COULD THIS BE THE ANSWER? ACCURATE AND TIMELY FLASH FLOOD FORECASTING

Authors

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Abstract

With more intense storm bursts and rainfall patterns associated with changing climate, a community's desire and increasing expectations for more information, endless technological advances, and the ongoing significant risk to life associated with floods with little warning time; what is the most effective way to manage highly urbanised catchments at risk of flash flooding occurrences?
In recent years, Ipswich City Council has pioneered the development of an innovative and highly effective approach to real-time flash flood forecasting and response.

This paper will discuss Ipswich City Council's evolutionary and revolutionary flash flood forecasting system designed and built in partnership with industry, the Bureau of Meteorology and other Council's.

This paper highlights the approaches' "journey", including the technology, systems, overall philosophy, and the history leading to approaches development.
Using a case study from an actual event (and "near" events), this paper will discuss the practical applications of the approach, linking to past performance, lessons learned and continued improvements following these events.

Introduction

This paper relates to the development and application of Ipswich City Council's overall process in disaster management and flood operations, with a particular focus on the evolution of the flash flood forecasting system and its use in practice.

Flash floods in general are a very dangerous more localised flood event that provide a range of difficulties for the forecaster to provide timely and accurate responses to significant rainfall events. The area is generally largely unchartered due to issues such as accountability, risk, response and technology. Flash flood forecasting is a relatively new and generally unrefined process that is subjected to a variety of recent technology advances that have made development in this space possible. Up until recently most local authorities in Queensland have either been apprehensive, cautious or indeed unable to pursue developments in the flash flood forecasting space.

With the advent of this technology and a variety of recent dangerous flash flood events with tragic loss of life across the nation have sparked a renewed interest and drive to produce the capability to respond to such events.

Background

Ipswich City Council is situated in south east Queensland approximately 40 minutes west of Brisbane. The Council covers an area of 1,090 km2 with a current population of 190,000. The area is one of the fastest growing cities in Australia with an expected population of 435,000 by 2031 which represents a unique challenge to manage infrastructure and indeed provisions of floodplain and disaster management.

Overview of flooding

The City of Ipswich has experienced devastating floods during 1893, 1974 and 2011 with a variety of major floods in between as shown in Figure 1. Localised flooding during 2008 and 2009 also caused heavy damage within urban and rural areas across the City.

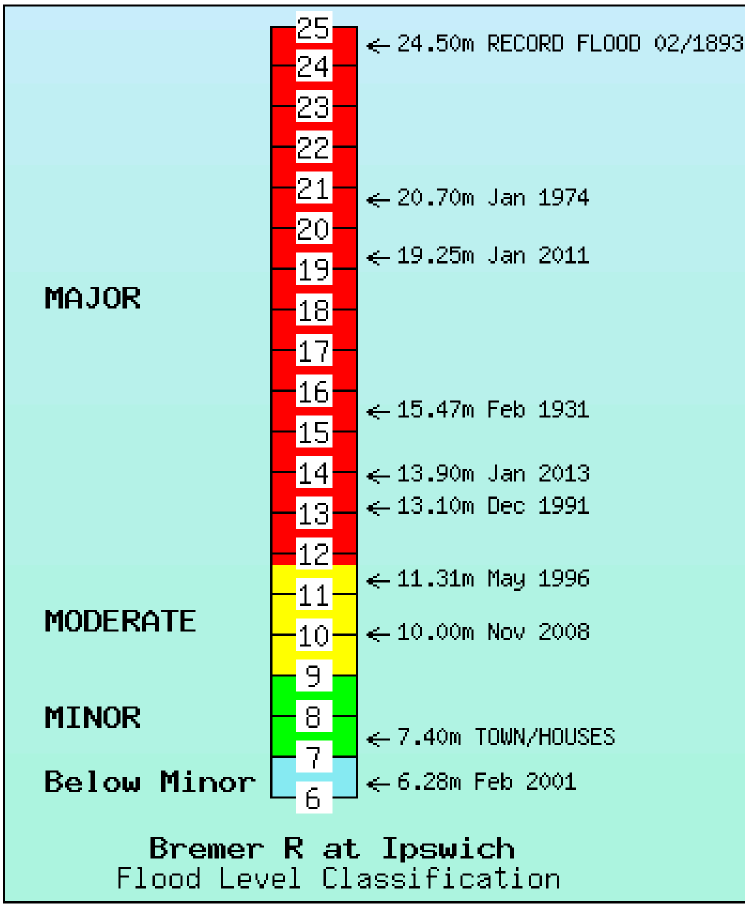

Figure 1. Historical Bremer River floods

Ipswich City itself has a very complicated flood regime in general and requires careful management and focus during rain events. The City can be impacted by tidal events, a Brisbane River tailwater flood event as evident in 2011 (including influence from Wivenhoe and Somerset Dams), a Bremer River flood event, Moogerah Dam and Warrill Creek flooding, large referable dams at Marburg and Rosewood and a variety of flash catchment creeks.

Figure 2. ICC Marburg dam 1% AEP spillway engaged in 2008 flood event.

Ipswich City Council owns and maintains in cooperation with BoM, 38 rain and stream gauges across the City as shown in Figure 3. The gauges are well placed throughout urban and rural areas on all major systems providing a very reliable network in order to manage flood events.

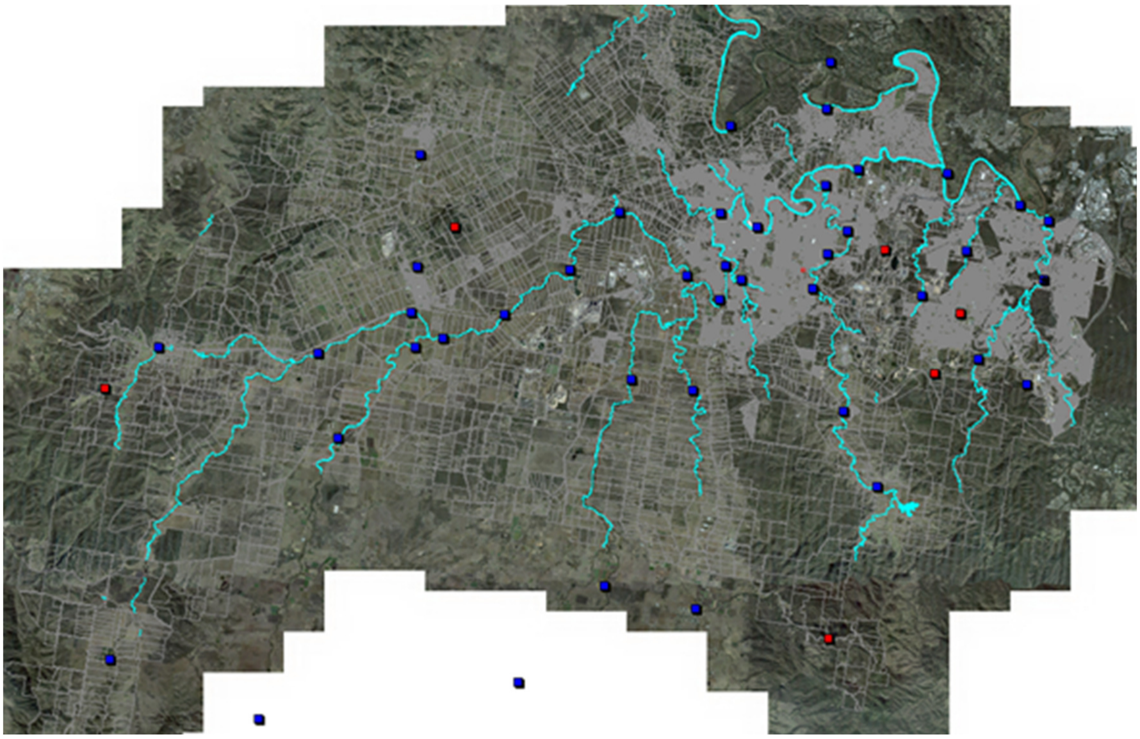

Figure 3. Ipswich Flood Gauge network

The flood forecasting team at Ipswich make use of a variety of tools in collaboration with neighbouring authorities including joint rain event teleconferences, GIS mapped and pre-cooked property and road data bases, Water RIDE Flood Forecasting Tool for the Bremer River (shown in Figure 4), the Disaster Management tool mapping developed jointly between Lockyer, Ipswich and Brisbane Council's, TARDIS. Enviromon and our flash flood forecasting system.

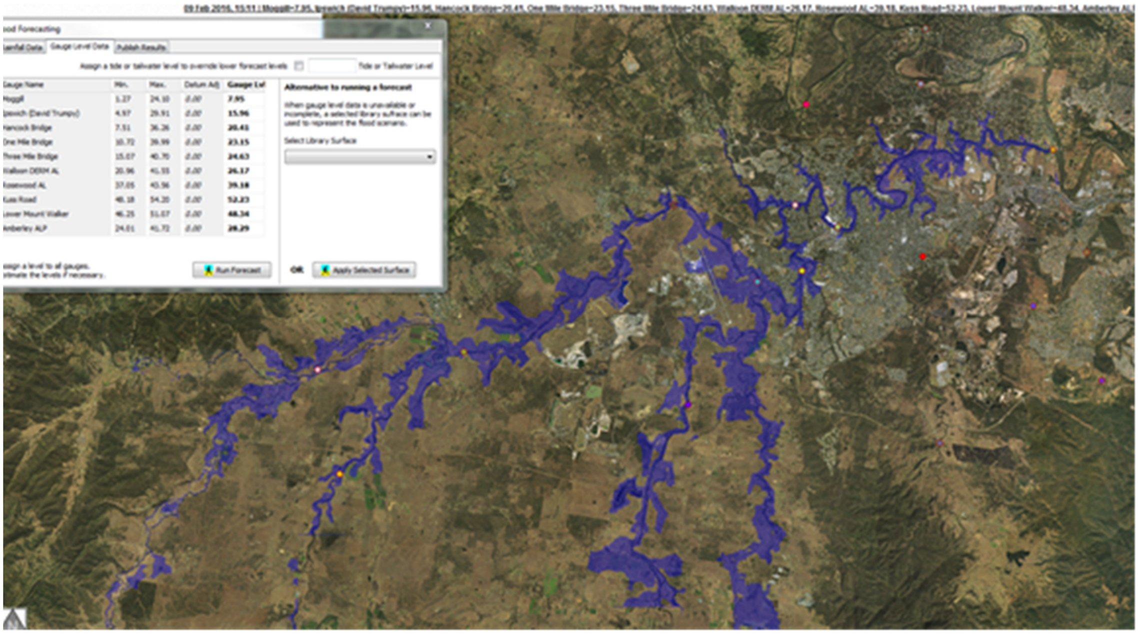

Figure 4. The Bremer River waterRIDE flood forecasting tool

Council operate the Bremer flood tools by collaborating with BoM and SEQ Water in order to be provided information on expected flood level heights at selected locations across the Brisbane and Bremer Rivers (as a result of rainfall and hydrological models and dam releases etc).

BoM undertake this modelling in accordance with the service level agreement with Ipswich that utilises BoM to provide model results for creeks and rivers above a 6 hour critical duration response time. The flood operations team functions with flow chart that triggers off more detailed monitoring and evaluation as shown in Figure 5.

