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

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UPLAND PEATLANDS IN THE UK

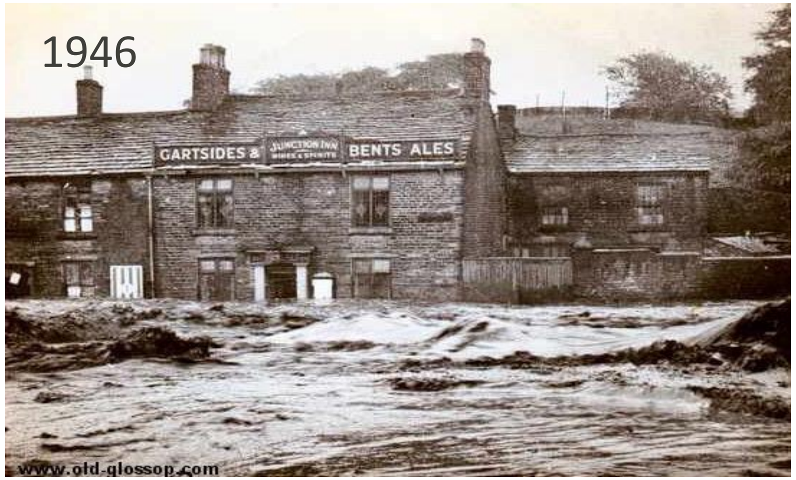
Too many UK peatlands look like this

RESTORATION OF DEGRADED PEATLANDS

…and lots of restoration work is going on to make them look like this

How does this impact downstream flood risk?

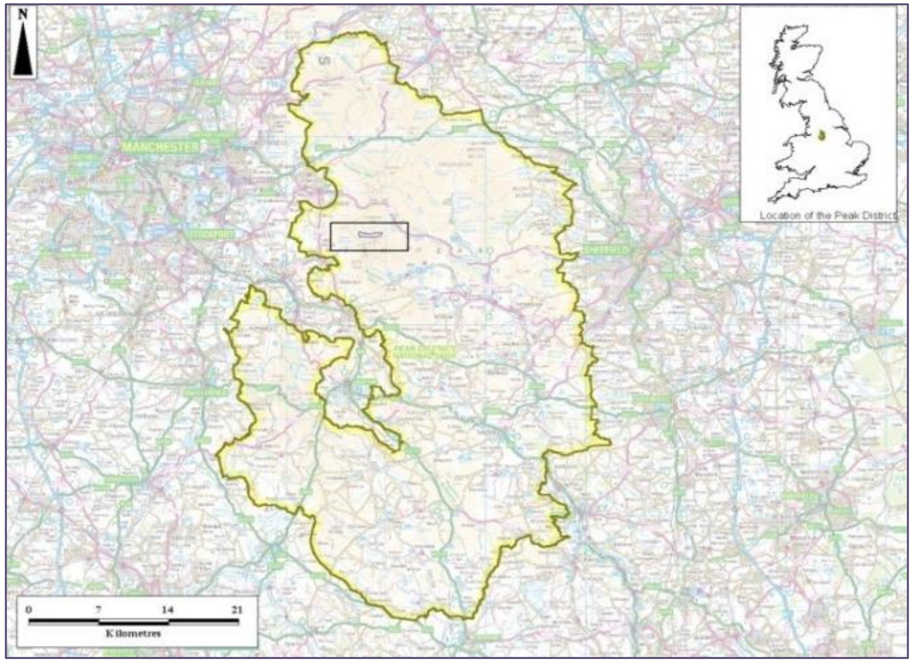
BLANKET PEAT EROSION AND FLOODING

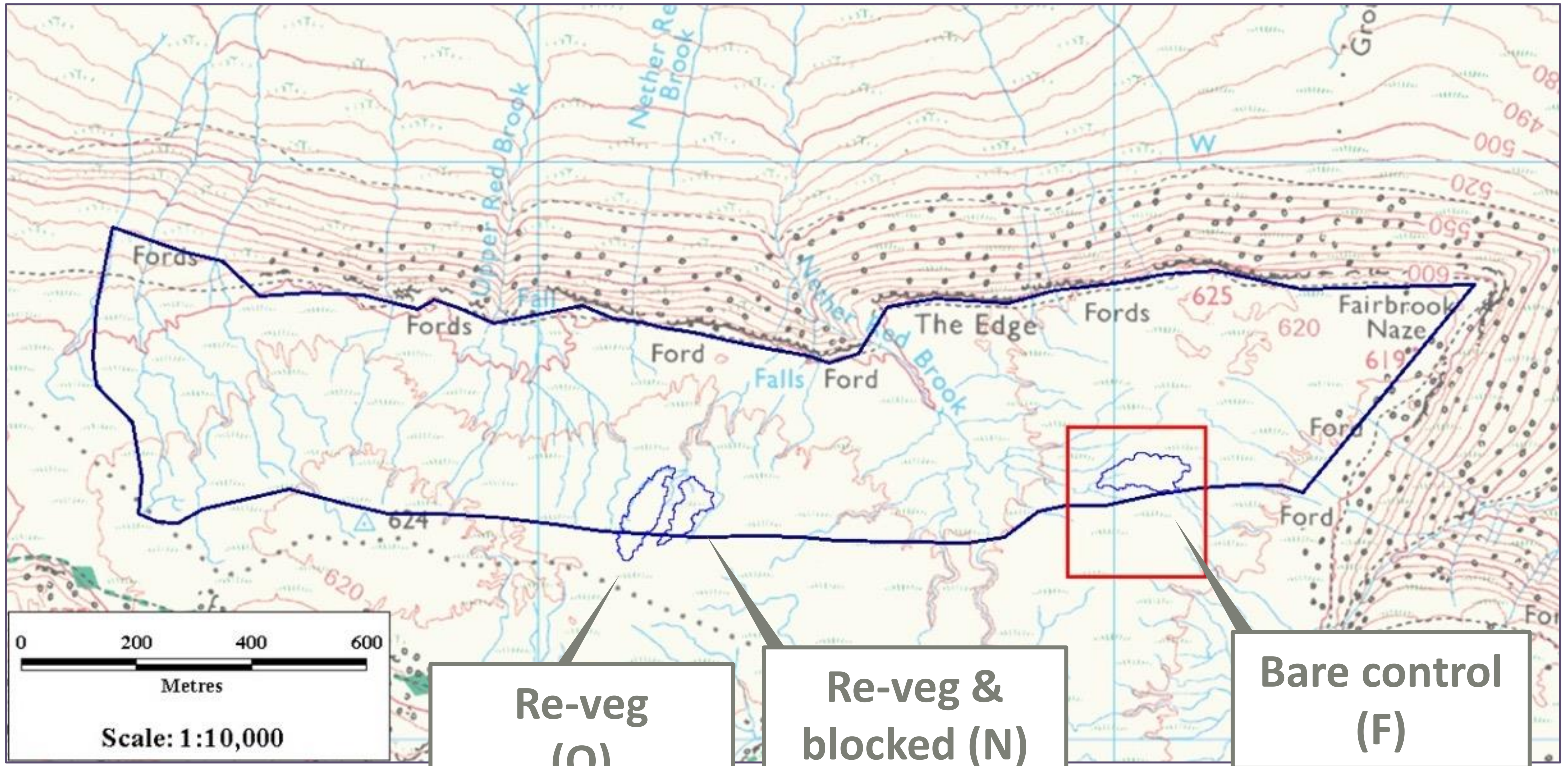


Optimising Natural Flood Management in Headwater Catchments to Protect Downstream Communities – the empirical data

Protect is based on BACI designs – here on Kinder Edge (Making Space for Water/ML20-20/Protect sites)

PROTECT NFM





Re-veg (O)

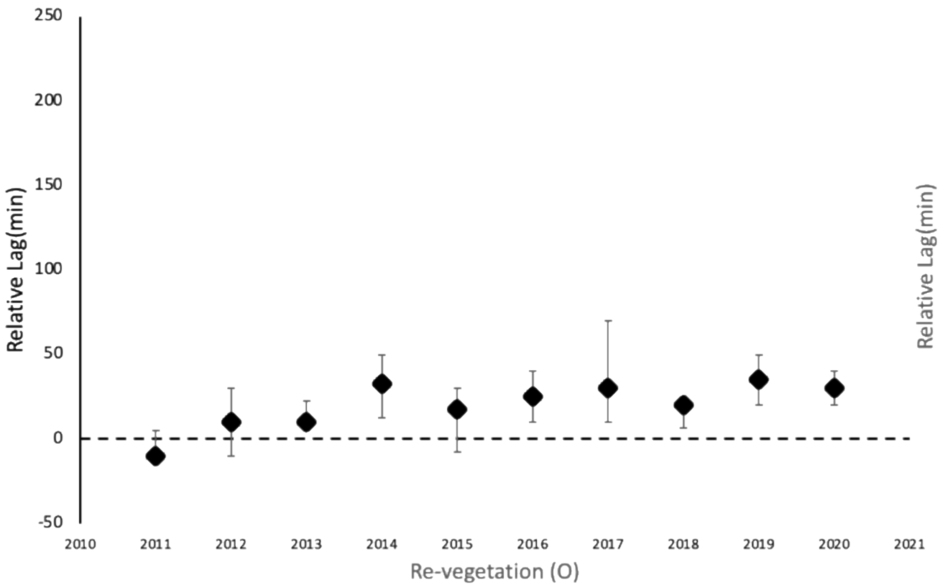
Re-veg & blocked (N)

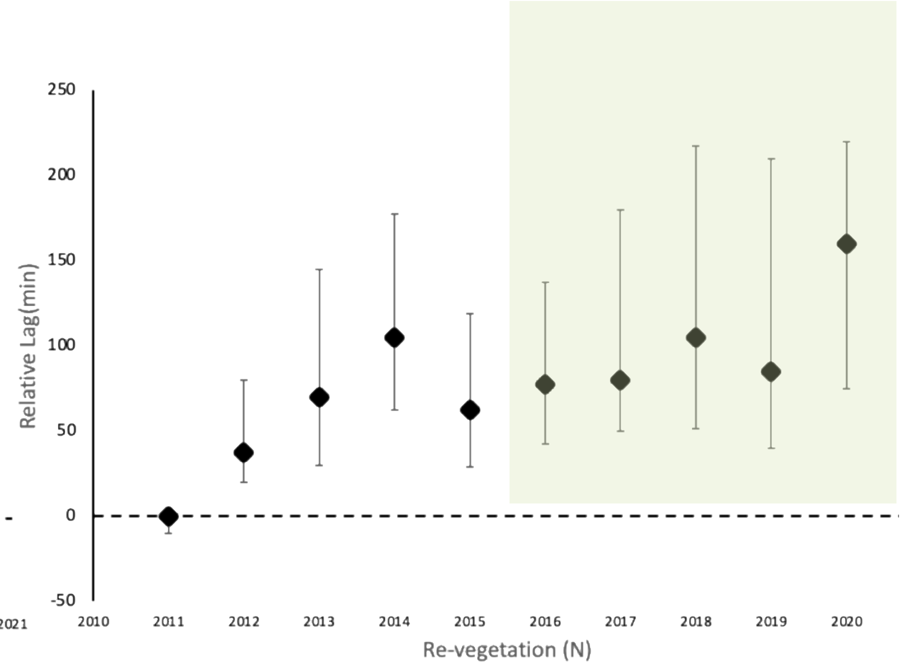
Bare control (F)

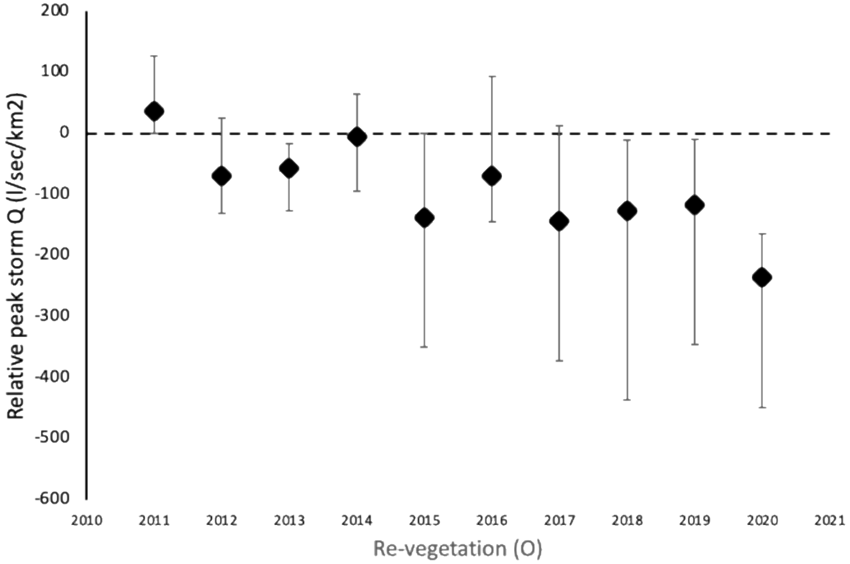
MOORS FOR THE FUTURE PARTNERSHIP

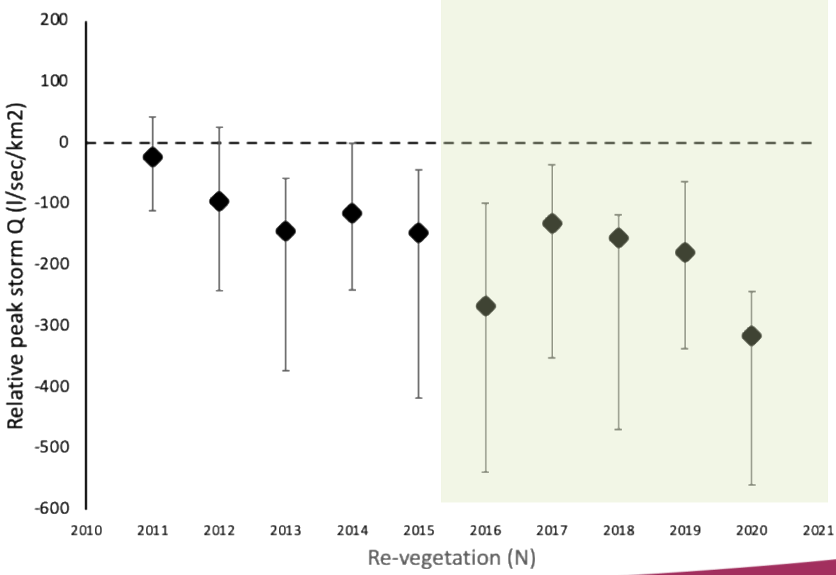
Department for Environment Food & Rural Affairs

