Preparing for Impact: Prototyping a Hazard Impact Model with Python, PostGIS and GeoServer.

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Summary

This paper describes recent work undertaken by the Met Office as part of its contribution to the Natural Hazard Partnership. In collaboration with NHP partners a prototype Surface Water Flooding Hazard Impact Model has been developed and deployed on a trial basis. Delivering outputs via OGC web services, the model is an early implementation of the NHP's emerging Hazard Impact Framework.

KEYWORDS: Web Services, Natural Hazards, Flooding, Impact, Standards

1. Introduction

The Natural Hazards Partnership (NHP) is a consortium of 17 government departments, agencies, and public sector research organisations which builds on partners' existing science, expertise, data and services to deliver fully coordinated natural hazard advice to civil contingencies and responder communities and governments across the UK.

The NHP is leading the way in moving from a hazard-based to a more impact-based approach to the assessment of natural hazard risk. Rather than focussing purely on the extent and magnitude of the natural hazard itself, we aim to improve our understanding of the impacts on people, property and infrastructure. The Partnership is developing a series of Hazard Impact Models (HIMs) that combine partners' data and expertise to identify the impacts resulting from a range of natural hazards.

2. HIPS

A key aim of the HIM development work is that the outputs of these models can be used in parallel to enable assessment of and prepare responders for multi-hazard scenarios. Early work on this envisaged the HIMs as components of an overarching software package called the Hazard Impact Production System (HIPS). The HIPS acronym survives, but now refers to a "virtual" system - portrayed in Figure 1 - composed of multiple self-contained "modules" (the HIMs), all conforming to a set of standards (the Hazard Impact Framework, or HIF). This approach means that individual partners can work with the software and hardware most suited to their task with the confidence that their outputs will be compatible with those of the wider group. Practical constraints may require operational HIMs to be run at a single location, but the design does not dictate this. It is envisioned that the use of the HIF will eventually extend beyond NHP partners to the wider risk community.

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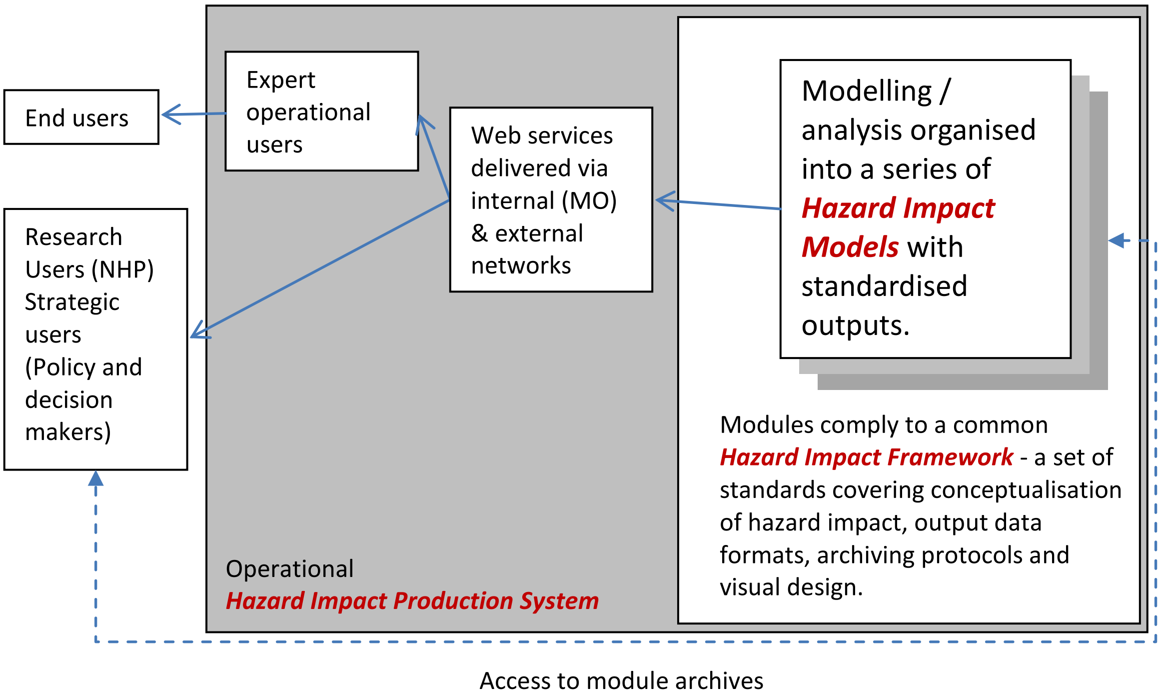

Figure 1: The Hazard Impact Production System (HIPS)

A core principle of the HIPS concept is that all HIMs will make their outputs available via web services conforming to the internationally recognised standards set by the Open Geospatial Consortium (OGC). The key strength of this approach is that both HIMs and downstream systems (e.g. desktop front-ends) can be added or updated without disrupting other elements of the system.

