



Flood Study Report
Fitzroy River Flood Study
Rockhampton Regional Council

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Abbreviations

1-D	One-dimensional
2-D	Two-dimensional
AEP	Annual Exceedence Probability
ARI	Average Recurrence Interval
AR&R	Australian Rainfall and Runoff
BoM	Bureau of Meteorology
CCIS	Climate Change Impact Statement
CMPS&F	Camp, Scott and Furphy Pty Ltd
DAF	Decay Amplitude Factor
DERM	Department of Environment and Resource Management
DES	Department of Emergency Services
DFE	Defined Flood Event
DIP	Department of Infrastructure and Planning
TMR	Department of Transport and Main Roads
EPW	Extreme Precipitable Water
FFA	Flood Frequency Analysis
FRW	Fitzroy River Water
GIS	Geographic Information Systems
GTSMR	Generalised Tropical Storm Method
HAT	Highest Astronomical Tide
LDMG	Local Disaster Management Group
LGAQ	Local Government Association of Queensland
MAF	Moisture Adjustment Factor
MHWS	Mean High Water Springs
NDRMS	Natural Disaster Risk Management Study
NDMP	Natural Disaster Management Program
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
QR	Queensland Rail
RCC	Rockhampton City Council
RRC	Rockhampton Regional Council
SES	State Emergency Service
SPP	State Planning Policy
TAF	Topographic Adjustment Factor

Executive summary

Introduction

Rockhampton is situated on the banks of the Fitzroy River, the second largest river catchment in Australia. Rockhampton has a long history of flooding, with flood records dating back to 1859. The 1918 flood peaked at 10.1 m at the Rockhampton Gauge and is the largest event on record. The next three largest floods peaked at 9.4 m, 9.3 m and 9.2 m in 1954, 1991 and 2011 respectively. These large floods have the impact of cutting road, rail and fixed-wing air access and potentially isolating the city, sometimes for weeks at a time.

Aurecon was commissioned to undertake a Flood Study of the Fitzroy River through Rockhampton. The primary objectives of the Flood Study were to:

- Undertake a hydrologic assessment of the Fitzroy River catchment
- Develop a calibrated two-dimensional hydraulic model of the Fitzroy River and its floodplain in the Rockhampton area
- Undertake design flood event hydrologic and hydraulic modelling for the 2, 5, 10, 20, 50 and 100 year ARI and the Probable Maximum Flood events
- Provide Council with flood mapping to be incorporated into their GIS system
- Prepare tools to assist with development assessment and emergency management planning activities

Study area and model setup

Flood behaviour in and around Rockhampton is generally well understood. During minor floods, flows back up Gavial Creek towards the Yeppen area and break the river banks in the Port Curtis area. Floods of a medium to large magnitude break the banks of the river to the north of Rockhampton at the Pink Lily meander. Flows from this breakout then pass through Nine Mile, towards the airport, Fairy Bower and Yeppen where they join with flows which have backed up Gavial Creek, creating a continuous flowpath around the western side of the city. The study area was selected to cover this entire area.

Hydrologic modelling was undertaken using the URBS modelling software. The URBS model developed for the *Rookwood and Eden Bann Weirs Design Flood Hydrology* (SunWater, 2008) assessment was sourced and adopted for use in this study.

Hydraulic modelling of the Fitzroy River floodplain within the Rockhampton area was undertaken using the two-dimensional TUFLOW modelling package. The TUFLOW model consists of a two-dimensional domain covering the study area around the city of Rockhampton and a one-dimensional branch from the downstream end of the two-dimensional domain representing the river to the its mouth at Port Alma.

Model calibration

The March 1988, January 1991 and January/February 2008 event were selected as calibration events. Model predictions were compared to recorded data for the three events. A summary of the calibration results for the March 1988 and January 1991 events are presented in Table 1. Calibration for both of these events was considered acceptable. Calibration for the 2008 events was not as well matched, however this event is much smaller in magnitude and therefore of much less importance for calibration.

Table 1 Calibration result summary: March 1988 and January 1991 events

Calibration Parameter	March 1988	January 1991
Peak Water Level at Rockhampton Gauge	8.32 m (-0.08 m)	9.19 m (-0.11m)
Locations in which model predictions are within calibration tolerances	18 (of 26)	125 (of 155)
Locations in which model predictions are below calibration tolerances	1	4
Locations in which model predictions are above calibration tolerances	2	14
Locations in which modelled inundation extents did not match recorded (ie no water in model where a flood level was recorded)	4	12
Average difference between calculated and recorded levels	±0.20 m	±0.14 m

Design event flood modelling and mapping

A flood frequency analysis (FFA) of the available historical flood data was carried out. Design event peak discharges were matched to the FFA results and design event modelling was carried out for the 2, 5, 10, 20, 50 and 100 year ARI and the Probable Maximum Flood events. The modelled peak water levels at the Rockhampton Gauge are presented in Table 2.

Table 2 Design event gauge levels

Return Period (years)	Peak Flood Level	
	m AHD	m Gauge Datum
2	4.20	5.65
5	5.96	7.41
10	6.65	8.10
20	7.23	8.68
50	7.59	9.04
100	7.93	9.38
PMF	10.86	12.31

The TUFLOW model results were analysed and a series of maps were developed to present the results for each modelled return period. Three sets of maps were produced including:

- Inundation extents, peak water surface levels and velocity vectors
- Peak depths
- Peak hazard

Climate change assessment

An assessment of the potential impacts of climate change on the 100 year ARI event flood extents was undertaken. Two scenarios were assessed in which the rainfall intensities were increased by +20% and +30%. Peak water levels are predicted to increase by +0.5 to +0.75 m throughout much of the study area under the 20% increased rainfall case. Under the 30% increased rainfall intensity case, peak water levels are predicted to increase +1.0 to +1.5 m throughout the study area.

Emergency management planning

A suite of study outputs were produced to assist Council and the Local Disaster Management Group with emergency planning and management. These outputs included:

- Gauge level mapping: depth and hazard maps for flood levels between 7.0 and 10.0 m at the Rockhampton Gauge
- A list of critical infrastructure and the Rockhampton Gauge level at which it is likely to be inundated
- A decision support tool consisting of two flowcharts which identify the major decisions, outcomes and follow-on tasks to be made during a flood event and during an evacuation
- Pre-written flood warnings were prepared to be readily available for dissemination to the media during a flood event

Building community awareness

Text to be used in the preparation of a community awareness brochure was developed. To assist with communicating the various levels of flood risk to the community, a series of flood zones were defined based upon the gauge level at which a property starts to become inundated. Seven zones were used to define areas affected by flooding.

Development planning input

A review of Council's existing planning scheme documents was undertaken and recommendations for inclusion in a planning scheme review were made. Floodway, flood storage and flood fringe areas were redefined based upon the hydraulic modelling results for the 100 year ARI event.

Conclusions and recommendations

Through close consultation with Council, the study has provided a suite of information to allow better preparation for and management of flood events. A number of additional studies are recommended to further improve Council's understanding of flooding, including:

- Modelling of the December 2010/January 2011 flood event
- A review of climate change impacts
- Modelling of local catchment flooding

1. Introduction

1.1 Rockhampton and the Fitzroy River

Rockhampton is situated on the banks of the Fitzroy River in Central Queensland, to the north of the Tropic of Capricorn and inland from Keppel Bay. The Fitzroy River at Rockhampton has a catchment area of approximately 140,000 km^2 and is one of the largest catchments in Australia. The catchment includes the Dawson, Mackenzie, Comet, Nogoa, Connors and Isaac river systems.

Rockhampton has flood records dating back to 1859 which indicate a long history of major flood events. The January 1918 flood event is the highest in recorded history with a flood peak of 10.11 m (8.66 m AHD) at the Rockhampton Gauge. This event isolated the city for approximately six weeks. In more recent history, the 1991 flood event reached 9.30 m (7.85 m AHD) at the Rockhampton Gauge and isolated the city by cutting road, rail and fixed-wing air access for 13 days. During the 1991 flood, significant direct flood damage was incurred by approximately 1360 properties, representing major economic and social costs to the city.

Two flood events occurred in early 2008, with recorded gauge levels of 7.55 and 7.75 m (6.10 and 6.30 m AHD). These floods caused inundation of the Riverside carparks and through the Depot Hill and Port Curtis areas. The flood event which occurred in December 2010/January 2011 was similar in magnitude (9.20 m at the gauge) and impacts to the 1991 event.

1.2 Study background

A Natural Disaster Risk Management Study (NDRMS) undertaken for Rockhampton Regional Council (RRC) in 2003 identified a number of requirements in relation to the risk management of natural disasters, in particular those associated with Fitzroy River flooding. This study indicated that hydraulic modelling of the Fitzroy River completed in 1992 was no longer consistent with current software and modelling techniques. It was also identified that the outputs of this previous modelling were in a format not easily used by RRC.

Following the outcomes of the NDRMS, RRC received funding through the Federal and State Governments under the Natural Disaster Mitigation Program (NDMP) to undertake a new flood study. The NDMP has been initiated by the Commonwealth Government to anticipate and mitigate disaster, rather than similar types of programs which, in the past, have just reacted to disaster events. The NDMP provides funding for measures such as risk management studies and mitigation works to assist communities to better plan to withstand the effects of natural disaster. The Queensland Government, through the Department of Emergency Services (DES) is responsible for the administration of the NDMP in Queensland.

Aurecon was commissioned in March 2008 to undertake the Fitzroy River Flood Study for Rockhampton Regional Council. The flood study and this report were almost complete when the December 2010/January 2011 flood event occurred; therefore this event has not been included in the analysis or in the discussions throughout this report. Section 13 of this report presents a summary of the December 2010/January 2011 event.

1.3 Study objectives

The primary objectives of the study were to:

- Undertake a hydrologic assessment of the Fitzroy River catchment
- Develop a calibrated two-dimensional hydraulic model of the Fitzroy River and its floodplain in the Rockhampton area
- Undertake design flood event hydrologic and hydraulic modelling for the 2, 5, 10, 20, 50 and 100 year ARI and the Probable Maximum Flood events
- Provide Council with flood mapping to be incorporated into their GIS system
- Prepare tools to assist with development assessment and emergency management planning activities

2. Study data

A significant amount of data was collected from a range of data sources for use in this study. This data is detailed in the following sections.

2.1 Previous studies

A number of previous studies have been undertaken of both the Fitzroy River and flooding in the Rockhampton area. These studies are outlined below.

2.1.1 Rockhampton Flood Management Study (Camp, Scott & Furphy, 1992)

The Rockhampton Flood Management Study was completed in 1992 and provided an extensive review of historical hydrology in the Fitzroy River and flooding behaviour in Rockhampton. The study included a flood frequency analysis, flood damage and impact assessment and included inundation mapping for historical floods in 1918, 1954 and 1991.

Hydraulic modelling was undertaken using the one-dimensional (1-D) flood modelling package, MIKE 11. The hydraulic model included representation of the Fitzroy River as well as major creeks and overland flowpaths via a complex 1-D network with numerous junctions and linkages. The model was calibrated to several historical events. The calibrated model was used to undertake design event analyses for return periods ranging between 20 and 1000 years. The study provided various potential mitigation measure recommendations, including a number of levee options in Splitters Creek, Port Curtis, Depot Hill and around the airport.

2.1.2 Rockhampton Airport Runway Extension – Flood Study (GHD, 1998)

A flood study was undertaken to assess the impacts of the proposed runway extension and Nine Mile Road diversion on flooding of properties both upstream of and surrounding the airport. The MIKE 11 model developed as part of the Rockhampton Flood Management Study was updated and used for this study. Hydrologic and hydraulic assessment of Lion Creek flows was also undertaken.

2.1.3 Fitzroy River Floodplain Management Policy – Rockhampton Flood Mapping (Willing & Partners, 1999)

This study was undertaken to develop a Floodplain Management Policy for inclusion into Council's Town Plan and to prepare flood maps which were suitable for use in planning purposes. During this study the MIKE 11 model used in the Runway Extension Study was rerun for the 1991 and 100 year ARI events. A two-dimensional Surface Water Modelling System (SMS) model was also developed using 5 m contour data to assist with identification of hazard zones across the floodplain.

2.1.4 Nine Mile Road Report on Flood Impacts (GHD, 2001)

The assessment undertaken in the Airport Runway Extension Flood Study was revised to represent the as-constructed Nine Mile Road diversion. This was carried out as the final constructed levels of the Nine Mile Road diversion were higher than those in the original design. Mitigation options were recommended to reduce the impact of the road under the 10 year ARI event.

2.1.5 Rookwood and Eden Bann Weirs Design Flood Hydrology (SunWater, 2008)

SunWater was commissioned in October 2007 to undertake a flood study as part of the Preliminary Design of the proposed raising of Eden Bann Weir (approximately 100 km upstream of Rockhampton) and proposed new Rookwood Weir, located on the Fitzroy River approximately 225 km upstream of Rockhampton. A key component of this study was the development of an URBS runoff routing model of the Fitzroy River to Rockhampton. This model was calibrated against historical floods from 1918 to

1991 and a flood frequency analysis was undertaken using data from key gauging stations. The URBS model was used to simulate a range of design flood events in order to assess various flow conditions for the proposed weirs.

2.2 Topographic data

A number of survey datasets were available for use in this study. The extent of each dataset and the areas over which each dataset was adopted is presented in Figure 4. These datasets are discussed further in the following sections.

2.2.1 Light Detection and Ranging (LiDAR) contours

Rockhampton Regional Council and the Department of Environment and Resource Management (DERM) commissioned LiDAR survey of a large part of the Gladstone and Rockhampton region, including the Fitzroy River and its floodplain in and around Rockhampton. This LiDAR was flown in June 2009 and provided to Aurecon as 1 m grid DEM (xyz) tiles over the study area. This data has a vertical accuracy of ± 0.15 m and a horizontal accuracy of ± 0.30 m.

It is important to note that LiDAR survey does not penetrate the surfaces of water bodies such as rivers, creeks and lagoons. In this regard, the resultant survey dataset represents the surface level of these water bodies at the time of survey capture and in no way represents the bathymetric surfaces. In addition, bridge structures over major waterways are removed from the dataset such that watercourses are represented as being uninterrupted wherever a bridge occurs.

2.2.2 River bathymetry

Very little bathymetric data is available for the Fitzroy River. The cross-sections used for development of the MIKE 11 model in 1991/92 were based upon cross-sections which were surveyed for the Port Authority in the 1950s. These cross-sections represent the most extensive bathymetric data available.

2.2.3 Airport contours

Survey data of the airport and surrounds which was undertaken in the mid-1990s was sourced from Airport Technical Officers. This data represents the ground surface levels in the area prior to extension of the runway and diversion of Nine Mile Road. These contour extents are shown on Figure 4.

2.2.4 Airport levee survey

The airport levees were raised following the 1991 flood event. Detailed survey of the airport levee crest elevations was undertaken in August 2009 and provided to Aurecon for use in this study.

2.3 Aerial photography

Aerial photography of the study area was sourced from Fitzroy Basin Association. This aerial photography has been used to identify and confirm topographic and vegetative characteristics of the study area.

2.4 Historical flood data

2.4.1 Stream gauges

Several stream gauges exist at various locations along the Fitzroy River and its tributaries. The historical stream gauge data for a number of gauges in the lower reaches of the Fitzroy was sourced for this study, as presented in Table 3.

Table 3 Stream gauge data

Stream Gauge Location	Gauge Operator	Approximate Distance from River Mouth (km)	Period of Record
Rockhampton	BoM	54	1959 – present
Yaamba	DERM	108	1914 – 1974
Wattlebank	DERM/SunWater	138	1918 – 1956 and 1995 – present
The Gap	DERM	141	1964 – present
Riverslea	DERM	276	1922 – present

The stream gauge at Rockhampton is a manually read gauge. Fitzroy River Water (FRW) (a business unit of RRC) has an automatic gauge located adjacent to this manual gauge. The automatic gauge data was not collected for use in this study as it is not the official gauge at this location. FRW also has an automatic gauge on the upstream side of the Barrage. Recorded data for this gauge was collected for the 2008 flood events.

Opportunity exists for the automatic gauge data collected by FRW to be used in BoM's flood warning network.

2.4.2 Recorded flood levels

A number of recorded flood level datasets were sourced from Council and other sources:

- Plans for each of the 1988, 1991 and 2008 flood events were sourced from RRC. These plans showed recorded water levels and their surveyed locations. Approximately 26 levels were available for the 1988 event, 123 for the 1991 event and 16 for the 2008 event
- A plan of surveyed water levels in the Pink Lily area from the 1991 event was sourced from Council
- Recorded water levels over time for the 1991 event were sourced from Airport staff for three locations at the Airport. Unfortunately the exact location of these recordings is unknown
- Recorded water levels over time at a number of bridge crossing locations were sourced from the Department of Transport and Main Roads (TMR) for the 1991 flood event
- Recorded water levels over time at the Barrage were sourced from Fitzroy River Water for the 2008 flood events

2.4.3 Aerial flood photography

Available aerial flood photography was sourced from Council and included:

- Flood photo mosaic of the 1988 flood event. This was available as a scanned image
- Flood photo mosaic of the 1991 flood event. This was available as a hard copy only
- Oblique aerial flood photography for the 1991 flood event at a number of locations
- Flood photography for the 2008 flood event

2.4.4 Other flood photography

A number of additional flood photographs were sourced for the 1988, 1991 and 2008 flood events from Council.

