

LIVE SEWER NETWORKS – OPERATIONAL MODELLING AND PREDICTIVE REAL TIME DECISION SUPPORT TOOLS

Patrick Bonk ¹

1. Innovyze, Brisbane, Qld

KEYWORDS

Predictive, Live, Operational, Decision-Support

ABSTRACT

Operational modelling and predictive real-time decision support tools are being utilised in sewer networks globally. The intent of this paper is to methodically demonstrate ways in which Australian Councils and Utilities are well positioned to successfully implement and utilise with existing skillsets, data sets, IT infrastructure and software tools.

If one assumes the project cost of rebuilding a master planning model every 3-5 years for a population of 250,000 people is approximately \$500,000, reallocating these funds into development and maintenance of live hydraulic operational/master planning models will allow both optimised planning and operations without increasing model centric expenditure.

INTRODUCTION

Nationally, the Australian Water industry is moving towards an Intelligent Water Network (IWN) framework that incorporates real-time and predictive Asset Management Maintenance, Real-time Monitoring in conjunction with Live Operational & Predictive Hydraulic Models for Water and Wastewater networks.

The intent of this paper is to focus on how operational modelling and predictive real-time decision support tools are being utilised in sewer networks globally and to methodically demonstrate ways in which Australian Councils and Utilities are well equipped and positioned to successfully implement and utilise with existing skillsets, data sets, IT infrastructure and software tools.

OVERVIEW OF SYSTEM BENEFITS

The benefits of using real-time modelling to support an Intelligent Water Network (IWN) are significant and may be realised immediately. Simply stated: Telemetry, hydraulic predictions and other data collection processes are generating bigger/better but underutilised data sets.

The “Big Data” era provides potential for a higher degree of integration between operations, planning and management. When the skill sets of technical staff from all segments of the utility can access live data, the hydraulic networks will in effect be monitored by many more staff by way of stored logic and associated alert generation.

- The ability to predict what is likely to happen in the future based on current/past data.
- Successfully implement and utilise with existing skillsets, data sets, IT infrastructure and software.
- The need to reduce the loss of knowledge when a workforce ages.
- Cost savings from increased energy efficiency and effectiveness of daily pump operations.
- Forecasting flows/levels at treatment plants (multiple, primary and secondary).

PURPOSE

Utilising an Operational Interface users may now predict near term future flows, levels and water quality at every point in the network to contain predicted flows or limit the impact of spills.

Technology Drivers:

Overall, Live Sewer Models are being driven by:

- The ability to predict what is likely to happen in the future based on current/past data.
- Provides information to the user which can be used to make operational choices.
- The need to reduce the loss of knowledge when a workforce ages.
- Cost savings from increased energy efficiency and effectiveness of daily pump operations.
- Forecasting flows/levels at treatment plants (multiple, primary and secondary).
- Detection of system blockages.
- Reducing sewer spill and quantifying how the system can be operated more efficiently.
- Optimally prioritise current and future data collection.
- Improved hydraulic model calibrations to lower the cost of continually recalibrating planning models.

TECHNOLOGY DISCUSSION

Operation and predictive hydraulic models on first impression can be interpreted as complex and difficult to implement. Yet, the technology has been proven to be implementable and regularly used within water authorities by utilising existing skillsets, data sets, IT infrastructure and software applications.

Transitioning from Planning Models:

Predictive operational models are composed of the same key model inputs and components that make up a standard hydraulic planning model: Infrastructure, Inflows, Controls and Settings. Calibrated sewer models used for planning purposes are the norm across Australia.

Table 1 provides an overview of the ingredients and key elements involved in progressing from Planning to Operational Sewer models.

An Operational Interface:

The application has two main views - the overview page and the network page. The overview page provides a visual summary of the alerts, grouped within areas of interest. The network pages allow operators to access live data from modelled network objects in greater detail.

Through the application's Operator Interface, users have the ability to initiate additional runs and view observed data (rainfall, flow, level, pump status etc) and results from any of the simulation runs (automated or user initiated) in the form of dynamically themed maps, tables or graphs.

The decision support tool based on the future state of a network enables users to carry out "user-runs" in which initial conditions are manually selected for a run, initiate runs based on previous forecasts and edit any of the observed or forecast data to be used in the run. Figure 2 shows the operational interface of the application that has a coherent view of the network, live data feeds and system response from a multitude of modelled events.

Adding "What-ifs" to Network Decision Support:

For the derivation of operational strategies, a user-run simulation will carry out a sequence of model runs where scenarios differ only in the operation of selected control structures. Users can run alternative scenarios (close this valve, activate a weir, start this pump etc) to work out a strategy to minimise detrimental effects and mitigate consequential events (ICMLive Technical Review v1.0, 2012).

The ability is now in place to utilise forecasts to send and direct tanker trucks to pump out a critical section of a system or to alert people to evacuate their homes. Alerts can be generated and information can be disseminated to the relevant people via email notification and results made available for updating websites.