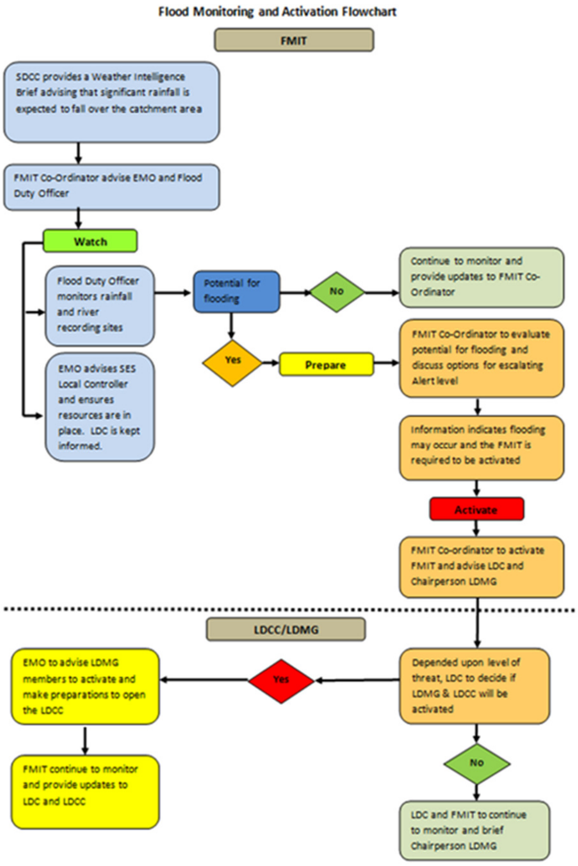

Figure 5. ICC Flood Forecasting flow chart

Bundamba Creek Overview

Bundamba Creek is the main focus of this paper with regards to its flash flood nature. As discussed above, BoM under service level agreements will not provide formal hydrologic modelling advice or expected river levels if catchments are equal to or less than a 6 hour critical duration response time. Bundamba Creek as shown below in Figure 6, within its lower catchments, is a 6 hour critical duration catchment, thus Ipswich City Council must manage the flood forecasting on this catchment.

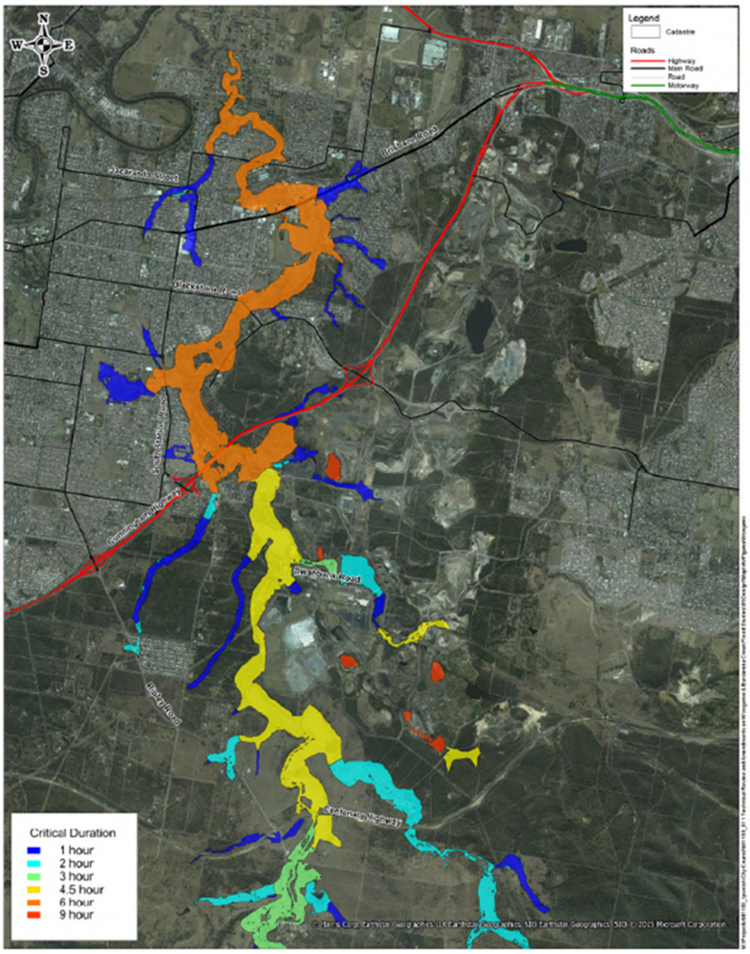

Figure 6. Bundamba Creek Critical Storm Durations

Ipswich City Council at this point in time also will not focus efforts below a 6 hour critical duration due to the difficult nature of current data sets and response time, although there are already plans in place to improve upon this capability in the near future.

Bundamba Creek itself is a fairly complicated catchment with a steep slope resulting in fast flowing water with relatively high velocity depth products surrounding inundated houses as shown below in Figure 7. This obviously presents a situation that requires a flash flood forecasting platform that is fast and relatively accurate in order to manage the severity of the flooding encountered.

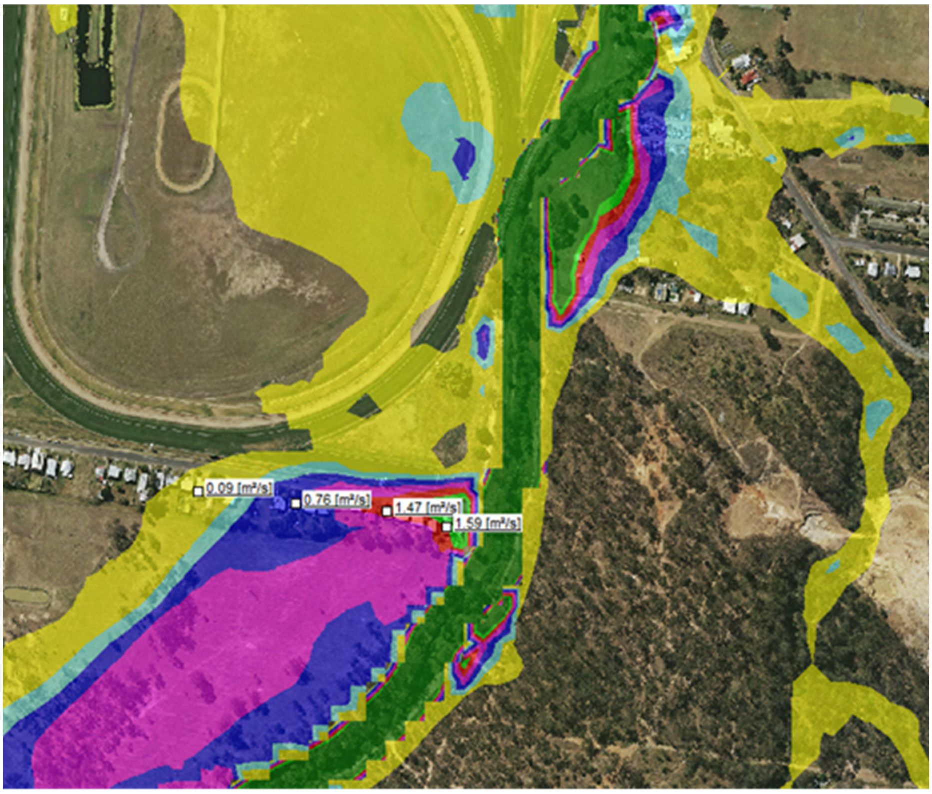

Figure 7. Depth Velocity Products Bundamba Creek

As an example of the very quick response and destructive nature of the creek, in 1991, 42 people had to be rescued from their flooded homes. Hence Ipswich City Council have a very close working relationship between our flood operations and disaster management officers and the State Emergency Service to respond to events like this in time.

Operational Flood Model Calibration

Ipswich City Council undertook a 1D/2D coupled model in Tuflow with XP-Rafts hydrology in 2012 to produce the Bundamba Creek Flood Study which has been used for a variety of floodplain management techniques across this catchment. Figure 8 provides an overview of the sub catchments and extent of area within the study.

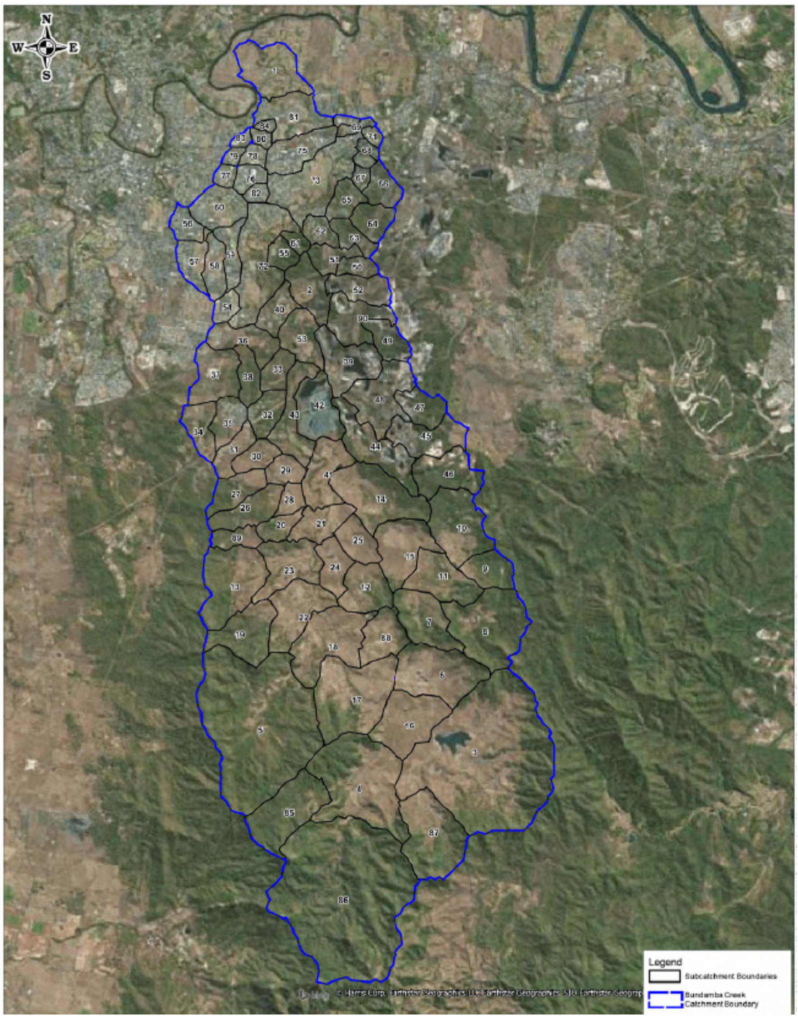

Figure 8. Bundamba Creek catchment

This study was calibrated to a variety of flood events including major events in 2008 and 2009 with estimates of this event approaching Q100 and Q50 respectively in the lower parts of the catchment. Urban residential, commercial and industrial flooding occurred during these events.

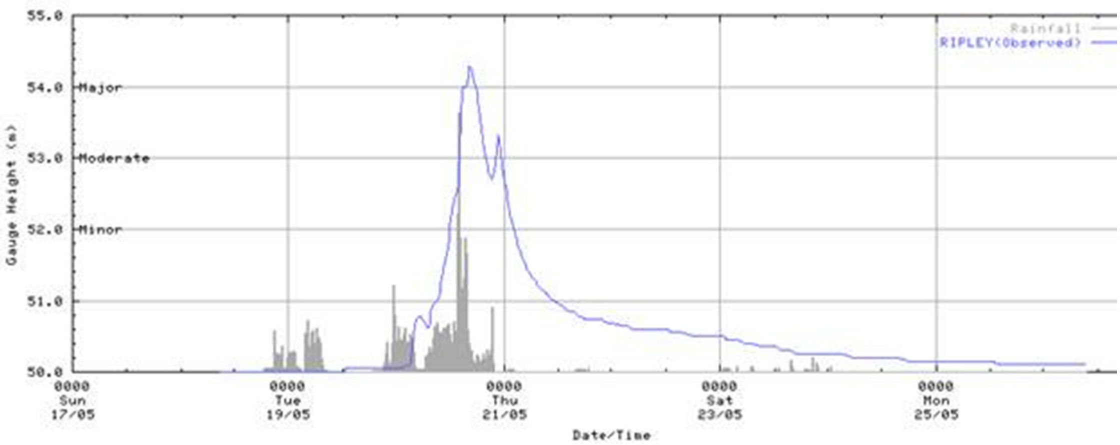

Figure 9. Ripley Alert Bundamba Creek May 2009

With the onset of further flooding during 2011, 2013, recently during February 2015 (Tropical Cyclone Marcia) and a further rain event in May 2015 (the focus of this paper), plus extensive development within the upper reaches of the Bundamba Creek catchment, it was seen necessary to begin a major revision process of the flood study and recalibrate more accurately to a wider range of storm events.

