Case Study List

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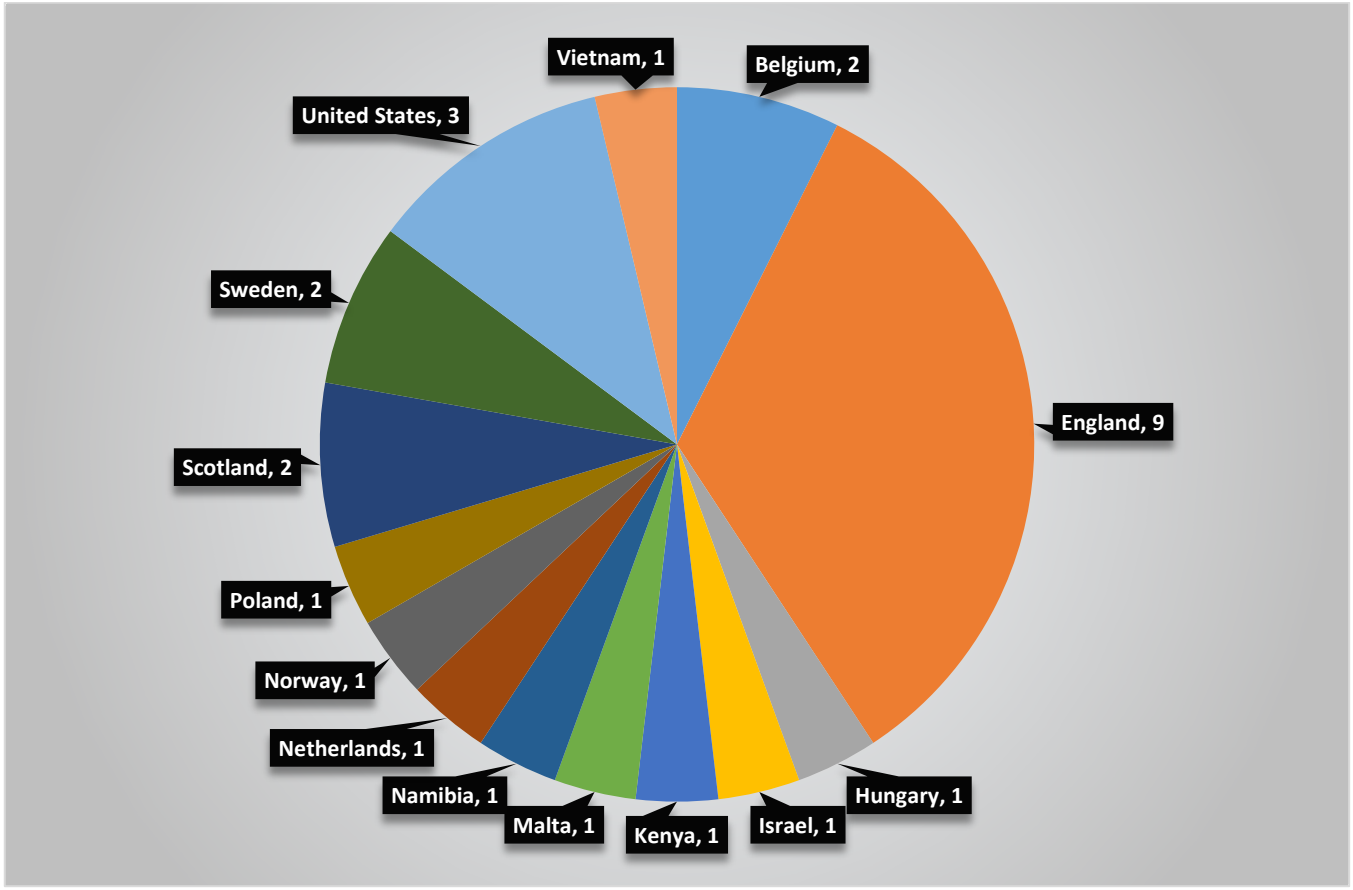
	Name	Organisation	Case study location
1	Andrew Vella	Ministry for Transport, Infrastructure and capital projects, Malta	Malta
2	Anita Bergstedt	County Administration of Västra Götaland, Vänersborg	Sweden
3	Anna Ternell	PE	Sweden
4	Brian Bledsoe	University of Georgia	Fort Collins, USA
5	Carlos Loureiro	University of Stirling	Namibia
6	Chris Haring	USACE ERDC	Nolin River, USA
7	Dave Brown	Environment Agency	Millbrook, England
8	Dave Kennedy	Environment Agency	Bannisdale, England
9	Duncan Harrison	Environment Agency	Lustrum Beck, England
10	Gábor Ungvári	Regional Centre for Energy Policy Research	Hungary
11	Gary Brown	Forth Rivers Trust	Allan Water, Scotland
12	Holly Radcliffe	Environment Agency	Leeds, England
13	Ine Rosier	KU Leuven	Melsterbeek, Belgium
14	Jenia Gutman and Rachelle Alterman	Ministry of Agriculture Technion - Israel Institute of Technology	Israel
15	Joe Rooms	Environment Agency	Anwa, Kenya
16	Karen Gabriels	KU Leuven	Belgium
17	Martina Egedusevic	Heriot Watt University	Menstrie, Scotland
18	Nick Chappell	Lancaster University	Cumbia, England
19	Nick Chappell	Lancaster University	QNFM, England
20	Paul Hudson	University of Potsdam	ResilNam, Vietnam
21	Paul Quinn	Newcastle University	Haltwhistle, England
22	Paula Whitfield	NOAA	Swan Island, USA
23	Rachel Glover	Environment Agency	West Mids, England
24	Rhys Evans	University College of Agriculture and Rural Development	Norway
25	Rinse Wilmink	Rijkswaterstaat	Houtribdijk, Netherlands
26	Rory Hunter	Environment Agency	Belford, England
27	Weronika Marynowska	Adam Mickiewicz University in Poznań, Poland	Poland

Number of Case Studies by country.



Case Study 1. Andrew Vella

Name of project: **Natural Water Retention Scheme (NWRS) in Wied il-Ghasel Valley Sub-Catchment, Malta**

Date project started and duration: **Projected Q4 2019 – Q1 2021**

Total value of the project (£/$/E): **Estimated € 2,157,000**

Measure(s) included or addressed: **earth-filled dam retentions, riparian vegetation, groundwater recharge**

Project funder(s): **European Structural and Investment Funds 2014 – 2020, Government of Malta**

Case study author contact details: **Andrew Vella**

MTIP, Project House, Francesco Bounamici Street, Floriana, Malta

andrew.vella@gov.mt

What was the scale of flood risk impact? (Select a scale from table below)

Scale	Yes or No
0-10 km²	**Yes**
10-100 km²	
100-500 km²	
500-10,000 km²	
>10,000 km²	

Description - What did the project do? **Proposed**

- Removal of accumulated sediment from upstream/downstream from Wied il-Ghasel existing dam.
- Formation of earth embankments on the banks of the exposed valley watercourse. The consolidated earth embankments will also support the usable side paths throughout the length of the valley.
- The planting of indigenous trees based on the concept of restoration ecology along the side embankments to re-establish ecological corridors along the valley.
- The construction of six earth-shaped dam retentions to maximise the water retention and aquifer recharge capability of the valley.

What were the flood risk impacts of project?

Did the project achieve wider ecosystem service benefits? **(Tick Yes or No in table below)**

Issue	Yes or No
Flood risk	
Erosion/incision of river banks	
Land use change and impacts	
Navigation	
Freshwater supply	
Flora and fauna	

Salt water intrusion	
Deforestation	
Loss of floodplains	
Channelization	
Pollution	

Were there any lessons learn (both positive & negative)?

Further information

Photo

earth-shaped dam retention

Case Study 2. Anita Bergstedt

Name of project: Keep the water in the landscape. How do we disseminate knowledge and get measures installed?

Date project started and duration: (2015) 2018 and going on

Total value of the project (£/$/E): 30 % of my time at the County Administrative Board of Västra Götaland

Measure(s) included or addressed: I inform municipalities, other authorities, water boards and landowners about why they should keep the water where it falls and how it can be done. I write applications together with universities, municipalities, the Swedish Forest Agency, water boards and others. The aim is to get funding for projects which will get measures installed in the field, disseminate the ideas, give more knowledge through research and documentation and give possibilities for study tours.

Project funder(s): Governmental funding for climate adaptation through the County Administrative Board.

Case study author contact details: Anita Bergstedt, anita.bergstedt@lansstyrelsen.se

What was the scale of flood risk impact? (Select a scale from table below) Not relevant

Scale	Yes or No
0-10 km²	
10-100 km²	
100-500 km²	
500-10,000 km²	
>10,000 km²	

Description - What did the project do?

We have made a guide on how to proceed to manage flooding with Nature Based Solutions:

https://www.lansstyrelsen.se/vastra-gotaland/tjanster/publikationer/ovriga/naturbaserade-losningar-mot-oversvamning.html

https://www.lansstyrelsen.se/vastra-gotaland/tjanster/publikationer/2018/naturanpassade-atgarder-mot-oversvamning---ett-verktyg-for-klimatanpassning.html

I found it difficult to reach municipalities with flooding problems, in a way that made them start projects for NBS. This made it difficult to find an arena to reach the landowners in an organized way, to get NBS projects started.

Where measures have been made systematically in catchments, a close dialogue with landowners seem to have been a key. In different basins, different methods have been used to communicate. Many projects to keep water in the landscape have the main goal to prevent loss and transport of nutrients. The problem with water quality in rivers, lakes and coastal areas caused by agriculture is well known in Sweden, as are methods to make matters better.

By educating consultants and officers who are successful in getting the landowners to make installations, we should have a fast dissemination of knowledge in NBS for flood risk management. Measures that already are known and used, will with some modification also keep the water in the landscape to prevent downstream flooding.

A project in Västra Götaland County has developed a system on how to communicate with landowners to enhance nature values in the landscape:

http://www.hnvlink.eu/innovations/vaestra-goetaland/

http://www.hnvlink.eu/download/D2.6_HNVLinkCOMPENDIUM.pdf pages 306-321.

After the project leader got information about NBS against flooding, they have now extended the digital manual for the dialogue, to also contain NBS.

What were the flood risk impacts of project?
Add a paragraph to describe Not relevant?

Did the project achieve wider ecosystem service benefits? We only propose measures which are neutral or give positive impact on biodiversity and water quality.

Issue	Yes or No
Flood risk	Yes
Erosion/incision of river banks	Yes
Land use change and impacts	Yes
Navigation	?
Freshwater supply	Yes
Flora and fauna	Yes
Salt water intrusion	No
Deforestation	Yes
Loss of floodplains	Yes
Channelization	Yes
Pollution	Yes

Were there any lessons learn (both positive & negative)t?

- We need to finance some projects to practically show how it works and how it can be done, before stakeholders dare to start projects of their own.
- Get involved in small projects. A few installations are better than none, and will disseminate knowledge and give inspiration.
- By educating consultants and officers who are successful in getting the landowners to make installations for other purposes, we should have a fast dissemination of knowledge in NBS for flood risk management. Installations will be made in the field faster than if you have to start a new project.
- People who already have reasons to communicate with landowners about measures and new habits, will get installations in place quicker, than if you have to start a new project.

Further information
https://www.lansstyrelsen.se/vastra-gotaland/tjanster/publikationer/ovriga/naturbaserade-losningar-mot-oversvamning.html

https://www.lansstyrelsen.se/vastra-gotaland/tjanster/publikationer/2018/naturanpassade-atgarder-mot-oversvamning---ett-verktyg-for-klimatanpassning.html

http://www.hnvlink.eu/innovations/vaestra-goetaland/

http://www.hnvlink.eu/download/D2.6_HNVLinkCOMPENDIUM.pdf pages 306-321.

Photo

Save or recreate natural habitats along and in watercourses. This will protect the water quality, reduce water speed and erosion and enhance biodiversity. Photo: Linnéa Jägrud.

Case Study 3. Anna Ternell

Name of project: Business models for bluegreen solutions to prevent flooding and drought

Date project started and duration: 1 January 2019, 1 year

Total value of the project (£/$/E): Euro 90 000

Measure(s) included or addressed: 1) Anchoring and engagement of stakeholders and European outreach, 2) effects and values of nature-based solutions, 3) analysis of compensation or trading schemes for climate related measures, 4) legal barriers and possibilities regarding management of blue green solutions and 5) validated business model for a financial instrument for upstream water retention through blue-green structures.

Project funder(s): Climate KIC/EIT

Case study author contact details: Anna Ternell, anna.ternell@pe.se, +46 706 047022

What was the scale of flood risk impact? (Select a scale from table below)

Scale	Yes or No
0-10 km²	
10-100 km²	X
100-500 km²	
500-10,000 km²	
>10,000 km²	

Description - What did the project do?

The aim of this project is to develop a financial instrument for upstream water retention through blue-green structures. Re-occurring major floods is expected in a future scenario of climate change, and the damages and costs of this are expected to be immense. In e.g. the City of Gothenburg in Sweden, flooding risks are in general subject to technical control through the construction of river defences through the means of grey infrastructure. Technical solutions are however costly and some take many years to implement. Lower flows would provide an opportunity to build or avoid large and costly solutions providing opportunities to make savings on operating costs, investments and claimed land for installations. Through nature-based solutions water can be stored in upstream areas until there is room for water flows that do not exceed a level that causes unacceptable damages. Storing water in the landscape also have positive effects to meet the problems of drought.

A key is for the beneficiary and landowner to agree on how the benefits of avoiding flooding are valued, and how any inconvenience for landowners to periodically store water should be valued. It is reasonable that the landowner is remunerated by those who gain from the measure. The business model aims to turn the landscape into a resource for landowners, such as, municipalities in a new way, whereby the landowner can sell water-holding services and by that decrease the risk for future flooding or drought.

What were the flood risk impacts of project?

Delaying the water upstream through various approaches has several benefits, such as controlling flood risks and reducing costly effects of flooding, as well as reducing water scarcity and effects of droughts downstream. This includes that surface runoff and water peaks are reduced with less erosion and less sediment and nutrient movements. Achieving more steady water streams through nature-based solution can also provide benefits, such as keeping the groundwater basins well stocked, with the purpose to avoid problems with drought in warmer weather. Increased

storage of water in the landscape also benefits biodiversity, water quality, nutrient retention, creation of ground water, and farming activities.

Did the project achieve wider ecosystem service benefits? (Tick Yes or No in table below)

Issue	Yes or No
Flood risk	Yes
Erosion/incision of river banks	Yes
Land use change and impacts	Yes
Navigation	
Freshwater supply	Yes
Flora and fauna	Yes
Salt water intrusion	
Deforestation	
Loss of floodplains	
Channelization	
Pollution	

Were there any lessons learn (both positive & negative)t?

