FloodWise: A Flash Flooding Emergency Management Tool

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Abstract

Brisbane is subject to flooding from storm-surge, large tides, creeks and the Brisbane River. While there have been historic river flood events, creek flash flooding proves to be a consistent feature during the summer season. The 35 creek catchments within the Brisbane City Council (BCC) area vary in size from a few km^2 to 260 km^2. Times of concentration range from less than 1 hour to greater than 18 hours and these short times of concentration in some catchments result in minimal warning time and limited opportunity for preparedness actions.

The FloodWise system allows BCC to respond to flash flooding by providing timely and accurate information. FloodWise monitors real-time telemetry gauges (rainfall and stream height) and provides the current readings on a web portal, updated every 5 minutes. BCC has taken this a step further by applying local knowledge and flooding history to develop trigger levels and alerts for flood-prone suburbs, roads and infrastructure.

Automated alerting via SMS or email is delivered to on-call duty officers across the organisation. This allows staff to take action as soon as possible to reduce the impact of flash flooding on residents. These actions include road closures, debris clean up, structure assessments and reporting. Alerts are also supplied to a third-party service provider for distribution to residents allowing them to take their own precautionary measures.

For business-as-usual activities the system is used to monitor tidal events and rainfall. On-demand reporting from the web portal allows users to conduct administration and QA checks, or more technical interrogation.

The system integrates with the Council's GIS technology and is hosted in a disaster resilient environment, with duplication providing redundancy in the event of a major IT system failure. The high standard of responsiveness from the web portal is scalable to handle heavy user loads during severe weather events.

Introduction

Brisbane, with its sub-tropical climate and coastal environs, is exposed to flood risks from both rainfall-induced and tidal sources. Specifically, occasional flooding of varying magnitude is generated from large tides; storm-surges accompanying cyclonic activity and east coast low pressure systems; numerous overland flow paths; creeks and the Brisbane River. While there have been large historic river flood events which have caused significant damage, flash flooding from creeks and overland flow proves to be a consistent feature during a typical summer season, causing nuisance, and in some cases loss, to the vulnerable portions of the community.

The 35 creeks which flow within the Brisbane City limits are fed by catchments ranging in size from a few km^2 up to 260 km^2. The largest of the creeks can take 18 or more hours to peak, but some smaller creeks can flood within 1 to 6 hours following heavy rain. Rates of rise within these streams can be quite fast with rises of up to 4 metres in less than 1 hour having been recorded in some parts of the city. It is these flash flood events which are the hardest to predict and respond to.

As Brisbane has developed and grown in standing as a world-class city, the call for resilience against the impacts of natural disasters including flooding has increased. The BCC has responded to this need through the development of its FloodSmart Future Strategy which outlines an integrated approach to managing and mitigating the impacts of flooding within the city. Effective response and recovery associated with flooding events is one aspect of the FloodSmart Future Strategy; and in addressing the risk of flash flooding one of the key response tools utilised by the BCC is FloodWise.

The FloodWise Solution

Development of the FloodWise Information System was prompted by a freak storm in 2001 which saw up to 200mm of rain fall in 3 hours. This storm caused widespread flooding with estimated 1% AEP flood levels reached or exceeded on several creeks and still quite significant flooding elsewhere. Impacts from the deluge included cars being swept from a car dealership into an adjacent waterway, people being evacuated by boat from a suburban sporting club, Friday peak hour traffic thrown into chaos with numerous roads flooded and substantial property damage recorded in pockets across the city. Whilst, at the time, flood risks within the city were known to exist, the severity of the actual event and the specific locations of the flooding were not able to be readily determined, hindering the response and recovery process.

Since 2003, the FloodWise system has been used by the BCC to assist in its response to flash flooding and (more recently) tidal flooding events. The system, originally developed by Council officer Ken Morris, utilises hydrometric data collected from more than 100 stream height telemetry and 250 rainfall telemetry gauges across the city and surrounding districts. Every five minutes of every day the incoming telemetry data is examined, summarised and the results displayed on an internal BCC web service. Alerts based on hydrometric triggers are issued in a timely and accurate fashion to report the potential flooding of roads and vulnerable communities. These alerts are issued to a host of relevant BCC staff to help facilitate management of the response and recovery efforts.

