Results of the Water Friendly Farming project and next steps

Jeremy Biggs, Simon Bonney, Colin Brown, Chris Stoate, John Szczur, Martha Villamizar Velez and Penny Williams (September 2020)

1. Introduction

Water Friendly Farming is a unique catchment-scale research and demonstration project that investigates how well 'nature-based' measures protect against flooding, reduce diffuse pollution (including sediment loss), and enhance freshwater biodiversity. **The project has national significance because of its focus on lowland farmed environments, its carefully designed research approach, and its rigorous testing of flood risk benefits and other 'multiple benefits'**. With the growing application of nature-based measures, Water Friendly Farming provides the Environment Agency and others with critical information that enables best value for money for public expenditure.

Initiated in 2010, Water Friendly Farming is providing ***unequivocal evidence of the flood risk benefits of Natural Flood Management measures***. As one of the first projects to evaluate leaky dam performance in lowland farmland, it has important lessons for their effectiveness, longevity and maintenance. ***The project has also demonstrated important gains for freshwater biodiversity but shows the limitations of nature-based measures in improving water quality*.**

FIG. 1 Leaky dam on Game & Wildlife Conservation Trust Allerton Project farm at Loddington, Leicestershire

Water Friendly Farming is based in a 30 km^2 area of the upper Welland catchment working with c.30 farms. Pre-works baseline descriptions of the physical, chemical and biological conditions of the three study catchments were made in 2010-13, with the first practical measures installed in 2014/15 (e.g. bunded ditches, interception ponds, flood storage areas, debris dams), followed by leaky dams from 2016 onwards. The project is run by Freshwater Habitats Trust, Game & Wildlife Conservation Trust's Allerton Project, University of York and the Environment Agency funded mainly through the EA Catchment Restoration Fund, with Anglian North RFCC support from 2016 to 2021.

2. Natural Flood Management

Linked SWAT (Soil and Water Assessment Tool) and EA Mike 11 models, validated with flow data from monitored storm events, were used to assess the effects of 28 leaky dams with a storage capacity of 17,700 m^3, installed in the Eye Brook catchment. We found that:

- The leaky dams ***reduced peak flows by a substantial 19-24% in storms up to 1:50 year events***, providing an unequivocal demonstration of the value of these simple structures. Even in 1:1000 year events the models predict c.11% reduction in peak flows from the headwater catchment (FIG. 2).
- The effects of the leaky dams can be detected ***10 km downstream***, probably because they are desynchronising flows (FIGS. 3, 4). At 10 km distance, flood levels are only reduced by 1-2 cm, but this could still be vital in preventing overtopping of defences during critical storms.

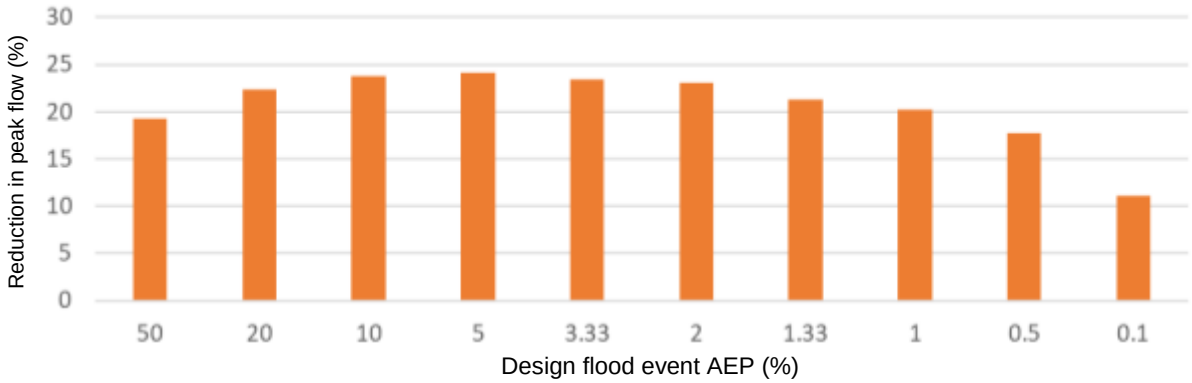

FIG. 2. Reduction in peak flow from the Eye Brook headwater catchment for a range of design flood events (AEP: Annual Exceedance Probability)