With experience with early flood forecasting techniques on this catchment, monitoring, knowledge of the response and validation of levels on site during floods, there was and always has been a concern that the flood model was somewhat inaccurate for its forecasting ability within some areas of the catchment. With this level of doubt in particular, it became necessary to look at all aspects of the calibration of the flood model and begin the revision process to produce more accurate flood forecasting capability on Bundamba Creek (and others throughout Ipswich).

Furthermore, a particular focus that is often missed on calibration and verification of flood models are not only the major flood events (Q50+) but also the minor events below this. For floodplain planning purposes (such as development and land zoning) it could be sufficient to calibrate and verify only large storms such as the Q100, however for an operational flood forecasting model, the importance of having a variety of storm events is often overlooked. Figure 10 below shows some of the initial comparison differences with changes to the model on a certain storm event, indicating possible variations which drastically impacts on robustness of the flood forecast platform overall.

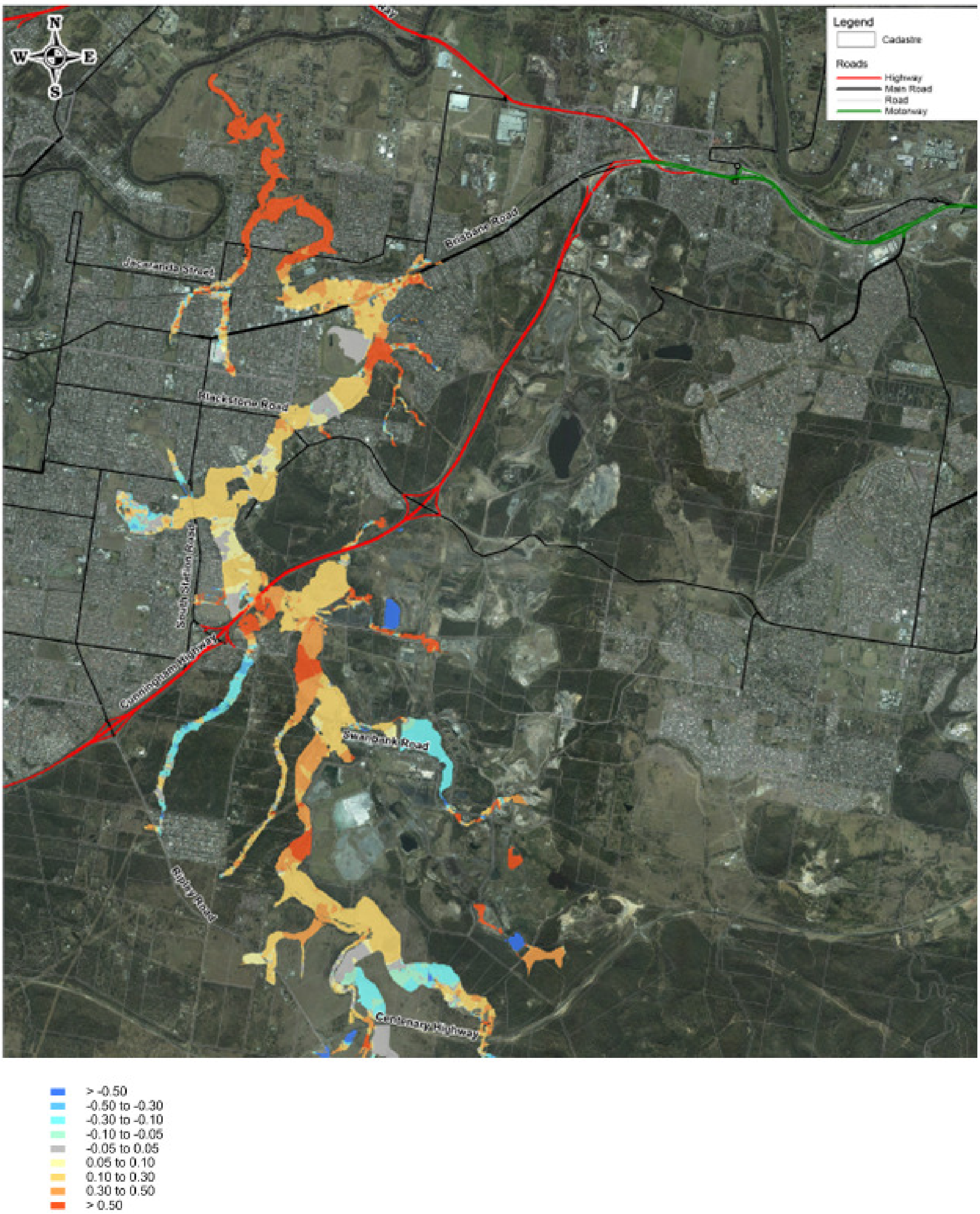

Figure 10. Initial flood level differences between studies.

Land use changes

The Bundamba Creek catchment contains a variety of complex aspects to flood modelling calibration that include:

- A highly forested steep upper catchment
- A variety of floodplains, branched sections and breakouts
- Extensive floodplain urban development within the Ripley Valley area which is subject to an additional 120,000 residents (one of the largest long term urban developments in Australia)
- Existing historical urban development, subject to existing flooding

In particular, Figure 11 demonstrates the large component of future urban land (of which there are thousands of lots already constructed. Whilst strict control of development in the Ripley Valley is incurred with full hydraulic impact assessment conducted, it was still deemed necessary that the major change in catchment required an update of the regional flood model with many more urban areas and the latest 2014 Lidar terrain data to reflect this.

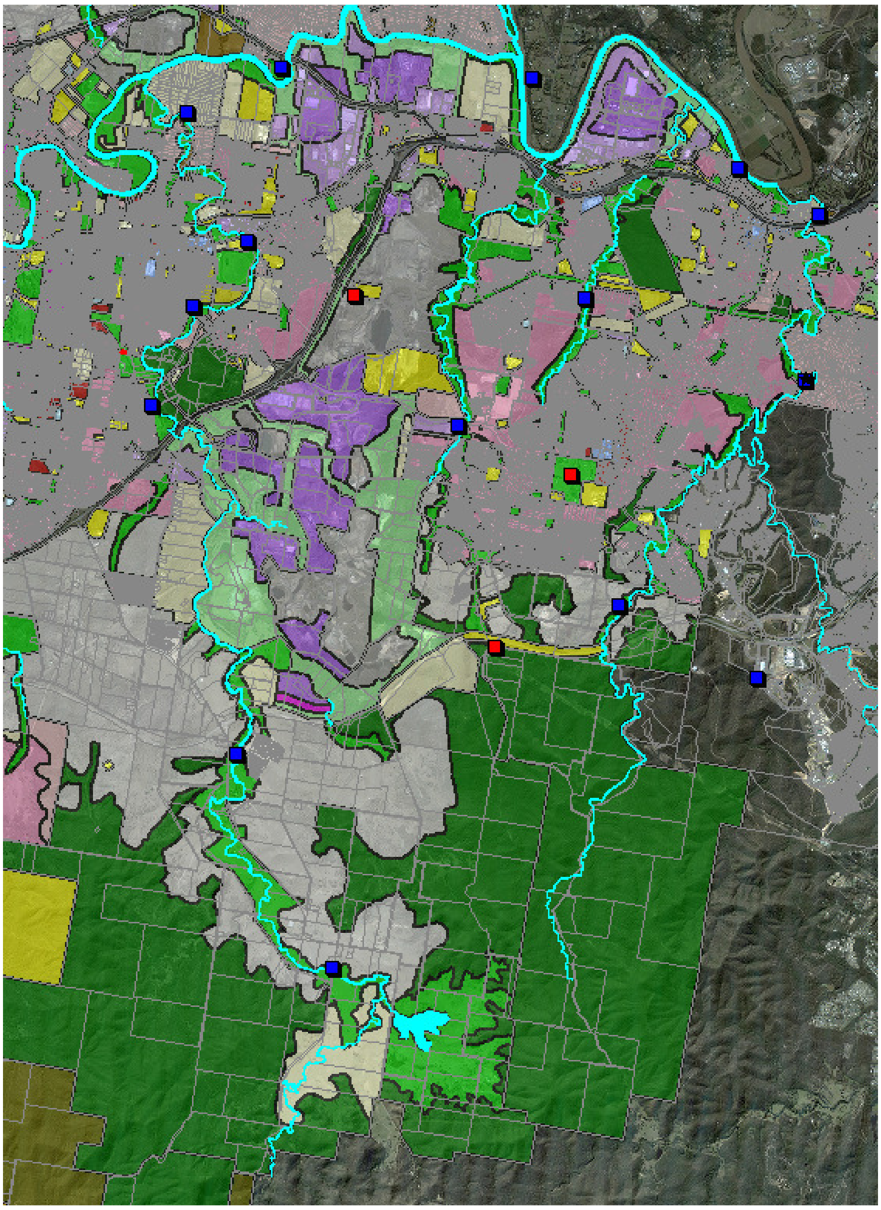

Figure 11. Future Urban Development within catchment (grey shading)

Terrain

The original study was undertaken 5 years ago with more limitations present on computing power and resources available. The original flood study had a coarse 20m grid applied over most of the catchment and as such a decision was made to reduce the grid to a more accurate and refined 5m, as well as updating major terrain changes and development.

The reduction in grid size is important for a number of obvious reasons, but in the particular case of the Bundamba Creek Flood Study, the higher definition and recognition of floodplain storage within the upper catchments was crucial for calibration. Additionally further investigations occurred around storage behind major 1D structures and the impact of only using 2D elements within the creek beds as shown in Figure 2.