2.4.5 Tidal gauge data

Tidal data for the Port Alma tidal gauge was sourced for the following periods of record:

- 20 February 1988 to 25 March 1988
- 20 December 1990 to 20 February 1991
- 15 January 2008 to 1 March 2008

2.5 Hydraulic structure data

Available Design or As-Constructed data for key hydraulic structures was sourced from the relevant parties. This data included details of the:

- Bruce Highway crossing of the Yeppen area
- North Coast Rail Line crossing of the Yeppen area
- Bruce Highway crossing of the Fitzroy River
- Fitzroy Street crossing of the Fitzroy River
- North Coast Rail Line crossing of the Fitzroy River
- Airport runway crossing of Lion Creek
- Nine Mile Road crossings of the Lotus Lagoons
- Fitzroy River Barrage

2.6 GIS data

GIS data provided by RRC included cadastral boundaries, City Plan data, major roadways, emergency facilities and critical infrastructure.

Cadastral boundary and City Plan data was provided on 26 May 2008 and represents the most up-to-date information at this time. The major roadways, emergency facilities and critical infrastructure data was provided on 17 May 2010.

2.7 Site inspection

Three site inspections were undertaken over the following periods:

- 8 to 9 April 2008
- 20 May 2008
- 24 to 25 September 2008

These site visits were used to review hydraulic roughness parameters and structure details.

3. Background

3.1 Catchment and rainfall characteristics

The Fitzroy River catchment runs from the Carnarvon Ranges in the west into Keppel Bay in the east. The catchment includes the Dawson and Mackenzie River systems. The Mackenzie River catchment includes the Comet, Nogoa, Connors and Isaac Rivers as shown in Figure 2.

The Fitzroy River itself runs from the confluence of the Dawson and Mackenzie Rivers at Duaringa to the river mouth at Keppel Bay. Rainfall within the catchment is generally higher in the eastern areas that are closer to the coast and lower in the western areas further from the coast. For this reason, the Connors-Isaac system has historically been the greatest contributor to major flood events in the lower reaches of the Fitzroy River.

Seasonal rainfall variations are evident within the Fitzroy River catchment, with most rainfall being received in the summer period. Historical flood events have typically occurred within the summer months between January and March. These flood events have often been the result of cyclone generated rainfalls as shown in Table 4 for a selection of the largest and the most recent floods.

Table 4 Causes of historical flood events

Flood Event	Cause	Recorded Flood Peak at Rockhampton
January 1918	Tropical cyclone (unnamed)	10.11 m Gauge Datum (8.66 m AHD)
April 1928	Tropical cyclone (unnamed)	8.72 m Gauge Datum (7.27 m AHD)
March 1940	Tropical cyclone (unnamed)	8.02 m Gauge Datum (6.57 m AHD)
January 1951	Tropical cyclone (unnamed)	8.30 m Gauge Datum (6.85 m AHD)
February 1954	Tropical cyclone (unnamed)	9.40 m Gauge Datum (7.95 m AHD)
March 1955	Tropical cyclone (unnamed)	8.23 m Gauge Datum (6.78 m AHD)
February 1956	Tropical cyclone (unnamed)	8.08 m Gauge Datum (6.63 m AHD)
April 1958	Tropical cyclone (unnamed)	8.15 m Gauge Datum (6.70 m AHD)
February 1978	Unknown	8.15 m Gauge Datum (6.70 m AHD)
May 1983	Unknown	8.25 m Gauge Datum (6.80 m AHD)
March 1988	Tropical cyclone Charlie	8.40 m Gauge Datum (6.95 m AHD)
January 1991	Tropical cyclone Joy	9.30 m Gauge Datum (7.85 m AHD)
January 2008	Tropical cyclone Helen	7.55 m Gauge Datum (6.10 m AHD)
February 2008	Tropical low pressure system	7.75 m Gauge Datum (6.30 m AHD)

3.2 Flood classifications

The Bureau of Meteorology maintains a flood warning network on the Fitzroy River and its tributaries. This network includes rainfall and river height observations at a number of locations throughout the catchment. Flood warnings at the Rockhampton Gauge are classified according to the levels presented in Table 5. These levels are discussed further in Section 10.5.

Table 5 Flood classifications at the Rockhampton Gauge

Classification	Gauge Level (m)	Likely Impacts*
Minor	7.0	Inconvenience such as closing of minor roads and the submergence of low level bridges Makes the removal of pumps located adjacent to the river necessary
Moderate	7.5	Inundation of low lying areas requiring the removal of stock and/or the evacuation of some houses Main traffic bridges may be closed by floodwaters
Major	8.5	Inundation of large areas, isolating towns and cities Major disruptions occur to road and rail links Evacuation of many houses and business premises may be required In rural areas widespread flooding of farmland is likely

** The likely impacts adopted in this table are those defined by BoM and are not specifically related to the impacts of Fitzroy River flooding.*

3.3 Study area flood behaviour

One of the primary objectives of the study was to represent flood behaviour in the city of Rockhampton and on the surrounding floodplain. The study area shown in Figure 3 was established such that it encompassed the entire floodplain to the east and west of the city and to ensure that its upstream and downstream boundaries would have no impact on predicted flood behaviour in and around the city.

The number of historical floods on record has ensured that the general flooding mechanisms and flooded route of major floods is well understood. Historically, during major floods flows back up Gavial Creek towards the Yeppen area and break the river banks in the Port Curtis area. Floods of a medium to large magnitude break the banks of the river to the north of Rockhampton at the Pink Lily meander. Flows from this breakout then pass through Nine Mile, towards the airport, Fairy Bower and Yeppen where they join with flows which have backed up Gavial Creek, creating a continuous flowpath around the western side of the city.

The study area has been selected in order to ensure that it extends above the Pink Lilly breakout to the north and below Gavial Creek to the south. It also extends to Mount Archer and the Berserker Ranges in the east as these constrain the eastward spread of flood waters; and to the slightly more elevated areas of Gracemere, Bouldercombe and the western portion of Nine Mile which prevent the spread of floodwaters further to the west.

3.4 Historical changes to the Rockhampton floodplain

Historical changes to the floodplain, and the river itself, have the potential to significantly affect the behaviour of flood waters. Whilst the features described in Section 3.3 above prevent the spread of floodwaters to the east and west, the behaviour of those floodwaters within the floodplain have been modified over time. Significant changes to the floodplain have included construction of the:

- Fitzroy River Barrage (1970)
- Bruce/Capricorn Highway and North Coast Rail Line embankments (upgraded in 1980)
- Airport runway and runway extension (2000)
- Nine Mile Road embankment (2000)

In addition to the above man-made features natural changes also occur, a recent example of which is the breakthrough of the river at the Pirate Point bend during the 1991 flood event.

It is important to represent these features accurately within the modelling, both as they existed at the time of the calibration events and as they currently exist for the design events.

3.5 Calibration event selection

The significant flood events presented in Table 4 were evaluated to select the historical events most suitable for model calibration. Event selection was based upon the following characteristics:

- Magnitude of event – calibration to a range of magnitudes is most desirable
- Time of event – changes in the catchment and on the floodplain over time create changes in flood behaviour. More recent events are generally better for calibration as documentation/information regarding the catchment and floodplain conditions is often more readily available and able to be represented within the hydrologic and hydraulic modelling
- Availability and completeness of calibration data

Based upon these characteristics, the following events were selected as calibration events:

- March 1988
- January 1991
- January and February 2008

3.6 Description of calibration events

3.6.1 March 1988 event

The March 1988 calibration event would be considered a "moderate" flood event in terms of the Rockhampton Gauge level classifications. The Pink Lily breakout occurred, however the flood was not severe enough to cause inundation of the Bruce Highway or the Railway at Yeppen, as shown in Image 1 and Image 2, however it did cause inundation of the Capricorn Highway to the left of Image 1. The March 1988 event did not overtop the airport levees.

Image 1 March 1988 event flooding: Bruce Highway and Railway at Yeppen

Image 2 March 1988 event flooding: Bruce Highway and Railway at Yeppen

3.6.2 January 1991 event

The January 1991 event would be classified as a “major” flood event. During this event, an initial flood peak of 7.45 m occurred at the Rockhampton Gauge and is thought to have been generated by runoff from local creeks (eg Alligator and Plentiful Creeks) (CMPS&F, 1992). The river then rose to above 8.5 m at the Rockhampton Gauge for 11.5 days. The Bruce Highway and Railway at Yeppen were closed for 11 days, the Main Runway at the Rockhampton Airport was closed for 13 days and the Capricorn Highway was closed for 20 days. Inundation occurred throughout Pink Lily. Image 3, Image 4 and Image 5 show some of the inundation which occurred in and around the city in the 1991 event.

Image 3 January 1991 event flooding: Port Curtis and The Common

Image 4 January 1991 event flooding: Port Curtis, The Common and Depot Hill

Image 5 January 1991 event flood: Rockhampton Airport

3.6.3 January and February 2008 events

The 2008 flood event was characterised by two separate flood peaks, both of which would be classified as “moderate” flood events. No breakout occurred at Pink Lily and as a result, the inundation extents were much smaller than either the 1988 or the 1991 events. As well as Fitzroy River flooding from upstream runoff, significant rainfall occurred in the city itself creating localised runoff and flash flooding in some areas. Photographs from the 2008 flood event are presented in Image 6, Image 7 and Image 8.

At the time of the 2008 flood event, the Bureau of Meteorology flood classifications meant that a flood of 7.5 m was a “major” flood. This caused much concern regarding the expected flood impacts and the flood was not as severe as expected. Following this event the classifications were modified to those presented in Table 5.

Image 6 January and February 2008 event flooding: The Barrage

Image 7 January and February 2008 event flooding: Riverside carparks

Image 8 January and February 2008 event flooding: Riverside pontoons

4. Hydrologic model setup

4.1 URBS modelling package

Hydrologic modelling of the Fitzroy River was undertaken using the URBS modelling software (Version 4.3). This software is a runoff-routing model which is used to simulate catchment and channel storage and routing behaviour in response to rainfall. The software has been developed for use in flood forecasting and design flood estimation and is used by the BoM for its flood forecasting/warning models.

Catchment parameters can be either derived or estimated and are set at the sub-catchment level. The variables which can be used by URBS are stream length, catchment area, channel slope, catchment slope, fraction urbanised (various degrees), fraction forested and channel roughness, with a minimum requirement that at least stream length be specified to define the extent of catchment and/or channel routing. Where recorded rainfall and stream flow data is available for a given model area, these parameters can be adjusted, within certain ranges, to obtain model calibration.

Two different routing models are available to model the sub-catchment and channel storage routing behaviour. These are the URBS Basic and Split models. In the Split model, which has been used for the Fitzroy River, rainfall on the sub-areas is firstly routed to the creek channel and then along the creek channel. This model is suitable for representing large creeks or rivers where the main channel hydraulic properties are largely unaffected by the extent of catchment urbanisation or forestation.

4.2 Model development

The URBS model developed for the *Rookwood and Eden Bann Weirs Design Flood Hydrology* (SunWater, 2008) assessment was sourced for use in this study. The model was reviewed and checked to ensure it met the criteria of this study. Key features of the SunWater model include:

- 113 sub-catchments (as shown in Appendix A)
- Representation of the flood storage that occurs at Fairbairn Dam and at the junction of the Dawson and Mackenzie Rivers
- Calibration data for the 1918, 1954, 1958, 1983, 1988, 1990, 1991 and 2008 events including recorded rainfall and stream flows
- Gauge rating data for the Riverslea, The Gap, Wattlebank, Yaamba and Rockhampton gauges as well as additional upstream gauges

The storage effect at the junction of the Dawson and Mackenzie Rivers was modelled using a trial and error approach in which the storage relationship was modified until the upstream and downstream hydrographs matched the recorded hydrographs. This process was carried out for all modelled events, up to and including the 1918 event. It is noted in the report that storage effects above the 1918 event magnitude have not been included in the model as it is unknown how the storage will impact upon these extreme events.

5. Hydraulic model development

5.1 TUFLOW modelling package

Hydraulic modelling of the Fitzroy River floodplain within the Rockhampton area was undertaken using the two-dimensional TUFLOW modelling package. As discussed in Section 3.2, floodwaters break out from the Fitzroy River during flood events creating widespread inundation with complex flow patterns across the floodplain. Flow situations of this type are best modelled using a two-dimensional approach in which modelling of free surface flows occurs and stratification can be neglected. TUFLOW simulates the water level variations and flows in response to a variety of forcing functions in floodplains, lakes, estuaries, bays and coastal areas. The water levels and flows are resolved on a rectangular grid covering the area of interest when provided with bathymetry (topography), bed resistance coefficients, wind field, hydrographic boundary conditions etc.

TUFLOW also includes the capacity to incorporate one-dimensional elements which are hydraulically linked to the two-dimensional floodplain, such as culverts. The one-dimensional modelling package within TUFLOW is called ESTRY.

The TUFLOW model development and data requirements for this project are detailed in the following sections.

5.2 Model development

The TUFLOW model consists of both one- and two-dimensional elements. The two-dimensional domain covers the study area presented in Figure 3. A one-dimensional branch was included downstream of this domain to join the model to the ocean and provide a realistic representation of tailwater conditions. The overall hydraulic model layout including the 1-D branch is presented in Figure 5 and more detail of the 2-D domain is presented in Figure 6.

5.2.1 Model grid

The purpose of the hydraulic modelling was to estimate the characteristics of Fitzroy River flooding. Given that Fitzroy River flood inundation can be extensive and the adopted study area was large (16.5 x 23.0 km) it was necessary to use a 50 m grid spacing in order to manage the model run times and file sizes. This grid spacing, whilst not sufficient to allow detailed modelling of small-scale flood characteristics, was sufficient to predict the overall flood characteristics of Fitzroy River flood events.

5.2.2 Topography

The topographic data discussed in Section 2.2 was used to create a terrain model of the study area. The datasets were used in the following order:

- Fitzroy River cross-sections were used to create a two-dimensional representation of the river bathymetry. This data was overlain onto the LiDAR data
- LiDAR data was used in all other areas

A single DEM was created over the study area using the above data. This DEM represents the floodplain as it currently exists. In order to calibrate the model to the 1988 and 1991 flood events it was also necessary to create separate topographic information to incorporate into the TUFLOW model for these events. The areas covered by these separate datasets are as follows:

- The airport prior to the runway extension – a separate DEM was created based upon the airport contours described in Section 2.2.3
- The Nine Mile Road area prior to construction of the road embankment which is up to 4 m above existing surface levels – this was done using interpolation between LiDAR levels on either side of the existing embankment

The crest elevations of the airport levees are also represented separately within the TUFLOW model. For the 1988 and 1991 events, the levee crest elevations were sourced from the airport contours. For the 2008 event the crest elevations were sourced from the detailed survey undertaken in August 2009.

5.2.3 One dimensional model network

The MIKE 11 model developed by Camp Scott and Furphy (CMPS&F) (1992) extended downstream to Port Alma, approximately 51 km from Rockhampton, enabling the modelling to account for the hydraulic impacts of tidal variations in the river. A similar approach was adopted for this study using details from the MIKE 11 model and incorporating them as one-dimensional (ESTRY) elements in the TUFLOW model.

The one-dimensional model network was developed between the downstream end of the two-dimensional domain (at Port Curtis) and the ocean. The MIKE 11 model between these two locations was converted to an ESTRY model. For the 1988 event, the Pirate Point bend was included in the modelling and for all later models this bend was removed.

5.2.4 Land use type (roughness)

The materials file represents the variations in land use across the model area. The materials file was based upon the Rockhampton Regional Council Planning Scheme zones, with further refinement in some areas based upon the site inspections and the aerial photography. Table 6 presents the adopted Manning's roughness values for each land use type and Figure 7 presents the adopted spatial variation in land use.

Table 6 Adopted Manning's n values for each land use type

Land Use	Manning's n
Residential	0.15
Commercial	0.15
Rural	0.05
High Density Residential	0.15
Rural Residential	0.05
Low Density Vegetation	0.05
Medium Density Vegetation	0.06
High Density Vegetation	0.10
Parks	0.04
Vacant Land	0.04
Roads	0.02
Lagoons	0.03
Rivers	0.03
Creek Channels	0.03
Wetlands	0.08

5.2.5 Hydraulic structures

There are a large number of bridge and culvert structures in the study area. Many of these structures are designed to convey flow from local catchments and are not designed to convey Fitzroy River flows. These structures generally have a small flow capacity and would not have significant impacts upon Fitzroy River flooding. For this reason, most of these structures have been excluded from the hydraulic modelling and openings in the embankments have been modelled instead. Whilst it is noted that this approach has the potential to yield less representative results in the immediate vicinity of the structures, any such variations would be minimal in the context of floodplain wide behaviour.

The key structures which are likely to impact upon Fitzroy River flooding and the capacity of the floodplain to convey Fitzroy River floodwaters have been included in the model. Culverts were modelled as one-dimensional structures linked to the two-dimensional model domain and bridges were modelled as two-dimensional structures with appropriate energy losses applied. The modelled structure details are presented in Table 7.