FloodWise MKII

In 2012, the longevity of the FloodWise system developed in 2003 was reviewed. It was found that the changing nature of software and IT systems, the limitations of the current system and the pending retirement of the system's author meant that FloodWise in its then current form could not be sustained. Its days were numbered and as the organisation had grown dependent on its ever watchful presence a replacement was a necessity.

A procurement process was undertaken to re-establish FloodWise on a new platform. The replacement system was to be sourced from a commercial third party, a move which would release BCC from ongoing software maintenance responsibilities. So in 2013, in

partnership with Aquatic Informatics, BCC began the process of renewing FloodWise. This has culminated in the FloodWise MkII version which after much development and testing was released on the Council's servers in 2014.

The process of replacing the original FloodWise has given BCC the opportunity to review the entire system architecture as well as its functions and features. As a consequence, a measure of future-proofing has been achieved to ensure the system can supply the organisation's ever-growing thirst for information in the days to come.

One area of concern with the original FloodWise system was the resilience of the IT infrastructure on which it was hosted and how this might perform during a major flood or storm event. As FloodWise is heavily relied upon to provide information to disaster management and operations areas, it was recognised that it must be fully functional during a significant natural disaster that might also impact the Council IT network.

To meet this requirement, the system has been setup internally on Council's network with a Production and a Development stream. The Production side is treated as the primary source for information, while the Development side is reserved for testing, training or a backup should the Production side fail. In addition, there is duplication of servers, hardware and transmission pathways within both the Production and Development streams. This effectively allows for a backup redundancy within the stream itself, or if that completely fails, the alternative stream can be brought forward. Regular testing and monitoring is used to ensure the disaster resilient setup is functioning as designed, with automated alarming in place to alert of any failures or time-outs.

System Overview

As with the original version of FloodWise, the MkII system extracts hydrometric data from the telemetry stations via the Bureau of Meteorology's Enviromon program. The data is then converted into operational data by FloodWise and stored on a database. The data and statistics derived therefrom can be accessed via a graphical web interface.

Rainfall

Rainfall gauges, indicating rainfall over a selected period are displayed on a map – refer Fig. 1. Where rain has fallen the totals are colour-coded to represent the magnitude of the event. As well as rainfall totals, rainfall intensities corresponding to standard ARI values can be selected. Floating the cursor over a gauge location reveals a drop down menu providing further specific gauge data. Clicking on the gauge generates a rainfall hyetograph.

Gauges in neighbouring council areas can also be seen on the map. This provides the opportunity to know with some degree of certainty the magnitude of a storm event which may be approaching Brisbane and further enhance preparatory activities.

A coloured rainfall contour (or heat) map is also available to indicate the zones of highest rainfall across the city and hence areas of likely flooding.