This is an ongoing project and lessons are still to come.

- Important with stakeholder engagement and commitments
- Challenge to value the effects
- Challenge to set up a financial system

Further information

Add links to references of hyperlinks to webpages

https://nordic.climate-kic.org/success-stories/blue-green-compensation-projektengagemang-ideation/

Photo

Paste a project photo here and say what it is of and who the photo should be referenced to

Wetland for water storage and supporting forestry and biodiversity.

Case Study 4. Brian Bledsoe

Name of project: Cache la Poudre River: Floodplain Reconnection in an Urban Corridor – Fort Collins, Colorado

Construction date: 2014 - ongoing

Total cash cost of the project: ?

Measure(s) included: Floodplain reconnection, oxbow restoration, riparian forest restoration, streambank bioengineering

Project funder(s): City of Fort Collins, Great Outdoors Colorado

Main contact(s): John Stokes, naturalareas@fcgov.com, 01-970-416-2815

What was the scale of flood risk impact? (Select a scale from table below)

Issue	Yes or No
Extra Small (0-10 km²)	Yes
Small (10-100 km²)	Yes
Medium (100-500 km²)	No
Large (500-10,000 km²)	No
Extra Large (> 10,000 km²)	No

Description - What did the project do?

The project involves reconnecting the Cache la Poudre River with its floodplain in the urban corridor of Fort Collins CO by removing levees and gravel mining berms. This project is part of a larger master plan for flood management and revitalization of the urban river corridor. This specific design at McMurry Ponds Natural Area focused on lowering elevated gravel pond edges, creating shallow wetlands, and revegetating a ca. 44 acre riparian area. A diverse assemblage of five vegetated zones were created including emergent wetland, wet meadow, willow, cottonwood, and upland grasses. To facilitate public use and stewardship of the site, the design included a pedestrian trail and designated fishing areas. Grading and planting of Phase 1 was completed in June 2011. Phase 2 of the project was initiated by the City in 2013 to expand the restoration to the eastern gravel pit as well as include streambank and channel improvements. Phase 2 included removing concrete and debris from the stream bank, lowering high berms to reconnect the floodplain, regrading the ponds' shorelines and berms to more gradual slopes, and using the excavated soils to create shallow water wetlands along the edges of the ponds.

What were the flood risk impacts of project?

Reduces peak flows downstream. Floodplain lands were acquired by the City beyond the 0.2% annual exceedance inundation area.

Did the project achieve wider ecosystem service benefits? (Tick Yes or No in table below)

Issue	Yes or No
Flood risk	X
Erosion/incision of river banks	X
Land use change and impacts	X
Navigation	
Freshwater supply	X
Flora and fauna	X
Salt water intrusion	
Deforestation	X
Loss of floodplains	X
Channelization	X
Pollution	X

Were there any lessons learnt?

- Uncertainty of future hydrological conditions / nonstationarity is a challenge for design
- Establishing baseline data is difficult in heavily modified systems
- Project functioned as planned through overbank flood events
- Room for the river can work in urban contexts
- Plains cottonwood recruitment was re-established

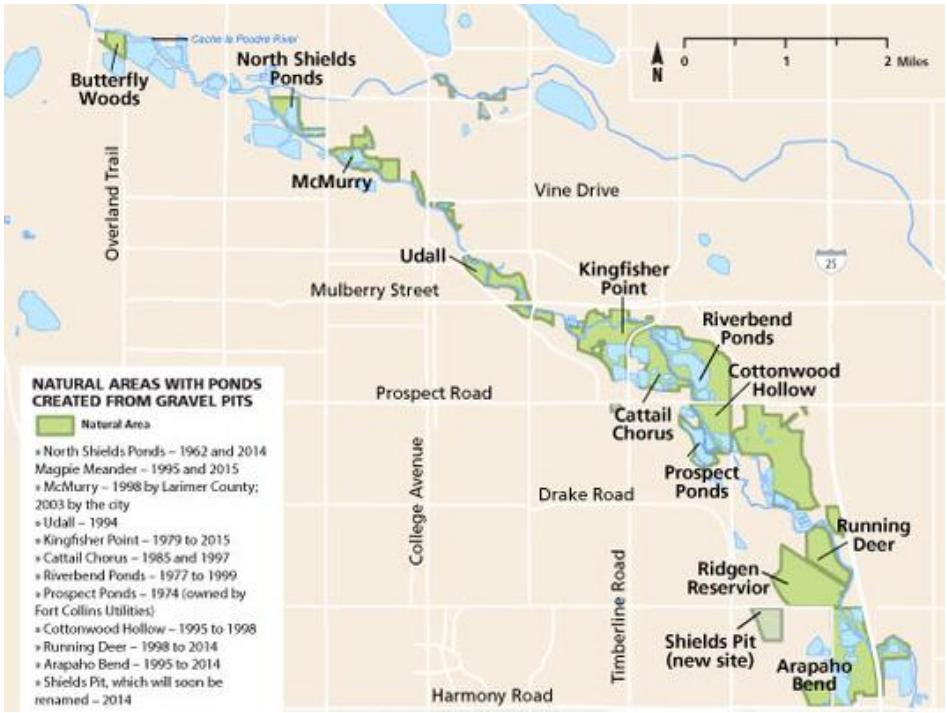
Further information

https://www.youtube.com/watch?v=Z2uKS0S82q4&feature=youtu.be

https://www.biohabitats.com/project/mcmurry-poudre-restoration-phase-1-2/

https://www.fcgov.com/poudre-downtown/pdf/final-plan.pdf?1416436605

Photo



Case Study 5. Carlos Loueiro

Name of project: Large-scale beach nourishment in Southern Namibia: challenges of rapid shoreline advance and barrier resilience

Date project started and duration: 01/2018 – 12/2020 (3 years)

Total value of the project (£/$/E): Industrial partnership subjected to a non-disclosure agreement covering financial information.

Measure(s) included or addressed:
NNBF – beach and barrier building/restoration
BWN – mega nourishment/feeder beaches (nature-based flood defence)

Project funder(s): Namdeb Diamond Corporation (Namibian Government & DeBeers)

Case study author contact details: Carlos Loureiro, University of Stirling, UK & University of KwaZulu-Natal, South Africa, carlos.loureiro@stir.ac.uk / loureiroc@ukzn.ac.za

What was the scale of flood risk impact? (Select a scale from table below)

Scale	Yes or No
0-10 km²	No
10-100 km²	Yes
100-500 km²	No
500-10,000 km²	No
>10,000 km²	No

Description - What did the project do?
In Oranjemund, Southern Namibia, a large-scale beach nourishment project for diamond exploration has been ongoing since the mid-2000's, creating the largest shoreline accretion area in the world. While the motivation is commercial/extractive, not explicitly implementing nature-based flood or coastal protection, there are similarities to mega-nourishments currently being implemented elsewhere. Using standard dredging and earth-moving techniques, approximately 20M m^3 of sand and gravel are being placed annually along different sections of a 50km long high-energy shoreline, leading to consistent and rapid shoreline advance. As the coast advances seaward, large pits are excavated and maintained dry for mining, and afterwards allowed to flood by seawater, creating a series of closed lagoons with variable dimensions, fronted by a sandy barrier. By promoting a barrier configuration that is in dynamic equilibrium with the environmental conditions (waves, tides and sediment, nearshore bars) this project is trying to develop beaches that are resilient to coastal erosion and flooding during extreme storms, embedding some of the concepts of building with nature in an industrial context.

What were the flood risk impacts of project?
This mega nourishment project has modified the coastal area extensively and contributed to a rapid steepening of the coast, which impacts beach and nearshore processes (more energetic wave breaking and intense sediment transport). Because of the modified coastal dynamics, the barriers become more vulnerable to overwash and breaching, which has exposed active mining areas and closed lagoons to flooding during extreme storm events. By promoting a barrier configuration that is in dynamic equilibrium with environmental conditions, the coastline is able to adjust naturally to high-energy conditions and reduce flooding risk. However, when breaching and flooding occur, supplying the newly formed inlets with large amounts of sand to accelerate the expansion of flood deltas has been shown to produce better results than other options that don't consider inlet dynamic processes.

Did the project achieve wider ecosystem service benefits? (Tick Yes or No in table below)

Issue	Yes or No
Flood risk	Yes
Erosion/incision of river banks	Yes
Land use change and impacts	No
Navigation	No
Freshwater supply	No
Flora and fauna	No
Salt water intrusion	No
Deforestation	No
Loss of floodplains	No
Channelization	No
Pollution	No

Were there any lessons learn (both positive & negative)?

- Supporting the development of barriers in dynamic equilibrium with environmental conditions increases resilience to coastal erosion and flooding.
- The impacts of breaching are better mitigated by working with natural inlet processes to accelerate inlet closure.
- Complex modification of the coastal environment by mega nourishments can drive unintended development of erosional hotspots.
- Erosional hotspots are highly vulnerable to the cascading effects of overwash, breaching and flooding.

Further information

N/A

Photo

Aerial view of a section of the mega nourishment in southern Namibia, showing the artificial barrier, enclosed lagoons and the margin of a breached section of the barrier following an extreme storm in September 2018 (Source: Edmund Nel, Namdeb).

Case Study 6. Chris Haring

NNBF Guidelines Case Study

Information Sheet

1. **RELEVANT GUIDELINES CHAPTER:** Natural Resource Management sedimentation reduction and erosion control.
2. **Project Name:** Nolin River Lake Moutardier Point Bank Stabilization
3. **Project Location:** Corps of Engineers Nolin River Lake Edmonson County, Kentucky 37°18'35.0"N 86°13'54.8"W
4. **Project Sponsors and Affiliated Organizations:** US Army Corps of Engineers
5. **Person Submitting Case Study:** Libby Watt
6. **POC for Case Study:** Libby Watt
7. **Affiliation and Contact Info:**
   Libby Watt
   Nolin River Lake
   Natural Resource Specialist
   Nolin Dam Road
   Bee Spring, KY 42207
   270-286-4511
8. **Project Description:**

   Problem: With a large area of open water, heavy recreational boating activity and periodic flooding, the exposed shoreline in several locations of Nolin River Lake are eroding exponentially. There is no aquatic vegetation available or terrestrial vegetation succeeding at a rate fast enough to stabilize the banks. The accelerated erosion also contributes to siltation and degrading water quality.

   Objective: Bank stabilization through Longitudinal Peak Stone Toe Protection (LPSTP) and rip rap revetment.

   - ✓ *Pre work research* – communication with barge operators and companies on what type of vessel would be appropriate for the job considering the delivery and access to the site, modifications required to the access/launching site for the equipment accessibility and storage, logistics of delivery and coordination with the public due to the facility being a public boat ramp (bass tournament & weekend visitation), cultural resource clearances, Threatened & Endangered species, communication with local rock quarries being able to supply the amount of rock at the time of season installation of LPSTP was planned, take the prospect course Stream bank Erosion.

Pre-project site conditions with bank erosion.

Post-project site conditions with bank erosion protection

Original Details of work:

- Remove debris located along the eroded bank and dispose of prior to erosion control installation of rock. At the discretion of the Technical POC, this debris may be suitable for placement behind the completed LPSTP following completion of work.
- Install a 700' long x 12'deep x 6' tall longitudinal peak stone toe protection barrier. The LPSTP shall be 12' deep at the base and be sloped at a 2:1 slope to form a triangular protective barrier. The ends of the LPSTP will be keyed into the natural bank a minimum of 5' with excavating equipment and tiebacks will be placed every 100 feet (approximately 6 tiebacks). Approximately 2,120 cubic yards of stone will be placed here. The LPSTP shall be installed a distance equal to ½ to 1/3 the height of the eroded bank as measured from the typical summer pool shoreline. The summer pool shoreline is lake elevation 515'msl. Rock and materials for this work will be transported to the site by vessel. No equipment or vehicles will travel on land for installation.
- Rock tiebacks shall be 6' wide x 4' tall. Length shall be determined by the distance from the shoreline. Tiebacks shall be installed as the LPSTP is installed to ensure the rock is locked into the LPSTP. The tieback shall be excavated and installed at least 5' into the existing bank.
- Water depths 12' from the shoreline average 3 feet. Refer to Maps, drawings, and photos provided.

Total tonnage = 1539.42 tons
Cost for contractor: $180,754.60
Additional Cost = 783 tons provided by the Corps to the Contractor: $12,540.30

- ✓ *Issues addressed*:

Due to the shoreline contours, water depths, draft of the boat, and reach of equipment the tiebacks shortened with the exception of no less than 5' where the water meets the shoreline at summer pool level. Locations for tiebacks were selected and flagged where natural rock armoring was evident and contour of the shoreline showed minimal to no erosion, this extended the original length of LPSTP from ~500' to ~700'.

Original target dates for starting were to adhere to USFWS conservation strategy and restrictions for Indiana Bats and Northern long-eared bats (November 15 – May 31), but due to rain and other delays tree removal was restricted to only trees less than 3" diameter and overburden work where reachable with equipment was not completed. It was believed the objective would be met through natural processes, but just take a little longer.

Questions from the contractors concerns for specs of 12' base with 6' height resulting in the LPSTP being too short in some areas and too tall in others due to water depths at ½ and 1/3 of the bank height. Clarification was made through specifying a target height above summer pool of 3'.

There were two 2 locations that were in the original scope of work. Due to bid summaries falling outside the target amount the second location for erosion control was dropped and later submitted as a proposal in partnership with Kentucky Fish and Wildlife Fisheries department for a Reservoir Fish Habitat Grant.

9. **Project reports available. Y**
10. **If so, have you included reports with the information sheet. N**
11. **Website with this project: No – PSA released to public for ramp closures and barge activity**
12. **Did you include Pictures with this information sheet. Y**
13. **Any additional information you would like to share?** Project scope of work was completed in-house by the Project Manager, Deryck Rodgers and Park Ranger Libby Watt utilizing the

prospect course Streambank Protection lead by Chris Haring, US Army Engineer Waterways Experiment Station Stream investigation and streambank stabilization handbook, example scopes of work submitted to Louisville district for the Ohio river and reservoir tailwater bank revetment projects, and a multitude of powerpoint documents available online from ERDC instructor Dave Derrick

Case Study 7. Dave Brown

Name of project: MillBrook NFM scheme phase 1

Date project started and duration: Jan 2016, 3 months

Total value of the project (£/$/E): £13,500

Measure(s) included or addressed:

- 1.5ha of priority habitats created
- Wider and improved riparian zone and wildlife corridor
- Reduced diffuse agricultural pollution, to help meet WFD objectives
- Increased floodwater storage upstream (1000m3) and flood peak attenuation, via 3 Leaky barriers and floodplain re-connection, slowing the flow and helping with flood risk reduction benefits to the downstream village of Tattenhall (7 properties at risk).

