Case study 9

River Elwy runoff attenuation modelling - Denbighshire

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1. Catchment summary

Study location

Elwy catchment, North Wales (catchment area 253km2)

Catchment summary

Following severe flooding in St Asaph in Denbighshire (Figure 1) within the downstream reaches of the Elwy in November 2012, Natural Resources Wales is examining how traditional hard-engineered approaches, such as the proposed St Asaph flood alleviation scheme can be complemented with Natural Flood Risk Management (NFRM) measures – termed Working with Natural Processes (WwNP) in this case study for consistency with the main report. The investigation recognises that WwNP has the potential to provide multiple benefits within the catchment while providing additional resilience for the towns within the Elwy catchment (Figure 2).

Other significant hydrological features in the Elwy include:

- water supply reservoirs in the Aled subcatchment (part of the Clwyd Augmentation Scheme water supply)
- artificial grips in the moorland headwaters

Figure 1: St Asaph, November 2012 flooding

Source: Natural Resources Wales

Study summary

The aim of the investigation was to:

- provide a technical assessment to identify the efficacy of WwNP to reduce flood risk
- provide key information for strategic decision making and secure funding for implementation

A wide range of WwNP measures were examined from soil structure improvement to on-farm storage. The approach is part of a strategic assessment to help prioritise distributed interventions and identify what is feasible before consulting landowners.

The run-off generation was based on using Revitalised Flood Hydrograph (ReFH) design event modelling and routing based on simplified ISIS–TUFLOW, with cross-sections based on light detection and ranging (LiDAR). Ecosystem service benefits and the dis-benefits of different WwNP measures

were ranked and combined with spatial opportunity mapping to create a shortlist based on opportunity and constraints.

Community involvement

Following this opportunity mapping approach, engagement with landowners was considered as the 'next step' towards implementation. Natural Resources Wales is working closely with the Welsh Government to ensure Glastir funding is available to support landowners making use of these opportunities. Natural Resources Wales is also liaising with Coed Cymru, Afonydd Cymru and other groups working in the catchment to advise on how WwNP measures can be built into other planned work.

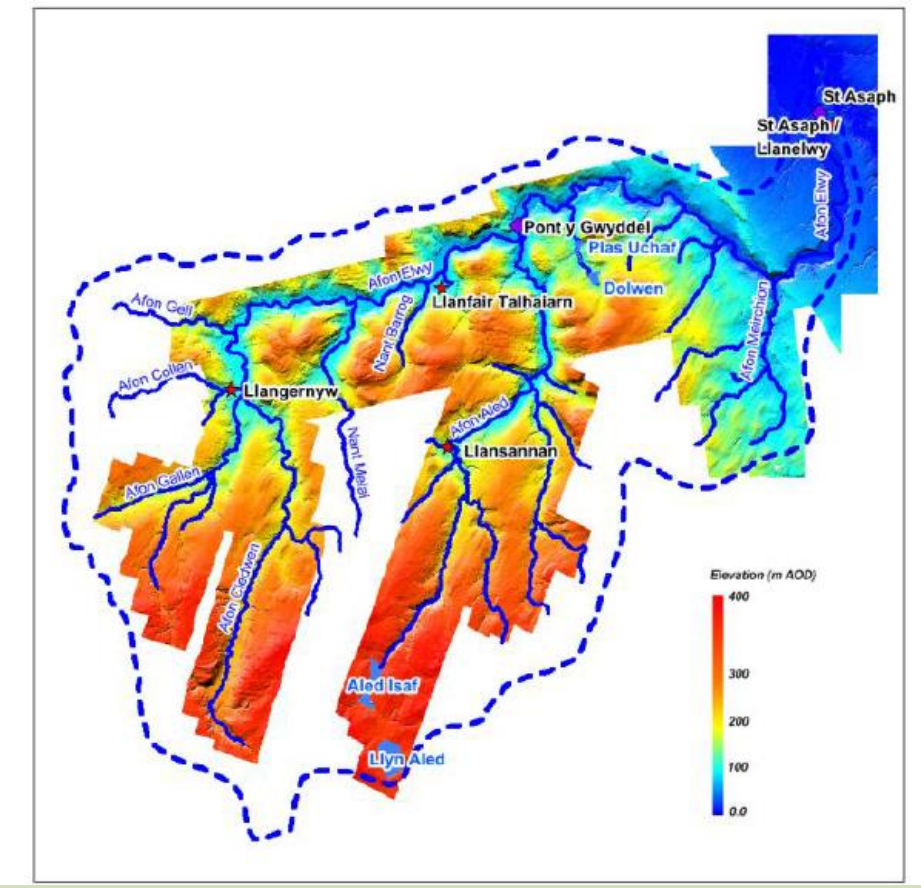

Figure 2: Elwy catchment, river network and LiDAR

Notes: Contains Ordnance Survey data. Crown Copyright and database right 2010.

