ISIS case study – Real-time flood forecasting for the Mersey Estuary

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Background to the project:
Warrington is classified as one of the top 10 places in the country at risk of flooding [1,2] and timely and accurate forecasts are essential to provide the necessary flood warning service.
The Environment Agency currently provides Flood Warnings to around 2500 properties along the Mersey Estuary based on forecasts of water levels at key locations within the estuary.
At present, these forecasts are issued based on the Triton flood forecasting system, which is a type of pre-computed outcome table, fed by forecasts of surge, tide and wind. Performance analysis highlighted scope for improvement to this system.

In order to improve forecasts for the Tidal Mersey, a new hydrodynamic forecasting model was developed, extending from Gladstone Dock to the Woolston Siphon Weir and including the lower reaches of Padgate Brook and Sankey Brook. Development of the model involved recycling and joining up three previously developed hydrodynamic models and constructing a new model section for the Mersey estuary from Gladstone Dock to Runcorn Bridge (see Figure 1).

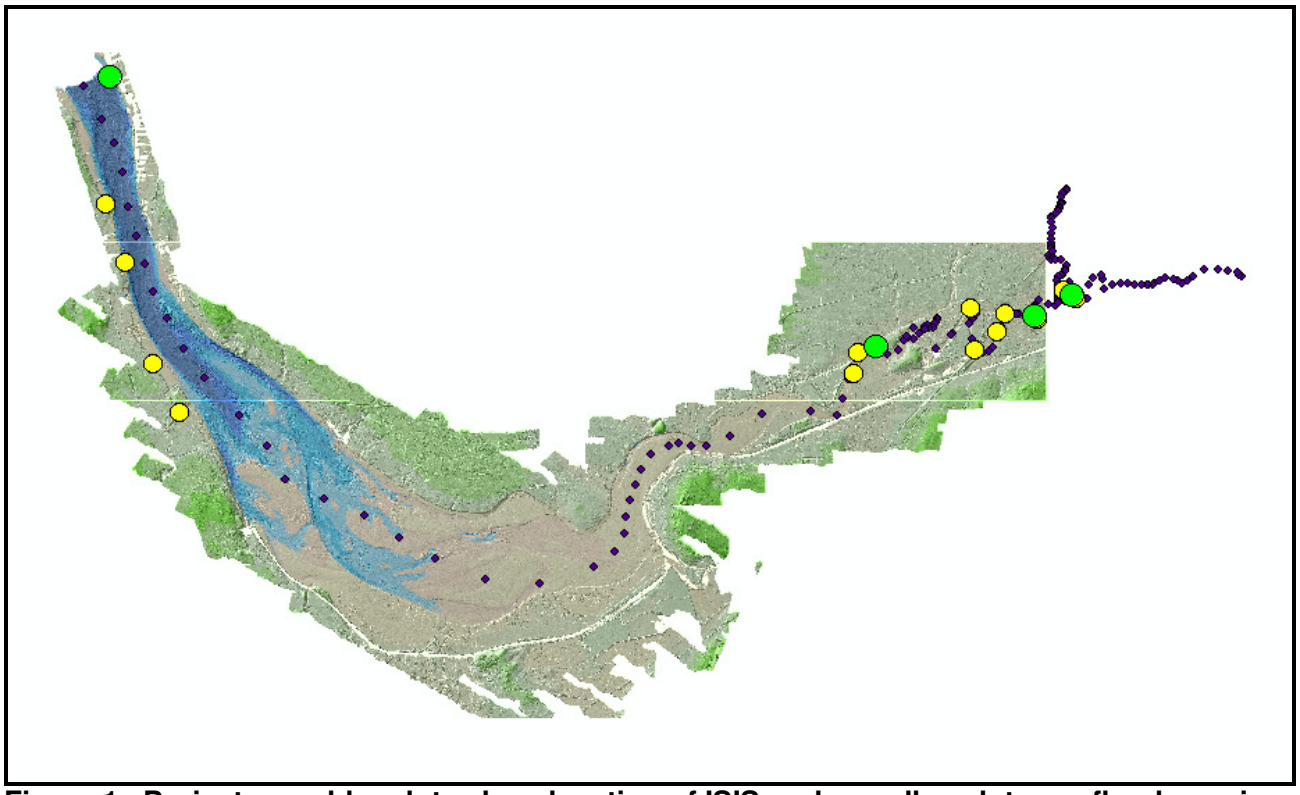

Figure 1. Project area, blue dots show location of ISIS nodes, yellow dots are flood warning points, and green dots indicate the position of Environment Agency gauging stations.