- Dam peak effectiveness was seen at 1:20 storm events (FIG. 2), but was also valuable in more extreme events. This new evidence contrasts with the common view that it is only small floods that may be reduced by NFM.
- Dams can vary substantially in their leakiness and still perform well; detailed modelling of dam 'permeability' shows that a range of different designs could be effective and the dams can continue to function well even after some settling in and adjustment.
- Performance of leaky dams changed after winter floods when high flows scoured stream beds below some dams, and caused some movement of dam structures. Modelling of the flood-adjusted dams showed that they held back less water during smaller storm events (because of larger gaps at the bottoms of some dams) but, importantly, performed as efficiently during the largest events.

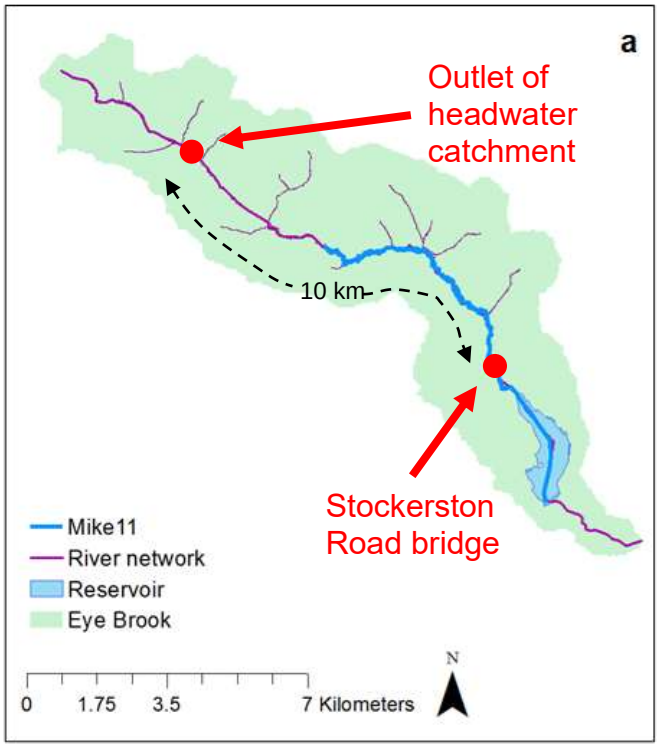

FIG. 3. Flow modelling and monitoring locations in the Eye Brook

- The large flood flows during November 2019 damaged some dams but provided valuable information on their robustness, and has enabled us to refine designs to make them more resilient. We have written ***a new practical guidance document*** to make our experience on the optimum design of dams widely available.
- Leaky dams proved to be easier to install and more effective at holding back flood water than other measures we tested such as flood storage ponds and bunded ditches.

Overall, our results show that leaky dams have the potential to play a valuable role in flood risk management. Their effects are strongest near the dams but reduced flood levels can still be seen 10 km downstream. Our findings also have important lessons about dam longevity, maintenance and future design.