Simulation Server and Automatic Model Runs:

Simulations of the model(s) can be set up to run automatically – how frequently this happens can be changed depending on the incoming data or the model results. The application's simulation server allows real-time data to be fed directly into the software as well as manages automatic simulations based on user defined run intervals and run types. Whenever a new forecast is initiated, the various live (external) data sources are queried to ensure the most recent available data has been loaded into the software's built-in database. Figure 3 shows the application's operational interface automatically tracking the current and historical state of the network (ICMLive Technical Review v1.0, 2012).

The up to date data is automatically validated (an example being data remaining between user specified maximum and minimum thresholds) to ensure its reliability. With validation complete, the data required for the duration of the forecast

simulation, utilising both the hindcast and forecast periods, is loaded and the simulation is carried out. Simultaneously the application ensures suitable initial conditions from earlier model runs for the simulation. Figure 4 shows the differentiation of a hindcast and forecast period relative to when the model run was simulated. The model's accuracy and level of trust in the forecast period being understood based on the hindcast period.

Discernment of Predictive Results:

The software allows users to derive meaning and system context through alert themes (colour coordination and symbolic representation of network events), a grid summary table that provides a grid view of alert start and end timings along with the viewing of coloured graphs for flow, levels and water quality. Graphs automatically display both observed (measured) and forecast data.

Upon completion of simulations, the results are automatically processed to assess whether any alert thresholds have been met. If alerts (threshold values or duration) have been exceeded then alerts are generated and sent to recipients and made available to the operators via alert summary boards. Alerts may be applied to any network model object result. The complete set of input data and results are stored, including the alerts generated and any log information.

Application results analysis also includes:

- Special alerts can be assigned to increasing the run frequency (i.e. rainfall intensity, level readings) to trigger the application to adjust the frequency of the automatic simulations.
- The areas of interest which can be themed to indicate the severity of any alert occurring within its boundary, showing a simple yet effective view of the current forecast.
- The software's network view showing the location of the objects generating any alerts.

SUCCESS STORIES

Through scenario management, Operational Sewer Models may be used to test different operational strategies without real-world intervention. The following case studies will discuss global successes of this technology.

Fukui, Japan - B-DASH Project

The Fukui Municipal Wastewater Drainage District is utilising operational models for the optimisation of their wastewater system. MetaWater has been undertaking pilot studies as part of the Breakthrough

by Dynamic Approach in Sewage (B-DASH) Technology project to use the Innovyze operational model to provide:

- A monitoring system.
- Forecast sewer water levels.
- Support flood preparation.
- Improve operation of sewer system.

Fukui with a population of 265,000 has a warm climate with an average rainfall of 2400mm of rainfall per year. The area receives "guerrilla" rainfall with very short, and severe events that often appear unexpectedly.

For the operational model's input high resolution rainfall radar data is collected via Furono Radar and is automatically imported into the model. Figure 5 shows a screen capture of MetaWater's public website with a visualisation of forecasted radar rainfall. The early warning and prediction system against flash events has a radar system, short-term rainfall prediction model and fast run-off analysis from the model results. Figure 6 shows a schematic of the inputs and outputs of MetaWater's operational model (schematic created by MetaWater).

The model provides simulation outputs including water levels and flood extents (using a 2D coupled model) for up to 30 minutes ahead of the actual event. The data is outputted from the operational model and posted to a public website so that residents can take actions to the upcoming extreme event. Forecasts are available for 10, 20 and 30-minute periods (Kitts, 2017).

Level 1: "Utilization of radar precipitation measurements and short-term prediction of rainfall for preparation of pump operation."

Level 2: "Utilization of flood analysis results for information applied in decision making for local mobilization and self-help promotion."

Level 3: "Utilization of Real Time Control analysis results for maximization of facility functions and capacity." (Metawater Co., 2018)

Through the MetaWater public website, water levels are presented graphically and schematically showing a visual of observed water levels, 30-minute forecasted water levels, pipe levels and threshold levels of levee protection. From here, flood extent maps are posted to represent the spatial extents of anticipated flooding events. Figure 7 shows a screen capture of the MetaWater real-time model operational interface actively displaying pump state, status, catchment rainfall and overview of the network.

The operational model has been optimised to the degree that in addition to being utilised as a public warning application the forecast system also allows MetaWater operators to observe what will happen to the system. By utilising forecasted system levels, operators can commence real-time control of the pumps better understanding how the sewer system drains prior to the event occurring. The proactive and predictive approach opens capacity in the sewer system to alleviate flooding as well as optimizing the system for energy reduction purposes (Kitts, 2017).

Fukui has been able to maximise the benefits from use of facility functions for preparation and operation of pumps and gates as well, as promoting a community assistance program for notification of anticipated flooding events.

After the success of the B-Dash project in Fukui Japan as well as Hiroshima City and Toyama, the system is planned to be rolled out across Japan.

Thames Water, United Kingdom – Beckton, Mogden and Deephams Catchments

Thames Water has implemented live sewer models within their Beckton (30,000 Nodes), Mogden (50,000 Nodes) and Deephams (50,000 Nodes) networks where the key study criteria revolved around developing operational management strategies for flood forecasting, real time model calibration from logged level data as well as CSO monitoring and operational performance of the network.