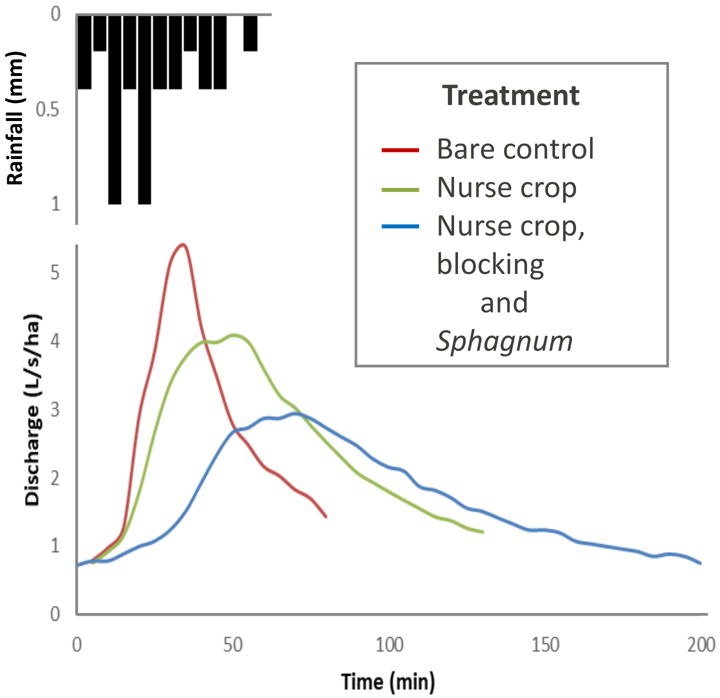
RESTORATION ON KINDER EDGE


Relative Lag(min)
Re-vegetation (O)

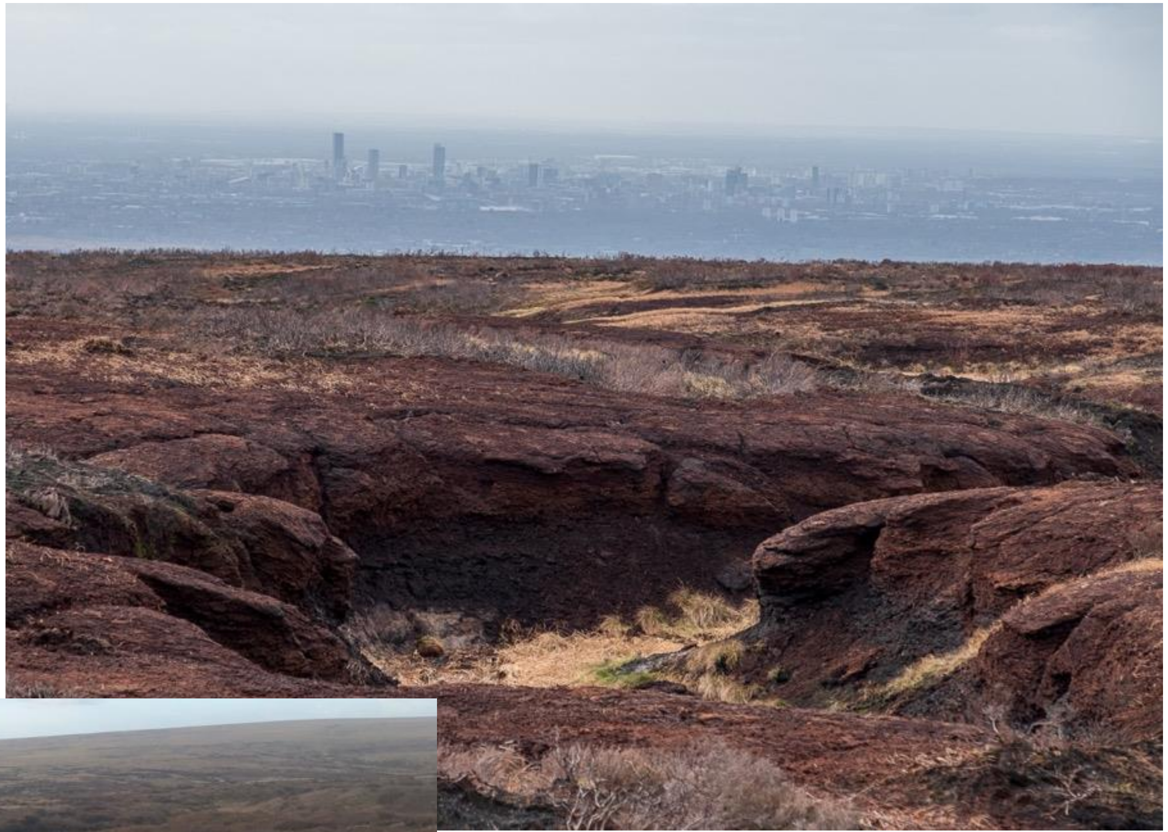

Relative Lag(min)
Re-vegetation (N)


Relative peak storm Q (l/sec/km2)
Re-vegetation (O)


Relative peak storm Q (l/sec/km2)
Re-vegetation (N)

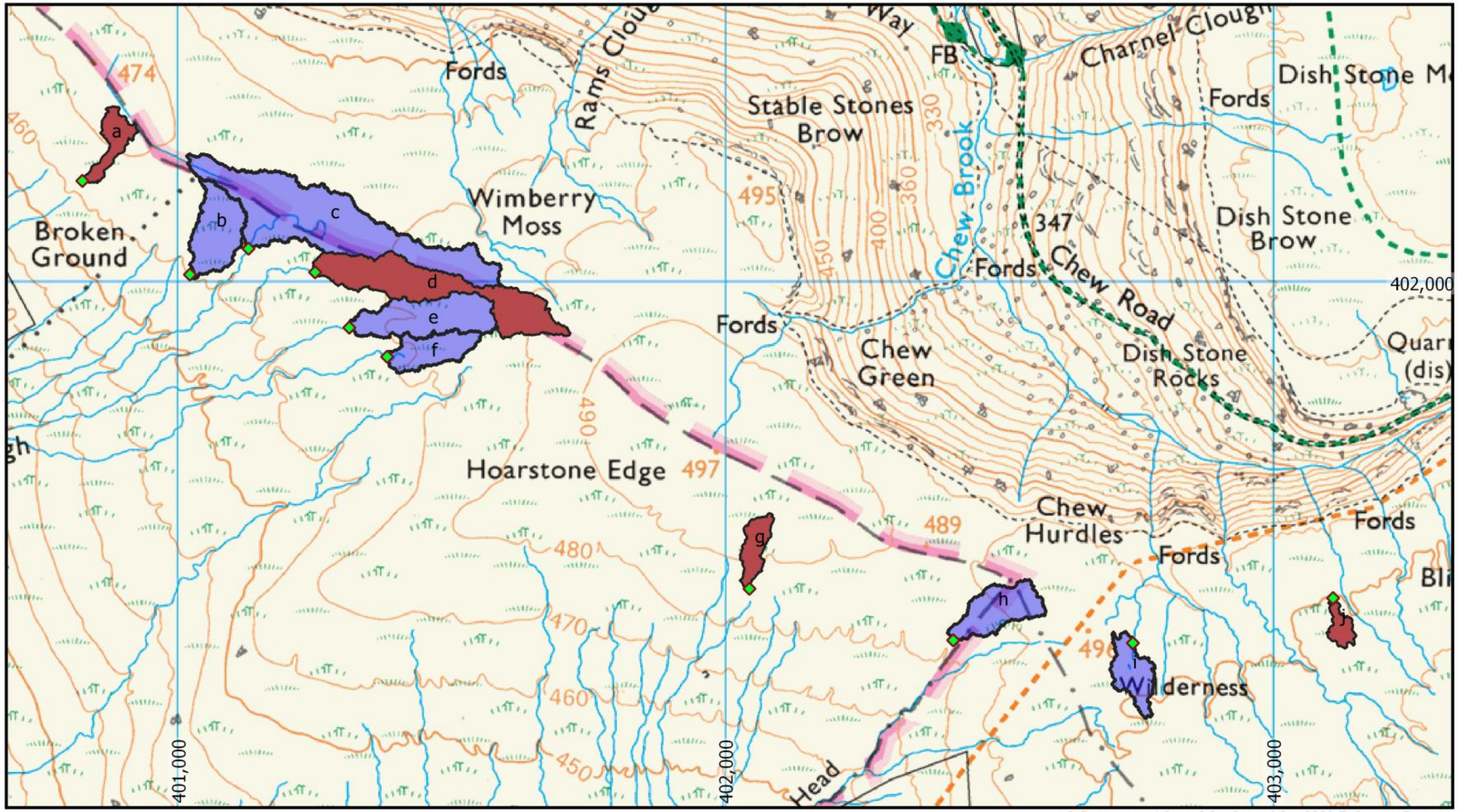

Rainfall (mm)
Discharge (L/s/ha)
Time (min)
Treatment
Bare control
Nurse crop
Nurse crop, blocking and *Sphagnum*

Optimising gully blocking at Stalybridge



3 controls, Stone Dams, Peat Dams, Timber dams, timber dams with slots, piped peat dams, peat and stone dams

PROTECT NFM



N

0 100 200 300 400 500 m

PROTECT NFM

- Gully block
- Catchment area
- Control Catchment Area

Catchment area and gully block locations at Stalybridge for Protect NFM. Control catchments A, D, G & J are highlighted in red. OS 1:25 000 Scale Colour Raster basemap.

Stalybridge: Catchments A - J

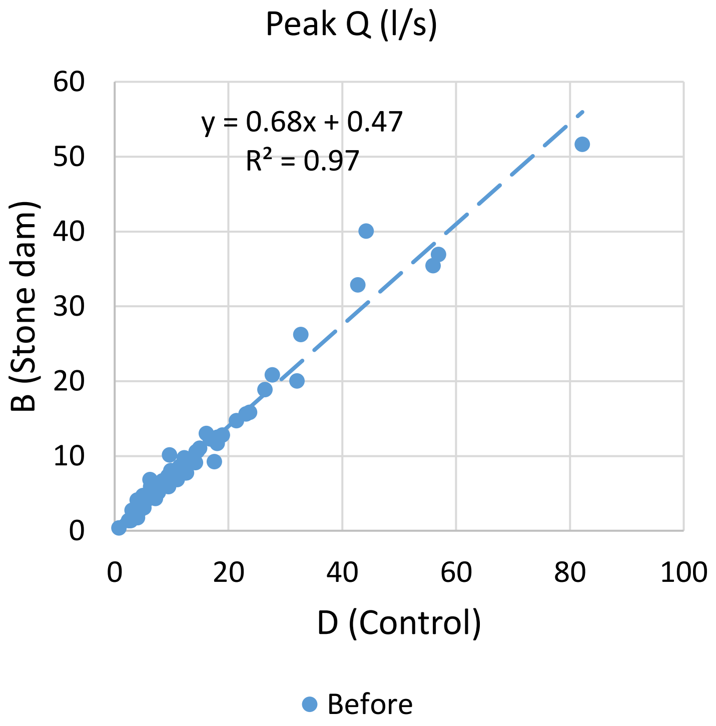
UoM Gully Code	Notional gully/ catchment gradient	Treatment	Area m^2	Drainage Density km/km^2
A	Steep	CONTROL – mineral floored in parts	4636	46.9
B	Steep	Stone dams	12056	41.2
C	Shallow	Stone dams in lower gully, peat dams in upper gully	42680	51.1
D	Shallow	CONTROL	23930	47.3
E	Shallow	Peat dams with pipes	15972	44.9
F	Shallow	Peat dams	8175	38.3
G	Steep	CONTROL	4400	44.0
H	Steep	Extra-wide peat dams	10421	47.0
I	Steep	Wooden slot dams	7215	39.6
J	Steep	UNBURNT CONTROL	2425	35.5

