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Queensland Floods Commission of Inquiry

Technical Report on the Toowoomba Flood of 10 January 2011

Prepared for Local Government Association of Queensland Ltd

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GLOSSARY

ARI	Average Recurrence Interval is the measure of the rarity of the event; it is the estimate of the interval of time between events. For a 100 year ARI event, there is a 1% chance that this event can occur in any given year. However it should be noted that planning for a 1 in 100 ARI event does not guarantee immunity for the next 100 years.
backwater effect	The effect which an obstruction has in raising the surface water upstream of it.
catchment	The catchment at a particular point is the area of land that drains to that point.
design flood	The hypothetical flood used for planning and floodplain management investigations. It is defined by the probability of its occurrence and represents a flood which has a particular chance of happening in any year.
detention basin	Stormwater management facility installed on or adjacent to a creek or river designed to reduce the risk of flooding.
discharge	The rate of flow of water measured in terms of volume over time. It is not the velocity of flow, which is a measure of how fast the water is moving rather than how much is moving. Discharge and flow are interchangeable.
hydraulic	The term given to the study of water flow in rivers, estuaries and coastal systems.
hydraulic model	A mathematical model that simulates the movement of water through creeks and other waterways, giving flood levels and flow patterns as its output.
hydrograph	A graph showing how a river or creek's discharge changes with time.
hydrological model	A mathematical model which calculates the rainfall runoff that occurs after a particular rainfall event. The primary output are hydrographs at chosen locations.
hyetograph	Graphical representation of rainfall over time.
probable maximum flood (PMF)	An extreme flood deemed to be the maximum flood likely to occur.
rating curve	Graph of discharge versus level for a given point on a stream.
runoff	The amount of rainfall from a catchment that actually ends up as flowing water in the river or creek.
stream gauge	A site along a stream where measurements of water surface elevation and or volumetric discharge (flow) are made.
velocity	The speed at which the flood waters are moving. Typically, modelled velocities in a river or creek are quoted as the depth and width averaged velocity, i.e. the average velocity across the whole river or creek section.

1 PURPOSE OF THE REPORT

BMT WBM Pty Ltd was commissioned by LGAQ on behalf of Toowoomba Regional Council (Council) to provide expert advice on flooding in relation to the devastating flood which took place in Toowoomba on 10 January 2011. This technical report provides information on:

- the circumstances and layout peculiar to Toowoomba and antecedent conditions that resulted in the flooding;
- details of what occurred in the flood;
- previous flood studies carried out in the catchment;
- flood mitigation works currently in operation and planned in the catchment; and
- limitations to flood warning effectiveness.

The Report is being specifically prepared to assist the Queensland Floods Commission of Inquiry, as requested in their letter of 28 February 2011 to Toowoomba Regional Council (Reference: 1539303).

The Report has been prepared by Neil Collins, Principal Hydraulic Engineer with BMT WBM Pty Ltd, a firm of specialist water and environmental professionals. Neil specialises in water, in particular, flooding and stormwater management. A copy of Neil's CV is included as Appendix A to this Report.

The information provided in this Report is based on a detailed investigation by Toowoomba Regional Council following the 10 January 2011 flood event. This investigation was overseen by Neil Collins and technically reviewed by Dr Ian Brodie of the University of Southern Queensland. Neil has been assisted by senior BMT WBM staff, including Flood Group Manager, Jo Tinnion. Key Toowoomba Regional Council staff who carried out the detailed work were Peter Keane, Avril Campbell and Craig McMahon.

In preparing this Report, key BMT WBM staff have visited Toowoomba on several occasions.

2 BACKGROUND

2.1 Catchment and Creek Description

Toowoomba City is located on the escarpment and on the western side of the Great Dividing Range approximately 700 metres above sea level with most of the City on the west of the divide (Figure 11-1). The vast majority of the City drains to the west (the far eastern areas drain to the east over the escarpment).There are a number of ridges and valleys within the City which divide it into six distinct catchments. Four of these six catchments, East Creek, West Creek, Black Gully and Gowrie Creek were impacted by the flood event of 10 January 2011 (Figure 11-2).

These four catchments combine to form the Gowrie Creek System within Toowoomba and cover an area of approximately 56km^2 within Council's jurisdiction. The Gowrie Creek system is at the headwaters of catchment of the Condamine River which subsequently flows into the Murray-Darling system.

There are no major water storage areas within the Gowrie Creek system although several detention basins have been constructed since the adoption by Council of the Gowrie Creek Catchment Management Strategy in 1999 as part of a broader flood mitigation strategy.

East Creek

The catchment area of East Creek is approximately 14.1 km^2 and extends from the southern extents of the City north to the CDB and westwards from the Great Dividing Range to a ridgeline historically referred to as Middle Ridge. The catchment is characterised by moderately steep side slopes with rainfall runoff travelling quickly over impervious ground to the watercourse. The waterway of East Creek itself is steep and consequently flow velocities within the stream are quite high. East Creek meets West Creek in the northern part of the CBD and forms the start of Gowrie Creek.

The catchment of East Creek is almost entirely developed with residential areas with commercial areas in the northern parts and around the CBD. Approximately 37% of the catchment is impervious (i.e. roads, roofs and other hard surfaces). East Creek is crossed at 15 locations along its length with the majority of structures having only modest hydraulic capacity. East Creek is predominately owned by Council and consists of a broad grassed area with a small concrete invert in the base of the channel.

West Creek

West Creek catchment is 16.4 km^2 and extends from the southern extent of the city north to the CBD and westwards from the Middle Ridge to a ridgeline historically known as West Ridge. The catchment is characterised by moderately steep side slopes with rainfall runoff travelling quickly over impervious ground to the watercourse. The waterway of West Creek itself is steep and consequently flow velocities within the stream are quite high.

As with East Creek, the majority of the catchment is almost fully developed with residential areas in the south, industrial uses in the central areas and commercial uses in the northern areas in and around the CBD. Approximately 37% of the catchment is impervious. The waterway of West Creek is predominantly owned by Council and consists of ponds, wetlands and detention basins in the southern sections and concrete lined channels in the northern sections adjacent to the industrial and commercial areas. West Creek is crossed at ten locations along its length with the majority of structures having reasonable hydraulic capacity.

Black Gully

The catchment area of Black Gully is located north of the CBD and has an area of approximately 6.4 km^2. It extends westwards from the Gowrie Creek confluence at North Street to Toowoomba Airport. The catchment is characterised by moderately steep side slopes with rainfall runoff travelling quickly over impervious ground to the watercourse. The waterway of Black Gully itself is steep and consequently flow velocities within the stream are quite high.

The catchment is fully developed with mostly with residential areas with industrial areas in the eastern parts near Gowrie Creek. Approximately 32% of the catchment is impervious. The Black Gully waterway is under Council ownership and consists of a broad grassed area with a small concrete invert.

Gowrie Creek

East Creek and West Creek converge to the north of the CBD and the catchment area of Gowrie Creek extends from this confluence northwards to the Wetalla Water Reclamation facility. The catchment is characterised by moderately steep side slopes with rainfall runoff travelling quickly over the impervious ground to the watercourse. The waterway of Gowrie Creek itself is steep and consequently flow velocities within the stream are quite high.

The catchment area is 18.9 km^2 and the catchment is almost fully developed and a mix of residential and industrial areas. Approximately 32% of the area is impervious. Gowrie Creek is crossed at 12 locations along its length with the some of the structures only having modest hydraulic capacity. The Gowrie Creek waterway is predominantly under private ownership and consists of a notched essentially natural creek, although substantial filling of the banks has occurred in the industrial areas.

Types of flooding

Floods can arise from a number of different sources; when the natural capacity of the creek system is exceeded, when the capacity of the urban drainage infrastructure is exceeded, or where intense rainfall results in overland flows, particularly over parts of the catchment which are imperious and/or saturated. These sources can occur in isolation, or in combination.

The nature of a flood is dependent on both the catchment characteristics and the intensity and duration of the rainfall over it. For example small, steep and/or, heavily developed catchments will tend to experience flood events of which are shorter in duration with faster moving flood waters. Furthermore rainfall of high intensity tends to be of shorter duration. Therefore a combination of the two factors can often result in a rapidly responding, highly damaging flood event. Conversely, larger more gently sloping catchments subject to prolonged lower intensify rainfall, will generally respond much slower and the flood level can remain high for many weeks or months (e.g. the Murray Darling system).

In comparison to most other creeks in Queensland, the Gowrie Creek system has a steep main channel gradient and the catchment is quite steeply sloping. Consequently Toowoomba, particularly the CBD area, has been affected by flooding on many occasions in the past due to rapid runoff from the steep catchment. Flood events in Toowoomba are typically caused by intense, short duration periods of rainfall, resulting in sheet flow off the entire catchment, including street flow from the edge of the Range down the road network into the central streams which then flow directly to and through the CBD.

2.2 Historic Development of Toowoomba and its effect on drainage

Toowoomba's history can be traced back to 1816 and at the time of European settlement, the Gowrie Creek system comprised a long, narrow swamp with a narrow watercourse through its centre. There were major changes to the swamps in the mid-1800s. In 1874 action was taken to drain the swamps, channels were cut in the swamps and complete drainage occurred over two years (WBM, 1998). This included the construction of a new drainage channel passing along the lower reaches of the West and East Creeks to their confluence at Gowrie Creek and for some distance along Gowrie Creek as well.

Development of the city continued over the next hundred years, fanning away from the railway (which itself follows the line of West Creek and Gowrie Creek). The majority of the floodplain area adjacent to the creeks has been built on, leaving little natural storage area for overland flows. The progressive development of Toowoomba has also resulted in a large number of waterway crossings being built. These crossings all have the potential to constrict flows down the creek and when blocked up with debris during a flood event, can exacerbate the flooding.

As the City developed, a main rail station and associated rail sidings have progressively expanded requiring filling and channelisation of Gowrie Creek and the lower portions of West Creek. These early works to facilitate the Railway and the development of the commercial hub of Toowoomba immediately upstream severely restricted the drainage capacity of Gowrie Creek and its tributaries.

Over the last 30 years, as our knowledge of flooding has improved, Council has carried out a number of flood studies and mitigation works aimed at improving the standard of drainage and flood immunity for the city. It is against this background of historic constraints and associated channelisation and minimisation of the creek systems that flood mitigation works and their effectiveness should be considered. Figure 11-3 shows the CBD area including Gowrie Creek and the lower reaches of East and West Creeks in the mid-1940s compared with the situation today. Encroachment onto the creek system and filling for the rail sidings is apparent.

3 WHAT OCCURRED IN THE FLOOD?

Around lunch time on 10 January 2011, the significant rainfall event that led to the flooding in Toowoomba commenced. Peak rainfall occurred around 1.30pm, with rainfall effectively ceasing by 2.30pm. The rainfall was extremely intense with over 30mm in two consecutive 15 minute periods recorded in the area. Within 15 minutes of the rainfall commencing, the creeks of Toowoomba rose rapidly and within an hour, had risen several metres. Because the intensity of the rainfall was experienced over the full catchment extent, considerable flooding occurred, not only in the main creek system, but also right across the catchment, including on roadways elevated well above the main creek system, where sheet flow up to 0.5 metres deep was observed.

The rapid rise in flood waters and overland flow depths peaked within 1.5 to 2 hours of rainfall commencing, and only 0.5 hour to 1 hour after the peak rainfall burst, giving little warning time. The flood wave is estimated to have taken about 30 minutes to travel the 6kms from the CBD to the Cranley gauge, providing an indication of the speed of the event.

All roadway crossings of East, West and Gowrie Creeks were overwhelmed by the event, becoming impassable to pedestrians and vehicles. Many pedestrians were trapped in their cars and elsewhere by the rising flood waters. Several cars were swept away as attempts were made to cross flooded roadway crossings and two people lost their lives in the flooded waters. Parked cars were swept away or inundated by the flooding and the very high velocities caused extensive damage to a number of buildings and structures along the waterway system, including to railway lines, pedestrian crossings, and trunk drainage infrastructure. In total, over 50 businesses were inundated, and more than 300 vehicles damaged.

4 CAUSES AND NATURE OF THE 10 JANUARY 2011 FLOOD

Antecedent Conditions

In the week or so prior to the 10 January 2011 event, Toowoomba received a considerable quantity of rainfall. The total rainfall measured from the Bureau of Meteorology (BoM) station at Toowoomba Airport from 2 January to 9 January was over 160mm and at the Middle Range station was over 140mm for the same period. This rainfall saturated the catchment. On the morning of 10 January 2011, an additional 11.6 mm of rainfall was received between 9am and noon further reducing the capacity of the ground to absorb the rainfall. Because of the antecedent conditions, virtually all the rainfall that occurred from noon on 10 January 2011 would have been in excess of the ability of the ground and storm drainage systems to infiltrate or convey the water away resulting in overland runoff.

During the Event

On the afternoon of 10 January 2011 Toowoomba was affected by a storm that developed at the Sunshine Coast and travelled in a south westerly direction before arriving at approximately 1pm. BoM rainfall radar images indicated the storm to have a moderate to high intensity but not a very high intensity. The BoM rainfall plots indicated that the size of the storm more or less matched the width of the Gowrie Creek system resulting in the majority of the catchment receiving the rainfall (Figure 11-4). The most intense period of rainfall lasted about 75 minutes. Figure 11-5 shows the hyetograph for Prince Henry Drive, with two 15 minute bursts of over 30mm rainfall each.

Within the creek system, the water levels rose rapidly, overtopping road crossings and spreading. Peak flood levels in East and West Creeks and the CBD occurred within 1 to 1.5 hours of the heavy rain starting. Due to the combination of a saturated catchment and the intense rainfall duration lasting for 75mins, the resultant rainfall runoff overwhelmed the storm water drainage systems which are generally designed for between a two year Average Recurrence Interval (ARI) storm or a five year ARI storm in the case of the CBD. Figure 11-6 shows the rapid rate of rise for hydrographs in West Creek, East Creek and Gowrie Creek near the confluence occurring from around 1pm.

The detention basins constructed since 1999 for the purpose of storing rainfall runoff in the West Creek catchment filled quickly and overtopped their embankments. The East and West Creeks both flow in the same direction and as result of the rainfall being coincident on both catchments the flows peaked at the same time. This dual peak resulted in a significant backwater effect at their confluence as both waterways could not discharge into the Gowrie Creek, inundating several businesses.

Within the CBD many parked cars were displaced with some being swept into the creek system causing further problems as they became trapped against bridges or culverts. Significant structural damage occurred to buildings, many collapsed and the roads and railway lines were badly damaged. Worse still, tragically two people lost their lives in the heavy flows that travelled through the city. It was reported in the Chronicle (Chronicle, 2011) that 50+ businesses were inundated and 300+ were vehicles damaged. The majority of the properties that were inundated were developed before planning restrictions requiring ARI 100 year immunity were implemented.

Almost all of the bridges and crossings on East and West Creek were overtopped and these structures further exacerbated the flooding by restricting the flow due to blockages from debris, causing further flooding upstream,

Further downstream in Gowrie Creek, all five bridges crossing the creek were overtopped, many suffering significant damage. The only crossing that remained open following the event was at the entrance to the Wetella Water Reclamation facility.