The Thames Water real-time model coverage includes (Lang, 2016):

- 32 models in the real time environment.
- 10 models with actionable, live alert definitions.
- 78% population coverage.
- All models have observed rainfall with 6 hour forecast and five day forecast rainfall.
- Models include 294 live data points connected (235 depth monitors, 49 groundwater sites, 10 river level sites).

The operational interface for the control room provides (Lang, 2016):

- Summary page displaying rainfall and model alerts.
- Rainfall model showing intensities and cumulative volumes.
- Hydraulic model displaying time varying results in grid and graphical format.

Thames Water operational model's telemetry data and model results generation:

1. Radar actuals (Nimrod) data arrives every five minutes.
2. Radar forecast (Nowcast) data arrives every fifteen minutes.
3. Level data recorded every 2 minutes and transmitted every 2 hours*.
4. Telemetry loaded as it arrives in the software's server (instantaneous load time).
5. System runs.
6. 3hr hindcast and 6hr forecast.
7. Automatic system run every 30 minutes.
8. Run time approx. 10 to 30 minutes depending on rainfall.

According to Thames Water the operational support application was implemented for the following main reasons (Lang, 2016):

- "Improving safety for construction works".
- "Support during unforeseen events".
- "Alerting to potential pollutions proactively".

Safe working practices improved with the ability to monitor early warnings generated (daily weather updates of 5 days, short term prediction of 6 hours) by the model to allow for longer evacuation times during tunnel construction works in the event of overflows. Evacuation planning incorporated the depths generated in the 6 hour predictive model results.

For unforeseen events during the daily operation of the network, modelling teams are contacted to work on rerouting options and anticipated flow when instances such as network blockages occur.

Portsmouth, United Kingdom – Eastney Project

Operational Sewer Models were implemented by Portsmouth, UK in order to forecast pump operation, forecast flows to the treatment plant as well as forecast water levels for flood forecasting. Figure 8 shows an overview of the Portsmouth network located in Eastney with the locations of several sewer level monitors and rain gauges (Cockcroft J, Body R, 2015).

The Eastney project commenced due to known flooding issues due to inefficient use of Eastney pump stations. The live model was built by converting the existing calibrated hydraulic sewer model. The intention of developing an early warning system for the Portsmouth system were as follows:

- Forecast water levels for flood forecasting.

- Forecast pump operation.
- Forecast flows to Fort Cumberland storage tanks.

Figure 9 shows a schematic of the live model configuration for the Eastney Project in Portsmouth, United Kingdom.

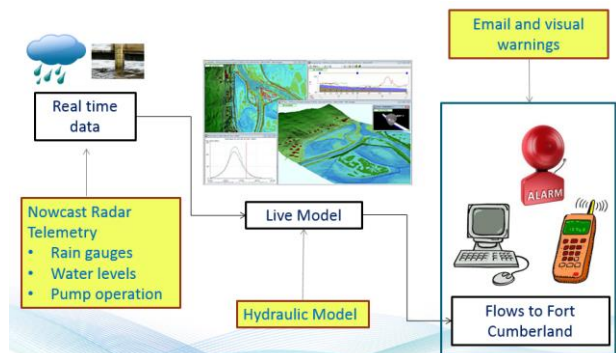


Figure 9: Eastney Project -Live Model Configuration

The system allows for real-time rain gauge, water levels and pump operation data to be fed directly into the software. Telemetry feeds from four major pumping stations are used with a feed available for each pump running and pump availability (Cockcroft et al., 2015). The live model's runs incorporate the status of the system's pumps in real-time. If a pump is out for maintenance or has failed the model will adjust accordingly. Operators explore 'what if' scenarios by overriding pump signals and changing pump settings in the forecast period (Cockcroft et al., 2015). Figure 10 shows a screen capture of the application's operational interface of the early warning system for Portsmouth UK.

Simulations to the models are set to run automatically – simulation frequency is set based on the anticipated conditions of the network from incoming data or from the simulated model results. Alerts are generated via email, website and visual cues on the software interface. Users can run alternative model scenarios (start a specific pump, close a valve) to determine a strategy to mitigate impacts from the incoming events before the weather event hits the network.

The main benefits from the Eastney Project were (Cockcroft et al., 2015):

- Real-time understanding of the network.
- Optimisation of system performance using the models "what if" scenario capabilities.
- Advanced warning of storm events for operators.
- Alerts on flows to sea outfalls as well as the potential risk to bathing waters.

- catchment wide view of the network, alerts on divergence for hindcast and forecast periods.
- Long term calibration of hydraulic models.
- Alerts on missing telemetry data.
- Maintenance planning.

CONCLUSION

Hydraulic models and retrospective time varying hydraulic and water quality measurements are widely used and well understood in most water utilities across Australia. Planning models contain all of the same attributes as live operational models. Accordingly, the majority of skillsets, data sets, IT infrastructure and software tools required for Live Sewer Networks are already in place.

If one assumes the project cost of rebuilding a master planning model every 3-5 years for a population of 250,000 people is approximately \$500,000, reallocating these funds into development and maintenance of live hydraulic operational/master planning models will allow both optimised planning and operations without increasing model centric expenditure.

ACKNOWLEDGMENT

This document acknowledges the contribution's from the Innovyze Technical Team Engineers Rui Daniel Pina, Duncan Kitts, Ruth Clarke and Andrew Walker for their leading edge work in successfully implementing the operational and predictive modelling technologies for the Innovyze global user base.