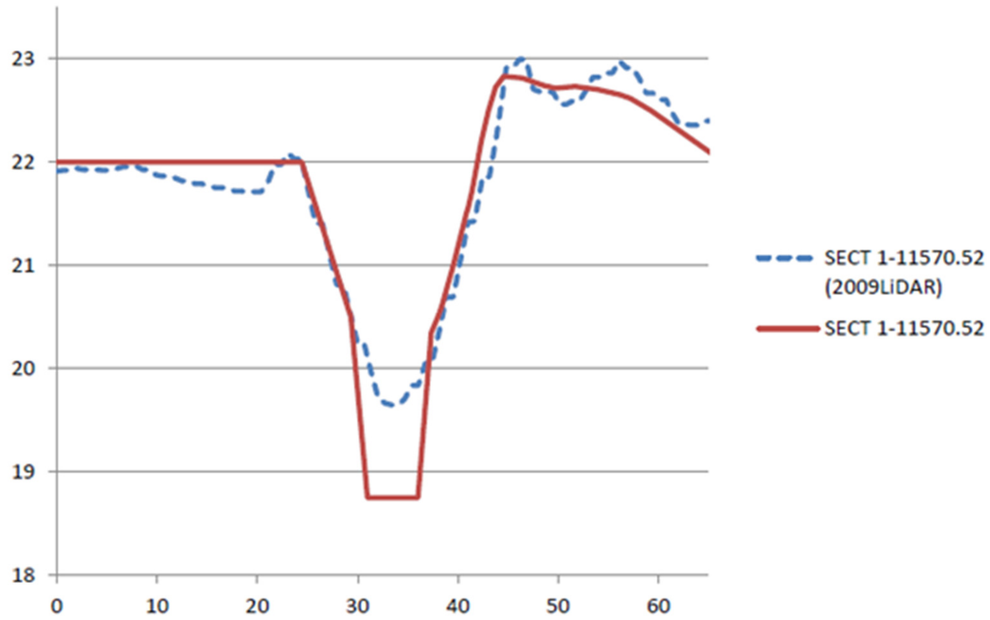

Figure 12. Comparison of Lidar verse 1D creek elements

Hydrological routing

Often overlooked or not enough focus in many flood models, storage, lags and routing can be quite critical on a flood forecasting model due to the heavier reliance on the accuracy of the hydrological model with less interaction with the hydraulic model. This component at the time of writing is still undergoing revision, however it has become apparent that some of these parameters when calibrated for a wide range of storm events, will become crucial in aligning a comprehensive model. In particular how the catchments are routed and ultimately connected to the hydraulic model will require sensitivity testing with multiple calibration events to ensure the hydrological model is as robust as possible in this area.

Rainfall losses

Rainfall losses in Ipswich City Council's Woogaroo and Bundamba Creek flood models and forecast platforms had a high focus placed on producing a robust model.

It is becoming apparent it is no longer appropriate to simply adopt a 15mm initial, 2.5mm continuing (often standard in most of South East Qld) design loss approach after undertaking significant calibration for a forecast flood model which may show a wide variety of losses across different storms. Whilst this approach may be appropriate for floodplain planning purposes, the true nature of rainfall losses must be understood and exemplified in a forecast model. Essentially Ipswich City Council now possess and utilise two separate models for the time being (one for planning, one for forecasting) until further information is released, reviewed and correlated with the new Australian Rainfall and Runoff Guidelines for losses, temporal and spatial patterns etc.

Where a number of stringent calibration and verification checks are done as above and quality checked for robustness, it becomes necessary to think outside the box with rainfall losses. The experience on calibrating 6 storm events has shown that both initial and continuing losses were much higher than expected, but rather than excluded from use, due to the extensive exercise undertaken for accuracy, these losses were rationalised across the events and adopted. This approach will be adopted until such time that further supporting information and work on the models is undertaken. It is worth noting, the conclusions reached in the interim on losses, could be considered investigative at best at the present point in time.

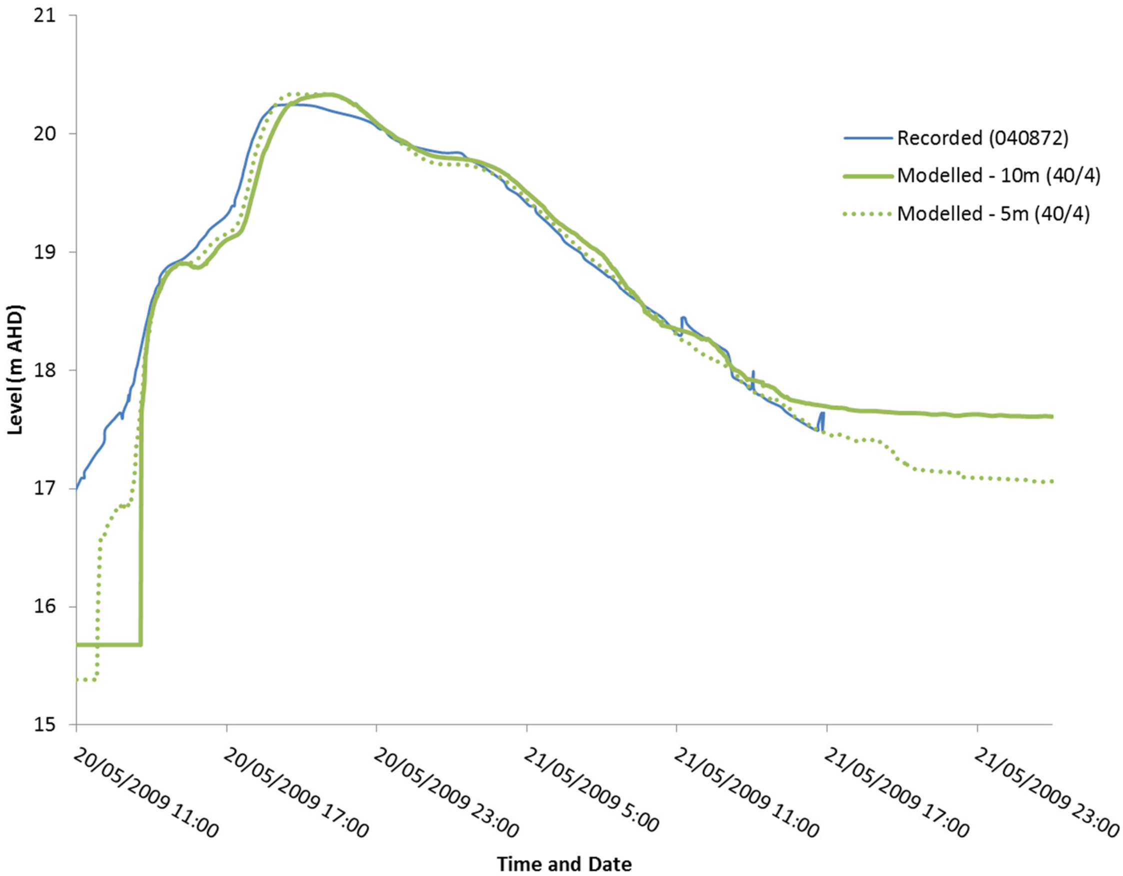

Figure 12. Initial Calibration runs with higher rainfall losses

As the flood forecast platform also allows the ability to verify rainfall losses during a storm (from dry, average and wet) by applying multipliers within the input files, losses again become a crucial component in calibration.

Again at the time of writing, further analysis is being undertaken of the actual evidence of catchment conditions during these storm events to further verify the acceptance of the rainfall losses. Any calibration comparisons are only investigative in nature at this stage and still require many more parameters to be assessed for appropriate rainfall losses.

Rainfall accuracy

Further assessment of rainfall was undertaken at the time of calibration to ensure aspects were not missed in the original assessment and due to the issue of much higher rainfall losses: however the data available at the time was proved suitable. At the time of writing, more investigative methods are currently being pursued with radar rainfall methods due to some concerns on initial checks on gaps, accuracy and suitable spread of data. It is expected that radar rainfall data entry may provide a more robust method of assessment for identifying some of the calibration issues going forward.

Summary

The current Bundamba Creek Flood Model (forecast version) has had a higher level of calibration undertaken which further increases the accuracy, reliability and most importantly for the forecast engineers: confidence. It is far from complete, but continues to evolve to match the expectations of the flood forecasting engineers.

As more local authorities will find however, the task of properly calibrating an *operational* flood model is difficult, time consuming, expensive and often very frustrating! The task becomes much wider than originally thought and will be ongoing and span many years. Ipswich City Council will continue to analyse data and new technology to ensure the flood forecast platforms provide confidence to its operators.

It is apparent that through external multiple consultants and detailed in house modelling that the issues of calibrating this flood model are not as simple as first thought and are the subject of the debate currently as to an appropriate way forward. It is not appropriate, sufficient or accurate to say that one party is incorrect, rather that more focus, effort and resource is required to gain adequate results on what can be a overlooked yet extremely complicated issue.

Early platform forecasts

Following the January 2013 flood event, Ipswich City Council triggered the improvement to its Bremer River flood forecasting capability but at the same time the start of a solution to areas of flash flooding across the City. Prior to 2013, no tools other than monitoring flood gauges were available to provide early warning to disaster management teams or residents and business.

Council applied an innovative approach to flash flood forecasting utilising both real-time hydrology and hydrologic interpolation, in conjunction with the widely used hydraulic surface interpolation functionality in waterRIDE (Druery et al, 2014).

The intent of this approach was to utilise recorded rainfall and catchment-wide forecast rainfall totals to provide information on what the affectation of likely flooding would be (what would it look like, who would be affected, etc).

This approach employed a lumped approach to rainfall distribution, as the available hydrologic models were constructed using global rainfall profiles in RAFTS.

During the February and May 2015 rain events, Council operated both the Bundamba and Woogaroo Flood Forecast Systems to good effect. Although primarily a lumped rainfall model, it provided a conservative assessment of hot spots across the catchment that would require more focus and attention for management of evacuations.

On initial forecasts, SES volunteers were sent to door knock and advise residents at risk of forecasted levels to monitor creek level rises and prepare for a required evacuation. With further forecasts, a number of residents were evacuated, that eventually had very minor inundation throughout their properties.

Whilst the early system provided some early forecasting ability, it did lack in accuracy, robustness and confidence overall. Essentially these events and unacceptable limitations became a trigger for Council to investigate more innovation, creativity and possibilities within the platform to provide and ongoing long term improvement program for the systems. It exposed weaknesses and a long list of possibilities to begin extensive redevelopment of the flood forecasting tools and procedures.

From this, Council began developing the current platform, revisiting flood study calibration and also began discussions with BoM national about acquiring the Nowcast 1km gridded rainfall data as a trial, perfectly suited to the application of the current waterRIDE system and proving to be an industry leading tool. Additionally, Council invested in more flood gauges and also relocated gauges to better represent required forecast gauge locations. Rather than these gauges becoming merely a tool to monitor events, they now form a crucial part in the flood forecasting system overall.

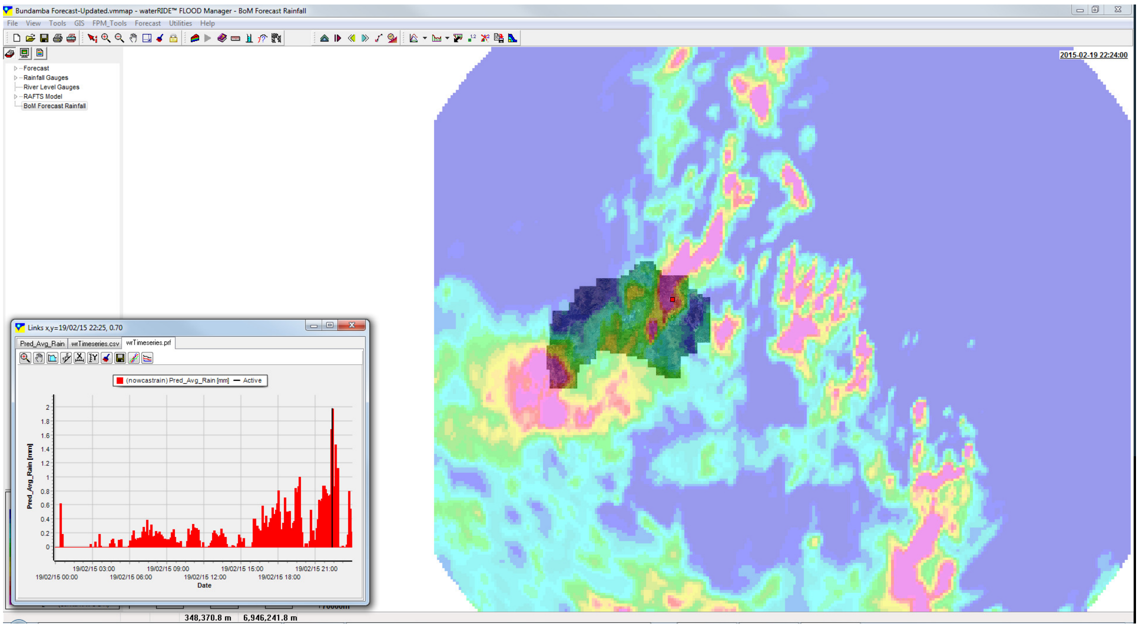

Figure 13. Spatially and temporally varying forecast rainfall – BoM NowCast surface.

