Whole Catchment Modelling to Assess Natural Flood Management Options

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1. What is Whole Catchment Modelling?

Whole Catchment Modelling represents the catchment as a virtual hydrodynamic model including physical features, processes and systems as shown in the below image, driven with real world data to test and simulate different conditions and scenarios for the purpose of understanding the catchment performance for flood management purposes.

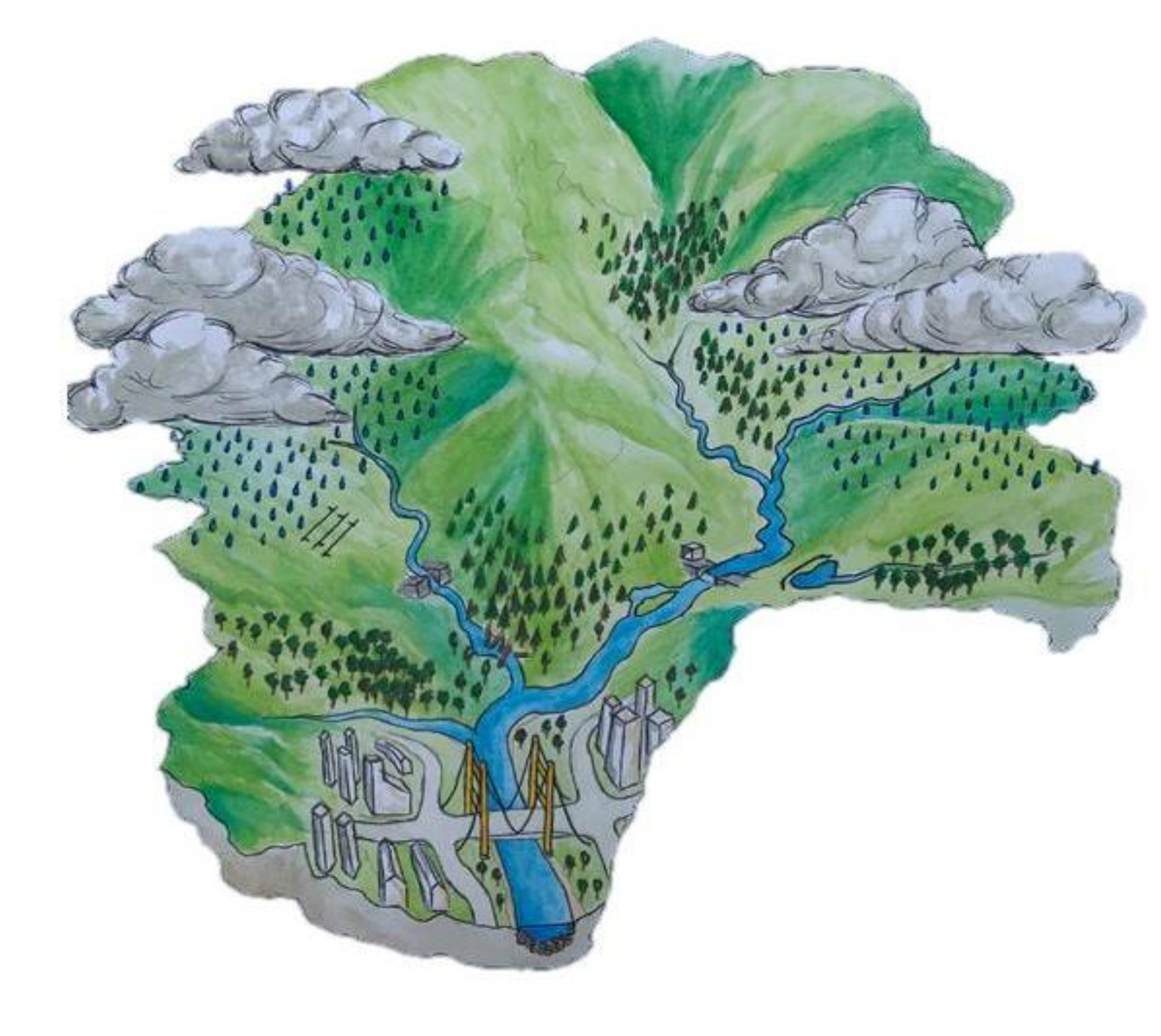


Figure 1: NFM Whole Catchment Model Schematic (image courtesy of Kieran Bird)

2. How can virtual models be applied to catchment Natural Flood Management (NFM)?

NFM involves implementing measures to protect and restore natural hydrological functions to slow the flow. Virtual models objectively assess the **catchment wide hydrological and hydraulic interdependencies** to identify where NFM interventions will have the most impact to downstream flooding.

