QUEENSLAND'S STATE-OF-THE-ART FLOOD EARLY WARNING SYSTEM PIONEERED AT OAKEY TOWNSHIP

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Abstract

The Toowoomba region was impacted by flash flooding starting from 10th of January 2011. Whilst the flooding of the city of Toowoomba dominated the headlines, regional townships such as Oakey were subjected to flood levels that were the highest on record. About 130 homes and 10 businesses were flooded and 80 residents were evacuated including 40 from an aged care facility. In 2013, two significant rainfall events occurred causing further flooding across the region. On both occasions, a common comment from residents and emergency services was the lack of accurate and timely information to enable them to make informed decisions.

To fill this identified gap and provide emergency services with the necessary information, Toowoomba Regional Council, with the support of state government funding, has developed a state-of-the-art, $750,000 Flood Early Warning System for the township of Oakey. This system is first of its kind in Queensland, combining ten day rainfall predictions, with real time gauge data collection via Enviromon; hydrological modelling for flood forecasting using URBS; generating digital maps using waterRide™, and is connected via telemetry to a network of stream and rainfall gauges.

The system is backed up by a paper based system of flood intelligence cards and flood depth maps that can be deployed with the assistance of 'Flood Wardens' – residents located adjacent to water level gauges upstream of the township who can report flood levels and behaviour to Council's Disaster Coordination Centre.

This paper details the development of the Oakey Township Flood Early Warning System including the community consultation processes, rolling out of the gauging network, implementation of Enviromon, and customisation of URBS™ and waterRide ™

In 2013, another significant rainfall event occurred over the Australia Day long weekend. On this occasion, widespread flooding did not occur. However, emergency services were again forced to make difficult decisions around evacuation and emergency response without accurate information.

Communication with long term residents of the area revealed that transit time of flood waters from the confluence of the three upstream creek systems to the township of Oakey is approximately six hours in a large flood and approximately nine hours in a moderate flood. Subsequently a flood early warning system was conceived.

Catchment Overview

The Oakey Creek catchment is approximately 550 km^2 and encompasses the towns of Goombungee, Hampton, Cabarlah, Highfields and Meringandan. The catchment is characterised by steep headwaters transitioning to moderate slopes before meeting the flat open floodplain at Oakey Township. Oakey Creek is fed from the tributaries of Cooby Creek (when it spills from Cooby Dam), Meringandan Creek and Gomaren Creek. Constructed on Cooby Creek in 1936, Cooby Dam is a town water supply reservoir of 23,100 ML full supply volume intercepting about one-third of the Oakey Creek catchment. The spillway is ungated and therefore releases uncontrolled to Cooby Creek when above full supply level.

To the north of the Oakey Creek catchment lies the Doctors Creek catchment. The Doctors Creek catchment is approximately 140 km^2 and has similar characteristics to the Oakey Creek catchment. The catchment is shown in Figure 1.