REFERENCES

- Cockcroft, J., & Body, R. (2015). Portsmouth Flood Alleviation: Early Warning System managing storm flows using the early warning system from 'just in case' to 'just in time' (pp. 3-5). Wastewater Treatment & Sewerage.
- ICMLive Technical Review v1.0 (2012) (pp. 2-8).
- Kitts, D. (2017). InfoWorks ICM and ICMLive in Japan. Innovyze Insider Blog. Retrieved from <http://blog.innovyze.com/2017/09/18/infoworks-icm-and-icmlive-in-japan/>
- Lang, P. (2016). Early Warning System Applications at Thames Water. Presentation.
- Metawater Co., Ltd.. (2018). Metawater.co.jp. Retrieved 20 April 2018, from <http://www.metawater.co.jp/eng/>

Table 1: Transitioning from Planning to Operational Models

Type of Model Input	Planning Model	From -> To	Operational Model
Infrastructure	GIS, Design Drawings, Pump Curves	→	GIS, Existing Hydraulic Planning Model
Model Inflows (Historical, Theoretical)	Dry Weather: <ul style="list-style-type: none"> - Billing Data Sets with Return to sewer ratio - Population data/projections with per/litre/capita (Historical, Theoretical) Wet Weather: <ul style="list-style-type: none"> - DWF Multiplier (5x DWF) - Design Storms (1,5,10,25 yrs etc) - Historical Events 	→	Re-predicted 'just-in-time' for every scheduled live model run <ul style="list-style-type: none"> - Live Spatial/Scalar Rainfall - Live DWF from Demand Feeds - Hydrologic runs to maintain antecedent conditions
Controls	SCADA Historian, Asset Registers, Anecdotal Data	→	Set-points taken directly from live SCADA feed Pump on/off- Pump Schedules, System Response (tank level data)
Model Settings	Typical Model Run Period: <ul style="list-style-type: none"> - Design Events (1,6,12,24 Hrs) - Historical Events (Intensity/Volume) - Extended State Sims 	→	Model runs kick-off at present time, runs a <u>hindcast</u> period for verification and into a forecast period for alert generation. Model runs automatically; frequency of runs pre-defined.

