Case study 1

Tarland Burn runoff attenuation modelling - Aberdeenshire

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1. Catchment summary

Study location

The Tarland Burn is located in Aberdeenshire in north-east Scotland. It is a 74km2 subcatchment of the River Dee catchment (2,105km2) and has an average annual rainfall of ~800mm. The major land uses are arable (25%), plantation forestry (19%), improved and unimproved grassland (36% and 10% respectively), heather moorland (8%) and mixed/broadleaved woodland (2%).

Catchment summary

The Tarland Burn and its tributaries (Figure 1) have been extensively deepened and straightened to drain the surrounding floodplain and wetlands for farming (Aberdeenshire Council, 2007). Aboyne and Tarland are the 2 main towns and villages in the Tarland catchment and both have witnessed flooding in the past 15 years.

To address the flooding issues in Tarland, previous studies have investigated which Working with Natural Processes (WwNP) measures could be implemented in the catchment to reduce flood risk. There is a historical legacy of land improvement and intensification of land management in this catchment and so another strand of work has investigated diffuse pollution and the impacts of riparian buffer strips on improving water quality.

Figure 1: Riparian management in the Tarland Catchment

Source: James Hutton Institute

Study summary

The study incorporated strategic and detailed flow and water quality modelling. The 2 main areas of investigation in the Tarland catchment are:

- applying a modelling framework to assess the effectiveness of current WwNP measures (wetlands, storage ponds and riparian management) and potential WwNP measures (for example, offline storage areas and tree planting) in the catchment
- investigating diffuse pollution in the catchment looking at the role of buffer strips and other measures for improving water quality

This study developed a modelling framework by using a combination of one-dimensional (ISIS) and 2-deimesnional (TUFLOW) flood models that can be used to assess the bemefits of different WwNP

options. Linsey McLean (Heriot Watt University) is undertaking a PhD to investigate the role of established buffer strips on riparian hydrology during storm events using the US Soils and Water Assessment Tool (SWAT).

There are also simulated nitrate, suspended sediment and phosphorus time series for calibration and validation periods (2000 to 2010), a baseline period (1981 to 2010) and a future period (2030 to 2060) under baseline and future land management, land use and climate. Model outputs from STREAM-N and the Integrated Catchment Model (INCA) suite (INCA-N and INCA-P) as part of the EU Seventh Framework Programme (FP7) REFRESH project and, more recently, a Defra project are also available.

Community involvement

Community and stakeholder engagement was undertaken by a range of organisations including the Dee Catchment Partnership, Aberdeenshire Council, River Dee Trust, the Scottish Environment Protection Agency (SEPA), Scottish Natural Heritage and the MacRobert Trust. These organisations have all implemented WwNP measures in the catchment.

2. Data summary

Datasets and analysis techniques used

High resolution datasets have been collected by the James Hutton Institute, Aberdeenshire Council, SEPA and other groups for the past 15 years. You can learn more about the environmental monitoring sites maintained by the James Hutton on its website (www.hutton.ac.uk/research/themes/managing-catchments-and-coasts/environmental-monitoring-sites).

Example datasets include:

- rainfall data and weather data (nearby Met Office station)
- discharge at 4 locations in the catchment
- river chemistry
- ecological data

Onsite data collection has included:

- measurement of river discharge at 4 locations
- precipitation
- temperature
- stream chemistry
- channel surveys and soil moisture surveys

Other licensed datasets have been used including:

- light detection and ranging (LiDAR)
- land use datasets
- Met Office gridded rainfall and temperature

Potential evapotranspiration was calculated using the modified Penman–Monteith method.

Data restrictions

The data have been collected by the James Hutton Institute and are largely owned by them. Other datasets were licensed through third parties such as SEPA and the Met Office.

3. Model summary

Catchment processes investigated

Two catchment processes were investigated.

Run-off generation mechanisms and patterns were studied through the buffer strip PhD project which is investigating run-off processes and how riparian management could potentially reduce flood risk. This is being examined and upscaled with the SWAT model. The hydrodynamic modelling approach is looking at the impact of offline storage ponds in reducing downstream flood peaks.

The mobilisation and inputs of diffuse pollutants from the land was investigated at the catchment scale using the STREAM-N and INCA-N models, and the INCA-P sediment model. Work included looking at the effectiveness of a suite of larger scale measures in terms of reducing diffuse pollution inputs from the land, including reductions in fertiliser and manure application rates, conversion to lower intensity land use and reductions to larger scale soil erodibility (for example, through maintaining winter stubble).

Model assumptions

A modelling framework was set up using a combination of one-dimensional (ISIS) and 2-demiensional (TUFLOW) flood models to assess the impacts of different WwNP options such as flood storage ponds. This model initially used high resolution Digital Elevation Model (DEM) data (LiDAR), Flood Estimation Handbook design flood estimates and river discharge data (Ghimire, 2013).

Data and model outputs

Model outputs were visualised as flood inundation maps. The maps can be viewed in the James Hutton Institute's Virtual Landscape Theatre and have been discussed with catchment stakeholders who were able to cross-check the outputs. A time lapse camera in the catchment will be used to validate flood inundation outputs for future events. Learn more about the flood inundation modelling and visualisation approach developed by the James Hutton Institute (www.knowledgescotland.org/briefings.php?id=366).

Model performance

Model performance was assessed using correlation coefficients and the Nash–Sutcliffe efficiency goodness of fit.

The failure of the different WwNP measures was not modelled explicitly, although long-term performance is being assessed through monitoring of sediment depths in the storage pond. These surveys are being conducted using a real time kinematic global positioning system (RTK GPS) to allow spatial depths to be calculated. This information will enable the project to assess the sediment capture rate of storage bunds. In addition, stream chemistry is being recorded monthly to assess impacts on water quality.

4. Lesson learnt

Choice of tools

This case study highlights outputs from a range of different investigations in the Tarland catchment, all of which use different datasets, models and tools. It was found that:

- data from a dense multiscale hydrometric network helps to inform models and allows both data and trend analysis
- high resolution LiDAR data allows detailed terrain and flow pathway analysis

Catchment scale and typology

By combining the multiscale hydrometric network with the modelling tools, this case study has improved understanding of the model performance at a range of different spatial scales.

Wider benefits

Multiple environmental benefits are currently being studied as part of PhD research and a SEPA funded pilot catchment project (www.sepa.org.uk/environment/water/river-basin-management-planning/actions-to-deliver-rbmp/pilot-catchments/).

Future research needs

There is a need to develop more bespoke or new modelling tools that can model WwNP measures effectively. Not all WwNP measures can be implemented accurately using the structures available in the current generation of software packages. For instance, there is no 'leaky log dam' unit in ISIS, HEC-RAS ((Hydrologic Engineering Centre's River Analysis System) or MIKE11, necessitating use of the nearest equivalent structure such as a bridge with a low decking.

Preliminary results suggest a network of 14 ponds (5,000m3) could potentially attenuate flows by as much as 12% (1 in 2 year design events). Further work is needed to refine the modelling simulations and this is ongoing.

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Project background

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