Project funder(s): North West RFCC, Local Levy council tax funding

Case study author contact details: Duncan Revell, Lee Swift and Dave Brown.
David.j.brown@environment-agency.gov.uk

What was the scale of flood risk impact? (Select a scale from table below)

Scale	Yes or No
0-10 km²	
10-100 km²	Y
100-500 km²	
500-10,000 km²	
>10,000 km²	

Description - What did the project do?

This was a habitat creation scheme (Photo 1) which incorporated innovative, Natural Flood Management (NFM) techniques along 230m of Mill Brook, upstream of Tattenhall near Chester (Map 1). This partnership project with the Bolesworth Estate and Tattenhall Wildlife Group created 1.5ha of priority reedbed and wet grassland habitats within a new excavated and re-connected floodplain area. The project helps attenuate flood peaks and reduces risk downstream in Tattenhall.

What were the flood risk impacts of project?

1,000 m3 of additional storage, and increased channel and floodplain roughness, upstream of Tattenhall, a village with a history of flooding. Benefits are small magnitude, but have allowed confidence for a phase 2 scheme, with plans for > 10,000m3 of storage.

Did the project achieve wider ecosystem service benefits? (Tick Yes or No in table below)

Issue	Yes or No
Flood risk	Yes
Erosion/incision of river banks	Yes
Land use change and impacts	Yes
Navigation	No
Freshwater supply	No
Flora and fauna	Yes
Salt water intrusion	No
Deforestation	No
Loss of floodplains	Yes

Channelization	Yes
Pollution	Yes

Were there any lessons learn (both positive & negative)?

- Project opportunity arose via good partnership working with the community wildlife group.
- Good value for money; works carried out by the Environment Agency's Operations Field Team
- Priority habitat creation and enhanced biodiversity in wider, reconnected floodplain and improved riparian zone and wildlife corridor.
- Agricultural interest offset by land swap to elsewhere in the catchment.
- Reduced maintenance costs for the Environment Agency, with the Tattenhall Wildlife Group managing the site in the long term.

Further information

Working with Natural Process Case Study 7 (link).

Photo

Photo 1: Mill Brook scheme following construction (source: Environment Agency)

Case Study 8. Dave Kennedy

Name of project: Cumbrian NFM Sub Project - Bannisdale

Date project started and duration: 21st July 2018 to 31st March 2021

Total value of the project (£/$/E): £287,100

Measure(s) included or addressed: primarily is looking at leaky stone structures on a large scale. Will also look at re-meandering, tree planting, and leaky wooden dams.

Project funder(s): DEFRA £15m NFM Fund

Case study author contact details: Dave Kennedy (Environment Agency: david.kennedy@environment-agency.gov.uk)

What was the scale of flood risk impact? (Select a scale from table below)

Scale	Yes or No
0-10 km²	
10-100 km²	YES
100-500 km²	
500-10,000 km²	
>10,000 km²	

Description - What did the project do? What is it going to do.

A research project designed to monitor hydrological change arising from reinstalling the choke of a previously drained upland tarn. Using large boulders the aim is to create temporary flood attenuation during storm events greater than 1 in 10. The effects will be monitored using a doppler radar at the downstream point, the intention is to store between 20,000 and 60,000m3 of water with an 8 hour draw down time.

Significant modelling needs to be done to get the design right and to do failure modelling to ensure it becomes a Cat D reservoir.

The area is also subject to major river restoration works returning the watercourse to a naturalised channel.

What were the flood risk impacts of project?

The potential is to reduce the risk to local residents, but more importantly if it proves to be workable and successful it could be used in more vital locations to provide a genuine flood risk reduction.

Did the project achieve wider ecosystem service benefits? (Tick Yes or No in table below)

Issue	Yes or No
Flood risk	YES
Erosion/incision of river banks	Yes
Land use change and impacts	Yes
Navigation	
Freshwater supply	
Flora and fauna	Yes
Salt water intrusion	
Deforestation	Yes

Loss of floodplains	Yes
Channelization	Yes
Pollution	Yes

Were there any lessons learn (both positive & negative)?

- The amount of money needed on modelling to ensure people are comfortable is more than the intervention itself, one would hope that this won't always be the case.
- The time required to get all the relevant permissions is protracted and will mean that there is less time for observed changes to the hydrograph after the intervention.

Further information: Contact David Kennedy
Photo rough Artists Impression

Case Study 9. Duncan Harrison

Name of project: **Lustrum Beck Flood Alleviation Scheme**

Date project started and duration: 2014 – 2021 (ongoing)

Total value of the project (£/$/E): £4mil total, £660k for NFM measures

Measure(s) included or addressed: Online and offline storage features, woody debris features, run-off attenuation features, wetland creation and river restoration.

Project funder(s): Partnerships have been forged with the Tees Rivers Trust and Stockton Borough Council, with assistance and funding being provided by Highways England, Forestry England, local landowners and the European Union.

Case study author contact details: Duncan Harrison: duncan.harrison@environment-agency.gov.uk

What was the scale of flood risk impact?

Scale	Yes or No
0-10 km²	
10-100 km²	Benefitting catchment is 50km²
100-500 km²	
500-10,000 km²	
>10,000 km²	

Description - What did the project do?

The Lustrum Beck flows through Stockton-on-Tees and has a long history of flooding. Phase 1 of the project has been completed and has seen the construction of new flood walls, flood embankments and the replacement of a road bridge. This traditional FAS offers a 1.33%AEP protection to over 150 properties in Stockton. However, by storing additional flood water in the upper Lustrum Beck catchment, the flows passing through the urban area in Stockton can be reduced by 8% which will increase the standard of protection of the overall FAS to 1%AEP. A traditional storage dam was investigated but it was found to be technically and economically unviable in this location. Phase 2 of the Lustrum Beck FAS will see multiple NFM features installed across the of the Lustrum Beck catchment to slow flows, work with natural processes and create 30ha WFD compliant water dependent habitat. Works have already started on site and several features have been constructed already (see photographs below).

What were the flood risk impacts of project?

Lustrum Beck FAS phase 1 reduced the risk of flooding to 150 properties to a 1.33%AEP standard of protection. The cumulative effect of all the proposed NFM features will be to improve the standard of protection to the 150 properties to 1% AEP.

Did the project achieve wider ecosystem service benefits?

Issue	Yes or No
Flood risk	Yes
Erosion/incision of river banks	Yes
Land use change and impacts	No
Navigation	No
Freshwater supply	No
Flora and fauna	Yes
Salt water intrusion	No
Deforestation	No
Loss of floodplains	Yes
Channelization	Yes
Pollution	Yes

Were there any lessons learn (both positive & negative)?

- Quantify vs Qualify – One of the main lessons learnt has been the need to qualify the effectiveness of some NFM measures and quantify others. FCERM GIA funding depends on both reducing downstream flows, creating 30 hectares of water-dependent habitat and maintaining these benefits into the future. By clustering essential NFM features together it is possible to have greater certainty over the benefits delivered by those features. Through clustering it is possible to quantify the reduced flows caused by the group of features through appropriate modelling techniques, reduce ongoing maintenance costs and reduce the number of affected landowners that require engagement. Other individual NFM features that are likely to reduce flood risk but cannot be modelled economically have been spread around the catchment as the opportunity arises. A qualitative approach has been used to understand the likely benefits of these features.
- Collaboration with the varied partners mentioned above has been vital to the success of the project.

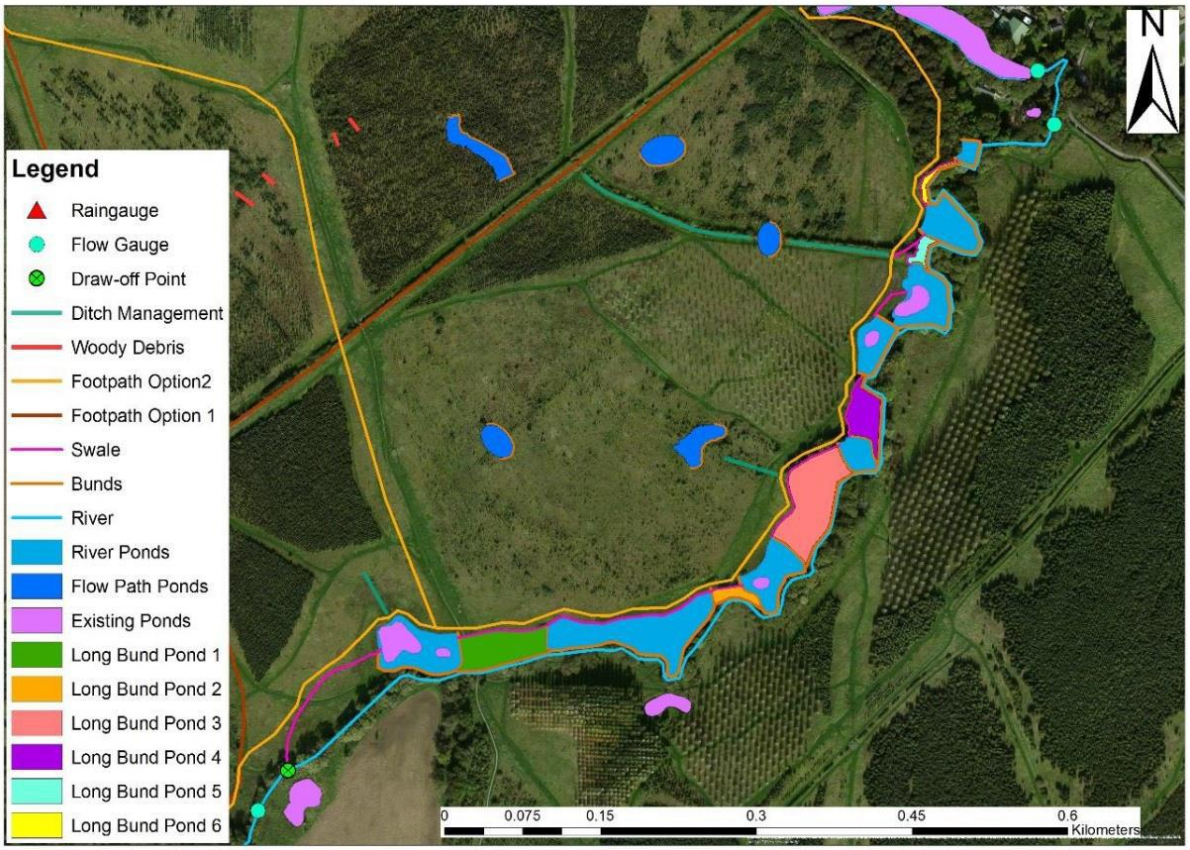
Further information

https://www.therrc.co.uk/sites/default/files/projects/21_lustrum.pdf

Photos

A woody debris dam constructed in early 2019.

Sediment trap and rivulet storage pond constructed in spring 2019.



High level schematic of major offline water storage proposed for delivery at Coatham Woods in summer 2019.

Case Study 10. Gabor Ungvari

Name of project: Incentivized storage of pluvial flood water
Location: Mirhó (10.07, 10.08) sub-systems of the Middle Tisza Water Directorate, Hungary

Date project started and duration: 2014 ongoing

Total value of the project (£/$/E): It is not a definite project

Measure(s) included or addressed: Enhanced trans-seasonal storage of pluvial flood waters

Project funder(s): no specific funds were required

Case study author contact details: Gábor Ungvári (BCE-REKK), gabor.ungvari@uni-corvinus.hu ; Tamás Právetz (KÖTIVIZIG)

What was the scale of flood risk impact?

Scale	Yes or No
0-10 km²	
10-100 km²	
100-500 km²	x
500-10,000 km²	
>10,000 km²	

Description - What did the project do?
Agricultural water users face a combined tariff that contains a water resource fee element and an operation cost element (albeit it doesn't cover the full cost of the operation). Neither the calculation method of the resource fee nor the infrastructure fee incentivized users to be sensitive to the water transfer and resource issues. In 2012 the method of the water resource fee calculation was modified. The fee was reset for water withdrawals from the channel network during the winter period (1st October – 31st March) what is the pluvial flood season. (The fee is a central budget revenue) The case focuses on the service area of the Middle-Tisza Water Directorate where (inland) fisheries started to take advantage of the modification of the tariff scheme by storing water for later use, these took place during the pluvial flood situations in 2014, 2017, 2018.

What were the flood risk impacts of project?
In the service area of the Middle-Tisza Water Directorate there were two sub-districts where in 2017 and 2018 both elements happened: fisheries applied for the preferential withdrawal/storage and pluvial flood event occurred in the same area. This way a mapping of the impacts were identifiable. The fee exemption from incentivized storage is a miniscule reduction in the central budget's taking while for the Water Directorate (that is also operates from the central budget sources) it saves from the pumping cost during the directorate's defence activity. Calculated from the information of the defence reports in the case of the two events the fee exemption was only 7-8% of the pumping cost that the Water Directorate could save. On the ground the stored volumes varied 40% and 2% of the volume that was pumped out of the area (2.3 mill m3 and 18 mill m3 respectively). The inversions reduced the coverage and the duration of the pluvial inundation on agricultural land that decreased the damage. Quantifiable estimations would have needed more detailed data on sub-district level. This is our next step plan.

Did the project achieve wider ecosystem service benefits? (Tick Yes or No in table below)

Issue	Yes or No
Flood risk	YES

Erosion/incision of river banks	
Land use change and impacts	
Navigation	
Freshwater supply	YES
Flora and fauna	
Salt water intrusion	
Deforestation	
Loss of floodplains	
Channelization	
Pollution	

Were there any lessons learn (both positive & negative)?

