

1. Introduction

- Winter 2015/2016 was defined by a procession of severe storms, bringing extreme rainfall, and widespread flooding.
- There were severe impacts on properties, infrastructure and livelihoods across northern Britain.
- This paper¹ describes the hydrological characteristics, impacts, and historical context of the event.
- Meteorological aspects and records are explored in companion papers^{2,3}.
- The full National Hydrological Monitoring Programme report on the winter 2015/2016 will be published by November 2016.

2. Rainfall

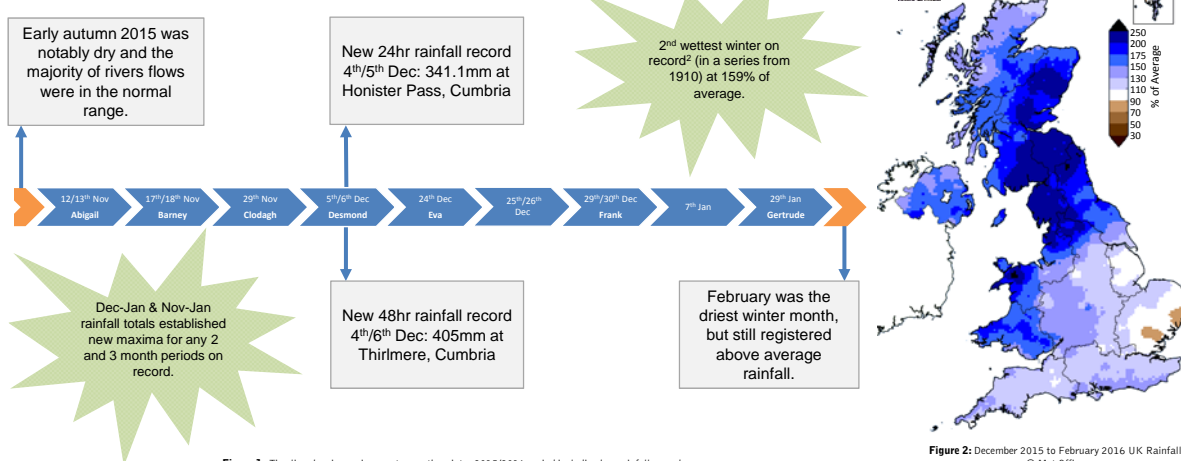


Figure 1: Timeline showing major events over the winter 2015/2016 period including key rainfall records

Figure 2: December 2015 to February 2016 UK Rainfall © Met Office

3. River Flows

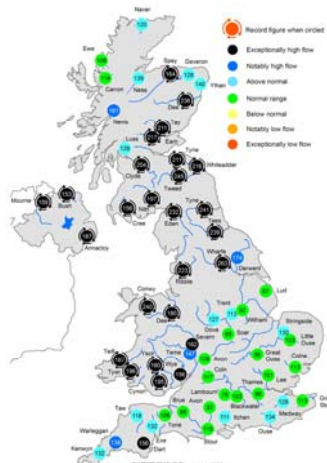


Figure 3: Average November 2015 to January 2016 river flows as % of long term average. New period of record maxima circled with arrows

- November to January mean flows (Fig. 3) show the widespread nature of peak flow maxima – with many catchments recording more than 200% of average.
- Great Britain outflows for winter 2015/2016 were the largest on record in a series from 1961 (Fig. 4).
- Highest recorded peak flow in the England & Wales instrumented record. The Eden, Lune & Tyne each recorded $\sim 1700\text{m}^3\text{s}^{-1}$ on 5th/6th December (Fig. 5).
- Return periods over 1-in-200 years in many catchments across northern Britain (Table 1).

Table 1: Selected new peak flow records established December 2015, and their associated return periods

River	Peak Flow (m^3s^{-1})	Date	Return Period
Scottish Dee	1362.5	30 th Dec	>200
Cree	476.2	30 th Dec	150-250
Eden	1680.0	6 th Dec	>200
Tyne	1730.0	5 th Dec	100-200
Lune	1740.0	5 th Dec	100-200
Wharfe	582.0	26 th Dec	>200
Calder	276.0	26 th Dec	>200

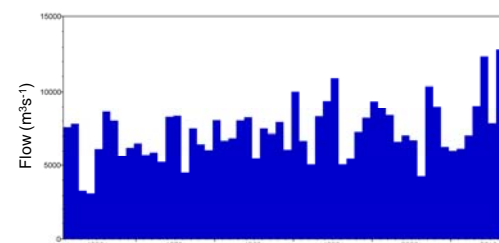


Figure 4: Average winter (December-February) outflows (m^3s^{-1}) for Great Britain