Work on the HIF has proceeded in parallel with that on the first two prototype HIMs, with the experience gained directly informing the Framework. The Vehicle OverTurning (VOT) HIM, developed internally at the Met Office, piloted the use of Web Map Services and was based on ESRI technologies (ArcPy and ArcGIS Server). This has been followed into development by the Surface Water HIM (SWF HIM).

3. SWF HIM

The SWF HIM is being developed collaboratively by NHP partners (the Centre for Ecology and Hydrology (CEH), the Health and Safety Laboratory (HSL) and the Met Office) and associates (JBA Consulting and Kings College London) for use by the Flood Forecasting Centre (FFC). The FFC, a partnership between the Environment Agency (EA) and the Met Office, combines meteorological and hydrological expertise into a specialised hydrometeorology service. The centre forecasts for all natural forms of flooding: fluvial (river), surface water, tidal/coastal and groundwater.

Figure 2 illustrates the broad structure of a HIM. Thresholds are used to identify locations where a forecasted natural phenomenon (e.g. wind or rainfall) of is sufficient intensity to present a hazard. Data on the receptors (broadly speaking, people, property and infrastructure) at those locations is then used to estimate potential impacts. For some – largely meteorological, at present – natural phenomena it is possible to obtain ensemble forecasts. These are similar to Monte-Carlo analyses in that multiple forecast runs are made (with slight perturbations to initial conditions) to give a spread of possible outcome scenarios. The core HIM process is run multiple times, once for each ensemble member forecasting the natural process, adding a probabilistic element to the impact forecast which results in a risk forecast for the particular natural hazard.

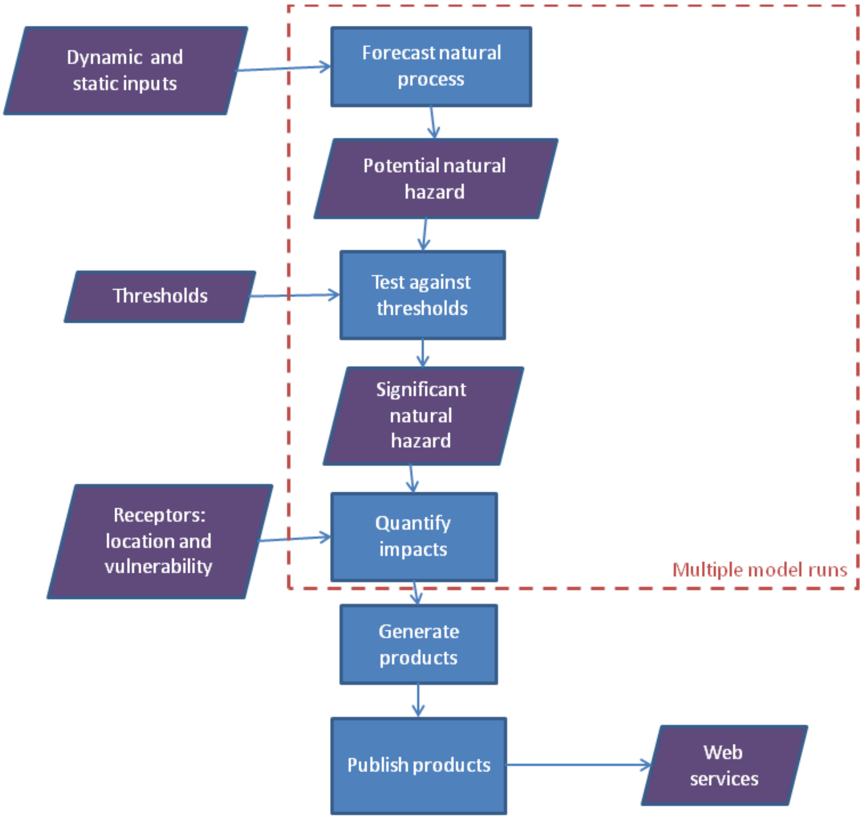

Figure 2: Generic Hazard Impact Model Process

The SWF HIM prototype described in this paper has been created as part of Phase 2 of the overall SWF HIM project. Phase 1 developed a pragmatic impact modelling methodology that reconciled the desire to benefit from detailed spatial data on receptors with the short processing time required when providing timely information during a fast changing hazard incident.