Table 7 Modelled structures

Waterway	Crossing Location	Crossing Structure Details
Fitzroy River	Barrage	22/14 m span barrage[1]
Fitzroy River	Railway	2/77 m + 3/31 m span bridge
Fitzroy River	Bruce Highway	4/71 m + 2/56 m span bridge
Fitzroy River	Fitzroy Street	5/53 m + 2/44 m span bridge
Fitzroy River Breakout – Yeppen	Railway	20/10 m span bridge
Fitzroy River Breakout – Yeppen	Bruce Highway	20/10 m span bridge
Fitzroy River Breakout – Lotus Lagoons	Nine Mile Road[2]	1/0.375 x 0.375 m RCBC 2/0.45 x 0.45 m RCBC 3/1.2 x 0.3 m RCBC 7/1.2 x 0.45 m RCBC 3/1.2 x 0.6 m RCBC 4/3.0 x 2.1 m RCBC 2/3.0 x 2.4 m RCBC 1/3.0 x 3.0 m RCBC
Lion Creek	Airport Runway[2]	1/9.1 x 4.43 m arch culvert

[1] Three structure invert levels were adopted for the barrage to represent the three distinct sections
[2] These structures were not included in the 1988 or 1991 calibration runs as they did not exist at this time

5.2.6 Boundary conditions

Boundary conditions define the hydraulic conditions at the model boundaries and are selected in order to provide a suitable representation of the model within the larger catchment basin system. For the model area, shown in Figure 5 and Figure 6, the boundary conditions are:

- Inflow at upstream model extent – a time-varying discharge was sourced from the URBS model
- Tailwater level at the downstream model extent – time-varying water levels (as described in Section 2.4.5) were applied for the calibration events and static water levels were applied for the design events

Inflows from local catchments may occur across the floodplain. These catchments have not been considered in the floodplain modelling as:

- They are much smaller than the Fitzroy River catchment and are therefore considered negligible
- Runoff from these catchments would occur much quicker than that of the Fitzroy River and would have already passed through the system before Fitzroy River flooding reached Rockhampton

6. Model calibration

6.1 Calibration procedure

Several different datasets were available to assist with calibration, including time-varying river levels at the Rockhampton Gauge, surveyed peak flood levels across the floodplain and aerial photographs showing flood extents. In order to achieve calibration, the model is required to replicate the recorded flood data within specified tolerances. For each type of flood record, a different tolerance is specified, reflecting the reliability and accuracy of the historical flood data. Surveyed peak flood levels are generally based upon flood debris marks or reported flood marks and are of varying levels of accuracy; therefore they are less reliable than recorded gauge levels. Adopted calibration tolerances for the Fitzroy River model are as follows:

- Surveyed flood debris marks/peak flood levels ± 300 mm
- Rockhampton Gauge ± 150 mm

A joint calibration procedure was used in which the URBS model was run and the resultant Fitzroy River discharges were input to the TUFLOW model. The predicted water level time series at the Rockhampton Gauge and peak water levels across the floodplain were then compared to historic flood level records. The URBS model parameters were then modified to produce changes in the TUFLOW inflow hydrograph and the TUFLOW model was rerun. Once a reasonable calibration was achieved, the TUFLOW model parameters were modified to make smaller scale changes to the flood behaviour and further improve the calibration. This process was used for the 1991, 1988 and 2008 flood events to determine a set of model parameters which produced good calibration for all three events.

The calibration process usually involves calibration of the hydrologic model as well as the hydraulic model. A gauge rating provides a relationship between flood levels and discharges and the model discharge predictions are compared to the recorded levels. Discussions with DERM officers indicated that the ratings for stream gauges on the lower Fitzroy River have only been developed for low flow events and are not reliable for high flow events. For this reason, the calibration process focussed upon calibrating the hydraulic model.

6.2 URBS model parameters

URBS model parameters are used to modify the shape, timing and magnitude of the calculated discharge hydrograph. Two sets of parameters are used, with one set responsible for the model routing and the second responsible for defining the rainfall-runoff relationship. These are described further below.

The SunWater URBS model was calibrated to a range of flood events. The calibration process used by SunWater included variation of the model parameters for each event to achieve the best match for that particular event. As a result, the best model parameters for calibration are different for each event. When a model is being calibrated with the intention of then being used for predictive flood modelling it is desirable to use parameters which are consistent across a range of events. If a consistent set of parameters can be derived, it provides better justification for using these parameters in predictive modelling. For this reason, the calibration process was based around developing a consistent set of parameters for use in the design event modelling.

6.2.1 Routing parameters

Channel lag parameter (α)

The Channel lag parameter governs the rate at which flows are routed between the sub-catchments, using the non-linear Muskingum model. The SunWater model used an α value ranging between 0.25 and 0.37 for the nine different calibration events and an α value of 0.3 for design events.

Catchment lag parameter (β)

The catchment lag parameter is used in the catchment storage-discharge relationship. The SunWater model used a β value ranging between 2.0 and 3.0 for the calibration events and 2.5 for design events.

Catchment non-linearity parameter (m)

This parameter provides control of the linearity of the catchment storage-discharge relationship. The SunWater (2008) model used an m value of 0.8 for all calibration and design events.

6.2.2 Loss parameters

Loss parameters allow hydrologic models to approximate the effect of infiltration and other catchment losses on the rainfall-runoff relationship. The continuing loss model contains estimations of initial losses, such as catchment storage, and continuing losses, such as infiltration, which are discussed below. The variation in catchment characteristics, such as preceding rainfall, between each runoff event means that loss parameters vary from event to event and are rarely consistent between events.

Initial loss (IL)

Initial loss refers to the absolute quantity (expressed in millimetres) of rainfall initially absorbed by the catchment at the beginning of a rainfall event. The initial loss generally impacts upon the timing of the catchment response and the shape of the early part of the hydrograph. The range of initial loss rates for eastern Queensland recommended by *Australian Rainfall and Runoff* (AR&R) (1987) is 0 to 140 mm. Values outside this range are acceptable when calibration data is available and provides justification for modifying these values. The initial losses used in the SunWater model ranged from 0 to 200 mm.

Continuing Loss (CL)

Continuing loss refers to the ongoing losses (expressed in millimetres per hour) once the initial loss capacity has been exceeded by the rain falling on the catchment. The continuing loss generally impacts upon the shape of the hydrograph. An ongoing loss rate in the order of 2.5 mm/hr is recommended by AR&R (1987). The continuing losses used in the SunWater model ranged from 0 to 3 mm/hr.

6.2.3 Adopted URBS model parameters

The adopted URBS model parameters for the calibration events are presented in Table 8. Whilst every effort was made to calibrate the model using consistent parameters for all events, the change in alpha value for the 1991 event was necessary to obtain an acceptable calibration for this event. A lower alpha value reduces the routing effects within the model and causes the flood waters to travel quicker, therefore creating a higher flood peak which occurs earlier in the flood.

Table 8 Adopted URBS model parameters

Event	Alpha (α)	Beta (β)	m	Initial Loss (mm)	Continuing Loss (mm/hr)
March 1988	0.32	2.5	0.8	50	2
January 1991	0.28	2.5	0.8	215	0
January 2008	0.32	2.5	0.8	150	3
February 2008	0.32	2.5	0.8	150	0.5

The URBS model peak discharges which were input as boundary conditions at the upstream extent of the TUFLOW model are presented in Table 9.

Table 9 URBS model peak discharges

Event	Peak Discharge (m^3/s)
March 1988	8,083
January 1991	14,573
January 2008	4,643
February 2008	4,968

The predicted peak flow values for the 1988 and 1991 events are similar to those identified in the CMPS&F *Rockhampton Flood Management Study* (1992). This previous study predicted peak flows at Yaamba/The Gap of 9,660 m^3/s for the 1988 event and 14,550 m^3/s for the 1991 event.

6.3 March 1988 event calibration

For the 1988 event the following features were included in the model:

- No breakthrough of the river at Pirate Point
- Pre-2000 Nine Mile Road and airport ground levels (ie no runway extension and no Nine Mile Road upgrade)

6.3.1 Rockhampton stream gauge

Figure 8 compares the predicted water levels from the TUFLOW model to the recorded water levels at the Rockhampton Gauge. This figure shows a good match of shape for the rising limb of the flood and for the peak of the flood, with a difference of 0.08 m between the predicted and recorded peak values. The timing of both the rising limb and falling limb of the flood event are predicted to occur slower in the TUFLOW model than actually occurred. Given that the shape and peak were well matched, it was considered that the timing was of much less concern, and therefore a good calibration had been achieved.

6.3.2 Recorded peak water levels

Peak water levels were recorded at 26 locations around the city. Figure 9 and Figure 10 present the comparison of water levels at these locations, with the differences between the calculated and recorded flood levels characterised into bands. Locations where the model predictions are within the tolerance ranges (as presented in Section 6.1) are shown as orange, yellow and green points. Locations where the model predictions are outside the tolerance ranges are shown as red and blue points. Locations where there were recorded peak water levels and no predicted water levels are shown as purple points.

These figures show that the calibration results are generally within the specified tolerances. Key outcomes of the calibration are:

- Of the 26 recorded points, 19 of the calculated values were within the 0.3 m tolerances, 5 were outside the tolerances and the inundation extents did not reach the other two locations
- The average difference (absolute) between the calculated and recorded water levels is ±0.20 m
- Water levels in Splitters Creek (Park Avenue) are well matched
- The calculated water level in Lion Creek near the airport runway is -0.31 m lower than the recorded level
- The airport was not predicted to be flooded which is consistent with anecdotal information
- Model predictions near Murray Lagoon and the Rockhampton Golf Course are -0.21 m below recorded levels
- Water levels in Depot Hill and Port Curtis are well matched

- Water levels in Moores Creek, Frenchmans Creek and Thozet Creek are predicted to be higher than the recorded values. It is possible that the structure modelling approach adopted within the model is over-predicting the backflow into these areas
- The flood extents did not reach areas in Victoria Park, Wandal and north-east of Lakes Creek Road, Lakes Creek where peak water levels were recorded

6.4 January 1991 event calibration

For the 1991 event the following features were included in the model:

- Breakthrough of the river at Pirate Point
- Pre-2000 Nine Mile Road and airport ground levels (ie no runway extension and no Nine Mile Road upgrade)

6.4.1 Rockhampton stream gauge

The correlation between calculated and recorded water levels at the Rockhampton Gauge is shown in Figure 11. This figure shows a difference in calculated and recorded peak water surface levels of -0.12 m. There is a good match of shape and timing throughout the main part of the flood event.

The stream gauge calibration plot shows disparity between the calculated and recorded levels for the first 150 hours of the event. This occurs as a result of the URBS model inflow hydrograph. To obtain an inflow hydrograph which better matches the early stages of the recorded results, unreasonable changes to the URBS model parameters would be required. It was considered that matching shape and timing through the main part of the flood was more important during this event.

The falling limb of the TUFLOW model predictions is much better matched to the recorded data in the 1991 event than for the 1988 event.

6.4.2 Other recorded time series

A number of other recorded water level time series were sourced during the data collection phase of the study. Figure 12 and Figure 13 present the comparisons of predicted and recorded values at a number of locations in the airport and at a number of TMR bridges respectively. With both of these datasets there is uncertainty regarding the exact location of the gauges and therefore the calibration tolerances for peak flood levels (±0.3 m) have been adopted for these datasets.

Airport time series

Information regarding the approximate locations of the recorded flood level time series at the airport was provided, however the exact locations are unknown and anecdotal evidence from a number of sources indicates a number of different locations for each gauge. These generally indicated:

- Gauge 1 is located between the taxiway and the main runway (15/33 runway) to the south of the apron
- Gauge 2 location may be to the south-western side of the crossing of the two runways
- Gauge 3 was on the inside of the levee near Lion Creek, on the western side of the main runway

Figure 12 and Table 10 show that an acceptable match is achieved at Gauges 1 and 3 (generally being 0.2 m to 0.3 m higher), whilst the predicted values at Gauge 2 appear to be greater than 0.6 m above recorded values. The model predicts a significant change in water levels across and to the south of the 04/22 runway, therefore the location at which the water level time series are extracted from the model can have a large impact upon the water level values. Given the uncertainty regarding the locations of the recorded data, this was considered a reasonable match. Figure 12 also shows that, at all three locations, the recorded flood event was of a shorter duration than that predicted by the model. The recorded flood duration throughout the airport was also shorter than the recorded duration at the Rockhampton Gauge.

Table 10 Peak water level comparisons: Airport data

Location	Recorded Peak Water Level (m AHD)	TUFLOW Calculated Peak Water Level (m AHD)	Difference (m)
Gauge 1	9.05	9.27	+0.22
Gauge 2	9.35	9.98	+0.63
Gauge 3	10.28	10.56	+0.28

TMR time series

Recorded time series data was available from TMR at the locations shown in Table 11.

Table 11 TMR time series locations

TMR Location	Assumed Location
Lion Creek	Lion Creek at Rockhampton-Ridgelands Road
Fairybower	Scrubby Creek at Capricorn Highway
Yeppen	Bruce Highway at Yeppen
Gavial Creek	Gavial Creek at the Bruce Highway

Figure 13 shows that the duration of the flood event is well matched by the TUFLOW model. The second peak of the flood event is not as well predicted in the model as the first peak. The comparison of peak values in Table 12 shows that model predictions at all four locations are within the adopted tolerances.

Table 12 Peak water level comparisons: TMR data

Location	Recorded Peak Water Level (m AHD)	TUFLOW Calculated Peak Water Level (m AHD)	Difference (m)
Lion Creek	10.39	10.55	+0.16
Fairybower	9.10	8.93	-0.17
Yeppen	8.64	8.44	-0.20
Gavial Creek	7.24	7.18	-0.06

6.4.3 Recorded peak water levels

Peak flood levels were recorded at 155 locations around the City and Pink Lily. The comparisons presented in Figure 14 and Figure 15 show that good floodplain-wide calibration was achieved for this event. Key outcomes of the calibration include:

- Of the 155 recorded points, 130 of the calculated values were within the 0.3 m tolerances, 18 were outside the tolerances and the inundation extents did not reach the other seven locations
- The average difference (absolute) between the calculated and recorded water levels is ±0.14 m
- A good match of water levels is achieved throughout most of Pink Lily and along Lion Creek and the old Nine Mile Road. Of the 38 recorded points, 30 are within the adopted tolerances, 5 are approximately +0.31 to +0.39 m above the recorded levels and a single point is +0.62 m above the recorded levels. A single point near Lion Creek is -0.36m below the recorded level; however the comparison to TMR data at this location (Table 11) shows that predicted levels are higher than recorded. During the calibration process the recorded Pink Lily levels were raised by +0.413m as the recorded data indicated a PSM level of 9.80 m AHD near the intersection of Osborne Road and Ridgelands Road and DERM information indicated that the level of this PSM is 10.213 m AHD

- Predicted water levels near Limestone Creek and Splitters Creek (Kawana and Park Avenue) are a good match to the recorded values, with a single location near Farm Street showing water levels higher than the adopted tolerance
- Water levels in Jardine Park at slightly lower than recorded values, although they are still within the adopted tolerances. The flood in this area is not as extensive as the recorded data, which is shown by the two points at which no inundation is predicted
- A comparison of recorded and predicted flood levels around the airport shows that a good match is achieved, with most model predictions within the adopted tolerances. The exception is the calculated water levels near Garland Park, which are +0.37 to +0.39 m above the recorded values
- Water level predictions in the Yeppen area are within the adopted tolerances and are lower than the recorded values by approximately -0.22 m. This is consistent with the findings of the TMR time series comparison (Table 12).
- The model predictions around Gladstone Road in Allenstown are within the adopted tolerances however there is a general trend in this area with the model predictions -0.20 to -0.24 m lower than recorded
- Predictions around the Depot Hill area are a good match to recorded values
- A good match to recorded water levels through Berserker and Koongal was achieved

During the calibration process a number of changes were made in the model to better predict the inundation in specific locations. These changes included:

- Modification of the levels at the airport terminal to better represent the terminal floor elevation
- Modification of the model to allow flow into areas where flood waters back up through the piped stormwater system and cause inundation of low lying surfaces. These areas are:
  - Jardine Park
  - Park to west of Lion Creek Road and north of railway
  - Area west of railway line near Gladstone Road/Stanley Street
  - East Stanley Street
  - Berserker, between Moores Creek and the landfill

6.5 January and February 2008 event calibration

For the 2008 event the following features were included in the model:

- Breakthrough of the river at Pirate Point
- Nine Mile Road upgrade including road crest levels and cross-drainage culvert structures
- Airport runway extension and Lion Creek culvert

6.5.1 Rockhampton stream gauge

The correlation between calculated and recorded water levels at Rockhampton Gauge is presented in Figure 16. This figure shows the calculated peak water levels are -0.25 m lower than recorded for the first flood peak and -0.22 m lower than recorded for the second flood peak, both of which are outside of the adopted tolerances. In terms of timing, the model shows a more rapid rise in the water surface level for both peaks than was recorded. This results in an approximate time difference of 30 hours at both the peaks between the calculated and recorded levels at the gauge. These timing and peak water level issues could have been modified through the use of different URBS model parameters, however, given the relatively small magnitude of the 2008 events, it was considered more prudent to have consistent URBS model parameters than to have an improved calibration for the 2008 events.

6.5.2 Barrage SCADA gauge

Figure 17 shows the comparison of calculated and recorded water levels upstream of the Barrage. This figure shows that the recorded water levels were higher for the first flood peak (the January event) than for the second flood peak (the February event). At the Rockhampton Gauge 3.3 km downstream of this point, the second flood peak was higher than the first.