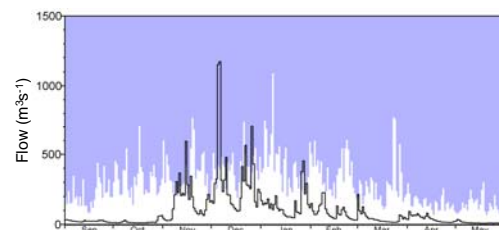


Figure 5: Daily mean river flows (m^3s^{-1}) September 2015 to May 2016 – Eden at Sheppmunt. Blue envelope shows previous daily maxima

4. Impacts

- **Flooding:** Widespread flooding across northern Britain, in rural areas as well as cities (e.g. Carlisle, Leeds, Manchester, York).
- **Property:** Approximately 16,000 properties flooded in England in December alone more than double that of winter 2013/2014 (7,000 properties flooded⁴).
- **Transport infrastructure:** Heavily affected with numerous roads, bridges, canals and sections of railway damaged and closed.
- **Business:** Nearly 5,000 affected businesses across Cumbria, Lancashire, Yorkshire, Greater Manchester & Northumberland.
- **Agriculture:** Extensive flood plain inundation, cattle swept downstream, 2,000 sheep were lost in Cumbria.
- **Cost:** At the time of writing, £200million additional investment pledged to aid recovery. Figures suggest pay-outs will be more than £1.3billion⁵.

5. Historical Context & Trends

- Events came only two years after winter 2013/2014 flooding, making these two winters the wettest on record for the UK (in records from 1910).

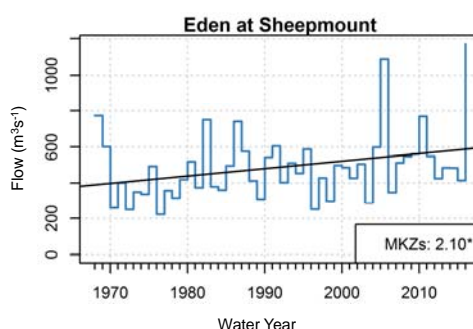


Figure 7: Trends in annual maximum daily flows. Trend line given by linear regression and evidence of monotonic trend by the non-parametric Mann-Kendall test

- As well as further demonstrating the exceptional nature of winter 2015/2016, Fig. 7 shows a statistically significant increase in high flows on the Eden in Cumbria (since records began in 1967).

- Currently little compelling evidence for any upward trend in long instrumented records of flood magnitude or frequency⁶.

- A 'real time' attribution study published in December 2015, claimed that the Storm Desmond rainfall was made 40% more likely as a result of anthropogenic warming⁷.

6. Summary

- Winter 2015/2016 was an extreme hydrological episode in many ways; new peak flow maxima were established across northern Britain; November to January runoff was exceptional in terms of its magnitude, duration and spatial context.

- As with previous events there was intense media coverage, some of it highly politicised; a particular focus on land use management and natural flood protection.



Figure 6: L: An RAF Chinook airlifts supplies needed to repair the Foss Barrier on the River Foss in York © Environment Agency
 R: Debris caught on metal fence at Ython at Eilon Gauging Station © Scottish Environment Protection Agency



References:

- ¹Barker, L., Hannaford, J., Muchan, K., Turner, S. & Parry, S. (2016) The winter 2015/2016 floods in the UK: A hydrological appraisal. *Weather*, (In review)
- ²McCarthy, M., Spillane, S., Walsh, S. & Kendon, M. (2016) The meteorology of the exceptional winter of 2015/16 across UK and Ireland. *Weather*, (In review)
- ³Burt, S. (2016) New extreme monthly rainfall totals for the United Kingdom and Ireland: December 2015. *Weather*, (In review)
- ⁴Muchan, K., Lewis, M., Hannaford, J. & Parry, S. (2015) The winter storms of 2013/2014 in the UK: hydrological responses and impacts. *Weather*, 70(2): 55-61
- ⁵ABP (2016). New figures reveal scale of insurance response after recent floods. www.abp.org.uk
- ⁶Hannaford, J. (2015) Climate-driven changes in UK river flows: A review of the evidence. *Prog. Phys. Geog.* 39: 29-48
- ⁷van Oldenborgh G., Otto, F., Haustein, K. & Cullen, H. (2015) Climate change increases the probability of heavy rains like those of storm Desmond in the UK: an event attribution study in near-real time. *Hydrol. Earth Syst. Sci. Discuss.* 12: 13197-13216