Modelling:
Operational Flood Warnings are based on accurate level forecasts at key locations (such as gauging stations, or known low points).

ISIS was chosen as the modelling software for this project as it is computationally fast and is compatible with the National Flood Forecasting System (NFFS) used by the Environment Agency for real-time flood forecasting. ISIS has the ability to easily model the effects of wind shear on open-channel sections using the new wind shear unit. Previous work had identified wind shear as

a key component of successfully represented flood levels within the Mersey Estuary – with modelled wind shear increasing levels by up to 300mm.

The model developed for this project is both computationally stable and very quick to run, with a model execution time of less than one minute.

A number of models already existed for the project area, and in order to minimise costs these were combined into a base model which was then modified so that the final flood forecasting model was fit for purpose. A number of alterations were required, such as: removing excess detail where not required; adding in detail to a number of bridges; modifying inflows; extending the model to Liverpool Gladstone Dock [3] in order to provide a suitable downstream boundary, and utilisation of wind shear.

Real-time tidal boundary:
To provide a suitable tidal boundary in real-time a Head-time boundary unit is utilised. These data are supplied to the ISIS model using NFFS. When available the model uses observed levels at Gladstone Dock. To extend the lead-time forecast levels based upon predicted astronomical tides (provided by the Proudman Oceanographic Laboratory - POL, now known as the National Oceanographic Centre) are combined with forecast surge from the POL CS3x model [4], which is run at the Met Office.