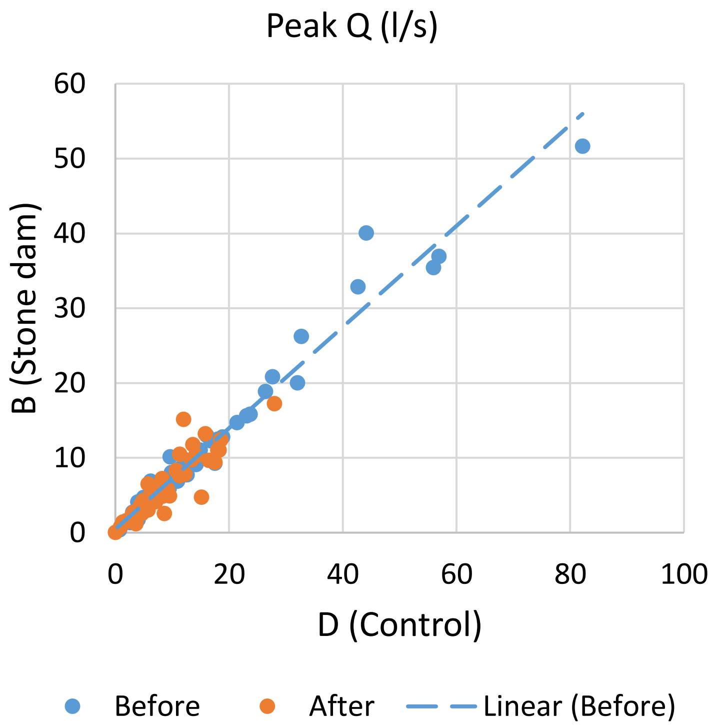
Before data is March 19-March 20, After data presented here is March 19 – June 21