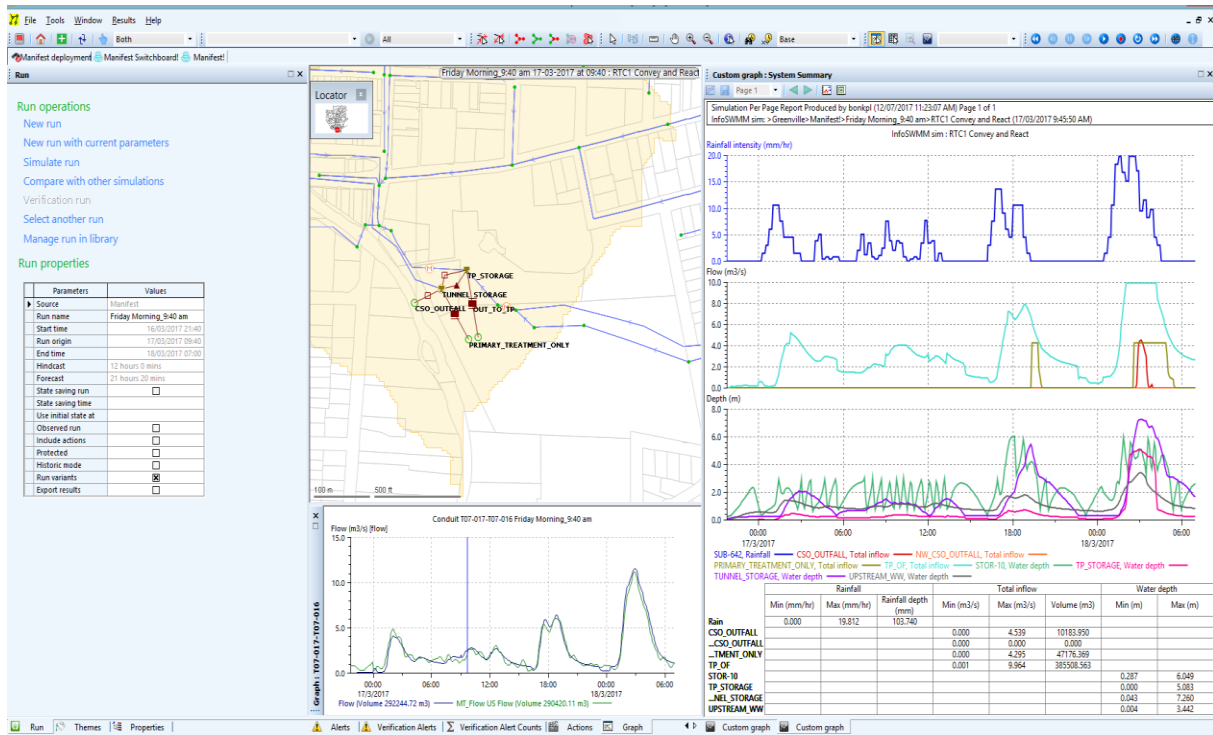


Figure 2: Predict spills before they happen with an operational interface

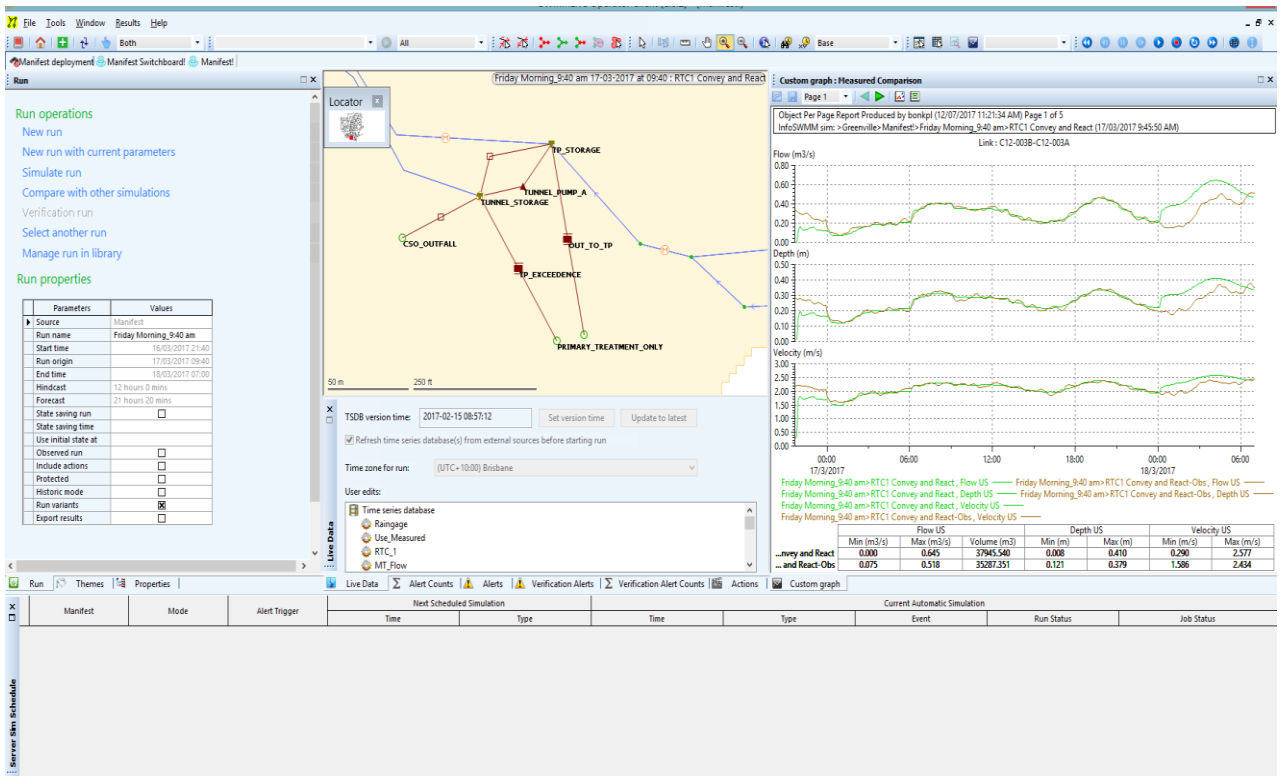


Figure 3: Continually verify and run forecast scenarios based on real-time network conditions