Figures 11-7 to 11-9 show the extent of the flood inundation for the 10 January event plotted against the flood outline for the design flood 100 ARI event. As can be seen, the 10 January outline exceeds the 100 ARI design flood outline.

It is likely given the catchment characteristics and the short intense rainfall duration that the "inland tsunami" that was described was the result of one or more surges in the flow triggered by West or East Creek reaching its peak flow or when the flood detention basins were overtopped.

When the rainfall subsided, the flows within the creeks moderated and continued to decline over several hours.

5 ANALYSIS OF THE 10 JANUARY 2011 EVENT

Background

The following information was gathered to help analyse the event:

- Stream flow information;
- Rainfall data; and
- Flood levels.

There is only one stream gauge in the locality of Toowoomba which is located approximately 5km downstream of the City on Gowrie Creek.

An existing hydrological model, developed in 2007 (WBM, 2007) which links rainfall to runoff was run for the 10 January event and various scenarios were tested to determine the effectiveness of mitigation measures within the catchment and to estimate the magnitude of the 10 January 2011 event.

Using the flood marks and debris levels as markers of the flood extent, some 700 survey points were used to create an inundation map for the event (Figures 11-7 to 11-9).

An existing hydraulic model (WBM, 2007) was also utilised to analyse flows against known flood levels from the event.

The purpose of the analysis was to determine the magnitude of the event by recreating the event and comparing it against previously calibrated flows and comparing the resulting flood levels with those recorded in the event.

Stream Flow Information

Flow and water level data is recorded for the Gowrie Creek system at the Cranley stream gauging station which is located in the lower part of Gowrie Creek and is calibrated and maintained by DERM. During the event of 10 January, the stream gauge was damaged and malfunctioned when water levels reached a level of 3.67m GH (ICA, 2011). As a consequence it has not been possible to obtain accurate peak water level and flow data for the event.

Using the revised rating curve (the graph of discharge versus height calibrated for the stream gauge) for the Cranley gauge developed within the WBM 2007 report, even at the level where the gauge malfunctioned, the corresponding flow was in excess of the 300m^3/s which indicates the 10 January event was greater than an ARI of 1 in 100 years.

Statistical analysis of data previously collected from the Cranley stream gauge allows the magnitude of flood events to be estimated. The flood frequency analysis carried out following the 10 January event indicates for the peak discharge calculated at the Cranley gauge (the discharge rate at the Cranley gauge was extracted from a hydrological model (WBM, 2007) due to the malfunction at the gauge) to be greater than a 1 in 100 ARI flood event, possibly as high as 1 in 400 ARI.

Rainfall Data

Council operate a series of rain gauges across the City and data from these stations and a further three gauges operated by USQ, DERM and BOM has been used to analyse the 10 January event.

Intensity Frequency Duration (IFD) data were used to compare the severity of different rainfall events, relating information regarding both the depth of rainfall and the duration of the storm. If rainfall intensity and duration are known then a measure of the event rarity can be made. This rarity is expressed in terms of ARI which gives the statistical frequency of an individual event occurring. Use of IFD data to obtain an estimate of the ARI of a storm is a standard technique from the Australian Rainfall and Runoff Manual.

The data from Council operated gauges for 10 January event are shown in Table 5.1 and the gauge locations are presented in Figure 11-2.

Table 5.1 Rainfall Data Frequency Analysis (years)

Name	Rain Total (mm)	Duration (ARI years)				
		30 minutes	1 hour	1.5 hours	2 hours	3 hours
SPS42	138	200	1000	1000	600	500
Middle Range	122.5	75	200	200	150	100
SPS52	117	200	50	50	50	50
Alderley Street	101	100	200	100	100	50
Wetella AWS	88.5	5	20	20	10	10
Picnic Tank	92.5	<5	5	10	20	30
Eastern Valley	120	75	200	200	200	100
Gabbinbar	89	10	20	20	15	10
Prescott Street	129	50	350	300	200	200

The rainfall data indicates the flooding in Toowoomba was a result of the rainfall that fell on the catchment between 12pm and 3pm on 10 January. The most intense period of rainfall occurred across the Gowrie Creek system between 1.30pm and 2.15pm.

For five of the nine gauges the rainfall severities were greater than 100 year ARI rainfall event. The rainfall intensity was reasonably consistent across the whole of the catchment with a magnitude in the order of a 1 in 200 to 1 in 300 year ARI for a one hour duration storm event.

The rainfalls with the greatest intensities occurred in a northeast-southeast bank across the centre of the catchment (ICA, 2011) and included the CBD.

The hydrological model was used to calculate the runoff for the Gowrie Creek system and hence the associated discharges within the waterways at discrete locations along each of the creeks using the rainfall data recorded on 10 January. This data was then compared with existing discharge data obtained for the design flood events previously modelled in the WBM 2007 study. The 2007 study estimated the discharge rates for a range of design flood events using the equivalent design rainfall data. In the absence of actual stream gauge data for the peak flow, this model has been used to estimate the discharge rates for the 10 January event using actual rainfall data.

To provide validation of the results obtained from the hydrological model, the existing hydraulic model (WBM, 2007) was independently run and discharge rates were estimated using recorded flood levels from the 10 January event at key locations, such as bridges. The discharge rates calculated from both exercises showed good correlation in terms of magnitude of the discharges through the city.

The results of hydrological and hydraulic analyses are presented within Figures 11-10 to 11-12.

Given that the actual rainfall data was in excess of the 100 year ARI event, the model has shown an estimated discharge much higher that the 100 year ARI.

The results for West Creek also include a comparison of the case whereby the detention basins which were constructed in 1999 were not in place. It can be seen that the detention basins have the affect of reducing the discharge, if they were not in place, the calculated discharges are higher.

Figure 11-6 shows three hydrographs, which have been extracted from the hydrological model for the 10 January event. The hydrographs clearly indicated a very rapid rise in discharge through the Gowrie Creek system from 1pm onwards.

Flood Levels/Extents

Using the flood level data gathered by Council which showed the flooding occurred as a relatively narrow band of inundation some 50-100m on either side of East, West and Gowrie Creeks, the greatest width of flooding was 700m around the junction of the creeks (ICA Hydrology Panel 2011)

Figures 11-7 to 11-9 show the flood level data inundation map along with the previously calculated 100 year ARI and 500 year ARI events. The 10 January inundation is beyond the 100 year inundation extent in all locations.

6 PREVIOUS FLOOD INVESTIGATIONS AND FINDINGS

Issues associated with flooding in Toowoomba, particularly the CBD area have been well documented for over a century. As a result Council has periodically commissioned studies examining the issue. Previous studies include:

- West Creek Flood Retardation and Improvement Study (Sinclair Knight and Partners, 1987);
- Gowrie Creek Flood Study (Creedon Reid and Associates, 1988); and
- Study to Underground West Creek to Facilitate Toowoomba CBD Revitalisation (Sinclair Knight Merz 1995).

The most recent studies completed in the area are the Gowrie Creek Catchment Management Strategy (WBM 1998), the Gowrie Creek System Flood Risk and Mapping Study (WBM 2007) and Toowoomba Regional Planning Project Flood Study Options Report (2009). These studies and their recommendation and implementation actions are described in more detail below.

Gowrie Creek Catchment Management Strategy, WBM 1998

Following a significant rainfall event in 1996, Council commissioned the development of the Gowrie Creek Catchment Management Strategy (GCCMS). This strategy examined a wide range of storm water related issues including flooding, erosion, water quality, public access and re-vegetation. The Strategy was presented to Council in 1998 and subsequently adopted by Council. In relation to flooding, it recommended the construction of flood detention basins in East and West Creeks and Black Gully to manage flooding within the CBD and also aid in reducing stream erosion in Gowrie Creek. The Strategy estimated the cost of the implementation to be $36M and based on Council's resource availability, the estimated programme for completion of the recommendations was 25 years.

Gowrie Creek System Flood Risk and Mapping Study, WBM 2007

Unlike the GCCMS, this study concentrated solely on flood risk and the accurate mapping of design flood events. The study included the refinement of previously development hydrologic and hydraulic models by calibrating them against previous flood events. The study investigated possible flood mitigation measures (e.g. detention basins) to control flooding events up to and including the 100 year ARI flood.

The study mapped five design flood events: 20, 50, 100, 500 and Probable Maximum Flood. Assessments were undertaken of property inundation, road crossing immunity and critical facilities access in Toowoomba. With the completed flood mapping extents for the different design flood events, three criteria were assessed to determine potential flooding problems within the catchment:

1. Property inundation – best management practice of 100 year ARI immunity;
2. Highway crossing immunity, best management practice of 50 year ARI immunity; and
3. Critical facilities (hospital) access, best management practice of 500 year ARI immunity.

The issues identified for each criterion are:

- The study identified that a total of 152 properties would be affected by the 100 year ARI event;
- Ruthven Street on East Creek and James Street on West Creek have 50 year ARI immunity;
- James Street on East Creek has low immunity and requires to be upgraded;
- Critical facilities access is achievable in 500 year ARI event;

Council adopted the study in 2007, including the following recommendations;

- Planning controls to limit impact of 100 year ARI flooding;
- Road crossing updates to provide 100 year ARI immunity for James Street;
- Channel improvements;
- Detention basins; and
- On site detention controls for new development.

The study also recommended that Council should investigate methods for collecting flow data and flood levels and undertake the preliminary design of the detention basins recommended. These actions are currently being undertaken within this financial year.

Toowoomba Regional Planning Project Flood Study Final Report, 2009

This study was commissioned to inform and give the Regional Planning Project guidance and advice on the applicability of existing flood and other waterway data for use in the Planning Scheme. TRC are currently undertaking to develop one integrated Planning Scheme policy for the entire regional council area.

In developing or modifying planning schemes, State Planning Policy 1/03 sets out specific requirements in ensuring the natural hazards are adequately considered when making decisions about development. The State's position is the appropriate flood event for determining a natural hazard area is 100 year ARI. The requirements were summarised and three options in relation to developing planning controls associated with flooding were considered as described below:

1. undertaking comprehensive studies for the entire area;

2. incorporating existing information and supporting this with comprehensive studies for the remaining area;

3. using existing information and generating pseudo flood data for the remaining areas.

The study recommended option 3, maximising the use of existing flood information and accepting the incorporation of pseudo flood data within the new planning scheme.

The draft Planning Scheme has subsequently been prepared incorporating the recommendations and has been submitted for the first State's Interest Check.

7 FLOOD MITIGATION IMPLEMENTATION

Work on implementing the GCCMS commenced in 1999 and five detention basins have been constructed, four on West Creek and one on East Creek as flood mitigation measures. Channel improvement works within the CBD were also completed.

West Creek detention basin works:

- Murray Clewett Environmental Wetlands, cost $1.3M, 1999
- Between Spring Street and Stenner Street, cost $1.7M, 2000
- Between Stenner Street and Alderley Street, cost $1.9M, 2002
- South Street and Long Street, cost $2.2M, 2008

Other West Creek Works:

- 600m channel improvement, cost $12.1M , 2007

East Creek detention basins works:

- On park – NE corner of Ramsay Street and Spring Street, $0.6M, 2004

Following adoption of the Gowrie Creek Flood Risk and Mapping Study in 2007, the following actions have been completed:

- Potentially flood affected property owners have been notified and surveys of flood levels of buildings have been undertaken. The revised property flood maps were issued in 2009;
- Notification message added to each affected property in the Council's property and rates system;
- Information sessions arranged for owners of potentially affected properties;
- The flood maps have been listed for inclusion within Council's Planning Scheme.

The 2007 study also refined the proposed detention basin works recommended in the GCCMS, recommending that eight in total be built. The concept design for the remaining three detention basins is currently underway and $130K has been allocated within the current financial year for additional stream gauges within the catchment.

8 FLOOD WARNING AND EMERGENCY MANAGEMENT

In order for flood warnings to be effective, there must be sufficient response time built into the warnings so that appropriate authorities can make an informed decision as to action or emergency response to take place. There will be a delay between the warning being initiated and it being received by the emergency responders and the general public. It is generally understood that for flood warnings and any associated response to be effective, a minimum of two hours lead time is needed. Research has shown that up to six hours is optimal.

The Gowrie Creek system physical characteristics combined with the occurrence of short high intensity rainfall events mean that achievement of short lead times for flood warning is extremely challenging.

9 SUMMARY OF FINDINGS

In summary, our investigation has found the following:

- The rainfall event that caused the 10 January 2011 flooding in Toowoomba was extreme, with some rain gauge stations recording 500 year to 1000 year rainfall events. The rainfall intensity was reasonably consistent across the whole of the catchment with the magnitude of 1 in 100 to 1 in 300 years for the 1 hour critical duration storm event.

- Based on an analysis of actual recorded flood heights, versus design flood heights at all stations in East Creek, West Creek and Gowrie Creek, the January 2011 flood was close to double the flow of the ARI 100 year event, the current national standard and State standard for setting development levels. None of the waterway systems of East Creek, West Creek and Gowrie Creek are in a natural condition, and the early settlement and development of Toowoomba, particularly around the main railway station, resulted in the waterways being treated as drains, and being progressively filled, narrowed and channelised. Within the CBD area, valuable real estate was developed very close to and, in some cases, upon the main waterway channels. Over the last 30 years, Council has been actively investigating the flooding potential of the Gowrie Creek system, and have been progressively implementing mitigation works with the aim of upgrading the drainage system progressively to current ARI 100 year standards.

  At the time of the 10 January 2011 flood, approximately 2/3 of the programmed flood mitigation works for the Gowrie Creek system had been implemented. Had these not been the case, flooding and the consequences of the flooding, would have been significantly worse.

- In relation to flood warning, because of the steep nature, short distance to the top of the catchment, and rapid rate of rise of the flood wave in the creek system, it is not feasible to install an early warning or evacuation system, with 2 to 6 hours being the minimum time required for effective warning and evacuation.

- The most recent flood mitigation and public awareness works commenced in 1998 and five detention basins out of a total of eight proposed have already been constructed. The remaining three detention basins are currently in the design phase. Channel improvement works within the CBD have also been completed and two major culvert upgrades carried out.

- Even if all mitigation works had been complete, because of the magnitude of the rainfall event and associated flood at being almost twice the size of the ARI 100 year design event, there would have still been significant overtopping of crossings and property damage.