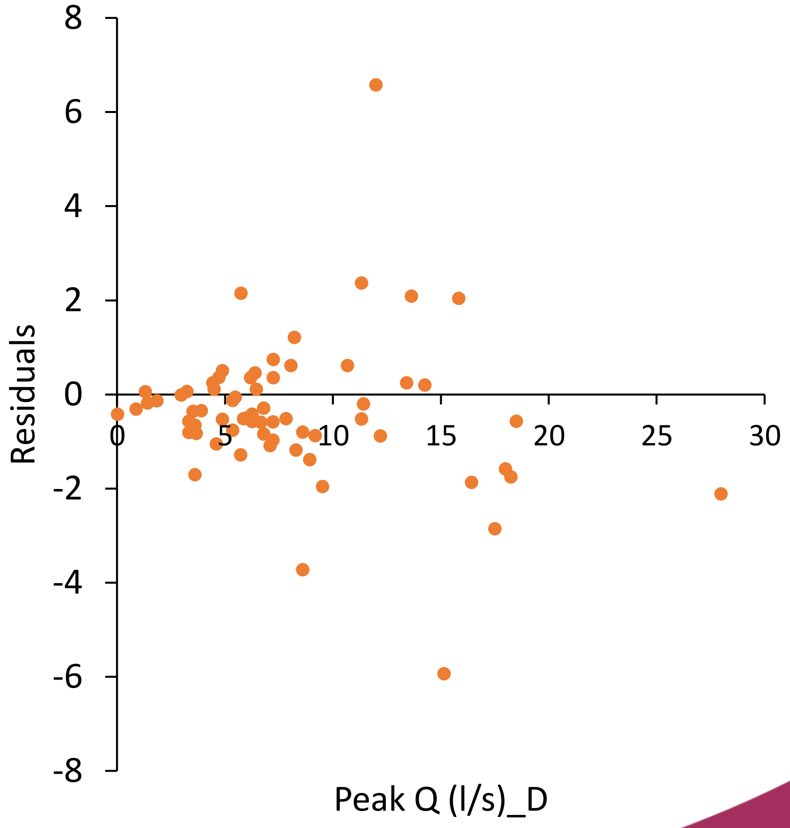
PROTECT NFM

Standard Interventions

Stone dam – Peak Discharge

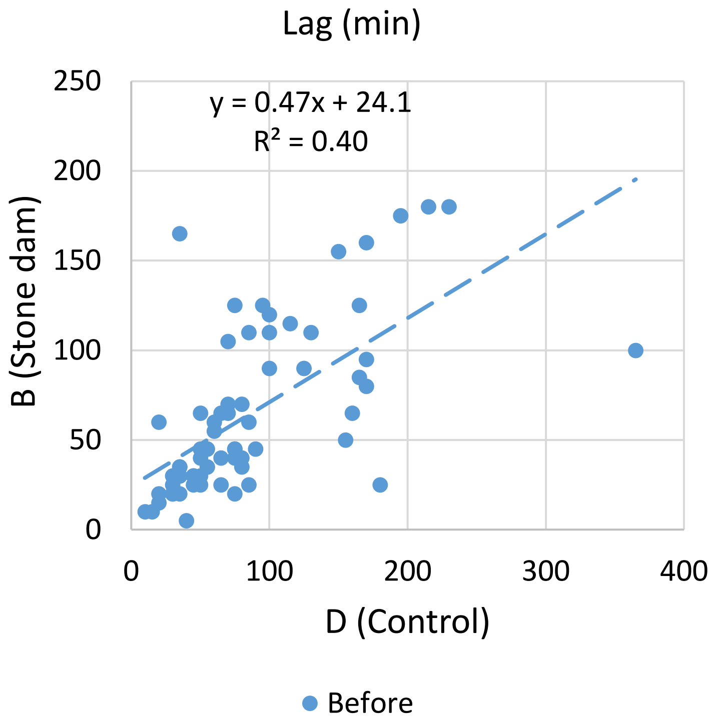


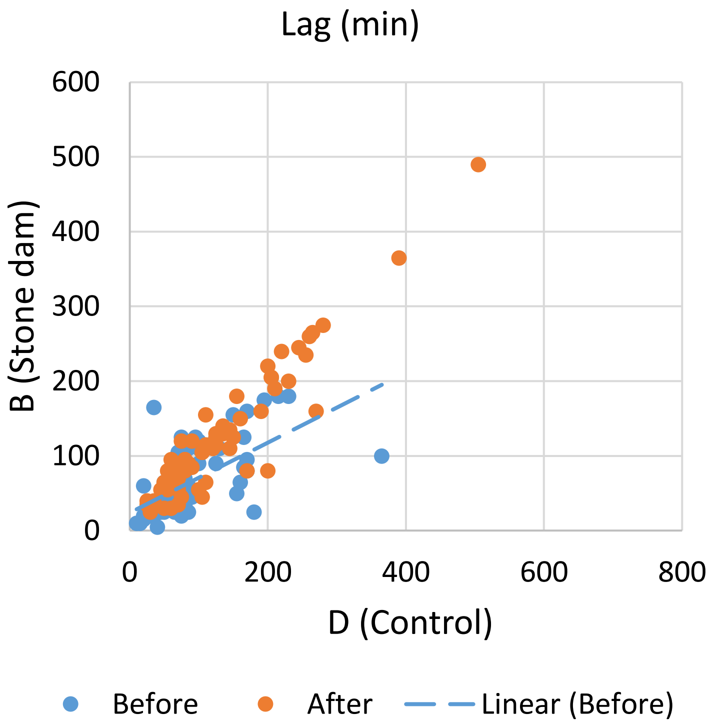


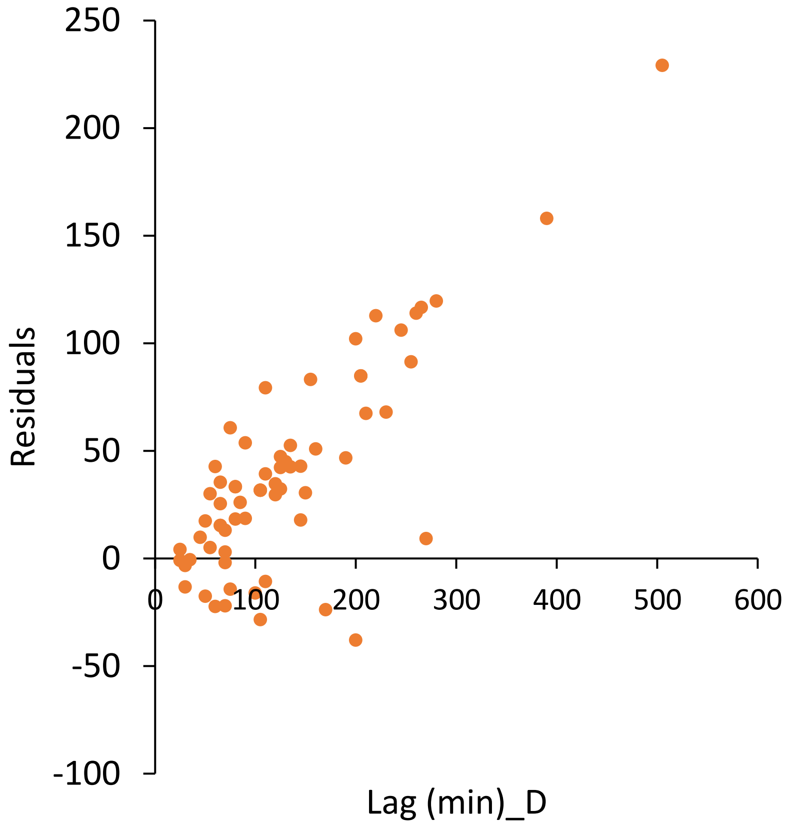


Standard Interventions

Stone dam – Lag time

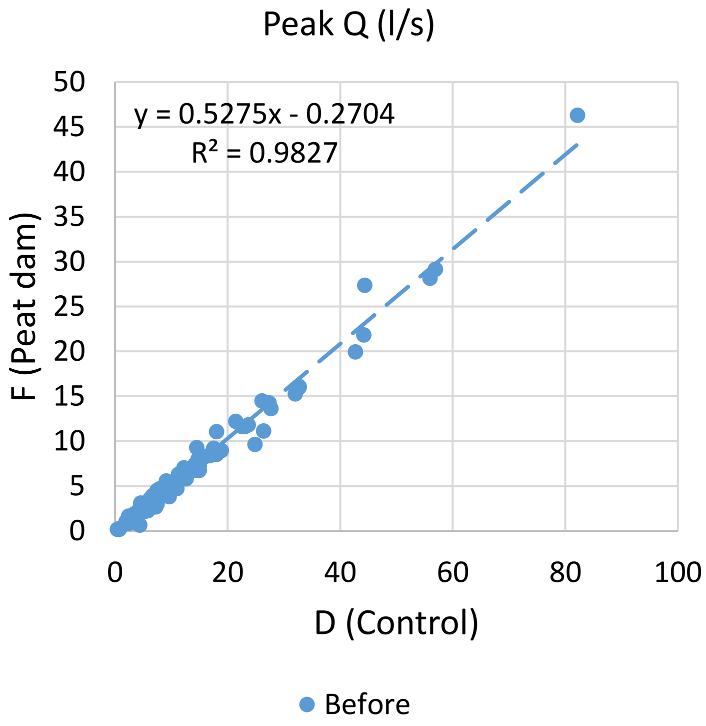


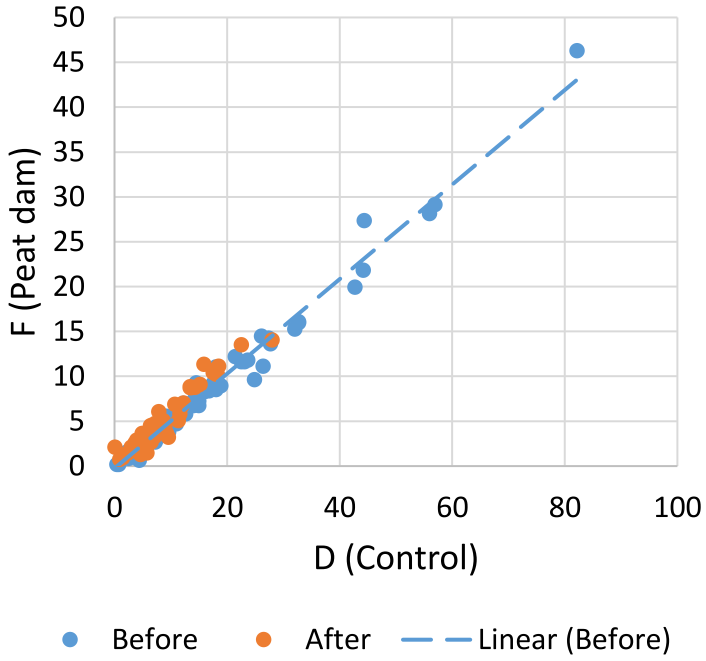


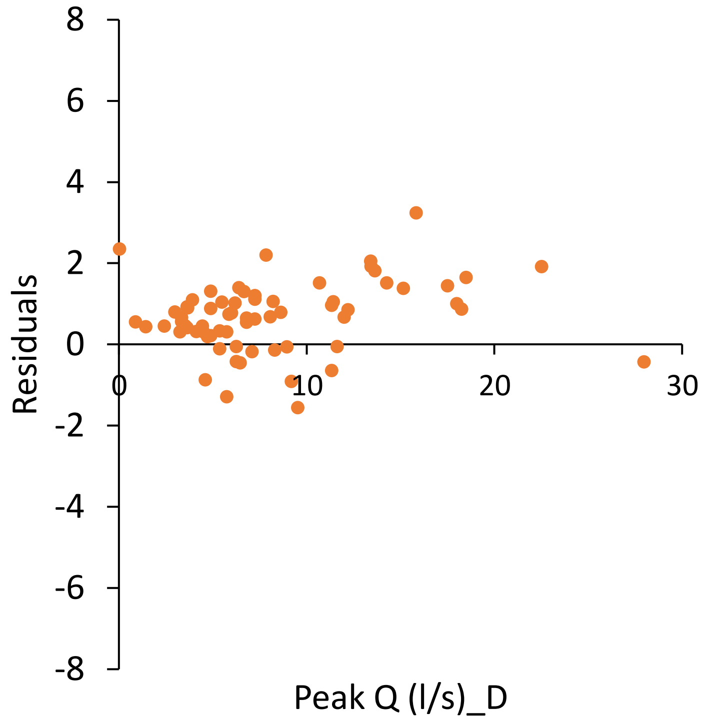


Standard Interventions

Peat dam - Peak Discharge

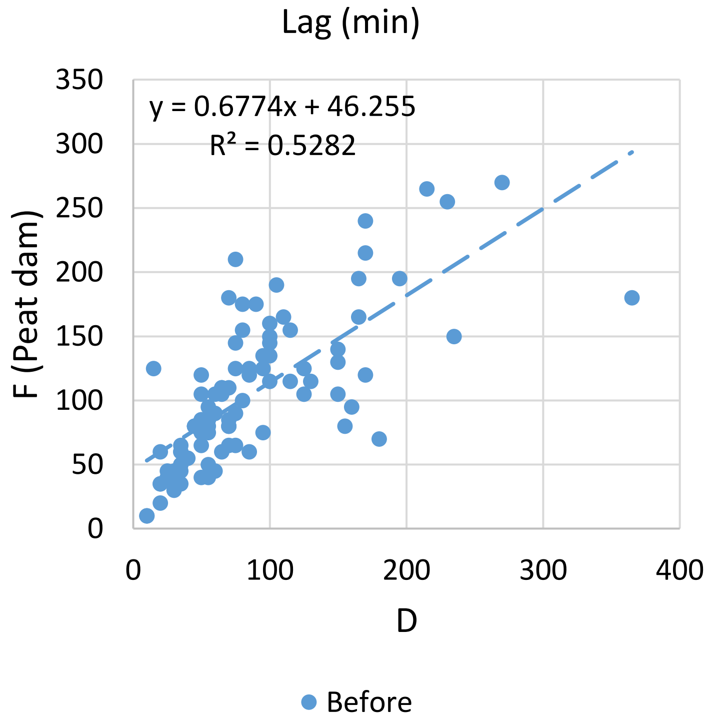


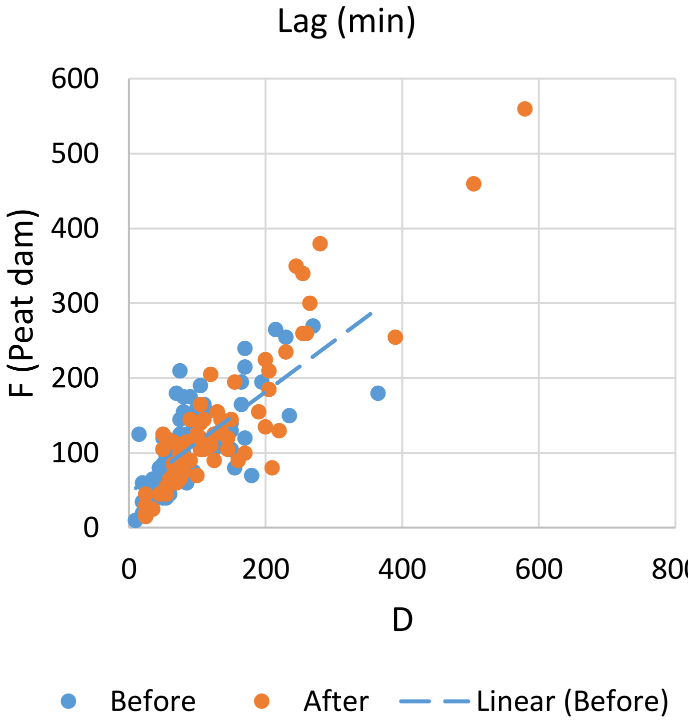


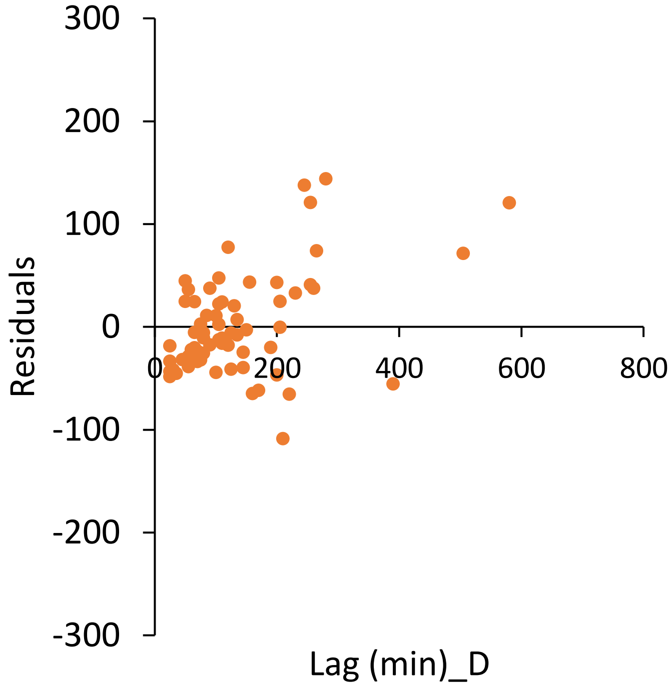


Standard Interventions

Peat dam - Lag

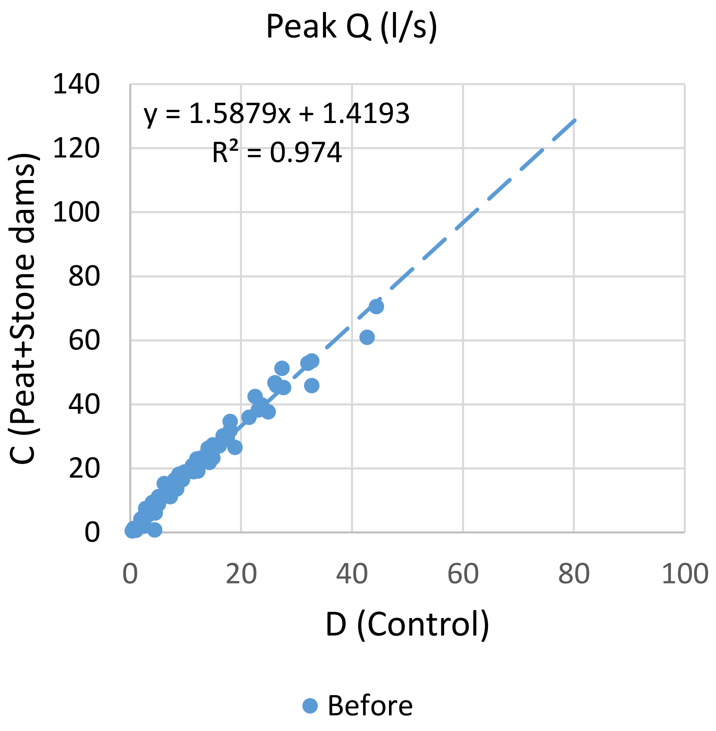


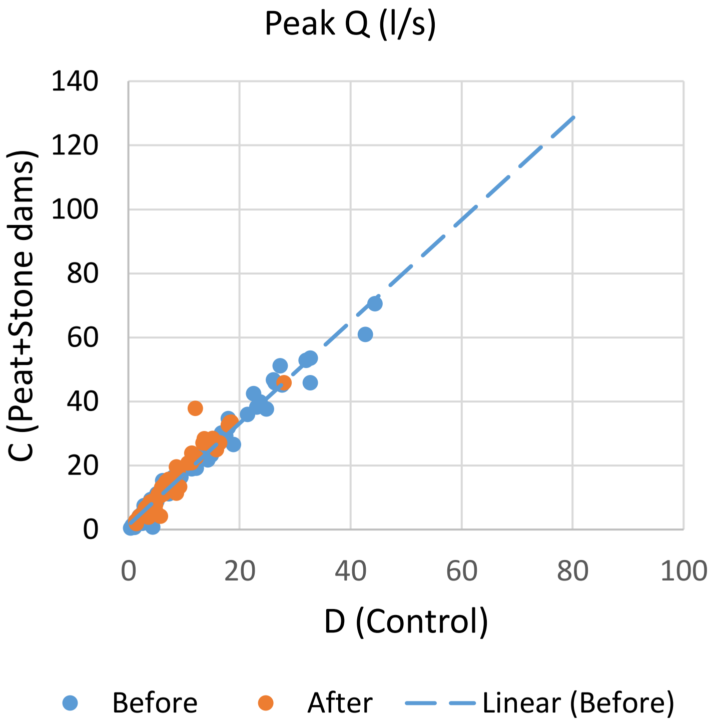


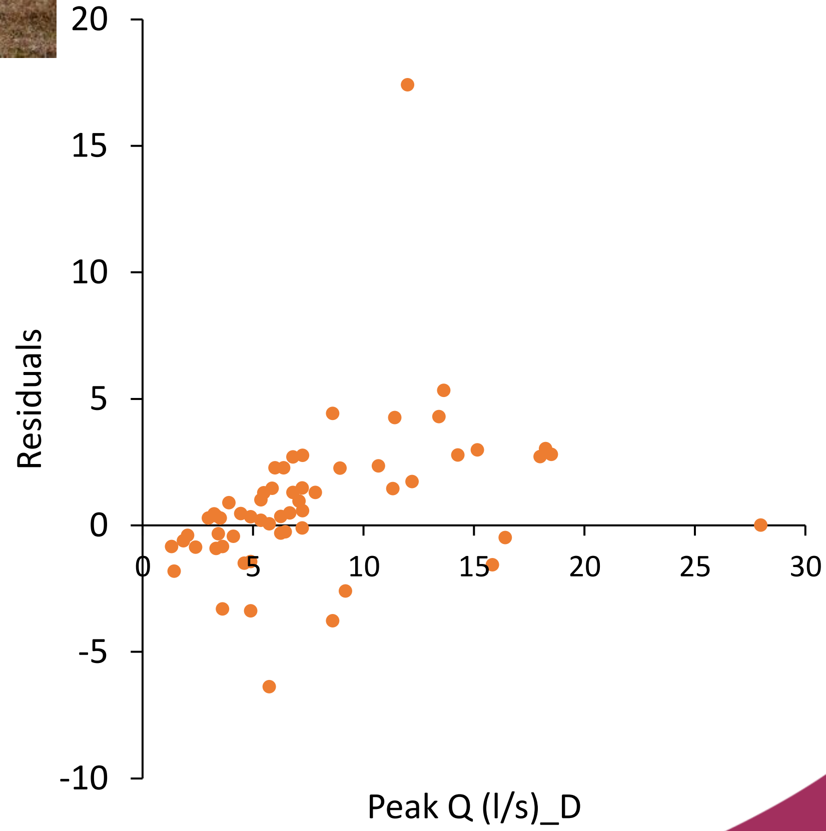


Standard Interventions