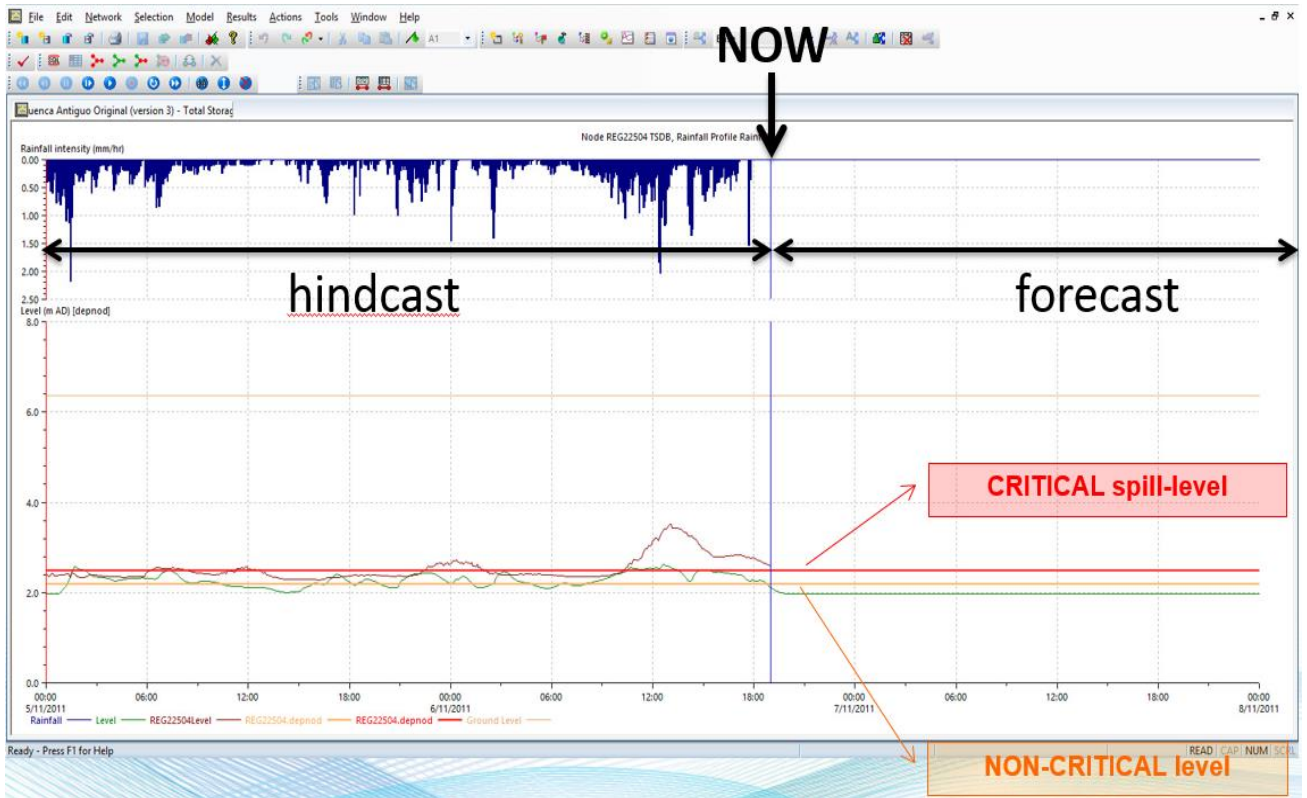


Figure 4: A visual of a model run's hindcast and forecast periods for a known degree of trust in model

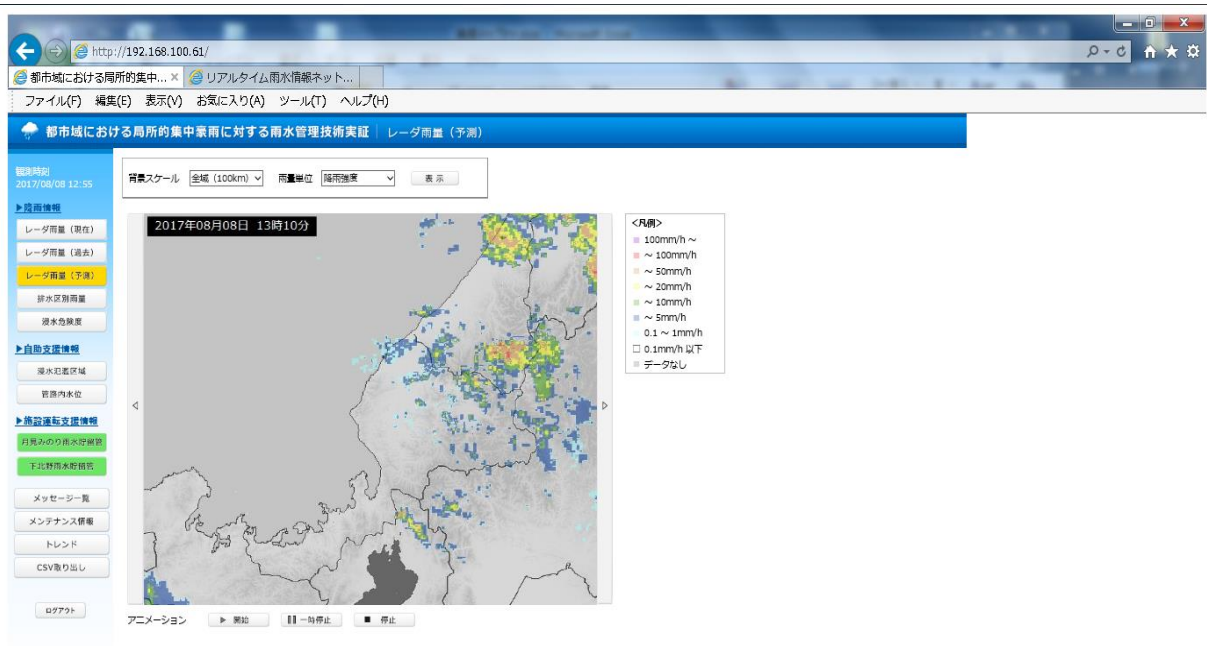


Figure 5: MetaWater's public website showing the forecast rainfall radar for Fukui, Japan (created by MetaWater)