10 REFERENCES

Insurance Council of Australia, (ICA) 2011 The Nature and Causes of Flooding in Toowoomba 10 January 2011,

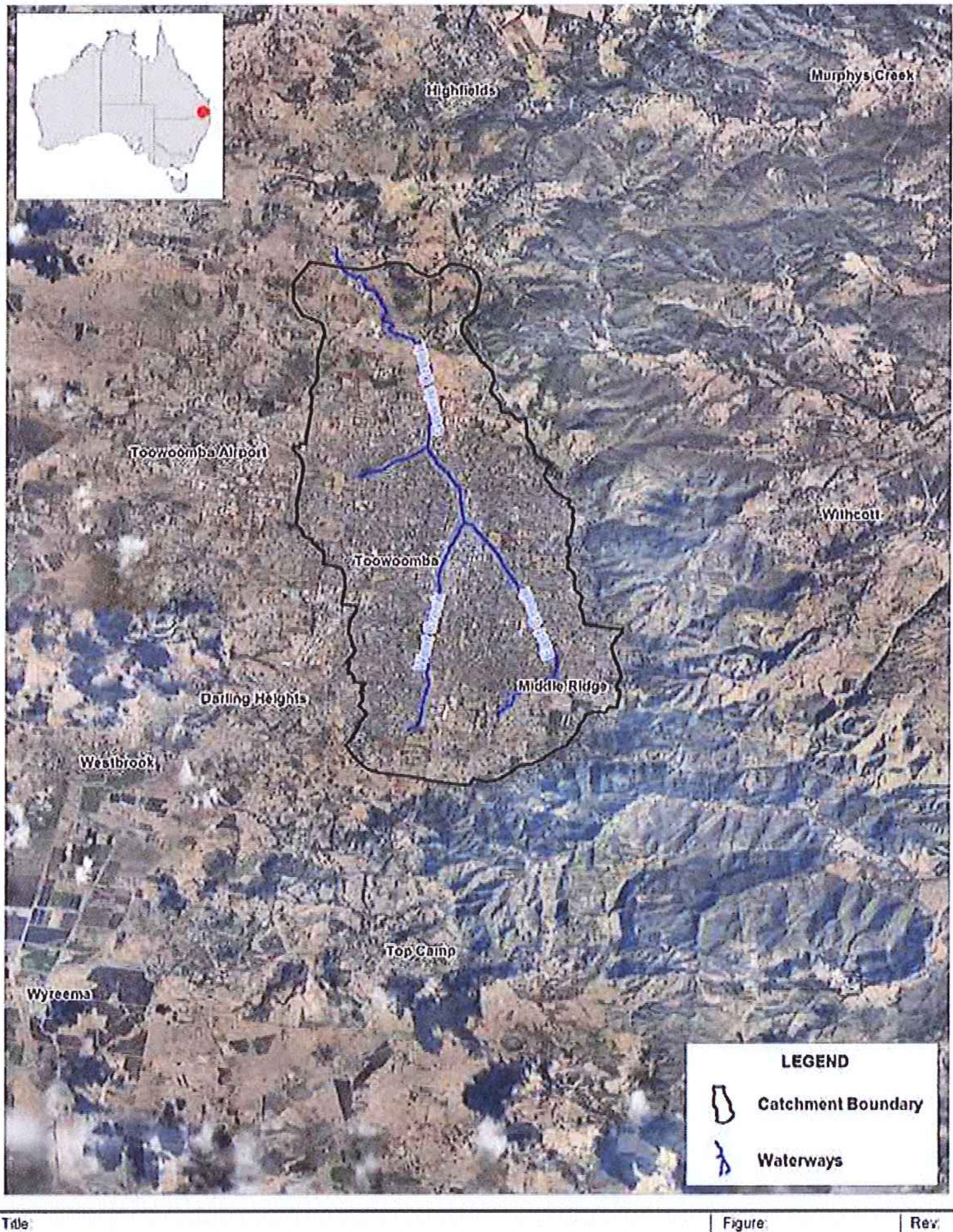
WBM Oceanics & Hassell, 1998, Gowrie Creek Catchment Management Strategy, prepared for Toowoomba City Council

WBM 2007, Gowrie Creek System Flood Risk Management Study, prepared for Toowoomba City Council

Water Technology 2009, Toowoomba Regional Planning Project Flood Study Final Report, prepared for Toowoomba Regional Council

Chronicle 2011, The 2010-2011 Flood Crisis Special Commemorative Publication, February 2011

11 FIGURES



Title: **Locality Map**

Figure: 11-1 | Rev: A

BMT WBM
www.bmtwbm.com.au

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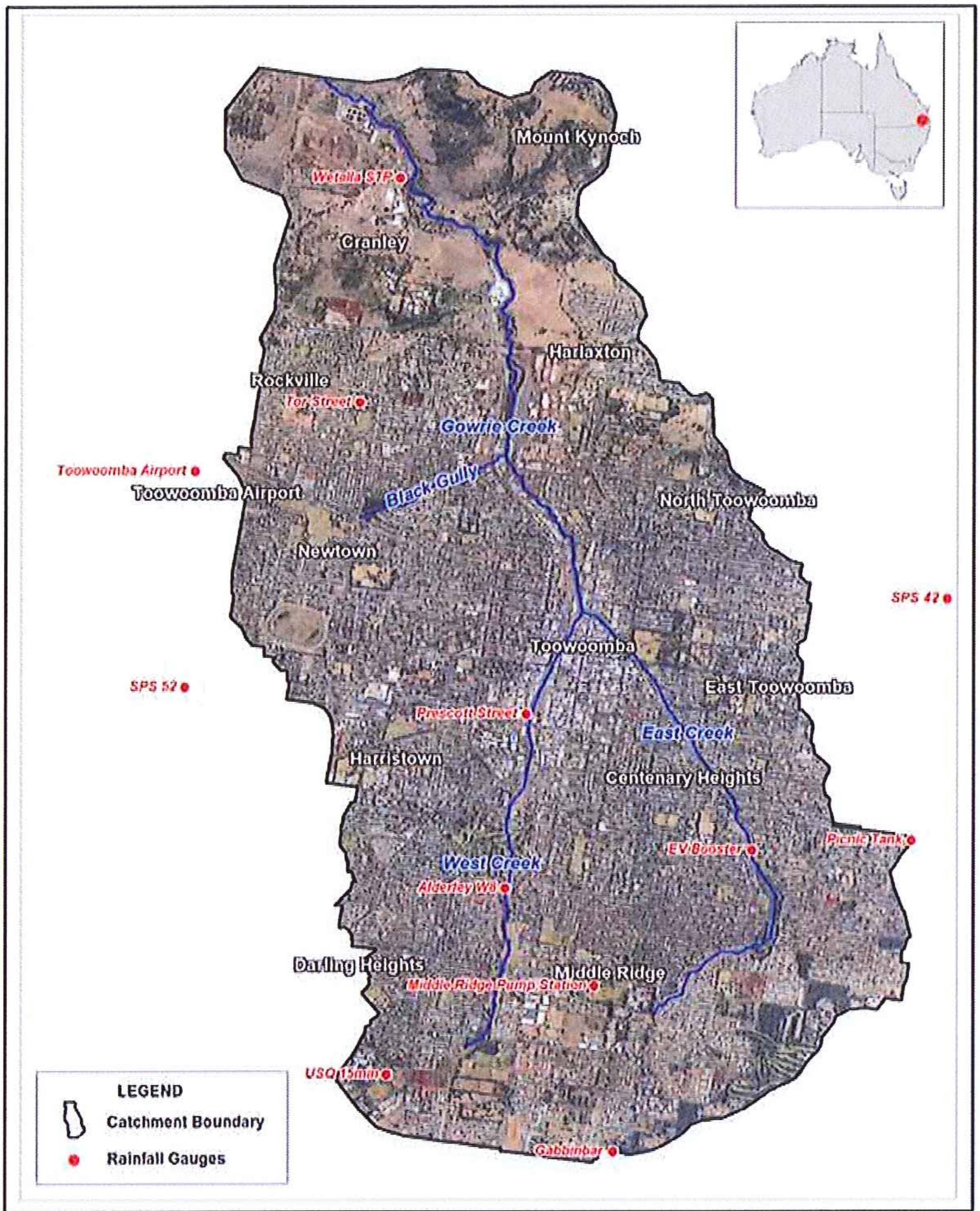

Title:
Gowrie Creek System Catchments and Rainfall Gauge Locations

Figure: 11-2

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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Approx. Scale

BMT WBM
www.bmtwbm.com.au

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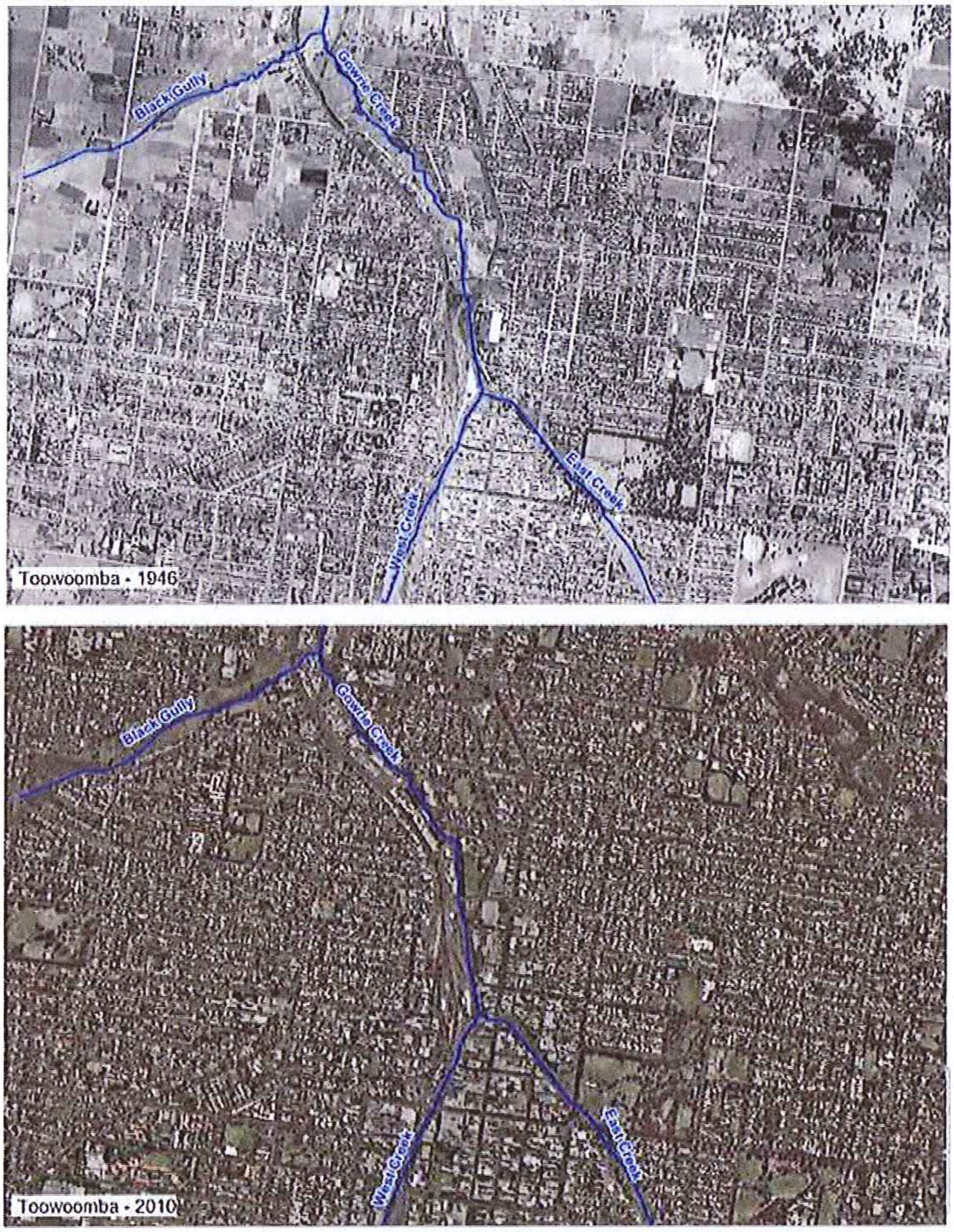

Title:

Toowoomba 1946 and 2010

Figure: 11-3

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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Approx. Scale

BMT WBM

www.bmtwbm.com.au

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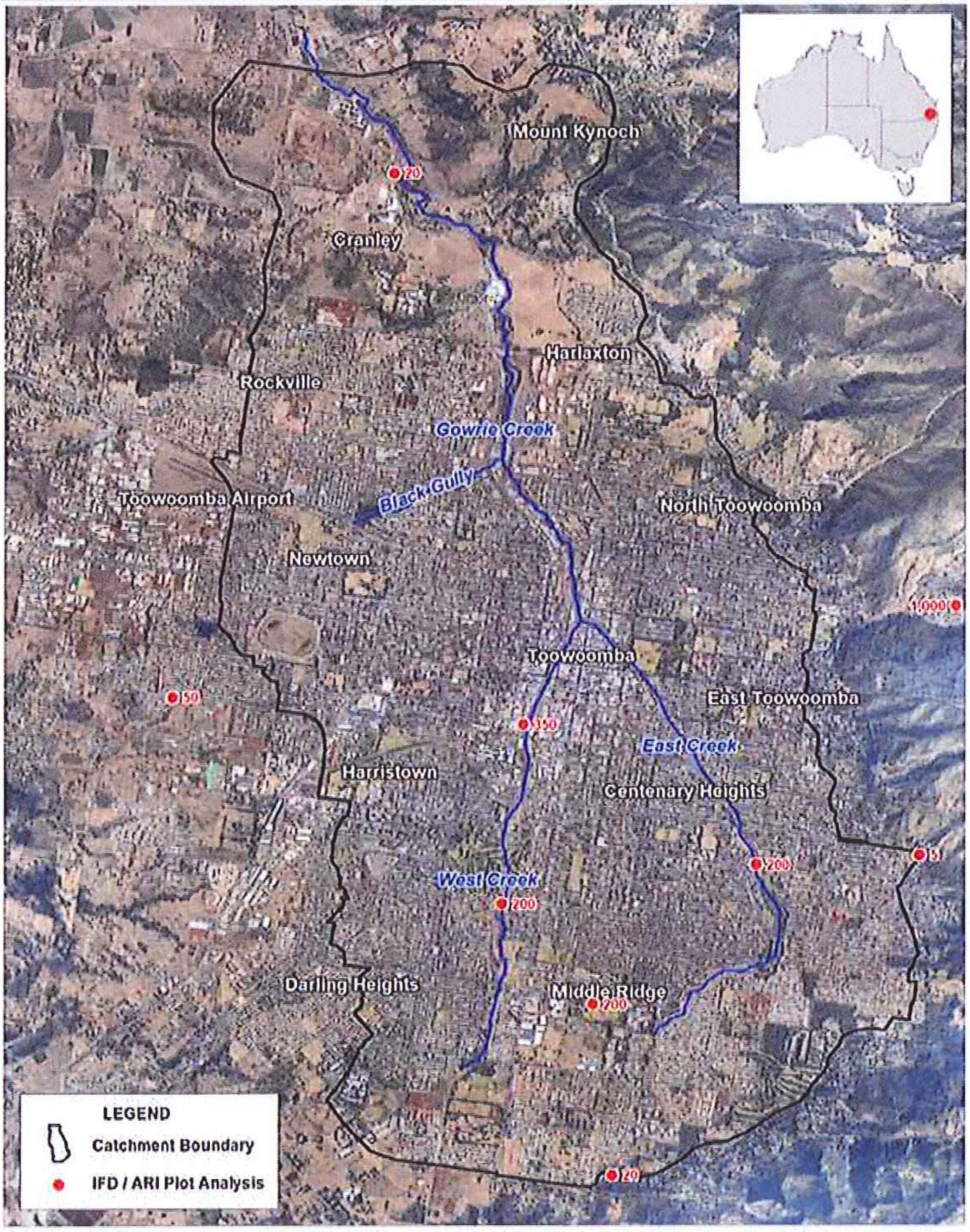