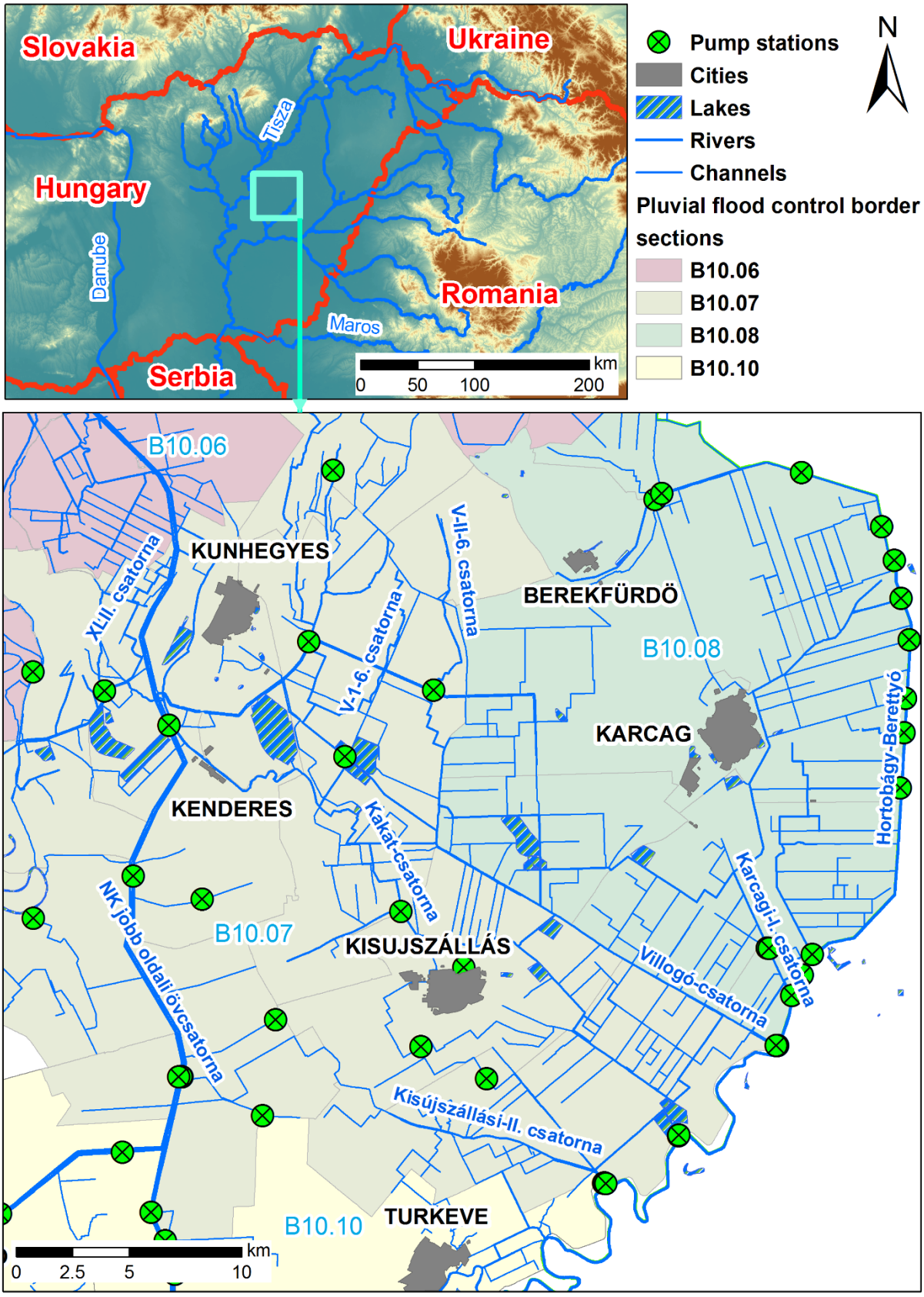
- Agricultural entrepreneurs / farmers are rational actors among irrational regulation conditions not the opposite.
- Proper incentive elements can be activated even in the frame of a far-from-optimal financing scheme
- Economic instruments are best suited to reveal hidden adaptation potential of multi-actor issues.

Further information

Case is under development

Photo

Sources:Courtesy of KÖTIVIZIG


Slovakia
Ukraine
Hungary
Romania
Serbia
Tisza
Danube
Maros
0 50 100 200 km
Pump stations
Cities
Lakes
Rivers
Channels
Pluvial flood control border sections
B10.06
B10.07
B10.08
B10.10
N
B10.06
KUNHEGYES
XI.II. csatorna
V-II-6. csatorna
V.1-6. csatorna
BEREKFÜRDÖ
B10.08
KARCAG
Hortobágy-Berettyó
KENDERES
Kakat-csatorna
NK jobb oldali övcsatorna
B10.07
KISUJSZÁLLÁS
Karcagi-I. csatorna
Villogó-csatorna
Kisújszállási-II. csatorna
B10.10
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0 2.5 5 10 km

Case Study 11. Gary Brown

Name of project: Allan Water Improvement Project

Date project started and duration: 2012 - Ongoing

Total value of the project (£/$/E): £30k per annum plus other funding from various organisations for projects

Measure(s) included or addressed: NFM (with benefits also for WFD, biodiversity, land and community engagement)

Project funder(s): Core funding: Scottish Government, ancillary funding from Woodland Trust, RPID, SEPA WEF depending on the measure.

Case study author contact details: Gary Brown G.Brown@forthriverstrust.org

What was the scale of flood risk impact? (Select a scale from table below)

Scale	Yes or No
0-10 km²	Yes
10-100 km²	Yes
100-500 km²	No
500-10,000 km²	No
>10,000 km²	No

Description - What did the project do?

The Allan Water Improvement Project is looking at natural flood management between Perth and Stirling. This area is susceptible to flooding in both urban and rural environments due to the land use both current and historical. Large parts of the river towards its source have been canalised for agriculture, weirs implemented for water extraction and drains constructed on most of the surrounding peatlands.

The projects aim is to reduce flood risk impact and reinstate lost salmonid migratory routes, by working with landowners and other stakeholders to implement NFM (and other measures) to benefit the catchment as a whole and NFM in particular.

The project is managed by the steering group consisting of representatives of Scottish Government, Forth Rivers Trust, SEPA, SNH, Stirling Council, Perth & Kinross Council, RSPB, Forestry Scotland and Stirling University.

This is an ongoing project with individual projects delivered including peatland/bog restoration, tree planting, green bank work and agro-forrestry.

What were the flood risk impacts of project?

The flood risk impacts have been identified as having serious financial cost to stakeholders through loss of earnings by crop and animal loss (forestry, sheep and cattle), property damage, major loss in biodiversity.

Flooding of Bridge of Allan (2006) and Potential vulnerable areas (Blackford). Complicated catchment arrangement which can impact on flood risk management of Stirling and the management of peak flow timing from three rivers which converge in the city.

Did the project achieve wider ecosystem service benefits? (Tick Yes or No in table below)

Issue	Yes or No
Flood risk	Yes
Erosion/incision of river banks	Yes
Land use change and impacts	Yes
Navigation	No
Freshwater supply	Yes
Flora and fauna	Yes
Salt water intrusion	No
Deforestation	Yes
Loss of floodplains	Yes
Channelization	Yes
Pollution	Yes

Were there any lessons learn (both positive & negative)t?

- Achieve multi benefit goals required positive working between all organisations, conflicting drivers of some of these including government agencies impact on ability to deliver.
- Landowners are key to delivery – without them implementation is not possible.
- To be honest and open with stakeholders to compromise to plans and ideas
- Hold relevant organisations to account
- Be self-critical of your own organisations and flag these up

Further information

http://forthriverstrust.org/project/allan-water-improvement-project/

Photo

Figure 1 Flooding on the River Allan, picture referenced by SEPA

Case Study 12. Holly Radcliffe

Name of project: Leeds Flood Alleviation Scheme Natural Flood Management

Date project started and duration: January 2018- March 2025 (Still in Progress)

Total value of the project (£/$/E): Authorised spend: £15m; Funding secured: £4m, currently planning to spend: £8m

Measure(s) included or addressed: A range of all NFM measures, the project has defined 11 NFM measures that we hope to implement:

1. **Catchment Woodland**
2. **Cross-Slop Woodland**
3. **Flood Plain Woodland**
4. **Riparian Woodland**
5. **Soil and Land Management- including hedgerows and buffer strips**
6. **Headwater drainage management**
7. **Run-off Pathway Management- including non flood plain wetlands and overland sediment traps**
8. **Flood Plan/ Wetland Restoration**
9. **River Restoration**
10. **Leaky Barriers**
11. **Offline storage areas**

Project funder(s): Leeds City Council, Flood Grant in Aid, DEFRA (tbc), third parties (tbc)

Case study author contact details: Holly Radcliffe, holly.radcliffe@environment-agency.gov.uk , leedsFAS.NFM@environment-agency.gov.uk

What was the scale of flood risk impact?

Scale	Yes or No
0-10 km²	Yes
10-100 km²	Yes
100-500 km²	Yes
500-10,000 km²	Yes
>10,000 km²	No

Description - What did the project do?

On Boxing Day 2015, the north of England suffered devastating flooding caused by Storm Eva. Almost 5000 properties across Leeds were flooded following the highest river levels ever recorded across the River Aire. As part of the Leeds Flood Alleviation Scheme, Leeds City Council, in Partnership with the Environment Agency, have commissioned a £15m programme of NFM measures. The project will be delivered between 2018 and 2025, to meet a target of flood risk reduction in 2069.

Transformational in scale, the NFM aspect of the project aims to reduce flood peaks and limit damage by implementing the following measures that mimic natural processes:

- Woodland creation: increasing canopy cover from 7% to 15% across the catchment
- Land management: run off reduction via various means, including in urban areas
- River and flood plain restoration: storage ponds and re-meandering of river

The NFM measures will be implemented on the upper and mid stretched of the River Aire between Malham to Armley. The study area covers 687km2. The project is currently in the development phase, and is undertaking hydrological modelling and catchment screening to determine where to implement the NFM measures. In parallel to the development works, a number of pilot sites have been delivered.

Once complete the project will provide protection to homes and business in Leeds and the wider Aire catchment whilst providing wider enhancements for commuters, the environment and ecology.

What were the flood risk impacts of project?

The project **aims** to reduce peak flood flows in Leeds by 5% in a 1 in 200 year event by the year 2069 by delivering a selection of 11 defined NFM measures. It is anticipated there will also be local flood risk benefits, however, this is yet to be confirmed.

Did the project achieve wider ecosystem service benefits?

Issue	Yes or No
Flood risk	Yes*
Erosion/incision of river banks	Yes*
Land use change and impacts	Yes*
Navigation	No*
Freshwater supply	Yes*
Flora and fauna	Yes*
Salt water intrusion	No*
Deforestation	Yes*
Loss of floodplains	Yes*
Channelization	Yes*
Pollution	Yes*

*The project is not yet complete, and these are projected

Were there any lessons learn (both positive & negative)?

The project is still underway, so these are lessons learned to date.

- Success of project is reliant on long term buy-in of landowners. Partnership working is required to ensure there is no net loss for landowner and that the measures will be maintained in the long run.
- Catchment screening can be hindered by the vast amount of data available; the level of information used needs to be proportionate to the delivery of measures.

Further information

https://www.leeds.gov.uk/parking-roads-and-travel/flood-alleviation-scheme/flood-alleviation-scheme-phase-one

https://www.leeds.gov.uk/parking-roads-and-travel/flood-alleviation-scheme/flood-alleviation-scheme-phase-two

https://www.gov.uk/government/news/horse-power-slows-the-flow-in-the-aire-catchment

https://www.bbc.co.uk/news/uk-england-leeds-43469636

Photo

Figure 2 Ghalm, the Swedish Forest Horse, helps to build Leaky Barriers in Bradford

Figure 3 Leaky Barrier Built in Bradford

Case Study 13. Ine Rosier

Name of project: Collaboration Land & Water Melsterbeek catchment
Date project started and duration: 2002 – 2008

Total value of the project (£/$/E): € 2.335.000

Measure(s) included or addressed: List NNBF/NFM/BWN measures covered by project

- Earth dams
- Plant material dams
- Ditches
- Erosion pools
- Grass buffer strips
- Flood retention basins

Project funder(s): Flemish government, Provincie Limburg, municipalities (Gingelom, Sint-Truiden, Nieuwerkerken, Geetbets, Herk-de-Stad)

Case study author contact details: Ine Rosier, ine.roser@kuleuven.be

What was the scale of flood risk impact?

Scale	Yes or No
0-10 km²	
10-100 km²	Yes
100-500 km²	
500-10,000 km²	
>10,000 km²	

Description - What did the project do?

I examine to what extent landscape elements - such as drainage ditches and hedgerows - upstream in a catchment contribute to downstream flood protection in the Flanders region, Belgium. To do this, I will develop a procedure to complete and update inventories of hydrological meaningful landscape elements, based on LiDAR- and Sentinel-2 data for small sub-catchments (ca. 10km²). The sub-catchments are situated upstream of areas prone to flooding, and are selected based on the abundance of these landscape elements. distributed within Flanders. In order to estimate the flood hazard mitigation value of the identified elements, they will then be incorporated in a distributed rainfall-runoff model.

In this case study, I focus on the hydrological meaningful landscape elements installed in the Melsterbeek catchment in the province of Limburg, Belgium. To reduce erosion and flood risk in the catchment, 100 ha of grass buffer strips, 15 ha of grassed waterways, and 40 earth dams were installed. Further, buffer basins and erosion pools were created.

What were the flood risk impacts of project?

After the installation of the flood mitigation structures, a decrease in peak discharge (-69%) and runoff coefficient (-50%) was observed. Further, an increase of runoff duration (+ 5 to 12 h) and lag time (+75%) could be seen. I want to evaluate if the same flood risk changes can be observed when the structures are included in a hydrological model.

Did the project achieve wider ecosystem service benefits? (Tick Yes or No in table below)

Issue	Yes or No
Flood risk	Yes
Erosion/incision of river banks	Yes
Land use change and impacts	Yes
Navigation	No
Freshwater supply	No
Flora and fauna	Yes
Salt water intrusion	No
Deforestation	No
Loss of floodplains	No
Channelization	Yes
Pollution	No

Were there any lessons learn (both positive & negative)t?