By modelling as a whole catchment using near real-time observation data we can simulate how the catchment and its tributaries behave under different rainfall events. Is the event multi peaked? What is the influence of holding back the flow in one subcatchment in another catchment, or on subsequent flood peaks?

3. Why use TUFLOW for Catchment Modelling?

- **Speed:** Use of GPU hardware – up to 80 times quicker. Runs more scenarios faster.
- **Accuracy**: Sub-Grid Sampling (SGS) functionality allows representation of fine scale topography at coarse grid resolutions. See Figure 2 below for schematic. Run more scenarios faster with greater accuracy.

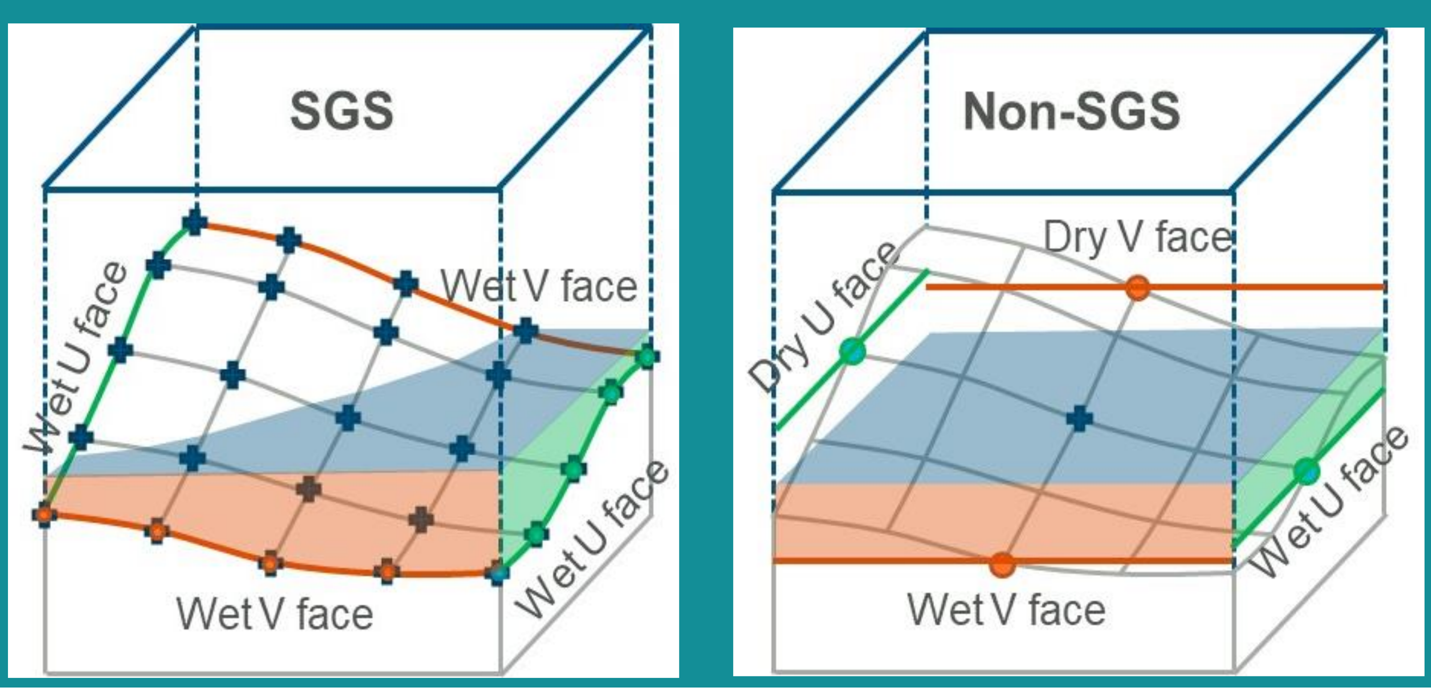


Figure 2: Cell Schematisation for SGS and Non-SGS (conventional hydraulic modelling approach). SGS allows the sampling of the sub-grid topography providing a better representation of the underlying topography.

4. Case Study - Afon Gwy Whole Catchment Model

- Small (~13km^2) flashy catchment in mid-Wales
- Response times of approximately 1.5 hours.

A TUFLOW model was created which used observed rainfall as boundary input.

