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A Forecasting Modelling System to Help Protect the South East of England from the Impact of Flooding

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The Environment Agency of England and Wales1 (the Agency) was established "to protect and improve the en-vironment" and make it "a better place for people and wildlife." Its Corporate Plan 2011-2015 includes the following theme: "to reduce the risks to people and properties from flooding."

Over 5.5 million properties in England and Wales, or one in six, are at risk from flooding. The latest UK Climate Projec-tions 2009 (UKCP09)2 indicate that rising sea levels and increasingly severe and frequent rainstorms mean the risk of floods will increase for people, communities, and key infrastructure like roads, railways, power substations, and water treatment plants.

The Agency's South East Region (see Figure 1), created by integrating the former Southern and Thames Regions, has 781 miles of coastline and 2,212 miles of main rivers with 668,900 properties at risk of surface water flooding and 403,000 properties at risk of flooding from rivers and the sea. The South East Region, like others across the UK, has experienced a number of severe flood events as well as periods of water shortages over the last two decades. The need for additional tools to help the region forecast river and sea levels, and thereby be better able to warn the population of likely events, has been recognized. Also recognized is the need to manage water resources and flood defence assets to mitigate flood and drought risk and to obtain the best outcome for people and their property.

This article provides an introduction to the management of flood events and the conceptual framework introduced by Parsons Brinckerhoff as part of a National Flood Forecasting Modelling System Strategy. The article also explains how the Southern Region Flood Forecast Scheme (SuRFFS) was implemented

Figure 1 – Map showing the location of the Environment Agency's South East Region

Managing Flood Risk

Although the risk of flooding cannot be completely eliminated, the Agency seeks to minimise the effects of flooding and reduce the damage it causes by working with stakeholders (e.g., utilities, local authorities, central government, emergency services, and contractors) to:

- manage land and river systems;
- build and maintain flood and coastal defence;
- raise the awareness of flood risk through flood mapping;
- encourage people to take action to protect Themselves and their property;
- take effective control of development on flood plains;
  And
- provide flood warnings and work with emergency responders to help people who are at risk.

To accomplish this, and as part of the National Flood Forecasting Modelling System Strategy, Parsons Brinckerhoff worked with the Environment Agency, providing strategic advice and support in specifying a real-time operational systems framework which is described below.

Operational Systems Framework

This operational systems framework is strongly related to the natural cycle of an environmental 'event' (e.g., a flood) which progresses from detection to clearance. The framework is based on 3 major concepts:

1. High Quality Data - provides current, historic, and future (forecast) data which is reliable and accurate. This refers to the quality of both input and resulting output or forecast, data. A model can be compromised by poor quality input data or by poor calibration when it is set up and will not then be able to produce a high quality output, or forecast;
2. Openness - allows for modular development and progressive upgrade or replacement. This system allows models of different types produced by different suppliers to be run to produce flood forecasts. The system is open because the model interface is declared in a published document which is available to all model suppliers, so the model platform is not locked into a model from one supplier; and
3. Flexibility - can be adapted to changes in requirements and technology and is 'scaleable'.

The activities in the natural cycle of an environmental event are:

- Detection - identification of conditions (often achieved through receipt of 'alarms' from telemetry systems) which indicate a potential abnormal situation (e.g., heavy rainfall, high or very low river levels).
- Forecasting - providing routine and 'on-demand' prediction (usually by running a simulation model) of future conditions. For flood forecasts this would normally be up to 24 hours prior to occurrence.
- Warning - issue warnings and disseminate information to the public and to the emergency services and professional partners (e.g., local authorities).
- Response - by the Agency in terms of operating its resources and assets (e.g., pumps, river/sea defences and structures), and mobilising its operations and maintenance workforce; by the emergency services;
  by businesses and industry; and by the public in protecting themselves and their property.
- Event Monitoring & Management - continuous monitoring of environmental factors (e.g., weather, river and sea levels) which contribute to

the flood conditions; monitoring forecasts and their accuracy; monitoring the progress of the dissemination of information and warnings and the effectiveness of the response to determine how the event is progressing; and evaluating and managing the performance, as appropriate, of the cycle.

- Clearance – determining that the potential incident is not going to occur or that the event has passed. In the case of flood events the cycle can last from just a few hours (normally when the conditions change and a flood does not actually take place) to several days (when adverse conditions persist and widespread flooding occurs).

The stages in the event cycle and their relationship to the operational systems are shown in Figure 2.