Peat + Stone dams – Peak Discharge

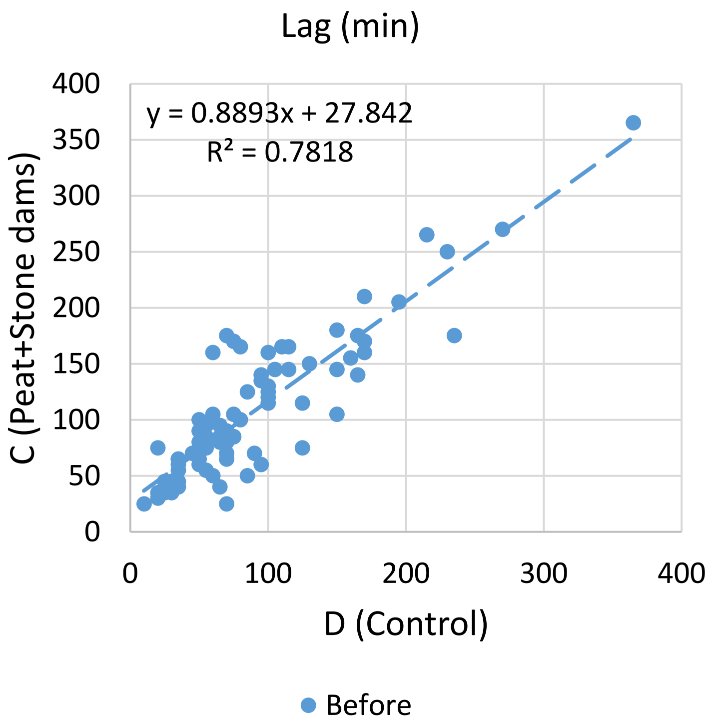


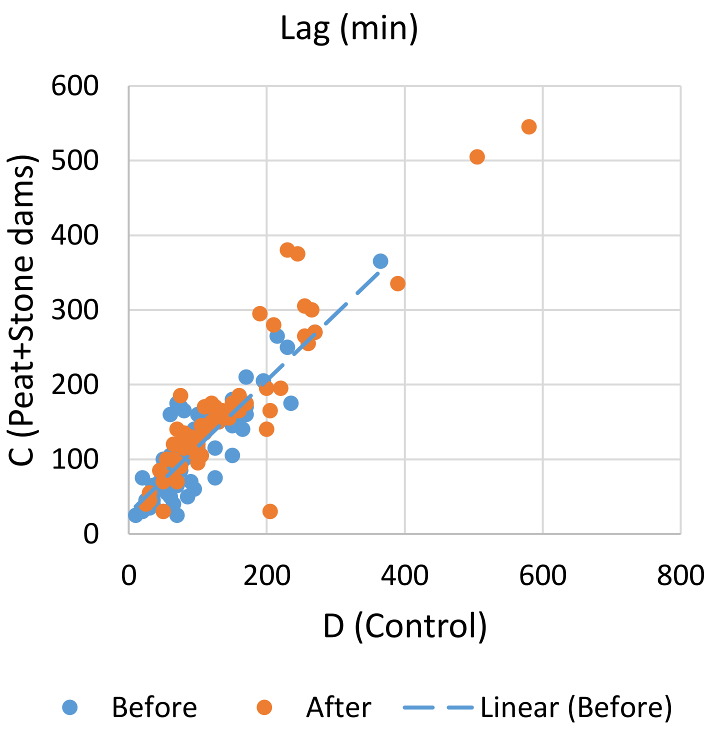


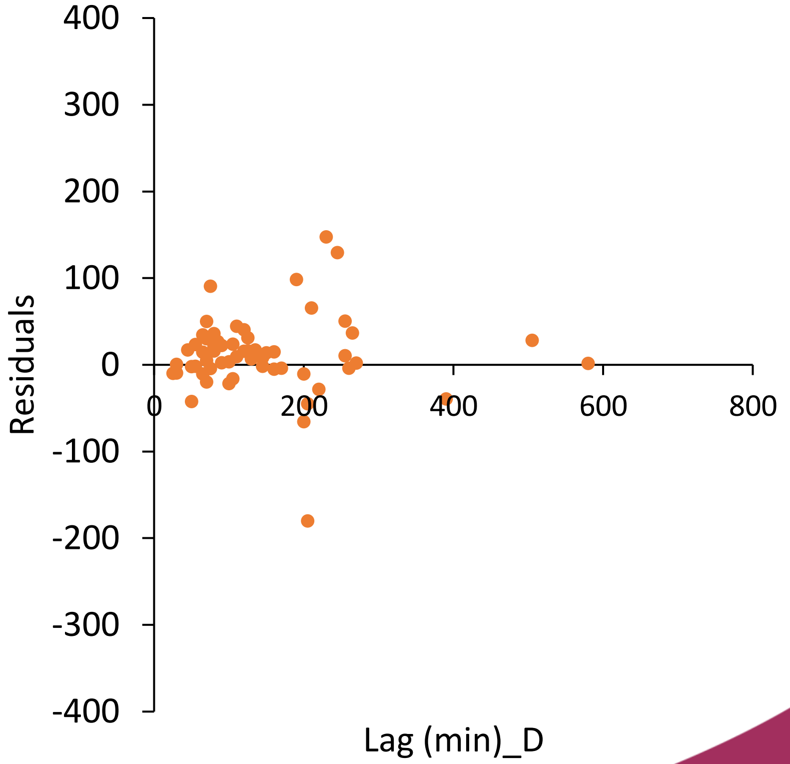


Standard Interventions

Peat + Stone dams – Lag

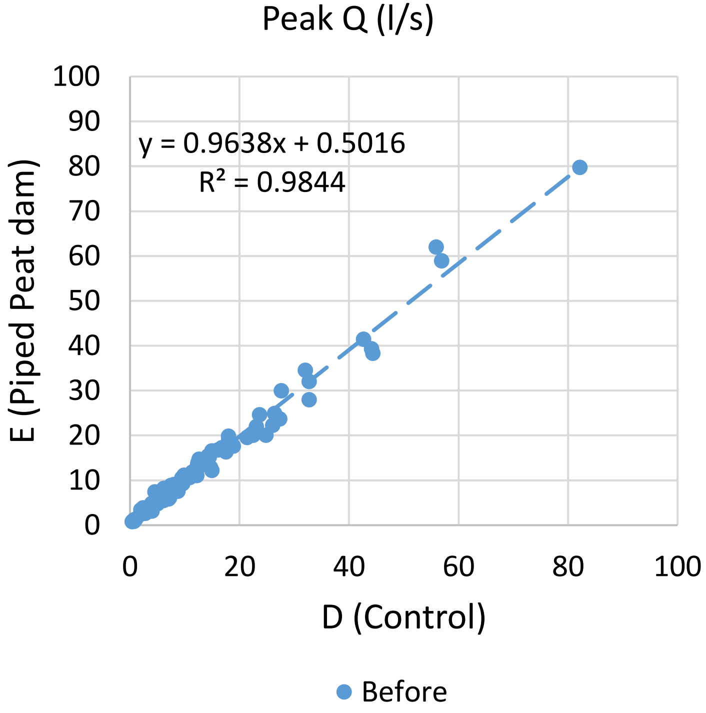


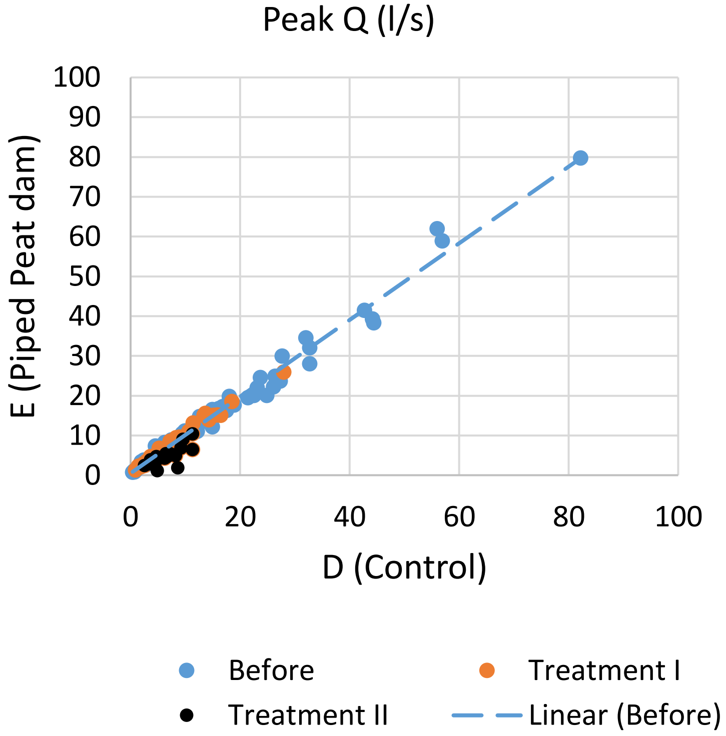




Optimised NFM Intervention

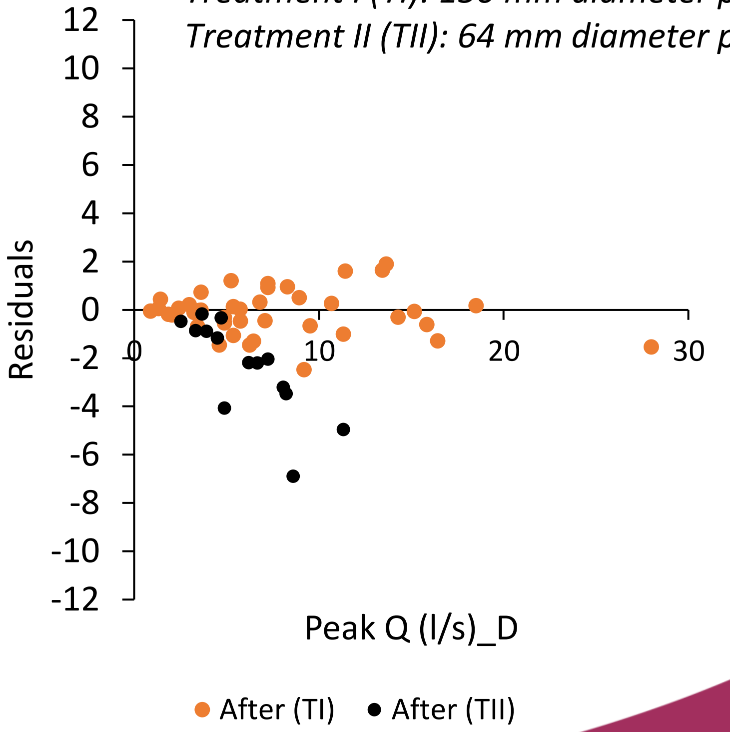
Piped peat dam – Peak Discharge





Treatment I (TI): 150 mm diameter pipe

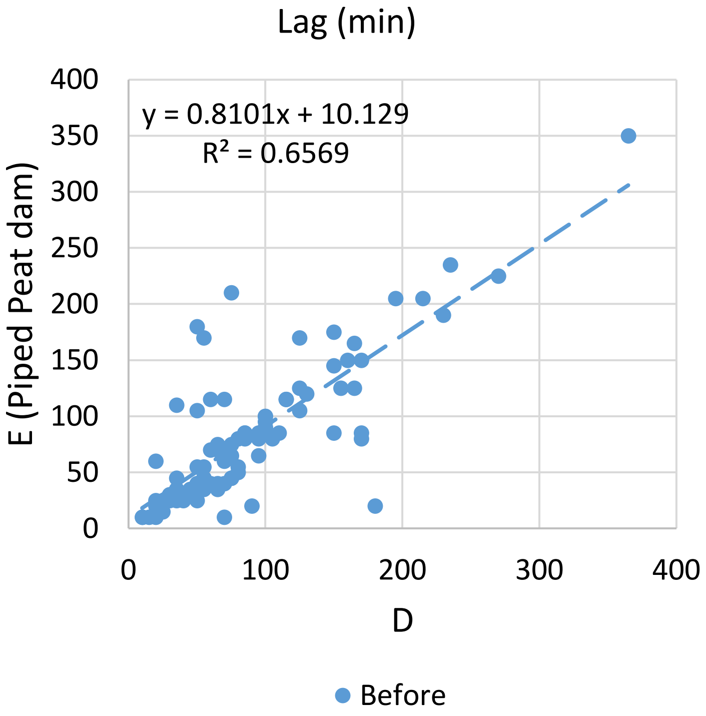
Treatment II (TII): 64 mm diameter pipe

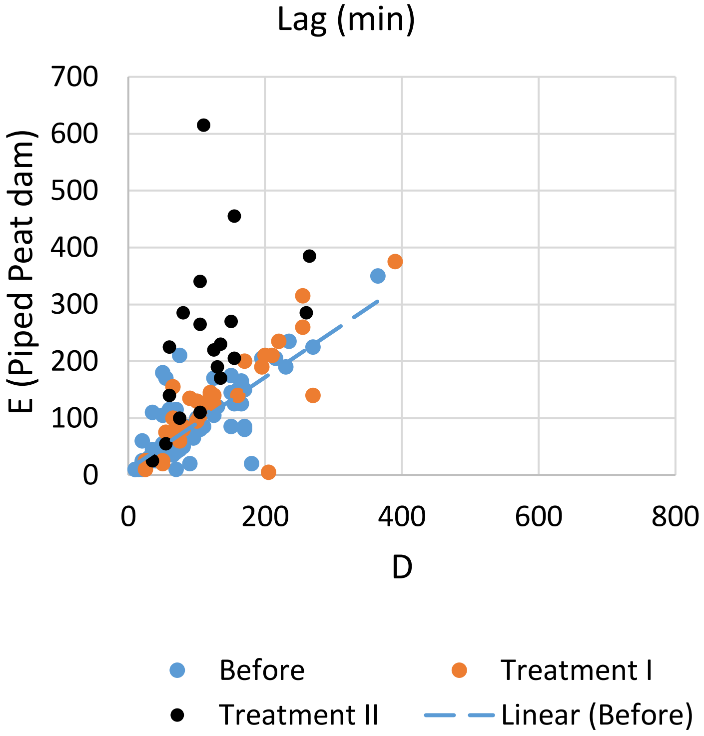


Optimised NFM Intervention

PROTECT NFM

Piped peat dam – Lag





Treatment I (TI): 150 mm diameter pipe

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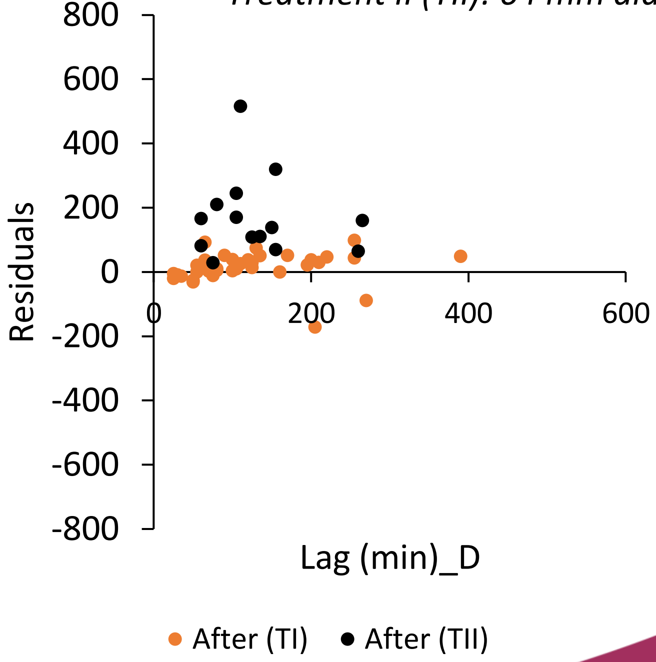
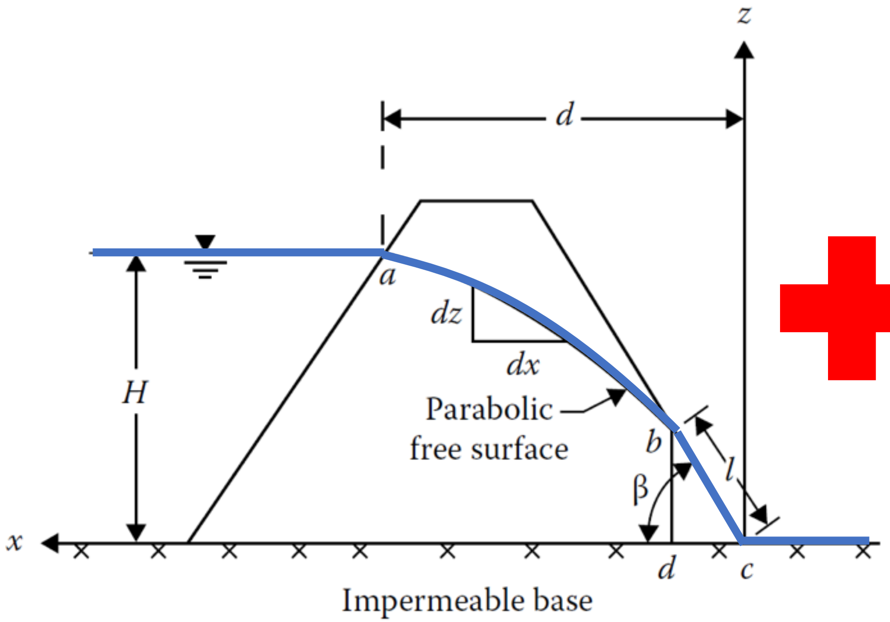