A physical model (Grid-2-Grid, developed by CEH) takes Met Office ensemble rainfall data as an input and generates a surface water depth on a 1km grid basis at 15 minute intervals. This data is then accumulated (using a 1-hour moving window) and thresholds used to determine (for each of the model's 1-hour output timesteps) whether one of three "flood scenarios" is in effect in a given grid square. Appropriate impact ratings are then assigned to the grid square by reference to the Impact Library. This dataset provides four thematic impact ratings (relating to People, Property, Infrastructure and Transport) for each grid square under each scenario. The Impact Library was generated by HSL through the combination of detailed hazard zone mapping (the EA's updated Flood Map for Surface Water, or uFMfSW) with data on receptors derived from the National Receptor Database (NRD) and the National Population Database (NPD), along with Ordnance Survey transport datasets. The library uses impact categories (Minimal, Minor, Significant and Severe) based on the number of receptors affected.

4. The End-to-End Prototype

During planning for Phase 2 of the SWF HIM project it was decided to create a prototype of the model in parallel with ongoing methodological development work. The G2G hazard model was already in use at the FFC, which is housed in the main Met Office building, so a system providing live impact forecasts to the former could be developed without the complexity of passing live data between sites.

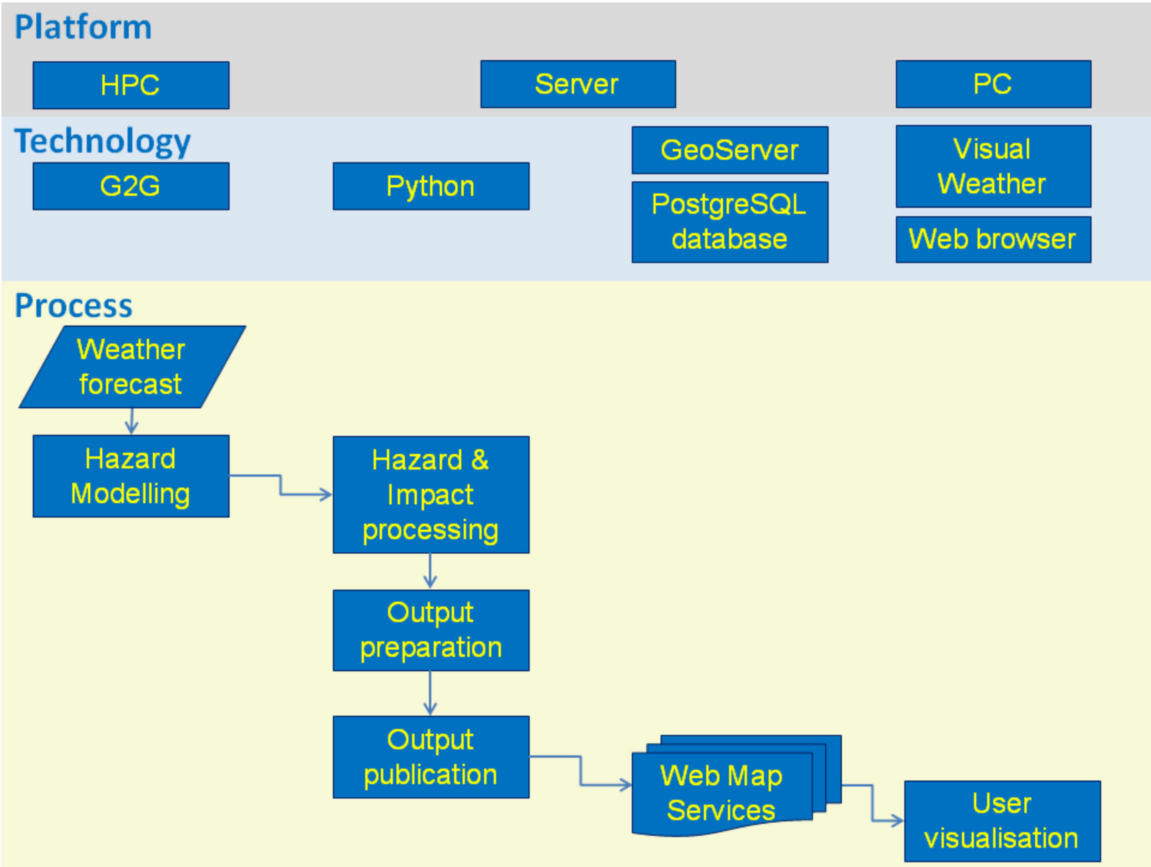

Figure 3: the SWF HIM prototype architecture.