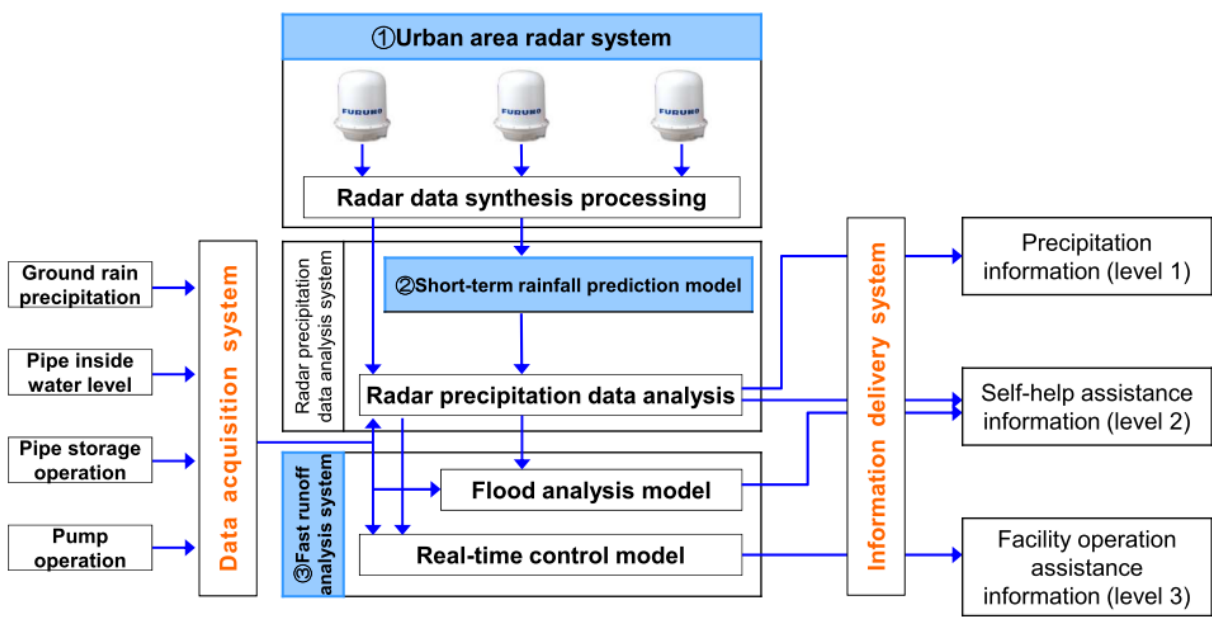


Figure 6: Schematic of the inputs and outputs of MetaWater's Operational Model (created by MetaWater)

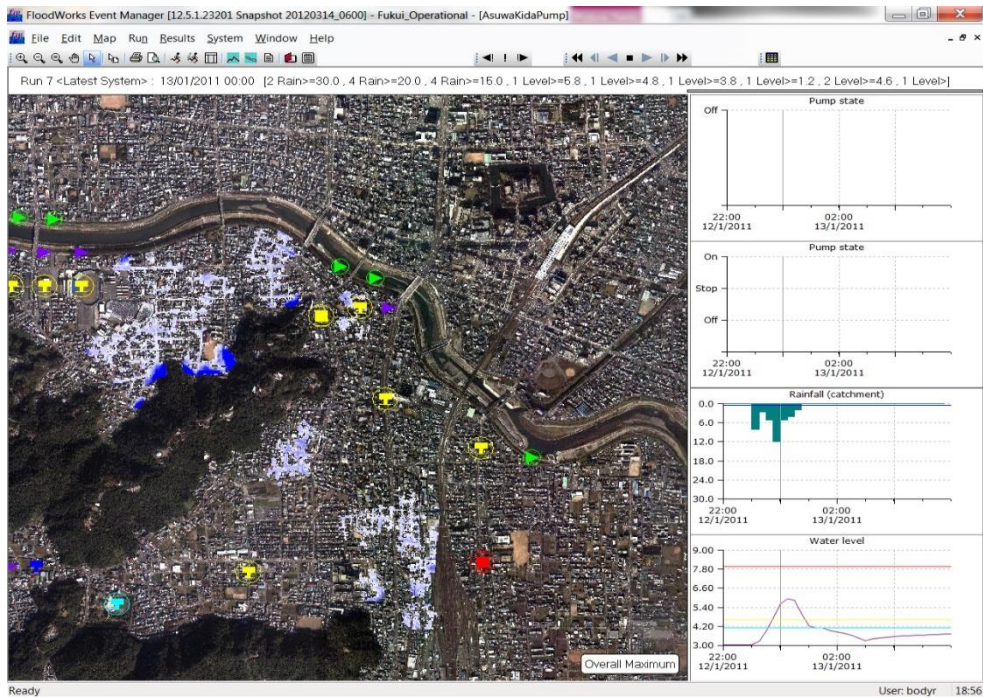


Figure 7: Operational Interface of the City of Fukui with pump state, status, catchment rainfall etc. (created by MetaWater)