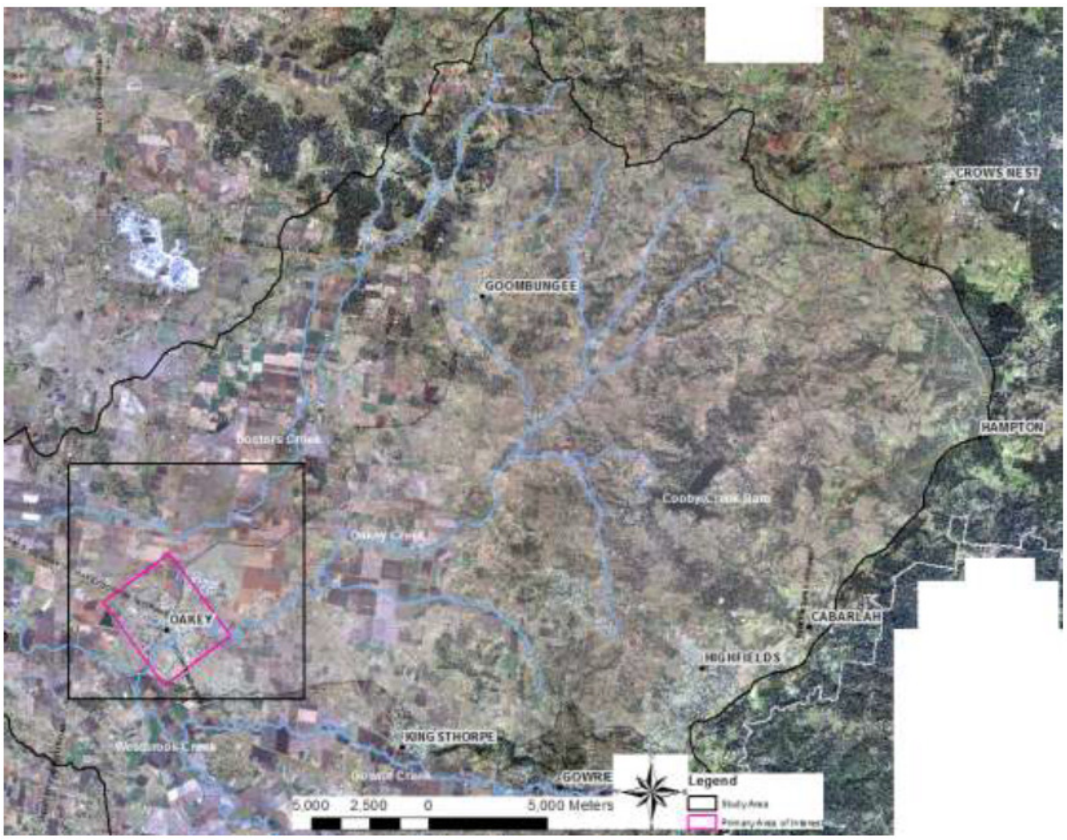

Figure 1 Oakey and Doctors Creek Catchment

Immediately downstream of Oakey township, Oakey Creek joins Westbrook Creek, and further downstream, Doctors Creek. The Westbrook Creek catchment receives the water originating in the urban areas of Toowoomba City.

Floodplain Overview

The township of Oakey is located on the lower, flat portion of the floodplain. Oakey Creek dissects the township as it runs through the centre of town in a southerly direction. A railway line bisects the centre of the township, approximately perpendicular to the direction of Oakey Creek. The railway embankment has a height of approximately one to two metres above the natural ground surface level and is a dominant feature of the floodplain in this area. The rail bridge opening is approximately the same width as the creek channel and there are no further flood relief culverts along the embankment. A low level road bridge is located immediately downstream of the railway.

Flooding in Oakey mainly occurs from flood water rising from Oakey Creek at the township and from water travelling overland. Oakey has also been reported to be impacted by backwater from Gowrie and Westbrook Creeks during major flood events. Upstream of the township of Oakey, multiple breakouts occur and flood runners convey significant flows across large distances. The 2011 flood extent in Oakey is shown in Figure 2.

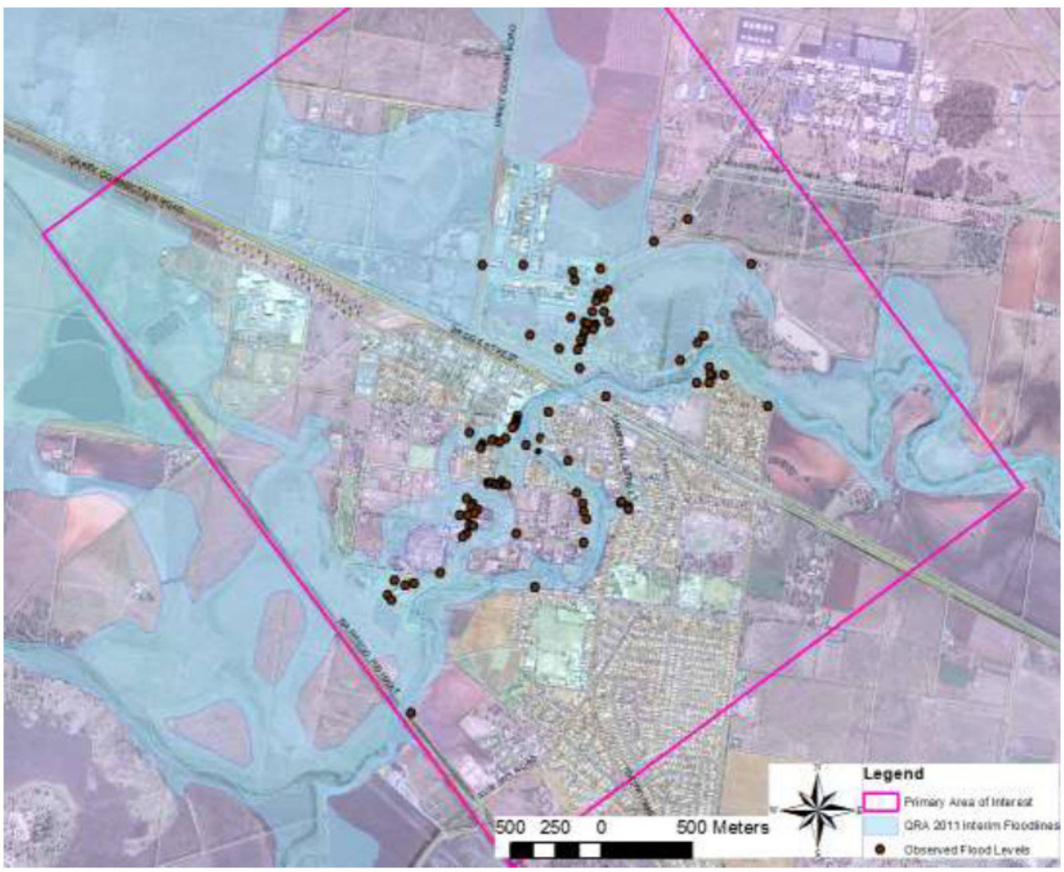

Figure 2 Oakey Township with 2011 Flood Extent

Draft results from the Oakey Flood Study scheduled for completion in 2015, show property flooding starts to occur in a 20% AEP flood event whilst widespread inundation of buildings and roads occurs in a 2% AEP flood event.