Figure 3 portrays the infrastructure of the prototype. The G2G model runs on the Met Office supercomputer (referred to as the HPC – High Performance Computer). Data on rainfall and surface water depths is passed to a Windows server, where a Python script undertakes the process described in Figure 2 before building output products (imagery and database tables) and publishing them to Web Map Services (WMS). In contrast to the Vehicle OverTurning model, the server-side software used for SWF HIM is largely open source. The client software (Visual Weather, running on Windows desktops) is a proprietary meteorological package that can utilise WMS.

The prototype produces two forecasts: the "nowcast" based on weather data extending 7 hours into the future and the short range forecast looking 30 hours ahead (at the time of writing, an upgrade to 54 hours is in development). Over a given 24 hour period the system processes 28 (24 nowcast plus 4 short range) forecast runs totalling approximately 56G of input data. A total of 63 web services are updated per forecast run.

5. Example outputs

The following examples (figures 4 to 7) are drawn from the same short range forecast. They illustrate the main forms of output published via (WMS):

- Probabilistic mapping (Figure 4)
- Maximum impact mapping (Figure 5)
- Area impact "verdict" mapping with supporting data tables (Figures 6a & 6b).
- Time series graphs (Figure 7)

The outputs shown in figures 6b and 7 are delivered in response to WMS GetFeatureInfo requests. Use of this technique revealed a shortcoming in the client software: unlike text and tabular data, images returned by this method were not displayed. To overcome this, FFC were provided with a customised (Open Layers based) web page to view the time series graphs.

The area verdicts are intended to allow a high level view of the outputs that does not give undue weight to outliers in the impact data. Within each administrative area used the grid-square based impacts are counted and compared with a threshold based on the total number of grid squares vulnerable to SWF within that area. The area verdict is the lowest level of impact that exceeds this threshold. The map area is styled after the highest impact predicted, with a getFeatureInfo return used to communicate the range of verdicts across the ensemble.

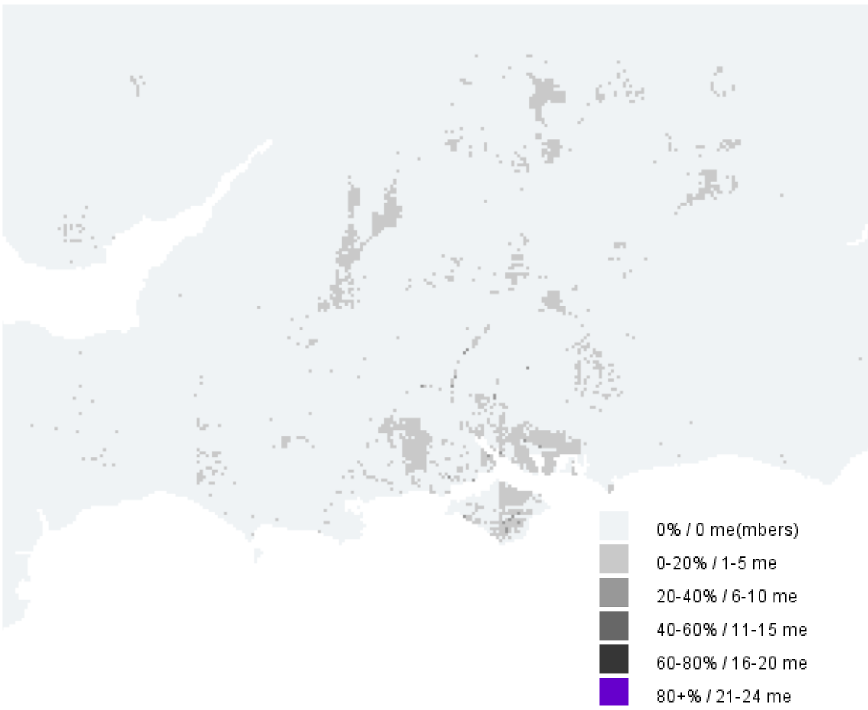

Figure 4: Probability map of surface water flow exceeding 30 year return period (based on a 24 member ensemble).