Source: Natural Resources Wales

2. Data summary

Datasets and analysis techniques used

LiDAR data were used to estimate cross-section geometry, roughness, reach lengths and slopes. This is a good approximation and a useful model to try and apply to other catchments to save survey costs and enable network analysis. When increasing the resolution to the sub-catchment level, however, some of the interventions originally proposed were found to not be possible dues to for example actual gradients being steeper than estimated at the broad scale.

ReFH was used for hydrological boundaries. This is still considered to be the best approach for estimating ungauged catchment flows in the absence of monitoring data.

A systematic review of aerial imagery and Ordnance Survey mapping was used to identify morphological features and potential locations for WwNP, which requires expert judgement.

Follow-up, more detailed drone surveys have been used to monitor the impacts of interventions such

as bank revetment work, which also requires expert judgement.

Data restrictions

The image obtained from Digital Terrain Modelling (DTM) shows some missing data which means a few parts of the channel do not have as accurate data. This is probably because LiDAR has not been flown at these locations. Natural Resources Wales LiDAR holdings were used.

3. Model summary

Catchment processes investigated

The following catchment processes were investigated:

- run-off generation – modelled by altering ReFH depth duration frequency (DDF) parameters for design events
- land use change, soil de-compaction and afforestation
- changes to attenuation properties of catchment

Model assumptions

A one-dimensional (1D) routing model of the main river network was constructed in ISIS-TUFLOW, based on the use of LiDAR to define cross-sections and using Google Earth, Bing aerial imagery and digital imagery. ReFH flow boundaries were developed based on catchment descriptors.

Measures affecting roughness were explicitly modelled through varying this based on tables of Manning's roughness coefficients for different broad types of land cover and bed roughness values based on reach classification process.

Changes to the time-to-peak (Tp) value would be the only parameter to impact on both peak timing and magnitude. Modelled events used antecedent conditions based on initial soil moisture (Cini), as formulated in ReFH based on catchment descriptors. This was considered crucial to deriving model outcomes.

The November 2012 event was modelled (Figure 3) with an estimated return period of between 1 in 100 and 1 in 200 years. The range of return periods considered were:

- 1 in 2 years
- 1 in 25 years
- 1 in 100 years
- 1 in 200 years

The distributed routing approach lent itself well to considering the interaction of peaks following WwNP. however, the timing of the flows from the various subcatchments needs to be considered carefully to ensure the flows are de-synchronised and the resulting flow hydrograph in St Asaph is longer and flatter.

Data and model outputs

Ecosystem services were ranked, giving qualitative benefits and dis-benefits of a range of WwNP options. This was combined with opportunity mapping.

Model performance

Flood risk reduction was quantified in terms of increased Tp flow for the November 2012 event and for design events.