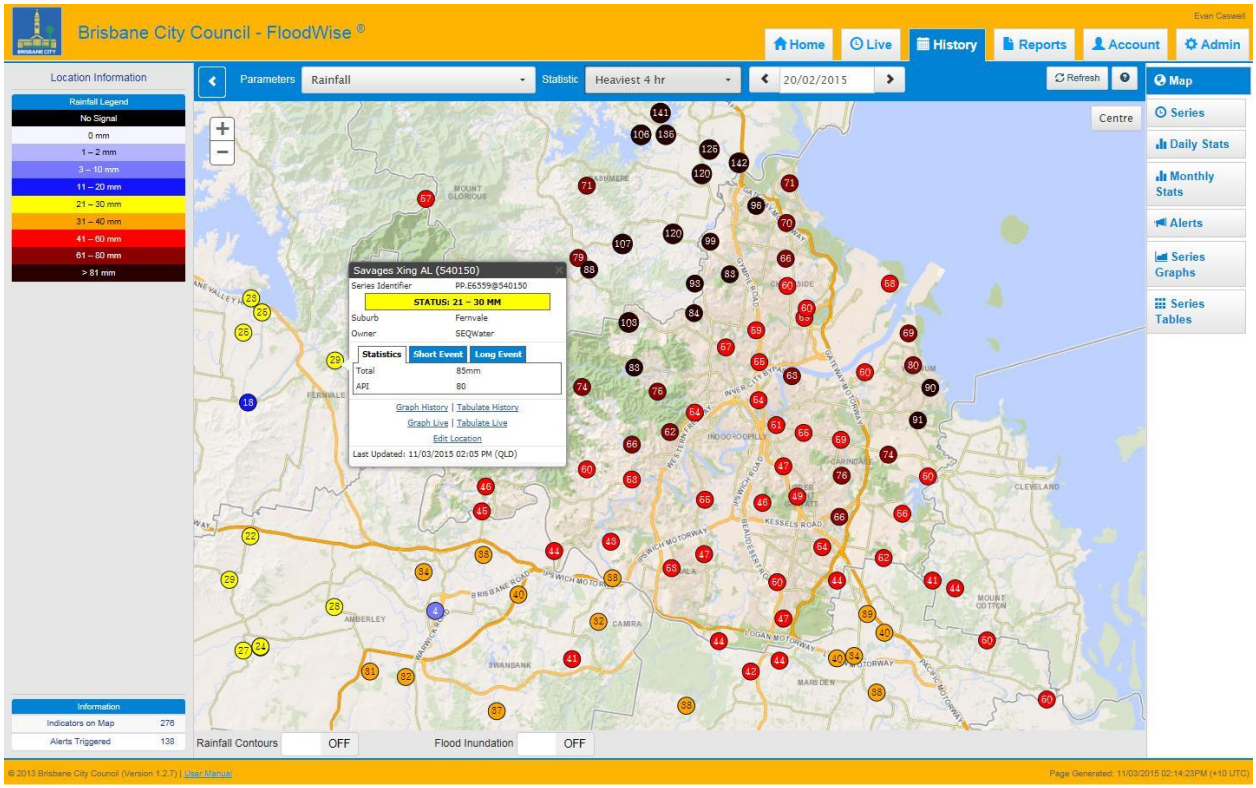

Fig.1: Rainfall gauge map demonstrating colour-coded rainfall totals

Stream Height

Stream height gauges indicating water level are displayed on a map – refer Fig. 2. These are colour coded based on the degree of flooding being experienced – minor, moderate, major or normal. Clicking on the gauge will generate a stage hydrograph. The graph also has the ability to depict the critical levels of nearby infrastructure and alerting triggers.

A multi-station view of stream hydrographs is possible, allowing the migration of the flood peak down a stream to be viewed on successive gauges, simultaneously.

Reservoir Level

Similar to stream height gauges, reservoir level gauges can also be selected on a map either alone or in combination with the stream height gauges. Monitoring of these gauges is necessary in order to indicate the magnitude of overflows and likely stream conditions immediately downstream during a flow event.