Figure 17 shows that the differences between the calculated and recorded flood peaks are -1.06 m for the first peak and -0.69 m for the second peak. This indicates that the model predictions of flood grade between the Barrage and the river gauge during this small event are not well matched. It is possible that the model representation of the Barrage and the impacts it has on peak water levels are not well modelled for small events.

6.5.3 Recorded peak water levels

Recorded water level calibration

A small data set of 16 calibration points was collected following the 2008 events. The collection of this data was based upon flood debris marks and anecdotal flood information. Figure 18 and Figure 19 show the comparison of predicted and recorded peak water levels for this event. These figures show that the calibration for this event is not as accurate as it was for the 1988 and 1991 events. Given the smaller magnitude of this event, this was considered to be of less importance than accurate calibration of the 1988 and 1991 events. The comparison of flood levels generally shows:

- Low predictions of peak flood levels along the main river channel
- High predictions along Main Drain in Depot Hill
- Good match to other points in Depot Hill, Allenstown and Port Curtis
- Low and high predictions of peak flood levels in The Common, Berserker and Koongal

It is understood that the approximately 180 mm of rainfall was recorded in Rockhampton during the February 2008 flood event. This was not included in the model as, while it would be expected to increase the flood extents and provide a better calibration in areas which local flooding was an issue, it is not expected to increase predicted water levels in the river itself.

6.6 Calibration summary

The model is well matched to the recorded flood data for the 1988 and 1991 events. The calibration of the 2008 event is not as well matched, however this event is much smaller in magnitude and therefore of much less importance for calibration.

Some general comments regarding the calibration are as follows:

- The model predictions through Allenstown are generally low for the 1991 event. Freeboard on model predictions in this area may need to be higher than in other areas of the model
- The sewage treatment plant may not have been in place in earlier events; however it is not expected to have a significant effect on peak water levels
- Landfill levels have changed over time but are represented in model using 2008 levels. The landfill topography is not expected to have a significant effect on peak water levels

7. Flood frequency analysis

A flood frequency analysis (FFA) of the available historical flood data (as presented in Table 3) was carried out. This was based upon the process described in the following sections.

7.1 Riverslea, The Gap, Wattlebank and Yaamba Gauges

Recorded water level and associated discharge data was supplied by DERM for the periods of record identified in Table 13. An annual flood series analysis was carried out for each gauge, with the annual peak discharge based upon a water year from 1 June to 30 May.

Table 13 Stream gauge data analysed for flood frequency analysis

Stream Gauge Location	Period of Record	Number of Years Analysed
Yaamba	1914 – 1974	60
Wattlebank	1918 – 1956 and 1995 – present	51
The Gap	1964 – present	44
Riverslea	1922 – present	86

Results for each of the four gauges are presented in Table 14. The Yaamba gauge contains much higher estimates for the extreme return periods as records for this gauge stopped in 1974 and are therefore skewed as a number of significant flood events occurred after this date.

FFA at The Gap also shows higher values for the extreme events as records for the gauge only commenced in 1964 and therefore a number of the earlier significant flood events have not been included in this calculation.

FFA calculations at Riverslea and Wattlebank are similar. The data used for the Wattlebank Gauge contains a 39 year gap in the record and therefore the FFA for the Riverslea Gauge is considered the most reliable of the four gauges.

Table 14 Flood frequency analysis results

Return Period (years)	Peak Discharge (m^3/s)			
	Riverslea	The Gap	Wattlebank	Yaamba
2	2145	1715	1977	2574
5	5195	4188	4790	5141
10	7848	6556	7300	7791
20	10762	9401	10127	11308
50	14961	13961	14323	17765
100	18362	18064	17824	24477
200	21926	22774	21588	33279
500	26845	29996	26939	49164
1000	30695	36265	31251	65415
2000	34631	43274	35772	86451

7.2 Rockhampton Gauge rating

Gauge rating data for the Rockhampton Gauge was sourced from BoM and from the SunWater URBS model. Following collection of gauging data at Riverslea during the 2008 flood event, BoM revised their rating curves at Riverslea and the gauges downstream of this location. At the Rockhampton Gauge this reduced the discharges associated with water levels up to 8.0 m. These rating curves are presented in Figure 20.

Gauge rating data was also sourced from the calibrated TUFLOW model by undertaking model runs with a number of input hydrographs of varying magnitude. The adopted rating curve for the Rockhampton Gauge was based upon the TUFLOW model predictions, with the low flow values based upon the Post 2008 BoM rating. Figure 20 shows that the adopted rating curve is similar to the Post 2008 BoM rating curve for the lower flows, with water levels being slightly higher in the adopted rating curve than those of the BoM rating curve. For the higher flows the adopted rating curve has lower water levels than the BoM or SunWater rating curves.

7.3 Rockhampton Gauge flood frequency analysis

Historical recorded peak water levels were supplied by DERM for 149 years of record. A total of 85 flood peaks have been recorded during this period. Peak flood levels have not been recorded for years in which only low flow events occurred.

The data supplied by DERM was analysed to test independence of the flood peaks. Independent peaks were considered to be at least 14 days apart. Of the 85 records supplied 76 were considered to be independent and were carried through to the FFA. These peak recorded water levels were converted to discharges based upon the adopted rating curve at this gauge (see Section 7.2 for more information on the adopted rating curve).

Partial duration series analysis was carried out as historical data was only supplied for years in which water levels reached above the gauge threshold. This means the FFA results for Return Periods (or Average Recurrence Intervals (ARI)) of less than 5 years are not valid.

Figure 21 presents a comparison of the FFA for the Rockhampton Gauge and the four gauges discussed in Section 7.1. The Rockhampton FFA results are lower than the results at the other gauges as a result of the revised rating curve used at this gauge. The different methods of analysis (ie partial versus annual series) may also be contributing to the different results. The FFA results for the other gauges generally sit within the upper 95% confidence limits of the Rockhampton Gauge analysis. The peak water levels were calculated using the adopted gauge rating curve.

Table 15 Rockhampton Gauge flood frequency analysis results

Return Period (years)	Peak Discharge (m^3/s)	Upper 95% Confidence Limit	Lower 95% Confidence Limit	Peak Water Level (m Gauge Datum)
2	N/A	N/A	N/A	N/A
5	4569	5164	4063	7.24
10	6698	7763	5891	8.03
20	9056	10822	7810	8.51
50	12675	15774	10626	8.97
100	15876	20351	13030	9.33
200	19547	25779	15714	9.70
500	25233	34492	19754	10.21
1000	30258	42451	23235	10.61
2000	35995	51786	27125	11.04

7.4 Magnitude of historical floods

The magnitudes of a number of historical flood events at the Rockhampton Gauge have been estimated from the FFA results and are presented in Table 16. The peak discharges and the return periods have both been calculated using the adopted rating curve.

Table 16 Estimated magnitude of historical floods

Flood Event	Recorded Flood Peak (m Gauge Datum)	Peak Discharge (m^3/s)	Estimated Return Period (years)
January 1918	10.11	24030	1823
April 1928	8.72	10630	23
March 1940	8.02	6678	9
January 1951	8.30	8006	13
February 1954	9.40	16502	152
March 1955	8.23	7651	12
February 1956	8.08	6915	10
April 1958	8.15	7245	11
February 1978	8.15	7245	11
May 1983	8.25	7753	13
March 1988	8.40	8514	15
January 1991	9.30	15581	88
January 2008	7.55	5246	6
February 2008	7.75	5782	7

The FFA undertaken by Camp, Scott & Furphy (1992) predicted that:

- The 1918 event equated to a 220 year ARI event
- The 1954 event equated to a 70 year ARI event
- The 1991 event equated to a 60 year ARI event

The FFA in the CMPS&F study was based upon an analysis of recorded gauge levels, whilst the FFA used in Table 16 was based upon an analysis of discharges (and therefore reliant upon the rating curve adopted). The CMPS&F approach also used the Gumbel distribution whilst the Log Pearson III approach has been used in this study. These differences in approach both impact upon the FFA estimations as shown in Table 15. It is important to note that both methods show that the 1954 and 1918 events were extreme events and the 1918 event was much larger than a 100 year ARI event. Development control and emergency management planning should therefore take into account the fact that such an event has occurred and include measures to deal with an event of such a large magnitude.

8. Design event flood modelling

8.1 URBS model rainfall data

The hydrologic model developed for the calibration events was used as the basis for the design event hydrologic modelling as defined in the following sections.

8.1.1 2 to 100 year ARI events

Rainfall data for the design events was set up using a similar process to that adopted by SunWater (which was based upon recommendations from AR&R). The following information was used:

- Temporal patterns from AR&R Zone 3 were used for the 2 to 100 year ARI events
- IFD data was developed using the CRC-Forge method. This method does not provide estimates of rainfall intensity for the 2 year ARI event. The intensities for the 2 year ARI event were based upon those in the SunWater report. The adopted rainfall intensities are presented in Table 17
- Areal reduction factors were included in the CRC-Forge rainfall intensities
- 36 hour event rainfall intensities were linearly interpolated between the 24 and 48 hour event intensities
- The size of the catchment means that rainfall will not occur evenly across the entire catchment. Topographic adjustment factors (TAF) were used to vary the rainfall across the catchment extents. The TAFs from SunWater's model were adopted for this analysis

Table 17 Adopted Rainfall Intensities

Duration (hrs)	Rainfall Intensity (mm/hr)					
	2 yr ARI	5 yr ARI	10 yr ARI	20 yr ARI	50 yr ARI	100 yr ARI
6	0.00	8.55	9.77	11.39	13.59	15.42
12	0.00	5.10	5.85	6.85	8.21	9.32
18	0.00	3.93	4.53	5.33	6.42	7.29
24	2.71	3.26	3.78	4.45	5.39	6.11
36	2.22	2.72	3.14	3.71	4.48	5.07
48	1.98	2.44	2.83	3.33	4.03	4.56
72	1.60	1.94	2.24	2.64	3.20	3.62

8.1.2 Probable maximum precipitation event

Probable Maximum Precipitation (PMP) has been defined by the World Meteorological Organisation (2009) as 'the greatest depth of precipitation for a given duration, meteorologically possible for a given size storm area at a particular location at a particular time of year'. In other words, it is the most rainfall that could possibly fall within a catchment. The PMP event results in a Probable Maximum Flood (PMF) event. This is a theoretical event which is very unlikely to ever occur within any given catchment.

The PMF event is typically used in design of hydraulic structures, such as dams. Its most common use is in design of dam spillways to minimise the risk over overtopping of a dam and prevent the likelihood of dam failure. Other than this practical use, it is also used to provide an indication of the largest flood extents expected within any given catchment. This data can be used by emergency management agencies in their understanding of and planning for flood events.

Using the methodology set out in the *Guidebook to the Estimation of Probable Maximum Precipitation: Generalised Tropical Storm Method* (BoM, 2003) the following data for the PMP was determined:

- The coastal Generalised Tropical Storm Method (GTSMR) is applicable as the catchment lies on the QLD coast
- The TAF, Decay Amplitude Factor (DAF), Extreme Precipitable Water (EPW) and Moisture Adjustment Factor (MAF) were calculated as 1.0578, 0.9378, 88.5486 and 0.7379 respectively
- PMP parameters were calculated as shown in Table 17

Table 18 Adopted PMP parameters

Duration (hrs)	Rainfall Total (mm)	Rainfall Intensity (mm/hr)
24	290	12.08
36	350	9.72
48	400	8.33
72	490	6.81
96	550	5.73
120	580	4.83

The ARI of the PMP event was calculated as recommended in AR&R. Using a catchment area of 140,000 km^2, the PMP event is approximately a 7000 year ARI event.

Temporal patterns for the PMP event were sourced from data provided with the GTSMR guidebook. Patterns from coastal_avm_150000.xls were used as this was the closest applicable data for a catchment area of 140,000 km^2.

8.2 URBS model parameters

Hydrologic model parameters from the calibration events were used as the basis for the design events. Loss parameters for the design events were selected in accordance with AR&R recommendations. The combination of hydrologic model and loss parameters was selected, within acceptable ranges, to produce peak discharges from the URBS model which closely matched the flood frequency analysis results presented in Table 15.

Adopted model and loss parameters are shown in Table 19. These parameters were used for all design events, including the PMF.

Table 19 Adopted design event URBS parameters

Parameter	Adopted Value for Design Events
Alpha (α)	0.3
Beta (β)	2.5
m	0.8
Initial Loss (mm)	30
Continuing Loss (mm/hr)	2.5

8.3 URBS model results

The predicted peak discharges for the design events are presented in Table 20. Figure 22 shows that these peak discharge predictions are close to the FFA calculations and are all within the 95% confidence limits of the FFA. Figure 23 presents the URBS model discharge hydrographs for the 2 to 100 year ARI design events and Figure 24 presents the 100 year ARI and PMF discharge hydrographs.

Table 20 Design event peak discharges

Return Period (yrs)	Peak Discharge (m^3/s)	Critical Duration (hrs)
2	2452	72
5	4908	72
10	7005	72
20	10305	72
50	13214	72
100	16290	72
PMF	56713	120

8.4 TUFLOW model setup

The final calibration model from the 2008 event was used as the basis for the design event modelling. This model contains the following floodplain features:

- Breakthrough of the river at Pirate Point
- Nine Mile Road upgrade including road crest levels and cross-drainage culvert structures
- Airport runway extension and Lion Creek culvert
- Raised airport levees

Other changes to the model include:

- Design event inflow hydrographs
- Adoption of Mean High Water Springs (MHWS) as an oceanic tailwater condition (consistent with industry practice)

8.5 Design event mapping

The TUFLOW model results were analysed and a series of maps were developed to present the results for each modelled return period. Three sets of maps were produced including:

- Inundation extents with peak water surface levels and velocity vectors – these maps present 0.1 m contours of the peak water surface levels, as well as peak velocities displayed as arrows. The velocity arrows show the direction of the flow and are scaled to represent the magnitude of the flow (ie larger arrows mean faster flow)
- Peak depths – the maps present peak depth contours in 0.5 m bands up to a depth of 5 m
- Peak hazard – hazard is a function of flood depth and flood velocity and is related to safety of the flood waters. The peak hazard contours presented in these maps are based upon the recommendations in *Floodplain Management in Australia Best Practice Principles and Guidelines* produced by the Standing Committee on Agriculture and Resource Management (SCARM) (2000). Image 9 is an extract from the guidelines and presents the adopted hazard category relationship

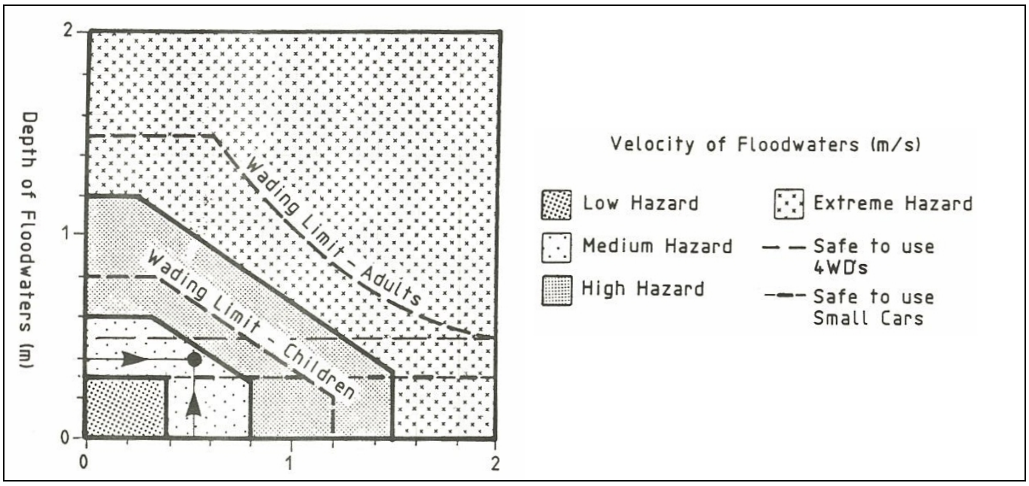

Image 9 Hazard categories

For the 2, 5, 10, 20, 50 year ARI and PMF events a single map covering the entire model extents has been prepared. For the 100 year ARI event, a more detailed set of maps have been prepared to show the model results at a much closer scale. A series of 14 sheets has been used to cover the entire model area and key infrastructure has been included on these maps. This mapping information has also been provided to Council in GIS format.

8.6 Design event gauge levels

Flood levels at flood gauges are usually based upon a “gauge zero” level which represents the level of the stream or river in a low flow event. Hydraulic models are typically based upon ground surface levels expressed in metres to Australian Height Datum (m AHD) – a common datum used across Australia. At the Rockhampton Gauge, the gauge zero is 1.448 m AHD and all hydraulic model predictions need to have 1.448 m added to them if they are to be expressed in gauge level. Flood warnings provided by the BoM will always be expressed in gauge level.

The model results were assessed to determine the predicted gauge level for each event. These are presented in Table 21.

Table 21 Design event gauge levels

Return Period (years)	Peak Flood Level	
	m AHD	m Gauge Datum
2	4.20	5.65
5	5.96	7.41
10	6.65	8.10
20	7.23	8.68
50	7.59	9.04
100	7.93	9.38
PMF	10.86	12.31

8.7 Design event results

The following sections describe the predicted inundation for each of the modelled events. In these descriptions, inundated areas are only described within the first event that affects them (eg the description for the 20 year ARI event does not include areas which are already described in the 2, 5 and 10 year ARI events). For the 100 year ARI event all inundated areas are described.

