Portsmouth Flood Alleviation: Early Warning System

managing storm flows using the an early warning system moving from *'just in case'* to *'just in time'*

by Jody Cockcroft BSc MSc & Richard Body

The Eastney Wastewater Pumping Station (WPS) catchment covers an area of around 35km^2 which is split between the mainland and Portsea Island. Portsea Island area is around 25km^2 of which 10km^2 is paved and drains to Eastney WPS. The catchment has seen significant development over the last 150 years to the point where Portsmouth is now the most densely populated area in the UK outside London. The city is set to grow by a further 14,500 population by 2020. Large areas of the south and east of the catchment are reclaimed land and were, prior to settlement, made up of marshland and mud. Much of Portsea Island lies between 1-4m AOD with peripheral areas lying close to or below sea level. Pumping of both foul and storm flows is therefore critical for the effectual drainage of Portsea Island.

Figure 1: Eastney catchment and pumping station - Courtesy of MWH

Background

Eastney Wastewater Pumping Station is the terminal pumping station serving the south coast settlements of Portsmouth and Southsea. There has been a pumping station on this site since the 1860s when a system of combined drains was laid to bring both stormwater and foul waste from the population to Eastney. Approximately 75% of the current catchment drainage is combined or partially separate.

Four major trunk sewers, each greater than 1m diameter, enter the high-level headworks at Eastney WPS. Two further 2.45m diameter interceptor sewers run north to south on the eastern and western sides of the island. These interceptor sewers enter the low level pumping station at Eastney (shown in blue in Figure 1 above).

Eastney WPS consists of seven discrete pumping stations which are manned and operated by Southern Water Operations staff. Six

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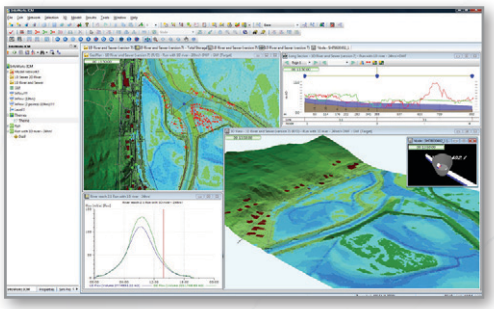

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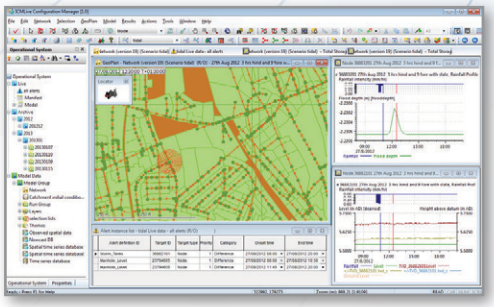

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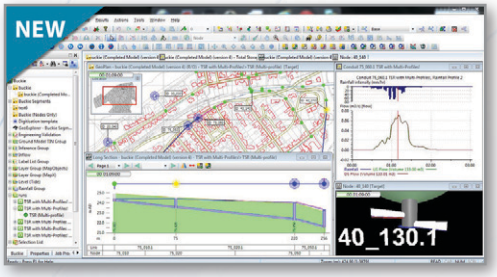

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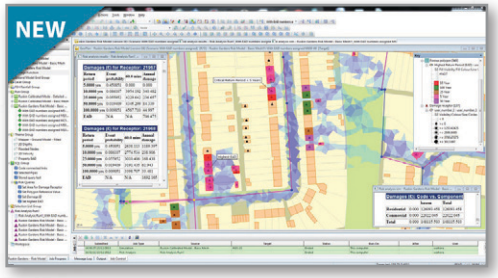

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of these pumping stations are used to manage the storm output of the entire catchment and these are manually controlled by the operations staff.

The most significant of these stations is the Low Level Storm Pumping Station (LLSPS) which can discharge approximately 15m^3/s via twin 72" mains and comprises around 75% of the entire pumping capacity of the catchment.

This station consists of 6 (No.) diesel driven pumps, which have been in use since the 1960s. Whilst the storm output from this station is significant, the operator needs over 5 minutes to warm up each of the 6 (No.) pumps before it can achieve its full capacity.

During a severe storm event this delay can mean the difference between the station coping with incoming flows or it being overwhelmed and flooding occurring in the catchment upstream.

The need

The layout and characteristics of the drainage network mean that flows arriving at Eastney WPS can change very rapidly. The operator's response to changes in flows is crucial in successfully managing storm flows and risk of flooding in the catchment.