- The combination of grassed waterways, grass buffers, earth dams and conservation tillage was proven to be effective in eliminating the risk of muddy flooding in the Melsterbeek catchment, Belgium.
- Flood mitigation measures can help to prevent gully formation and reduce sediment discharge
- Despite these measures, floods still occur in the region
- Structural and integrated approach at catchment scale is required

Further information

http://www.land-en-water.be/english.html

Photo

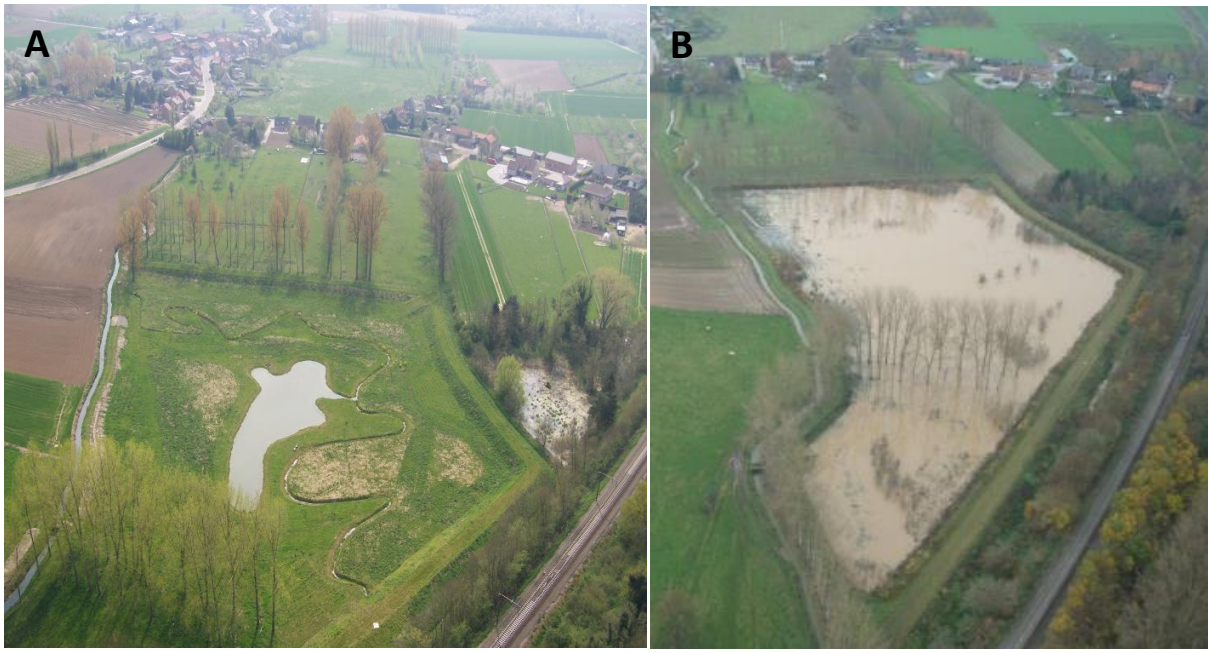

Figure 4 - Flooding zone in Stayen, Belgium. A: retention pond and earth dam one year after installation; B: Flooding zone after a rainfall event in November 2010 (source: land-en-water.be).

Case Study 14. Jenia Gutman and Rachelle Altman

Name of project: Controlled Shutter under the road num. 79 allowing temporal flood water retention

Date project started and duration: The project was an inherent part of a road construction. Altogether it took 1 year to plan it, and few months to construct. It is active for 6 years, since 2013

Total value of the project (£/$/E): 1 mil. Eur.

Measure(s) included or addressed: List NNBF/NFM/BWN measures covered by project
Temporal Floods retention on farmland

Project funder(s):
Roads and Traffic Company, Min. of Agriculture, Kishon Drainage Authority

Case study author contact details: Rachelle Alterman (Technion) alterman@technion.ac.il, Jenia Gutman (Department of Drainage and Soil Protection Division, Mi. of Agriculture) gutman.jenia@gmail.com, Uri Regev (Eng. Of the Kishon Drainage authority) uri@rnkishon.co.il, Haim Hemi (Head of Kishon Drainage Authority) haim@rnkishon.co.il,

What was the scale of flood risk impact? (Select a scale from table below)

Scale	Yes or No
0-10 km²	YES
10-100 km²	
100-500 km²	
500-10,000 km²	
>10,000 km²	

Description - What did the project do?
The project took advantage of a traffic infrastructure planned upstream of the often flooded town. The newly built road interchange serves as a hydraulic restriction in a certain sub –watershed, where the road crossed a topographic socket. The engineering construction imbedded under the road allows, in the time of need, to partially shut the opening under the road, so to allow flood water accumulation upstream of the road, retaining the water on farmland. The closure is controlled from a long distance device. The retention time is no longer than a few hours, so the crops and the orchard are not damaged permanently.

What were the flood risk impacts of project?

The installed measure allows retention of 360,000 m^3, in 1:100 scenario. The maximal total retention area in such a case is 16 hectares. The project is a part of a watershed –scale upstream retention areas, on farmland, which reduce the flood risk on a Haifa metropolis the its satellite cities.

Did the project achieve wider ecosystem service benefits? (Tick Yes or No in table below)

Issue	Yes or No
Flood risk	YES
Erosion/incision of river banks	
Land use change and impacts	YES
Navigation	
Freshwater supply	

Flora and fauna	
Salt water intrusion	
Deforestation	
Loss of floodplains	YES
Channelization	YES
Pollution	

Were there any lessons learn (both positive & negative)t?

- The area is not protected and might be rezoned, since the Israeli Drainage law (1957) restrics Authorities to act on the streams only
- Such project relies on exceptionally good personal relations between the farmers and the Drainage Authority
- The crops are not permanently damaged, and this is a key point in this project
- It is a good example for the rest of the Authorities, who are copying the win-win project between the road construction and flood risk mitigation project

Further information

Add links to references of hyperlinks to webpages
http://www.rnkishon.co.il/%D7%A4%D7%A8%D7%95%D7%99%D7%99%D7%A7%D7%98%D7%99%D7%9D/%D7%95%D7%99%D7%A1%D7%95%D7%AA-%D7%91%D7%9E%D7%A2%D7%9C%D7%94-%D7%92%D7%9C%D7%A2%D7%9D

http://www.rnkishon.co.il/uploads/files/363048181624212892-%D7%AA%D7%9B%D7%A0%D7%99%D7%AA-%D7%95%D7%99%D7%A1%D7%95%D7%AA-%D7%91%D7%9E%D7%A2%D7%9C%D7%94-%D7%92%D7%9C%D7%A2%D7%9D.pdf

Photo

Paste a project photo here and say what it is of and who the photo should be referenced to
In the photo: Retention area during the flood. Orchard covered by flood for a few hours. Reference: Uri Regev.

Case Study 15. Joe Rooms

Name of project: Anwa Sustainable Landscape Design

Date project started and duration: August 2018 – January 2020

Total value of the project (£/$/E): $2000

Measure(s) included or addressed: Infiltration pit, grey water storage, French drains

Project funder(s): Kounkuey Design Initiative, Anwa Junior Academy, The Jeffrey Cook Charitable Trust

Case study author contact details: Joe Rooms - Joe.Rooms@environment-agency.gov.uk

What was the scale of flood risk impact? (Select a scale from table below)

Scale	Yes or No
0-10 km²	Y
10-100 km²	
100-500 km²	
500-10,000 km²	
>10,000 km²	

Description - What did the project do?

Anwa School has a network of three water tanks holding a total of 21000l, the tanks are filled during rains and are used as grey water for cleaning and flushing. The roof area that feeds this tank system is 292m^2. Excess rain water at Anwa is diverted to an infiltration pit created in a central courtyard. The infiltration pit is designed to a 1:100 plus 25% climate bias. The local context, where costs and the local availability of materials are unique, required an alternative approach. The infiltration pit is constructed from used soda crates to form a storage area below ground, wrapped by maize sacks acting as a pervious geotextile. The crates are held in place with re-bar and are surrounded by crushed 40mm gravel layers. The final cost of crate solution was $730, a 'storm crate' solution was estimated at $11,000.

What were the flood risk impacts of project?

- Reduction in pluvial flooding in the local area
- Reduction in foul flooding from open drains outside the school site
- Educational benefit to the school and local community

Did the project achieve wider ecosystem service benefits? **(Tick Yes or No in table below)**

Issue	Yes or No
Flood risk	y
Erosion/incision of river banks	y
Land use change and impacts	
Navigation	
Freshwater supply	
Flora and fauna	
Salt water intrusion	
Deforestation	
Loss of floodplains	
Channelization	
Pollution	

Were there any lessons learn (both positive & negative)t?

- Re-used material provided robust and economic solution
- Low budget did not constrain the project
- Lack of communication on infiltration pit purpose caused an element of friction in the community affecting project programme
-

Further information

http://www.kounkuey.org

Photo

Infiltration pit progress using around 280 used soda crates surrounded by sewn maize sacks and gravel. Pictures - Joe Rooms

Case Study 16. Karen Gabriels

Name of project: Identifying upstream locations critical for downstream floods (part of PhD 'Flood insurance value of land use systems and its application in spatial planning')

Date project started and duration: start PhD 2017 (duration 4 years)

Total value of the project (£/$/E): No costs have been assessed yet, though in the next stage of my PhD project I will collaborate with insurance companies to monetize the flood hazard reduction of nature-based solutions.

Measure(s) included or addressed: List NNBF/NFM/BWN measures covered by project
The developed decision support tool assesses the impact of land use changes on runoff generation. The impact of afforestation can thus be quantified, but also the negative impact of urbanization can be assessed.

Project funder(s): PhD project funded by FWO (Research Foundation Flanders)

Case study author contact details: Karen Gabriels, karen.gabriels@kuleuven.be

What was the scale of flood risk impact?

Scale	Yes or No
0-10 km²	
10-100 km²	Yes
100-500 km²	
500-10,000 km²	
>10,000 km²	

Description - What did the project do?
In the context of my PhD project, I'm developing a decision support system, which iteratively ranks grid cells' potential for reducing runoff in a flood prone, downstream location. The runoff is calculated using a rainfall-runoff model, which is based on the Curve Number method and takes into account antecedent soil moisture conditions. The runoff is subsequently propagated through the landscape, allowing it to be abstracted along the way by natural ecosystems. This results in the accumulated runoff in each pixel. Consequently, the change in this accumulated runoff in a downstream area of interest can be assessed for different land use changes and rainfall events. The tool uses this information to iteratively find the locations in the landscape where certain nature-based flood protection measures have the highest impact on runoff reduction. This has been tested on the Bellebeek watershed (87 km²) in Flanders, where optimal afforestation locations were identified which yield the highest reduction in runoff at the watershed's outlet.

What were the flood risk impacts of project?
Our tool aims to support spatial planners and decision makers to implement nature-based flood protection measures by quantifying their potential for runoff reduction and identifying where they have the largest impact.

Did the project achieve wider ecosystem service benefits?

Issue	Yes or No
Flood risk	Yes
Erosion/incision of river banks	
Land use change and impacts	Yes

Navigation	
Freshwater supply	
Flora and fauna	
Salt water intrusion	
Deforestation	Yes
Loss of floodplains	
Channelization	
Pollution	

Were there any lessons learnt (both positive & negative)?

- The runoff reduction potential of nature-based flood protection measures depends on the measures' locations in the landscape, since they capture incoming runoff from an upstream area. Therefore, spatial interactions are explicitly taken into account by our decision support system.
- The results of the tool indicate that afforestation is an efficient runoff reduction measure up to a certain rainfall amount, which can also be determined using the decision support system.

Further information

/

Photo

/

Case Study 17. Martina Egedusevic

Name of project: Assessing impacts on new woodland creation in Menstrie catchment, Scotland

Date project started and duration: 15/06/2016; for three years

Total value of the project (£/$/E): 15.000£

Measure(s) included or addressed: NFM measures: woodland creation, runoff reduction, sediment control, debris movement

Project funder(s): Scottish Forestry Trust, Heriot-Watt University

Case study author contact details: Martina Egedusevic, mve1@hw.ac.uk

What was the scale of flood risk impact? (Select a scale from table below)

Scale	Yes or No
0-10 km²	No
10-100 km²	Yes
100-500 km²	No
500-10,000 km²	No
>10,000 km²	No

Description - What did the project do?

Menstrie village in Clackmannanshire, central Scotland, has a history of recurrent floods due to overbank flow from the Menstrie Burn (a hillslope tributary of the River Forth). In August 2004 approximately 30 properties were flooded (Clackmannanshire council, 2005). An even more significant event occurred in 2012, demonstrating a continuing vulnerability of this village to flooding. In 2015 one of the most significant modern-day woodland creation projects was implemented in Clackmannanshire upstream of Menstrie village. In total, 47% of the Menstrie Burn catchment (1200 ha) was subjected to the planting of, predominantly, productive conifer woodland (Sitka spruce). This scale of land use change was expected to provide elements of NFM in the medium to long-term, but concerns were raised about the potential for pre-planting cultivation to increase flood flows in the shorter-term.

In response to this research has been undertaken in Menstrie catchment since 2016 to analyse the different processes which affect flood generation namely: planting technique, overland flow sediment loading. This has been monitored at seven different locations (according to cultivation) and surface flow in the main watercourse and its tributaries.

Seven study plots (one unplanted plot, three plough cultivation plots, two excavation mounding technique plots, and one hand screefing cultivation plot) with secured repetition have been modelled over two years using GR4H rainfall runoff conceptual model. This model used an hourly time step of observed rainfall, flow, evapotranspiration, and temperature data time series to generate a behaviour of each monitored plot with similar preferences of observation.

The GR4H model optimises four free parameters: maximum capacity of production store (mm), groundwater exchange coefficient (mm), the maximum capacity of routing store (mm) and time peak ordinate of hydrograph unit UH1 (day). This model has been built for two tributaries of Menstrie burn, the Menstrie burn and all seven study plots.

This approach has simplified output from field observation, assisted in a better understanding of the data gaps and elaborated on the observed trends of vegetation processes.

Moreover, the initial outputs from this model can be useful for future climate change mitigation via nature-based solutions.

What were the flood risk impacts of the project?

This project will have possible outcomes on the reduction of flood risk in downstream village Menstrie that has a history of repeated flooding in past years. Modelling results from this project can be considered during the preparation of the new cycle of flood risk and flood hazard maps. Those maps will be updated shortly.

Did the project achieve more extensive ecosystem service benefits?

Issue	Yes or No
Flood risk	Yes
Erosion/incision of river banks	Yes
Land use change and impacts	Yes
Navigation	No
Freshwater supply	No
Flora and fauna	No
Salt water intrusion	No
Deforestation	No
Loss of floodplains	No
Channelization	No
Pollution	No

Were there any lessons to learn (both positive & negative)?

- The monitoring process can be challenging but still possible
- Land use changes can significantly improve our understanding of hydrological processes behind it
- We have were able to observe possible hydrological changes on sub-catchment level and cultivation technique level and make a comparison in between them

Further information

Photo

Woodland creation in Menstrie catchment, 2015. Photo was taken by Till Hill Forestry.