8.7.1 2 year ARI event

The results for the 2 year ARI event are presented in Figure 25, Figure 26 and Figure 27. These figures show that the 2 year ARI event is contained within the river banks throughout most of the study area. Minor inundation occurs in parts of The Common and flood waters back up Gavial Creek and break out into the areas adjacent to the creek.

Analysis of the sensitivity of the model to the adopted MHWS tailwater condition was undertaken for all design events. This analysis showed that the only event which may be impacted by the tailwater assumption is the 2 year ARI event. A model run undertaken with a Highest Astronomical Tide (HAT) tailwater condition showed that inundation extended into Port Curtis and peak water levels were predicted to be approximately 0.32 m higher in The Common and 0.30 m higher in Port Curtis and Gavial Creek.

8.7.2 5 year ARI event

In the 5 year ARI event, Port Curtis and the Common are almost entirely inundated, as shown in Figure 28, Figure 29 and Figure 30. Flood waters travel back up Gavial Creek and into low-lying parts of Fairy Bower and Gracemere. Floodwaters also start to flow back up Moores Creek, Frenchmans Creek and Thozet Creek into Koongal and Berserker. In Kawana, floodwaters which flow back up Splitters Creek inundate low-lying areas adjacent to Haynes Street. Inundation occurs in parts of Depot Hill, including:

- The western end of Arthur Street
- West Street
- Properties adjacent to the rail yards on Arthur Street and Alma Street
- Properties adjacent to the Main Drain on Wood Street
- O’Connell Street between Main Drain and Denison Street
- The southern end of Wharf Street and The Bend

8.7.3 10 year ARI event

Figure 31, Figure 32 and Figure 33 present the results of the 10 year ARI event. Under this event, the Pink Lily breakout occurs and floodwaters reach into Alton Downs, Nine Mile and around the western side of the airport. Populated areas which become inundated include:

- Berserker
  - The western end of Lucas Street, Kirkellen Street, Bernard Street and Macaree Street near Moores Creek
  - Between Water Street and Frenchmans Creek, south of Rodboro Street and north of Peter Street
  - Between Tucker Street and Frenchmans Creek
  - Witt Street and Rodboro Street between Dean Street and Water Street
  - Properties near the corner of Rodboro and Berserker Streets
  - Elizabeth Park and McLeod Park and some adjacent properties
  - Properties along the flowpath leading from Tomkins Street to McLeod Park and the across Dean Street and Water Street towards Frenchmans Creek
- Koongal
  - The western end of Grubb Street
  - Between the Railway and Lakes Creek Road, adjacent to Thozet Creek
  - To the northern side of Lakes Creek Road adjacent to Thozet Creek and Little Thozet Creek
  - The flowpaths which runs between Frenchmans Creek and Thozet Creek, near Betascapes
- Lakes Creek
  - Properties adjacent to the river to the south of Dorly Street
- Port Curtis
  - East of the Railway and north of Harvey Street

- Depot Hill
  - All properties adjacent to the Main Drain
  - Most properties to the south of Arthur Street, except those up higher on the Hill
  - Quay Street between Francis Street and Stanley Street
  - Properties between Main Drain and Caroline Street
- Allenstown
  - Properties between Prospect Street, Railway, Port Curtis Road and Gladstone Road
  - The eastern end of Elizabeth Street and Bartlem Street
  - Properties adjacent to Main Drain, between Stanley Street and South Street

8.7.4 20 year ARI event

Under the 20 year ARI event, Bruce Highway, North Coast Rail Line and parts of the Airport become inundated as shown in Figure 34, Figure 35 and Figure 36. Inundation in Pink Lily is more widespread and inundation extends into the areas described below:

- Kawana
  - Most areas between Haynes Street and the River
  - Between Haynes and Unmack Streets, to the east of Byrne Street
  - Adjacent to Haynes Street between Byrne and Farm Streets
- Park Avenue
  - Adjacent to Werner Street and Parris Street
  - Between Wattle and MacAlister Streets
  - Dowling Street to the east of Moores Creek Road
- Berserker
  - Most areas between Lakes Creek Road and Fitzpatrick Street, McKean Street or Rodboro Street
  - Princess Street and Berserker Street, north of the Rodboro Street intersections
- Koongal
  - Most areas between Grubb Street and Lakes Creek Road
  - Stack Street between Lakes Creek Road and Stenhouse Street
- Lakes Creek
  - The corner of Totteridge Street and Lakes Creek Road
  - Between Synge Street and the Railway, to the north of Hartington Street
- Port Curtis
  - All of Port Curtis
- Depot Hill
  - Between the River and East Street
  - Between East Street and Bolsover Street, south of Francis Street
- Allenstown
  - Adjacent to the Main Drain
  - Between Elizabeth Street and Bartlem Street
  - Most areas between Gladstone Road and the Railway, except near John Street
- Rockhampton City
  - Between East Street, Stanley Street, Quay Street and South Street

8.7.5 50 year ARI event

Figure 37, Figure 38 and Figure 39 show that, under the 50 year ARI event, inundation extends further into Pink Lily, West Rockhampton and Berserker. Additional locations which become inundated under this event include:

- Kawana
  - Farm Street, between Withers Street and the River
  - Between Cramb Street and Vick Street
- Park Avenue
  - Between Thompson Street, Wattle Street and the River

- Berserker
  - Between Queen Elizabeth Drive and Musgrave Street
- Allenstown
  - Near the corner of Talford Street and Stanley Street
  - The upper end of Main Drain near Derby Street
- Rockhampton City
  - East Street and Bolsover Street between Derby Street and Stanley Street
- West Rockhampton
  - Canoona Road
  - Hunter Street and Victoria Street, west of Gorle Street
  - North Street Extended and Melbourne Street to the west of Lund Street

8.7.6 100 year ARI event

The 100 year ARI event results are presented in detail in Figure 40, Figure 41 and Figure 42. The inundation extents for this event are similar to those of the 50 year ARI event. Areas which are inundated include:

- Glenlee
  - Between the River and Belmont Road, and properties on the north-eastern side of Belmont Road
- Parkhurst
  - Adjacent to Limestone Creek, especially between Gregory Street and Alexandra Street
- Kawana
  - Adjacent to Splitters Creek, including much of the area to the west of Hollingsworth Street and Withers Street
- Park Avenue
  - Adjacent to Splitters Creek, including much of the area between Wattle Street, Thompson Street and the River
  - Adjacent to the flowpath which runs from the Haynes Street/Wackford Street intersection then across Glenmore Road near Highway Street
  - Adjacent to Moores Creek, between the creek and Moores Creek Road
- Berserker
  - Western ends of streets near Moores Creek
  - Adjacent to Frenchmans Creek
  - Much of the area between Moores Creek and Frenchmans Creek to the south of Painswick Street, Charles Street and Mason Street
- Koongal
  - Adjacent to Frenchmans Creek
  - Between Frenchmans Creek and Thozet Creek, south of Grubb Street
  - Stack Street, south of Stenhouse Street
  - Much of the area between Lakes Creek Road and the River
- Lakes Creek
  - Much of the area between Lakes Creek Road/Rockhampton Emu Park Road and the River, including the meatworks
  - Most properties on the northern side of Lakes Creek Road/Rockhampton Emu Park Road
- Nerimbera
  - Much of the area between Rockhampton Emu Park Road and the River
  - Most properties adjoining the western side of the railway
- Port Curtis
  - Almost the entire suburb
- Depot Hill
  - All areas except the top of the hill and the northern portion of the rail yards (ie except Campbell Street and Kent Street between Wood Street and O'Connell Street and some properties on the eastern side of George Street)

- Allenstown
  - Most areas to the east of Lower Dawson Road and Gladstone Road
  - Properties adjacent to the Main Drain
  - Some properties on the western side of Gladstone Road on Talford Street, Stanley Street, Derby Street and Grant Street
- Fairy Bower
  - The entire suburb
- Gracemere
  - North of the Central Railway Line
  - Some properties on the southern side of the railway line
- Rockhampton City
  - Properties at the northern end of the Main Drain
  - Most properties east of Alma Street and south of Derby Street
  - Some properties on East Street and East Lane, north of Derby Street
- Wandal
  - Some properties adjacent to Jardine Park
  - Most properties between Hamilton Avenue and the River
  - Most properties between Pattison Street and the River
- West Rockhampton
  - Most properties to the west of Western Street and Gorle Street
  - Properties on the southern end of Melbourne Street and North Street Extended
- Nine Mile
  - Most of the area to the north and east of Malchi Nine Mile Road
- Pink Lily
  - Most of Pink Lily except the northern end of Edmistone Road
- Alton Downs
  - Some of the properties along the south eastern portion

8.7.7 PMF Event

The model results for the PMF event are presented in Figure 43, Figure 44 and Figure 45. These figures show that in the PMF event only the higher areas of The Range, Rockhampton City and Wandal are outside the flood extents. On the northern side of the river, only those areas which are significantly higher than the river remain dry. Most areas between the Railway and the river are inundated and most areas between Elphinstone Street and the Railway are inundated.

9. Climate change impacts

9.1 Relevant literature

A suite of climate change literature is available, covering global, national and more localised state-based climate change discussion and analysis. This literature covers a range of natural phenomena including (but not limited to) temperatures, rainfall intensities and totals, sea levels, evaporation rates and extreme storm events. A review of relevant literature was undertaken with the intention of identifying likely impacts upon Fitzroy River flooding.

The Intergovernmental Panel on Climate Change (2007) stated that, in subtropical and mid-latitude regions, average rainfall is projected to decrease, yet rainfall intensity is predicted to increase and longer periods between rainfall events are likely. This means that intense, heavy rainfall events with high runoff amounts are more likely, yet they will be interspersed with longer dry periods. For the Queensland region, this was reinforced in 2002 when CSIRO predicted that annual average rainfall is likely to decrease in parts of South-East Australia and Queensland (–10% to +5% by 2030 and –35% to +10% by 2070).

The *ClimateSmart Adaption: What does climate change mean for you?* document produced by the Department of Natural Resources and Mines (now DERM) (2005) stated that, whilst Queensland is getting less rainfall (-250 mm per annum in some areas), the rain we do get is falling in shorter, more intense bursts. Rainfall burst totals could potentially increase from 700 mm in a day to 900 mm which will cause increased flooding, landslides and erosion. This document also stated that the occurrence of tropical cyclones is reduced, yet the ones we do get are slightly more intense. This was reiterated by the Queensland Office of Climate Change, Environmental Protection Agency (now DERM) in their 2008 publication *Climate Change in Queensland: What the science is telling us*.

The Australian Greenhouse Office (now the Department of Climate Change and Energy Efficiency) (2005) noted that the projected changes pose risks to existing urban infrastructure while our capacity to prevent these impacts upon new infrastructure is high if planning and building regulations take projected climate change into account. The Local Government Association of Queensland (2007) further defined the primary issue as being more frequent overflows from stormwater networks which in turn has the following effects:

- Planning and development: Low lying areas vulnerable to more frequent flooding
- Infrastructure: Damage to roads and other infrastructure caused by flooding
- Community services: Increased demand on emergency management resources
- Environment: Risk of contaminants being carried to waterways due to flooding

Whilst much of the literature states that, for Queensland, total annual rainfall is decreasing and rainfall intensity during rainfall events is increasing, there is comparatively little literature recommending actual values to adopt for these changes. The Queensland Climate Change Strategy (QLD Government, 2007) indicated that cyclone intensity is expected to increase by 2050 with cyclone associated rainfall expected to increase by up to 20-30%. The most extensive documentation regarding values to adopt for climate change assessments in Queensland is the *Guidelines for Preparing a Climate Change Impact Statement (CCIS)* which was published by the Queensland Office of Climate Change, Environmental Protection Agency (now DERM) 2008. The other recently published document which provides guidance on the adoption of climate change values, and also provides guidance on the use of these scenarios in development planning is the *Increasing Queensland's resilience to inland flooding in a changing climate: Final report on the Inland Flooding Study* published by DERM, The Department of Infrastructure and Planning (DIP) and the Local Government Association of Queensland (LGAQ) in 2010.

The CCIS guideline specifies scenarios under which a proposal to the Cabinet will require a Climate Change Impact Assessment. Whilst the current study and this report are not prepared as a submission to Cabinet, this document provides good guidance regarding the potential climate change impacts.

The document states that impact assessments are required under the following rainfall scenarios for proposals which are expected to exist between 2031 and 2070:

- Where it is expected that an increase of 10 to 20% in rainfall would impact upon a proposal, and
- Where it is expected that an increase in cyclone intensity (including a 20 to 30% increase in rainfall) would impact upon a proposal.

The DERM, DIP and LGAQ Inland Flooding Study (2010) was specifically aimed at providing a benchmark for climate change impacts on inland flood risk. Whilst Rockhampton is not considered to be an inland area, this document does provide guidance on the adoption of climate change scenarios for development planning and also provides recommendations for consideration in a review of the *State Planning Policy* (SPP) *1/03*. Key recommendations of this document are that:

- A 5% increase in rainfall intensity should be included for each degree of global warming
- This approach should be adopted for the 100, 200 and 500 year ARI events
- The rates of global warming to be adopted are 2°C by 2050, 3°C by 2070 and 4°C by 2100
- Development planning should be based upon a range of hazard areas which apply to various events and various land uses. This shifts the focus from the 100 year ARI event and considers that there are various flood hazard levels and associated risks which need to be considered by local governments
- Consideration should be given to applying various flood constraints upon a development depending upon the asset life and location of that development, including the development of flood overlay maps for different planning horizons

In addition to impacts upon rainfall, sea level rises are also commonly discussed in climate change literature. The most recent publication that relates to Queensland is the *Draft Queensland Coastal Plan* (and more specifically the *Draft State Planning Policy Coastal Protection* (DERM 2009)). The second document outlines sea level rises that should be considered when planning for development in coastal areas of Queensland. Table 22 details the projected sea level rise up to 2100.

Table 22 Projected Sea Level Rise (DERM, 2009)

Year of end of Planning Period	Projected Sea Level Rise (m)
2050	0.3
2060	0.4
2070	0.5
2080	0.6
2090	0.7
2100	0.8

In addition to the Draft Coastal Plan, the Australian Government Department of Climate Change and Energy Efficiency report *Climate Change Risks to Australia's Coast – A First Pass National Assessment for Australia* (2009) identified that 1.1 m sea level rise by 2100 is a plausible value to adopt. Whilst this document is not a policy document, its recommendations should be considered.

9.2 Adopted approach

The two most relevant documents to be considered in a climate change analysis are the CCIS guidelines and the Inland Flooding Study recommendations. At this time there are no requirements for including climate change scenarios into development planning, however the Inland Flooding Study recommends that they should be included through the use of different flood overlay maps for different planning horizons. It is expected that more guidance on this subject will be available when the new version of AR&R is released in 2014 or when a revised version of the SPP 1/03 is released (timing for this is unknown).

Both documents recommend that, for consideration of climate change on rainfall, an increase in rainfall of 10-20% is appropriate. The CCIS guidelines also discuss the climate change impacts on cyclonic rainfall. As discussed in Section 3.1, flooding in the Fitzroy River is often the result of cyclonic rainfall and therefore it was considered appropriate to adopt the recommendations of the CCIS guidelines for this study. Using these recommendations, the following two climate change scenarios have been assessed:

- Climate Change Scenario 1 (+20%) – represents a 20% increase in rainfall intensity
- Climate Change Scenario 2 (+30%) – represents a 30% increase in rainfall intensity

For these two scenarios, the increased rainfall has been represented in the URBS model as an increase in the rainfall intensity. This has been carried out for the 2, 5, 10, 20, 50 and 100 year ARI events. For the 100 year ARI event the URBS model output hydrograph was then used as input to the TUFLOW model.

For the Fitzroy River at Rockhampton, no assessment of sea level rise was undertaken. The sensitivity analysis undertaken during the design event modelling showed that changes to the ocean levels only impacted upon the 2 year ARI event and had no affect under the 100 year ARI event.

9.3 Climate change analysis results

9.3.1 URBS model results

The URBS model was run with increased rainfall intensities. The resulting peak discharges are presented in Table 23 for Scenario 1 (+20%) and Table 24 for Scenario 2 (+30%). Also included in these tables are the existing case peak discharges for each event and the equivalent return period for that discharge in the climate change scenario. These have been calculated using linear interpolation.

Table 23 Climate change event peak discharges for Scenario 1 (+20%)

Return Period (years)	Scenario 1 (+20%) Peak Discharge (m^3/s)	Existing Case Peak Discharge (m^3/s)	Equivalent Existing Case Return Period (years)
2	4750	2452	<2
5	7685	4908	2
10	10617	7005	4
20	13948	10305	9
50	17965	13214	18
100	22095	16290	37

Table 24 Climate change event peak discharges for Scenario 2 (+30%)

Return Period (years)	Scenario 2 (+30%) Peak Discharge (m^3/s)	Existing Case Peak Discharge (m^3/s)	Equivalent Existing Case Return Period (years)
2	5903	2452	<2
5	9414	4908	<2
10	12121	7005	3
20	15911	10305	7
50	20464	13214	13
100	28446	16290	22

For the 100 year ARI event the discharge hydrographs are presented in Figure 46. The hydrographs in Figure 46 show that, for Scenario 2 (+30%), the shape of the hydrograph at the peak of the flood is modified from that of the 100 year ARI event and the Scenario 1 (+20%) event. Modelling of the storage impacts at the junction of the Dawson and Mackenzie Rivers has only been included up to the magnitude of the 1918 event. Scenario 2 (+30%) produces a peak discharge significantly greater than the 1918 event and the shape of the hydrograph at the peak of the event is modified as the storage effects at these discharges are unknown, and therefore are not included in the model. The resulting hydrograph is considered to be a conservative estimate of the 30% increased rainfall climate change scenario and therefore we recommend that Scenario 1 (+20%) should be adopted for climate change assessments.