Flood Early Warning System Gauging and Enviromon Integration

The Oakey Flood Early Warning System comprises of three main components – Gauging, Flood Forecasting and Field Intelligence. The gauging consists of the installation of new water level gauges and pluviographs within the catchment.

A critical requirement of the forecasting system was that it operates in adverse conditions. It was therefore decided that the main software (URBS, Enviromon, and WaterRIDE TM) be placed on a 'virtual server'. The virtual server was set up to be on servers at TRC's main data centre and a back-up server at the auxiliary data centre five kilometres away. Both server rooms have back-up generators.

Two types of information needed to be streamed to the forecasting system; forecast rainfall information and real-time data from site sensors. The forecast rainfall was sourced from the Bureau of Meteorology (BOM). URBS was adapted to read and interpret the data. Rainfall and water level data was streamed from the rain and water level gauges.

The Oakey area had three sources of site sensors. There were a number of rain gauge sensors transmitting to the BOM, these sensors were owned by the BOM, Sunwater and TRC. TRC also had rain gauge sensors in the area attached to water storage facilities with the information transmitted running through a supervisory control and data acquisition (SCADA) system. Additionally, TRC had a number of stream height sensors scheduled for installation as part of a separate warning system.

In order to receive the information from the rain gauge sensors transmitting to the BOM, TRC would need radio receivers, decoders and an Enviromon server installed. Discussions with the BOM and the maintainer of the Sunwater gauges (Transport and Main Roads, Queensland) identified that TRC would be best served by attempting to receive signals, not only directly from the sensors, but also from the repeater stations. The result was that TRC would need to receive four different radio frequencies to be able to receive the rain gauge information. A desktop radio path survey was conducted for a number of sites, and an elevated site at Mount Kynoch was identified as the best possible location for a receiver. A radio path survey was conducted at the site and confirmed the desktop study. An existing Police relay tower and equipment shack was at the site. The Police kindly let TRC install their receiving antenna on the tower once TRC conducted a structural check on the tower. TRC then used an existing microwave link to transmit the information to the data centres. The BOM installed their Enviromon server on TRC's 'virtual server'.

The existing rain gauges in the Oakey area were typically located at water storage facilities and were not used for operational purposes. A survey was conducted of these gauges and maintenance was required to ensure reliability of the data received. The gauges' signals ran through a separate SCADA system used for water and waste control systems. That particular system was out-dated and no longer supported by the original supplier, so TRC had to engage a consultant to write scripts to extract the data in a way that would not compromise the control systems. At the time of writing this work was not yet completed.

The final source of live data was to come from new stream height sensors that were scheduled to be installed. Before these gauges were installed, the team analysed all the available (or soon to be available) data in the catchment. It was decided that the number of rain gauges in the catchment was inadequate, so five extra gauges were proposed to be installed with the river gauges. The locations of the gauges were determined based on the catchment characteristics. The final locations were adjusted so that the gauge towers would be situated on road reserves, and would have sufficient radio signal strength to reach a radio repeater at Oakey. The sensors were battery powered, with solar charging. Each site had a stream gauge sensor (Ott Bubbler) and rain gauge, both to meet BOM standards. Communications was by UHF radio signal with 3G phones backup. A script was written to import the data into the BOM Enviromon system.

The arrangement of the three systems is depicted in Figure 3.