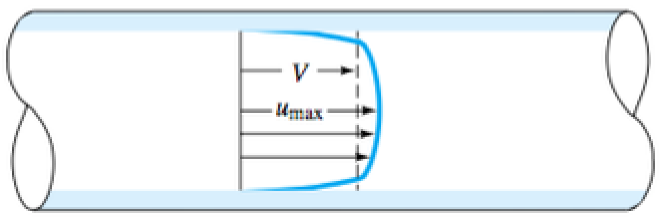
Tentative findings

- 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*

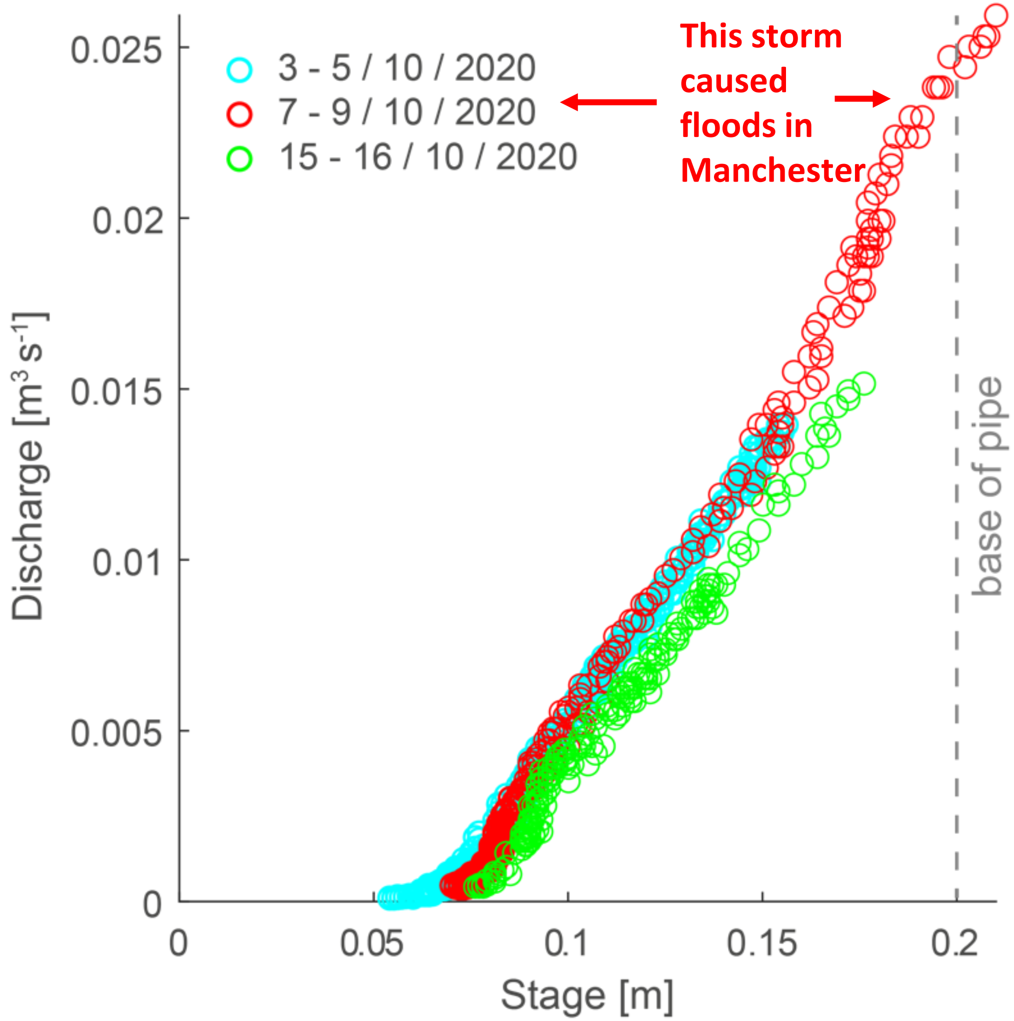
Modelling stone dams (with & without pipes)

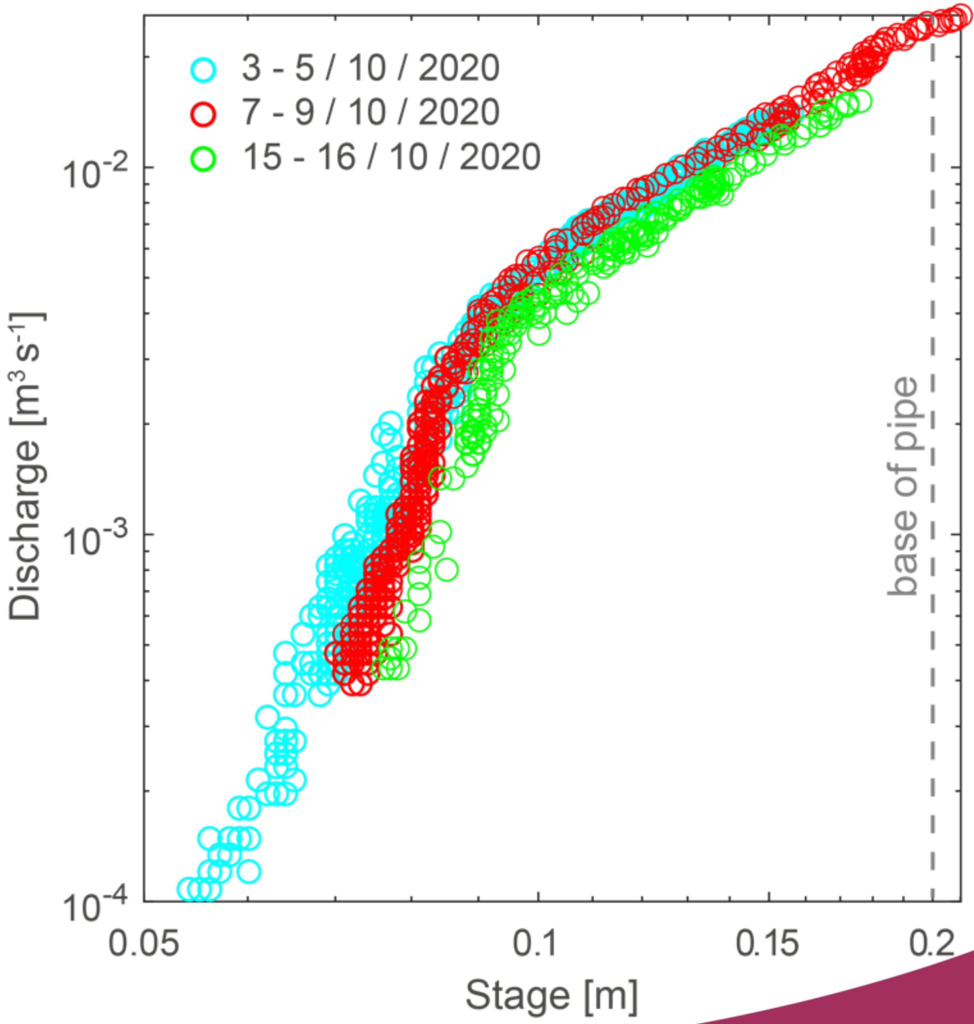
Seepage through dam + Flow through pipe = Feature discharge



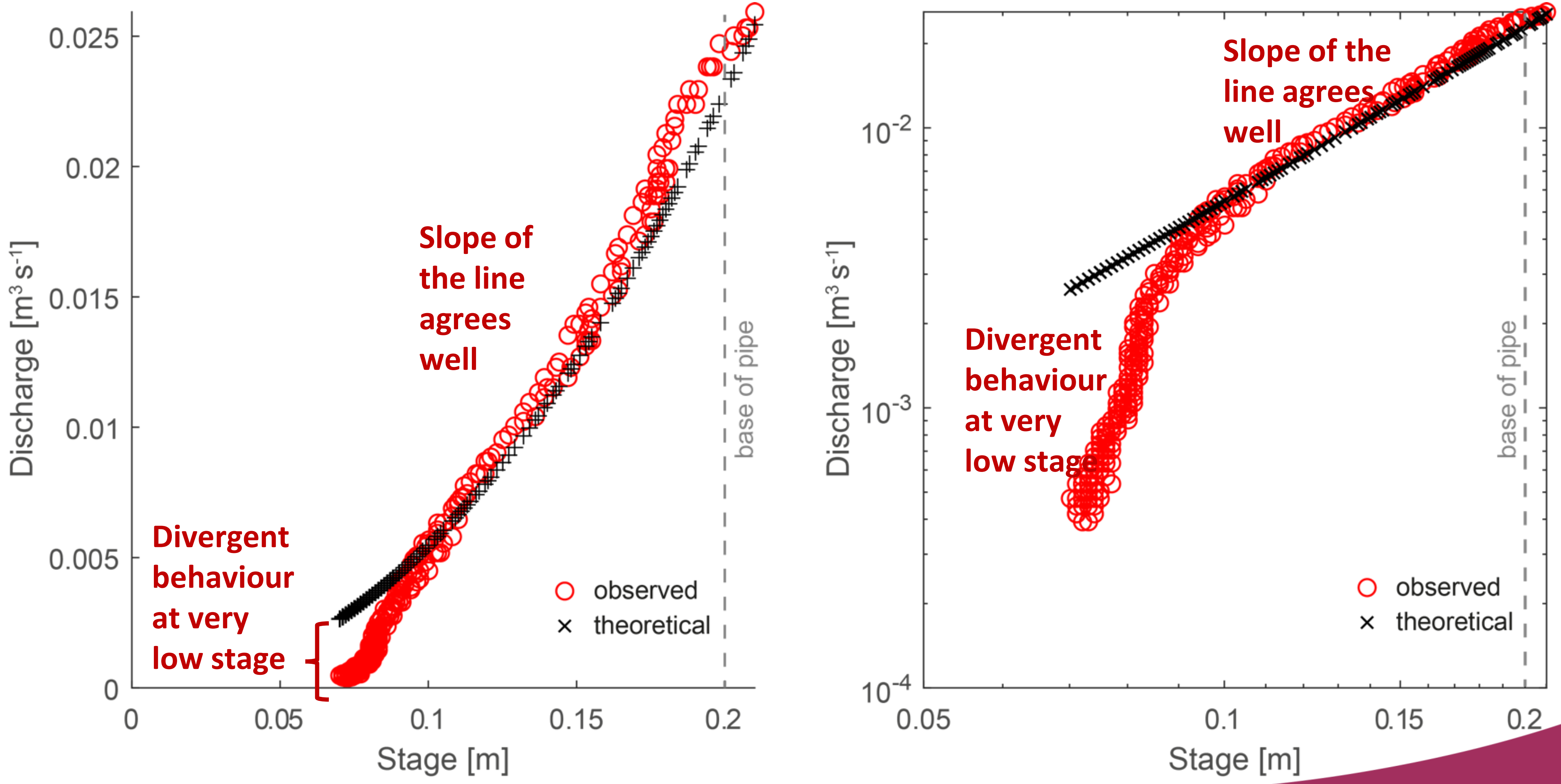


Stage-discharge relationships appear broadly consistent between rainfall events.