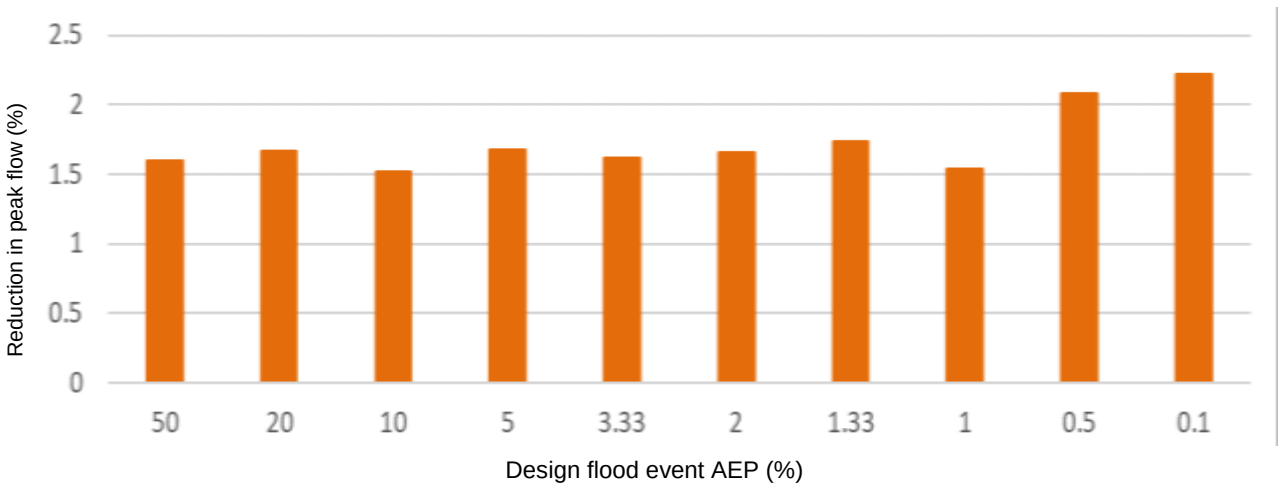

FIG. 4. Reduction in peak flow 10 km downstream for a range of design events. Desynchronisation is the dominant effect on downstream flow and this is predicted to be retained even for the largest events.

3. Sediments and diffuse pollution

A wide range of nature-based measures (interception wetlands, sediment traps, bunded ditches, woody debris) were used to trap sediments and pollutants. Sediments are of concern because when deposited downstream they often increase flood risk. We found that:

- **Sediment**: small scale measures to reduce sediment loss (interceptions basins, bunded ditches) quickly accumulated sediment, but could trap only a small proportion of the c.300 tonnes sediment lost from each sub-catchment annually. ***Increasing buffer strips to 20-m width on all streams or implementing no-till cultivation on all arable land could reduce this loss by one third***. Greater reductions could be achieved if large parts of the catchments were afforested.
- **Water quality** has shown limited responses to the nature-based measures. Our models and intensive field monitoring show that to reduce levels of nitrogen and phosphorus pollution would require substantial changes in the catchments. **This would need to include *substantial reduction of phosphorus discharges from rural sewage works* alongside land management measures such as *conversion of arable land to low-input grass* or *substantially improved nutrient use efficiency in arable systems*.**
- **Pesticides:** a case study using the blackgrass herbicide propyzamide showed that stream contamination could only be controlled effectively by reducing use of the compound.

Our evidence suggests that achieving worthwhile water quality improvements will require a combination of extensive buffer zones around cropped areas, changes in land use to reduce inputs and better management of sewage effluents in headwaters.

4. Freshwater biodiversity

Wetland plant surveys were undertaken annually in all waterbodies in the catchments and provided data and unexpected results that are internationally significant.

- **There was a *slow background loss of freshwater plants***, with 1% of species lost per annum over the 10 years of the project, caused by many factors including diffuse pollution and habitat loss.
- **Adding nature-based measures** that hold back contaminated water (water detention basins, bunded ditches, field drain interception ponds) **stopped the catchment-wide decline of common freshwater plants** although it did not prevent loss of rare species.
- **Creating clean ponds** (not attached to streams or ditches) played a critical role in catchment freshwater biodiversity ***increasing species diversity in the whole landscape by 25%***.

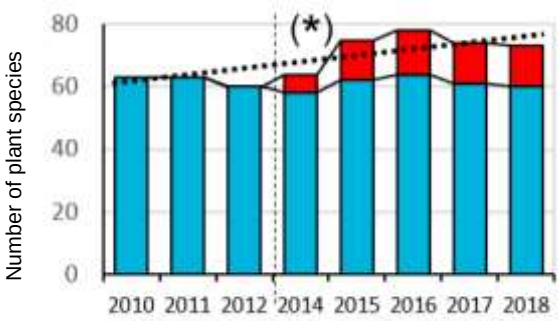

FIG. 5. Effect of adding clean water ponds to the catchment

The results provide clear evidence of the biodiversity benefits of nature-based measures, and highlight the unprecedented benefits of clean water pond creation.