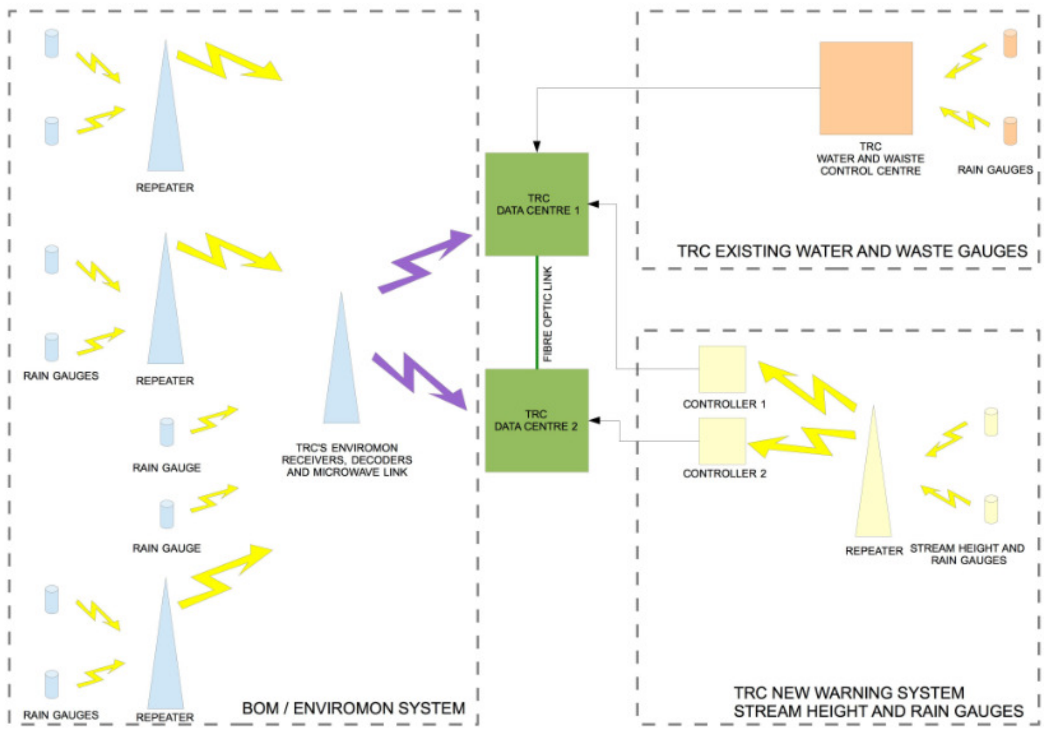

Figure 3 Communication System Diagram

All the data received from the numerous sources was stored in the Enviromon database. Any site that met BOM requirements was assigned a BOM identification number so that BOM could use the data if they so wished. Sites with non-BOM approved equipment did not receive a BOM identification number. The advantage of storing all incoming information on the Enviromon server were: the data would be filtered by the standard BOM algorithms; URBS and WaterRIDE™ already had well tested and reliable ways of extracting the data; and the Enviromon server would become the single location of the data, allowing future projects to 'tap into' with only one interface to maintain.

Once the data was in Enviromon, then URBS extracted the data it required for forecasting, and WaterRide^{TM} also could extract the data for display.

Flood Forecasting

The goal of the Oakey Flood Early Warning system is to provide advance warning to the emergency management team of a likelihood of a flood event occurring. Flood forecasting is focused on the township of Oakey and not the upstream, downstream or surrounding areas. The system is underpinned by an URBS hydrological model that can be driven by WaterRIDE^{TM}. The system may use forecast and/or real-time rainfall as input for simulations or issue mapping based on gauge heights or interpolation of modelled design flood extents.

The system is hosted on the same virtual machine as Enviromon allowing access from any of Council's offices or any remote location with the correct user permissions.

An overview of the system is shown in Figure 4.