9.3.2 TUFLOW model results

Predicted peak water levels at the Rockhampton Gauge for the climate change scenarios are presented in Table 25. This table shows that the climate change scenarios are predicted to increase peak water levels at the gauge by +0.59 m for Scenario 1 and +1.2 m for Scenario 2.

Table 25 Climate change scenario gauge levels

Scenario	Peak Flood Level	
	m AHD	m Gauge Datum
100 Year ARI	7.93	9.38
Scenario 1 (+20%) 100 Year ARI + 20% Increase in Rainfall Intensity	8.50	9.95
Scenario 2 (+30%) 100 Year ARI + 30% Increase in Rainfall Intensity	9.03	10.48

Scenario 1 (+20%)

The results for Climate Change Scenario 1 are presented in Figure 47 to Figure 49. Figure 50 presents the differences between Climate Change Scenario 1 and the 100 year ARI event results. This figure shows that, under Climate Change Scenario 1, peak water levels are increased by +0.5 to +0.75 m throughout much of the model area. In some areas, particularly to the west of the Airport and near Splitters Creek, water levels are increased by +0.75 to +1.25 m. Inundation extents are increased throughout the area, with significant increases occurring in the northern parts of Wandal and the southern parts of the City.

Scenario 2 (+30%)

Figure 51 to Figure 53 present the results for Climate Change Scenario 2. Figure 54 presents the differences between Climate Change Scenario 2 and the 100 year ARI event results. Under Scenario 2, peak water levels are increased by +1.0 to +1.25 m throughout Pink Lily, Nine Mile, Port Curtis, The Common. Berserker, Koongal, Lakes Creek and Nerimbera. Throughout Glenlee, Parkhurst, Fairy Bower and Gracemere water levels are increased up to +1.5 m. In Park Avenue Kawana, West Rockhampton and around the Airport, peak water levels are increased by more than +1.5 m. Inundation extents are increased significantly throughout most areas.

Climate change is not likely to impact upon emergency management planning measures within a community; however the impacts upon development planning have the potential to be significant. The results in Table 25 show that under Scenario 1, the predicted 100 year ARI gauge level is increased to a level almost equivalent with the 1918 flood event. Under Scenario 2, the predicted gauge level for the 100 year ARI event is 0.5 m above the 1918 flood event level. These potential impacts need to be considered in Development Planning.

10. Emergency management planning

During the 2008 flood events, the Local Disaster Management Group (LDMG) was responsible for coordinating local planning and response for the flood event. Information available to assist the LDMG was limited to various aerial images of the 1988 and 1991 flood events. The lack of available data was identified as being a limiting factor for the LDMG's ability to plan for the event and to communicate the expected impacts to local residents/media.

Upon finalisation of the design event modelling, a workshop was held with key members of the LDMG to determine the outputs which would be of most use during a flood emergency. The following sections provide a discussion on each key output and the processes by which these outputs were developed. These outputs will assist the LDMG with planning for a flood event and will provide information which can be readily disseminated to local residents and the media.

10.1 Gauge level mapping

Design event flood modelling provides a series of model results for various magnitude flood events. When a flood event occurs, the BoM provides the LDMG with a predicted flood level at the Rockhampton Gauge. It was determined that a set of maps showing expected flood characteristics for various gauge levels would be more useful to the LDMG than the design event mapping. These maps would then allow the LDMG to select the maps closest to the predicted gauge level in order to prepare for a predicted flood event.

The gauge level maps were prepared for Rockhampton Gauge levels ranging between 7.0 and 10.0 m, at 0.5 m increments. Some key features of these maps are:

- Depth and hazard maps were produced for each gauge level interval. Water surface level maps were not included as these provide little useable information during a flood event
- Depth contours at 0.25 increments were defined up to a depth of 2.0 m. Above 2.0 m it is considered that floodwaters are very deep and additional definition is not required for emergency planning. The 0.25 m increments were adopted as they provide a good level of detail for emergency planning
- The TUFLOW model results represent the channel invert, not the bridge deck; therefore the mapping was reviewed to ensure that bridge decks were shown as being dry if they were not inundated (note that this was done for the design event mapping as well)
- Mapping of each gauge level was based upon model runs in which the model inflows were modified until the required gauge level was achieved

These gauge level maps have not been included in the mapping provided with this report.

10.2 Critical infrastructure inundation

A list of critical infrastructure and the Rockhampton Gauge level at which it is likely to be inundated was prepared. This was based upon the results of the gauge level mapping and included the following infrastructure:

- Emergency services facilities (eg ambulance, police, fire, coast guard, airstrip, hospital)
- Significant facilities for evacuation (eg child care, education, retirement, nursing care, media)
- Key water and sewerage infrastructure
- Roads/bridges

A copy of the table is included in Appendix B.

10.3 Decision support tool

A decision support tool for emergency management procedures was prepared. This tool uses two flowcharts to identify the major decisions to be made during a flood event and during an evacuation. The outcomes and follow-on tasks for each decision are included. These tools will act as a trigger for the LDMG to identify which decisions are required depending upon the expected magnitude of the flood event. A copy of the decision support tool is provided in Appendix C.

10.4 Warnings

Pre-written flood warnings were prepared. The intention is for these warnings to be readily available for dissemination to the media during a flood event. A copy of these warnings is provided in Appendix D.

10.5 Review of flood classification levels

Table 4 presents the interim flood classifications at the Rockhampton Gauge. These classifications were adopted in October 2008, pending review at the completion of this study. A review of the results presented in the Gauge Level maps for levels 7.0 m, 7.5 m and 8.5 m shows that these levels match the applicable BoM descriptions and it is therefore recommended to adopt these interim levels as final flood classification levels.

10.6 Evacuation route assessment

No assessment of evacuation routes was undertaken. Due to the large lead time available in a Fitzroy River event there is also significant time available to prepare for and perform an evacuation, therefore an assessment of evacuation routes was not considered necessary.

11. Building community awareness

A key factor in reducing the flood risk of a community is the development of flood awareness within that community and maintenance of this level of awareness. Within the Rockhampton area, the recent flood event will have greatly raised the awareness of the community. As time passes, this awareness will reduce.

The following sections describe the adopted approach for providing flood information to the community. This includes information relating to the flood potential of the Rockhampton area as a whole and then the flood potential at each particular location (ie where people live). It also includes information regarding evacuation likelihood and what to do in the event of an evacuation.

11.1 Flood zones

All properties which have the potential to be fully or partially flooded were classified into a series of flood zones. Zones were defined according the Gauge Level at which a property starts to be inundated (based upon ground level not floor level). This classification process has not included any assessment of evacuation routes or the potential for isolation of properties.

Flood zones were defined in 0.5 m increments between Gauge Level 7.0 m and 9.5 m, with the final zone incorporating all properties between the 9.5 m and the PMF extents. Colours for each zone were selected to be different to the storm tide mapping colours (as defined in the *National Storm Tide Mapping Model for Emergency Response*, 2002), yet easily identifiable in both colour and name. The adopted zones and colours are presented in Table 26. The numbers of affected properties within each zone are also included in Table 26. The zone maps are included in Appendix E.

Table 26 Adopted flood zones

Zone	Gauge Level (m)	Colour	Colour Details (RGB*)	Number of Affected Properties
1	<7.0	Cream	255, 253, 208	1063
2	7.0 – 7.5	Khaki	195, 176, 145	315
3	7.5 – 8.0	Cyan	160, 255, 255	661
4	8.0 – 8.5	Maroon	112, 28, 0	1333
5	8.5 – 9.0	Blue	48, 117, 255	898
6	9.0 – 9.5	Yellow	255, 255, 144	1314
7	9.5 - PMF	Red	255, 64, 64	6166

** These values represent the proportion of red, green and blue mixed into the adopted colour (values range between 1 and 255)*

11.2 Community awareness brochures

Text to be used in the preparation of a community awareness brochure was developed. This text was based upon a combination of Council's Emergency Action Guide and the FloodSafe brochures prepared by the NSW SES. A copy of the community brochure text is included in Appendix F. The brochure text was intended to provide the community with information regarding:

- What floods are and history on flooding in Rockhampton
- Flood behaviour in Rockhampton
- Flood zones
- Flood warnings
- What to do before, during and after a flood
- Preparation of a household emergency plan
- The gauge levels at which key flood behaviour occurs (eg Pink Lily breakout)

12. Development planning input

Development planning input is required to assist Council with their planning of potential development areas. Development planning is governed by, and needs to account for, the requirements set out in *State Planning Policy (SPP) 1/03 (Mitigating the Adverse Impacts of Flood, Bushfire and Landslide, 2003)* (note currently under review).

12.1 Review of existing planning scheme

12.1.1 SPP 1/03 requirements

Under the *Sustainable Planning Act 2009* (SPA), the *State Planning Policy 1/03* (SPP) has effect when development applications are assessed, when planning schemes are made or amended and when land is designated for community infrastructure.

The SPP applies to development in a natural hazard management (flood) area as follows:

(a) To material changes of use and associated reconfigurations of a lot that:

- Increase the number of people living or working in the flood zone (eg residential development, shopping centres, tourist facilities, industrial or commercial uses) except where the premises are only occupied on a short-term or intermittent basis (eg by construction/maintenance workers, certain agricultural and forestry workers)
- Involve institutional uses where evacuating people may be particularly difficult (eg hospitals, education establishments, child care, aged care, nursing homes, and high security correctional centres)
- Involve the manufacture or storage of hazardous materials in bulk
- Would involve the building or other work described in (b) below as an intrinsic element of the development proposal

(b) To building or other work that involves any physical alteration to a watercourse or ***floodway*** including vegetation clearing, or involves net filling exceeding 50 cubic metres. [Note: this figure could be modified to suit the RRC floodplain needs in particular locations]

In addition, the SPP applies to community infrastructure that provides services vital to the wellbeing of the community (refer SPP for specific definitions).

Two things to note are:

- The Defined Flood Event is the flood event for management of development and is identified in the planning scheme as the “natural hazard management (flood) area”
- The SPP refers throughout to *Floodplain Management in Australia – Best Practice Principles and Guidelines* (2000)

12.1.2 General comments

A review of the existing floodplain planning documentation was undertaken. Documentation for RRC was not available as the Planning Scheme for the Regional Council has yet to be developed. Documentation for the four Councils which were amalgamated into the Regional Council was assessed and a review of the *Rockhampton City Council* (RCC) *City Plan* (2005) *Flood Prone Land Code and Planning Policy No. 14 – Flood Plain Management* was undertaken. These documents were considered to be the most advanced of the floodplain planning documents from the four Councils and therefore they should be the basis for the planning scheme of the Regional Council.

In general the two RCC documents are out-of-date and seem to be based upon the *NSW Floodplain Development Manual* (2005). In Queensland the basis for floodplain management is SPP 1/03 as discussed in Section 12.1.1 above. The RCC City Plan document sets the Defined Flood Event as the 1% AEP event.

Key differences between the RCC documents and the SPP are as follows:

- RCC refers to only low and high hazard categories whilst the SPP refers to low, medium, high and extreme hazard categories
- The RCC table which defines when the code is applicable relates to minor and other development only. Table A2.1 of the SPP provides a range of acceptable land uses within each specified hazard category
- The Performance Criteria and Acceptable Solutions tables in the RCC documents contain much of the required information but are not in the same format as that recommended in Table A, Appendix 5 of the SPP

Other comments regarding the RCC documents include:

- The use of the term “floodway” in the SPP document indicates that floodway areas need to be identified as part of the planning scheme. The objective is to try and identify the corridor that must be preserved for conveyance of flood flows – in the words of the SPP “Floodways are often aligned with naturally defined channels and even if partially blocked would cause a significant redistribution of flood flow, or a significant increase in flood levels.” Floodways are defined in the existing RCC documents and are discussed further in Section 12.2
- The RCC documents appear to address only Fitzroy River flooding and should also include overland flowpaths and local creek flooding
- The RCC documents should cover impacts under a full range of flood events up to and including the DFE
- Consideration should be given to climate change impacts (see Section 9.1 and 9.2 and Appendix G)
- Now that Council has a tool which can be used to assess the impacts of development on the Fitzroy River (ie the flood model) it would be possible to develop a procedure regarding the use of this tool for development assessment on a case-by-case basis

The SPP and the associated guideline (*State Planning Policy 1/03 Guideline: Mitigating the Adverse Impacts of Flood, Bushfire and Landslide, 2003*) prescribe a stepped approach to Development Outcomes/Development Assessment. It is recommended that RRC should adopt this approach.

A good example of a Flood Code is provided in the Gold Coast City Council Planning Scheme: Part 7, Division 3, Chapter 8: Flood Affected Areas (2003), a copy of which is included in Appendix G. Also included in Appendix G is a copy of the recommended *Policy options for incorporating climate change into the flood risk management framework in Gayndah (North Burnett Regional Council)* (2010) This document provides an example flood constraint code which takes into account climate change.

12.1.3 Comparison of RCC City Plan to SPP 1/03

Table 27 provides a comparison between the code requirements of SPP 1/03 and the current RCC code. It shows which elements of the RCC code can be correlated to the requirements of the SPP. As can be seen, many of the ingredients of the RCC code are applicable to the new SPP requirements, and can therefore just be re-written in the revised format.

Table 27 Comparison of RCC City Plan to SPP 1/03

New Specific Outcomes (from SPP 1/03)	Solutions (SPP 1/03)	Equivalent Existing Performance Criteria	Equivalent Existing Solutions
1. Development maintains the safety of people on the development site from all floods up to and including the DFE	1.1 Development is sited on land that would not be subject to flooding during the DFE OR	P9 (Residential buildings and re-classifications of buildings only considered) P13, P14	A9.1.1, A9.5 (assuming CBD is above DFE) A13, A14
	1.2 There is no increase in the number of people living or working on the site, except where the premises are occupied on a short-term or intermittent basis OR	P9	A9.2
	1.3 For residential development: dwellings are sited so that the floors of all habitable rooms can be located above the DFE flood level. OR	P8 P13, P14	A8.1 (A8.2 allows this to be relaxed provided a levee or equivalent is constructed) A13, A14
	1.4 For non-residential development and development involving temporary or moveable residential structures: a)buildings are located and designed so that floor levels(except areas used for car parking) are at or above the DFE flood level; or b)there is at least one evacuation route that remains passable for emergency evacuations during all floods up to and including the DFE; or	P11	A11 (permits that only need 30% of GFA above DFE)

New Specific Outcomes (from SPP 1/03)	Solutions (SPP 1/03)	Equivalent Existing Performance Criteria	Equivalent Existing Solutions
	c)the premises are located in an area where there is sufficient flood warning time to enable safe evacuation; or d) a safe refuge is available for people within the development site		A11
2. Development does not result in adverse impacts on people's safety or the capacity to use land within the floodplain	2.1 Works do not involve: a) any physical alteration to a watercourse or floodway including vegetation clearing; or b)net filling exceeding *50*m^3 (value to suit location) OR	P12 (seeks 'no worsening')	A12
	2.2 The development complies with any applicable development criteria set out in a floodplain management plan OR	P1 P4	A1.1, A1.2.1, A1.2.2 A4
	2.3 (Not relevant – FMP exists)	N/A	N/A
3. Development minimises the potential damage from flooding to property on the development site	3.1 Dwellings are sited so that the floors of all habitable rooms can be located above the DFE flood level	P8 P13, P14	A8.1 (A8.2 allows this to be relaxed provided a levee or equivalent is constructed) A13, A14
4. Public safety and the environment are not adversely affected by the detrimental impacts of floodwater on hazardous materials manufactured or stored in bulk	4.1 The manufacture or storage in bulk of hazardous materials takes place above the DFE flood level OR	Covered in Planning Policy (6.2) rather than in Codes	
	4.2 Structures used for the manufacture or storage of hazardous materials in bulk are designed to prevent the intrusion of floodwaters	Covered in Planning Policy (6.2) rather than in Codes	

New Specific Outcomes (from SPP 1/03)	Solutions (SPP 1/03)	Equivalent Existing Performance Criteria	Equivalent Existing Solutions
5. Essential services infrastructure (eg on-site electricity, gas, water supply, sewerage and telecommunications) maintains its function during a DFE	5.1 Any components of the infrastructure that are likely to fail to function or may result in contamination when inundated by floodwater (e.g. electrical switchgear and motors, water supply pipeline air valves) are: a) located above the DFE; or b) designed and constructed to exclude floodwater intrusion/infiltration AND	P6	A6.2 (all services and utilities above DFE)
	5.2 Infrastructure is designed and constructed to resist hydrostatic and hydrodynamic forces as a result of inundation by the DFE	Nil	Nil
Community Infrastructure is able to function effectively during and immediately after flood events	1 Community infrastructure development is not located in an area that has been identified by flood hazard mapping as being below the Recommended Flood Level (RFL) specified for that community infrastructure in the following table: [see Table in App 9 of SPP Guideline] OR	P5	A5
	2 The community infrastructure is located below the RFL but can function effectively during and immediately after the RFL event AND	Nil	Nil

New Specific Outcomes (from SPP 1/03)	Solutions (SPP 1/03)	Equivalent Existing Performance Criteria	Equivalent Existing Solutions
	3 Essential community infrastructure (emergency services and shelters, police facilities and hospitals, and associated facilities) has an emergency rescue area above the RFL	Nil	Nil
Climate Change – the potential adverse consequences of climate change on flooding need to be considered	Specific solutions should be formulated using the latest LGAQ study recommendations (2011)	Nil	Nil

12.2 Hydraulic category mapping

The 2005 RCC Planning Scheme includes six categories for definition of floodplain development potential. These categories are grouped into two separate criteria, being hazard and hydraulic criteria. Hazard is defined as being either high or low and the hydraulic function of the floodplain is categorised into either floodway, flood storage or flood fringe. Each of the hydraulic categories is also defined using a hazard category, eg high hazard floodway, low hazard flood storage.