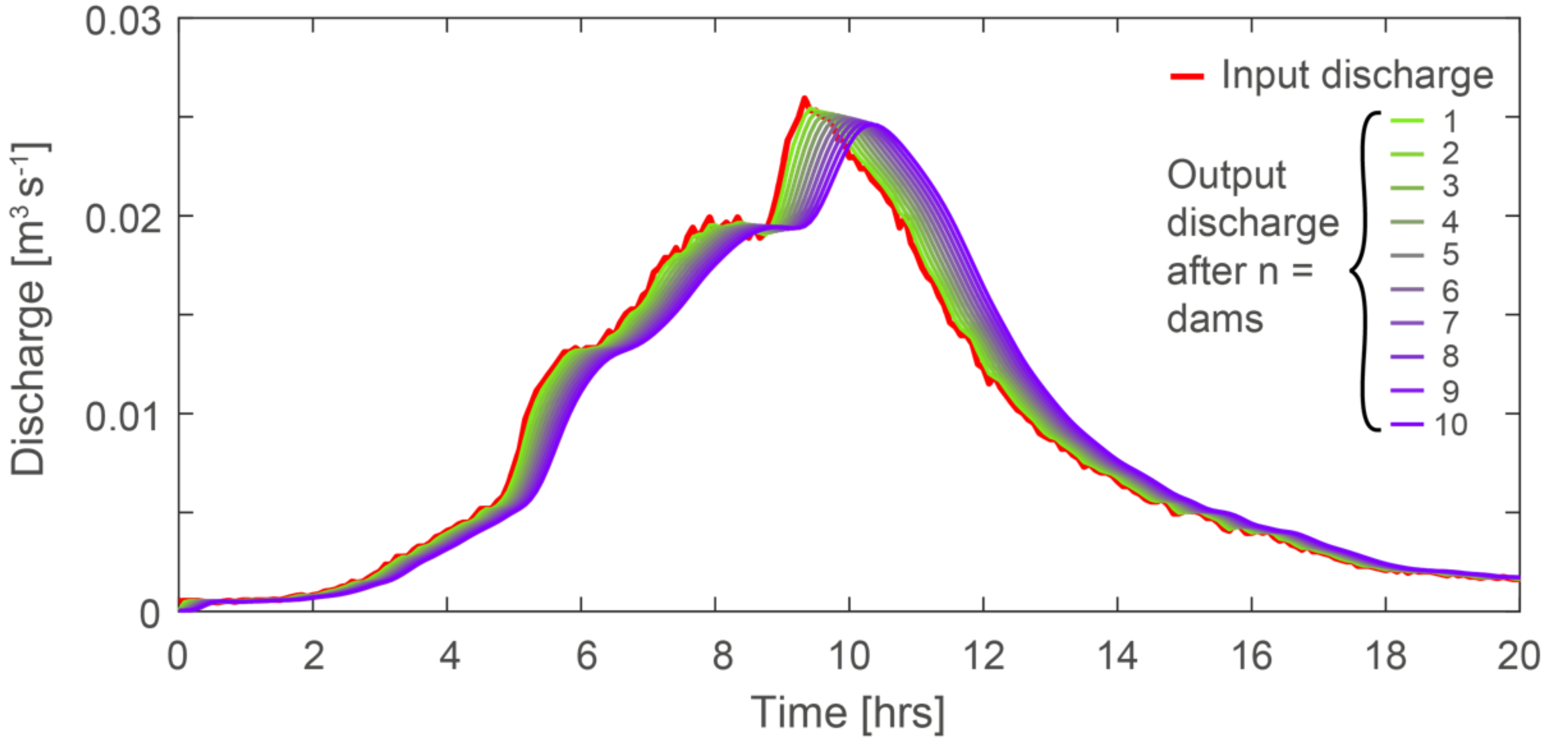


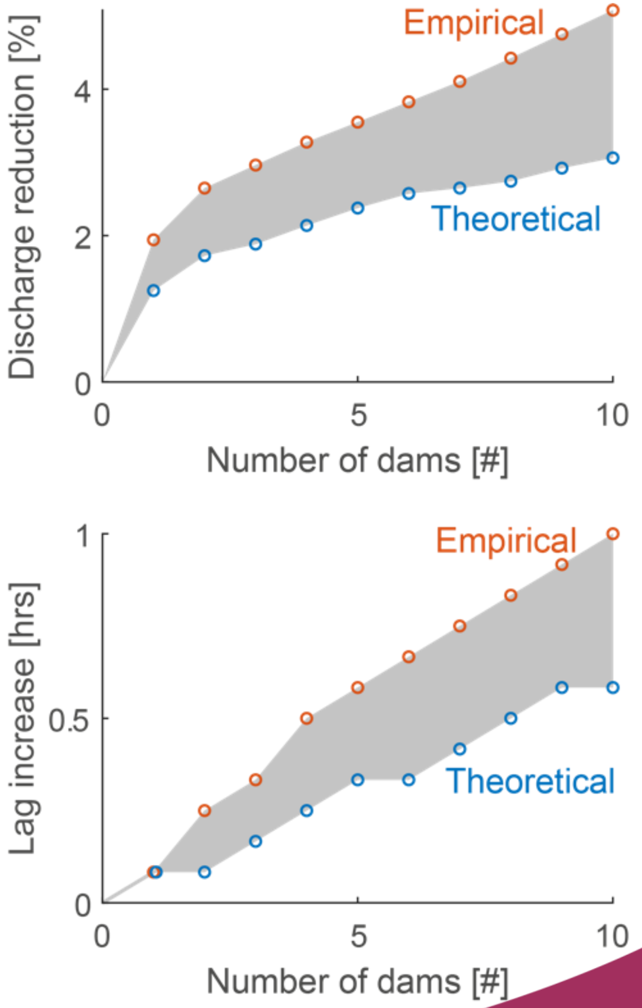
Stage-discharge relationships are well predicted by the theoretical model.



The (modelled) influence of stone dams on discharge is small*.

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

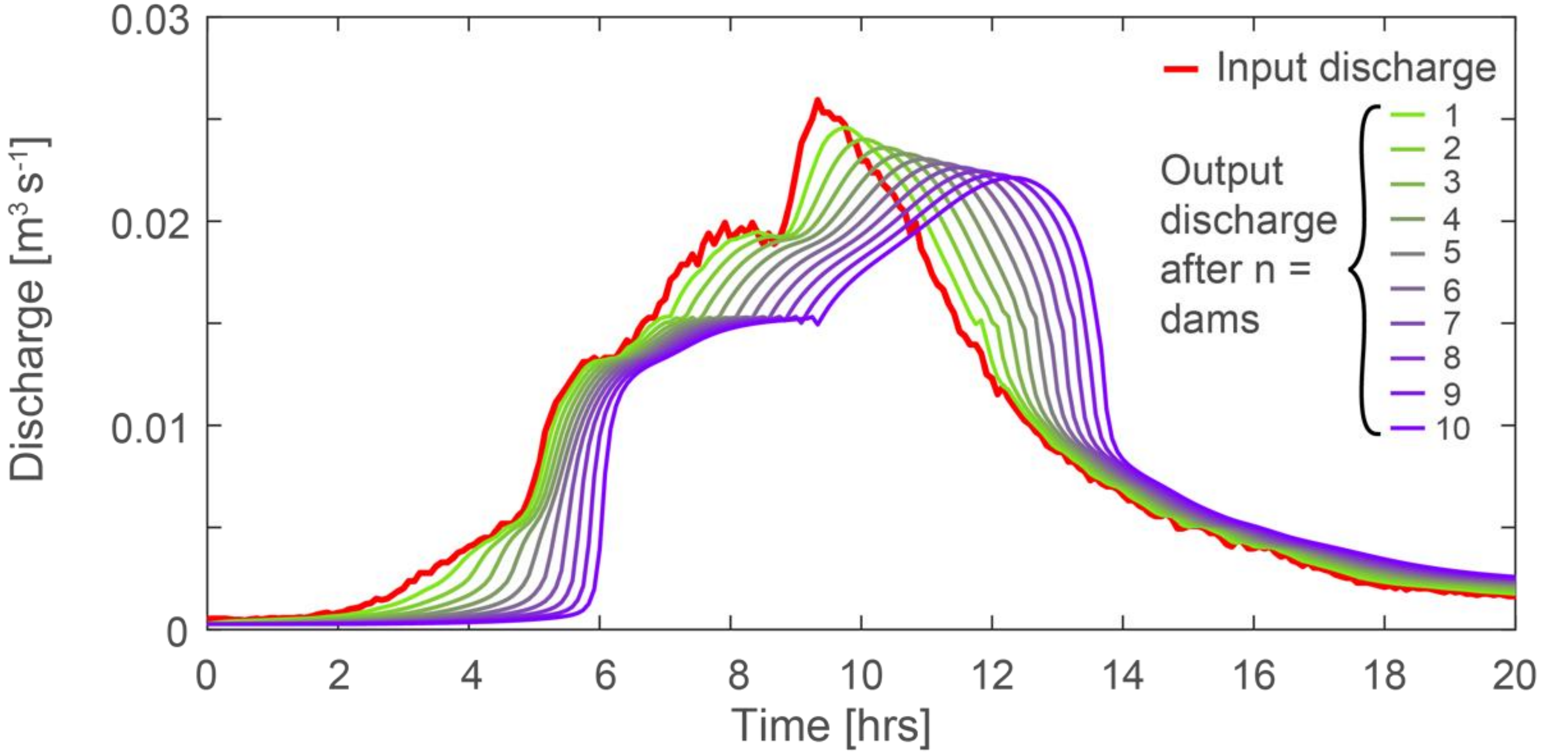


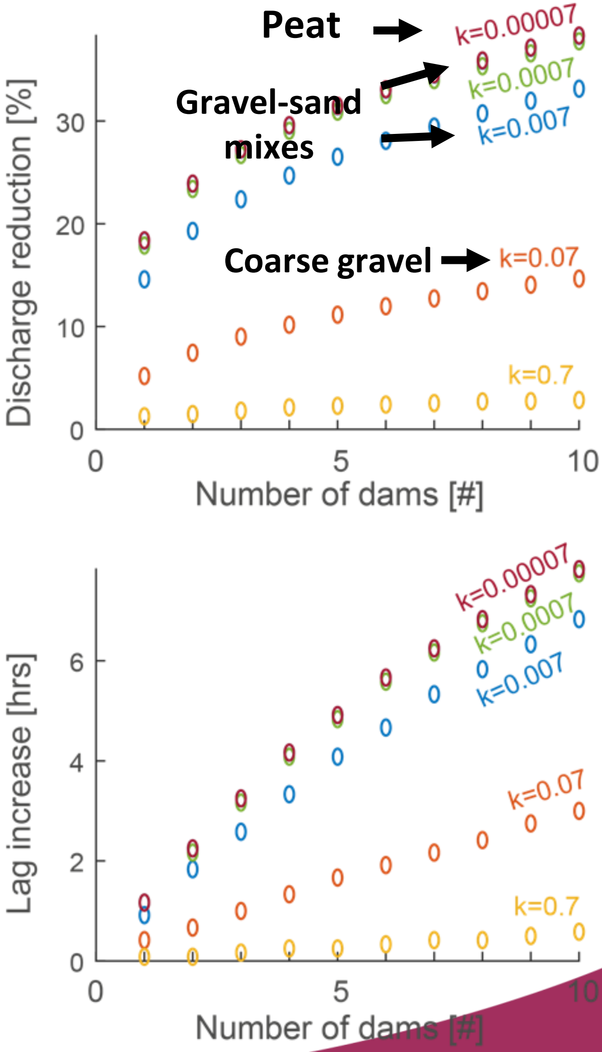


*NOTE: this is true for stone dams whether large or small, piped or not.

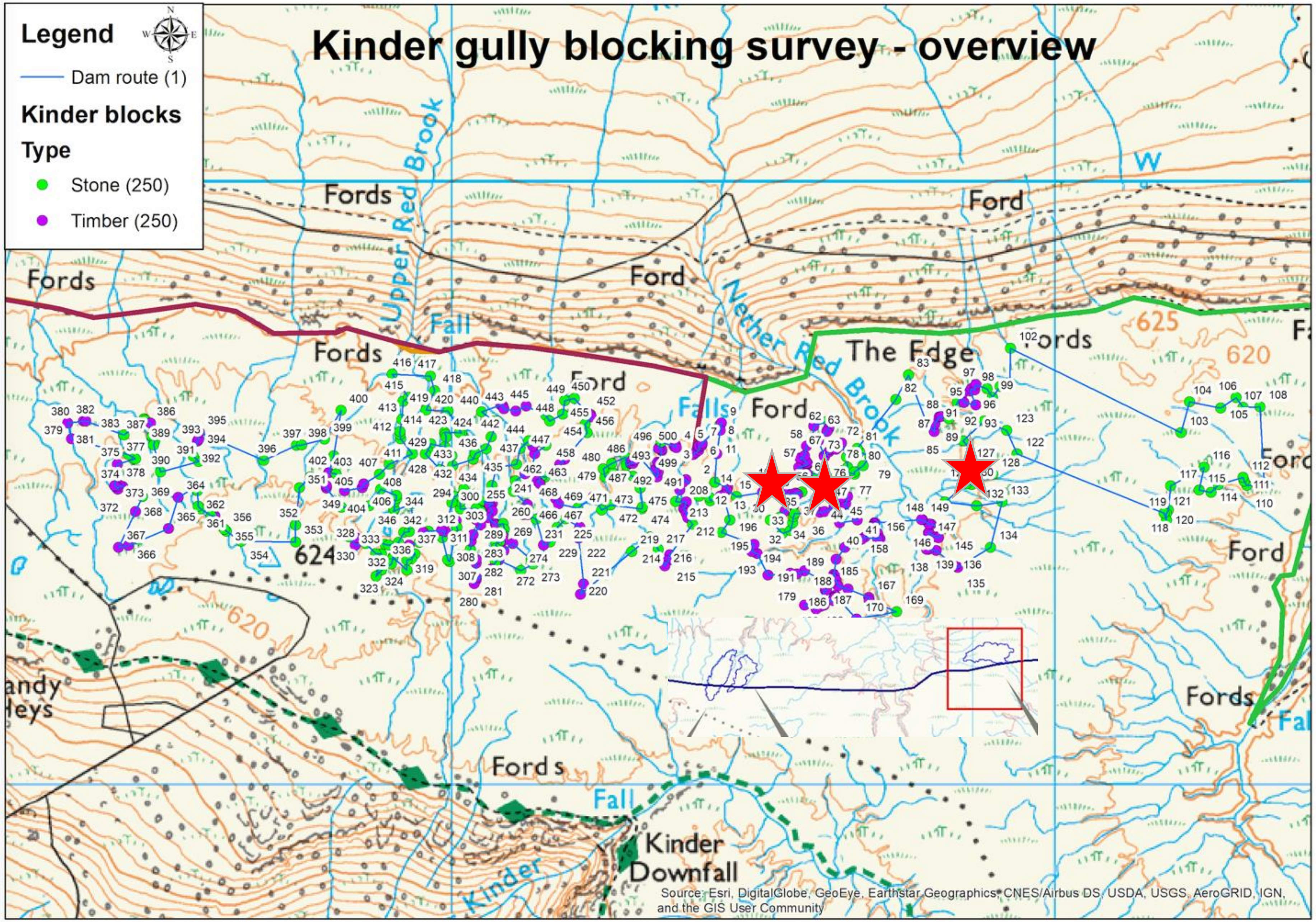
To increase their influence dams must be less permeable.