Bundamba Creek Forecast Platform

The current flash flood forecasting system covering Bundamba and Woogaroo Creeks combines the detailed hydrologic and hydraulic model outputs with an expanded gauge network and support for the BoM NowCast forecast rainfall surfaces.

The tool expands on functionality developed for forecasting systems in neighbouring Councils, providing a common platform for inter Council communication and potential information exchange.

Operationally, the system:

1. Prepares rainfall hyetographs at each sub-catchment of the hydrologic model using fallen rainfall (live gauge readings from Enviromon) supplemented forecast rainfall either extracted from the NowCast surface, or entered manually (eg 200mm over 4 hours).
2. Executes the hydrologic model using categorised losses (eg wet, dry or average catchment conditions).
3. Utilises ratings curves (extracted from the hydraulic modelling) to convert flows into peak levels at each gauge
4. Runs the hydraulic interpolation to prepare the forecast water surface
5. Integrates the forecast surface with GIS datasets to generate additional intelligence such as properties inundated above floor level, depths over evacuation routes etc
6. Outputs are accessible using waterRIDE or are automatically exported to GIS files.

A forecast is executed in under 30 seconds on a standard computer, and has the ability to incorporate a *sensitivity* on forecast rainfall to determine any implications of uncertainty on the resulting flooding outcome. For example, the following figure shows the outcome of flooding for 200mm of rain over 4 hours, with a +/- 20% variation in rainfall total (160mm to 240mm).

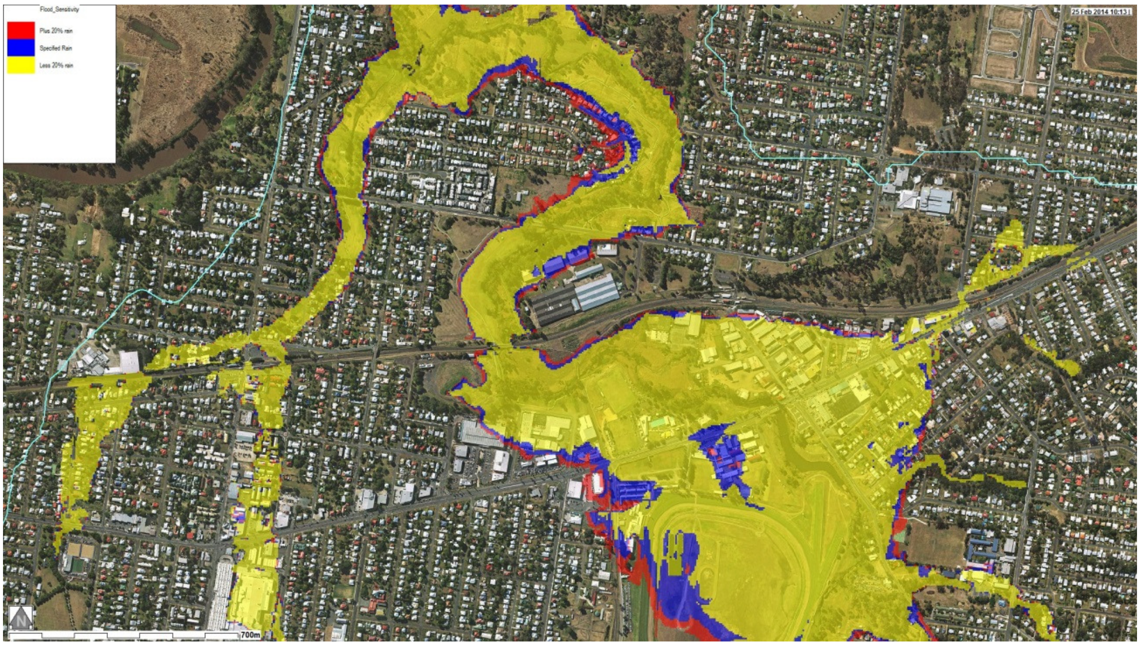

Figure 14. Managaing Uncertainty: Likely flood extents for 200mm of rain over 4hrs (blue), +20% more rain (red) and -20% more rain (yellow).

As shown in the figure 14, despite there being a 40% uncertainty band in forecast rainfall, there is “relative certainty” in the outcome as there is minimal difference in flood extents for the three rainfall scenarios.

Once the forecast surface has been created, it can be integrated with GIS datasets to generate specific flood intelligence. The system automatically combines the forecast surface with a GIS layer of property floor levels to determine not only what properties will be inundated, but those that will be affected above floor.

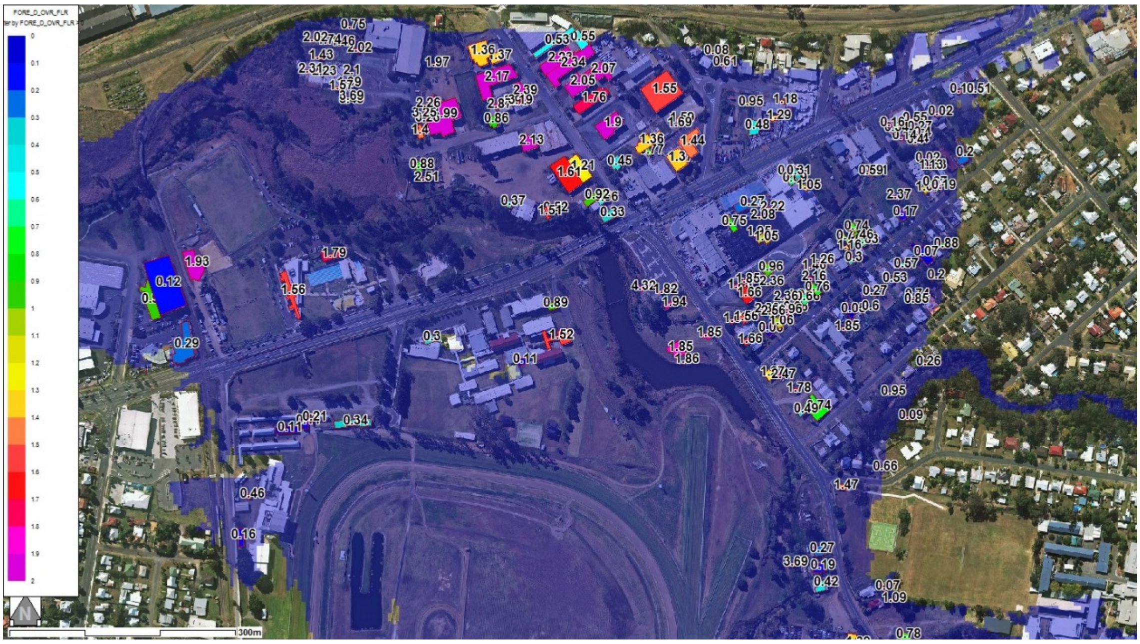

Figure 15. Specific Flood Intelligence: Properties Likely to be flooded above floor.

Benchmark test and application

As part of the development of the flood forecasting platform for the Ipswich flash catchments, BoM national was approached in order to undertake trials of the latest 1km nowcast gridded rainfall data. Data was acquired for the period of heavy rainfall during February and May 2015, with an example benchmark test provided below. The following information below presents a scenario with this new dataset that would have been followed in order to manage the flash flooding of this creek in a very accurate and responsive manner.

May 2015 Rain Event

An east coast low developed over the period of the 28th April to 2nd of May over much of South East Queensland bring one of the wettest may rainfall events in history. Areas hardest hit were within Brisbane but in particular north of Brisbane with areas such as Caboolture receiving over 300mm of rainfall. Tragically there were five deaths associated with this rainfall event as a direct result of flash flooding.

Within the Ipswich area rainfall was much less, although falls were still significant enough to activate the flood operations team with moderate flooding of flash catchments, particularly Bundamba and Woogaroo Creek. Figure 15 below shows the total rainfall that fell across the catchments on the 1st and 2nd of May

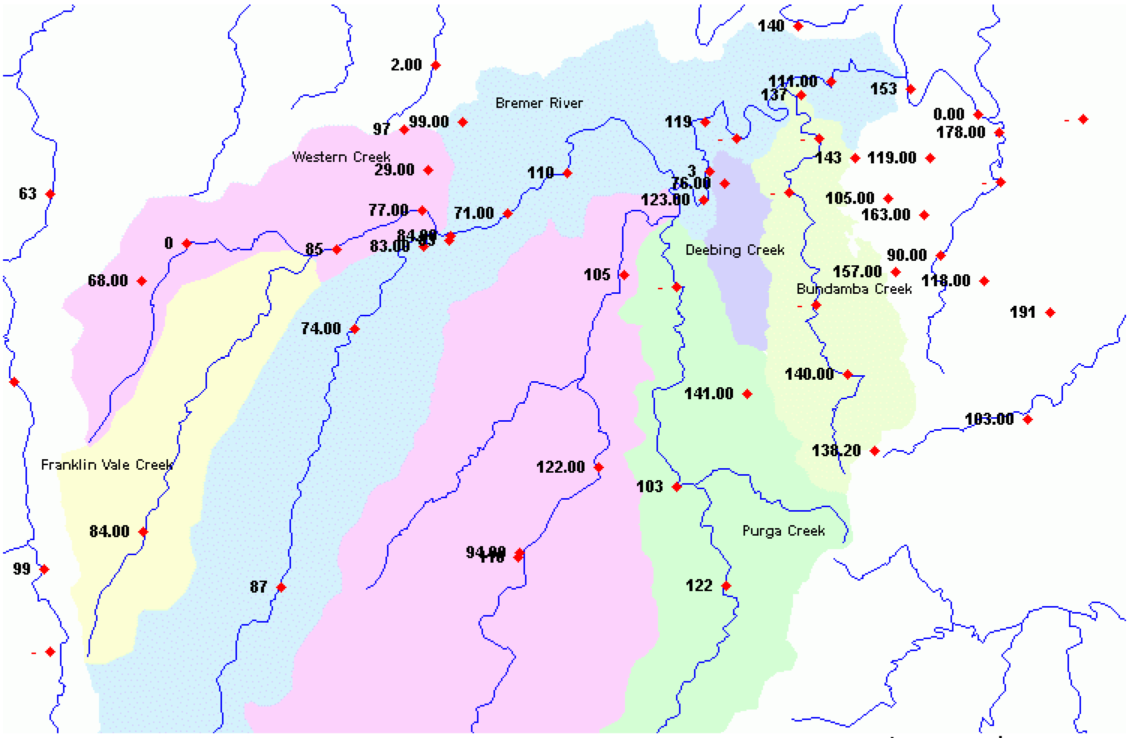

Figure 15. Extract from Ipswich Council's enviromon system 1st and 2nd May 2015

As it can be seen rainfall was highly varied, across the area however heavy falls of up to 163mm were experienced within the Bundamba and Woogaroo Creek catchments.

Figure 16 below also shows a direct extract from the systems of the intensity of rainfall at one of the Bundamba Creek rain gauges. Heavy rainfall occurred over a 6 hour period which resulted in some flooding due to the critical duration of Bundamba Creek being equal to the heaviest periods of rainfall.