Floodways are areas which convey a significant portion of flood flows and which would cause significant adverse impacts if they were to be blocked. Flood storage areas are those in which temporary storage of floodwaters occurs during a flood event and which could potentially cause increases in flood levels/discharges in other areas of the floodplain if filled. All other areas are considered flood fringe.

Section 8.5 discusses the hazard criteria adopted for use in this study. It increases the number of hazard categories from two to four and brings these categories in line with the recommendations of the SPP 1/03 (2003) and SCARM (2000).

The following sections present a discussion of hydraulic categories.

12.2.1 RCC Planning Scheme

The RCC Planning Scheme documents include definitions of floodway, flood storage and flood fringe. Further to the general definitions provided above, this document defines these categories as follows:

- Floodway
  - Depth ≥ 0.5m and/or
  - Velocity ≥ 1.2m/s and/or
  - Where blockage is likely to cause significant impacts
  - The floodway definition then goes on to say that floodways are generally defined where the velocity-depth product is ≥ 1 m^2/s

- Flood Storage
  - Where velocities are low and
  - Depth ≥ 0.5 m

- Flood Fringe
  - All other areas

12.2.2 State Planning Policy 1/03

The SPP 1/03 (2003) states that floodways should be defined as part of a flood study. If a flood study does not exist the following criteria should be adopted for floodway definition:

- Velocity-depth product ≥ 0.3 m^2/s or
- Velocity ≥ 1 m/s

12.2.3 SCARM: Floodplain Management in Australia Best Practice Principles and Guidelines

The SCARM document gives a general definition for floodway and flood fringe. It states that "the defined floodway will be an area of extreme to high hazard and the defined flood fringe will be an area of high to medium hazard."

12.2.4 Adopted category definitions

The 100 year ARI event flood depth, velocity and depth-velocity product results were reviewed based upon the above two sets of floodway definitions. This review showed that, using the RCC definition, the extent of floodway was not as extensive as expected. Using the SPP definition, the floodway extent covered almost the entire 100 year ARI event extents. The following intermediate definition has been adopted which improves the definition of floodway extent to focus upon the areas expected to be classified as floodways.

- Floodway
  - Velocity-depth product ≥ 0.5 m^2/s or
  - Velocity ≥ 1 m/s

Outside the floodway extents, the flood storage and flood fringe categories have been set based upon the depth of floodwaters as follows:

- Flood storage
  - Velocity-depth product ≤ 0.5 m^2/s and
  - Depth ≥ 0.5 m

- Flood fringe
  - Velocity-depth product ≤ 0.5 m^2/s and
  - Depth ≤ 0.5 m

A number of manual overrides to the above definitions were also required across the floodplain, including:

- Removal of isolated zones/areas within categories – eg if a small area of flood storage was completely surrounded by a large area of floodway the flood storage was redefined as floodway and vice versa
- Removal of small sections of categories – any location in which the category area was less than 1 km^2 was integrated into the nearby category

It is important to note that this process has been carried out for Fitzroy River flooding only. In areas where local creeks occur, the hydraulic categories may show the creek as being flood storage or flood fringe; however when local catchment flooding occurs the creek would be defined as a floodway.

A copy of the hydraulic category map is included in Appendix H.

13. December 2010/January 2011 event

The flood study and this report were almost complete when the December 2010/January 2011 flood event occurred; therefore this event has not been covered by the study or included in the discussions throughout this report. This section presents a discussion of this recent event.

The recent flood occurred after widespread rainfall across most of the catchment which caused flooding in the Dawson, Mackenzie, Comet and Nogoa Rivers. Unlike traditional floods in the Fitzroy River system, the Connors and Isaac River systems contributed very little to the magnitude of this event.

On January 4, 2011 the Fitzroy River peaked at 9.2 m on the Rockhampton Gauge. This is the fourth largest event on record. The recorded water level hydrograph for this event is shown in Figure 55. Image 10, Image 11 and Image 12 show the extent of flooding in this recent event.

Image 10 January 2011 event flooding: Roundabout at the Bruce and Capricorn Highways

Image 11 January 2011 event flooding: Port Curtis, The Common and Depot Hill

Image 12 January 2011 event flooding: Rockhampton Airport

Some of the key impacts of this event included:

- Closure of the Bruce Highway for 13 days
- Closure of the Capricorn Highway for 13 days
- Closure of the Airport for 3 weeks
- Approximate numbers of affected properties, by property type, are provided in Table 28

Table 28 Properties Affected by 2011 Event

Property Type	Number of Affected Properties
Aged Care/Nursing Homes	16
Agriculture	63
Business	258
Community	161
Industry	338
Livestock	791
Residential	2858
Vacant	826
Total	**5311**

Using the adopted rating curve (Figure 20), a flood peak of 9.2 m equates to a river discharge of 14670 m^3/s. This also equates to a 74 year ARI event using the flood frequency analysis (Figure 22).

Draft flood study outputs were used during this event to assist Council, the LDMG, the SES and the Police in their event response and management. These outputs have met the study objectives of providing better flood information for emergency management and have confirmed that the information formats (as discussed in Section 10) are suitable for use in a flood event.

14. Recommendations for further studies

Throughout the course of this study, in particular through the final stages of the study, a number of recommendations for further studies have been identified. These studies would provide additional information to Council and provide a better understanding of flooding throughout the Rockhampton Region.

14.1 Modelling of December 2010/January 2011 event

It is recommended that the recent flood event should be run as a verification event through the TUFLOW model. This would test the validity of the model in predicting flood characteristics for a large recent event. The suggested tasks to be undertaken include:

- Hydrologic analysis of the event
- TUFLOW modelling of the event
- Comparison of TUFLOW results to recorded data – comparison of both water levels and flood extents

14.2 Review of climate change impacts

The report from the recent Inland Flooding Study (DERM, DIP and LGAQ 2010) includes a recommendation that climate change effects should be accounted for in a planning scheme. Whilst it is not a policy document and at this stage there are no requirements for planning schemes to include climate change, we understand that Council is currently undertaking a review of their planning scheme and it may be prudent at this stage to assess the implications of these recommendations on Council's planning scheme.

It is expected that further documentation regarding climate change policy will be released over the next few years. This will include:

- The new version of AR&R which is expected to be released in 2014
- A revised version of the SPP 1/03, although the timing of release for this is unknown

We recommended that Council give consideration to the impacts of climate change and discuss whether to including climate change effects in their current planning scheme review or whether to wait for further documentation to be released.

14.3 Regional stormwater strategy

In order to protect the environmental values of waterways within the region, it is recommended that a regional stormwater strategy be developed. This strategy should address the need for an integrated approach to management of stormwater quantity and quality. Consideration would need to be given to the requirements for flood mitigation and stormwater treatment, including water sensitive urban design.

Stormwater has the potential to contribute a substantial amount of pollution from urban runoff to receiving waterways, therefore impacting the environment. The stormwater strategy should recommend treatment measures to improve runoff water quality and outline opportunities to capture and reuse stormwater.

Land use changes have the potential increase the volume of runoff which in turn has the potential to increase flooding and impact upon the environmental values of waterways. The stormwater strategy should recommend measures to mitigate increases in runoff and ensure flood impacts upon external properties are minimised.

14.4 Modelling of local catchments

Whilst the Flood Study presented in this report has focussed upon Fitzroy River flooding, it is possible for flooding to occur in Rockhampton and throughout the region from both local catchment flooding and flash flooding. Flood events of this nature have been experienced in the past and will be experienced again in the future. Currently, Council has little more than anecdotal information on flooding from these mechanisms. It is recommended that flood studies of each local catchment be undertaken. These flood studies should be consistent with the methodologies presented in this report and should include:

- Hydrologic analysis through the use of RAFTS, RORB or URBS
- Hydraulic analysis through the use of a suitable hydraulic modelling package – either MIKE 11 or HECRAS for one-dimensional modelling and MIKE 21 or TUFLOW for two-dimensional modelling
- Wherever possible the models should be calibrated to existing events. If no existing information exists these models should be validated using standard hydrologic and hydraulic methods and through comparison to anecdotal data
- Study outputs should be consistent with those of this study including
  - 2, 5, 10, 20, 50 and 100 year ARI design event modelling
  - PMP/PMF modelling
  - Mapping for the range of design events, including inundation extents, depth and hazard mapping as a minimum
  - Climate change assessment
  - Development planning information
  - Identification of critical infrastructure at risk of flooding

For these local catchment studies, Council should give consideration to the inclusion of emergency planning information which may include:

- Identification of communities at risk of isolation and the associated period of isolation
- Assessment of emergency evacuation routes consistent with the *Queensland Evacuation Guidelines for Disaster Management Groups* (published as a consultation draft by Emergency Management Queensland in October 2010) and the Evacuation Timeline Modelling principles developed by Opper et al (2010) and presented at the First International Conference on Evacuation Modelling and Management (paper titled *Timeline modelling of flood evacuation operations*)

14.5 Assessment of flood levee options

The *Rockhampton Flood Management Study* (1992) proposed a number of levee options to protect various parts of the city from flooding. It is recommended that the validity of these options be reviewed with reference to the current state of development in the city and at the airport. Key areas of concern should be identified and levee options for protection of these areas should be modelled. The hydraulic impacts of each levee option should be assessed to determine hydraulically feasible options. Further assessment could then be carried out to determine the feasibility of construction of these levees.

14.6 Standards for modelling methodologies and management

It is recommended that Council adopt a standard for modelling methodologies and model management. This recommendation is based upon Aurecon's knowledge of the standards/systems, and in some cases lack of standards/systems, which have been adopted by other local Councils. Well defined standards can:

- Allow Council to be confident that their modelling and model results are consistent across the region and therefore easily comparable from catchment to catchment
- Allow Council to better manage their files within their own systems
- Ensure that original versions of models are protected

Elements which could be considered in the standards include:

- Model and data management processes: a standard approach to model and data management within Council and to be adopted by consultants when developing models
- Model logs: for recording model versions and purposes
- Naming conventions: for standard naming to be used across all models
- Modelling methodologies: appropriate methodologies to be adopted for various model types
- Technical guidelines: detailed technical guidelines for various model types, including model parameters, events to be considered, outputs to be developed etc
- Appropriate reviews: requirements for reviews eg independent reviewer
- Adoption of a standard design storm: many other local Councils have adopted a standard design storm to suit their needs. This prevents the need to model (and manage) a range of event durations for each design event

14.7 Investigate opportunity to use FRW stream gauges in BoM warning network

Opportunity exists to enhance BoM's flood warning network through the inclusion of FRW's automatic stream gauges. This would then remove the need for manual readings to be taken at the Rockhampton Gauge. Investigation into the technical and operational implications of this would need to be undertaken in order to determine whether this is possible. This investigation would need to be undertaken in conjunction with BoM.

15. Explanatory notes and disclaimers

15.1 General notes

- This report and the associated mapping were developed to represent Fitzroy River flooding from Pink Lily in the north to Port Curtis in the south. Flooding continues beyond these upstream and downstream extents. No consideration of local catchment flooding has been made

- The topographic data used in preparation of the hydraulic model and this report was based upon the best information available as at November 2010 and relied upon LiDAR survey captured in June 2009 and river cross-sections used in the 1991 Rockhampton Flood Management Study. No bathymetric data was included for waterways other than the Fitzroy River

- The results presented in this report are based upon model results from the Fitzroy River Flood Study URBS and TUFLOW models as at December 2010

- Information presented in this report is indicative only and may vary, depending upon the level of catchment and floodplain development. Filling of land or excavation and levelling may alter the ground levels locally at any time, whilst errors may also occur from place to place in the local ground elevation data from which the data has been developed

- The hydraulic modelling presented in this report was based upon a 50 m grid hydraulic model. This model resolution is suitable for assessment of flooding on a floodplain-wide basis. It is not representative of features such as small, local drainage networks

- Flood hazard assessments have been based upon consideration of flood depths and velocities only. No consideration of evacuation times has been included as it was considered that ample time is available for evacuation

15.2 Important things you should know about this report

15.2.1 Exclusive use

- This report has been prepared by Aurecon at the request of Rockhampton Regional Council (“Client”) exclusively for the use of its Client
- The basis of Aurecon’s engagement by the Client is that Aurecon’s liability, whether under the law of contract, tort, statute, equity or otherwise, is limited as set out in the terms of the engagement

15.2.2 Third parties

- It is not possible to make a proper assessment of this report without a clear understanding of the terms of engagement under which the report has been prepared, including the scope of the instructions and directions given to and the assumptions made by the consultant who has prepared the report
- The report is a report scoped in accordance with instructions given by or on behalf of Client. The report may not address issues which would need to be addressed with a third party if that party’s particular circumstances, requirements and experience with such reports were known and may make assumptions about matters of which a third party is not aware
- Aurecon therefore does not assume responsibility for the use of, or reliance on, the report by any third party and the use of, or reliance on, the report by any third party is at the risk of that party

15.2.3 Limited scope

- The limited scope of Aurecon’s brief in this matter, including the limited scope of investigation requested by Client, means that the report necessarily concentrates on readily apparent major items
- Amongst other things, Aurecon’s brief expressly excludes investigation or advice in relation to the actual or potential presence of pollution, contamination or asbestos, or the actual or potential risk of any incident affecting the safety of operation

15.2.4 Limits on investigation and information

- Where site inspections have been made, they have been limited in their scope to external visual inspections
- The report is also based on information provided to Aurecon by other parties. Although the providers of the information have not warranted the accuracy of the data and have waived liability in respect of its use, Aurecon's report is provided strictly on the basis that the information that has been provided is accurate, complete and adequate
- Aurecon takes no responsibility and disclaims all liability whatsoever for any loss or damage that the Client or any other party may suffer resulting from any conclusions based on information provided to Aurecon, except to the extent that Aurecon expressly indicates in the report that it has verified the information to its satisfaction

15.2.5 Legal documents etc

- The report may contain various remarks about and observations on legal documents and arrangements such as contracts, supply arrangements, leases, licences, permits and authorities. A consulting engineer can make remarks and observations about the technical aspects and implications of those documents and general remarks and observations of a non legal nature about the contents of those documents. However, as a Consulting Engineer, Aurecon is not qualified, cannot express and should not be taken as in any way expressing any opinion or conclusion about the legal status, validity, enforceability, effect, completeness or effectiveness of those arrangements or documents or whether what is provided for is effectively provided for. They are matters for legal advice

If the reader should become aware of any inaccuracy in or change to any of the facts, findings or assumptions made either in Aurecon’s report or elsewhere, the reader should inform Aurecon so that it can assess its significance and review its comments and recommendations.

Nothing in this report shall be read or applied so as to purport to exclude, restrict or modify, or have the effect of excluding, restricting or modifying the application of all or any of the provisions of the Trade Practices Act 1974 or any other legislation which by law cannot be excluded, restricted or modified.