Title:
1 Hour Duration Rainfall Frequency, 10-Jan-2011

Figure: 11-4 | Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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BMT WBM www.bmtwbm.com.au

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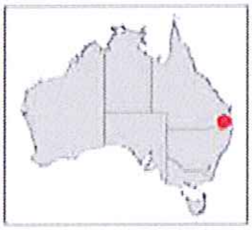

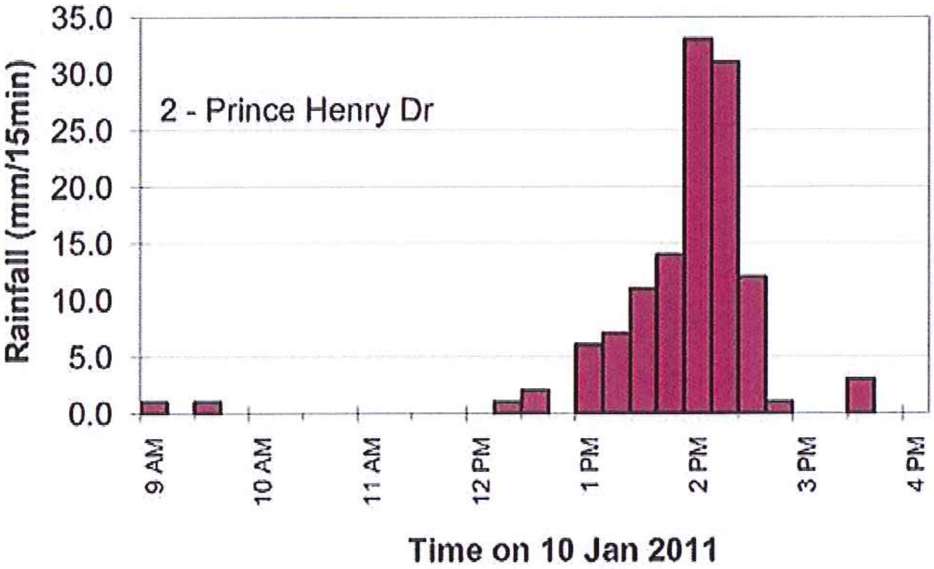

Title:
Hyetograph for Prince Henry Drive

Figure: 11-5

Rev: A

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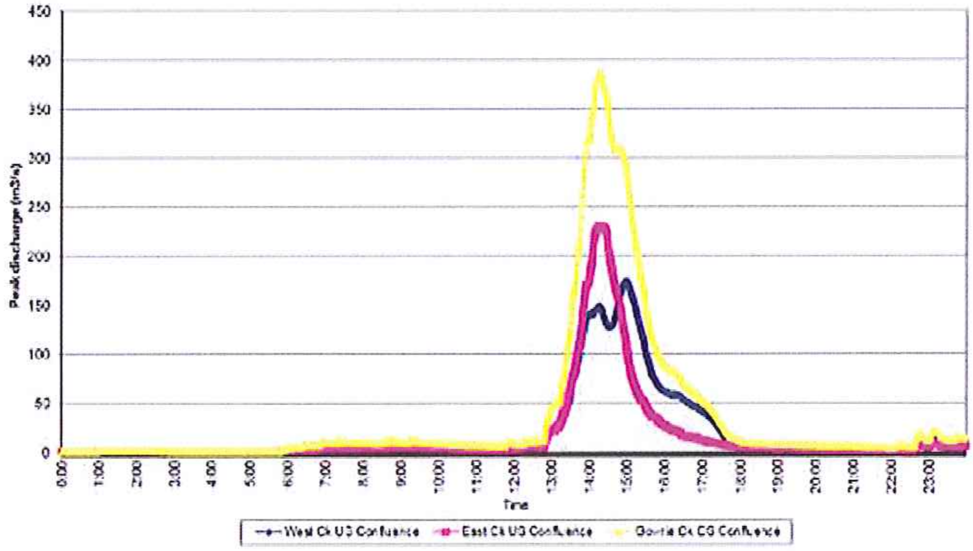
BMT WBM
www.bmtwbm.com.au

Filepath : I:\B18317_I_BRH Toowoomba JET\DRG\FLD_002_110315 Locality Map.wor



Title: **Hydrograph For Gowrie Creek System, 10 January 2011**		Figure: **11-6**	Rev: **A**
BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.	N	BMT WBM www.bmtwbm.com.au	
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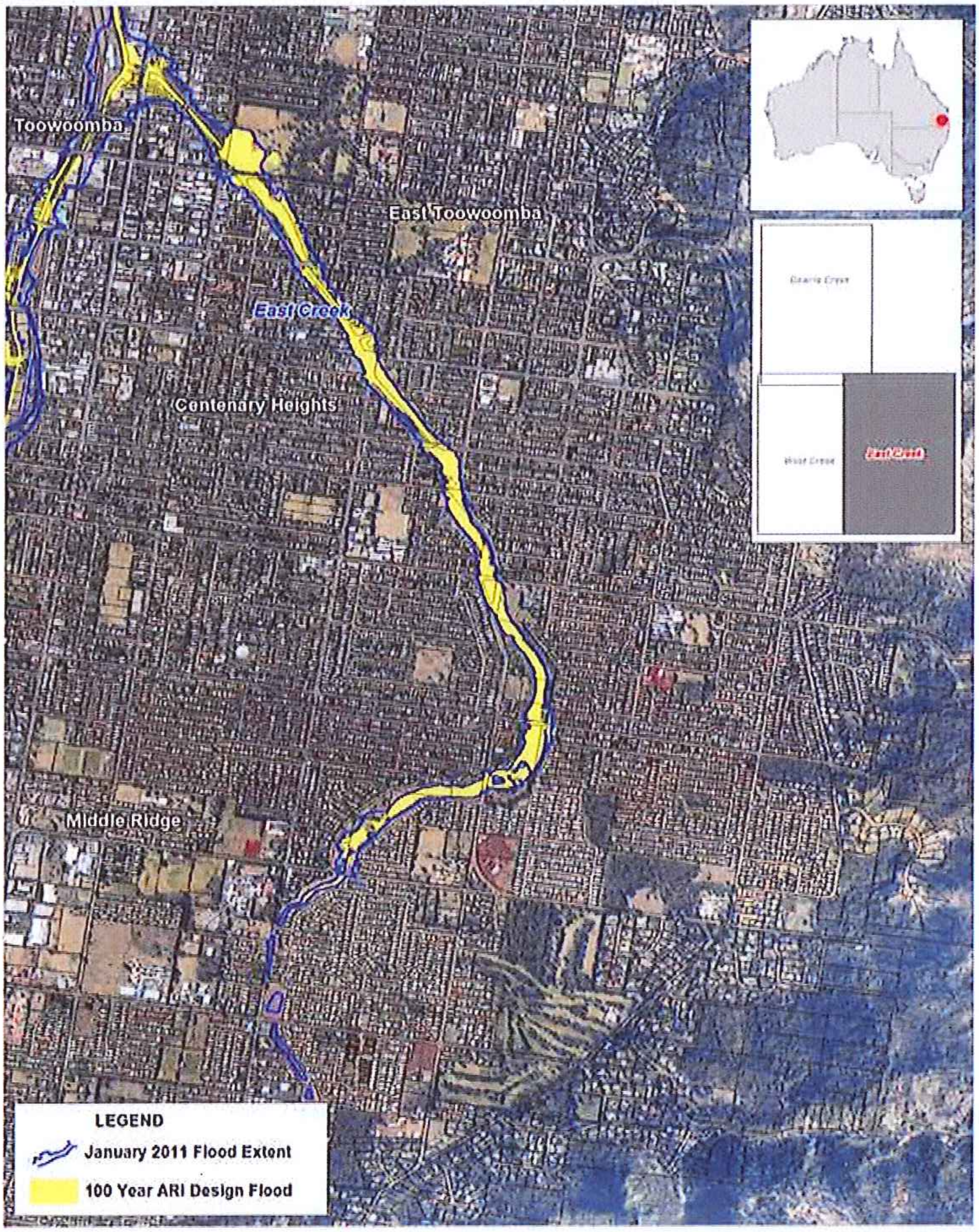

Title:

East Creek Flood Extents

Figure: 11-7 Rev: A

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Approx. Scale

BMT WBM
www.bmtwbm.com.au

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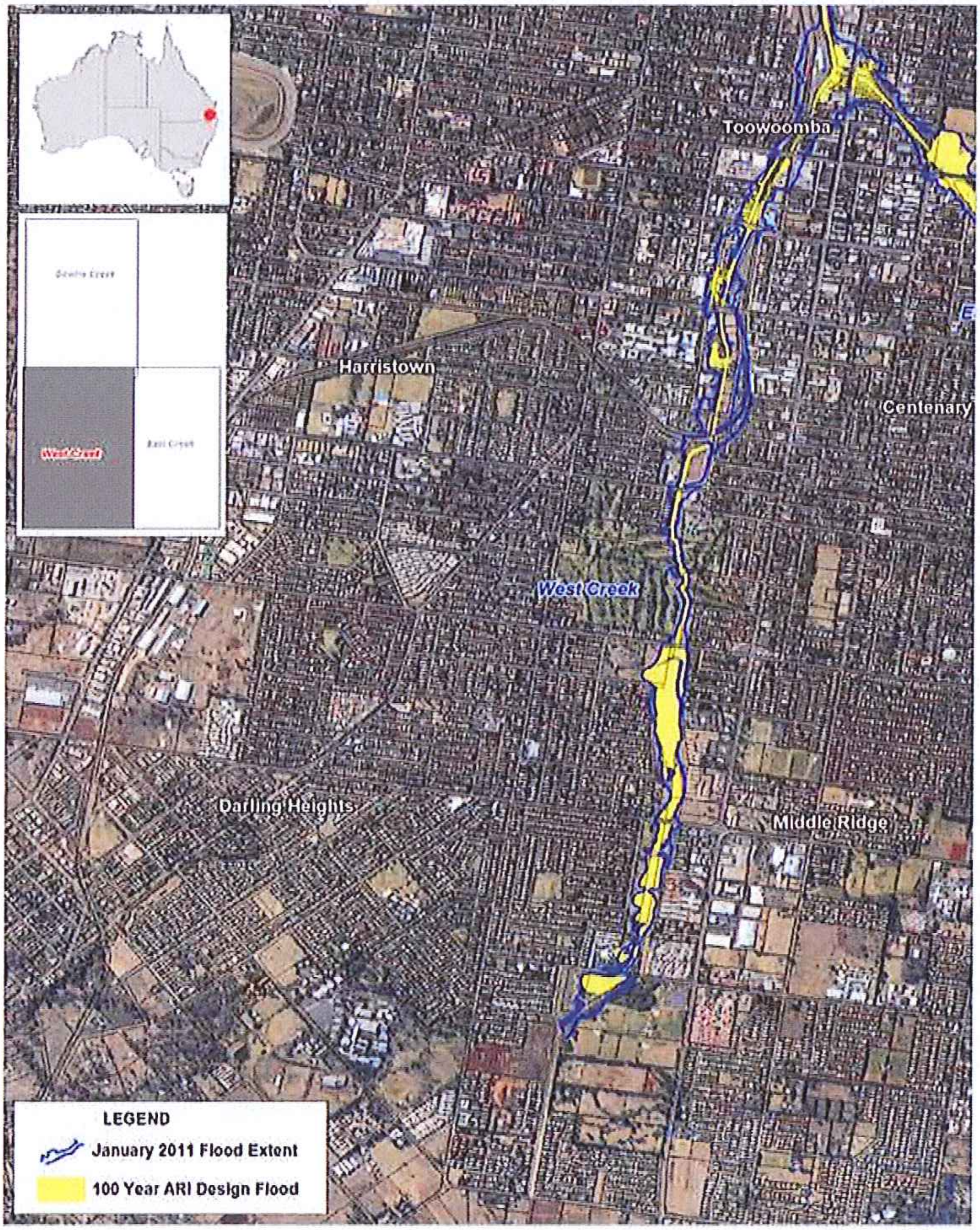

Title: **West Creek Flood Extents**	Figure: **11-8**	Rev: **A**

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BMT WBM www.bmtwbm.com.au

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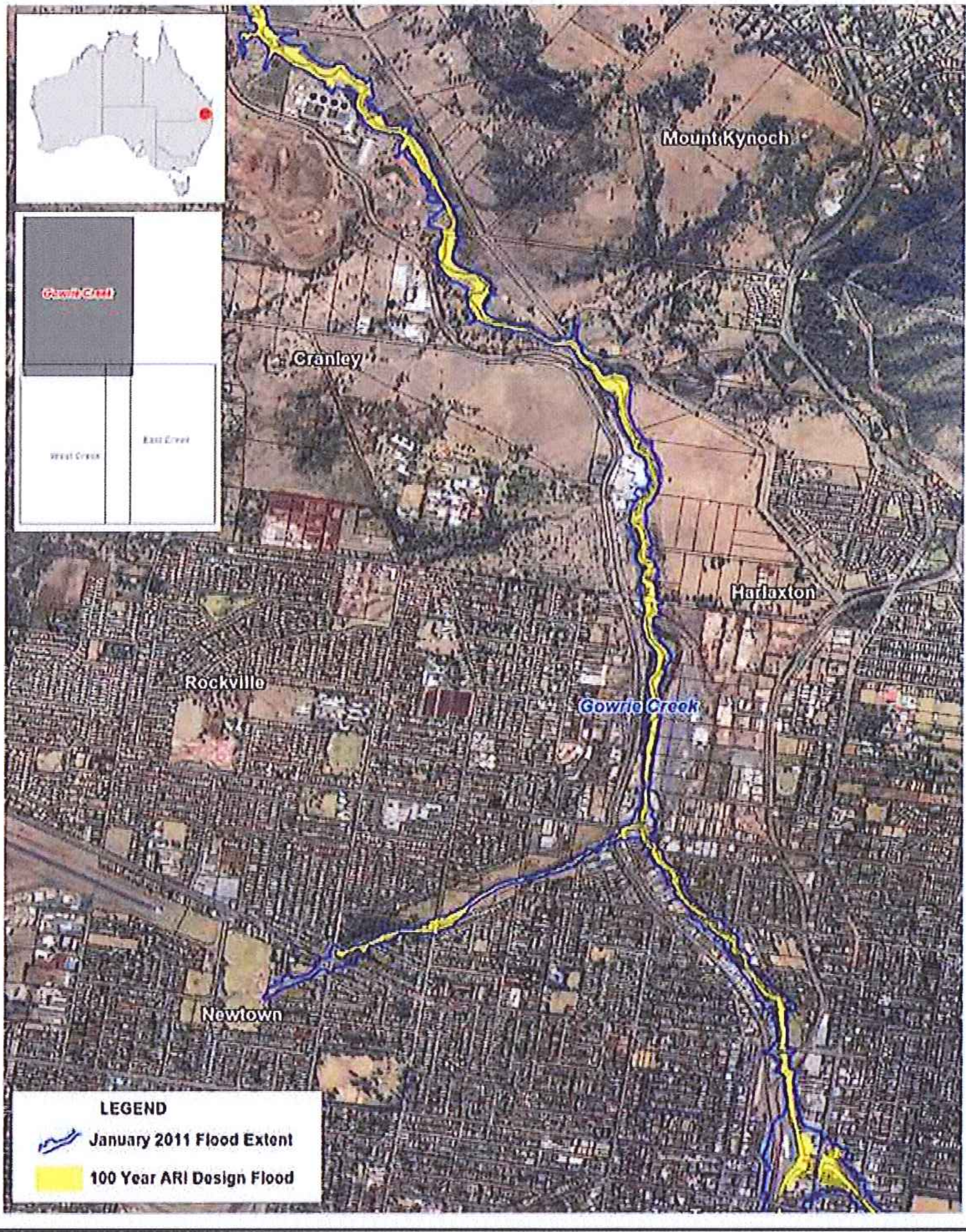