September 2000 flooding: Major flooding occurred in September 2000 as a result of exceptional rainfall (a 1 in 104 year event) at Eastney WPS. Operations staff described the storm flows arriving at the pumping station as a 'wall of water'. Within two hours of the station reaching full capacity, Eastney WPS was overwhelmed causing flooding to the main pump house and all pumps at the site had to be shut down.

The rate of water level rise and lack of warning of the approaching event played a significant part in the failure of the pumping station.

Significant damage and disruption was caused. Each of the 6 (No.) storm pumps took six months to refurbish and a further 12 months to restore the station to the full capacity.

Over 300 properties upstream were flooded internally and a further 530 properties flooded externally to reported depths of up to 1.5m.

The drainage of Her Majesty's Naval Base in the west of the catchment was also compromised.

August 2010 events: Data recorded in 2010 from two severe rainfall events also demonstrate the unique problems experienced at Eastney Wastewater Pumping Station. Figure 2 (below) shows pumped flow and wet well level data from a 1 in 16 year storm event on 22 August 2010.

Significant rainfall began at 21:40 on 22 August. Between 23:08 and 23:12 the level in the storm pumping station rose from -10m AOD to -5.5m AOD, filling around 35,000m^3 of storage in only 4 minutes, equivalent to 3½ Olympic swimming pools every minute.

Within 40 minutes the level in the pumping station had risen by 8.6m and nearly 50,000m^3 of tunnel storage in the network was full. During the peak of the storm event the LLSPS achieved only half of its capacity due to the speed of rise in the wet well and delays in starting the diesel pumps. Flooding was experienced in the catchment as a result of this event.

The solution

In April 2010, Southern Water commissioned 4Delivery (a joint venture between MWH, Costain and Veolia Water) to develop the Eastney Early Warning System (EWS), a tool to provide Southern Water's operators advance warning of approaching storm events and risk of flooding within the catchment. This EWS needed to utilise the existing hydraulic sewer model and run it automatically with minimal user interaction.

Initially Innovyze's FloodWorks software was preferred as this had previously been used successfully in the Beckton catchment in London (Body et al, 2013). As the project developed, the newer ICMLive software became available.

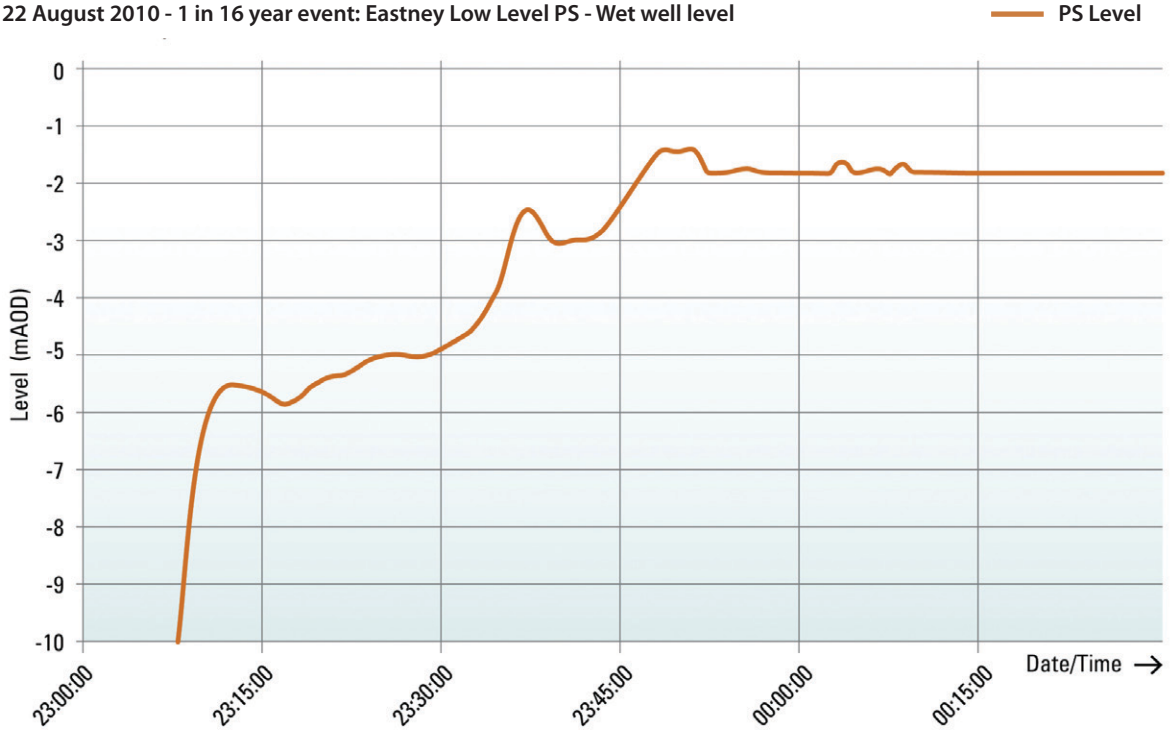

Figure 2: Shows the pumped flow and wet well level data from a 1 in 16 year storm event on 22 August 2010 - Courtesy of MWH