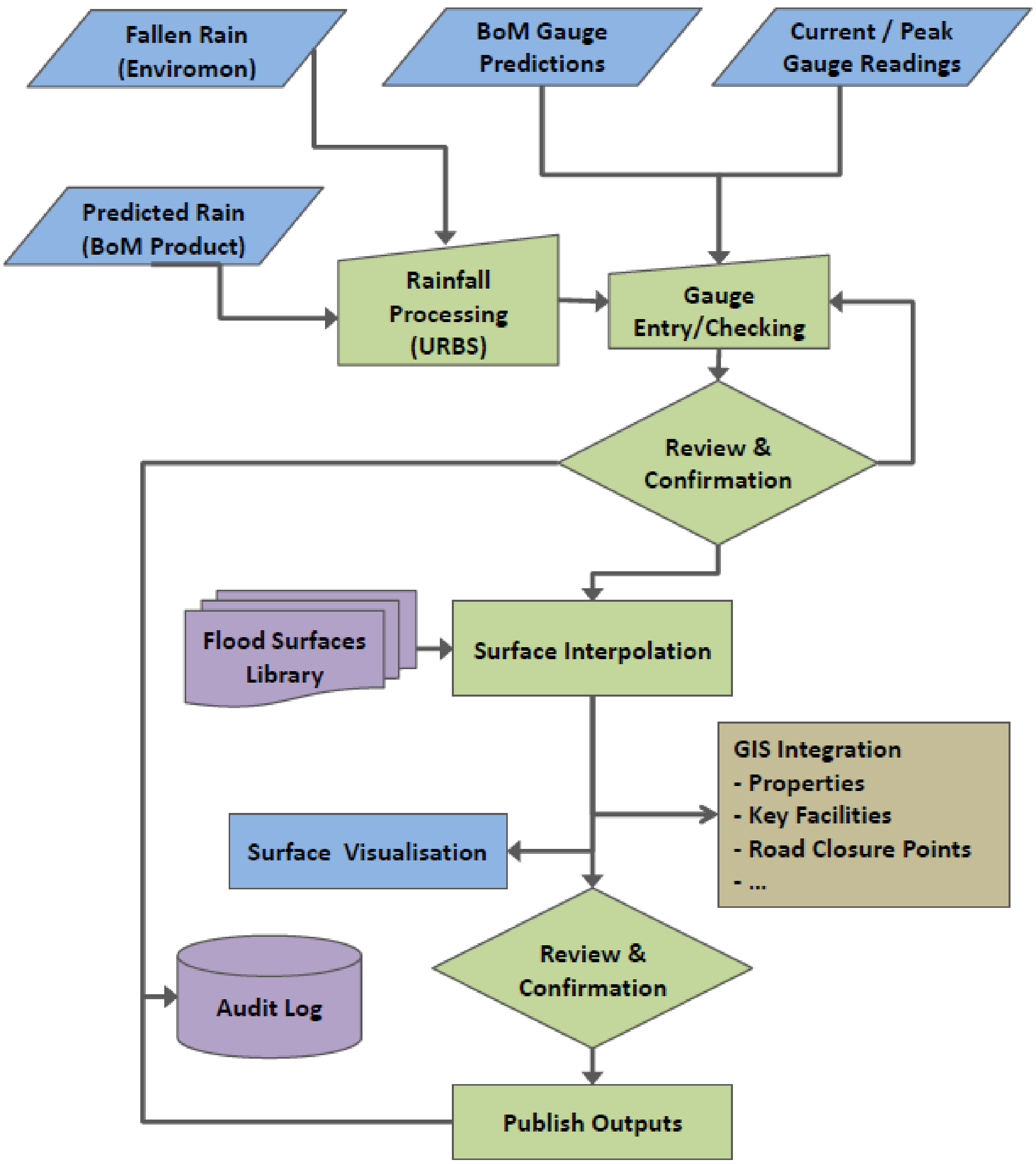

Figure 4 Overview of the Flood Forecasting System

URBS Modelling

URBS is a semi-distributed non-linear network model which has been adopted in flood forecasting systems in Australia by the Bureau of Meteorology, SEQWater and Melbourne Water Corporation and also in the Yangtze and Mekong Rivers. The Oakey Creek URBS model extends from the Oakey Creek headwaters to Jondaryan. The model was calibrated to eleven events between January 1974 and March 2014. However, the lack of good quality hydrometric data, particularly water level records at the forecast location of Oakey made calibration problematic. Ratings at most sites were relatively poor. The relatively poor quality of the rainfall and water level records and low rating reliability required a high degree of professional judgement to develop a model which could be used for real time flood forecasting. Recommendations for future improvements were also made by the model author to increase the reliability of the model when additional data becomes available

Model simulation time is measured in seconds and result files are generally a few megabytes. This ensures that performance is not compromised on a virtual computer.

Rating curves for forecast locations were developed from MIKE FLOOD modelling conducted as part of the Oakey Flood Study. Revision of the rating curves is planned to occur following the next continuous flow event within Oakey Creek.

As part of the project, URBS was customised to receive and process netCDF files – the format of the forecast rainfall product. This combined with the existing Environmon integration enables the user to access and utilise forecast rainfall directly through URBS in case other components of the system fail.

Forecast Rainfall

Forecast rainfall has been sourced from Bureau of Meteorology. Council has purchased two forecast rainfall products: PME and ADFD. The PME product includes forecast rainfall for ten days in advance generated from an ensemble of meteorological models and delivered on an approximately 40 kilometre grid. The ADFD product includes forecast rainfall for three days in advance in three hourly increments for 50 percent, 25 percent and 10 percent likelihoods. The ADFD product uses a variety of sources including the PME data and includes human validation. The ADFD product is delivered with a much finer grid spacing of approximately 4 km. Both products are delivered twice daily with increased frequency during significant rainfall events.

WaterRIDE™

WaterRIDE™ has been adopted for the Oakey system to seamlessly integrate the components of the flood forecasting through a customised, intuitive interface. Furthermore, the standard WaterRIDE™ features are retained providing an excellent communication tool within the disaster coordination centre.

The first step was to incorporate the MIKE FLOOD model results from the Oakey Flood Study into WaterRIDE™. The model results included the full suite of design simulations with some further interpolations carried out between events contained within Oakey Creek and events breaking out to the floodplain at Oakey.

Following this, as with URBS, WaterRIDE™ was customised to download and process PME and ADFD forecast rainfall products. WaterRIDE™ was also configured onsite to acquire gauge data from Environmon within Council's network. WaterRIDE™ was then further customised by Worley Parsons to run URBS simulations from within the WaterRIDE™ flood forecasting interface. As part of this customisation, various catchment parameters are able to be pre-set and selected from a drop down menu when simulating a forecast. For example, the user can select "Very Wet, Wet, Average or Dry" antecedent catchment conditions minimising the chance of the user inputting erroneous values. This enables the user to easily run various what-if scenarios. The WaterRIDE™ customised flood forecasting interface also allows the user to export flood map images and GIS files to a pre-set location.

A screen view of the interface is shown in Figure 5.