Case Study 18. Nick Chappell

Name of project: Cumbrian NFM effectiveness monitoring network (NFM-eye)

Date project started and duration: 1st January 2018 to 30th April 2026

Total value of the project (£/$/E): £112259 (Environment Agency) with additional support from £1.2m NERC Q-NFM grant

Measure(s) included or addressed: includes agricultural interventions in pastureland such as sward lifting and leaky bunds, hedgerow and wall restoration, leaky dams in peatland gullies and headwater channels, tree planting and floodplain reconnection in pasture and moorland landscapes

Project funder(s): Environment Agency (with additional support from UKRI NERC)

Case study author contact details: Dr Nick A Chappell (Lancaster University: n.chappell@lancaster.ac.uk) and Dave Kennedy (Environment Agency: david.kennedy@environment-agency.gov.uk)

What was the scale of flood risk impact? (Select a scale from table below)

Scale	Yes or No
0-10 km²	YES
10-100 km²	YES
100-500 km²	
500-10,000 km²	
>10,000 km²	

Description - What did the project do?

A research project designed to monitor hydrological change arising from a network of NFM pilot projects in Cumbria introduced with the support of £2.5m UK government (Defra) funding. This monitoring complements that undertaken by the individual pilot projects in the Defra programme locally and that undertaken by the £1.2m - primarily modelling - NERC Q-NFM project. There are four key elements to the project:

1/ Install telemetered stream flumes gauging micro-basins (< 1 km^2) upstream of flood-affected communities, where NFM interventions are to be introduced as NFM pilots in Cumbria. Five flumes (at Grange, Flimby, Sedbergh, Tebay dams, Mallerstang) are supported by this Agency funding, and add to the NERC-funded network that also covers locations with key NFM intervention types (Tebay Gill, Sware Gill, Darling How, Calthwaite, Ravensgill and Whiteoak – in Cumbria; and Bareleg upstream, Bareleg downstream, Trawsnant, Nant Rhesfa, Hillsborough – elsewhere in UK). With additional funding, additional gauging stations will be added to this network.

2/ The network of flumes is maintained (cleaned and calibrations checked) by the Q-NFM project until Apr 2021, thereafter using funding from this project (until Apr 2026). Data are provided live to the Agency, Cumbria County Council and the NGOs installing the NFM interventions. The team at Lancaster University throughout the duration of the project (2018-2026) undertakes analysis of the effects of NFM features with respect of the observed stream hydrographs.

3/ A pool of mobile data-logged water-level recorders are used to quantify level dynamics (and with surveying, derive storage dynamics) at individual NFM features associated with micro-basin flumes. The key objective is to show when surface flows are being added to NFM stores with respect of the local streamflow.

4/ An ADZ fluorometry system being purchased by the project, will be used by the Q-NFM team to quantify the additional "effective storage" (by ADZ analysis of the observed data) coming from

introduced NFM dams/bunds, channel realignments etc., and for BS3680-2D dilution gauging (for checks of flume calibrations, and spot gauging of sites without a gauging structure).

The gauged micro-basins are used in various experimental designs (upstream-downstream; paired catchment; reference for change in component hydrological processes; before-after intervention). Interventions include new/mature tree planting; sward lifting; leaky dams in headwater streams; bunds on pastureland; dams in restored peatland.

What were the flood risk impacts of project?

The project is ongoing – the primary objective is to quantify the magnitude (with uncertainty) of reductions in observed flood peaks and flood hydrographs at micro-basin scales (< 1km^2) linked to the dynamics of individual NFM features. The findings from across the *Cumbrian NFM effectiveness monitoring network* (NFM-eye) will be used to provide generic-Cumbrian evidence for NFM intervention locations in Cumbria lacking robust monitoring; as well as contributing towards the national and international evidence base.

Did the project achieve wider ecosystem service benefits? (Tick Yes or No in table below)

Issue	Yes or No
Flood risk	YES
Erosion/incision of river banks	
Land use change and impacts	
Navigation	
Freshwater supply	
Flora and fauna	
Salt water intrusion	
Deforestation	
Loss of floodplains	
Channelization	
Pollution	

With additional funding, the *Cumbrian NFM effectiveness monitoring network* (NFM-eye) has the potential to be expanded (notably with water quality sensors added to the existing telemetered flume network) to quantify wider ecosystem service benefits of the interventions.

Were there any lessons learn (both positive & negative)?

- The most robust evidence of NFM feature effectiveness at reducing flood peaks is based on direct observation of flood peak reductions (most likely on micro-streams for logistical/cost reasons), but then supported by direct observations of storage change or other component hydrological processes (wet-canopy evaporation, infiltration, overland flow etc.) to attribute the change in the flood peaks.
- Biases (stationary or shifting over time) and random errors present in observed streamflow (and to a lesser extent in related storage change of individual NFM features) needs to be quantified and minimised. This is essential to have faith that apparent hydrological contrasts or changes in space or time may be attributed to an NFM intervention or interventions (rather than to stochastic noise or climate / other environmental variability or different biases between gauging stations or same station over time).

Further information

Website not yet available, but some details given at:
https://www.lancaster.ac.uk/lec/sites/qnfm/t2.htm

Photo

One of the telemetered micro-basin flumes in the NFM-eye network in Cumbria. Photo for acknowledgement: NA Chappell, Lancaster University.

Case Study 19. Nick Chappell

Name of project: NERC Quantifying the likely magnitude of nature-based flood mitigation effects across large catchments (Q-NFM)

Date project started and duration: 1st November 2017 for 42 months

Total value of the project (£/$/E): £1.2m

Measure(s) included or addressed: includes agricultural interventions in pastureland such as sward lifting and leaky bunds, hedgerow and wall restoration, leaky dams in peatland gullies and headwater channels, tree planting and floodplain reconnection in pasture and moorland landscapes

Project funder(s): UKRI Natural Environment Research Council (https://nerc.ukri.org)

Case study author contact details: Dr Nick A Chappell, Principal Investigator Q-NFM (NERC NE/R004722/1) n.chappell@lancaster.ac.uk

What was the scale of flood risk impact? (Select a scale from table below)

Scale	Yes or No
0-10 km²	YES
10-100 km²	YES
100-500 km²	YES
500-10,000 km²	YES
>10,000 km²	

Description - What did the project do?

The project is ongoing. Our primary objective is to quantify the likely effectiveness of NFM to mitigate flooding for large catchment scales in the most credible way (Objective 4: https://www.lancaster.ac.uk/lec/sites/qnfm). Firstly, this demands that observed river flow time-series are simulated accurately at a fine time resolution, whilst also adequately representing distributed hydrological processes and inherent simulation uncertainties (Obj 3). This work focuses on all scales up to the 209 km^2 Kent, 663 km^2 Derwent and 2287 km^2 Eden watersheds in the Cumbrian mountains of UK. Representing NFM-related changes to the parameters of these simulation models is similarly undertaken in an uncertainty framework (Obj 4). Our approach constrains the former uncertainties by rejecting simulations that are not consistent with distributed field observations, and explicitly quantifies the latter uncertainties in the representation of parameter change. The evidence for parameter change is characterised by our comprehensive and systematic treatment of the current evidence, and by addressing critical evidence gaps (Objectives 1 and 2). New distributed observations within the catchments being simulated improve the credibility of the process representations (Obj 2). With improved constraint of these two sources of uncertainty, we then explore multiple spatial NFM scenarios (Obj 5). These include hydrologically-ideal scenarios and "real-world" scenarios co-developed with our experienced project partners – comprising 17 regional and national organisations (Obj 7). Non-optimal performance and failure of NFM interventions and their capacity to function under climate change is explored with additional scenarios (Obj 6). All of these component objectives are designed to strengthen the credibility of the results of our primary objective of quantifying the likely magnitude of NFM effectiveness for large catchment scales. It is by addressing these component objectives that we can deliver a step change in the confidence associated with estimates of NFM-related hydrological change at large scales. We believe this work will also form the basis for improved quantification of the wider environmental benefits of NFM.

What were the flood risk impacts of project?

The project is ongoing – the primary objective is to quantify the magnitude (with uncertainty) of reduction in flood peaks and flood hydrographs from micro-basin scales (< 1km^2) to a basin over 2000 km^2 in area.

Did the project achieve wider ecosystem service benefits? (Tick Yes or No in table below)

Issue	Yes or No
Flood risk	YES
Erosion/incision of river banks	
Land use change and impacts	
Navigation	
Freshwater supply	
Flora and fauna	
Salt water intrusion	
Deforestation	
Loss of floodplains	
Channelization	
Pollution	

Were there any lessons learn (both positive & negative)?

- Catchment models of NFM effectiveness need to represent the uncertainty inherent in the parameterisation of model parameters (e.g., "effective" saturated hydraulic conductivity) and the uncertainty in the magnitude of shifts of model parameter values that represent NFM effects.
- Catchment models of NFM effectiveness must be kept parametrically simple (while producing credible results) otherwise uncertainties in simulated hydrological states and flows are too great to be constrained.
- The most robust evidence of NFM feature effectiveness at reducing flood peaks is based on direct observation of flood peak reductions (most likely on micro-streams for logistical/cost reasons), but then supported by direct observations of storage change or other component hydrological processes (wet-canopy evaporation, infiltration, overland flow etc.) to attribute the change in the flood peaks.
- Errors and artefacts in observed hydrological data (including rainfall, streamflow, saturated hydraulic conductivity, overland flow volumes etc.) used for NFM studies need to be quantified and minimised to permit robust interpretations of hydrological change attributable to NFM.

Further information

https://www.lancaster.ac.uk/lec/sites/qnfm

Photo

One of the micro-basin flumes in the Q-NFM network with a Q-NFM end-user partner (from the Woodland Trust). Photo for acknowledgement: NA Chappell, Lancaster University.

Case Study 20. Paul Hudson

Name of project: ResilNam

Date project started and duration: 01/02/2017-31/07/2018

Total value of the project (£/$/E): 500.00US$

Measure(s) included or addressed: The two main nature based measures invested in were the restoration of a mangrove forest in two separate locations, while the second was the restoration of urban waterways and natural retention areas.

Project funder(s): The Global Resilience Partnership via Z Zurich Foundation

Case study author contact details: Paul Hudson (phudson@uni-potsdam.de)

What was the scale of flood risk impact? (Select a scale from table below)

Scale	Yes or No
0-10 km²	Yes
10-100 km²	No
100-500 km²	No
500-10,000 km²	No
>10,000 km²	No

Description - What did the project do?

The ResilNam took place in Thua Thien-Hue province, central Vietnam, where we invested in the restoration of nature based solutions in a coastal area (Quang Loi commune) and an urban area (the UNESCO protected citadel area of Hue city). The key hydrological features of the province are the Huong River and the Tam Giang Lagoon. These features are integral for the lives of a great number of households in the province are pressured by the rapid disappearance of natural areas.

At the Tam Giang Lagoon and the Bu Lu river delta, mangroves were planted jointly with two coastal communities and local stakeholders including the Women's Union and the Disaster Management Centre. In the historic city centre of Hue, traditional urban water bodies were restored in close cooperation with the provincial Disaster Management Centre, urban communities and the Women's Union In the past, nature based solutions played an important role in facilitating flood risk reduction and supporting local livelihoods. However, increasing urbanization and income development has created disincentives for their protection, which has led to their disappearance.

In restoring the local ecosystems we hope to contribute several things. The first is a reduction in flood risk, the second is an increase in flood resilience via the ecosystem services provided, and the third was to increase the role and presence of women in local flood risk management.

What were the flood risk impacts of project?

It is estimated that the urban project reduced flood risk by a net present value (5% discount rate, 30 years) of $600,000. Overall the urban project has a benefit-cost ratio of 34. However, these values assume that the city invests in a new sluice gate. Without this sluice gate the flood risk reduction benefits were estimated to be negligible. Though, the benefit-cost ratio is reduced to 2 due to the other ecosystem services.

It is estimated that the coastal project reduced flood risk by a net present value (5% discount rate, 30 years) of $55,000. Overall the urban project has a benefit-cost ratio of 3.2 if all of the ecosystem

service benefits are included. Focusing just on the flood risk reduction benefits the benefit-cost ratio falls to 1.45.

Did the project achieve wider ecosystem service benefits? (Tick Yes or No in table below)

Issue	Yes or No
Flood risk	Yes
Erosion/incision of river banks	Yes
Land use change and impacts	Yes
Navigation	No
Freshwater supply	No
Flora and fauna	Yes
Salt water intrusion	No
Deforestation	Yes
Loss of floodplains	No
Channelization	Yes
Pollution	Yes

Were there any lessons learnt (both positive & negative)?

- That the more socially marginalised members of the community (e.g. women, the poor) valued the benefits provided by the nature based solution more strongly than the rest of the community.
- The importance of making sure that all stakeholders, especially those with a negative view of the project, are engaged with to overcome their potential project blocking behaviour.
- Focusing the project on the most tangible benefits from the nature based solution to the community that will benefit. This is generated the strongest policy relevant results as it clearly demonstrated the value of nature as a complementary flood risk management option.
- The importance of making sure that there are mechanisms in place so that the measures are maintained over time, especially once the project is over.

Further information

Project website with all publications and reports: https://www.weadapt.org/placemarks/maps/view/35396
Related documentary: https://youtu.be/KBnlYXIGzI4

Photo

Planting of mangroves in Hai Duong Commune (Photos: René Arnold (left) and Philip Bubeck (right)).

Case Study 21. Paul Quinn

Name of project: Slaty Sike Haltwhistle

Date project started and duration: 2016 2 weeks to build

Total value of the project (£/$/E): £8000

Measure(s) included or addressed: 5 Ponds and 1 large scale Woody Debris 'Ker-Plunk' feature.

Project funder(s): Tyne Rivers Trust… EA Catchment Restoration Scheme

Case study author contact details: Paul Quinn and Eleanor Starkey
(eleanor.starkey1@newcastle.ac.uk)

What was the scale of flood risk impact? (Select a scale from table below)

Scale	Yes or No
0-10 km²	2km²
10-100 km²	
100-500 km²	
500-10,000 km²	
>10,000 km²	

Description - What did the project do?

An upland site with peaty soils dominated by sheep livestock. It proved to be a perfect location to demonstrate how to build upland ponds. 5 ponds were created in total all holding 500-1000m^3. The key point was to show that robust flood storage ponds could be built from local peaty soil material and that they could withstand and substantially impact upon any flood wave.
The town of Haltwhistle has suffered a number of flood events that have been exacerbated by stones blocking several bridge culverts. In Slaty Sike a source of these stones was clear to see as a deeply incised gully was eroding upstream. A 'knick' point was rapidly eroding the valley and during a 2 year period had propagated more 50m. So another NFM feature was installed that in theory could tackle flood waves, trap any stone sized debris and possibly stabilise the local slopes. The feature entailed 10 tonnes of logs over 60m length and is often referred to as 'gully stuffing'. Jimmy the horse was used to deliver the logs and the features are robust and working well. There are now 50m of stones sediment built up behind the feature.

