# Comparison of Storms Desmond, Ciara and 27th/28th October 2021 (Oct 21) Rainfall

## Main Conclusions

- Cumulative rainfall shows that the Oct 21 event was similar in scale to Desmond at Honister (370mm and 382mm respectively), but significantly less at Thirlmere (172mm and 405mm respectively).
- Thirlmere having space reduced peak flow and level of the River Greta at Keswick during the Oct 21 event (actual level 3.43m, modelled level if Thirlmere was full 3.7m).
- Had Thirlmere been full, the Oct 21 event would still have produced a much lower peak level at Greta Bridge, Keswick than Desmond or Ciara (3.7m, 5.345m and 4.237m respectively). As Ciara did not cause any serious property flooding, it is unlikely that the Oct 21 event would have.
- Had the rainfall pattern over Honister occurred over Thirlmere during the Oct 21 event (ie 370mm instead of 172mm), the resulting level at Keswick would have been ~4.3, very similar to Ciara, and therefore unlikely to have caused any serious property flooding.
- Comparison of daily averaged flows along the Derwent catchment during the Oct 21 event shows that had Thirlmere been full, the extra flows at Ouse Bridge (before Cockermouth) and Seaton Mill (Workington) could have been up to 25% and 15% respectively. Given that the peak river levels at both Cockermouth and Workington were above the level for possible property flooding, the extra flow if Thirlmere had been full, may well have resulted in flood damage to both towns.

## General Comments

Ciara rainfall was much shorter in duration that the other 2 events (17.5 hrs vs 36.75 hrs for Desmond and 38 hrs for 27th/28th October (now called Oct 21).

Oct 21 occurred after a dry summer with >6.5m space in Thirlmere, meaning that the Thirlmere catchment (42km$^2$ of a total 146km$^2$ above Keswick) played no part in the downstream flows.

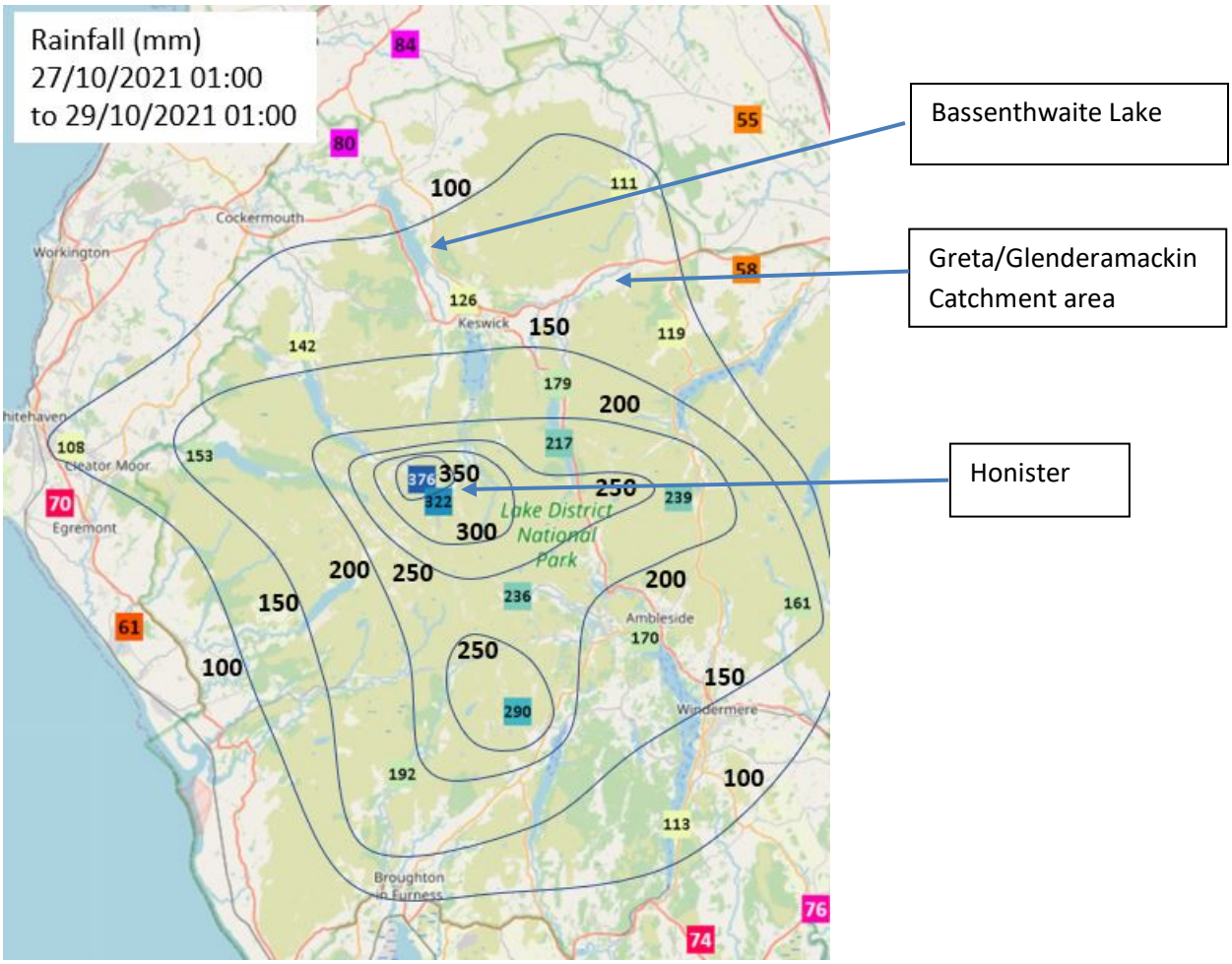
The concentrated nature of the rainfall during the Oct 21 event is well illustrated by the rainfall contour map below (curtesy of Dr Ed Henderson). This shows the particularly heavy rainfall over the upper areas of the Derwent and Cocker catchments (Honister), whilst much less over the Greta/Glenderamackin. catchment.

