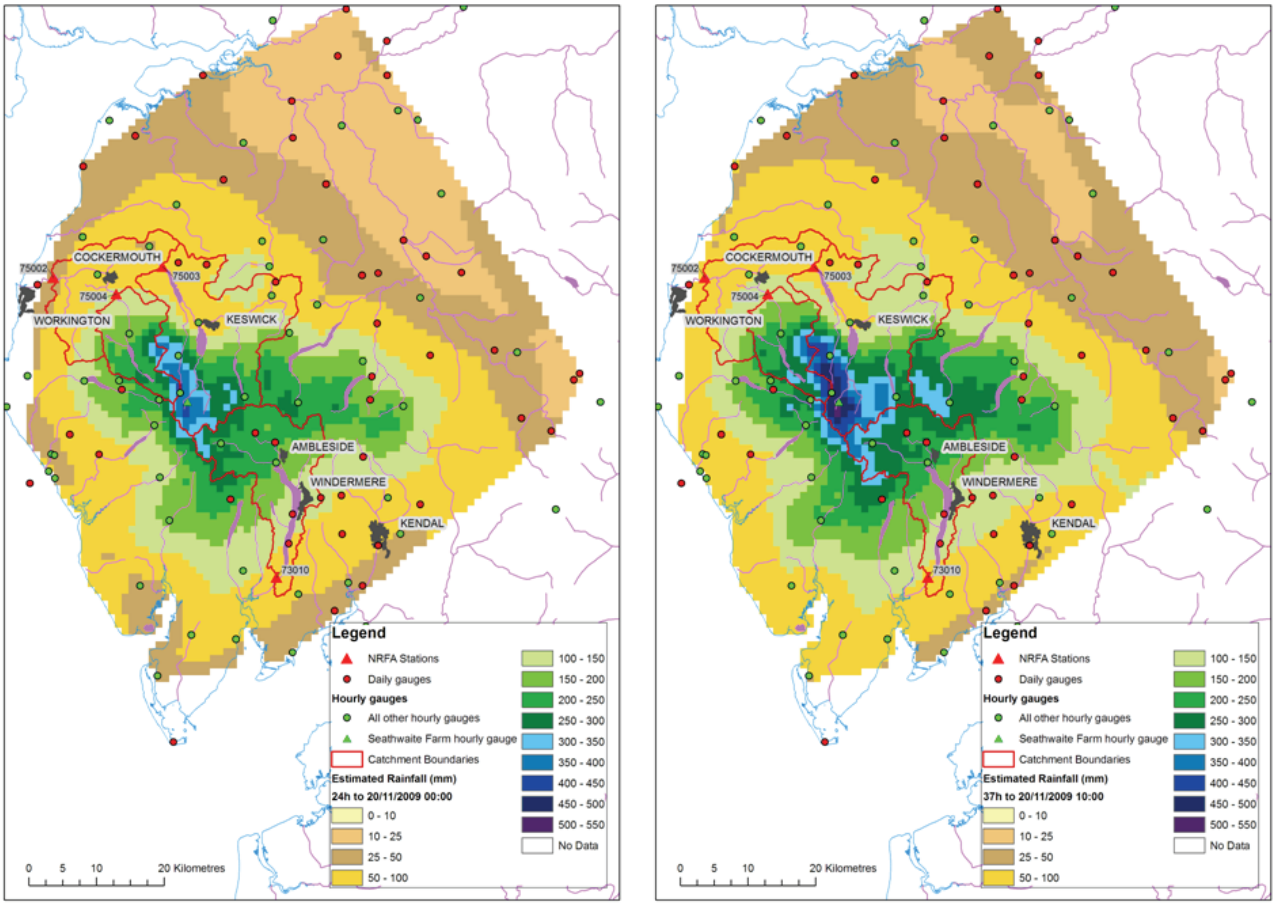

Figure 1: Gridded rainfall map for 24hr period ending 00:00 20/11/2009 and 37hr period ending 10:00 20/11/2009 (rainfall data provided by the Environment Agency)

River Flows

The extreme rainfall experienced across the northwest of England and southwest Scotland triggered widespread severe flooding. The peak river flows[4] recorded during the event were the highest on record at many gauged locations across the UK, but it was in Cumbria where the majority of the new records were observed: new peak flow records were established at 17 river flow monitoring sites in the county. The stations within Cumbria that experienced the highest flows are shown in Figure 2, expressing the November 2009 peak flow as a percentage of the

[4] Peak flow data for the 2009 event was provided by the Environment Agency and the Scottish Environment Protection Agency

previous highest. This highlights that the extreme flows were focused within the Lake District area, particularly those rivers which experienced the most extreme rainfall in their mountainous upper reaches. All of the most extreme flows, those registering more than 150% of the previous maximum, were recorded at stations downstream of lake systems.