This software provided a number of advantages to FloodWorks; specifically better run management, more efficient handling of spatial radar, ease of system updating and a user interface that was familiar to modellers. The existing sewer model was migrated from InfoWorks CS to InfoWorks ICM and then into ICMLive.

ICMLive combines the hydraulic sewer model with telemetry data to provide automatic forecasts and alerts on adverse system behaviour. Figure 3 (below) shows how ICMLive fits into the EWS.

The EWS take a series of inputs and uses these to forecast pump behaviour as well as expected flows to the Fort Cumberland storm tanks. A third benefit is the ability to forecast flows from the short sea and long sea outfalls.

The installed system runs every fifteen minutes and looks ahead three hours. When a run is initiated the system automatically checks the data sources for new data before simulating (note that the system additionally checks the data sources independently of the simulation). Every simulation is dependent on previous simulations so that system states are passed from one run to the next.

The total simulation time from initiation of the run through pre-processing through to results being generated and alerts generated is no more than four minutes.

An initial design of the FloodWorks system was presented to the operations staff in 2012 and the design was refined in response to their feedback. Initial deployments of the system were rolled out in April 2014 and December 2015. The completed ICMLive system went fully live in the May 2015.

System inputs to the Early Warning System

There are four key system inputs:

- Observed rainfall intensities from 5 (No.) OTT Pluvio rain gauges.
- Forecast radar rainfall.
- Pump operation data.
- Levels from sewer level monitors (SLMs).

All of the telemetry data was installed and commissioned by OTT and 4D.

Rainfall data: 5 (No.) Pluvio rain gauges report measured rainfall intensities every 5 minutes to the telemetry system. When a gauge is missing the system falls back to the next nearest available gauge.

As the ability to forecast pump operations is critical, the use of forecast rainfall data was essential to the viability of the EWS. The system uses the United Kingdom Meteorological Office (UKMO) Nowcast data on a 2km^2 grid.

The forecast data looks ahead 6 hours and new forecasts arrive every fifteen minutes. The radar data is 'draped' across the hydraulic model, which automatically detects the catchments lying underneath the cells.

Where both the rain gauge and radar is available the rain gauge data is used in preference to the spatial forecast data. The most recent radar data can also be used in the event that no rain gauge data is available in the observed period.

Pump data: Telemetry feeds from four major pumping stations within the Eastney catchment, Eastney, Cosham, Copnor and Mainland WPSs, are used as an input into the EWS. For each pump in each station two telemetry feeds are available; pump running and pump availability.

Where a pump is running this signal is passed directly to the ICMLive model and the pump is switched on. The pump availability signal allows the model to be told that a given pump is unavailable to be used in the run. This might occur if a pump is out for maintenance or has failed.

The real time control (RTC) within the ICM model has been adapted to allow for these two signals. Pump signals arrive every five minutes into the EWS and are automatically used by the ICMLive system. The operator has the capability to override pump signals, or to explore 'what if...' scenarios by changing pump settings in the forecast period.