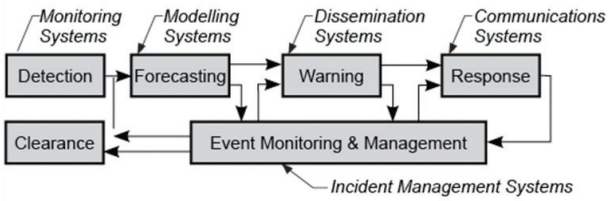

Figure 2 – The Event Cycle: once a potential event is detected the cycle is 'triggered' and is not complete until 'cleared' by one of the subsequent activities.

The Agency uses monitoring, forecasting, communications, data management, decision support, and visualization systems to manage events and it is important to consider each system individually as well as in the context of other systems with which it is closely connected. The strategic framework for operational systems which resulted from this evaluation is shown in Figure 3. It can be applied throughout the Agency and can be easily tailored for use on different applications (such as for flood, pollution, drought, and river management).

Southern Region Flood Forecast Scheme (SuRFFS)

The Agency's regions throughout England and Wales have been using and further developing real-time flood forecast models for many years. Parsons Brinckerhoff has provided assistance to many of the Agency's national and regional real-time telemetry, flood

forecasting, and event management initiatives, including providing project management support to the Southern Region Flood Forecast Scheme (SuRFFS) which set out the following objectives for the flood forecasting model development programme:

- Improve the flow and flood forecasting capability of all areas at risk of fluvial, tidal, and coastal flooding;
- Introduce water level forecasting for all flood warning areas; and
- ntroduce inundation mapping for key locations.

One of the main outputs of SuRFFS was the development of real-time river level models for main river catchments throughout the region, where sufficient data had been electronically collected from previous flood events. Many catchments had data recorded during the flooding in the year 2000, for some catchments this included flood return periods in excess of 1:1003 years.

A 'model brief' was developed to define the outputs required (river level forecasts) and the inputs available (realtime rainfall, river level, sea level, river flow data, weather radar rainfall forecasts, etc.) for each of the major river catchments (around 25 were modelled) in the region. The work to develop the models was let to modelling consultants and was divided into the following phases:

- Phase 1 – Catchment Inception Report including data review and detailed model design. The model design included consideration of the priority to be assigned to rainfall inputs available from rain gauges and weather radar forecasts, and the availability and possible use of"updating" of model states based on real-time Measurements of the modelled outputs.
- Phase 2 – Catchment Model Calibration Report Including development and calibration of rainfall runoff and hydrodynamic river models. Models were calibrated against five selected actual flood events.
- Phase 3 – Catchment Model Verification Report Including verification of rainfall runoff and hydrodynamic river models against data from a further three flood events (separate from those used for calibration).

Following initial work, it was found that the scope of work and costs of model development could be controlled more closely by awarding Phase 1 of the work separately from the later phases. This allowed phases 2 and 3 of the model development for each river catchment to be awarded when a full analysis of the data available for the catchment had been undertaken, thereby preventing unnecessary changes of scope and halving the time to develop a typical river catchment model, and increasing the opportunity for competition in the procurement of modelling services.

Development of hydrodynamic models was assisted in many catchments by making use of "donor" models, previously developed for offline purposes using the same modelling software. These models were then streamlined to allow them to run efficiently in real-time. The models were also modified as necessary to allow them to be run for events with a return period of 1:100 years with an additional 20% flow allowed for the increased river flows expected due to predicted changes in the future climate.