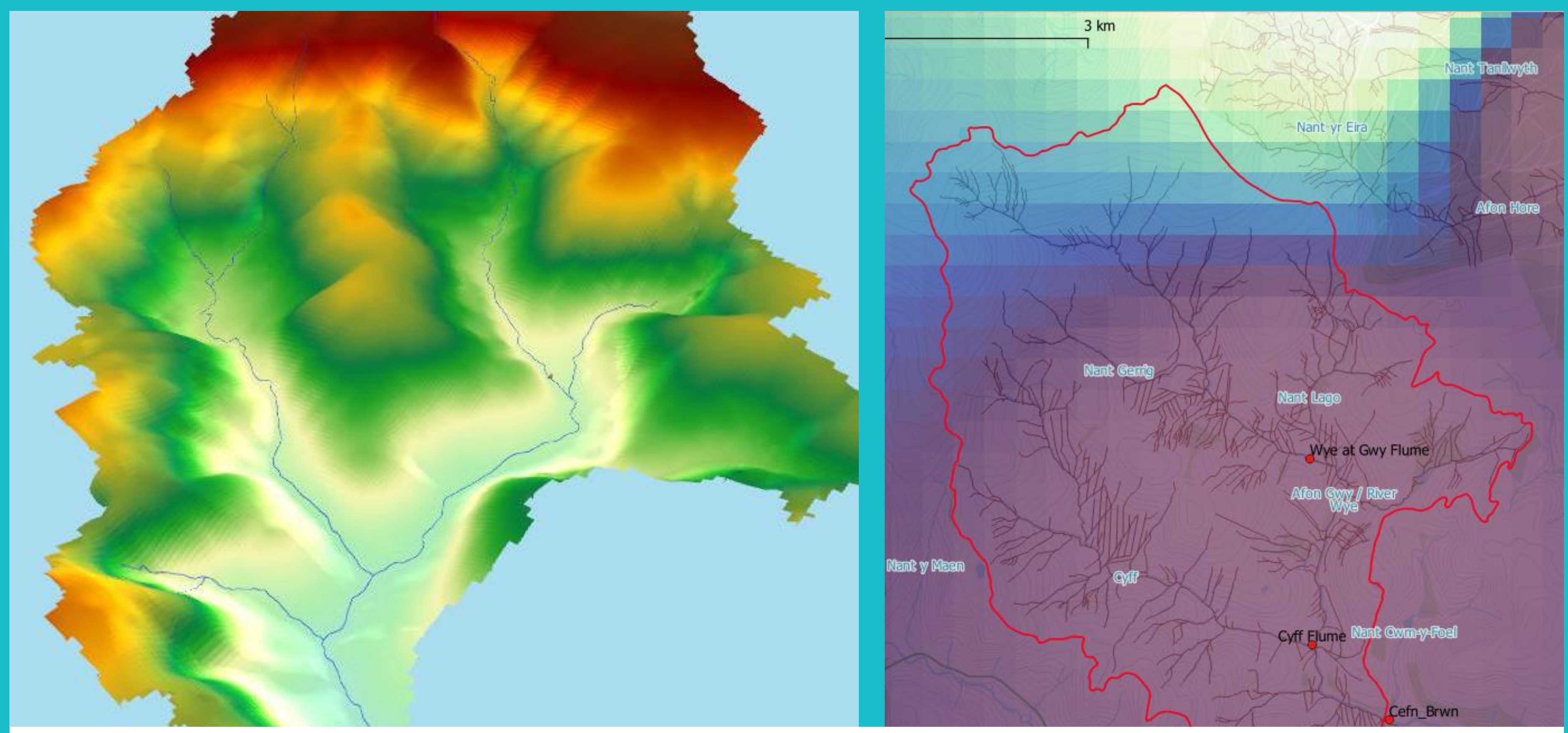


Figure 3: Afon Gwy catchment with gauge locations and example spatial rainfall distribution (Contains OS data © Crown copyright and database right 2020).

The grid cell size was 20m for the whole catchment and utilised the sub-grid sampling technique to represent the 2m topography despite using a larger 20m cell size for the hydraulic calculations. The use of sub grid sampling provides two major benefits:-

1. Speed: Sub-grid Sampling enabled 3-week simulations to be run in 1.5 hours. Demonstrates that longer time-series' and more scenarios can be run.

2. Accuracy: Results were comparable to a finer grid cell size but in a fraction of the time (~<5%). Figure 4a and b show the comparison of the simulated results vs observed flow. The Nash-Sutcliffe efficiency parameter was 0.85.