What were the flood risk impacts of project?

Local houses prone to flooding in Slaty Sike are now protected. The scheme is only a demonstration feature. The main problem of flooding and erosion leading to blockage of bridge culverts in Haltwhistle has not been resolved. There may also be a need for longer term protection of transport infrastructure in the Tyne valley. The full cheme would require many NFM features in order to impact on Haltwhistle (43km^2)

Did the project achieve wider ecosystem service benefits? **(Tick Yes or No in table below)**

Issue	Yes or No
Flood risk	yes
Erosion/incision of river banks	yes
Land use change and impacts	
Navigation	
Freshwater supply	

Flora and fauna	
Salt water intrusion	
Deforestation	
Loss of floodplains	
Channelization	
Pollution	

Were there any lessons learn (both positive & negative)?

- A range of NFM options are available in upland to slow and store flood flow.
- The structure are soft engineered features with a robust, long life capacity that can address local flooding.
- Difficulties with access were overcome by using skilled labourers and a horse
- At this scale it is effective, but many 100's of features would be needed for the Haltwhistle scale.
- Upland erosion may be more threat to flood risk than the rainfall itself.

Further information

Have a look at the Haltwhistle Hub and the following videos
https://research.ncl.ac.uk/haltwhistleburn/communityhub/

- Pond 4: https://www.youtube.com/watch?v=aPzlxV_fNMI&feature=youtu.be
- Logs: https://www.youtube.com/watch?v=bsVa5vSbTBU&feature=youtu.be

This work has been written up by Eleanor in her PhD thesis.

Photo

Paste a project photo here and say what it is of and who the photo should be referenced to

Jimmy 'helping' the gang to install the Ker-Plunk Feature. Photo by Paul Quinn

Case Study 22. Paula Whitfield

Name of project: Determining the Efficacy of Swan Island Restoration using Dredged Sediments

Construction date: Oct 2018 to April 2019 sediment placement and regrading. Planting is scheduled for July 2019.

Total cash cost of the project: Construction – least cost alternative for disposal of shallow water draft sediments- $1.2 Million USD, post-construction monitoring and modelling is approximately 300K per year.

Measure(s) included: NNBF measures employed for Island include beach/dunes (with and without concrete reinforcement in core), high and low marsh. Containment includes coir logs, hay bales and a-jacks.

Project funder(s): USACE Engineer Research and Development Center, USACE Baltimore District and NOAA

Main contact(s): Paula Whitfield, Paula.whitfield@noaa.gov; Danielle Szimanski, Danielle.M.Szimanski@usace.army.mil

What was the scale of flood risk impact? (Select a scale from table below)

Issue	Yes or No
Extra Small (0-10 km²)	yes
Small (10-100 km²)	
Medium (100-500 km²)	
Large (500-10,000 km²)	
Extra Large (> 10,000 km²)	

Description - What did the project do?

Baltimore District completed dredging and placement of ~78,000 cubic yards of sediment (April 2019), restoring the elevation capital and footprint of Swan Island located in the Chesapeake Bay, Maryland USA (Figure 1). The restoration plan includes creation of dunes and high and low intertidal marsh (Figure 2), where approximately 200,000 plants will be planted. The creation/expansion of these habitats is expected to have significant benefits in terms of ecosystem service provision, increased resilience of Swan Island to future sea level rise, and abatement of erosive losses for the town of Ewell on adjacent Smith Island (downstream of Swan Island). Monitoring of the island profile, waves, and biological community was conducted before restoration and will continue for up to 3 years post construction. Conceptual and quantitative ecological models are in development to evaluate whether the intended outcomes/benefits are achieved.

What were the flood risk impacts of project?

The flood risk benefits of this project will be measured as part of post-construction monitoring, but, there should be wave attenuation effects that will result in increased shoreline protection for communities located downstream of the island.

Did the project achieve wider ecosystem service benefits? **(Tick Yes or No in table below)**

Issue	Yes or No
Flood risk	Yes
Erosion/incision of river banks (marshes)	Yes
Land use change and impacts	
Navigation	Yes
Freshwater supply	
Flora and fauna	Yes

Salt water intrusion	
Deforestation	
Loss of floodplains	
Channelization	
Pollution	

Were there any lessons learnt?

- Lessons learned will be determined based on the findings from the post construction monitoring.

Further information

https://coastalscience.noaa.gov/project/evaluating-efficacy-of-island-restoration-and-enhancement-for-coastal-protection/

Photo

Figure 5. Aerial view of Swan Island prior to sediment placement in October 2018. Photo credit USACE Baltimore District.

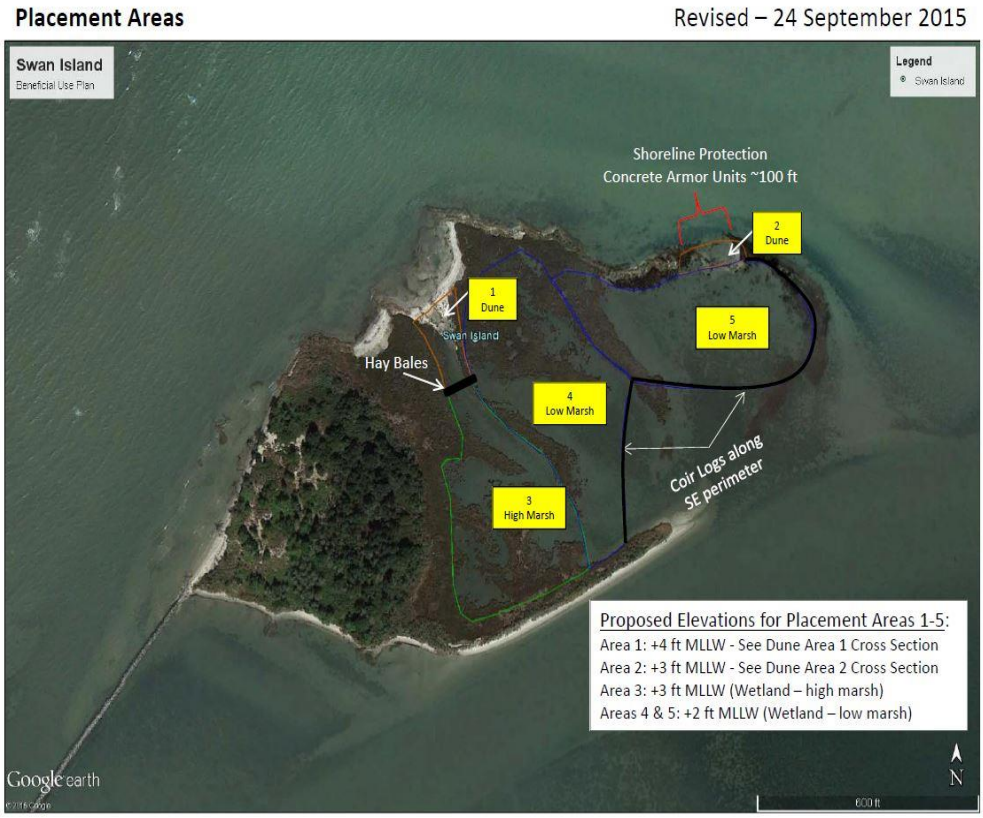

Figure 6. Google Earth image of Swan Island, with the beneficial use plan overlaid. Natural and nature-based features to be restored include low marsh, high marsh, dunes and strategic use of concrete armor units (image from: Environmental Assessment Twitch Cove and Thorofare Federal Navigation Channel Project, Dec 2015)

Case Study 23. Rachel Glover

Name of project: Shropshire Slow the Flow
(Pilot project to implement natural flood management techniques across the Corevale catchment) Shropshire, West Midlands, UK

Date project started and duration:
The project started in 2015/16 and was completed in 2017/18.

Total value of the project (£/$/E):
The project was granted £210,000 of FDGiA funding (Flood Defence Grant in Aid). Between 2015 and 2017, £140,000 was spent to implement NFM measures, with the remaining £70,000 spent on the scheme in 2018/2019.

Measure(s) included or addressed:
Natural Flood Management techniques were implemented, with the aim of slowing or reducing flood flows nearer to their source

- Debris dams
- Sustainable drainage measures, including swales
- Desilting ponds and online storage area improvements
- Green bank revetments
- Tree and hedgerow planting

Project funder(s):
The project was funded from FCREM (Flood and Coast Risk Erosion Management) Grant in Aid (GiA) from the English Severn and Wye RFCC (Regional Flood and Coast Committee). This partnership project was led by Shropshire Council, who employed Shropshire Wildlife Trust to run the project and liaise with landowners and contractors. Additional partner organisations included: the Environment Agency, English Severn and Wye RFCC, Severn Rivers Trust, National Farmers Union and National Flood Forum.

Case study author contact details:
Case study author: Rachel Glover – Environment Agency, West Midlands Partnership and Strategic Overview Team
rachel.glover@environment-agency.gov.uk
Additional contact: Rhian Townsend – Project Manager, Shropshire Council
rhian.townsend@shropshire.gov.uk

What was the scale of flood risk impact?

Scale	Yes or No
0-10 km²	
10-100 km²	
100-500 km²	Yes – the Corvedale catchment covers 160km² The project is thought to have also had wider flood risk benefits, beyond this catchment
500-10,000 km²	
>10,000 km²	

Description - What did the project do?
The overall aim was to use natural methods to 'slow the flow' in a number of catchments and reduce flood risk to downstream communities. The project adopted an innovative approach to managing

flood risk, considering catchments as a whole and striving to slow flows nearer to their source, rather than constructing traditional flood defences.
Three key approaches were applied across these Shropshire catchments:

1) Increasing infiltration into the soil
2) Slowing water down as it flows through the catchment – use of 'leaky dams' and other obstructions across the floodplain and in channels to reduce downstream flood levels
3) Upstream water storage – using existing storage areas, creating new ponds and basins

The project focused on the Battlefield and Culmington catchment areas. Work within the Battlefield area included NFM techniques, comprising of attenuation pools and debris dams, constructed in 2016. Within Culmington, work as part of the pilot project included the construction of 70 debris dams, field aeration and contoured hedgerow planting.

Along with the work within these catchments, the project is also focused on the Coverdale area, which includes the River Corve. Overall, the scheme involved taking a catchment-based approach by working with natural processes, by installing NFM measures across the River Corve catchment, by building on the work within the Battlefield and Culmington catchments.

What were the flood risk impacts of project?

The Natural Flood Management interventions used aimed slow the flow of the water but will also reduce and delay flood peaks. Within the project, the use of NFM techniques across the Corve catchment aimed to directly reduce flood risk to 134 properties. Furthermore, it is hoped that in the long term, the scheme will also see a reduction in flood risk to infrastructure and over 200 properties further downstream in other catchments. The project developed and tested a process methodology, with the hope of replicating such works in other catchments across Shropshire. Following the completion of the Shropshire Slow the Flow project, further funding was granted by DEFRA (Department of Environment, Food and Rural Affairs – UK government) to enable Shropshire Council and Shropshire Wildlife Trust to continue to implement NFM measures. The importance of developing an evidence base is the key focus of the new DEFRA funding, to increase understanding of the effectiveness of such measures. Anecdotal evidence of the benefits of the slow the flow measures have been reported. For example, following a small-scale (short, high intensity rainfall event) flood event in May 2018, the local community flood action group reported that some properties that would have typically flooded in previous similar flood events, did not experience flooding. They observed leaky woody debris dams holding flow water back higher in the catchment, in combination with the other mitigation measures.

Did the project achieve wider ecosystem service benefits?

Issue	Yes or No
Flood risk	Yes
Erosion/incision of river banks	
Land use change and impacts	Yes – farming practices have been adapted to reduce soil run off
Navigation	
Freshwater supply	
Flora and fauna	Yes
Salt water intrusion	
Deforestation	
Loss of floodplains	
Channelization	
Pollution	Yes – water quality benefits

Were there any lessons learnt (both positive & negative)?

Positive lessons learnt:

- The benefit of employing Shropshire Wildlife Trust (environmental charity, non-governmental organisation) in project delivery. As a charity, (rather than a public authority) the Wildlife Trust were able to develop a good rapport with landowners and the local community. These strong working relationships were essential in ensuring successful project delivery. An additional charity (National Flood Forum) were also instrumental in establishing and supporting community flood action groups.
- Recognising the importance on ensuring project time management is planned carefully. It was key to ensure that enough time was devoted to each stage of the project, from making initial landowner contact; conducting surveys and developing proposals and delivery of works.

Challenges:

- CDM (Construction Design and Management) regulations used in the UK are typically suited to large-scale, hard engineering projects. The project faced challenges in shaping the NFM project to meet the CDM criteria and guidelines. Additional time was taken to ensure all regulations followed.
- The future maintenance and liability for the structures implemented has not been fully agreed. This is an ongoing challenge for NFM projects across the UK.
-

Further information

https://www.shropshirewildlifetrust.org.uk/rivers/slow-flow

http://www.meresandmossesben.co.uk/files/uploads/docs/presentation/shropshire-slow-the-flowa-project.pdf

https://floods.newcivilengineer.com/system/files/kc/files/NCE_CON33_FLOOD_PROJECT%20PROFILE_V2.pdf

Photos

Hedgerow and tree planting in the Corvedale catchment.
Photo source: Luke Neal, Shropshire Wildlife Trust

Leaky woody debris dam, Corvedale catchment
Photo source: Environment Agency

Case Study 24. Rhys Evans

Name of project: Genuine participation as a socio-technical tool for improving implementation of new water practices at the Implementation level.

Date project started and duration: 2015 - onward

Total value of the project (£/$/E): n/a

Measure(s) included or addressed: Dialogue processes and implementation of water management issues with multiple farmers and landowners; and with local authorities.

Project funder(s): n/a

Case study author contact details: Rhys Evans: rhys@hlb.no Johan Barstad johan@hlb.no

What was the scale of flood risk impact? (Select a scale from table below)

Scale	Yes or No
0-10 km²	
10-100 km²	yes
100-500 km²	
500-10,000 km²	
>10,000 km²	

Description - What did the project do?
At HLB we are working to produce new socio-technical tools which can be used by *Implementers* to address this final phase of the policy process. The tool we focus upon in this workshop is a method of increasing participation at the lowest level, recruiting landowners to see their own contributions as essential to successful responses to climate change.