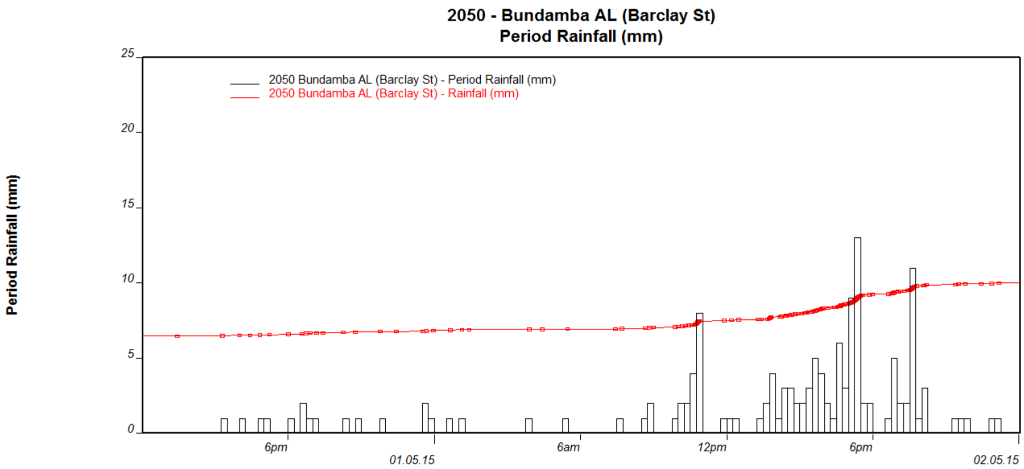

Figure 16. Rainfall intensity Bundamba catchment

Early rainfall predictions

With the onset of heavy rain predicted over the 1st and 2nd of May 2015, the nowcast 1km gridded rainfall data was used 24 hours in advance in conjunction with the platform to evaluate expected flooding in Bundamba Creek. A wet catchment parameter was used which decreases rainfall infiltration by 30% and accordingly updates the losses within the hydrology model. This forecast would be used by the flood operations team to demine the initial severity of the flooding, make a decision on the resourcing required, begin to organise shifts for the team, make provisions with the Local Disaster Coordination Centre key staff and ensure the SES are adequately resourced to meet the expected level of flooding.

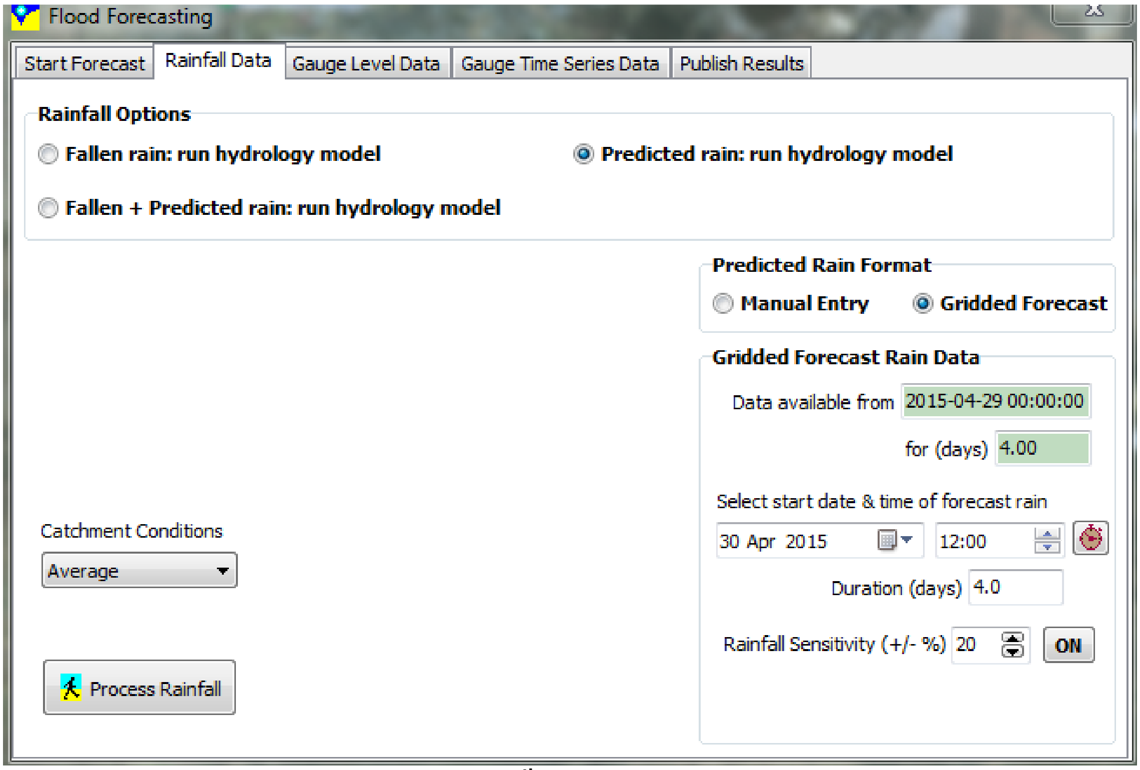

Figure 17. Early predictions 12pm 30th April 2015 incorporating sensitivity

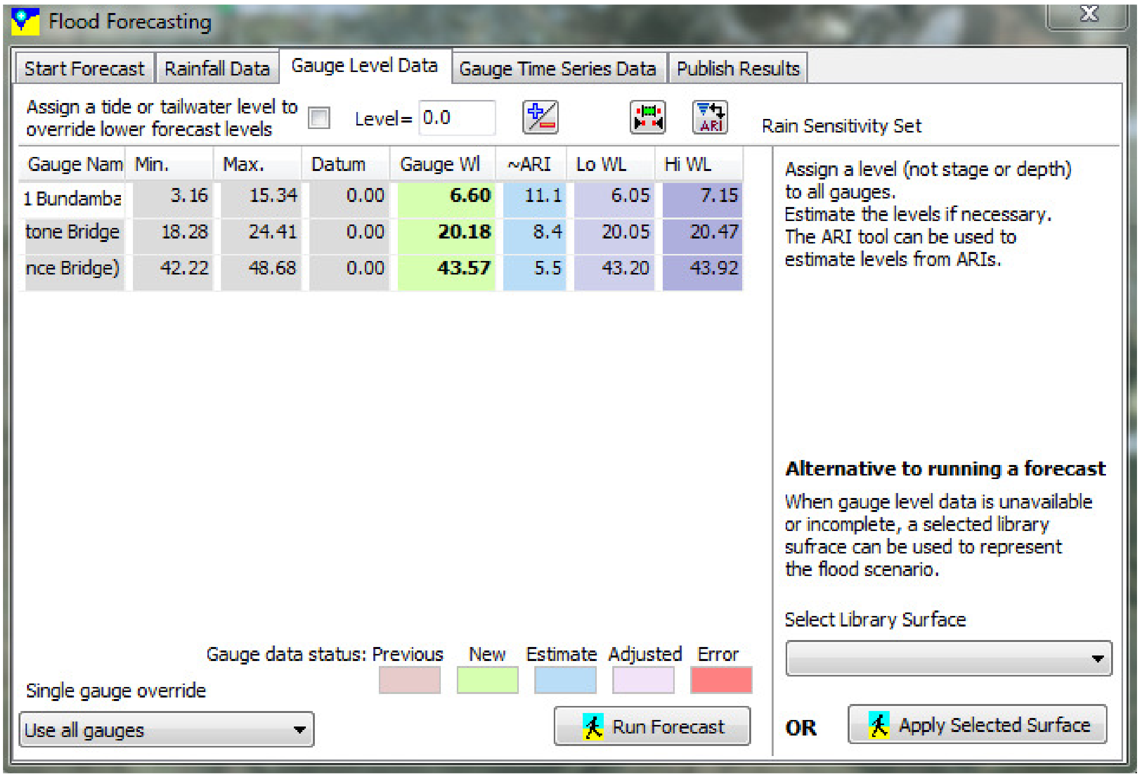

Figure 18. Early predictions Flood Gauge results with high and low sensitivity

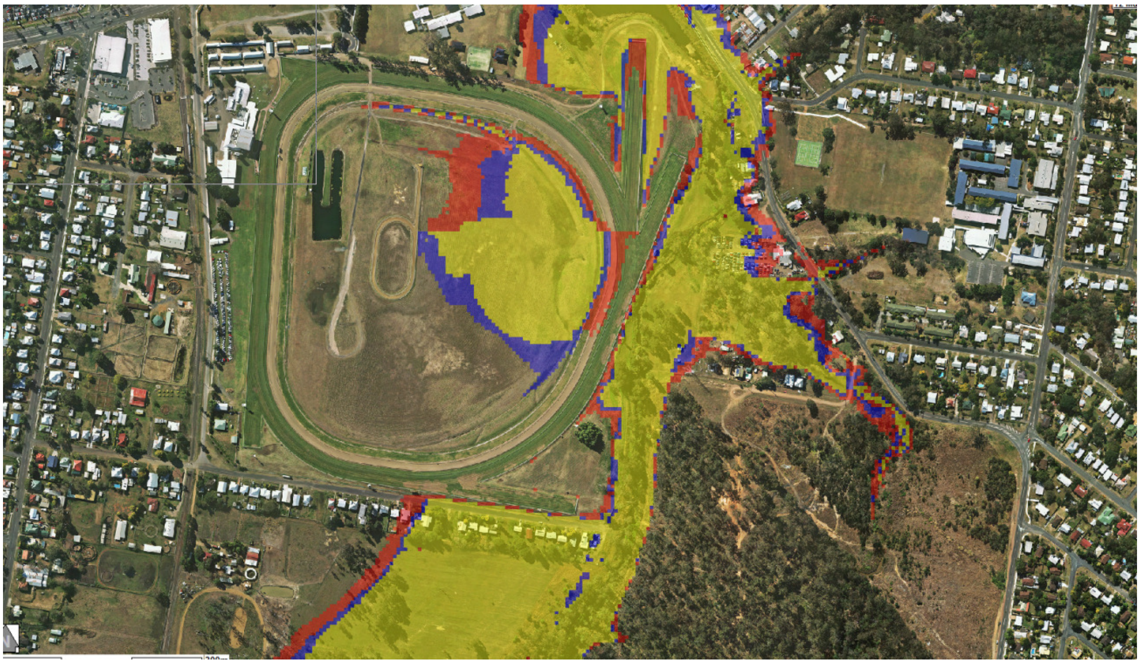

Figure 19. Early predictions Flood extents with +/- 20% rainfall sensitivity

Approximately 6 hours before the most intense rainfall another forecast was undertaken with the results shown below in Figure 20 (noting differences in gauge heights)

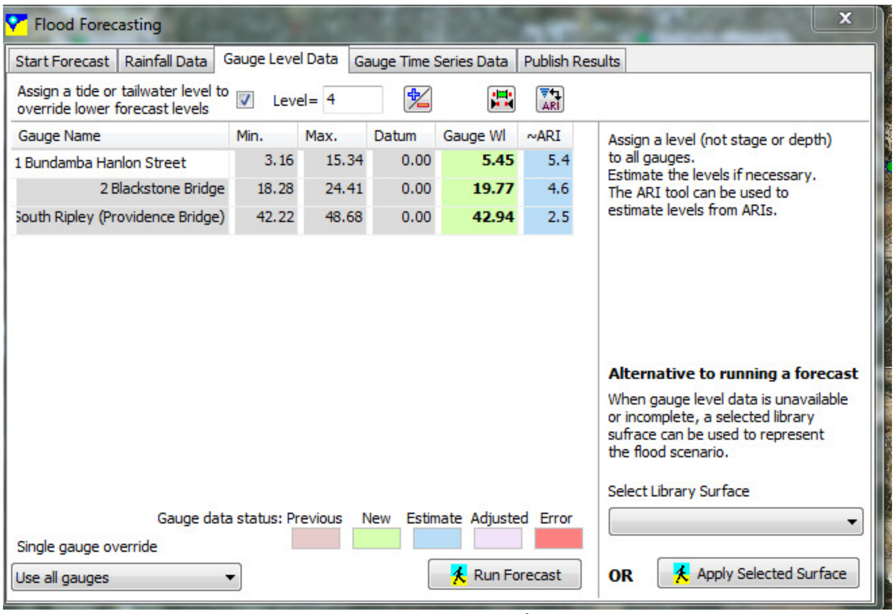

Figure 20. Predicted rain only 6am 1st May 2015

As rain began to fall before 12pm 1st May, fallen rain in that period plus predicted rain (a more advanced accurate phase of the forecast) for the remaining time allocated in the forecast was run as shown in Figure 21.