Title: **Gowrie Creek Flood Extents**

Figure: **11-9**

Rev: **A**

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BMT WBM www.bmtwbm.com.au

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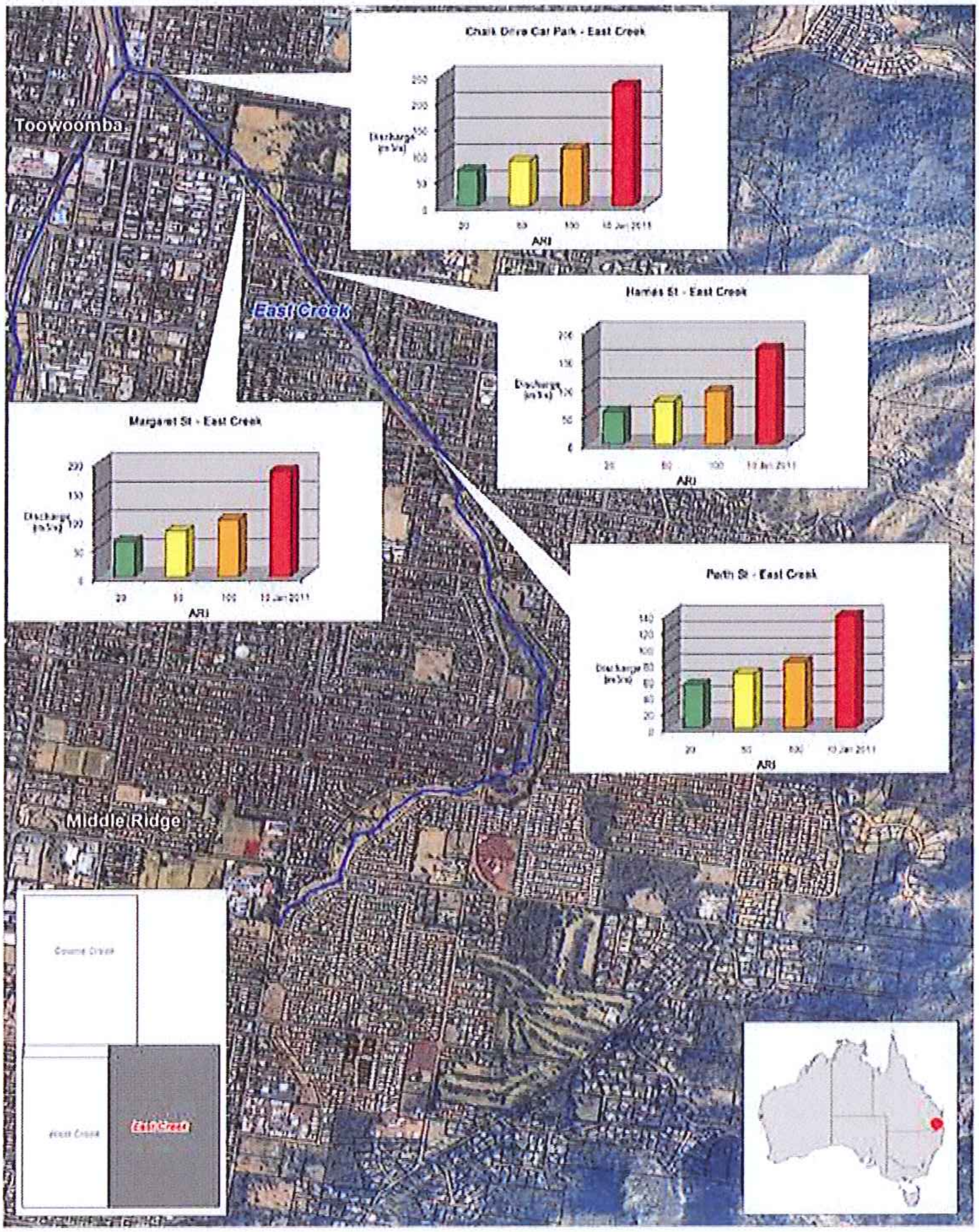

Title:
East Creek Rainfall Runoff Discharge Comparisons

Figure: **11-10**
Rev: **A**

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Approx. Scale

BMT WBM
www.bmtwbm.com.au

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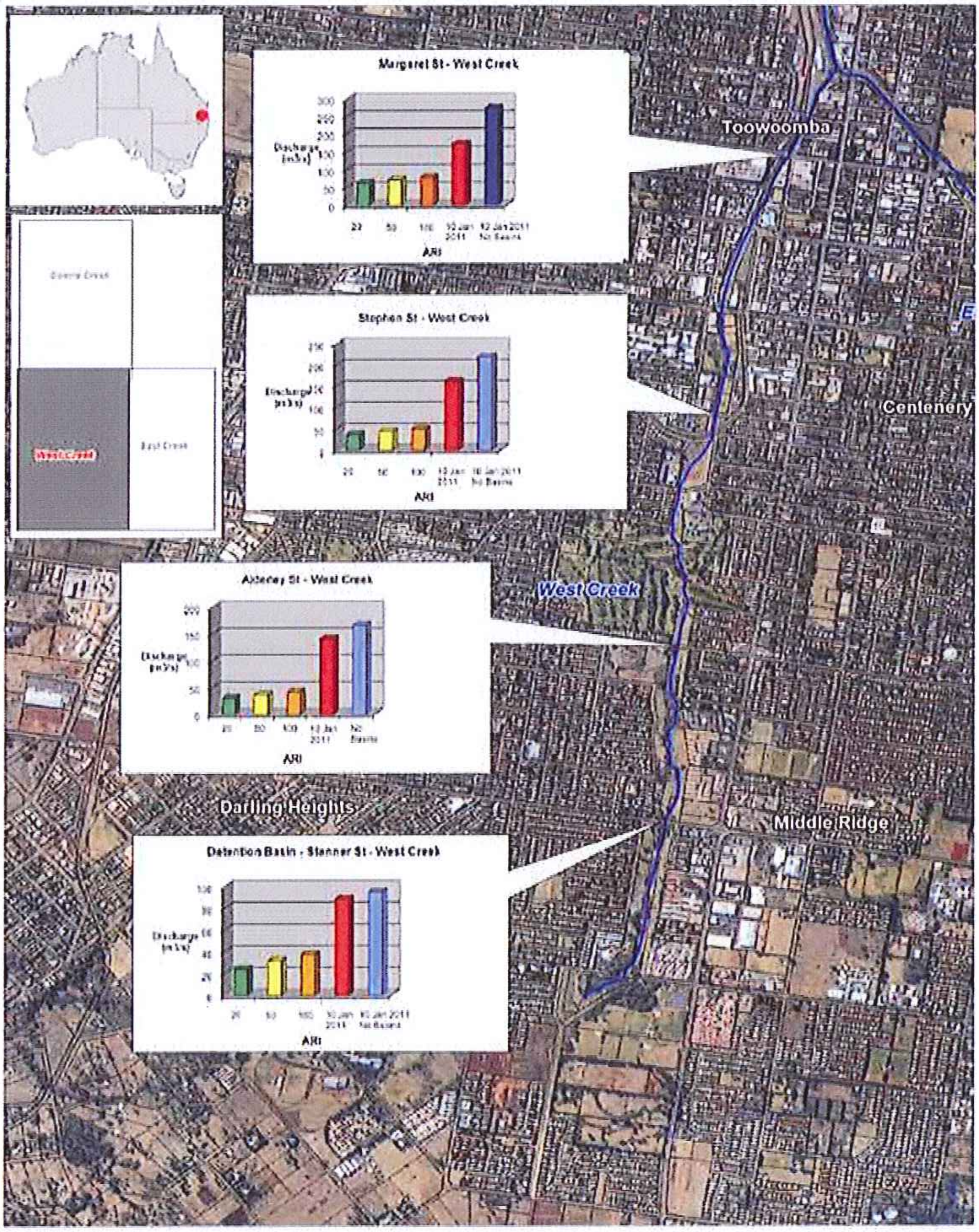

Title:
West Creek Rainfall Runoff Discharge Comparisons

Figure: 11-11 | Rev: A

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Approx. Scale

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www.bmtwbm.com.au

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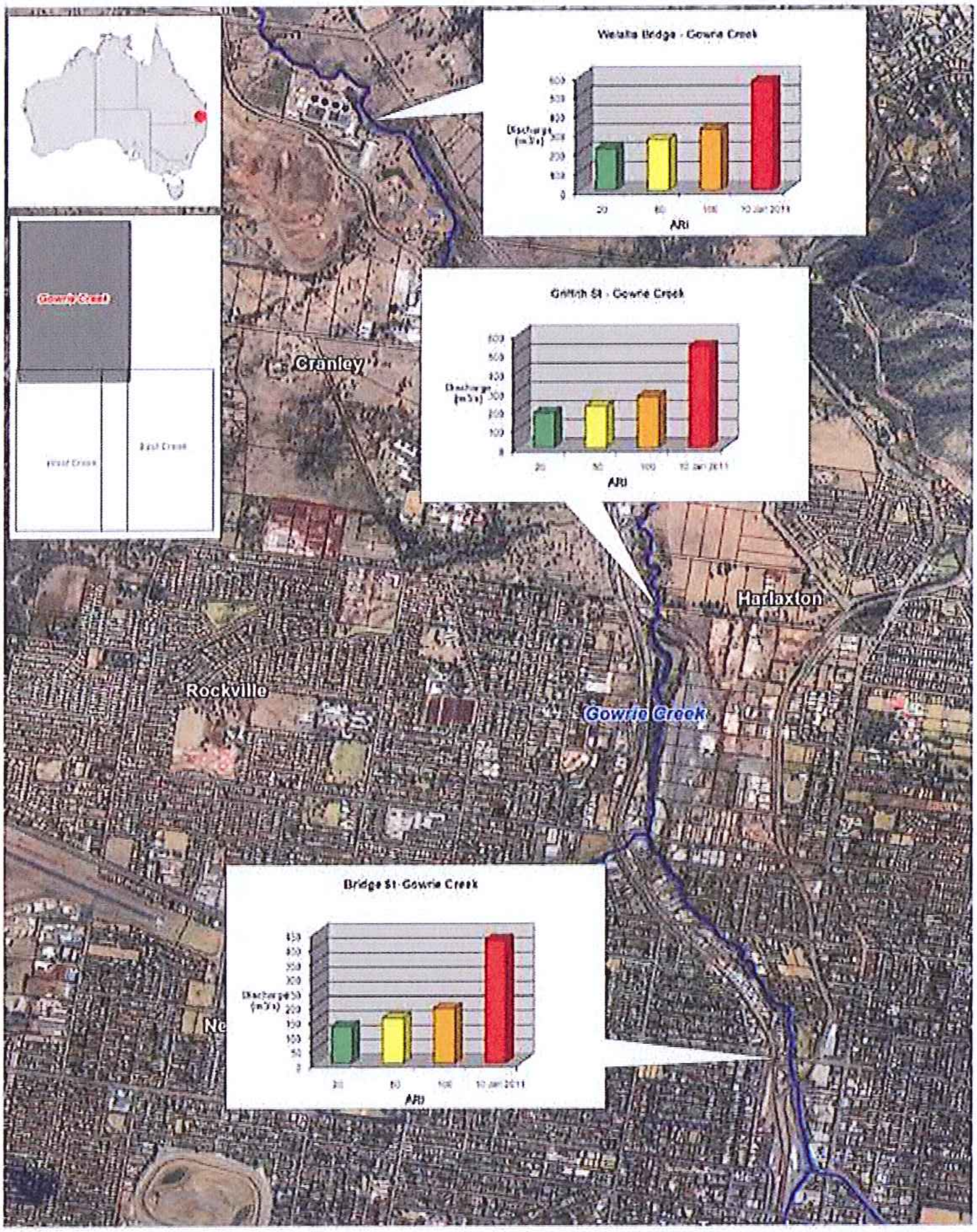

Title:
Gowrie Creek Rainfall Runoff Discharge Comparisons

Figure: 11-12

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map

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Approx. Scale

BMT WBM
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APPENDIX A: CURRICULUM VITAE OF NEIL IAN COLLINS

A part of BMT in Energy and Environment

BMT WBM

Neil Ian Collins

Position	Principal Hydraulic Engineer – Expert Services
Years of Experience	31
Professional Affiliations	PIANC NPER-3 RPEQ
Qualifications	Master of Science Engineering, University of Queensland Bachelor of Engineering (Civil) University of Queensland
Recent Employment Profile	2010 to Present BMT WBM Pty Ltd – *Principal Hydraulic Engineer - Expert Services* 2007 to 2010 Gilbert & Sutherland Pty Ltd – *Principal Hydraulic and Water Resources Engineer* 2004 to 2007 Cardno Lawson Treloar – *Director, Queensland Manager* 1993 to 2004 Lawson Treloar - *Director*

Career Overview

Neil is BMT WBM's Principal Hydraulic Engineer; part of the Expert Services team, based in our Brisbane office. He has 31 years experience and is an acknowledged expert in the P+E, Land Court and Supreme Court of Queensland in flooding, water quality and coastal processes. He was also the independent hydraulic expert to the Queensland Government for the North Bank project. Neil has worked on major infrastructure projects as an Hydraulic Specialist including Sydney Third Runway, Sydney Harbour Tunnel, Gateway Bridge and Arterial and several coal ports in Queensland and in Indonesia, power stations in Queensland and Thailand, hydro-electric schemes in PNG and port dredging management at Cairns, Townsville, Weipa and Mackay.