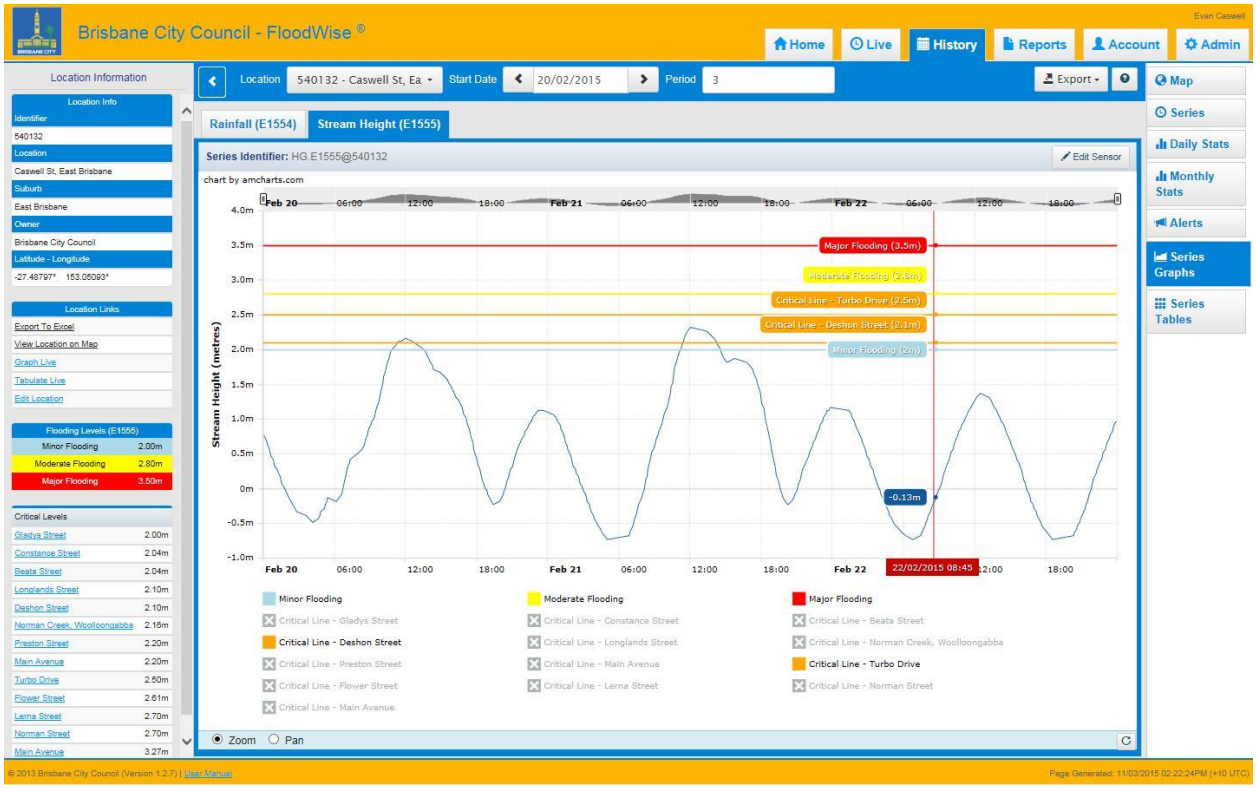

Fig. 2: Typical stream gauge plot with coloured alert trigger levels

Tidal monitoring

Similar to stream height gauges and reservoir level gauges, tidal gauges can also be selected on a map, either alone or in combination with the other water level gauges. Presently only one tide gauge is viewable for Brisbane located at the mouth of the Brisbane River.

Tidal monitoring and comparison against predicted tide levels is also possible – refer Fig.3. Tide data supplied in advance by Marine Safety Queensland is imported into FloodWise as a time series. This can be plotted over actual readings for comparison purposes. The residual (i.e. the difference between predicted and recorded levels) can also be plotted to give guidance on the effects of atmospheric anomalies on water levels. Anomalous tides up to 300mm above predicted levels are possible due to local weather influences (e.g. low pressure systems and wind action). By monitoring and applying the current anomaly to future tide predictions, Council is better able to estimate the impacts of coming tides and issue appropriate warnings and information to residents.

Fig. 3: Tidal gauge plot showing actual, prediction and residual

Flooded Roads and Areas

Key roads and areas which can be linked to the available stream gauges are represented on the map by a coloured symbol. The symbols change colour depending on the flooding status (e.g. green – not flooded, yellow – flooded in the next 30 minutes, red – flooded). The forecasted flooding potential is determined by a rudimentary calculation based on a rate of rise of the hydrograph.

SMS and Email Alerts

Alerts (in SMS or email form) can be generated to automatically trigger upon certain criteria being met. These criteria could be an amount of rainfall over a certain time period, a particular water level, even a particular rainfall Average Recurrence Interval (ARI), or a combination of these. The triggers and alert messages are completely user configurable.

Other features

Data History

The FloodWise database will store data and statistics from historic events. This data can be readily accessed in graphical or tabular form to assist with post-event interrogation. If required, specific events pre-dating the establishment of FloodWise can be loaded into the database. Once this raw gauge data is loaded, the full range of statistics is calculated by FloodWise. This information is then useful for comparison against other more recent events.

Historic Playback

Another feature added into FloodWise MkII was the inclusion of a historic playback function. This function basically allows for the 'replay' of a real historic event, using the already collected data in FloodWise. The replayed event will repeat at normal speed with gauge readings appearing as they were historically recorded.

This function allows for a range of training scenarios for any type of recorded rainfall or flood event. Mock events can be initiated where historic data and alerts are used to make decisions in a training environment.