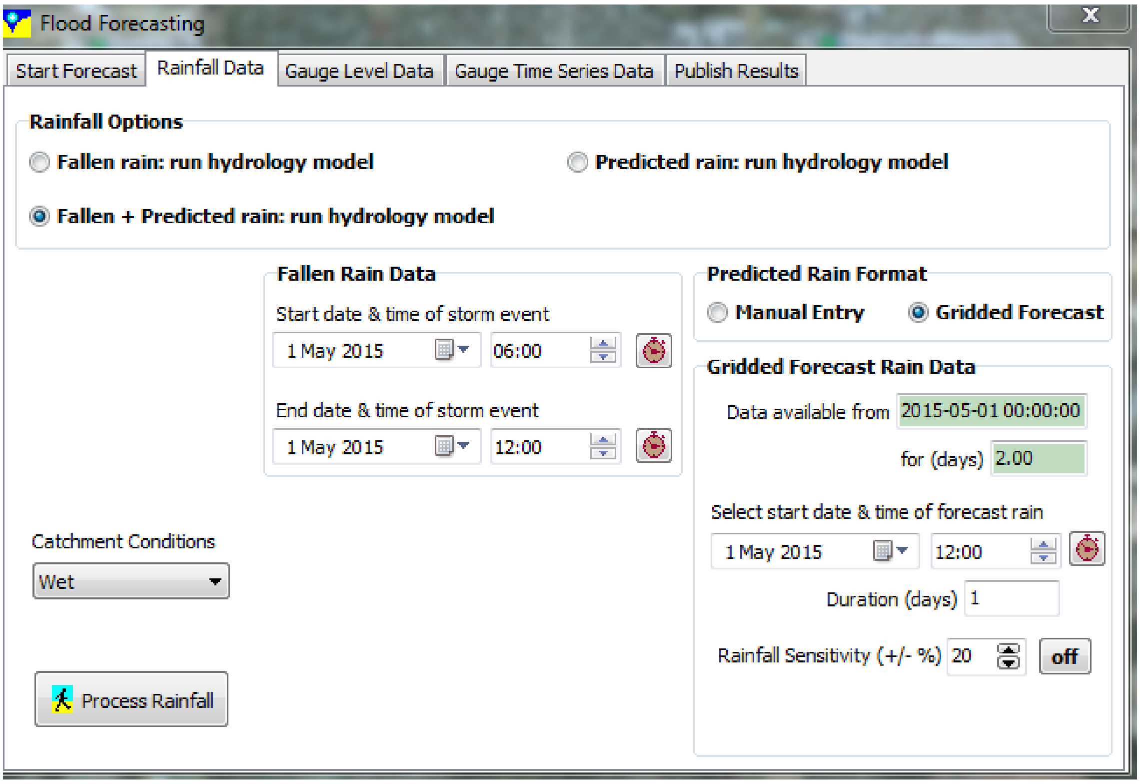

Figure 21. Fallen rain plus predicted 12pm 1st May 2015

The flood gauge levels are shown below in Figure 22. At this point in time flood maps would be published by the flood team, ASCII files extracted and GIS scripts used with property and road level data to begin building any predicted inundation areas. This information could then be considered by the flood operations team/LDCC for any distribution and mobilisation of Council road crews and SES units used for doorknocking and evacuation in predicted flood affected areas.

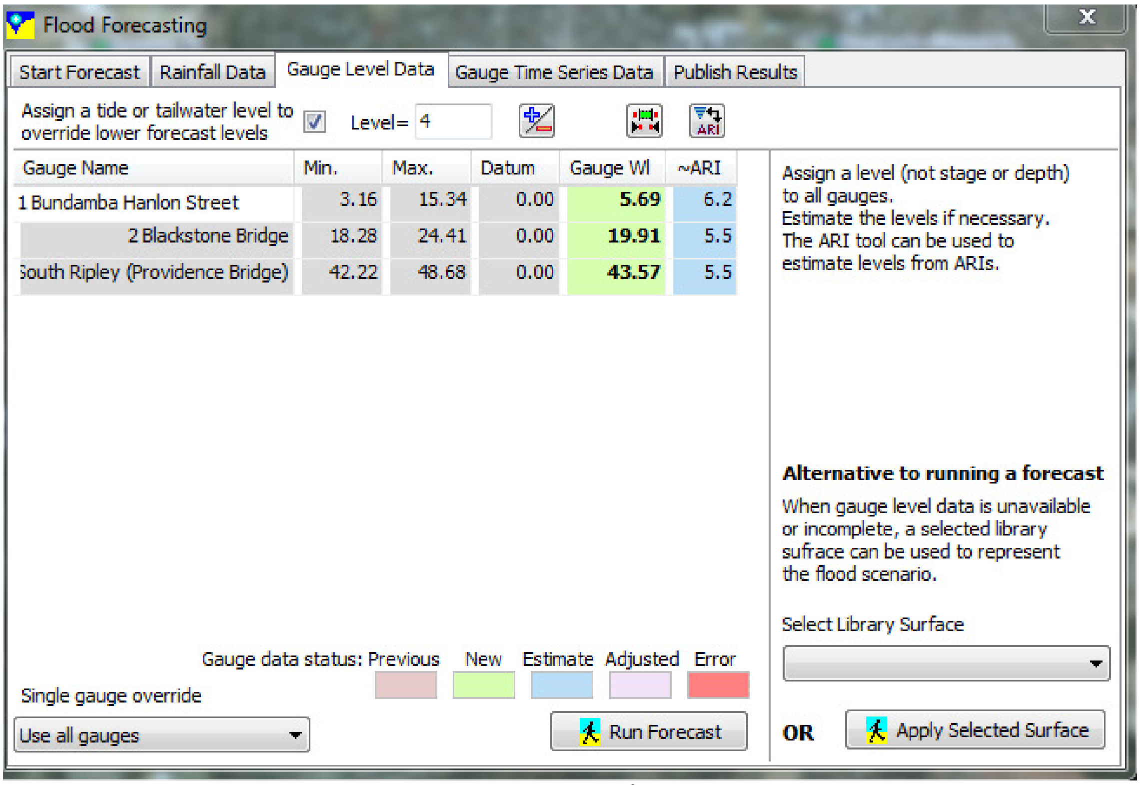

Figure 22. Flood gauge level results 12pm 1st May 2015

Figure 23 below shows an additional forecast at 6pm with the majority of rain already fallen with approximately 27mm of rain still to fall (late into the storm event).

This period is within the critical timeframe and where residents would be in the process of being evacuated as required. At this point in time there is still approximately 9 hours until the peak of the flood event at the Blackstone Bridge flood gauge giving ample time to organise components of the evacuation.

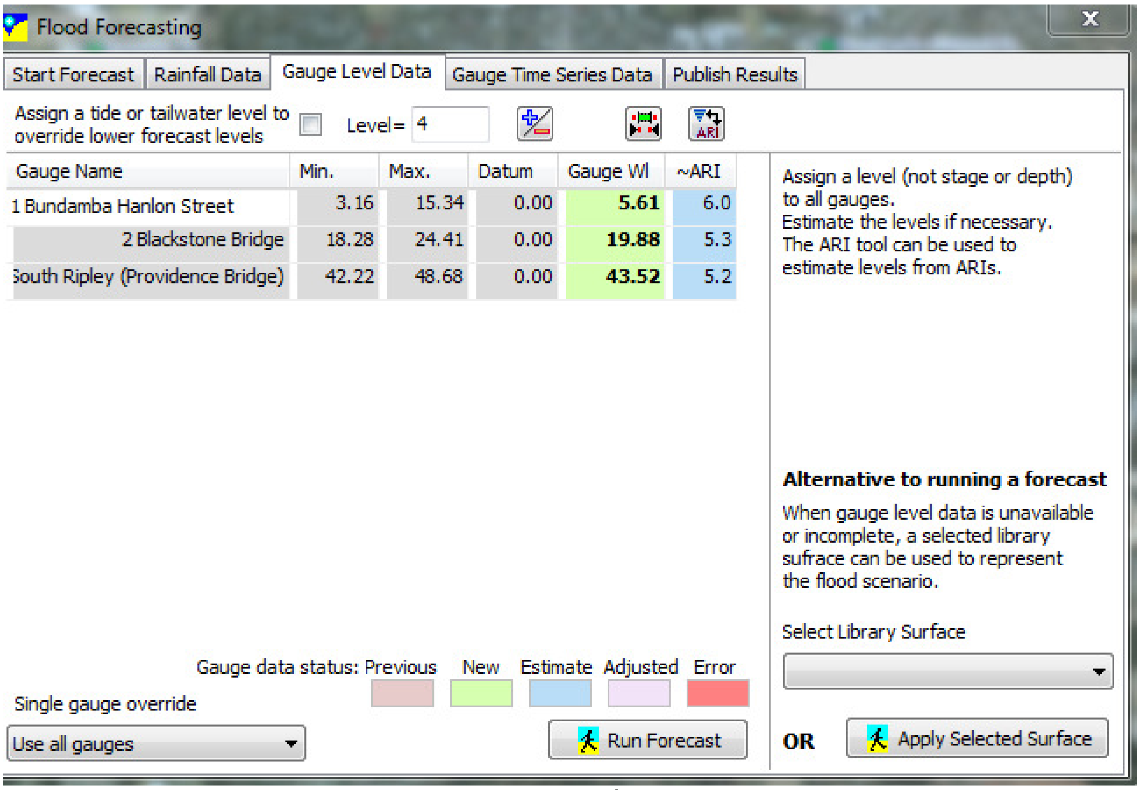

Figure 23. Flood gauge level results 6pm 1st May 2015

The last forecast in Figure 24 is undertaken at midnight on the 1st of May 2015 after all the major rainfall has already occurred and is a fallen rain forecast only (i.e. using just the information from the Enviromon system and no gridded rainfall).