Areas of Expertise

Hydraulics, Hydrology and Water Resources

Provision of Expert Witness Services in Flooding, Stormwater, Quality Control and Coastal Engineering

Summary of Major Projects

- Lauderdale Quay, Hobart – Coastal Hydraulics, Water Sediment Quality for IIS on a Major Marina Residential Reclamation Project.
- Brisbane Airport - International Terminal Drainage Design.
- Sydney Harbour Tunnel - Hydraulics Engineer for Immersed Tube Tow and Placement.
- Sydney Third Runway - Hydraulic Model Testing, Sea Wall Design and Environmental Management.
- Gateway Arterial - South East Freeway to Lytton Road - Civil and Hydraulic Design Manager.
- Gateway Bridge - Hydraulics and Approaches Services Relocations.
- Trade Coast Central - Flooding Review for BCC.
- Oak Flats to Yallah RTA Freeway Hydraulics.
- Kedron Brook Flood Impacts due to Airtrain.
- Tully and Murray River Floodplains Hydraulic Analysis and Modelling, for Drainage Scheme Design includes Large MIKE11 Modelling, with over 40 Bridges and 200 Channels.
- Expert Review - Mossman Daintree Road, Saltwater Creek Crossing: Independent Review of the Hydraulic Design of two Large Bridges.
- Hydraulic Design of Rock Armouring Works for the Barron River Bend at Cairns Airport.
- Eastern Corridor Study - Hydraulics and Hydrology investigation for Department of Transport.
- Relief Drainage Scheme Design for Albion Windsor Area Brisbane (Capital cost $2 million).
- Tarong Power Station - Design of Earthfill Dam (max. 23m height), Ash trench, Stormwater Diversion Channels.

Professional History

BMT WBM Pty Ltd

Principal Hydraulic Engineer providing expert witness services in flooding, stormwater, quality control and coastal engineering.

Gilbert & Sutherland Pty Ltd

Wet 'n' Wild, Sunshine Coast – site and soil assessments, input to and review of AGE groundwater assessment, conceptual stormwater quality assessment, hydraulic and flooding assessments including yield, medli modelling for onsite and input to S&B water balance, contamination investigation.

- Stockland, Twin Waters – Flooding Assessment
- Mackay Boat Harbour – Wave Investigation
- Bourton Road, Alkira – Flooding and Stormwater Management Plan
- The Glades, Robina – Water Quality Compliance and Inspection Report

Expert Services:
2007: Truloff Pty Ltd -v- Gold Coast City Council
2008: Jimboomba Turf Co Pty Ltd -v- Logan City Council
2008: Lechaim -v- Gold Coast City Council
2008: Sunnygold International Pty Ltd -v- Brisbane City Council
2008: Bon Accord -v- Brisbane City Council
2008: Blue Eagle -v- Beaudesert Shire Council
2008: Brian Paddison -v- Redland Bay Shire Council
2008: Monarch Nominees -v- Brisbane City Council
2008: Kunda Park Pty Ltd -v- Maroochy Shire Council
2008: Owl Projects & Hyder -v- Gold Coast City Council
2008: Port Pacific Estates Pty Ltd -v- Cairns Regional Council
2008: Joanne Shepherd & Ors -v- Brisbane City Council
2009: Lenthalls Dam, Hervey Bay
2009: Testarossa -v- Brisbane City Council
2009: Heritage Properties & Ausbuild -v- Redland City Council
2009: Samantha Skippen -v- Miriam Vale Shire Council
2009: Anthony Wan Pty Ltd -v- Brisbane City Council
2010: Over 25 appeals in progress this year

Professional History (cont)

Cardno Lawson Treloar
Sovereign Waters, Wellington Point - flooding, tidal exchange and water quality management.

EMP Water Quality Management Plan preparation and site stormwater management, including hydrodynamic, advection/ dispersion and catchment pollutant yield modelling for:

- Emerald Lakes Project, Carrara
- Glenwood Estate, Mudgeeraba
- 'The Glades' (Greg Norman Design Course), at Robina
- Sovereign Waters, Wellington Point
- Pacific Palisades, Gavin
- Freshwater Valley Estate, Cairns
- Carrara Golf Course Re-development, Carrara
- The Broadwater Development, Mudgeeraba
- Over a Dozen Major Residential Development Projects.

- Full Two-dimensional (MIKE 21) Floodplain Modelling for Cairns Airport Inundation, Nerang River Floodplain and Martins Creek, Maroochydore.
- Noosa River System Flood Study: Includes full G.I.S. Interfacing, Colour Inundation Plan Production and MIKE11 Modelling.
- Detention Basin Design for Development Consulting, Calamvale, Brisbane: Hydrologic and Hydraulic Design using RAFTS.
- Hydraulic and Water Quality Design, Lucinda Drive Main Drain, Port of Brisbane, including Catchment Pollutant Runoff Management.
- Moreton Bay College Flood Investigation: MIKE11 Analysis of Flooding, Including Culvert and Channel Diversion Options.
- Input on EIS Report on Water Quality for Freshwater Valley Development, including EMP.
- Townsville Port Road and Rail Access Study - Hydraulics.
- Freshwater Creek Flooding, for Main Roads, included Bridge and Culvert Sizing and Positioning of Channel Training Works. (RORB/RUBICON).
- Mountain Creek Flooding Investigation Examination of 1992 Floods using detailed Hydrologic/Hydraulic Modelling and Design of Mitigation Works.

Expert Services:
2004: T.M. Burke Appeal
2004: East Point Mackay
2004: Dore Appeal
2004: 900 Hamilton Road, McDowall
2004: Milton Tennis Centre
2005: P&E Appeal Mount Samonsvale
2005: BCC & George Pasucci
2005: P&E Appeal 48 Comley Street Sunnybank
2005: P&E Appeal 398 Wondall Road, Tingalpa
2005: Cabbage Tree Creek Appeal
2006: 35 Suscatand Street, Rocklea Appeal
2006: Leong - v- Redland Shire Council Appeal
2006: Barry Hilson & Bach Pty Ltd - v- GCCC Appeal
2006: 57 Longhill Road Appeal
2006: 699 Bargara Road Appeal
2006: Chevellum Road Appeal
2006: 10 Karridawn Street, Nudgee Appeal
2006: Australian Hardboards Limited Appeal
2006: Dell Road and Hawkin Drive, St Lucia Appeal
2006: 106 Munro Street, Auchenflower Appeal
2006: 10 Adsett Road, P&E Appeal
2006: Saunders Creek Appeal
2006: 64, 70 & 74 Washington Avenue, Tingalpa

Professional History (cont)

Lawson Treloar

- Coastal Data Gathering and Analysis for Projects in Bali, Lombok and Malaysia.

- Pandorah Gas Project, Gulf of Papua. Neil was Responsible for Project Management of all Coastal and Oceanographic Aspects of this Project, including Preparation of the Relevant Components of EIS. This included Extreme Climate, Wind/Wave and Current Modelling.

Chevron PNG to Cape York Gas Pipeline Project, Gulf of Papua
Neil Carried out Project Management for all Coastal/Oceanographic Components of this Project, including:

- Wind/Wave Modelling
- Extremal Climate
- Bed Current Prediction
- Kumul Platform Berthing
- Endeavor Passage Landfall
- Wave, Current and Wind Data Gathering.

- Tidal Lagoon, Breakwater/Groynes, Water Quality and Quantity Management at Pecatu Indah Resort, Lombok.
- Marina and Reclamation, S-W Bali, (Putri Nyale) including Coastal Investigations and Hydraulic Design of Breakwaters and Revetments.
- Sediment Sampling and Monitoring Program for the Albatross Bay Dumpsite, Weipa, for Dept. of Transport. Job Manager for this Investigation which includes Monitoring of Movement of Material Following Dumping, and its Impact on Water Quality and Benthic Communities.
- Wellington Point Canal Estate - Coastal Hydraulic Investigation of Proposed Marina and Dredged Channel.
- Weipa, Embley Inlet Environmental Monitoring: Review and Planning for Long Term Monitoring and Assessment of Water Quality (for Comalco).
- Full 2D flooding assessments for Dept of Main Roads using MIKE 21 on Yarrabah, Cairns and Warrego Highway at Marburg.
- Current Profiling, Warrego River (1994).
- Sovereign Waters, Wellington Point - Flooding, Tidal Exchange and Water Quality Management.
- Responsible for all Flood and Water Quality aspects for several Gold Coast Projects, including Emerald Lakes, Nifsan's Glenwood and Broadlakes, including Lake, Wetland and EMP Design.
- Stream Diversion, including Sloping Drop Structure, Hydraulic Design, at 'Coops' Development, Brisbane (1993).
- Northumbria Lakes Estate, Flooding, Drainage, Gross Pollutant Trap and Trash Rack Modelling and Design (1994).
- Barron River Delta Prawn Farm I.A.S., including Flooding and Water Quality Monitoring and Modelling, using MIKE11 (1995).
- Hydraulic Manager for Cairns Airport Master Drainage Study, 1995, including Complex Hydrodynamic Flow and Catchment Management Analysis.

Expert Services:

1993: for Mulgrave Shire Council; Land Resumption Compensation Case in Land Court. (Flooding)
1993: for Mulgrave Shire Council; Development Appeal (Kamerunga Villas) in Planning and Environmental Court. (Flooding)
1994: for Pullenvale Residents Action Group, on Rezoning Appeal. (Flooding and Water Quality)
1994: for Development Consulting, on Rezoning Appeal for a Development with a Large Detention Basin at Calamvale. (Flooding and Drainage)
1994: for an Earthworks Contractor Regarding a Disputed Claim Over Levee Bank Construction at Mungindi. (Flooding)
1995: for a Developer on Bohle River Works. (Flooding and Water Quality)
1995: for Residents on Flooding, Murrumba Downs. (Flooding)
1995: for Residents on Flooding, Dayboro. (Flooding)

Connell Wagner

- Current Profiling, Warrego River (1994).
- Sovereign Waters, Wellington Point - Flooding, Tidal Exchange and Water Quality Management.
- Responsible for all Flood and Water Quality Aspects for several Gold Coast Projects, including Emerald Lakes, Nifsan's Glenwood and Broadlakes, including Lake, Wetland and EMP Design.
- Stream Diversion, including Sloping Drop Structure, Hydraulic Design, at 'Coops' Development, Brisbane (1993).
- Northumbria Lakes Estate, Flooding, Drainage, Gross Pollutant Trap and Trash Rack Modelling and Design (1994).
- Barron River Delta Prawn Farm I.A.S., including Flooding and Water Quality Monitoring and Modelling, using MIKE11 (1995).
- Hydraulic Manager for Cairns Airport Master Drainage Study, 1995, including Complex Hydrodynamic Flow and Catchment Management Analysis.
- Tarong Power Station. Design of earthfill dam (max. 23m height), Ash trench, Stormwater Diversion Channels.
- Callide B Power Station. Evaporation Ponds Simulation; Hydraulic Design and Stormwater Bypass Channel. Design of (25m) Ash Dam.
- Hay Point Multi-User Coal Export Facility. Design of Dams, Stormwater Drainage, Water Supply and General Civil.
- Townsville Container Terminal. Design of Stormwater Drainage and General Civil.
- Abbot Point Coal Terminal. Design of an Offshore Causeway.
- Subdivisional Design and Supervision, on over a dozen Projects.
- Bulk Sugar Terminal - Brisbane. Feasibility Studies, including Flooding.
- Gladstone Power Station. Ash Handling including Piping.
- Stanwell Power Station. Design Check on General Civil.
- Patrick Container Terminal - Port of Brisbane. Flooding and General Civil.

Expert Services:

1993: for Mulgrave Shire Council; Land Resumption Compensation Case in Land Court. (Flooding)
1993: for Mulgrave Shire Council; Development Appeal (Kamerunga Villas) in Planning and Environmental Court. (Flooding)
1994: for Pullenvale Residents Action Group, on Rezoning Appeal. (Flooding and Water Quality)
1994: for Development Consulting, on Rezoning Appeal for a Development with a Large Detention Basin at Calamvale. (Flooding and Drainage)
1994: for an Earthworks Contractor Regarding a Disputed Claim Over Levee Bank Construction at Mungindi. (Flooding)
1995: for a Developer on Bohle River Works. (Flooding and Water Quality)
1995: for Residents on Flooding, Murrumba Downs. (Flooding)
1995: for Residents on Flooding, Dayboro. (Flooding)

Expert Services for Phillips Fox; Caboolture Shopping Centre Extension Appeal in Planning and Environment Court. (Flooding)

Expert Services for Mulgrave Shire Council; Land Resumption Compensation Case in Land Court. (Flooding)

Expert Services for Mulgrave Shire Council; Development Appeal (Kamerunga Villas) in Planning and Environmental Court. (Flooding).

Papers/Publications

May 2007 QELA Conference Presentation – The Approval and Appeal Process in QLD and NSW, Experts view on soil and water issues.

Nov 2004 Publication - 'Application of Australian Runoff Quality Draft Chapter 6 – A model approach', Water Sensitive Urban Design Conference, 2004, Adelaide.

Jul 2004 'Integrated High Order Water Quality and Hydrodynamic Analysis', 8th National Conference on Hydraulics in Water Engineering, July 2004.

Nov 2002 Publication - 'Hervey Bay Storm Surge', 30th PIANC Congress, Sydney 2002.

Nov 2001 'The Use of Runoff Event Monitoring in Validating Sediment Control Measures', 9th Annual Conference, International Erosion Control Association, Nov 2001.

Nov 2001 'Specialist 2D Modelling in Floodplains with Steep Hydraulic Gradients', 6th Conference on Hydraulics in Civil Engineering, Nov 2001.

Mar 2001 'Planning Implications of New Technology in Floodplains', RAPI Conference, Gold Coast, 2001.

Nov 1999 'Best Management Practices for Water Quality Control', and 'Zero Flooding Impact Assessments; the need for full two dimensional analysis', 8th International Conf. on Urban Stormwater Drainage, 1999.

Jul 1999 'Desktop Ship Simulation for a new Port Facility in The Gulf of Papua', Coasts and Port '99.
Mar 1997 'Implications of the Nifsan -v- G.C.C.C. ruling on floodplain hydraulics', Qld Envir. Law Assoc., 1997.

Jul 1994 'What the Community Needs to Know – Approaches to Community Construction for Water Engineering Projects', I.E. Aust., Queensland Division, 1994.

Nov 1993 'Hydraulic Assessment of Floodplain Development: Case Studies', The Institute of Municipal Engineering, Goondiwindi, 1993.

Jul 1993 'Long Term Environmental Planning – Weipa Port Dredging', 11th Australasian Conf on Coastal and Ocean Engineering. Townsville, 1993.

Mar 1993 Integrated Hydrologic and Hydraulic Modelling', WATERCOMP '93. The Second Australasian Conference on Technical Computing.

Mar 1992 'Russell and Mulgrave River Catchment Management', Invited Guest speaker for Queensland River Trusts Conference, Cairns, 1992.

Nov 1990 'Recent Studies of Port Dredging and Offshore Spoil Dumps', Third Australasian Port and Harbour Conference 1990, IE Aust.

Aug 1990 'Barron River Airport Bend Study - An Exercise in Joint Numerical and Physical Modelling', Conf. on Hyd. in Civil Eng., 1990, IE Aust.