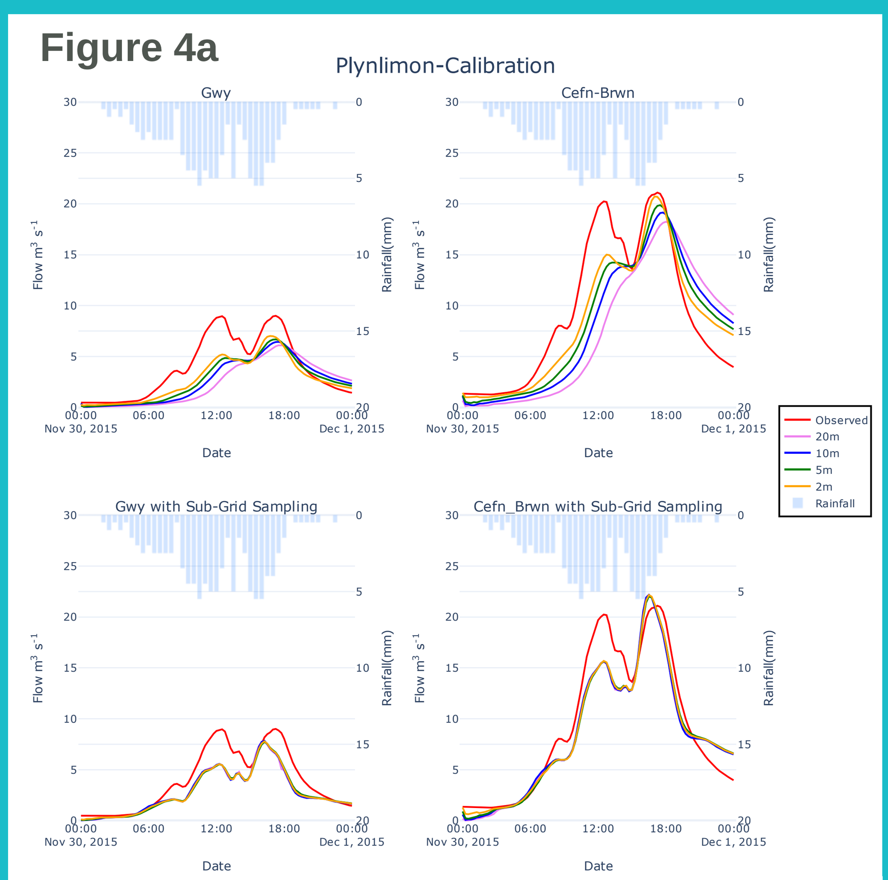
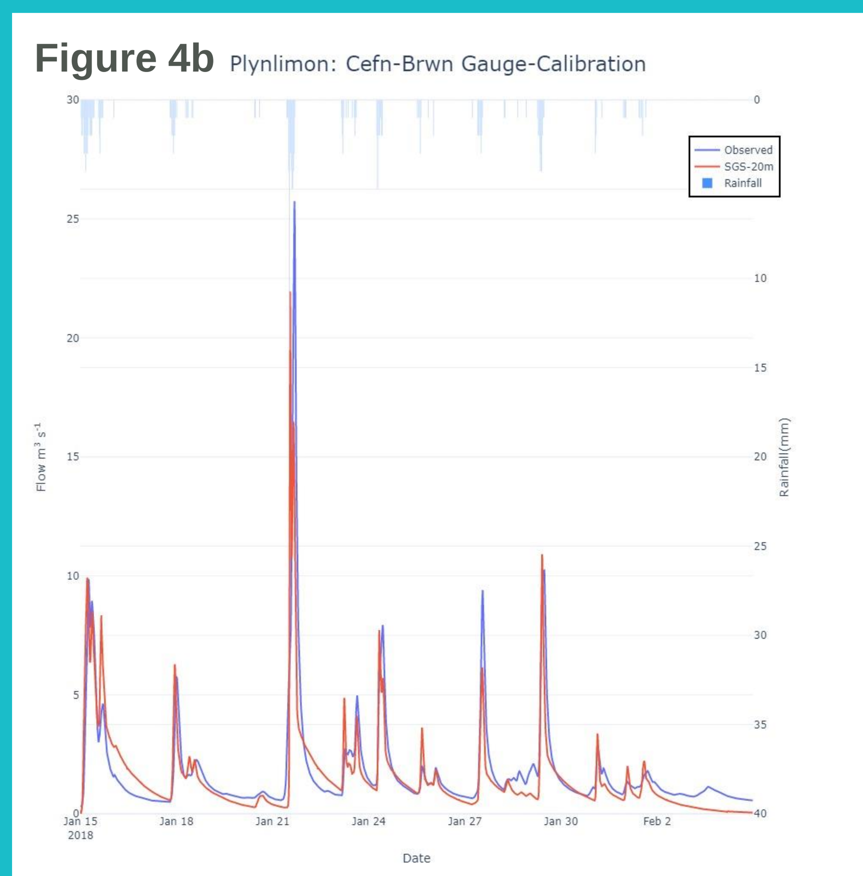