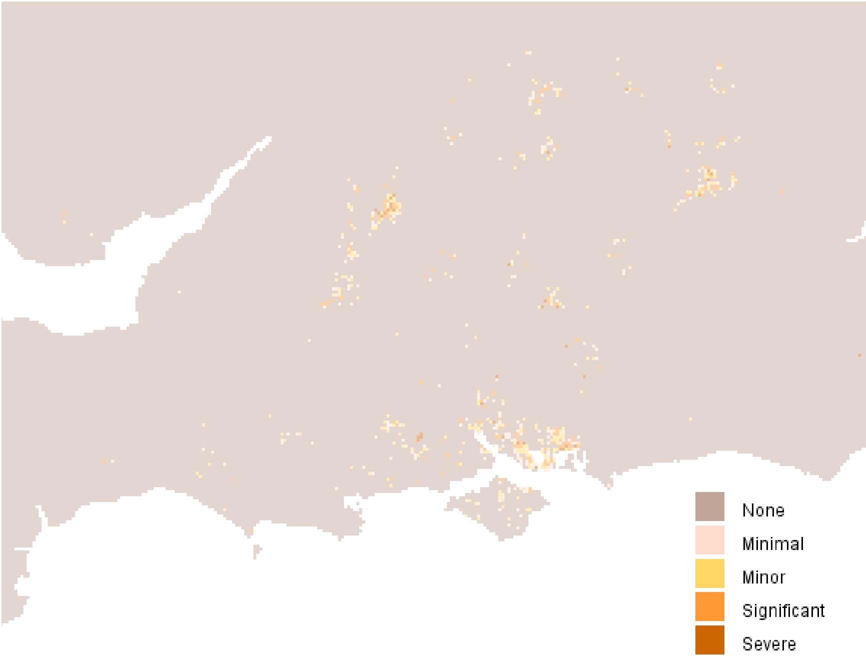

Figure 5: Maximum predicted impact over a single hour.

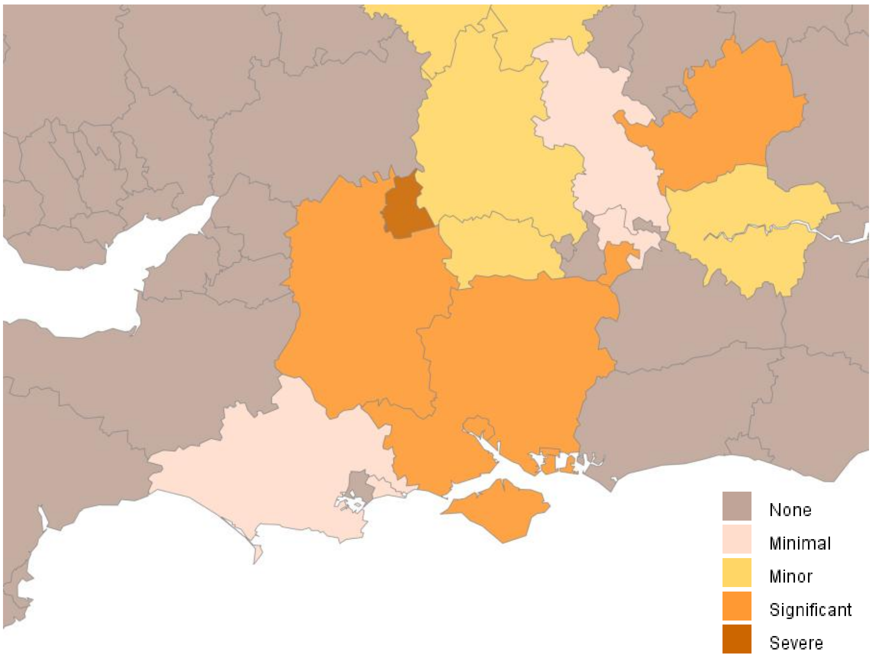

Figure 6a Map showing county level impact “verdict”

Hampshire

16-Sep-2016 04:00:00

Threshold = 14 sq. km.