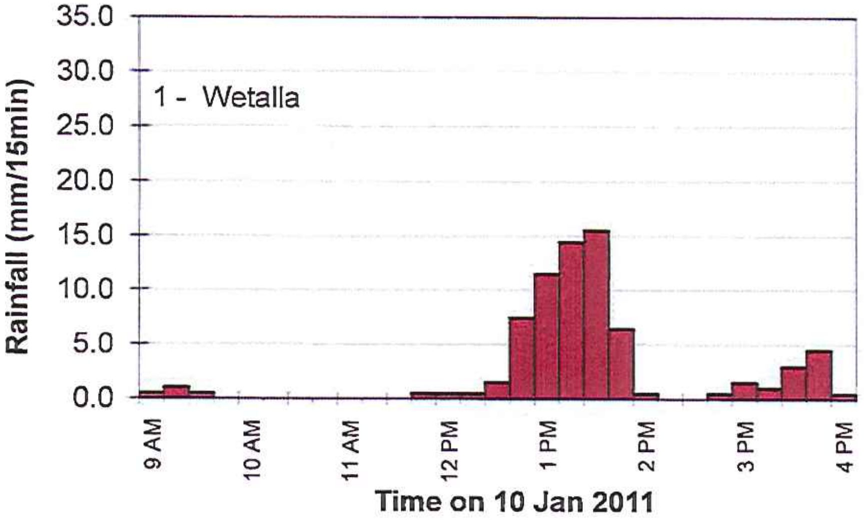
May 1989 'Comparison and Evaluation of Current Dynamic Flow Models', WATERCOMP '89. The First Australasian Conference on Technical Computing in the Water Industry, Melbourne, 1989.

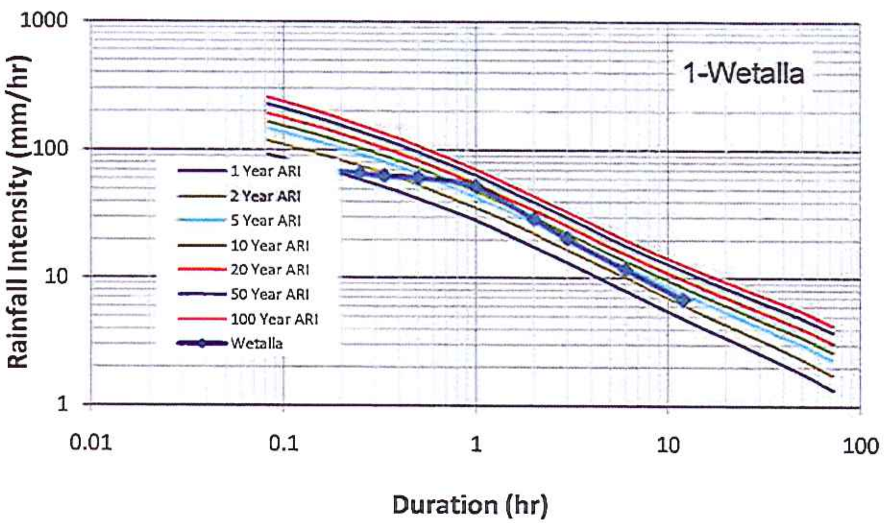
May 1989 Publication - Dynamic Flow Modelling : Comparison and Evaluation of Current Models - final Report', ACADS International publication No. U-249, May 1989.

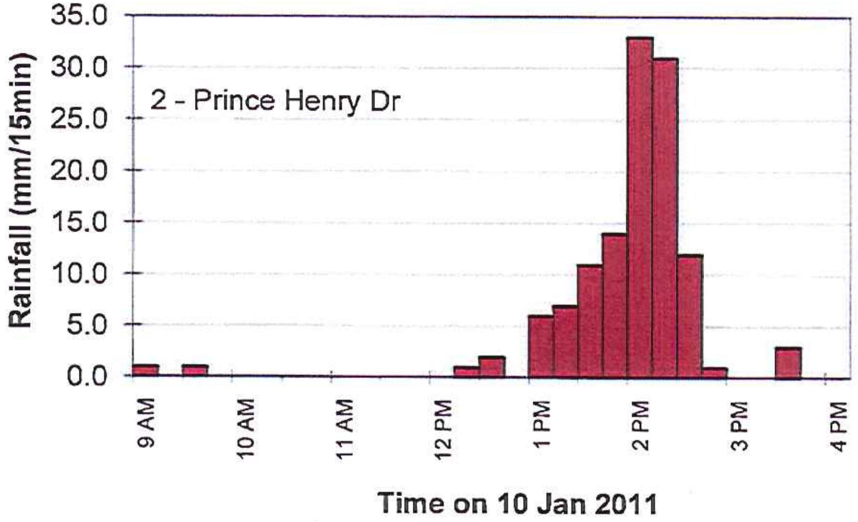
May 1988 'Comparison of Dynamic Flow Models', ACADS 2D Modelling of Flood Plains, Melbourne, 1988.

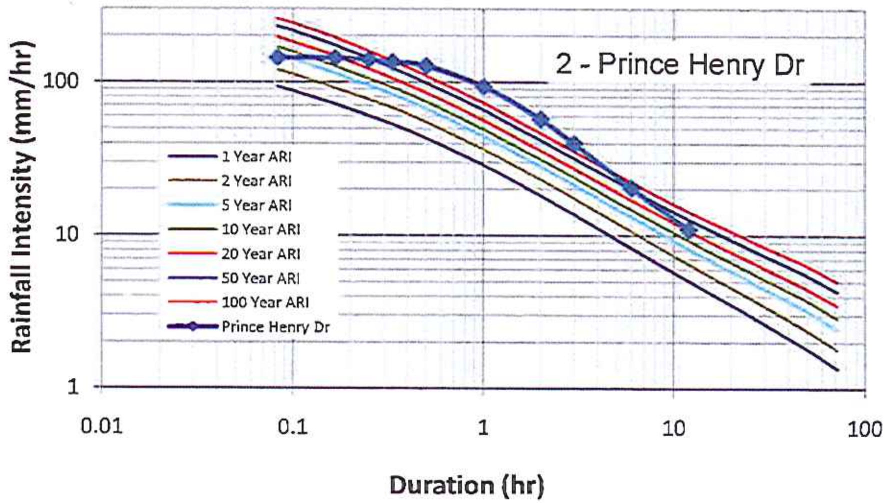
Jun 1985 'ACADS Project on Comparison of Unsteady Flow Models', ACADS workshop, Brisbane 1985.

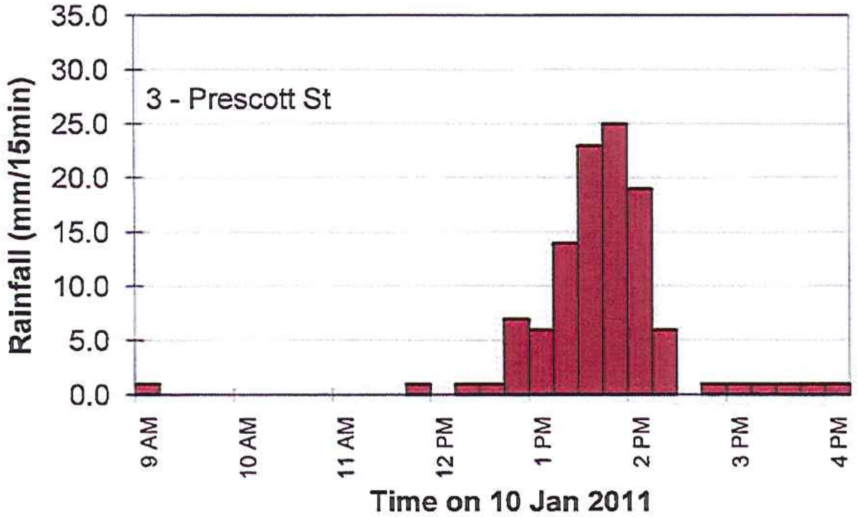
APPENDIX B: RAINFALL DATA ANALYSIS

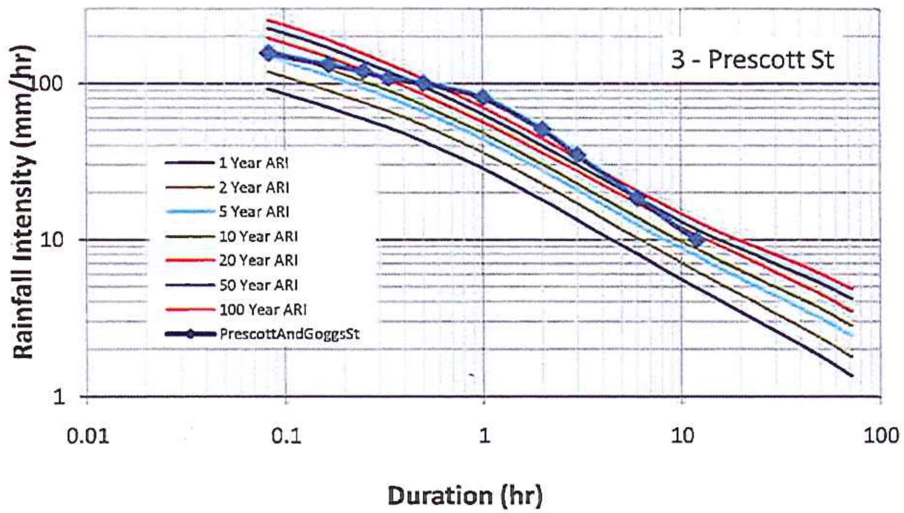

35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Rainfall (mm/15min)
1 - Wetalla
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
Time on 10 Jan 2011

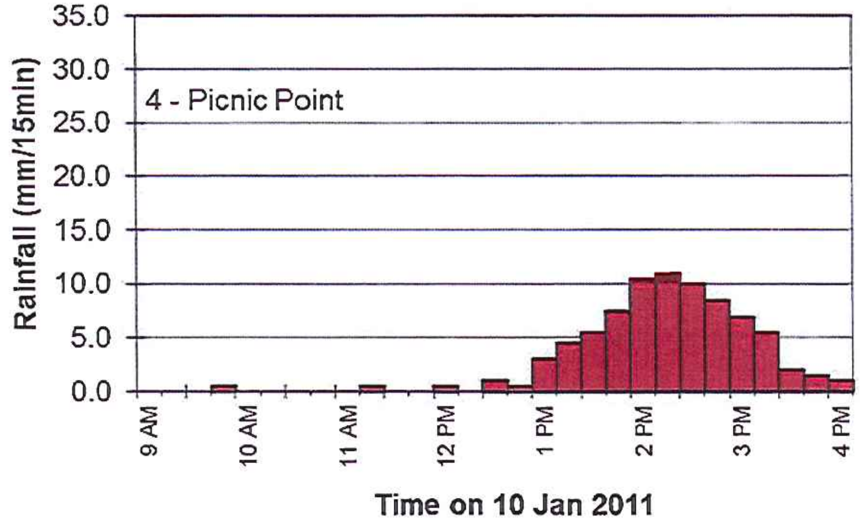

1000
100
10
1
Rainfall Intensity (mm/hr)
1-Wetalla
1 Year ARI
2 Year ARI
5 Year ARI
10 Year ARI
20 Year ARI
50 Year ARI
100 Year ARI
Wetalla
0.01
0.1
1
10
100
Duration (hr)

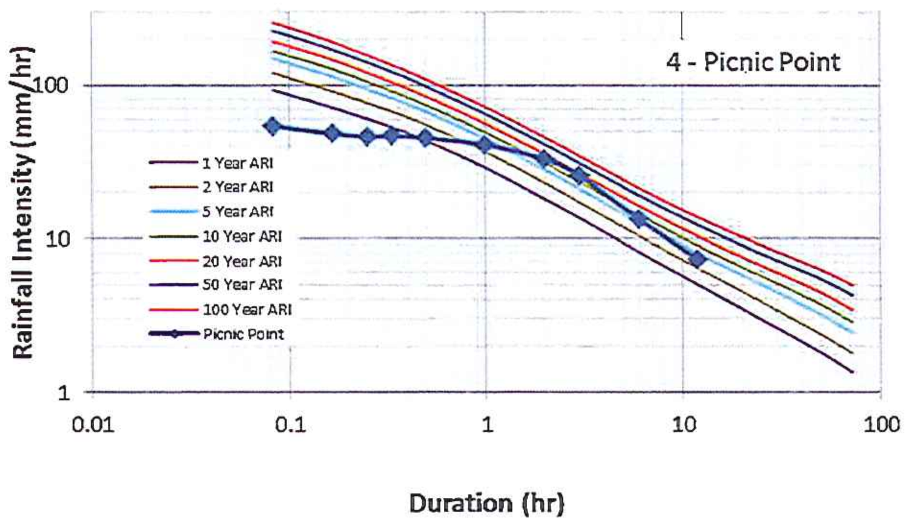

35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Rainfall (mm/15min)
2 - Prince Henry Dr
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
Time on 10 Jan 2011

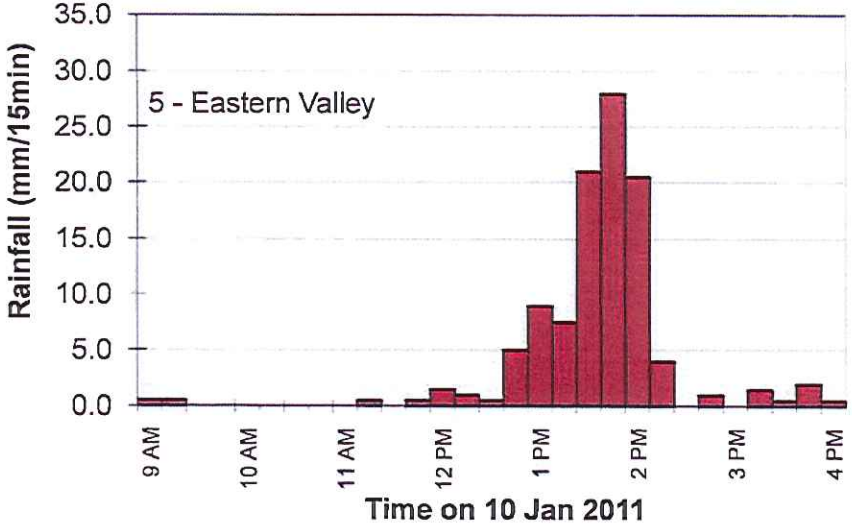

100
10
1
Rainfall Intensity (mm/hr)
2 - Prince Henry Dr
1 Year ARI
2 Year ARI
5 Year ARI
10 Year ARI
20 Year ARI
50 Year ARI
100 Year ARI
Prince Henry Dr
0.01
0.1
1
10
100
Duration (hr)

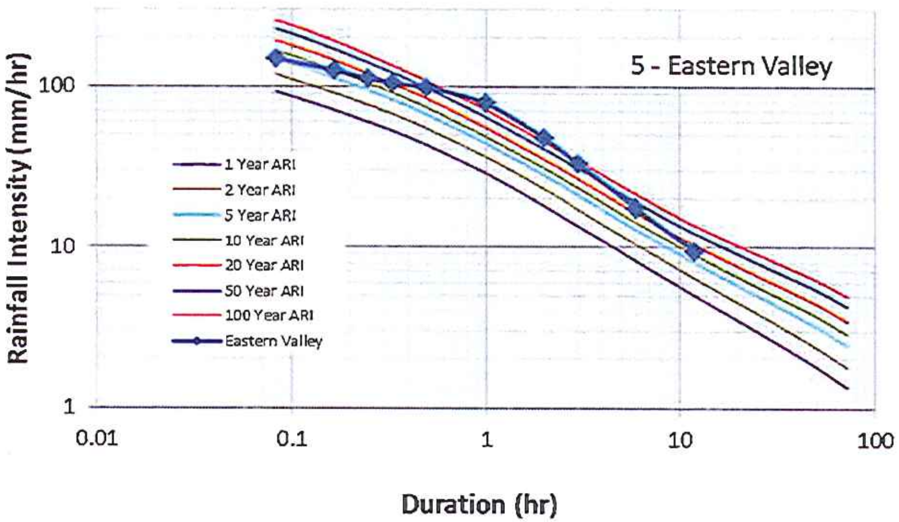

3 - Prescott St
Rainfall (mm/15min)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
Time on 10 Jan 2011