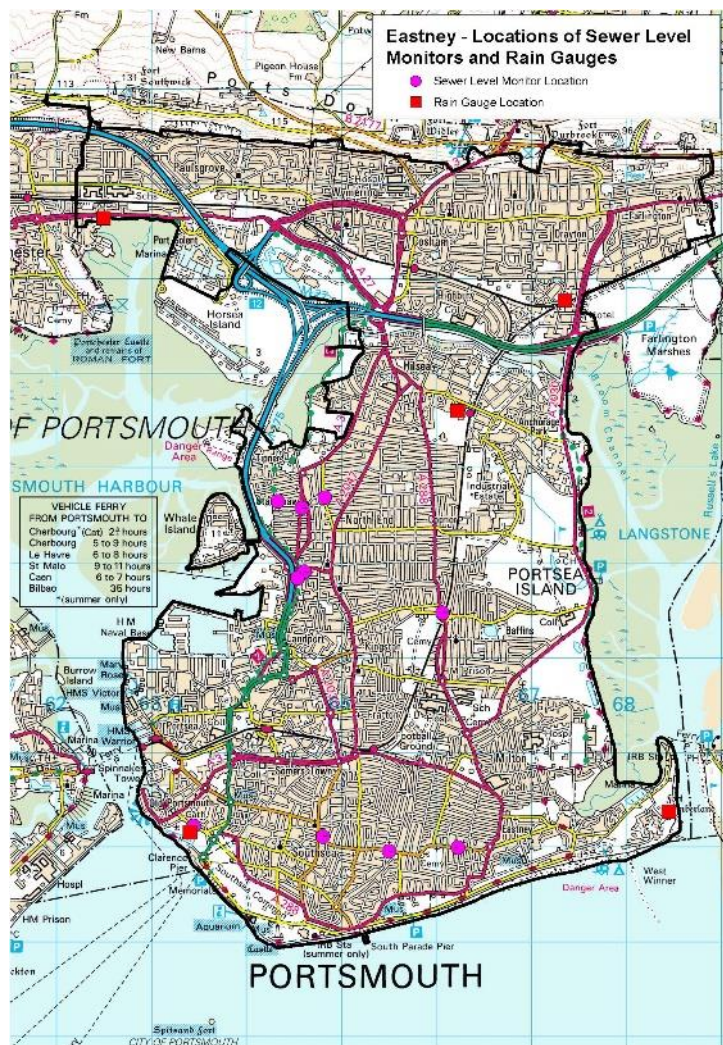


Figure 8: Portsmouth UK, Locations of Sewer Level Monitors and Rain Gauges

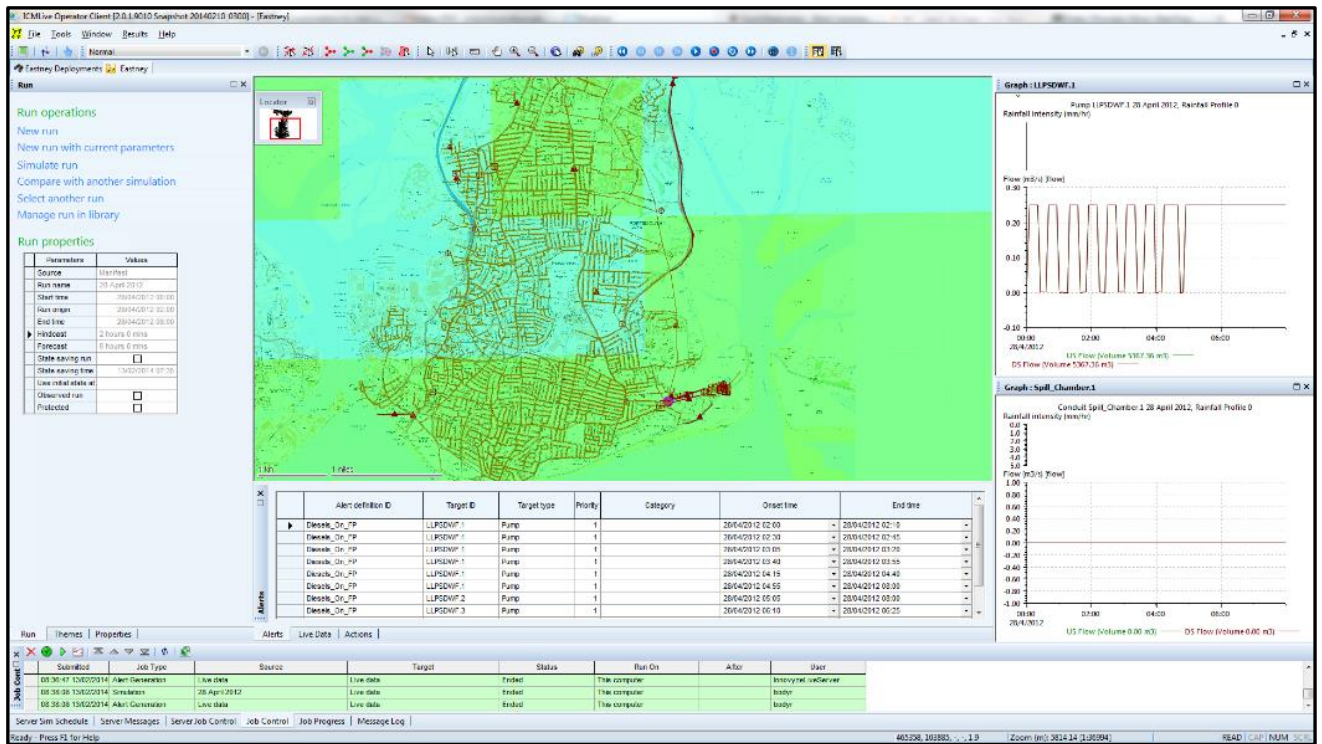


Figure 10: Operational Interface of the early warning system for Portsmouth UK