5. Application of the project's results

Water Friendly Farming has provided critical new understanding of the effectiveness, and limitations, of nature-based and NFM measures. The results are already being widely applied and shared by:

- disseminating information through the Allerton Project's advice programme for farmers and policy makers and the publication of the project's first scientific papers, with national media coverage[1]
- developing new practical guidance on the use of 'leaky dams', building on the experience of the project's testing, modelling and refinement of different leaky dam designs
- applying the projects findings in further practical projects that involve nature-based measures, both in the Anglian river basin district and beyond, including the Defra-funded Wootton Brook project with the Environment Agency, the R. Leck project (also Defra-funded, with Buckinghamshire County

[1]Villamizar, M.L., Stoate, C., Biggs, J., Morris, C., Szczur, J. and Brown, C.D., 2020. Comparison of technical and systems-based approaches to managing pesticide contamination in surface water catchments. Journal of Environmental Management, 260, p.110027. Williams, P., Biggs, J., Stoate, C., Szczur, J., Brown, C. and Bonney, S., 2020. Nature based measures increase freshwater biodiversity in agricultural catchments. Biological Conservation, 244, p.108515.

Council), in flood risk work supported by East-West Rail Consortium between Milton Keynes and Aylesbury and in a new 5-year demonstration project with Anglian Water in the Pitsford Reservoir catchment which is building on Water Friendly Farming's concepts. Outside Anglian region we are applying the project's learning across Yorkshire in collaboration with University of York, and in a new mid-Wales demonstration site, the 300 km^2 R. Irfon catchment.

- Water Friendly Farming has also been selected as **a European demonstration site in a new *EU Horizon 2020 research programme*** on nature-based measures for mitigating climate change impacts on biodiversity which runs from 2020-2024
- providing information and advice on NFM measures for RFCC-supported work in the R. Waring and R. Steeping catchments where serious flooding occurred around Wainfleet in summer 2019.

Next steps: future work in 2021-2026

Building on Water Friendly Farming's substantial progress and achievements, we propose a specific range of further work testing nature-based measures that currently have a limited evidence base. This work will help the RFCC to encourage knowledge-based use of nature-based solutions, as recommended in the National Flood and Coastal Erosion Risk Management Strategy for England, whilst promoting efficient and targeted use of public funds. Specifically, we plan to: (i) improve understanding of the long-term (10 years plus) maintenance demands of leaky dams, (ii) test new leaky dam designs to maximise their cost-effectiveness in terms of installation, effectiveness and robustness, (iii) apply NFM measures (leaky dams, floodplain reconnection and other measures) over a larger area of the Eye Brook catchment to assess whether larger flood risk benefits can be achieved, (iv) assess in more detail the potential to deliver runoff and sediment reductions by better soil management, and (v) provide the first data on the longer-term benefits of NFM measures on water quality and biodiversity in lowland farmed environments.

To achieve these goals we would like to request support from the Anglian RFCC at the level of **£75k / year over the period 2021 – 2026** to address the following questions**:**

- ***Can the design of leaky dams be refined and diversified to increase both their robustness and effectiveness under different flow conditions?*** Most NFM dams being introduced in the UK use a single design. Our modelling suggests different designs and placement may be more cost-effective and robust. This work would also evaluate the performance and maintenance of our existing dams in the longer term.
- ***Can the flood benefits of leaky dams be increased by adding more dams to further desynchronise flows across larger areas?*** To do this we would increase the number of dams installed in the Eye Brook catchment to c.50, doubling the number of headwater streams covered.
- ***How much additional benefit is gained from floodplain reconnection, an approach being widely recommended but so far little tested in practice?*** A total of 100,000 m^3 of storage is potentially available on the Eye Brook floodplain, roughly 5 times the amount retained by the leaky dams, enabling us to rigorously test the use of this approach.
- ***In practice, can we achieve runoff and sediment reductions predicted by our models?*** Working with farmers in the Eye Brook and Stonton Brook catchments we will test the value of (a) increasing soil organic matter and improving soil structure to increase infiltration and water storage, (b) increasing buffer widths on sloping arable fields, and (c) increasing use of no-till methods, all widely recommended for flood mitigation but with a limited evidence base so far.
- ***Can the biodiversity gains achieved be maintained in the medium to longer term?*** The biodiversity benefits of the project have been unprecedented and we now aim to investigate three further practical methods for improving freshwater habitats: (a) experimental tree/scrub coppicing to let light into heavily shaded streams (b) extending the programme of clean water pond creation to roughly double the area currently covered, (c) further reducing point and diffuse pollution to improve Water Framework Directive biological water quality in streams, monitored using freshwater invertebrates.

We also aim to develop a far larger and more comprehensive ***results dissemination programme*** with the Environment Agency, RFCCs and the Catchment Sensitive Farming programme to maximise the use and awareness of the project's results in flood risk and environmental management.