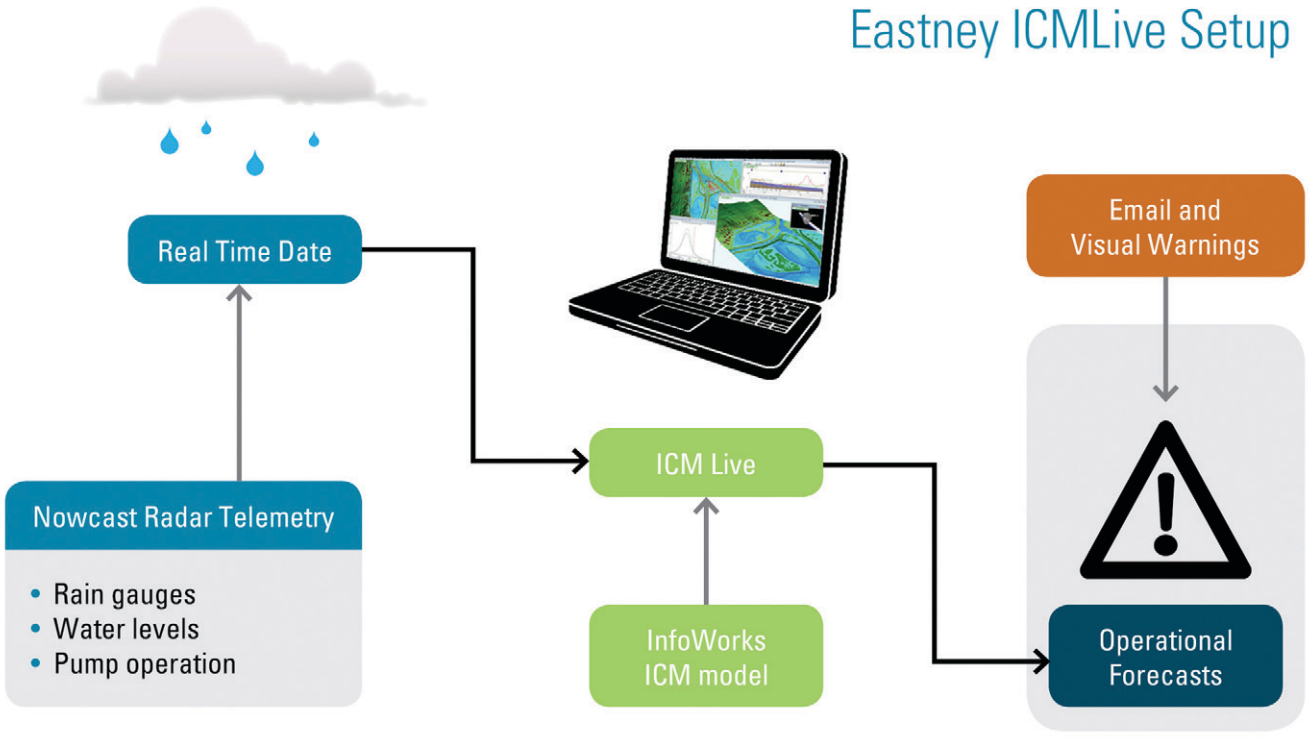

Figure 3: shows how ICMLive fits into the EWS - Courtesy of MWH

Sewer level monitors (SLMs): There are 5 (No.) SLMs within the system. Each is permanently powered and reports water levels to the telemetry system every five minutes. The SLMs allow the comparison of observed and predicted system behaviour.

These comparisons are used for observation only. However the system can be extended to alert on differences greater than user-defined thresholds as these differences may indicate adverse behaviour, including blockages, pipe collapse and screen blinding.

Operational system

The deployment of the EWS is being carried out in three stages.

- In May 2014 the system was made operational in its first phase. In this phase the system simply forecasts flows to Fort Cumberland storm tanks. When flows to the storm tanks are forecasted, email alerts are distributed to construction staff on site at Fort Cumberland.

  The EWS has been essential during the Fort Cumberland Screen Improvement scheme in 2014. Use of the EWS allowed 4D to reduce a programme of storm tank and screen modifications (which required existing storm tanks to be taken offline) from 12 months to 2 months reducing the impact from additional storm spills on the receiving environment.

- Phase two of the system went live early in 2015. In this phase the real time control will include the full range of pump signals and will alert Southern Water operators at Eastney Wastewater Pumping Station on predicted pump operations.

- Phase three (the fully implemented solution) will be implemented in Q2 2015.

Outcomes

The Eastney EWS provides significant benefits to the catchment and Southern Water's customers by:

- Providing Operations staff with regularly updated 3 hour forecasts of catchment state and flood risk enabling operator intervention to minimize flood risk in the catchment; providing the eyes and ears of Operations staff.
- Better understanding of the way the system operates in real time.
- Advance warning and alerts of likely pump operation.
- Alerts on flows to long and short sea outfalls and risk of impact on bathing waters.
- Long term calibration of the hydraulic model.
- Alerts on model divergence identifying:
  - Where the model needs improvement.
  - System failures due to blockage or collapse.
- Alerts on forecasted operations not being carried out.
- Alerts on missing telemetry inputs.
- Providing a training tool to understand 'what if' scenarios allowing operators to optimise system performance.
- Maintenance planning.

The approach adopted on the Eastney EWS can be applied to other catchments to facilitate improved operational performance, alerts for flooding, emergency response and knowledge of the network.

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References: Body R., Clarke R. & Neale W. 2013. Real-time Operational Modelling of Sewers: A Case Study. CIWEM UDG Conference.

Installed sewer level monitor & rain gauges - Courtesy of MWH (C) Crown Copyright