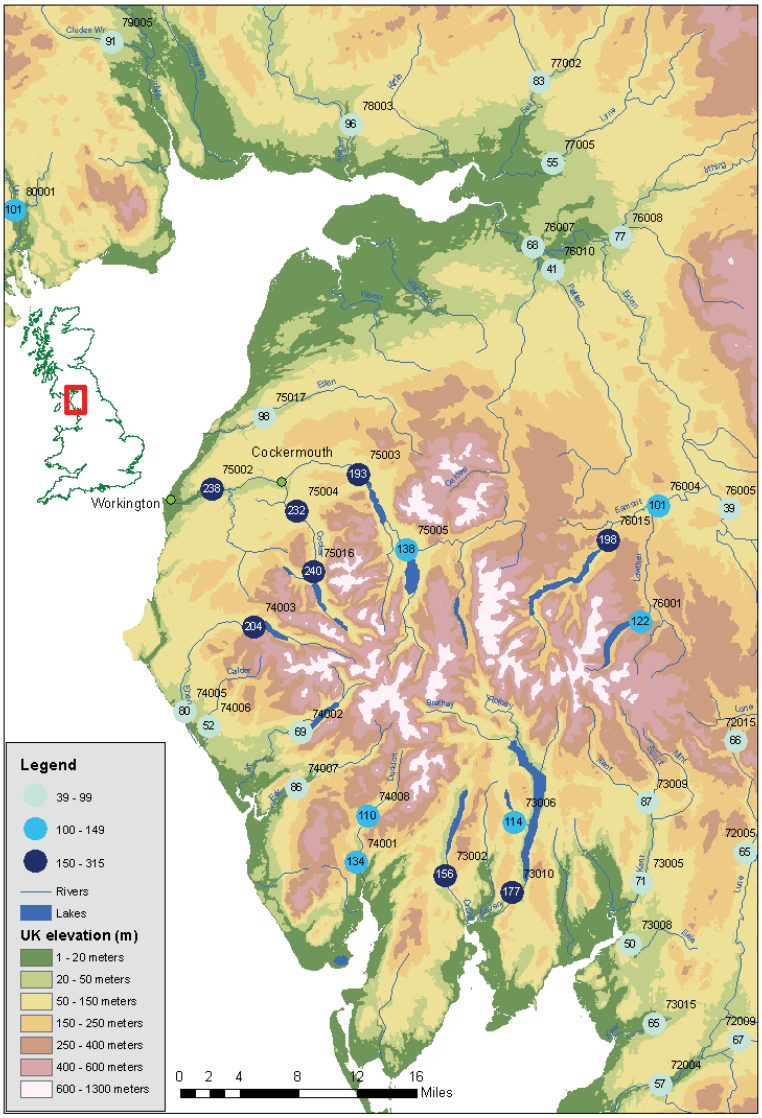

Figure 2: Peak flows during the November 2009 flood event; expressed as a percentage of the previous maxima (data supplied by the EA and SEPA)

The Cumbrian lakes had an important role to play in determining the impact of the extreme rainfall. Storm rainfall over the Lake District causes rapid flow from the hard rock, saturated thin soils and steep surfaces of the mountainous terrain. In a typical flood event, the lakes effectively act as giant storage tanks – they absorb much of the excess runoff from the mountains, smoothing out the 'flashy' runoff which flows into them thereby slowing down the flood response downstream. During the November 2009 event, the volume of water flowing into the lakes was so substantial that they filled up rapidly, and the levels in all the major lakes in the region reached the highest ever recorded; at Ullswater the levels exceeded the previous maximum by a metre. At

such high levels, the lakes were less able to store the vast volume of incoming runoff, and instead water was rapidly transmitted into the rivers downstream, causing a much more rapid flood response. This is illustrated in Figure 3, which compares flood hydrographs of stations immediately downstream of lake systems with those of stations without lakes in their catchments. Within all the lake-dominated catchments analysed, the November 2009 flood peak is substantially higher than all previous floods, and reaches more than four times the average annual peak. In the non-lake catchments, which experience flashy flows in response to rainfall events, the November 2009 hydrograph only exceeds the previous maximum on the Duddon catchment (74001). Undoubtedly this is in part due to the spatial distribution of rainfall across the region, but the comparison serves to illustrate the distinctly contrasting hydrological responses.