Impact	Members
None	18
Minimal	1
Minor	2
Significant	3
Severe	0

Figure 6b GetFeatureInfo return from verdict map.

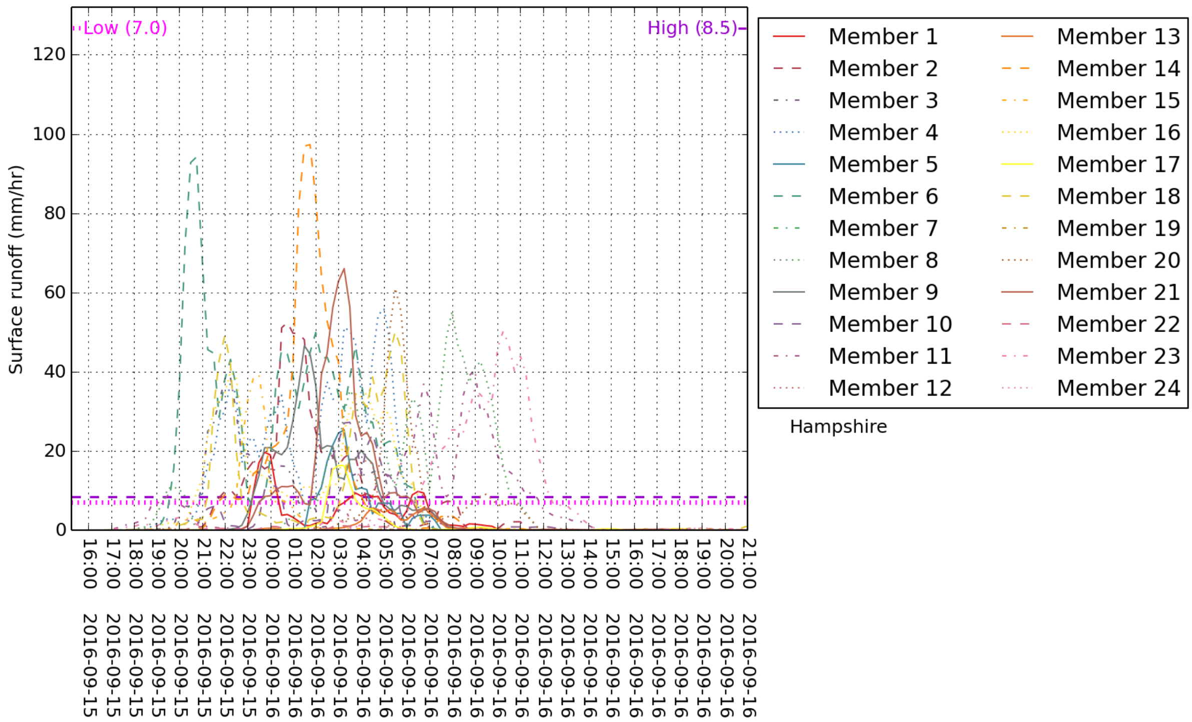

Figure 7: Time series data delivered via GetFeatureInfo showing peak SWF depths for Hampshire across an entire model run.

6. Conclusions

While the prototype SWF HIM system was not the first HIM to be developed by an NHP partner, the complexity and variety of its outputs have proven the flexibility of Web Services for data delivery. The prototype has enabled the customer (FFC) to undertake an ongoing operational trial of the system that is providing valuable feedback into the scientific side of the project

Most of the data associated with SWF HIM has a temporal element. This, allied with the need to process of a large volume of data in a restricted time, posed challenges during development. The practical experience acquired in the creation of the SWF HIM prototype has made an invaluable contribution to ongoing work on the Hazard Impact Framework.

7. Acknowledgements

This paper describes the implementation of the prototype SWF HIM. The methodology used was developed by Bob Moore and Steve Cole from CEH and by Tim Aldridge and Oliver Gunawan from HSL – all of whom were actively involved in the specification of the prototype. FFC have been an active customer and provided SWF hazard and impact expertise, with Graeme Boyce, Keith Fenwick, Daniel Lamb, Andy Lane, David Price and Matthew Winter all committing time and valuable effort to the work. Finally, Deborah Lee (Met Office) has overseen the project with diligence and enthusiasm.

8. Biography

John Mooney is a Senior GIS Analyst at the Met Office. Since completing his PhD thesis (on generating population data for hazard modelling) he has worked on a variety of GIS based projects in regional government, the insurance industry and academia.