Thirlmere was overspilling prior to Desmond (~0.2m above the weir) meaning its catchment was part of the downstream flows throughout the event.

Thirlmere had ~0.4m of space at the start of Ciara, meaning that the reservoir captured the first 8 hours of rainfall in its catchment before overspilling. This resulted in a separation of peak flows from St John's beck (SJB) and the Glenderamackin, and hence a lower peak flow at Keswick that would otherwise have been the case.

Desmond resulted in widespread overtopping of flood defences in Keswick, with 515 properties being flooded.

Ciara and Oct 21 resulted in flooding of low lying areas (eg Keswick Campsite and rugby club) from Derwentwater, but no flooding from the River Greta.




All data below was supplied by the EA from the Real Time data API.

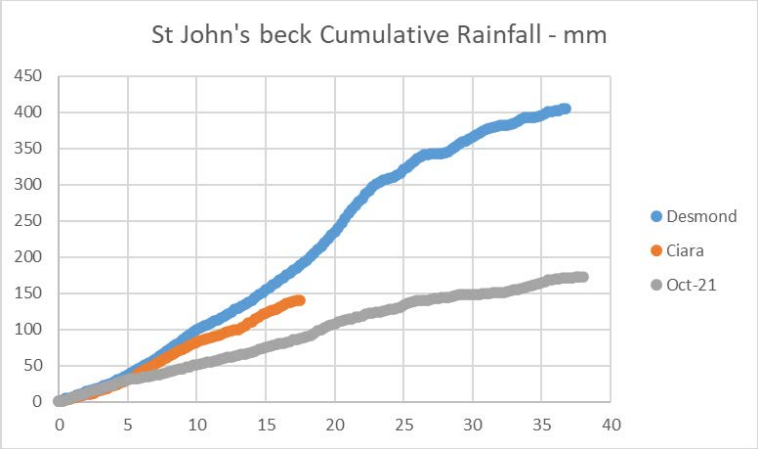
**Cumulative Rainfall**

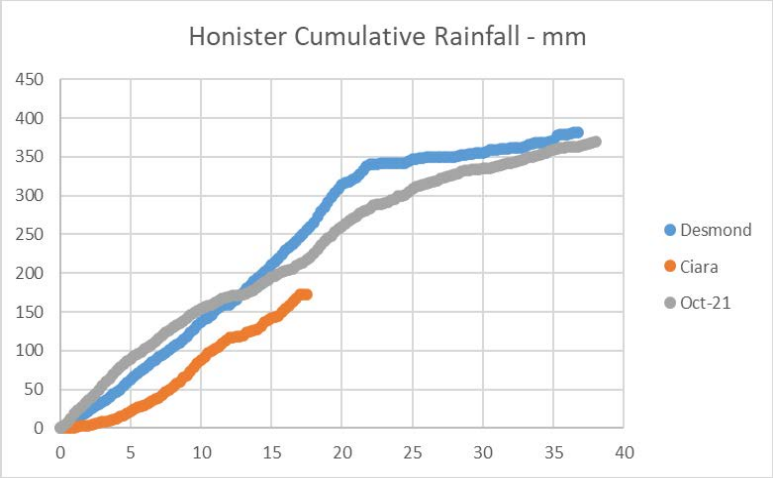
The graphs below show cumulative rainfall over the 3 events. Key points are:

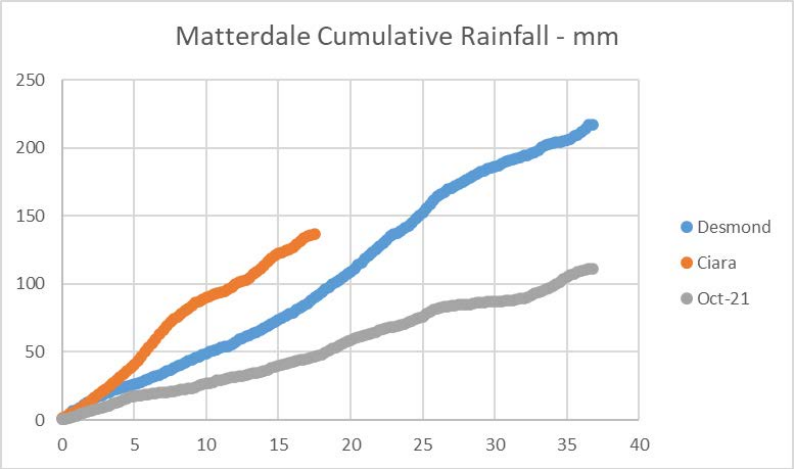
- Desmond had by far the greater rainfall over the Thirlmere catchment (SJB) and hence into the River Greta).
- Ciara matched the Desmond rainfall over the Thirlmere catchment for its first 10 hours, but then fell over slightly and ended much earlier. This, combined with the 0.4m space in Thirlmere at the start of Ciara, greatly reduced the impact of the flows on the Greta and hence Keswick.
- Ciara had the most intense rainfall over the Matterdale catchment, which feeds into the Glenderamackin via Mosedale beck and Trout beck. I do not have comparative data for the

other sections of the Glenderamackin catchments (eg Mundgrisdale and Threlkeld), however this is at least a partial explanation for the relatively high flow and peak level (see below for both) at Greta Bridge experienced the relatively short storm.

- Oct 21 had significantly less rainfall intensity over the Thirlmere catchment than Desmond and Ciara.
- Honister (inputs to Derwentwater and Bassenthwaite lakes, but not the Greta) were virtually equal for Desmond and Oct 21, and both more than double that of Ciara.