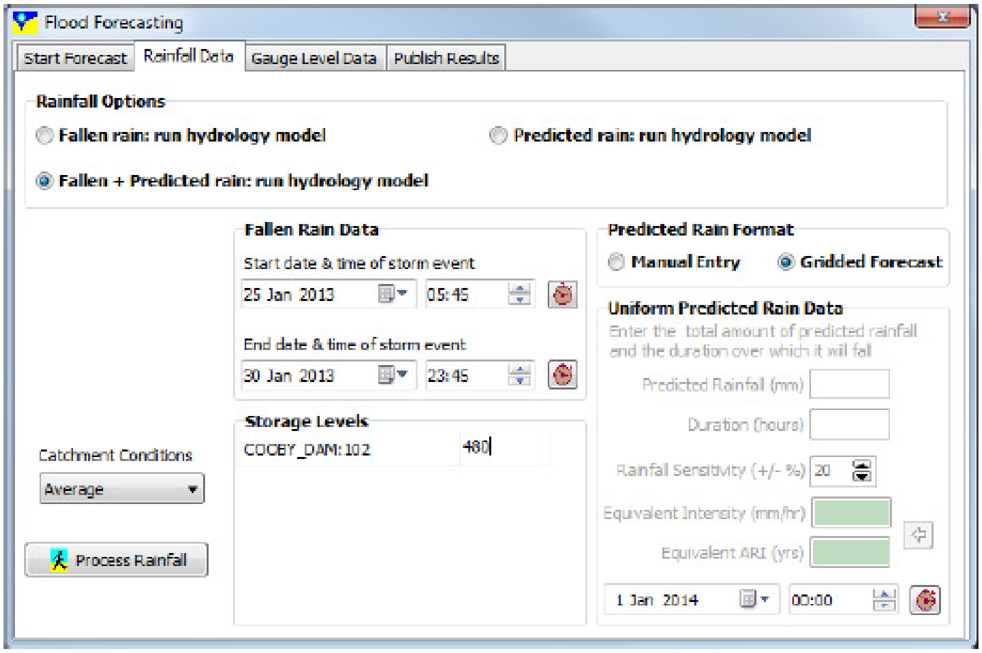

Figure 5 Screen View of the WaterRIDE Flood Forecasting Interface

Throughout the customisation process, it was important to Council that updates to the system could be undertaken by Council officers in the future without the need to involve WaterRIDE™ developers. Council officers received training in the following:

- Add and remove water level gauges and pluviographs;
- Change 2D flood model results;
- Change rating curves;
- Change URBS models;
- Change URBS model input parameters;
- Re-configure forecast rainfall downloads; and
- Re-configure export files and images.

Forecasting System Operation

The flood forecasting system is generally operated via a customised WaterRIDE™ interface but can also be operated using the URBS Command Centre. The system workflow when using WaterRIDE™ is detailed below.

At the beginning of every week, the duty officer checks that each element of the flood forecasting system is operational and produces a summary report that is emailed to the flood hazards technical team. The duty officer will also review the catchment conditions and the forecast rainfall for the week. Should a significant rainfall event appear likely, the duty officer will open WaterRIDE™ and start the flood forecasting process.

The first step of the process is to download the latest forecast rainfall data. The user can switch between the PME or ADFD forecast rainfall and choose between the various percentage likelihoods provided within the ADFD product. This generally occurs well before any rain has fallen. At this stage, animations of the rainfall forecast can be produced in AVI format for communication with the emergency management team (see Figure 6). Updated forecast rainfall issued by the BoM can then be updated within WaterRIDE™ as these are released.

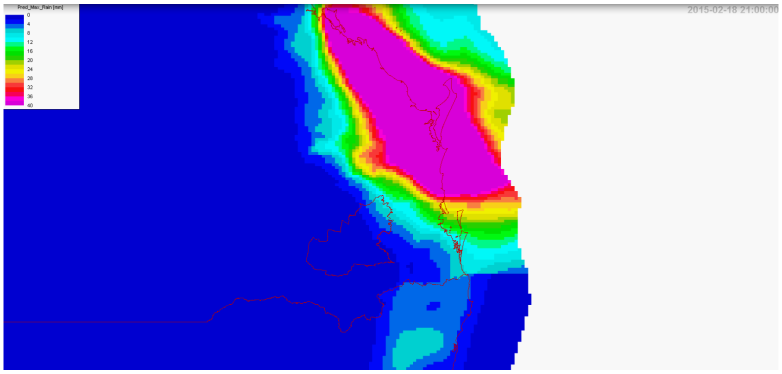

Figure 6 Forecast Rainfall (ADFD) shown within WaterRIDE

A flood forecast can be issued on the basis of forecast rainfall alone. In this instance a flood map is produced and issued to the emergency management team. The map is clearly identified as having been based on forecast rainfall alone. The other various model parameters and assumptions are also detailed on the map.

Once rain starts to fall within the catchment, WaterRIDE™ is used to import the rainfall data from Enviromon. The forecast can then be generated based on a combination of recorded rainfall and forecast rainfall, with recorded rainfall overwriting forecast rainfall. Again a map of the resultant flood can be generated or exported as an image file and GIS layers. The image file is configured to be displayed easily on the large screens in the Disaster Coordination Centre.

In addition, the system can be used to undertake sensitivity testing of the various parameters as well as undertake limited what-if analyses efficiently in a disaster setting.

Should the system fail, or where assumptions need to be verified on the ground, the field intelligence element of the system can be utilised.

Field Intelligence

Flood Wardens and Flood Boards

Flood preparedness consists of a plethora of elements (see Figure 7): flood forecasting and warning, emergency response planning and training, strengthening the resilience of the community, planning and development policies, flood proofing and community awareness raising and consultation.