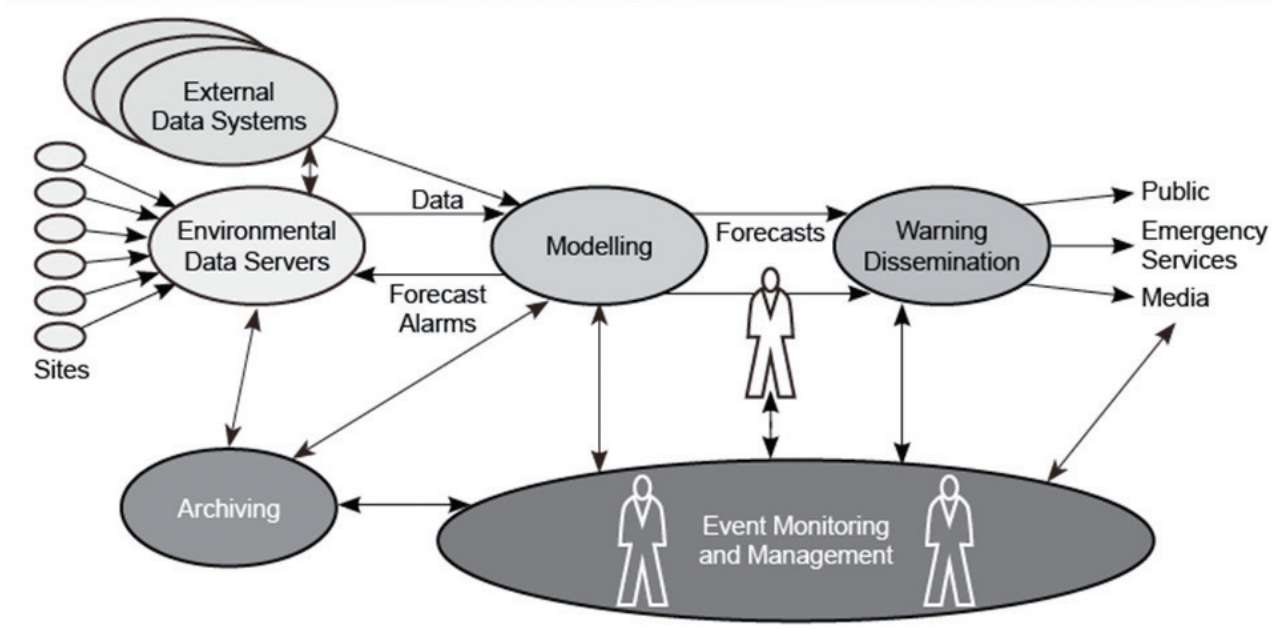

Figure 3 – A Real-time Operational Systems Strategic Framework.

Modelling systems used by the South East Region

As part of the Agency's National Flood Forecasting Modelling System (NFFMS) Strategy, the Agency implemented a National Flood Forecasting System (NFFS) to forecast water levels at specific river locations up to 24 hours prior to occurrence. As each of the Agency's regions has historically developed their own flood forecasting systems independently, a wide range of forecasting models and methods were in use. The NFFS uses an "open shell" concept which can run a variety of proprietary and bespoke forecasting models.

The following models are used by the South East Region for forecasting rainfall, runoff, river, and sea levels:

Hydrological Runoff Models – probability distributed model (PDM) supplied by the UK Centre for Ecology and Hydrology (CEH). PDM is a fairly general conceptual rainfall–runoff model which transforms rainfall and evaporation data to forecast water flow at the catchment outlet.

Hydrological Routing Models – kinematic wave (KW) model supplied by the UK Centre for Ecology and Hydrology (CEH). KW is a channel flow routing model designed for modelling and forecasting flow in river channels (natural or otherwise) with lateral inflows.

Hydrodynamic Models (1D) – ISIS is river modelling software used for flood risk management. ISIS makes available 1D and 2D simulation solvers, analysis isualisation tools, and flood inundation within one environment.

Lookup Table-type Models – model results generated offline by 3D modelling as used in coastal forecasting, for example. Figure 4 illustrates the concept of "openess' supported by the Agency's NFFS.

Conclusion

The development of the NFFS tool has significantly advanced the ability of the Environment Agency to mitigate the flood and drought risks faced by the people of England and Wales, thereby helping to achieve one of its main objectives. The South East Region has been bringing models developed by the SuRFFS project into operational use to support flow and flood forecasting since 2009.

However, assessment of model performance depends to a considerable extent on the incidence of significant rainfall events in the region and it is too early to accurately assess how the models will perform in the event of a severe flood.

The operational models have produced extremely useful forecasts in terms of flood warning threshold crossings, when these model outputs have been interpreted by experienced forecasters.

The rainfall runoff models have been found to perform better for wetter catchment conditions than for drier catchment conditions. To address this issue, selected rainfall runoff models have been recalibrated, resulting in a reduction of overestimation and, hence, a markedly improved performance in drier catchment conditions.

A programme of formal model performance assessments is currently underway which will direct the future development of forecasting models in the region and ensure that the operation and maintenance practices using the SuRFFS tool will continue to improve.

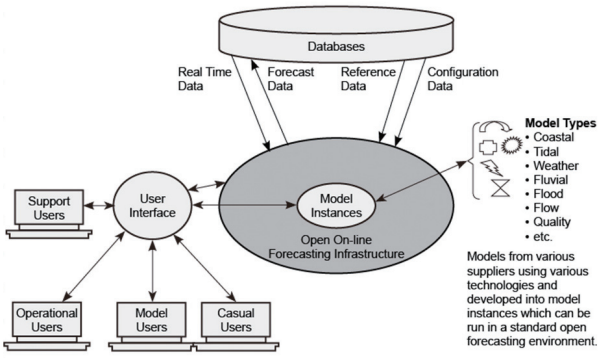

Figure 4 – Openness as applied to the design of the Agency's National Flood Forecasting System. The differences in model types and suppliers are transparent to forecasters.