This Case Study focuses on *Jæren Vannømrade (Jæren Water Region)* and specifically focuses on the sub-committee "Frivillige tiltak I jordbruket" (*Voluntary actions in agriculture*), a group working directly with the local farmers to identify needed activities, implement agreed actions and to solve conflicts that may arise around the actions. To do this, this sub-group has been practicing a highly proactive, dialogue based management process, getting involved with local farmers in direct dialogue to identify and solve what is and what could become problems. This is quite contrary to how such committees generally work. Ordinarily the focus would be on the activities in and around the committee meetings, with a secretariat preparing the issues, and the committee in session debating and making decisions for action and for posterity.

We will share some of the lessons learned from this Case Study, particularly focusing on mobilization and participation of local landowners and managers.

What were the flood risk impacts of project?
The flood risks were the usual which accompany highly straightened river beds during peak precipitation events, across the Jæren Vannømrade watershed. In addition, water quality was a key issue with farmlands contributing overloads of manure run-off, and erosion of banks by beasts.

Did the project achieve wider ecosystem service benefits? (Tick Yes or No in table below)

Issue	Yes or No

Flood risk	yes
Erosion/incision of river banks	yes
Land use change and impacts	yes
Navigation	
Freshwater supply	yes
Flora and fauna	yes
Salt water intrusion	
Deforestation	
Loss of floodplains	
Channelization	yes
Pollution	yes

Were there any lessons learn (both positive & negative)t?

- The key lesson is the need to engage dialogue with landowners, especially those making a living from the land. By recruiting them to address the challenges, more effective responses can be made to the challenges currently being faced. In addition, mobilization and participation mean that the landowners (especially farmers) will amend their practices over the long term and take personal responsibility for keeping the water regime functioning.

Further information

http://www.vannportalen.no/jaren

Report on Jæren vannområde:
http://hlb.no/organisasjonsevaluering-av-jaeren-vannomrade-aksjon-jaervassdrag/

Report on Jærsmia Dialogue for landscape management project:
http://hlb.no/jaersmia-prinsipp-for-nyskapande-og-berekraftig-arealforvalting-i-jaerregionen/

Photo

Case Study 25. Rinse Wilmink

Name: Houtribdijk case study NNBF guidelines

Construction: 2018-2019 (nearly finished)

Total costs: 100 mln. euro (construction costs)

Measures: NNBF, NFM

Funding: Dutch delta fund (Flood protection program & Ministry of Infrastructure and Watermanagement - Rijkswaterstaat)

Contact: Rinse Wilmink (Rijkswaterstaat – rinse.wilmink@rws.nl)

What was the scale of flood risk impact?

Issue	Yes or No
Extra Small (0-10 km²)	
Small (10-100 km²)	
Medium (100-500 km²)	
Large (500-10,000 km²)	Yes
Extra Large (> 10,000 km²)	

Description - What did the project do?

The Houtribdijk is a levee that separates lake Marken from Lake IJssel and is part of the system of primary water defences in the Netherlands. The levee (strictly it's a dam) protect the hinterland of Flevoland and the areas around Amsterdam from flooding. The levee curbs the water of both lakes, breaks the water level setup and acts as a wave breaker. The Houtribdijk failed the legal assessment of flood defences and had to be reinforced to comply with the standard again (obligated by law in the Netherlands).

The reinforcement was done in two ways; partly by conventional techniques using rouble mount and partly by construction of sandy shores that fulfil fully the protection of the levee (both solutions were applied on half of the levee). These sandy shores are unique as a flood risk management measure of a levee in a non-tidal freshwater lake system. Therefore this project has a good connection to the benefits and adaptive management chapter.

The project also realized 370 hectares of new nature. Two-third of this nature area was a benefit that originates from the choice to use sand to reinforce the levee. The 'good-quality sand' for the levee reinforcement (sand over 200 µm) is a deeper layer into the nearby borrow area. Therefore a lot of other material had to be removed from the pit first. This material was pumped into compartments that forms the (swampy) nature area (Benefits were not being taken into account when the decision for the project was made). Creating this nature area (Trintelzand) even attracted more financial resources from another ministry to extent the area. These resources were allocated to the project because creating the nature area contributes to the nature goals (N2000, European Water Framework Directive) for Lake Marken. At this moment also the interests for extensive

recreation on/around the sandy shores is growing. This is currently under discussion if that's desired or not.

What were the flood risk impacts of project?

The flood risk of the hinterland was brought back at the desired standard again (which is obligated by law in the Netherlands).

Did the project achieve wider ecosystem service benefits?

Issue	Yes or No
Flood risk	Yes
Erosion/incision of river banks	
Land use change and impacts	Yes
Navigation	
Freshwater supply	
Flora and fauna	Yes
Salt water intrusion	
Deforestation	
Loss of floodplains	
Channelization	
Pollution	

Were there any lessons learnt?

- Sandy shores are a good, flexible and nature-friendly solution for flood risk management in a non-tidal freshwater system;
- A good example does follow (attraction of additional funds);
- Other levee reinforcements projects are considering sandy solutions because of the additional flora and fauna benefits (not monetarised though);
- An extensive research and monitoring program and adaptive management strategy on the newly build, unknown in behaviour, sandy shores, minimizes the risks to not comply with the legal safety standard for flood risk management. This was an important element to convince the regional department of Rijkswaterstaat (local manager of the levee) that the solution is sufficiently good and manageable.

Further information

www.rijkswaterstaat.nl/houtribdijk/english

Photo

The picture underneath shows the levee (middle) and the newly constructed sandy shores as a full flood protection measure on both sides of the levee. On the left of the picture one can see the newly constructed nature area Trintelzand. This area was created due to the fact that a lot of soil had to be removed first (fines) to dredge the course sand from the lake floor. These fines are stored in compartments that will act as a shallow water nature area for fish.

Reference picture: Frank Janssens

Case Study 26. Rory Hunter

Name of project: Belford Catchment Solutions

Date project started and duration: The project started in 2007 with NFM features were constructed in 2008, 2012 & 2013

Total value of the project (£): 700,000

Measure(s) included or addressed: NFM

- Online ponds
- Offline ponds
- Ponds that intercept overland flow
- Large Woody Debris
- Features to increase channel and floodplain roughness

Project funder(s): Environment Agency

Case study author contact details: Rory Hunter (rory.hunter@environment-agency.gov.uk)

What was the scale of flood risk impact? (Select a scale from table below)

Scale	Yes or No
0-10 km²	Yes
10-100 km²	
100-500 km²	
500-10,000 km²	
>10,000 km²	

Description - What did the project do?

Belford village flooded 10 times between 1997 and 2007. One of the main problems for Belford is that the Belford Burn catchment has been intensively farmed and farm drainage and rapid run-off has resulted in a very flashy catchment. A traditional flood defence could not be justified in economic terms. In 2007, the Environment Agency commissioned Newcastle University to monitor the catchment, conduct hydrologic modelling, engage with landowners and design and construct NFM features.

A variety of different NFM techniques were constructed in 2008, 2012 and 2013 to slow and store flood water during times of heavy rainfall.

Techniques that have been used include:

- Online ponds
- Offline ponds
- Overland flow interceptors
- Large Woody Debris
- Online ditch barriers
- Features to increase channel and floodplain roughness

The RAFs also provided other benefits including sediment capture and water quality improvements.

What were the flood risk impacts of project?

The project is currently being hydraulically modelled to ascertain more definitively the reduction in flood risk as a result of the interventions but it is hoped it could provide protection up to the 1 in 25 year flow event. Previous estimates and calculations based on observations suggest the standard of protection of the residential property has increased but it is unknown to what degree. The frequency of small scale nuisance flooding has reduced with less detrimental impact experienced by the town. It has been shown that the flood peak has been delayed allowing more time to prepare for flooding.

Did the project achieve wider ecosystem service benefits? (Tick Yes or No in table below)

Issue	Yes or No
Flood risk	Yes
Erosion/incision of river banks	
Land use change and impacts	
Navigation	
Freshwater supply	
Flora and fauna	Yes
Salt water intrusion	
Deforestation	
Loss of floodplains	
Channelization	Yes
Pollution	Yes

Were there any lessons learn (both positive & negative)t?

- Considering future maintenance interventions with regard to funding streams
- Importance of relationship with landowners

Further information

https://www.therrc.co.uk/sites/default/files/projects/sc120015_case_study_14.pdf
https://www.therrc.co.uk/sites/default/files/projects/16_belford.pdf

Photo

©Newcastle University

Case Study 27. Weronica Warachowska

Name of project: Polder management in Poland

Date project started and duration: not applicable

Total value of the project (£/$/E): not applicable

Measure(s) included or addressed: Polders

Project funder(s): not applicable.

Case study author contact details: Weronika Warachowska; weronika.marynowska@amu.edu.pl

What was the scale of flood risk impact? (Select a scale from table below)

Scale	Yes or No
0-10 km²	No
10-100 km²	No
100-500 km²	Yes
500-10,000 km²	No
>10,000 km²	Yes

Description - What did the project do?

The project relates to polder management in Poland. Polders are an efficient measures in flood risk management, which fulfils several flood protection functions in various land use conditions. They use existing complex system processes of nature to safeguard and enhance the water storage potential of landscape, soil and aquifers by restoring and maintaining ecosystems, natural characteristics of water courses and by using natural processes mimicking ecological ones. Natural origin of polders is usually complemented by grey infrastructure (dikes, dams etc.). The strongest advantage of polders is that they combines more than one function such as flood protection, environmental production, agricultural production or settlement. Although polders theoretically fit to the nature-based solutions in flood risk management, their actual establishment and managing appears difficult. The research aims to the detection of this difficulties – their reasons and ways to cope with. It also relates to understanding of polders as a nature-based solution and provides the information about the advantages of this kind of approach.

What were the flood risk impacts of project?

The potential retention capacity of all polders in Poland is assessed for 491 million m^3 and about 390 km^2 area could be protected by this measures. The principle of operation is to catch the peak of flood wave and store it until the water level drops below safe level.
The real impact of polders is unknown because of the difficulties in managing the polders.

Did the project achieve wider ecosystem service benefits? **(Tick Yes or No in table below)**

Issue	Yes or No
Flood risk	Yes
Erosion/incision of river banks	No
Land use change and impacts	Yes
Navigation	No
Freshwater supply	No
Flora and fauna	Yes
Salt water intrusion	No
Deforestation	No
Loss of floodplains	No

Channelization	No
Pollution	No

Were there any lessons learn (both positive & negative)?

- Positives
  - Flood protection;
  - Fertaile soil acquisition;
  - Landscape protection;
  - Biodiversity preservation;
- Negatives
  - Social conflicts;
  - Construction and maintenance costs;
  - Threat to surrounding housing residents;
  - Inundation.

Further information

Polder management in Poland strongly requires formal regulations for establishing and managing polders. Lack of law conditions leads to many difficulties and conflicts – the potential of polder is untapped.

Photo

Paste a project photo here and say what it is of and who the photo should be referenced to

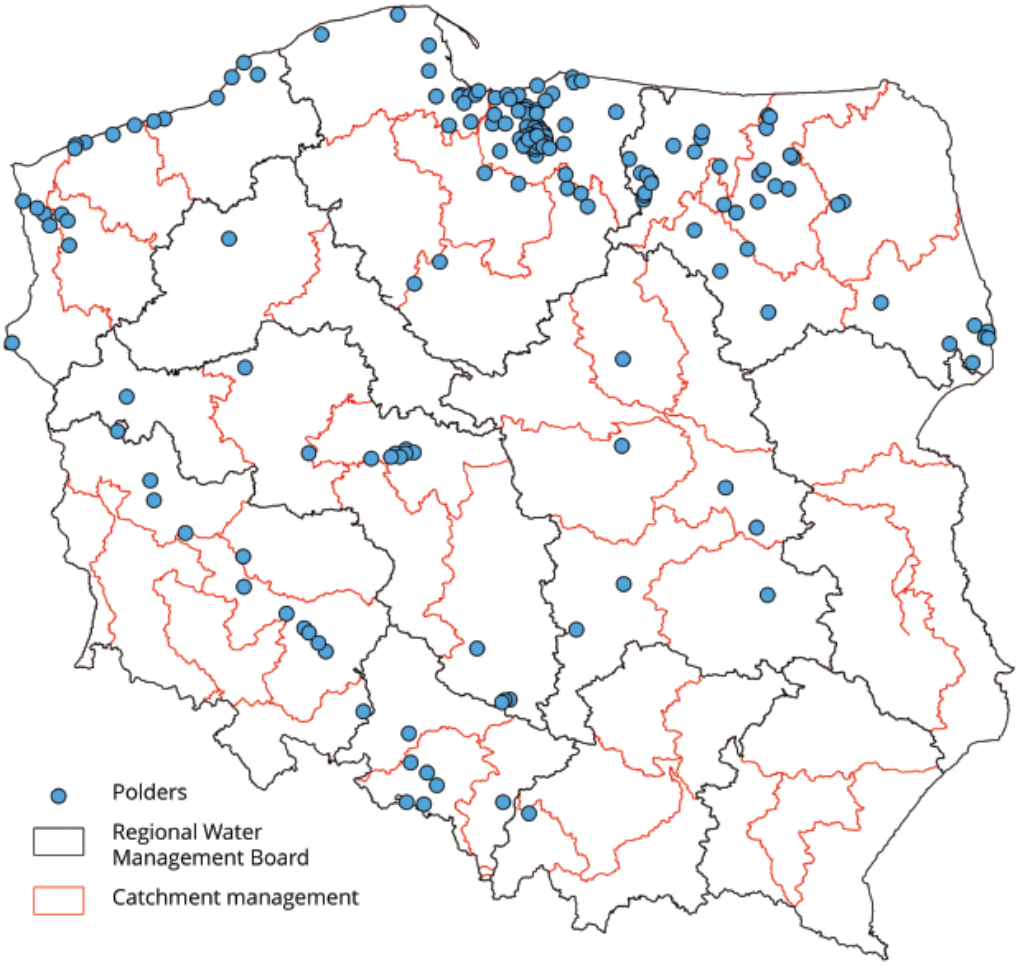

Figure 7. Polders in Poland

Figure 8 Sątopy-Samulewo Polder – nature reserve that protects the landscape of floodplains of Sajna and Ryn rivers.
At: Centralny Rejestr Form Ochrony Przyrody [on-line]. Generalna Dyrekcja Ochrony Środowiska.

Figure 9 Golina Polder – multifunctional flood protective polder with intense agriculture and settlement – Warta river.
Author: Izabela Kolasińska, web portal *Konin naszemiasto.pl*

Figure 10 Krzesin-Bytomiec Polder – flood protective polder situated in Krzesiński Landscape Park – Oder river.
At: Bisztynek Municipality web portal *bisztynek.pl*