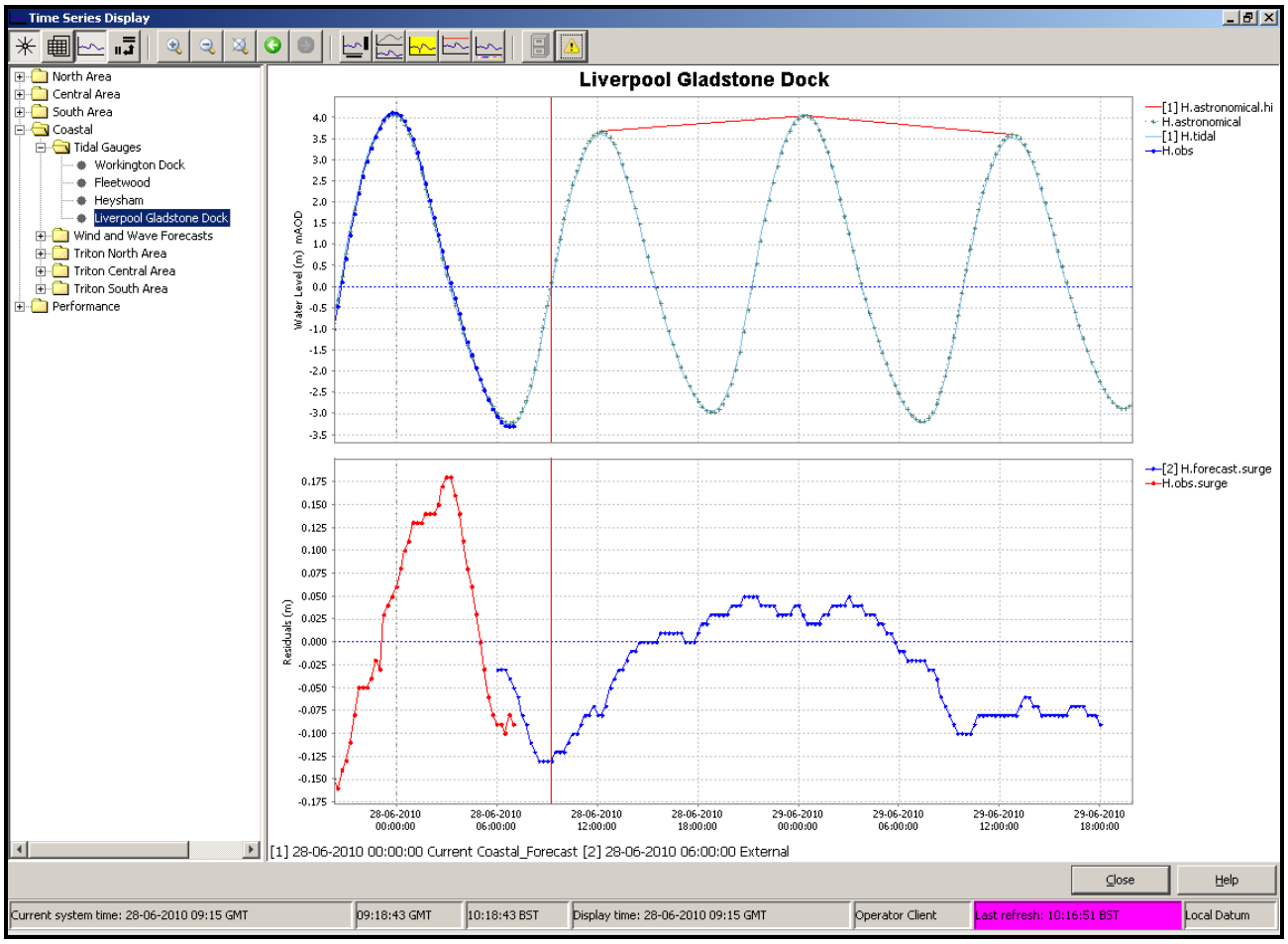

Figure 2. Example of tidal boundary, showing top window - observed tidal level (dark blue line), astronomical tidal predictions (green dots), and forecast total tide (light blue line) bottom window - observed surge (red line), forecast surge (blue line). The vertical red line signifies time now, to the left of the line is observed data, to the right is forecasts.

Wind boundary:
Wind setup in the Mersey Estuary in certain conditions can increase observed water levels of the order of 200-300mm. Capturing this behaviour in real-time is essential for accurate flood forecasts.

The ISIS wind unit was applied in the model, with the estuary split to use forecast data based upon the orientation of the estuary (see Figure 3). The two locations used corresponded to locations where historical data were available for calibration, namely Gladstone Dock and John Lennon Airport. Data for Gladstone Dock were applied to the outer part of the estuary which runs broadly North to South and wind speeds are generally higher. Data for John Lennon Airport were applied to all the nodes upstream of the airport where the estuary turns to run in a West to East direction. The data used to force the model comes from the Met Office mesoscale NWP model [5] which is available at a 12km grid resolution. NFFS is used to extract the forecasts from the grid point nearest to each location.