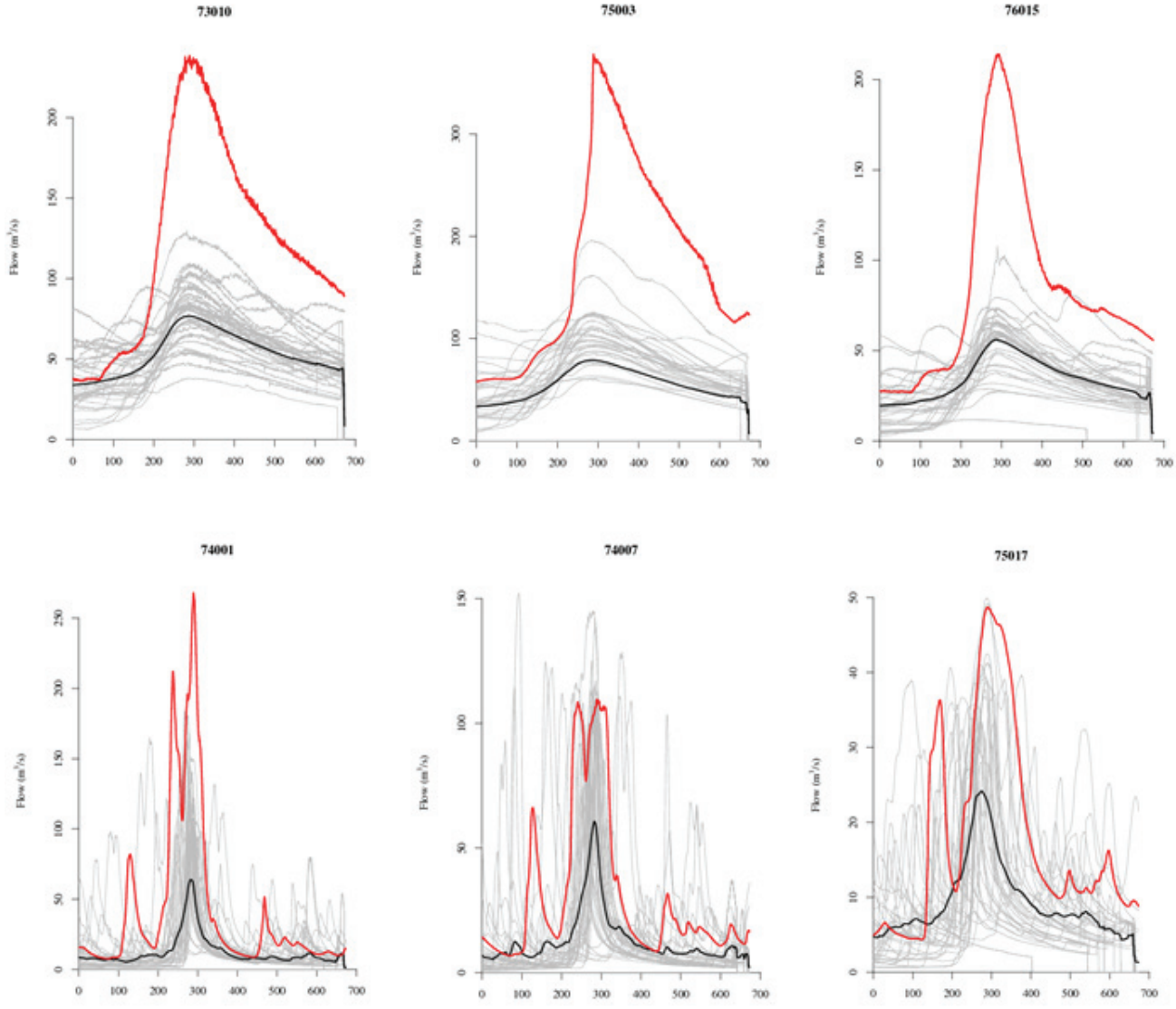

Figure 3: Flood hydrographs for stations downstream of lakes (above) and for stations for catchments with no lakes (below) - with the mean annual maximum flood hydrograph in black and the November 2009 event in red. The hydrographs of other observed annual maximum flood events are shown in grey. The units on the x-axis represent number of 15 min timesteps

