Optimising Natural Flood Management in Headwater Catchments to Protect Downstream Communities – the empirical data

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Too many UK peatlands look like this
...and lots of restoration work is going on to make them look like this.

RESTORATION OF DEGRADED PEATLANDS

2011

2014

2019

2010

2014

2019
How does this impact downstream flood risk?
Optimising Natural Flood Management in Headwater Catchments to Protect Downstream Communities – the empirical data
Protect is based on BACI designs – here on Kinder Edge (Making Space for Water/ML20-20/Protect sites)
RESTORATION ON KINDER EDGE
Optimising gully blocking at Stalybridge
3 controls, Stone Dams, Peat Dams, Timber dams, timber dams with slots, piped peat dams, peat and stone dams

Stalybridge: Catchments A - J
<table>
<thead>
<tr>
<th>UoM Gully Code</th>
<th>Notional gully/catchment gradient</th>
<th>Treatment</th>
<th>Area m²</th>
<th>Drainage Density km/km²</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Steep</td>
<td>CONTROL – mineral floored in parts</td>
<td>4636</td>
<td>46.9</td>
</tr>
<tr>
<td>B</td>
<td>Steep</td>
<td>Stone dams</td>
<td>12056</td>
<td>41.2</td>
</tr>
<tr>
<td>C</td>
<td>Shallow</td>
<td>Stone dams in lower gully, peat dams in upper gully</td>
<td>42680</td>
<td>51.1</td>
</tr>
<tr>
<td>D</td>
<td>Shallow</td>
<td>CONTROL</td>
<td>23930</td>
<td>47.3</td>
</tr>
<tr>
<td>E</td>
<td>Shallow</td>
<td>Peat dams with pipes</td>
<td>15972</td>
<td>44.9</td>
</tr>
<tr>
<td>F</td>
<td>Shallow</td>
<td>Peat dams</td>
<td>8175</td>
<td>38.3</td>
</tr>
<tr>
<td>G</td>
<td>Steep</td>
<td>CONTROL</td>
<td>4400</td>
<td>44.0</td>
</tr>
<tr>
<td>H</td>
<td>Steep</td>
<td>Extra-wide peat dams</td>
<td>10421</td>
<td>47.0</td>
</tr>
<tr>
<td>I</td>
<td>Steep</td>
<td>Wooden slot dams</td>
<td>7215</td>
<td>39.6</td>
</tr>
<tr>
<td>J</td>
<td>Steep</td>
<td>UNBURNT CONTROL</td>
<td>2425</td>
<td>35.5</td>
</tr>
</tbody>
</table>

Before data is March 19-March 20, After data presented here is March 19 – June 21
Standard Interventions

*Stone dam – Peak Discharge*

\[ y = 0.68x + 0.47 \]

\[ R^2 = 0.97 \]

- **Peak Q (l/s)**

  - Before
  - After
  - Linear (Before)

**Residuals**

- **Peak Q (l/s)_D**
Standard Interventions

*Stone dam – Lag time*

\[
y = 0.47x + 24.1 \\
R^2 = 0.40
\]
Standard Interventions

Peat dam - Peak Discharge

\[ y = 0.5275x - 0.2704 \]
\[ R^2 = 0.9827 \]
Standard Interventions

*Peat dam - Lag*

\[ y = 0.6774x + 46.255 \]

\[ R^2 = 0.5282 \]
Standard Interventions

*Peat + Stone dams – Peak Discharge*

\[ y = 1.5879x + 1.4193 \]

\[ R^2 = 0.974 \]
Standard Interventions

*Peat + Stone dams – Lag*

\[ y = 0.8893x + 27.842 \]

\[ R^2 = 0.7818 \]

**Graphs:**
- Scatter plot showing the relationship between \( C \) (Peat + Stone dams) and \( D \) (Control), with a regression line and equation.
- Scatter plot showing residuals with respect to \( Lag \) (min).
- Chart indicating changes before and after intervention.
Optimised NFM Intervention

Piped peat dam – Peak Discharge

\[ y = 0.9638x + 0.5016 \]
\[ R^2 = 0.9844 \]

Treatment I (TI): 150 mm diameter pipe
Treatment II (TII): 64 mm diameter pipe

Peak Q (l/s)

Before | Treatment I | Treatment II | Linear (Before)

Residuals

Peak Q (l/s) \_D

Before | Treatment I | Treatment II | Linear (Before)
Optimised NFM Intervention

Piped peat dam – Lag

Treatment I (TI): 150 mm diameter pipe
Treatment II (TII): 64 mm diameter pipe

**Equation:**

\[ y = 0.8101x + 10.129 \]

**R²:** 0.6569
Tentative findings

- We need more large storms to be sure that these effects persist in flood relevant storms.
- Peat dams have minimal impact on runoff.
- Stone dams lead to longer lag times.
- The largest impact on peak discharge and lag times comes from the piped peat dams once they are optimised.
Modelling stone dams (with & without pipes)

Seepage through dam + Flow through pipe = Feature discharge
Stage-discharge relationships appear broadly consistent between rainfall events.

This storm caused floods in Manchester.
Stage-discharge relationships are well predicted by the theoretical model.

Slope of the line agrees well

Divergent behaviour at very low stage
The (modelled) influence of stone dams on discharge is small*.

*NOTE: this is true for stone dams whether large or small, piped or not.
To increase their influence dams must be less permeable.

Stone dams with $k=0.07$ m/s, pipe @ 0.2 m diameter 0.1 m

[Image of discharge graph with output discharge labels and a legend for different materials like peat and coarse gravel]
• The importance of permeability potentially explains site to site differences (different erosion status and so sediment supply) and change in time (sedimentation in and around gully blocks and re-vegetation)

• Survey of 500 10 year old blocks on Kinder just completed to assess the variability of block evolution.
Legend

Blue: Dam route (1)

Kinder blocks

Type

- Stone (250)
- Timber (250)

Sources: ESRI, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community
Balancing co-benefits of peatland restoration: water table and NFM potential

Water Table Measurement

- Dipwell clusters (5 dipwells) at the gully edge and on interfluves (10 m from gully)
- Manual water table measurements – 5 dates before blocking and 6 dates after blocking
- Gully block installed 2 m downstream of dipwell clusters
Water table change before and after blocking: stone dam

![Diagram showing water table depth changes before and after blocking with a stone dam. The diagram compares measurements at different distances from the gully edge (≤ 2 m and 10 m) before and after blocking.](image-url)
Water table change before and after blocking: peat dam

Water table depth relative to control (mm)

Before | After
---|---
≤ 2 m from the gully edge

10 m from the gully edge
Water table change before and after blocking: piped peat dam

![Graph showing water table change](image-url)
Balancing co-benefits of peatland restoration: water table and NFM potential

Peat Dams – maximum water table benefit but limited NFM potential (?)

Stone Dams – minimum water table benefit *on installation* but some NFM potential

Piped Peat Dams – Clear NFM potential if optimized and better water table benefits than stone dams
Conclusions

• This is early data and we won’t firm up conclusions until the new year when we have another wet season in the loggers.
• Different approaches to gully blocking have differential NFM effects.
• Block permeability is an important parameter which may evolve over time.
• There is potential to optimize block types for NFM and for co-benefits by modifying permeability
• ...and it is not all about blocks and point storage. The Kinder data remind us that changing surface roughness which ‘slows the flow’ is critical in producing mobile storage on hillslopes

Thanks for listening!
Any questions?