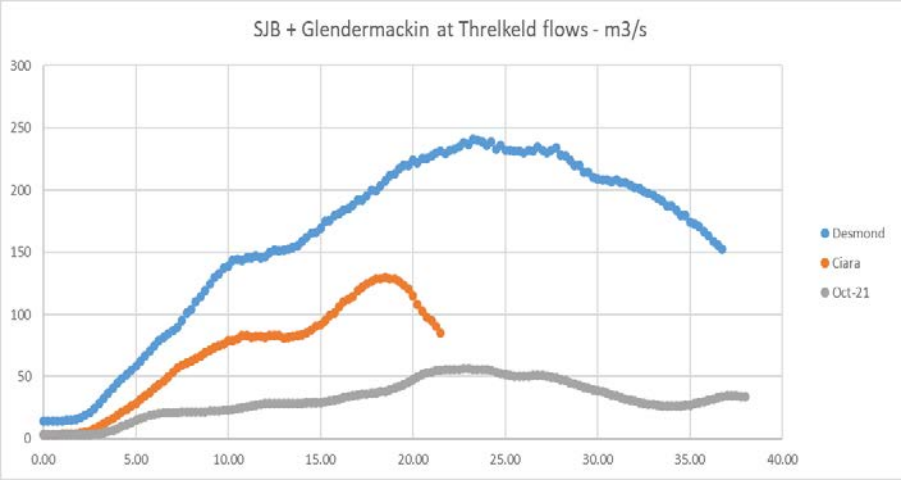






**SJB and Glenderamackin Flows**

The graph below shows the combined flows in the Glenderamackin at Threlkeld and SJB just downstream of Thirlmere (the 2 measured flows in the catchment). The following table shows the peak flow values and respective contributions of SJB and Threlkeld. Main points are:

- Desmond had by far the largest peak flow. These 2 flows combined contributed ~71% of the peak flow of ~340 $m^3/s$ recorded for the Greta at Keswick.
- Ciara peak flow was less than Desmond to the shorter duration of the storm and that Thirlmere was not overflowing at the start of the storm as was the case with Desmond.
- Oct 21 peak flow was much lower than both Desmond and Ciara due to the Thirlmere catchment not contributing.
- The contribution of SJB to the flow is hugely dependent on whether Thirlmere overflows during all or part of the storm.



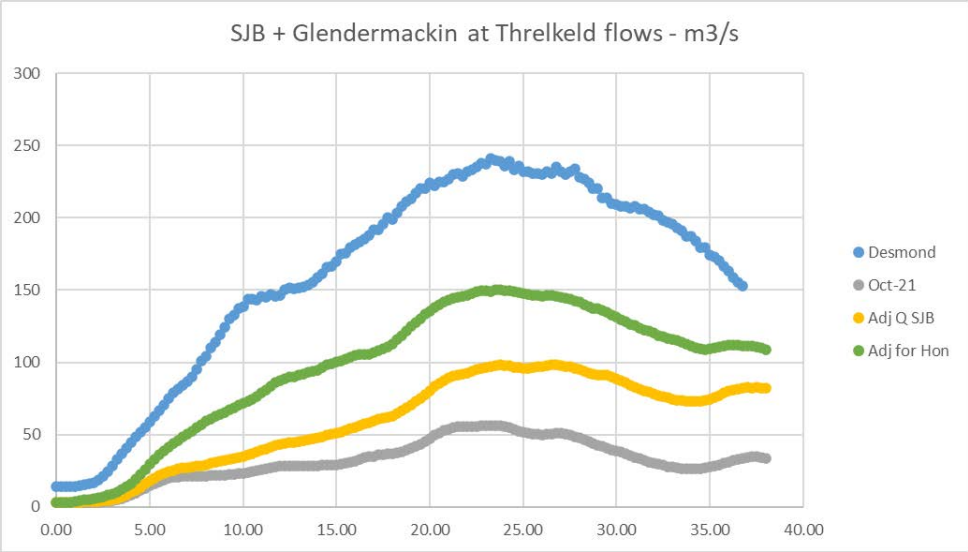
| | Peak flow | Contributions | |
|---|---|---|---|
| | m3/s | St Johns beck | Glenderamackin |
| Desmond | 241 | 46% | 54% |
| Ciara | 130 | 29% | 71% |
| Oct-21 | 56 | 2% | 98% |