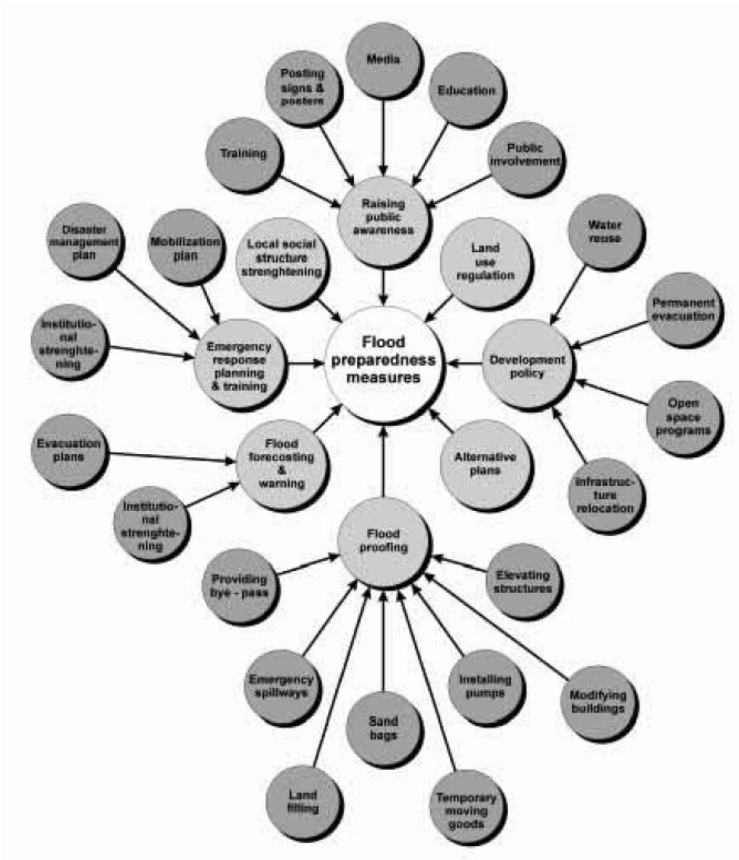

Figure 7 Components of Flood Preparedness Measures; Courtesy of Ivan Andjekovic, Technical Documents in Hydrology, No. 50, UNESCO, Paris 2001, http://unesdoc.unesco.org/images/0012/001240/124004e.pdf

This project encompassed flood forecasting, development of a warning system and raising community awareness, through community consultation throughout the planning and implementation phases. An important element of these processes included capturing local flood knowledge. This is where our Flood Wardens play an important role in assisting our flood modellers in better understanding of flood behaviour in real-time.

The Flood Wardens are volunteers who are reside near our Flood Early Warning Stations and have expressed a desire to assist with information about flood behaviour in a flood event. All Flood Wardens are long term residents who have farmed in the Oakey catchment for generations. As a result they have invaluable local knowledge of past floods. Their knowledge is based on personal experiences and stories told by relatives and neighbours. In some instances this knowledge has been supported by photographs and, more recently, video recordings.

The Flood Wardens were keen to share their knowledge about past flood events, specifically about the 1983, 2011 and 2013 flood events, and showed us where Oakey Creek burst its banks and the predominant direction of flow. We used this information to guide us in the installation of flood boards to indicate the approximate flood depth for the 1983 and 2011 flood events. These are reference points for the next flood and have been recorded in flood intelligence cards.

During a flood or impending flood event, the main tasks of the Flood Wardens are to:

1. Read the flood level boards during a flood event once the creek has broken out of its banks and report these back to our flood modellers;
2. Provide ‘ground truth’ to double check the readings returned by the flood monitoring stations;
3. Give us feedback about flood behaviour based on their observations of the creek’s behaviour.

Flood Intelligence Cards, Hardcopy Maps, and Post-Flood Survey Team

Using historical flood information and modelled data, flood intelligence cards were developed. An example of a flood intelligence card is shown in Figure 8.

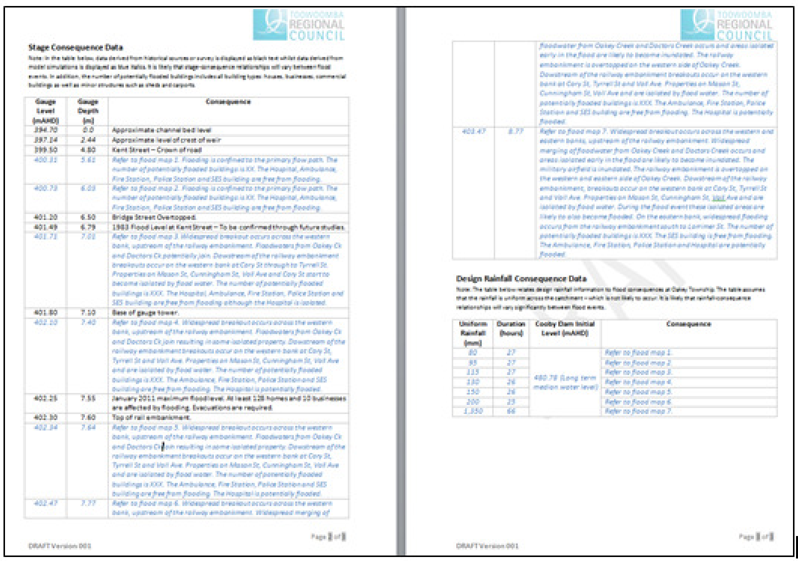

Figure 8 Flood Intelligence Cards

These cards are used as a guide to assess the possible consequences of flooding in the event of failure of the Oakey Flood Forecasting System and the Oakey Flood Early Warning System. The cards list consequences that might occur at particular gauge heights.