Figure 4: Simulated Flow vs Observed Flow for 2 gauges within the Afon Gwy catchment.



Simulation results against the observed flow for a 3-week simulation.

Outputs: Assessing Multiple NFM Measures

Figure 5 shows the baseline outputs for the 3-week simulation.

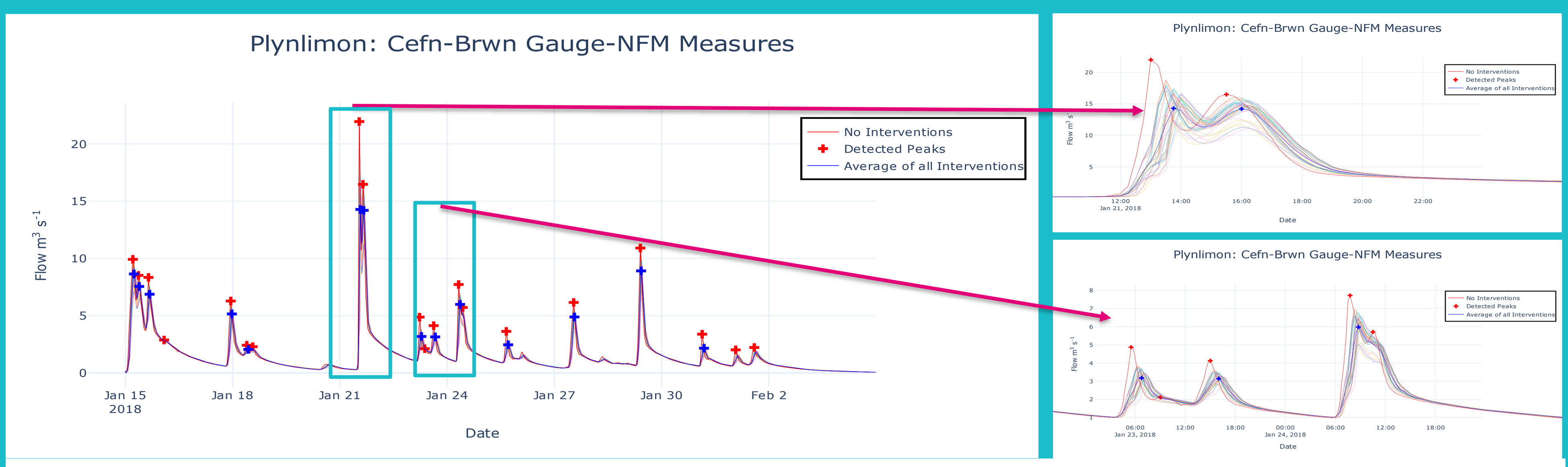


Figure 5: Comparison plots of simulated interventions, including the average output against a baseline no-intervention scenario. The simulated measures show a consistent reduction in the peak flow as well as attenuation of the timing of the peak.

The following table summarises the impact of the model outputs from the NFM scenarios versus the baseline scenario.

	Baseline	NFM Interventions
No of Flood Peaks over Threshold	19	13
Reduction in Peak Magnitude		20 - 30%
Increase in Flood Peak Travel time		29 - 150%

5. Where Next?

The ability to rapidly run multiple simulations quickly lends itself to investigation measures in an uncertainty framework. The approach is also being trialled on larger catchments with different hydrology to the Afon Gwy catchment. The whole catchment model can also be used to assess the impact of NFM such as the impact upon sediment dynamics, geomorphology and water quality.

Acknowledgements - The LiDAR data used contains public sector information licensed under the Open Government Licence v3.0. The Afon Gwy model contains data supplied by Natural Environment Research Council. The Afon Gwy observed rain gauge and flow data was provided by the Centre of Hydrology, Bangor.