Reporting

The current system is able to produce on-the-fly PDF reports on any statistic or reading generated by the system. These reports could be as simple as latest gauge readings ordered from highest to lowest, or more complex reports such as:

- Gauges with rising water levels close to Minor/Moderate/Major flooding level;
- A list of currently flooded roads or areas, their peak water level and current water level status;
- Duration of inundation at a certain gauge above a given critical level; OR
- Historic summary totals for key gauges over the last week, month or year.

This reporting functionality has a wide range of potential uses. Event response teams can use the reports to access up-to-date information regarding the current storm or flood event with a single click of a mouse button. Post-event reporting templates can be established to ensure consistent information is distributed throughout the business.

In everyday activities, the reports can provide audit information, weekly or monthly reporting statistics and basic QA information. Access to the reporting page can also be controlled so only users with proper training are able to use the reporting features.

The reports can be tailored to suit a specific type of audience. For example, reports can target technical staff who may be focused on hard data and figures, or non-technical staff who may want more wording and explanations in the text.

Current Users and Uses

Flood Management Unit / Flood Information Centre (FIC) / FIC 24/7 Duty Officer

The telemetry data collected by FloodWise is used post-event for a variety of purposes including development and calibration of flood models, investigation of flooding complaints and post-event advice and reporting. The latter is often forwarded to senior managers and administrators.

During an actual flood or severe rainfall event, the FIC staff use FloodWise to report on flash flooding from creeks, locations of likely overland flow based on gauge rainfall totals, the performance of backflow prevention devices and large tides in the River.

The FIC Duty Officer works remotely outside normal office hours to maintain a watch on adverse weather conditions. On-demand situation reports and trigger alerts are generated by FloodWise to enable the Duty Officer to quickly assess the severity of a rain event and any associated flood risks. Such information enables the Duty Officer to inform event response managers of the situation and can prompt the stand up of the FIC.

Brisbane Metropolitan Traffic Management Centre (BMTMC)

The BMTMC can access flooded road and rainfall reporting to assist in their traffic control operations. Whilst the Centre uses a host of CCTV cameras to support their activities only FloodWise can provide advance warning of impending road closures due to flooding.

Mosquito Management

The Mosquito Management team utilise rainfall and tide level reporting from FloodWise to hone their actions to control the mosquito populations in Brisbane. The tidal information is of particular importance as atmospheric conditions can alter tide levels well above or below predicted values and timely advice of such occurrences assists with the planning associated with mosquito control.

Natural Environment Water and Sustainability (NEWS)

The NEWS branch conduct regular monitoring of water quality and bacteria counts across Brisbane to monitor waterway health. Routine sampling is undertaken fortnightly in summer and monthly in winter. FloodWise historic data allows for spikes in water quality variables and bacteria counts to be linked back to recent rainfall events. In cases where no rainfall is recorded, an investigation can be undertaken into alternative causes.

Compliance and Regulatory Services (CARS)

The CARS branch contains two teams that frequently use FloodWise; Rapid Response Group and Environmental Health. The Rapid Response Group receives FloodWise alerts about flooded roads and areas, and conduct site inspections to confirm inundation. Where required, the Rapid Response Group will close off roads and display signage to warn traffic of flood hazards.

The Environmental Health team respond to complaints regarding sediment and erosion control. Where sediment and erosion control breaches are reported, they will use FloodWise to estimate the size of the rainfall event and whether the controls in place were adequate. In cases of confirmed breaches, fines are issued to the responsible parties.

Disaster Management Office (DMO)

The DMO staff access FloodWise to enhance their understanding of storm and flood events as they unfold across the city. Data collected and displayed in the system is used for situation reports and briefings to the Council administration.

Asset Services

Selected Asset Services staff receive alerts as to flooding of roads triggered by either stream level or rainfall totals or intensities. This messaging then prompts field crews to safely close roads and establish diversions. Over fifty flooded road sites are linked to FloodWise.

Australian Early Warning Network (AEWN)

AEWN is a third party service provider engaged by BCC to provide warnings to Brisbane residents. AEWN receive alerts from FloodWise which are then used as a basis for alerting residents in targeted areas of potential flooding.

Future Opportunities

The new iteration of FloodWise contains functions which were not present or available in the previous version. This has allowed Council to widen the capabilities of the system as well as its potential use across the business.