**Modelling of Oct 21 Event**

I have used the Thirlmere water balance model created by Alistair Cook and Dr Ed Henderson to model the overflows that would have occurred from the reservoir in 2 scenarios:

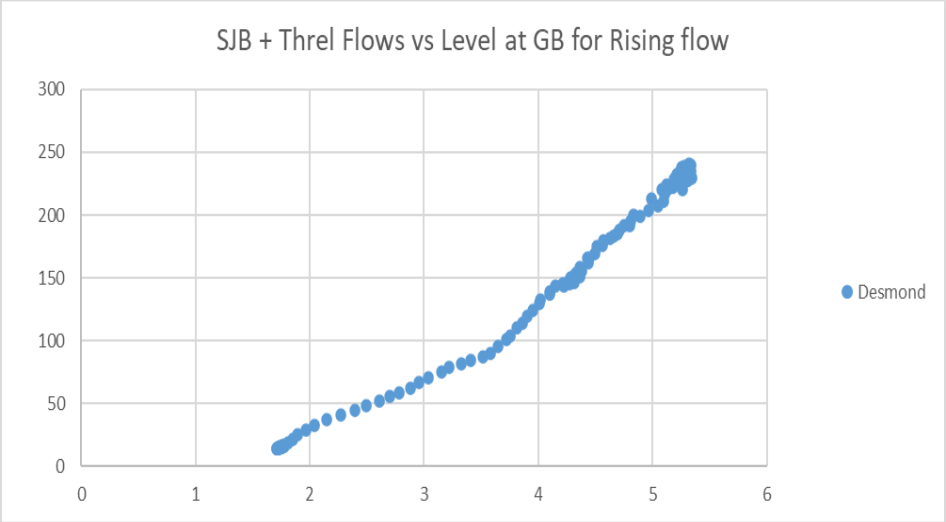
1. If Thirlmere were full (ie 16.55m) at the start of the event (yellow).
2. If Thirlmere were full (ie 16.55m) at the start of the event and the rainfall at Thirlmere was the same as that at Honister (green).

The graph below shows the resultant modelled sum of SJB + Glenderamackin at Threlkeld for each case, along with the recorded flows for Desmond and Oct 21. In both modelled cases the peak flows show significant increase, but are still less that that experienced during Desmond.




**River Greta Level at Greta Bridge**

Using data from Desmond, the graph below shows a good relationship between the level recorded at Greta Bridge (GB) and the total of the recorded flows at SJB and Glenderamackin at Threlkeld. This relationship holds for a rising flow and allows a prediction of the level at GB for a modelled rising or maximum flow.




This allows an estimation of the peak level at GB for each of the Oct 21 cases modelled above. The results are shown in the table below.

| Oct-21 | Greta Bridge Peak Level- m |
|---|---|
| Actual | 3.43 |
| Thirlmere full | 3.7 |
| Plus Honister rain | 4.3 |
| Ciara actual | 4.237 |
| Desmond actual | 5.348 |

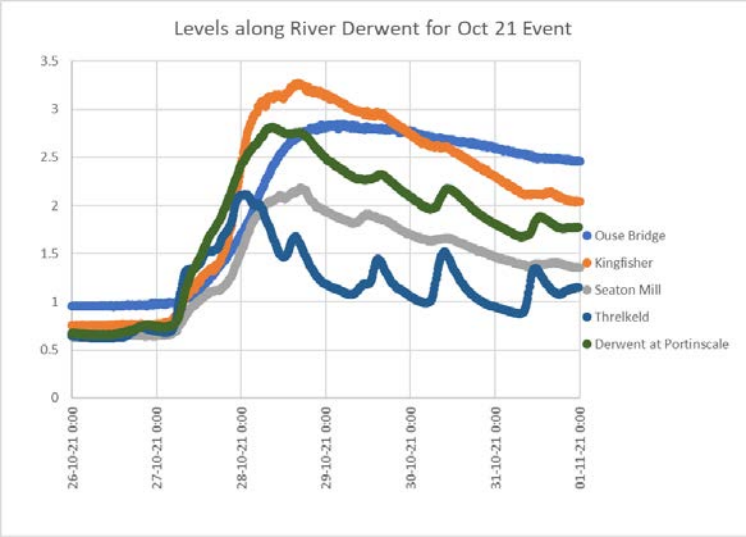
This shows that had the rainfall pattern during the Oct 21 event been centred over Thirlmere rather than Honister, but all other catchment rainfall staying the same, and the reservoir been full, the resultant level at GB would have been significantly higher, and above the level at which property flooding is possible (3.5m). However, overtopping of the flood defences at Keswick, which occurred at 4.75m during Desmond, would be unlikely.