At locations for which modelled results are available, the flood intelligence cards also have a table of design rainfall consequence data. This information relates the design rainfall to expected flood consequences, which are linked to relevant flood maps also available in hard copy.

Users of these cards will be emergency services personnel. It is important for users to be aware of the uncertainties associated with the flood intelligence cards. It is expected that the physical environment in which the flood developed in the past is very likely to have changed; therefore not every flood of equal magnitude will result in the same consequences. As a result, flood intelligence cards are used as a guide only and as a means of recording flood behaviour over time.

Because of the dynamic nature of the physical environment, a post-flood survey team has been established which collects debris marks to determine the flood extent of each flood. This data is used to revise and update the flood intelligence cards. It is anticipated that the post-flood survey team will be equipped with an UAV (Unmanned Aerial Vehicle) to cover a larger area in a shorter period of time, thereby enabling faster and more accurate collection of debris data.

Before the installation of the flood forecasting system, the establishment of the flood modelling team and the recruitment of Flood Wardens, Oakey residents had limited understanding of the behaviour and consequences of flooding. Nor was the Oakey creek system part of the Bureau of Meteorology flood warning network. Consequently, responses to flood emergencies were limited by inadequate availability of flood intelligence.

Our volunteer Flood Wardens are part of a unique flood intelligence system that contributes to mitigating flood damage to the Oakey township and save lives. By their generosity in sharing their knowledge of past events, we could capture historical and developing flood data which in turn enabled the creation of flood intelligence cards. The Flood Wardens are also available on site to observe and provide real-time flood behaviour information to our flood modellers during a flood event. Our post-flood survey team is ready to go into action at a moment's notice to collect data which will help us better understand flood behaviour in the Oakey catchment. All these elements, the Flood Wardens, flood boards, flood intelligence cards and post-flood survey teams, along with our flood modellers constitute a powerful combination to assist with flood mitigation in Oakey, reduce damage and make the town a safer place to live.

We perceive the flood intelligence gathering as an on-going process of tuning and improving our flood warning system.

Community Engagement

Community acceptance and ownership of the flood early warning system is considered of prime importance to the success and longevity of the flood early warning system. This will ensure that the community responds to directions issued in an emergency and to continue to collect intelligence on flooding within the region.

The community engagement campaign commenced with a town hall presentation in December 2013. The purpose of the presentation was to update the community on the progress of the flood study and to introduce the flood early warning system project. Discussions held after the presentation provided further leads for obtaining flood intelligence and identified several residents that could become champions of the system. During the continued development of the system, Council Engineers and Community Liaison Officers met with these residents several times. During the meetings, these residents were provided with progress updates and information on technical aspects of the system including key challenges. In return, Council was provided with further flood intelligence and anecdotal information.

In the weeks leading up to the launch of the system, Council's engineers prepared information and Frequently Asked Questions leaflets for distribution to the township. These leaflets described how the system operates, why it was being installed, the likely warning time, some key flood terminology and how residents would be contacted in the event of a flood. Also, during this period, Council staffed an information stand at the local IGA. The information stand allowed for informal, one on one communication with residents without the need to attend a specific information session at a fixed date and time. It also allowed residents who believed they would not be able to self-evacuate during an emergency to register their details.

The launch of the system was timed to coincide with Queensland State Government's 'Get Ready Week'. A Saturday was chosen to host the launch at the new gauge tower adjacent to the creek in the centre of town. A free barbeque with associated activities including jumping castle and face painting was provided by Council. Demonstrations and trade stands were provided by Police, Fire, Ambulance, SES and Rural Fire Service. The Careflight Rescue helicopter also landed and took off adjacent to the creek during the event. The Toowoomba Regional Council Mayor formally opened the system by spraying a fire hose over the newly installed pluviograph on the gauge tower (Figure 9). The ‘rain’ generated by the fire hose could then be viewed via Environmon on laptops at the event.

Figure 9 Formal Opening of the Oakey Township Flood Forecasting System

Where to from here?

Of prime importance is to further calibrate and validate the hydrological and hydraulic models of the Oakey Catchment. This is somewhat limited due to the lack of adequate data. Council engineers are waiting for the next continuous flows along Oakey and Doctors creeks – the first since the installation of the gauges.

Council also plans to trial improving estimates of antecedent catchment conditions through the establishment of an Antecedent Catchment Index (API) for the catchment. This work would leverage off the work already conducted by Don Carroll.

Other continuous improvement activities involve:

- Installation of new pluviographs and upgrading small diameter pluviographs to 205 mm diameter pluviographs;

- Establishment of ratings and flow measurements further upstream in the network including upstream of Cooby Dam; and
- Continuing the collection of anecdotal evidence.

In addition, plans to expand the system are currently under consideration. These may include consideration of flood flows along Westbrook and Gowrie creeks as well as forecasting of inflows into Cressbrook and Perseverance dams.