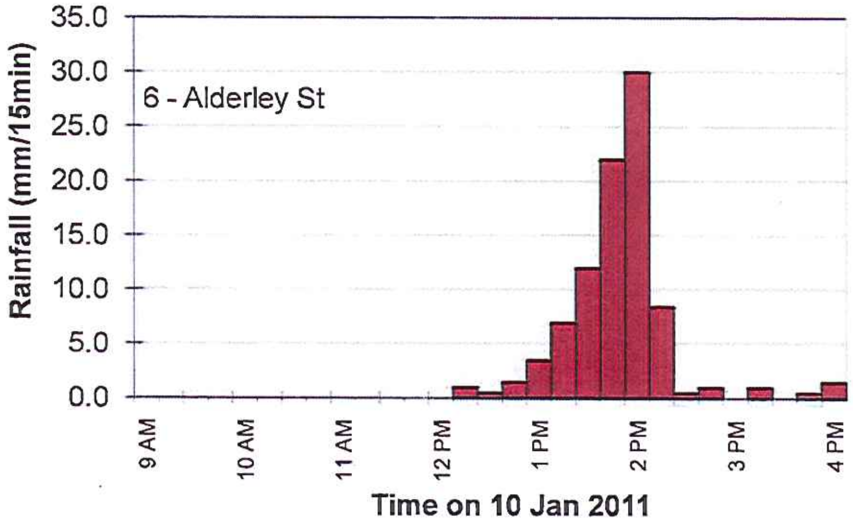

3 - Prescott St
Rainfall Intensity (mm/hr)
100
10
1
0.01
0.1
1
10
100
1 Year ARI
2 Year ARI
5 Year ARI
10 Year ARI
20 Year ARI
50 Year ARI
100 Year ARI
PrescottAndGoggsSt
Duration (hr)

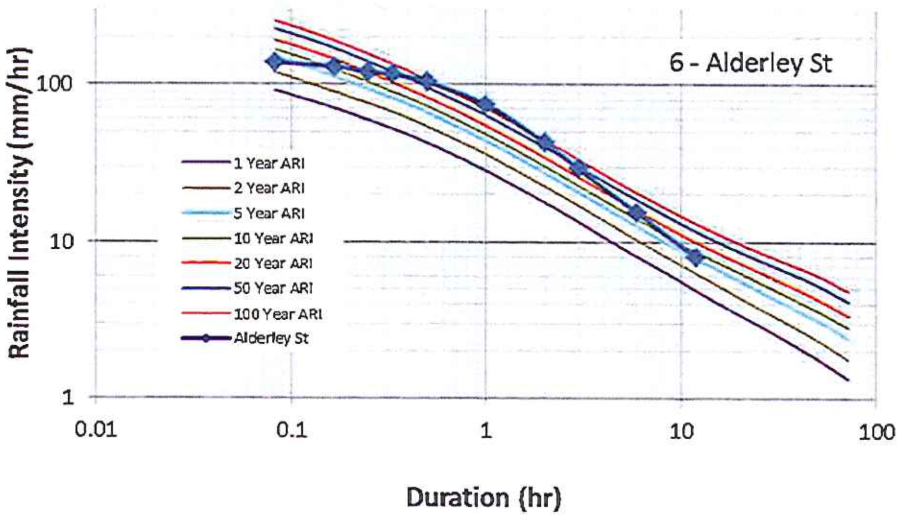

4 - Picnic Point
Rainfall (mm/15min)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
Time on 10 Jan 2011

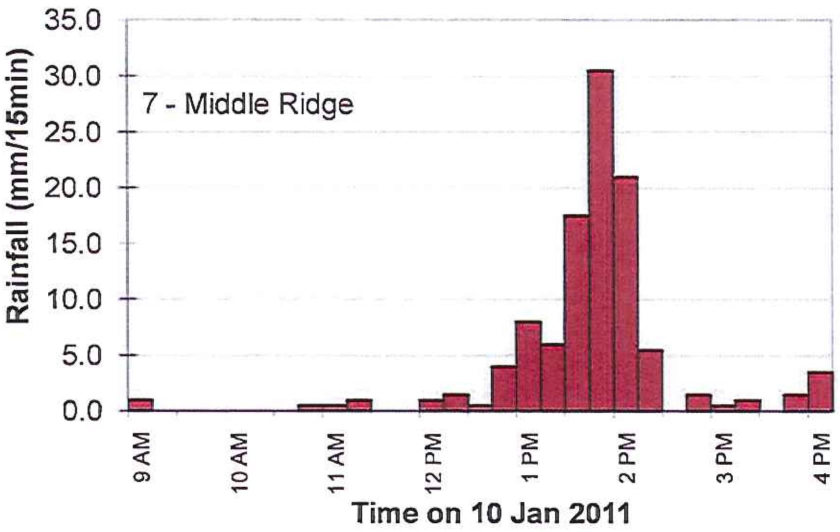

4 - Picnic Point
Rainfall Intensity (mm/hr)
100
10
1
0.01
0.1
1
10
100
1 Year ARI
2 Year ARI
5 Year ARI
10 Year ARI
20 Year ARI
50 Year ARI
100 Year ARI
Picnic Point
Duration (hr)

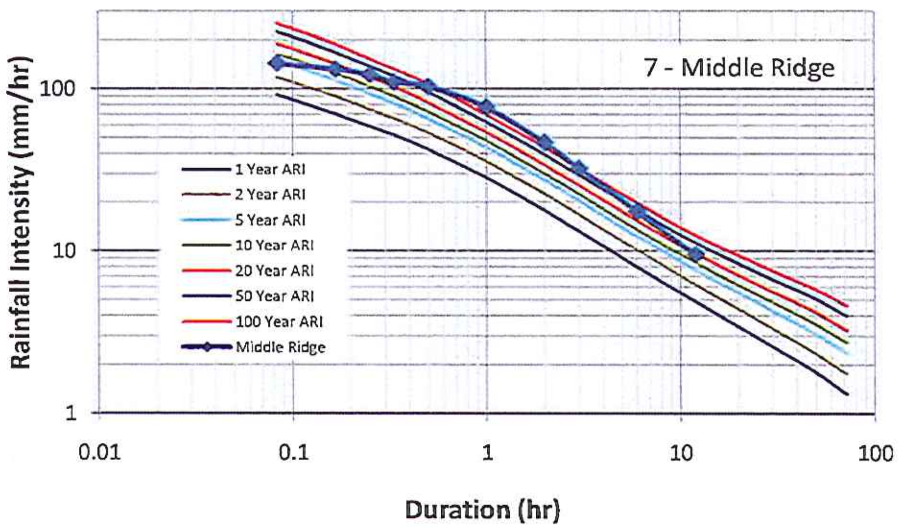

Rainfall (mm/15min)
5 - Eastern Valley
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
Time on 10 Jan 2011

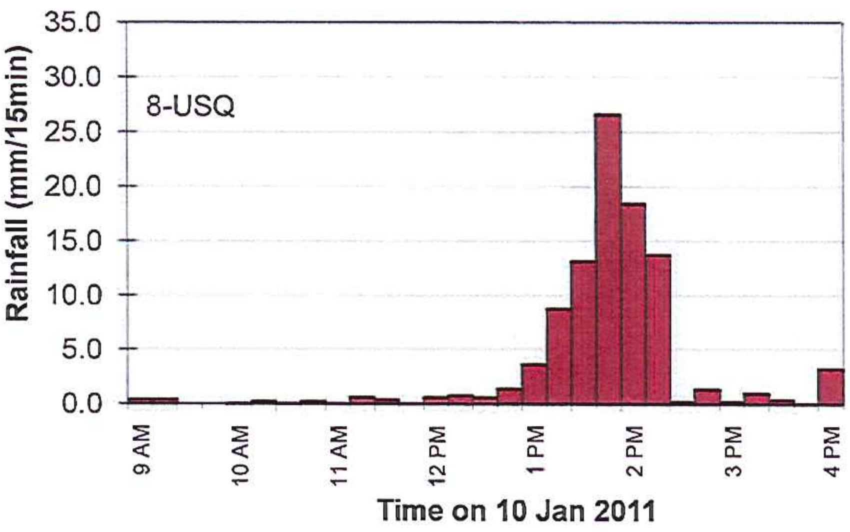

Rainfall Intensity (mm/hr)
5 - Eastern Valley
1 Year ARI
2 Year ARI
5 Year ARI
10 Year ARI
20 Year ARI
50 Year ARI
100 Year ARI
Eastern Valley
Duration (hr)

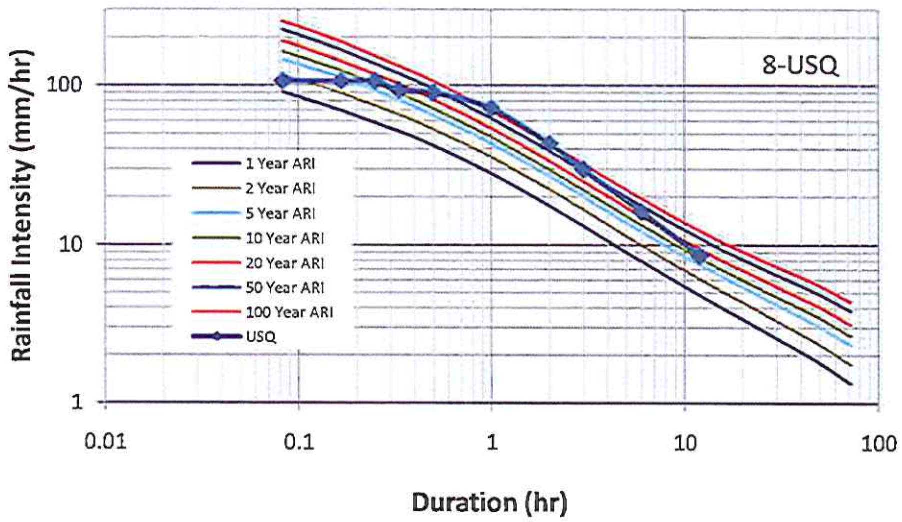

Rainfall (mm/15min)
6 - Alderley St
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
Time on 10 Jan 2011

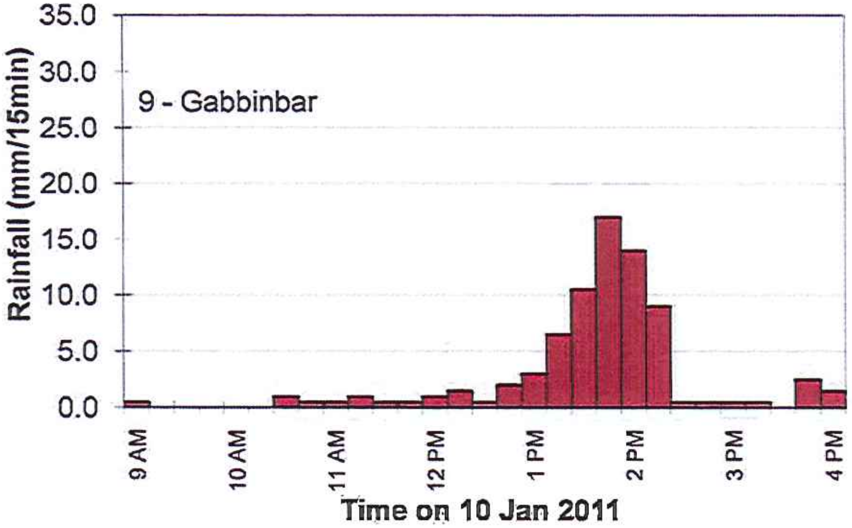

Rainfall Intensity (mm/hr)
6 - Alderley St
1 Year ARI
2 Year ARI
5 Year ARI
10 Year ARI
20 Year ARI
50 Year ARI
100 Year ARI
Alderley St
Duration (hr)

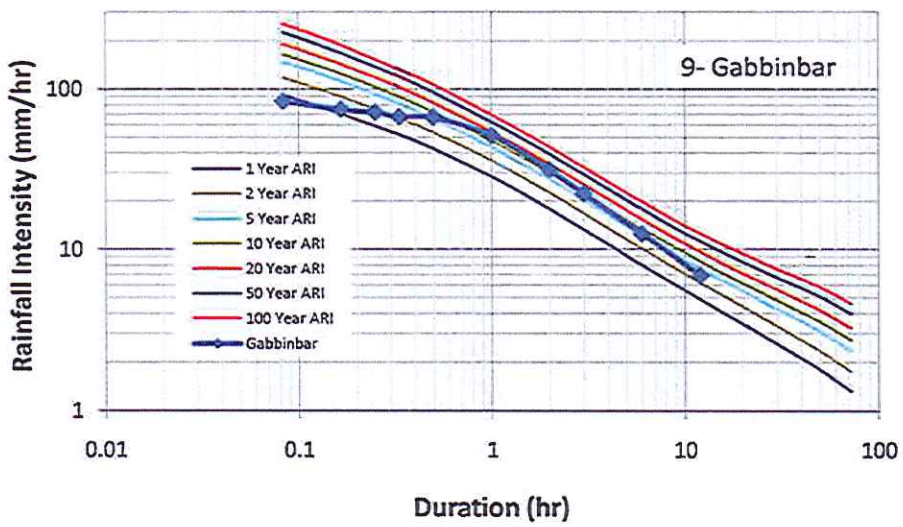

7 - Middle Ridge
Rainfall (mm/15min)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
Time on 10 Jan 2011


7 - Middle Ridge
Rainfall Intensity (mm/hr)
100
10
1
0.01
0.1
1
10
100
Duration (hr)
1 Year ARI
2 Year ARI
5 Year ARI
10 Year ARI
20 Year ARI
50 Year ARI
100 Year ARI
Middle Ridge


8-USQ
Rainfall (mm/15min)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
Time on 10 Jan 2011


8-USQ
Rainfall Intensity (mm/hr)
100
10
1
0.01
0.1
1
10
100
Duration (hr)
1 Year ARI
2 Year ARI
5 Year ARI
10 Year ARI
20 Year ARI
50 Year ARI
100 Year ARI
USQ


35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Rainfall (mm/15min)
9 - Gabbinbar
9 AM
10 AM
11 AM
12 PM
1 PM
2 PM
3 PM
4 PM
Time on 10 Jan 2011


100
10
1
Rainfall Intensity (mm/hr)
9- Gabbinbar
1 Year ARI
2 Year ARI
5 Year ARI
10 Year ARI
20 Year ARI
50 Year ARI
100 Year ARI
Gabbinbar
0.01
0.1
1
10
100
Duration (hr)

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