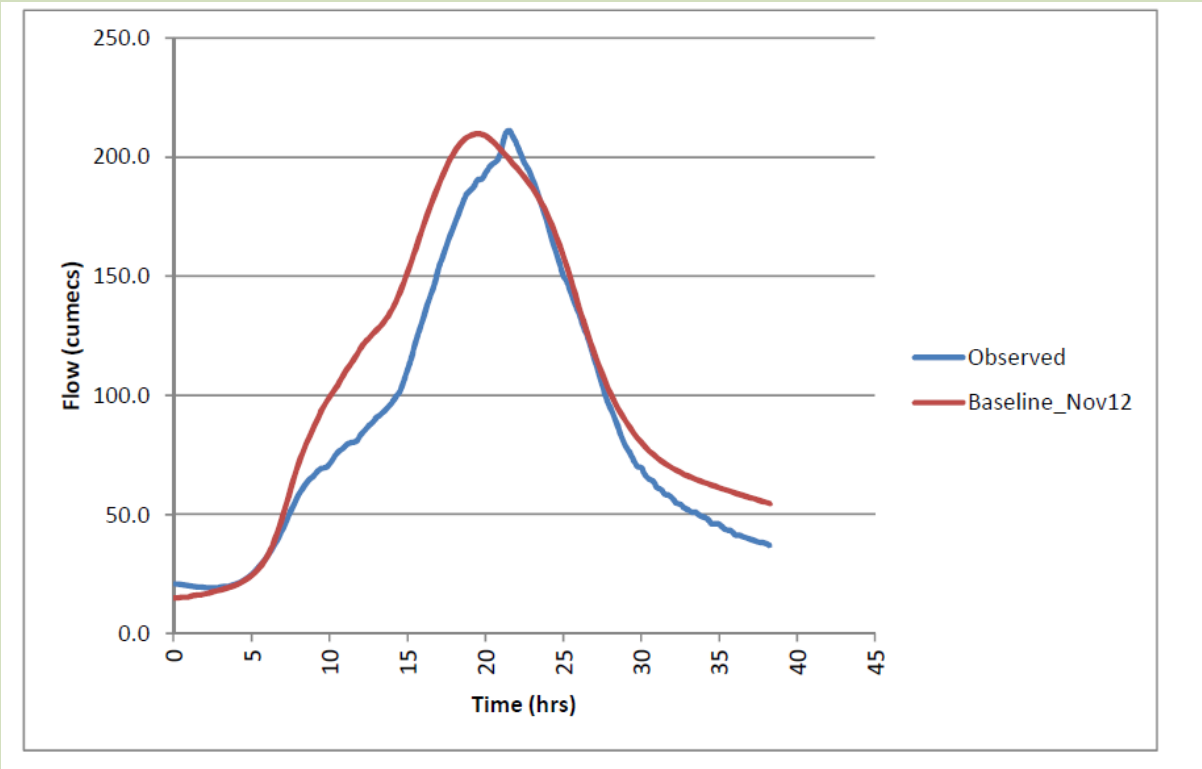

Figure 3: Modelled and observed flows at Pont-y-Gwyddel gauging station for the November 2012 event

Source: Natural Resources Wales

4. Lesson learnt

Choice of tools

- The strategic consideration of a broad range of WwNP measures took into account a ranking based on ecosystem services.
- The relatively inexpensive approach to setting up a network routing model based on LiDAR is a good idea for a previously unmodelled catchment. It is also useful to check on flood peak synchronicity issues.

Catchment scale and typology

The modelling of the implementation of WwNP measures within the Elwy catchment highlights the effectiveness of these measures with localised reductions in flood risk and some reduction in peak flows at the subcatchment scale.

The changeable catchment typology was recognised. Upstream watercourses are located in bedrock dominated, steep sided V-shaped valleys. In the lower sections, these upland tributaries generally have grassed slopes with sparse tree cover and some bracken. In the upper sections, the tributaries are generally characterised by deep gullies with varying levels of vegetation cover. The in-channel morphology in these watercourses is dominated by bedrock-influenced pool-rapid sequences. The headwaters drain open moorland which is largely flat and covered by heather and bracken. Moss-covered peat is characteristic over much of the moorland and drainage grips are evident from aerial imagery.

Wider benefits

This investigation provides a good example of how ecosystem services respond to a range of WwNP measures designed to change the hydrologic and geomorphic characteristics and functions of a catchment and drainage system. Based on a ranking approach, a matrix was used to identify and order the qualitative benefits and dis-benefits of various options for WwNP (Figure 4).

The following conclusions were drawn from the study:

- Regulating services are generally strongly beneficial, as would be expected from flood management measures. The main difference between subcatchments arise from the potential for measures to assimilate waste or sequester carbon (such as large scale grip-blocking/re-wetting and gully planting), which deliver greater potential benefits.
- Cultural services are generally less beneficial, resulting from the range of WwNP techniques and their associated benefits for nature and wildlife appreciation, recreation and landscape, recreation, tourism and natural settings.
- Provisioning services are undefined. Based on the current level of detail it is not possible to ascertain whether there are potential benefits to provisioning services. Furthermore, given the high coverage of agricultural land, measures with significant land take (such as floodplain storage) could be of dis-benefit to food production. This follows a similar approach to that developed by CIRIA in BeST (Benefits of SUDS Tool) for evaluating the multiple benefits of sustainable urban drainage systems (SUDS). It may be possible to adapt this generic tool for WwNP measures in general.

Future research needs

The approach demonstrates a relatively rapid way of investigating how distributed measures affect the timing of interactions with peak flow. Although there is a need to convert to fully dynamic modelling, an important contribution has been to provide a technique for rapid assessment of the effectiveness of WwNP interventions and to weigh up the ecosystem benefits and dis-benefits.

The modelling predicted peak flow reduction of 4% for the real event and 10% for the design events. It is difficult to make direct comparisons because a broad range of measures was considered, although these values appear to be quite high. For some catchments, figures as high as 28% are recorded for the 1 in 2 year event when accounting for potential farm storage, which is considerable. However, it has been partially explained with more detailed analysis of high resolution DTM, where the estimated increased farm storage is not actually feasible due to steep gradients.

The investigation recognises that many of the WwNP measures would take years or decades to implement as opportunities arise.

5. Bibliography

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Project background

This case study relates to information from project SC120015 'How to model and map catchment processes when flood risk management planning'.

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