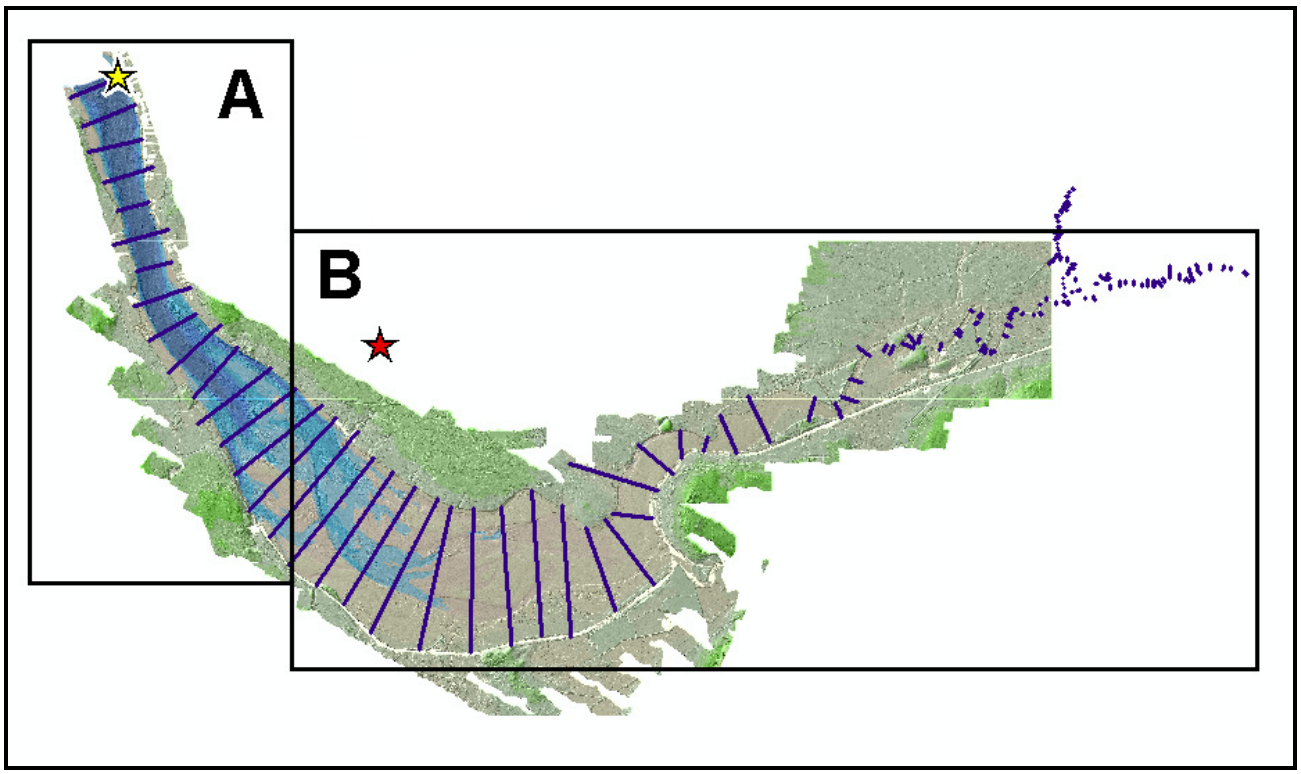

Figure 3. Box 'A' shows the outer estuary reach where winds are applied from Gladstone Dock (yellow star), Box 'B' indicates the extent of the reach forced by winds at John Lennon Airport (red star).

Fluvial boundaries:

There are three fluvial boundaries in the model. The main inflow is located east of Warrington at Woolston Weir. The interactions between the Manchester Ship Canal and flows in the Mersey make estimation of flow volumes at this point difficult and so smoothed observed flows from Westy gauging station (which lies approximately 5km downstream) are extrapolated to provide the inflow. The two other inflows are Padgate Brook and the Sankey Brook, which allow the model to predict the affect of the tidal levels on their lower reaches of these rivers. These are currently represented by fixed inflows as sensitivity analysis showed they only have minimal impact on levels. However in time PDM models may be developed to better represent the fluvial influence.
Environment Agency Flood Forecasting Duty Officers are able to run "what-if" scenarios where they specify inflow hydrographs based on flows at upstream sites.

Model performance:

30 events were identified for performance testing corresponding to the highest water levels recorded in Warrington. These events were run in ISIS using the available observed and forecast data. The model performance was found to be very good at the key gauging stations, meeting the target accuracy of +/-200mm of the peak for >75% of the events with full data availability. At Fiddlers Ferry gauging station the model performance was excellent (see figure 4 below). Model performance was less good at the top end of the estuary at Warrington, particularly when there

was a rapidly changing fluvial input. It is anticipated that improving the representation of inflows from the Manchester Ship Canal will improve the forecasts at these locations.