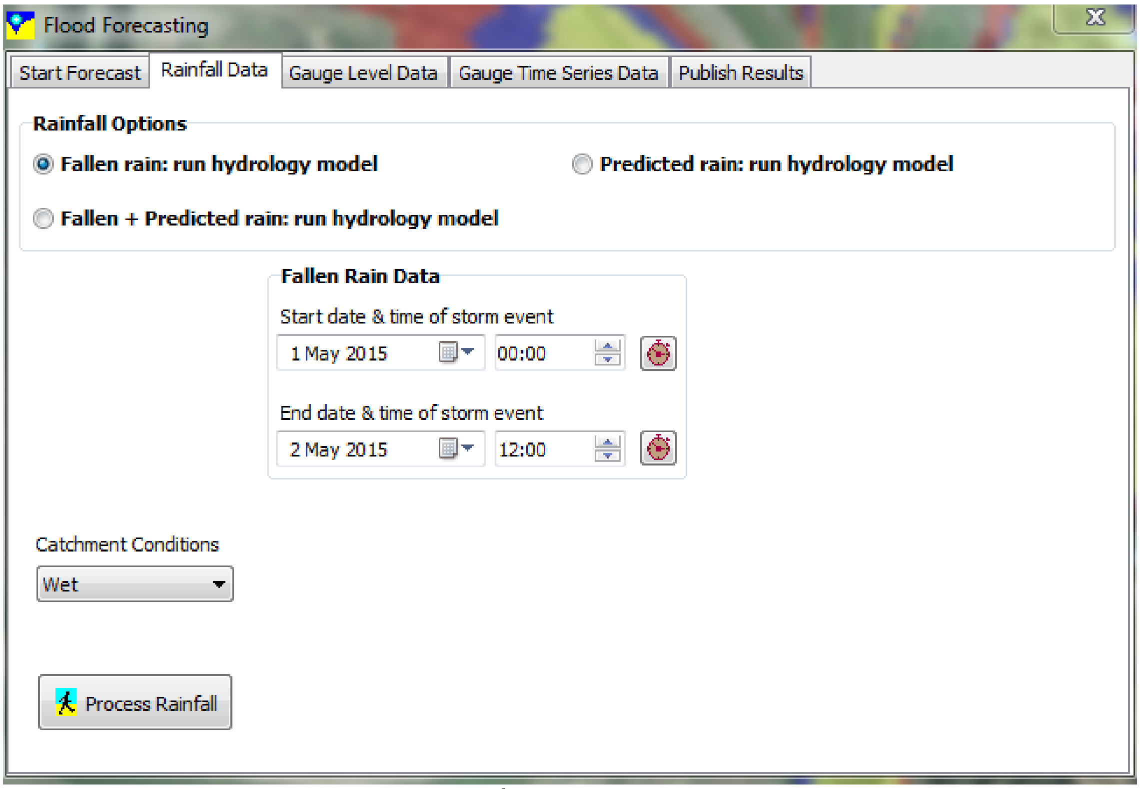

Figure 24. Fallen Rain only 12am 1st May 2015

Figure 25 below shows the final rain fallen forecast used (only 3 hours before the peak of the flood event) and would be used for final evacuations on border line properties and any road closures that were being monitored.

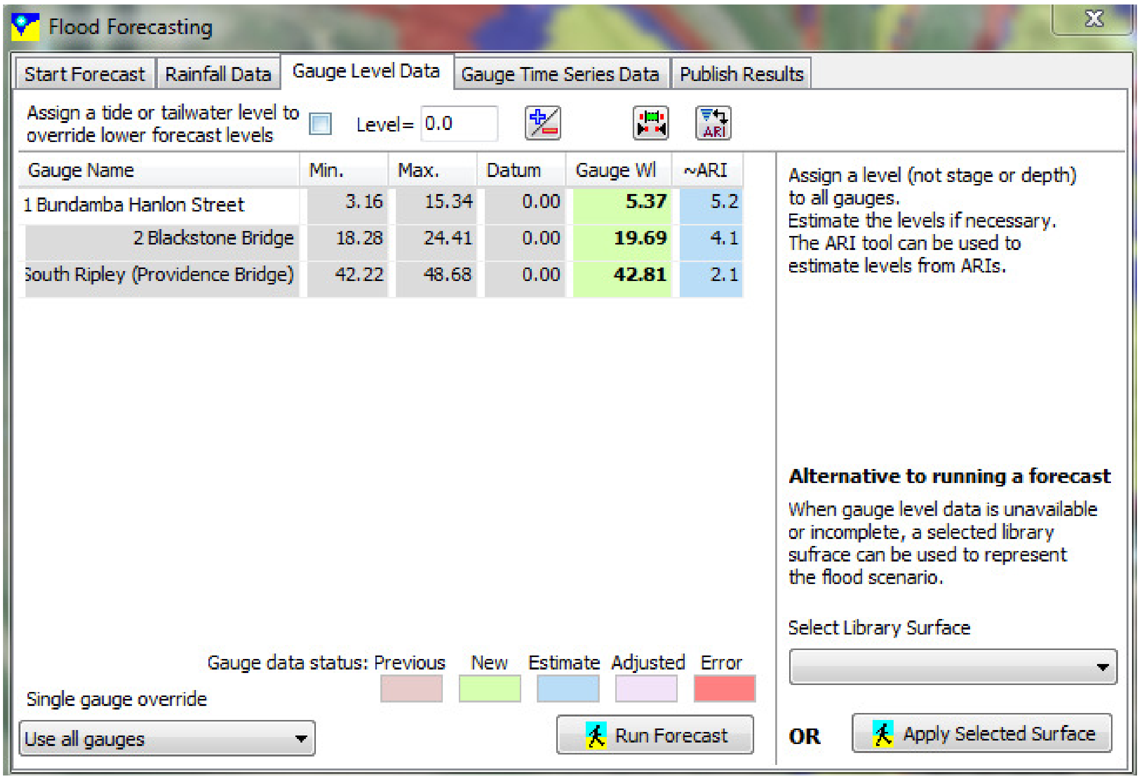

Figure 25. Fallen Rain only 12am 1st May 2015 Flood Gauge Results

The final figure below shows the last forecast run on rain fallen only and shows no major flooding within the area of interest. There were some very minor inundated properties (50mm) shown on these properties, however this flooding never eventuated. This was investigated in detail and is a direct result of the creek bed representation of this area which needs further calibration investigation and refinement of the flood model terrain in detail.

Some properties in the Bundamba catchment were extremely close to inundation, reflected in the results of the forecast. These residents were evacuated already with Council staff/SES on standby in the area to assist.

Figure 26. Final flood mapping published extract.

Figure 27 below shows the actual level of the Blackstone Bridge flood gauge that is used to forecast the levels within this area of interest. As it can be seen throughout the whole forecast process, the levels are very close to the actual eventual flood level at the gauge.

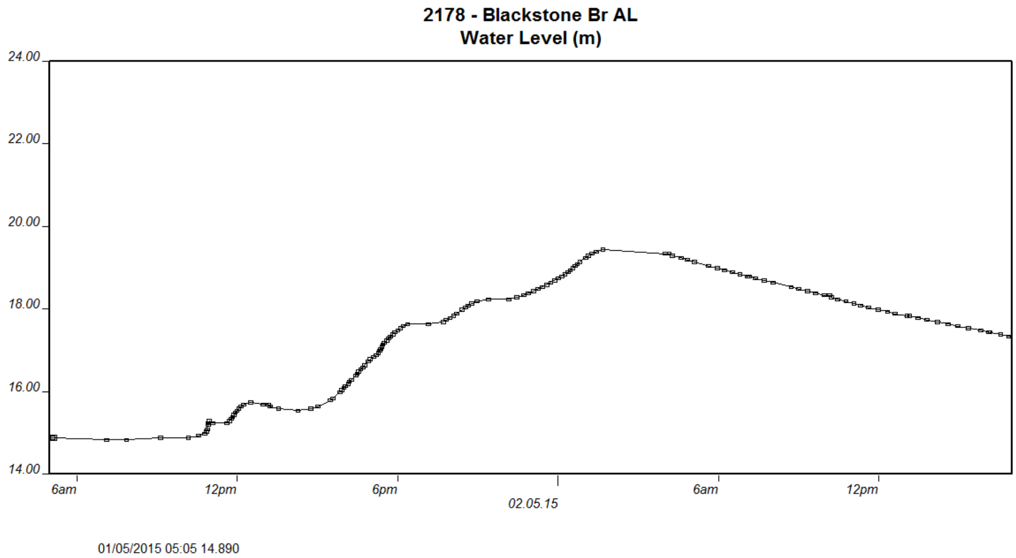

Figure 27. Blackstone Bridge Flood gauge level 19.62m

Table 1 below provides a comparison of all of the predicted rain forecasts, fallen plus predicted rain, fallen rain and the actual flood gauge height at Blackstone Bridge. Each forecast takes no longer than 30 seconds to run, which is important when multiple catchments within a Council may be at risk of flooding in one single event. As it can be seen, the waterRIDE Flash Forecast platform provides a very reliable, fast and accurate method enabling authority's longer lead times to mobilise staff and organise road closures and evacuations. Even 39 hours before the peak of the flood event, the system was able to provide accuracy of just over 0.5m. Considering the constraints associated with flash flood forecasting, it is the opinion of the authors that this level of error is more than acceptable for the warning time provided and an opportunity to plan ahead of time.

Table 1. Comparison of Forecasts

Time	Time to peak (hours)	Predicted Height (mAHD)	Actual Height (mAHD)	Difference (mm)
12pm 30th April	39	20.18	19.62	560
6am 1st May	21	19.77	19.62	150
12pm 1st May	15	19.91	19.62	290
6pm 1st May	9	19.88	19.62	260
12am 1st May	3	19.69	19.62	70

Future Improvements

As with the original flood forecasting system and subsequent operations, it has become more evident that evolution of this system will continue and improvements can be made.

Rainfall Gridded data

Ipswich City Council is currently working with BoM and other industry partners to ensure that the 1km Nowcast rainfall grids become commercially available due to the success of these trials through various parties. Whilst the current commercial data available as 6km grids often is sufficient for larger river catchments with longer critical durations, it does not provide the rainfall spread data necessary to operate on flash flood catchments.

Calibration

Council has already entered a third phase of refinement on various flood models across the city to provide a more in depth look at components that can be modified to provide a more suitable match to a higher number of verification events. Council is investigating the opportunity to calibrate numerous lower level storm events as well as improvements to the terrain and rainfall through radar opportunities.

Time to inundation

This capability currently exists through the Water Ride system and will be improved in order to provide more data with regard to time to inundation of critical infrastructure and property. This will provide Council more robust methods of using SES and road crews to provide timely and prioritised road closures and evacuations. Additionally, more focus in calibration needs to be applied for peak timing across a variety of events to provide this level of certainty which is currently being facilitated.

Flash flood system expansion

Council is currently investigating the potential and opportunity to forecast in even "flashier" catchments across the city and also in upper portions of Bundamba and Woogaroo Creek. There is also potential that all models can be run simultaneous with pre-determined alerts used to focus on catchments at risk specifically.

Conclusion

The aim of this paper was to provide an overview of the current risk of flash flooding, the opportunities that are present in this area, the strategies used to operate under these scenarios and the methods that will be employed in the future to combat the flash flood issue across Ipswich.

The system provides a very rapid means of determining what the implications of flooding are, allowing "what if" analysis to be quickly executed and evaluated. By incorporating forecast rainfall, the system effectively "buys time" during an event, allowing emergency response actions to be readied ahead of the onset of rainfall. A simple yet highly effective means of managing uncertainty provides emergency managers with relative confidence in utilising forecast rainfall datasets that inherently have large error bands the longer the forecast period.

Although, some local authorities may choose not to invest, focus and resource into the area of flash flood forecasting due to the corporate risk associated with the uncertainty of this level of operation, it is now evident accurate technology is now available, will continue to improve and provide a service that will reliable enough to act ahead of time.

Authorities should take note of the complexities and time required to build robust and accurate flood models and forecast platforms in order to facilitate a long term response to flash flood forecasting in the future. The lessons learned on the high level of complexity and time taken to get to this level by Ipswich Council should highlight the need to allocate resources immediately. This will ensure a reliable system is available in the medium term in order to respond to a flash flood event when the inevitable time comes.

References

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