The return period (RP), or average interval between occurrences, of a given flood magnitude can be assessed using the Flood Estimation Handbook[5] (FEH) methodology, the standard technique for flood frequency estimation in the UK. The FEH technique was recently updated as part of research conducted by CEH, and this latest generation of the method[6] was used to assess the return period of the peak flood flows recorded in Cumbria, for selected rivers in the area most affected by the extreme rainfall. Results attest to the extreme rarity of the event: at Portinscale (75005), downstream of Derwent Water, the estimated RP was over 100 years, whilst on the Cocker at Southwaite Bridge (75004), the estimated RP ranged from 500 to in excess of 700 years. On the lowest monitoring site on the Derwent, at Camerton (75002), close to the worst affected communities of Cockermouth and Workington, provisional analyses using several methods yield RPs ranging from 500 to in excess of 2000 years. The extraordinary nature of this peak flow is further underlined by an examination of the flood hydrograph at this location compared with previous observed floods (Figure 4).

With such extreme events, which eclipse previous flood peaks by such a substantial margin and where reliable measurement of the river flow presents a major challenge, return periods are subject to considerable uncertainties and should be used with appropriate caution. The unusual response resulting from the extreme lake levels in the November 2009 event also makes it very difficult to extrapolate from previous events where the lakes would have moderated downstream peaks. What is clear is that, on several Cumbrian rivers, the event was extremely rare indeed, and was certainly well outside the range of observed historical data.

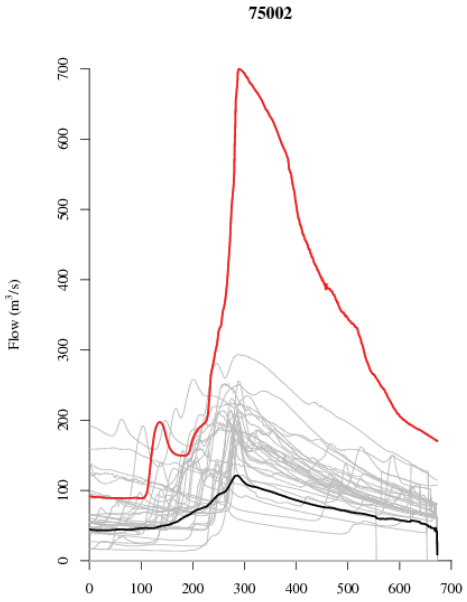

Figure 4: Hydrograph plot for Derwent at Camerton station (75002) - showing the mean annual maximum flood hydrograph in black and the November 2009 event in red. The hydrographs of other observed annual maximum flood events are shown in grey. The units on the x-axis represent number of 15 min timesteps

[5] Institute of Hydrology (1999) - The Flood Estimation Handbook. 5 volumes.

[6] Kjeldsen T. R. and Jones, D. A. (2009) A formal statistical model for pooled analysis of extreme floods. *Hydrology Research*, **40**(5), 465-480, doi: 10.2166/nh.2009.055.

Further information

National River Flow Archive

Understanding Floods - CEH Information Leaflet (PDF - 0.5mb)

Media enquiries should be directed to the **CEH Press Office**.

CEH scientists can provide explanation and analysis of historic flooding patterns, possible future scenarios under climate change and scientific understanding of the current flooding situation. We are not able to comment on immediate operational issues.

Some of the work reported in the briefing note was presented at the British Hydrological Society (BHS) Fourth International Conference at Newcastle in July, the proceedings of which can be accessed here **http://www.ceg.ncl.ac.uk/bhs2010/index.htm**

Historical information

Monthly hydrological summary for the UK - October 2009 (PDF - 2.03mb)

Monthly hydrological summary for the UK - November 2009 (PDF – 2.10mb)

CEH news story: **UK flooding situation - 20 November 2009** (updated 23 November 2009)