Presentation Mapping

The introduction of advanced ESRI GIS mapping has opened the door to importing other mapping or GIS features to FloodWise. Simple mapping layers such as catchment outlines or ground contours could be introduced easily and be synced to master GIS servers to ensure the latest layers are used.

More complex GIS integration could be achieved by incorporating feeds from other agencies. For example, overlaying the Bureau of Meteorology weather radar over the map page would allow for direct comparison of the radar-estimated rainfall intensity to the current gauge readings.

Forecast Flood Hydrographs

An obvious area of development in flood response is flash-flood forecasting. While FloodWise itself will never undertake flood forecasting processes, it has been configured to be able to receive flood forecasting model outputs. The vision may be to generate a hydrograph showing the current water levels combined with one or multiple ‘forecasted’

water level hydrographs. Each forecast scenario could generate statistics such as time to peak, flooded roads and areas affected and comparison to historic flood levels.

Additional gauges and monitoring

Network expansion

Not all of Brisbane's creeks are monitored by water-level gauges and there will always be room for more rainfall gauges to better capture the variability in precipitation across the city during a single event. FloodWise has the capacity to accommodate additional gauges and when the need arises for such monitoring, more gauges will be added to the network.

Leachate well monitoring

The BCC is presently embarking on a project to monitor leachate wells at landfill sites via FloodWise. Each major landfill site in Brisbane is fitted with one or more leachate wells which collect and discharge surplus liquid in the event of rainfall infiltration. Submersible pumps are located within the wells to pump the leachate into nearby sewers and so avoid spillage into waterways. Leachate levels within the wells are monitored to ensure that the pumps are operating correctly. Additionally, the amount of leachate leaving the landfill site is required to be reported to the appropriate agency. This is achieved with the use of in-line flow meters.

FloodWise is planned to assist the landfill remediation teams with the following aspects:

- Provide real-time monitoring of leachate levels within any well connected to the telemetry system. This means levels can be monitored in the office or remotely without the need to visit each landfill site.
- Provide SMS or email alerts should leachate levels rise above set trigger levels. This can be used to alert field staff of a potential pump failure or overflow risk. At present, reliance is on site visits and manual monitoring by multiple on-call staff.
- Provide real-time monitoring of leachate flows being discharged from the site. Again, this can alert staff to potential blockages or inefficiencies with the pumps, pipework or flow meter devices.
- Provide scheduled reporting on the number of overflow events, total volume of discharge and comparison to nearby recorded rainfall. Currently, this information is collected manually from each site.

Water quality and flow monitoring

The collection and monitoring of water quality parameters is possible through FloodWise and may be utilised in both event based and business-as-usual type scenarios. Linking fluctuations in water quality parameters to nearby recorded rainfall could prove useful in identifying problem areas and future project sites. Long-term data analysis could also be achieved from 'report card' statements.

Flow monitoring is another potential use for FloodWise. Installation of fixed flow measuring devices within a river such as the Brisbane River would allow for the collection

and reporting of long term river flow data, aiding in understanding the behaviour of the waterway under tidal and catchment flow conditions. Such information provides important historic records for use in future hydraulic modelling.

Monitoring of base flows can also assist in the management of aquatic ecosystems and waterway health.

Conclusion

Since its inception 12 years ago, the value of the FloodWise system has not waned; in fact its usefulness to the BCC has grown and the dependence of the organisation upon its continued and successful operation has prompted a renewal of the system and ongoing investment in its capabilities. The system is accessed on a near continual basis by officers from different Council departments to meet a variety of needs.

The latest version of the FloodWise system has been developed with the capacity and flexibility to absorb the knowledge and understanding of individuals who have experienced the storm and flood events of Brisbane and to transform their insights into meaningful and proactive flood response protocols. It also possesses the ability to inform and teach the less experienced.

Building and operating a system like FloodWise leads one to continually ask what more could it do and prompts the user to imagine and develop a means to find the answer. Though in its early days as a replacement system, the Council has confidence that the FloodWise MkII system will continue to grow with the needs of the organisation and that there is scope and capacity for new features to be added; new "imagineering" to take place.

References

Morris, K. 2010, ‘Improving Resilience with FloodWise’, 50th Annual Floodplain Management Authorities Conference, Gosford, Central Coast, February 2010