**Qualitative Consideration for Cockermouth and Workington**

The graph below shows River Derwent peak levels at key measurement points out to Workington. The smoothing effect of Bassenthwaite on its input flows (Derwent at Portinscale, Threlkeld) can clearly be seen, along with the delay in peak flow of ~15 hours from Portinscale to Ouse Bridge.

The Derwent at Kingfisher (Cockermouth after the Cocker has joined the Derwent) showed a peak level of 3.27m at 17:15 on 28th October. This is above both the level that property flooding is possible (2.51m) and the level for flooding up to the sill at Waterloo Street floodgate (2.65m) but well below the Desmond peak of 4.54m (all taken from River Derwent level at Kingfisher, Cockermouth - GOV.UK (check-for-flooding.service.gov.uk). There are reports of 6 properties being flooded that day, as compared to 466 during Desmond.

The Derwent at Seaton Mill (Workington) showed a peak level of 2.18m at 18:15 on 28th October. This is just above the level that property flooding is possible (2.1m) but well below the Desmond peak of 2.67m. I do not know if any flooding was reported at Workington.




Had Thirlmere been full at the start of the Oct 21 event, the increased flow from the reservoir catchment would have caused increased levels at both Cockermouth and Workington. Using the daily averaged flows available from the DEFRA Hydrology Data Explorer website, the table below shows the averaged flows in $m^3/s$ at various points along the catchment. The final column shows the modelled (using the Water Balance model) averaged daily flow into St John's beck had Thirlmere been full at the start of the event (ie reached 16.55m at ~2am on 27/10/21). As can be seen, a full Thirlmere would have added an addition 30 $m^3/s$ over the course of 27/10/21 and 40 $m^3/s$ over 28/10/21. This additional flow would have been smoothed and delayed by Bassenthwaite (as discussed above) but could still have added up to ~25% extra flow at Ouse Bridge and ~15% at Seaton Mill (allowing for ~24 hour delay) based on the figures in the table below.

| Oct 21 Event Daily Average 9am-9am | Glenderamackin at Threlkeld | St John's beck | Derwent at Ouse bridge | Derwent Seaton Mill | St John's beck - Thirlmere full |
|---|---|---|---|---|---|
| 24-10-21 | 2.63 | 0.319 | 12 | 22.7 | 0.319 |
| 25-10-21 | 2.68 | 0.319 | 13.4 | 21.9 | 0.319 |
| 26-10-21 | 4.38 | 0.426 | 14.3 | 27.7 | 0.426 |
| 27-10-21 | 37.6 | 1.24 | 44.8 | 178 | 29.8 |
| 28-10-21 | 21 | 0.979 | 146 | 327 | 40.3 |
| 29-10-21 | 15.3 | 0.719 | 147 | 249 | 21.5 |
| 30-10-21 | 12.3 | 0.598 | 121 | 194 | 14.7 |

The effect on peak flows and peak levels would be less than the numbers above, due again to the smoothing effects. However as both Cockermouth and Workington recorded peak levels were above the level of possible property flooding, any increase could have resulted in flood damage.

Therefore, it is my conclusion that had space not been available in Thirlmere throughout the Oct 21 rainfall event, flooding in both Cockermouth and Workington may well have occurred.

Dr Mark Roberts, 7th November 2021

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