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





- 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.



Kinder gully blocking survey - overview
Legend
Dam route (1)
Kinder blocks
Type
Stone (250)
Timber (250)
Fords
Ford
The Edge
Upper Red Brook
Nether Red Brook
Fall
Falls
Kinder Downfall
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

PROTECT NFM

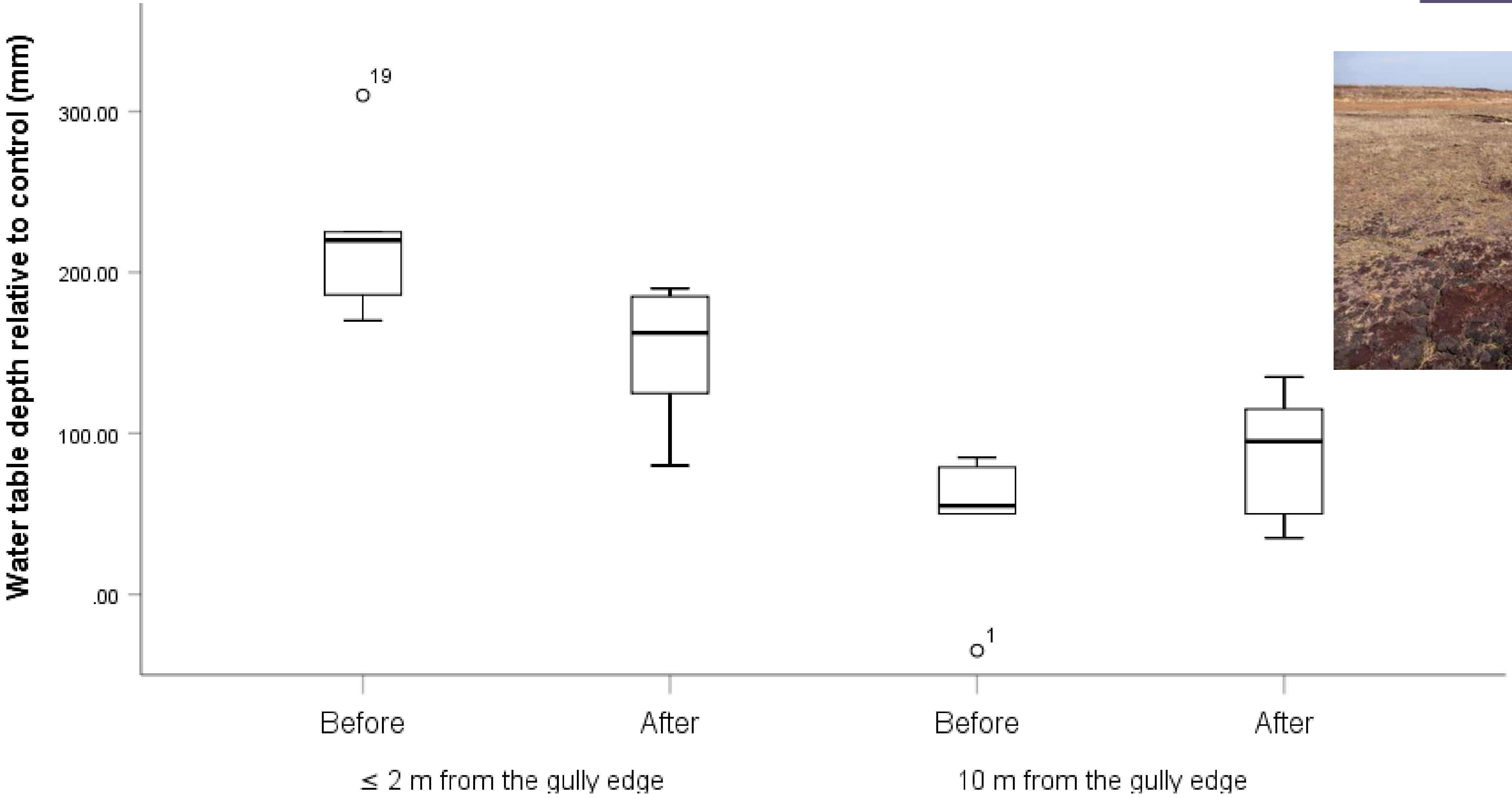
Balancing co-benefits of peatland restoration: water table and NFM potential

PROTECT NFM

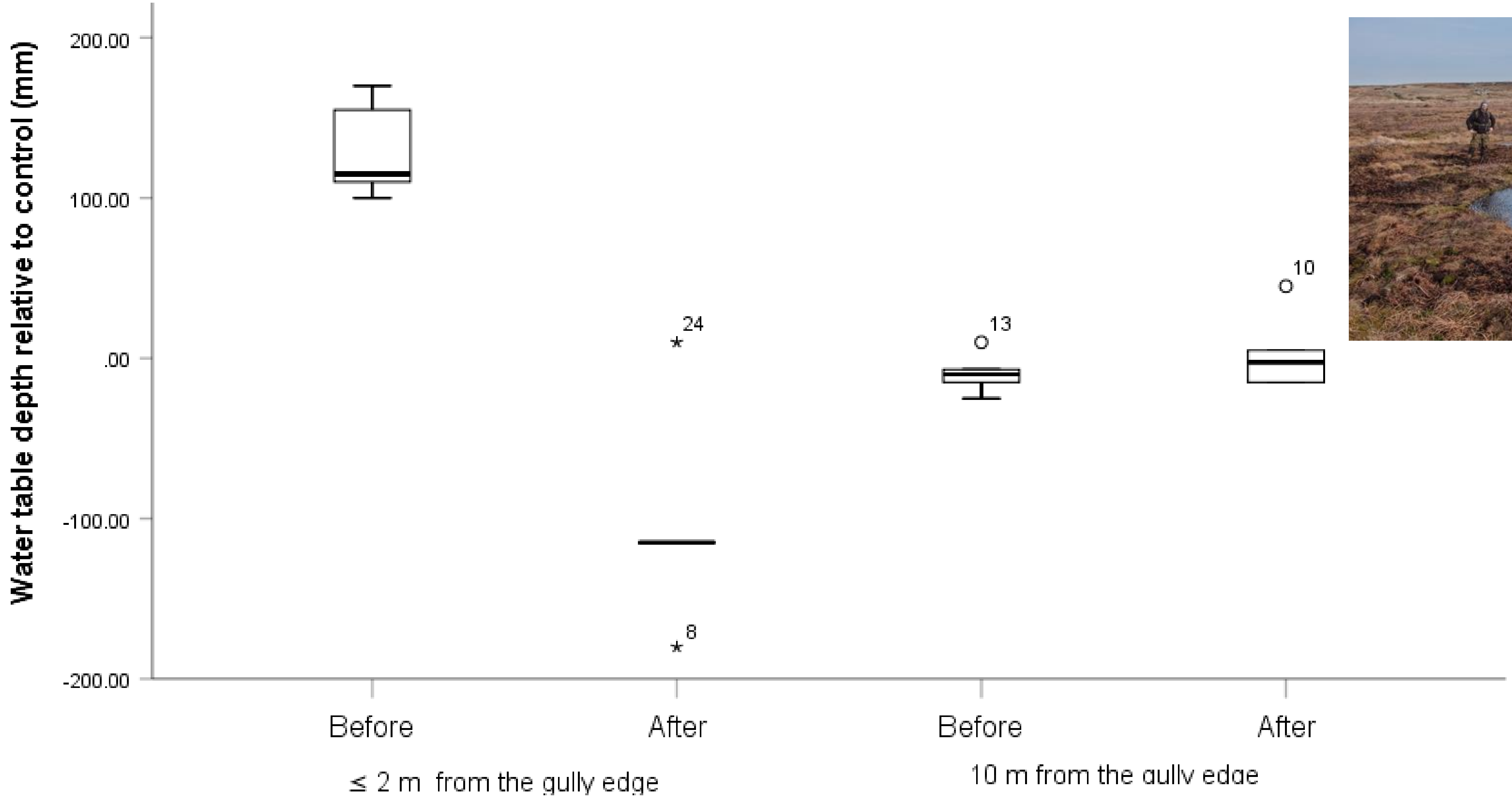
Water Table Masurement

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

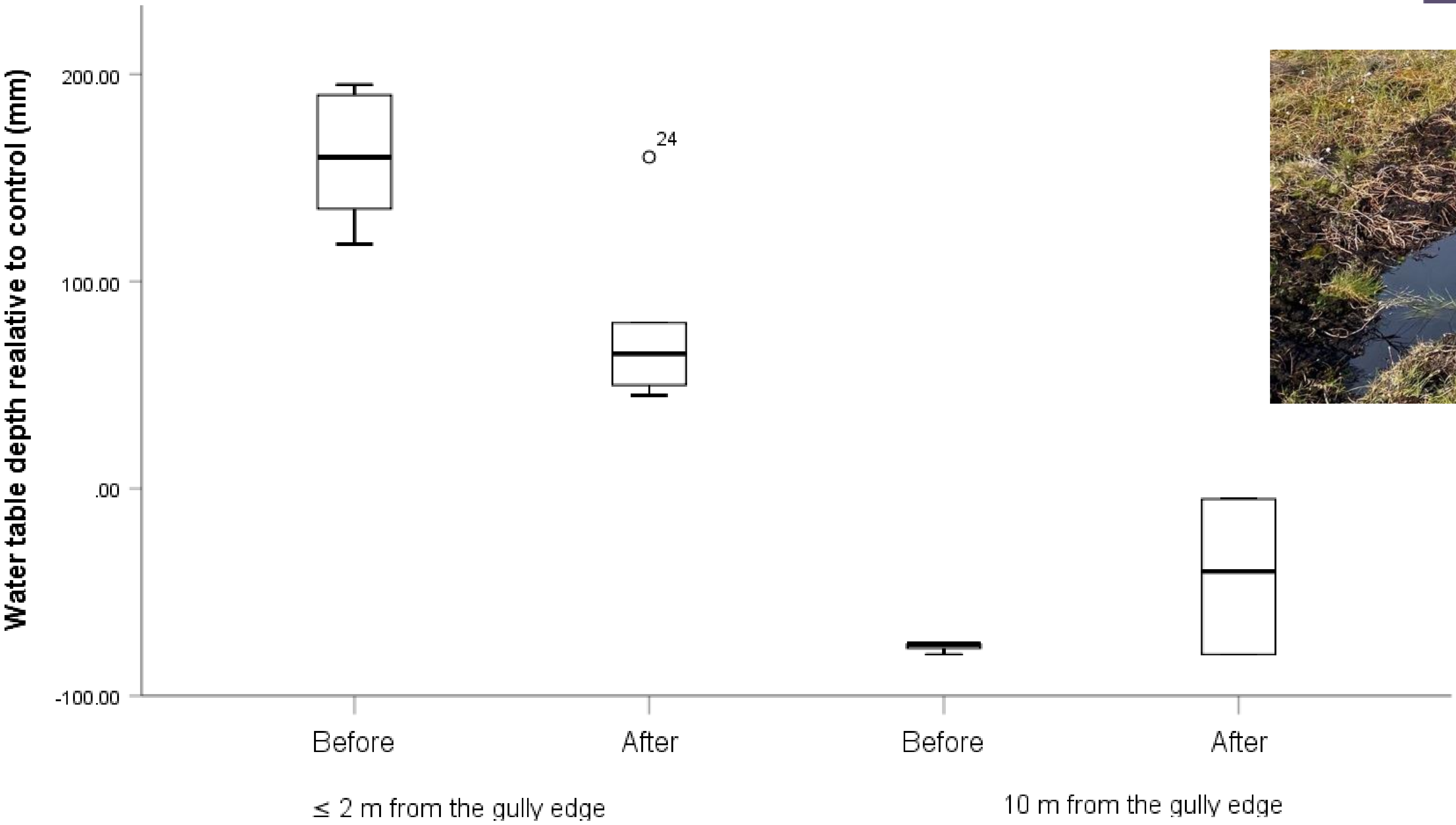
Water table change before and after blocking: stone dam



Water table change before and after blocking: peat dam



Water table change before and after blocking: piped peat dam



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

- Goudarzi, S., Milledge, D. G., Holden, J., Evans, M. G., Allott, T. E. H., Shuttleworth, E. L., et al. (2021). Blanket peat restoration: Numerical study of the underlying processes delivering natural flood management benefits. *Water Resources Research*, 57 (open access at https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2020WR029209)
- *Shuttleworth, E.L., Evans, M.G., Pilkington, M., Spencer, T., Walker, J., Milledge, D., Allott, T.E.H., 2019. Restoration of blanket peat moorland delays stormflow from hillslopes and reduces peak discharge. Journal of Hydrology X 2 https://doi.org/10.1016/j.hydroa.2018.100006*

Thanks for listening!

Any questions?