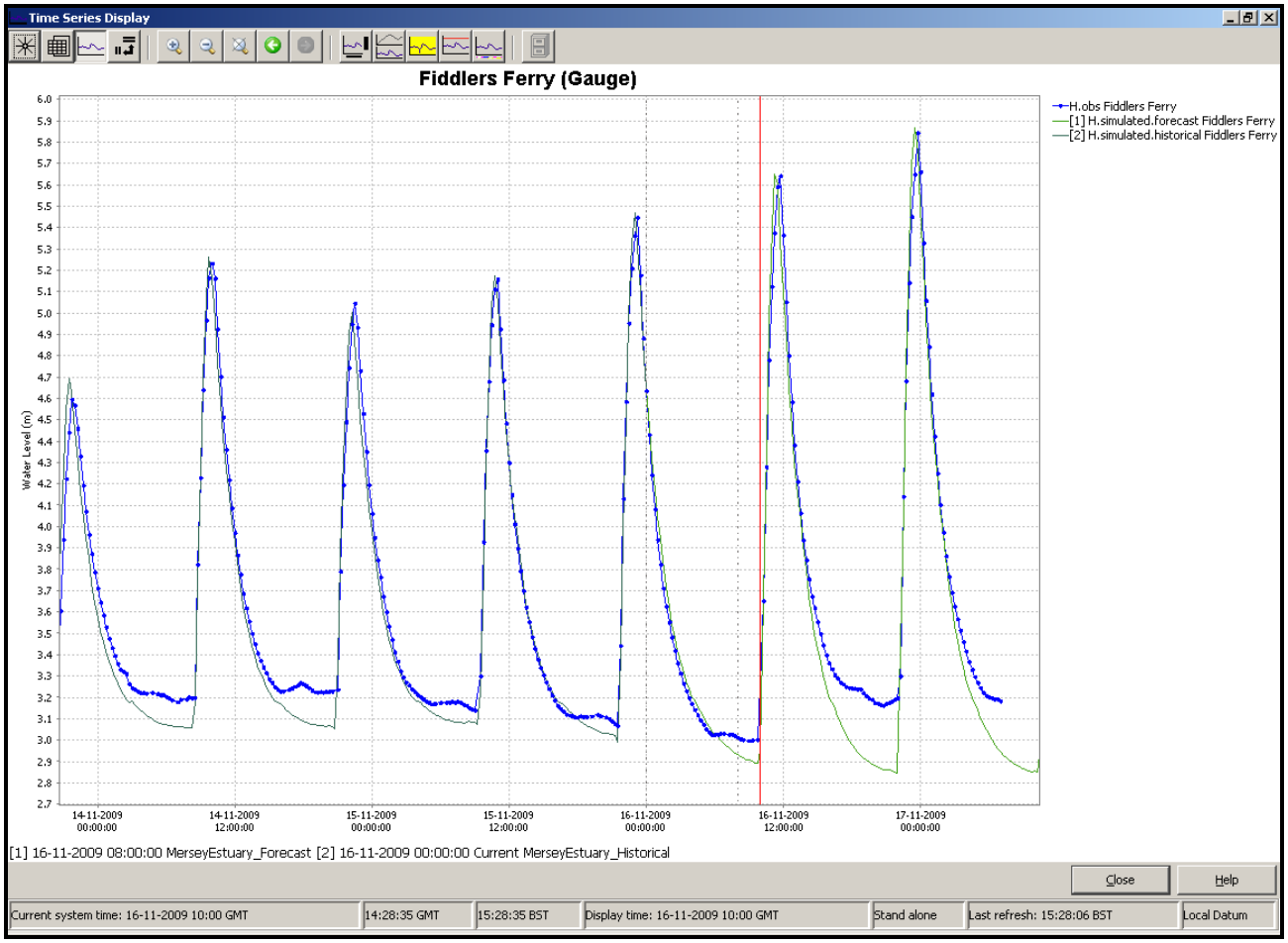

Figure 4. Indicative model performance at Fiddlers Ferry gauging station. Blue line is observed levels, Green line is forecast levels using real-time forcing data.

Conclusions:

- The operational model provides timely and accurate forecasts up-to 30 hours ahead
- Application of the new ISIS wind shear unit improves the forecast performance allowing more timely and accurate Flood Warnings
- The model performance could be improved by better representation of fluvial inflows, the EA regional flood forecasting team are currently investigating ways of accurately forecasting flows from the Manchester Ship Canal
- The model is suitable for probabilistic flood forecasting, it runs quickly enough to be forced with the 24 ensemble members being delivered as part of the “EA Surge ensemble project”

Links:

(1) http://www.warringtonguardian.co.uk/news/pload/4457259.Warrington_10th_most_%20at_risk_of_flooding_in_country/
(2) http://www.environment-agency.gov.uk/homeandleisure/floods/109697.aspx
(3) http://www.pol.ac.uk/ntslf/sadata_tgi_ntslf_v2.php?code=Liverpool&span=1
(4) http://www.pol.ac.uk/ntslf/model.html
(5) http://metoffice.com/research/nwp/index.html