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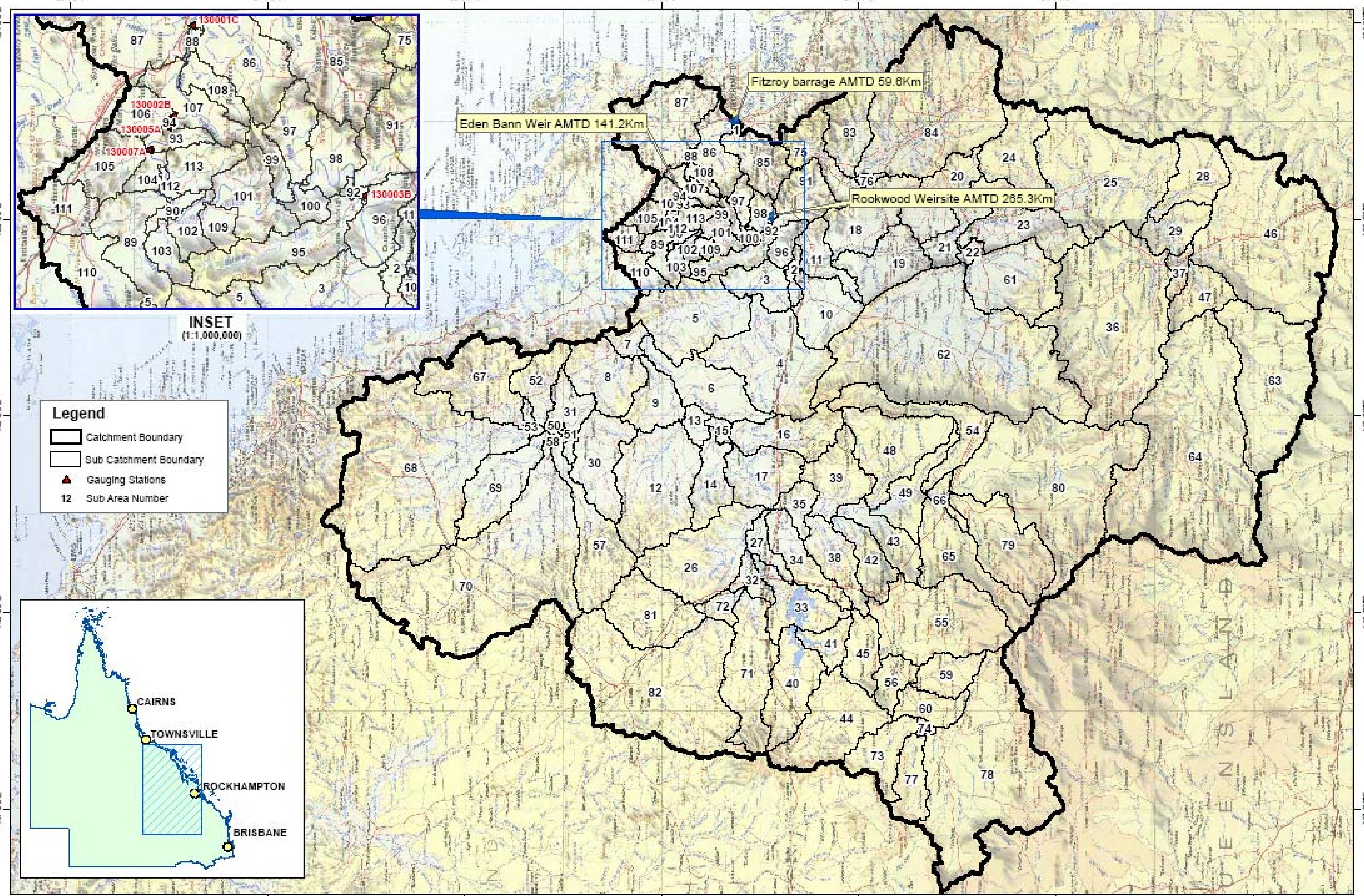
Appendix A
SunWater URBS model layout



NOTES

1. Datum : GDA94

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DRAWN RET	DESIGNED
CHECKED	CHECKED
APPROVED T.Malone	

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Tel: (07) 3120 0000

FITZROY RIVER BASIN
ROOKWOOD WEIRSITE AND EDEN BANN WEIR
DESIGN FLOOD HYDROLOGY
URBS MODEL LAYOUT

MAP NUMBER 230748

DATE MAR 2008

Appendix B
Critical infrastructure inundation levels

Appendix B – Critical infrastructure inundation levels

Critical infrastructure, emergency facilities and possible evacuation shelters

Approx Gauge Level at which Building Location Starts to Become Inundated*	Approx Gauge Level at which Property Starts to Become Inundated	Infrastructure Type	Address	Suburb	Name
<7.0	<7.0	Coast Guard	299 Quay Street	Rockhampton City	Rockhampton Coast Guard
8.0	8.0	Child Care	16-20 Bridge Street	Berserker	PCYC Child Care Centre Vacational Care
8.2	8.0	Education Facility	145 Port Curtis Road	Port Curtis	Port Curtis Rd Primary School
8.6		Airstrip	Rockhampton Airport	West Rockhampton	Rockhampton Airport Main
8.7		Airstrip	Rockhampton Airport	West Rockhampton	Rockhampton Airport Alternate
8.7		Airstrip		Glenlee	Orana-Lara Property
8.8	7.7	Education Facility	19 Reaney Street	Berserker	Central Queensland Christian College
9.0	6.8	Education Facility and Possible Evacuation Shelter	1 Campbell Street	Wandal	Rockhampton State High School
9.1		Helipad	Rockhampton Airport	West Rockhampton	Rockhampton Airport
9.1	8.7	Retirement Village	155-157 Glenmore Road	Park Avenue	Oak Tree Retirement Village
9.1	9.1	Education Facility	186 West Street	Allenstown	The Cathedral College
9.1	<7.0	Education Facility	53-63 O'Connell Street	Depot Hill	Depot Hill State School
9.3	<7.0	Retirement Village	228-230 Lion Creek Road	Wandal	Talbot Estate
9.6	<7.0	Nursing Care Homes	121 Maloney Street	Kawana	Shalom Good Samaritan Care
9.6	9.4	Education Facility	240 Quay Street	Rockhampton City	Rockhampton TAFE
9.6	9.2	Education Facility	282-284 Bolsover Street	Rockhampton City	St Andrews Church House

Approx Gauge Level at which Building Location Starts to Become Inundated*	Approx Gauge Level at which Property Starts to Become Inundated	Infrastructure Type	Address	Suburb	Name
10.0	10.0	Media	110 Victoria Parade	Rockhampton City	Rockhampton Media Centre
10.0	9.8	Media	236 Quay Street	Rockhampton City	Australian Broadcast Corporation
10.0	9.0	Nursing Care Homes	20 Withers Street	Kawana	PresCare Alexandra Gardens
10.0	9.8	Ambulance	57 Fitzroy Street	Rockhampton City	Rockhampton Ambulance Centre
10.1	9.9	Fire	59 Fitzroy Street	Rockhampton City	Rockhampton Fire Station
10.4	<7.0	Child Care	100 Water Street	Berserker	Tarumbal Kindergarten
10.5	10.3	Possible Evacuation Shelter	62 Victoria Parade	Rockhampton City	Pilbeam Theatre
10.6	9.2	Education Facility	13-33 Upper Dawson Road	Allenstown	Allenstown State School
10.6	10.4	Child Care	245 Campbell Street	Rockhampton City	A.B.C. Developmental Learning Centre
10.7	9.7	Child Care	55-57 Edward Street	Berserker	Lead Child Care Berserker
10.7	9.7	Possible Evacuation Shelter	92-94 Musgrave Street	Berserker	North Rockhampton Squash Bowl
10.8	8.6	Retirement Village	14 Pauline Martin Drive	Wandal	Rockhampton Gardens
10.8	10.8	Education Facility	5-13 Main Street	Park Avenue	Park Avenue Primary School
11.0	10.6	Media	130 Victoria Parade	Rockhampton City	Seven Queensland Rockhampton
11.1	9.6	Education Facility	99-109 North Street Extended	West Rockhampton	Crescent Lagoon State School
11.3	11.2	Possible Evacuation Shelter	229 Campbell Street	Rockhampton City	Squash World
11.4	11.3	Education Facility	29 Main Street	Park Avenue	St Josephs Primary Park Avenue
11.6	11.4	Police	161 Bolsover Street	Rockhampton City	Rockhampton Police Station
11.6	11.3	Education Facility	91-115 William Street	Rockhampton City	Rockhampton Special School
11.9	11.8	Child Care	27 Ross Street	Allenstown	Allenstown Childcare

Approx Gauge Level at which Building Location Starts to Become Inundated*	Approx Gauge Level at which Property Starts to Become Inundated	Infrastructure Type	Address	Suburb	Name
12.1	9.5	Nursing Care Homes	97 Campbell Street	Wandal	Eventide Home
12.2	11.9	Possible Evacuation Shelter	157 Campbell Street	Rockhampton City	Rockhampton Indoor Bowls
12.3	8.7	Education Facility and Possible Evacuation Shelter	128-140 Berserker Street	Berserker	Berserker Street State School
12.3	11.4	Police	109 Musgrave Street	Berserker	Police Station
12.3	12.3	Child Care	189 Alma Street	Rockhampton City	City Occasional Childcare Centre
	10.0	Education Facility	451 Paterson Street	Lakes Creek	Lakes Creek State High School
	12.0	State Emergency Service	90 Charles Street	Berserker	SES Rockhampton

** Building locations were determined from the aerial image and are indicative only*

Water and sewerage infrastructure

Approx Gauge Level at which Infrastructure becomes Inundated*	Infrastructure Type	Suburb	Name
<7.0	Water Intake	Parkhurst	
<7.0	Sewage Pump Station	The Common	Nth STP Pump (No1)
<7.0	Sewage Pump Station	The Common	Nth STP Pump (No2)
<7.0	Sewage Treatment Plant	The Common	North Rockhampton STP
<7.0	Sewage Treatment Plant	Depot Hill	South Rockhampton STP
7.1	Sewage Pump Station	Wandal	Harmon St
7.2	Sewage Pump Station	Depot Hill	Arthur Street
7.5	Sewage Pump Station	The Common	Reaney Street
8.2	Sewage Pump Station	Wandal	Jardine Park
8.3	Sewage Pump Station	Park Avenue	Wattle Street
8.3	Water Pump Station	Gracemere	WR-395a
8.5	Sewage Pump Station	Koongal	Water Street
8.5	Sewage Pump Station	Allenstown	Ferguson Street
8.7	Sewage Pump Station	Kawana	Capricorn Country Club
9.0	Sewage Pump Station	Wandal	Lion Creek Road
9.0	Sewage Pump Station	West Rockhampton	Canoona Road (Airport No3)
9.0	Sewage Pump Station	West Rockhampton	Millewa Street
9.2	Sewage Pump Station	West Rockhampton	Melbourne Street
9.3	Sewage Pump Station	West Rockhampton	Canoona Road (Airport Terminal Sth)
9.3	Sewage Pump Station	West Rockhampton	Canoona Road (Airport Carpark)
9.4	Sewage Pump Station	The Range	Blackall Street
9.4	Sewage Pump Station	Gracemere	Victoria Street (No1)
9.4	Sewage Pump Station	Gracemere	Old Capricorn Highway
9.5	Sewage Pump Station	Gracemere	Stanley Road
9.6	Sewage Pump Station	Wandal	Campbell Street
9.6	Sewage Pump Station	Koongal	Lakes Creek Rd (No1)
9.6	Sewage Pump Station	West Rockhampton	Kalare Street
9.7	Sewage Pump Station	Wandal	Victoria Park
9.8	Sewage Pump Station	Gracemere	Armstrong Street
9.8	Sewage Treatment Plant	Pink Lily	West Rockhampton STP
9.9	Sewage Pump Station	Lakes Creek	Lakes Creek Rd (No2)
10.2	Sewage Pump Station	Rockhampton City	Denison Lane
10.6	Sewage Pump Station	Parkhurst	Plover Street

Approx Gauge Level at which Infrastructure becomes Inundated*	Infrastructure Type	Suburb	Name
10.8	Sewage Pump Station	Rockhampton City	East Lane
11.0	Water Reservoir	Parkhurst	Reservoir (G.T.P. 4.5ML)
11.0	Water Pump Station	Parkhurst	WP002-Pump (Highlift Glenmore WTP)
11.1	Sewage Pump Station	Gracemere	Victoria Street (No2)
11.3	Sewage Pump Station	Gracemere	Breakspear Street
11.4	Sewage Pump Station	Kawana	Elsie Marsh Park
12.3	Sewage Pump Station	Parkhurst	Belmont Road (No3)

** Gauge level was determined based upon the location of the water/sewerage point object, as provided in GIS. It may not be representative of the facility as a whole.*

Roads

Approximate inundation levels of major roads

Approx Gauge Level at which Road becomes Inundated (not Closure Level)	Road/Street Name*	Suburb	Road/Street Section*	Location where Road/Street First Becomes Inundated
<7.0	Lakes Creek Road	Berserker, Koongal, Lakes Creek	Bridge Street to Dorly Street	Thozet Creek crossing
<7.0	Port Curtis Road	Allenstown, Port Curtis	Gladstone Road to Gavial Creek	Gavial Creek crossing
7.5	Lion Creek Road	Wandal, West Rockhampton	Lion Creek to North Street	Victoria Park
8.0	Berserker Street	Berserker	Lucas Street to Lakes Creek Road	Rodboro Street intersection
8.0	Bolsover Street	Rockhampton City, Depot Hill	North Street to O'Connell Street	North of Wood Street
8.0	Dean Street	Berserker	Elphinstone Street to Lakes Creek Road	Rodboro Street intersection
8.0	East Street	Depot Hill, Rockhampton City	Archer Street to Broadway Street	O'Connell Street intersection
8.0	Lower Dawson Road	Allenstown	Upper Dawson Road to Gladstone Road	Ferguson Street intersection
8.0	O'Connell Street	Depot Hill	Bolsover Street to Wharf Street	Bolsover Street intersection
8.0	Ridgelands Road	Alton Downs, Pink Lily	Woodford Road to Lion Creek Road	South of Pink Lily Road
8.0	Thozet Road	Koongal	Grubb Street to Lakes Creek Road	South of Grubb Street
8.4	Gladstone Road	Allenstown, Rockhampton City	George Street to Lower Dawson Road	Prospect Street intersection
8.4	Lakes Creek Road	Berserker, Koongal, Lakes Creek	Bridge Street to Dorly Street	Frenchmans Creek crossing
8.5	Capricorn Highway	Fairy Bower, Gracemere	McLaughlin Street to Bruce Highway	Fairy Bower Road to Bruce Highway
8.7	Canoona Road	West Rockhampton	Lion Creek Road to Hunter Street	North of the Airport carpark
8.7	Upper Dawson Road	Allenstown	Canning Street to Gladstone Road	Canning Street intersection
8.8	Bruce Highway	Allenstown, Fairy Bower, Port Curtis	Gladstone Road to Gavial Gracemere Road	Burnett Highway to Lower Dawson Road
8.8	Burnett Highway	Bouldercombe, Gracemere	Bruce Highway to Gavial Gracemere Road	Bruce Highway intersection
8.8	Emu Park Road	Lakes Creek	Dorly Street to Hartington Street	Near Totteridge Street

Approx Gauge Level at which Road becomes Inundated (not Closure Level)	Road/Street Name*	Suburb	Road/Street Section*	Location where Road/Street First Becomes Inundated
8.8	Glenmore Road	Park Avenue	Haynes Street to Moores Creek	East of Moores Creek Road
8.8	Haynes Street	Park Avenue	Richardson Road to Dooley Street	East of Wackford Street
8.9	Lakes Creek Road	Berserker, Koongal, Lakes Creek	Bridge Street to Dorly Street	North of Dorly Street
9.4	Elphinstone Street	Berserker, Koongal	Moores Creek to Ascot Lane	Part Street intersection
9.4	Gladstone Road	Allenstown, Rockhampton City	George Street to Lower Dawson Road	Stanley Street intersection
9.4	Hunter Street	West Rockhampton	Canoona Road to Melbourne Street	Canoona Road intersection
9.4	Lion Creek Road	Wandal, West Rockhampton	Lion Creek to North Street	West of Huet Street
9.4	Lion Creek Road	Wandal, West Rockhampton	Lion Creek to North Street	Near Canoona Road
9.4	Rockhampton Emu Park Road	Nerimbera	Hartington Street to Black Creek Road	South of Nerimbera School Road
9.4	Wandal Road	Wandal	Lion Creek Road to Campbell Street	Near Western Street
9.5	Bridge Street	Berserker	Queen Elizabeth Drive to Lakes Creek Road	Near Queen Elizabeth Drive
9.5	Bruce Highway	Allenstown, Fairy Bower, Port Curtis	Gladstone Road to Gavial Gracemere Road	Gavial Creek crossing
10.0	George Street	Rockhampton City	Fitzroy Street to Gladstone Street	William Street intersection
10.0	Glenmore Road	Park Avenue	Haynes Street to Moores Creek	West of Highway Street
10.0	Lakes Creek Road	Berserker, Koongal, Lakes Creek	Bridge Street to Dorly Street	Near Bawden Street
10.0	Main Street	Park Avenue	Fitzroy River to Bertram Street	Near the Fitzroy River
10.0	North Street	Rockhampton City, Wandal	Campbell Street to Victoria Parade	Victoria Parade intersection
10.0	Queen Elizabeth Drive	Berserker	Bridge Street to Macaree Street	Brown Street intersection
10.5	Bolsover Street	Depot Hill, Rockhampton City	North Street to O'Connell Street	Archer Street intersection
10.5	Fitzroy Street	Rockhampton City	George Street to Quay Street	Denison Street intersection
10.5	Richardson Road	Kawana, Park Avenue	Haynes Street to Alexandra Street	Haynes Street intersection

Approx Gauge Level at which Road becomes Inundated (not Closure Level)	Road/Street Name*	Suburb	Road/Street Section*	Location where Road/Street First Becomes Inundated
10.6	Dooley Street	Park Avenue	Glenmore Road to Haynes Street	Glenmore Road intersection
10.6	Musgrave Street	Berserker	Queen Elizabeth Drive to Charles Street	At Queen Elizabeth Drive
10.8	Albert Street	Rockhampton City	Kent Street to Victoria Parade	West of Victoria Parade
10.8	Elphinstone Street	Berserker, Koongal	Moores Creek to Ascot Lane	Craig Street to Rush Street
10.8	Gavial Gracemere Road	Bouldercombe, Gracemere, Midgee	Watts Road to Bruce Highway	Breakspear Street intersection
11.0	Moores Creek Road	Park Avenue	Alexandra Street to Glenmore Road	North of Knight Street
11.4	Hinchliff Street	Kawana	Farm Street to Alexandra Street	South of Munro Street
12.0	Alexandra Street	Kawana	Hinchliff Street to Richardson Road	Mungarra Drive intersection

** Based upon major roads information supplied by Council*

Approximate Lengths of Inundation/Closure for Major Roads

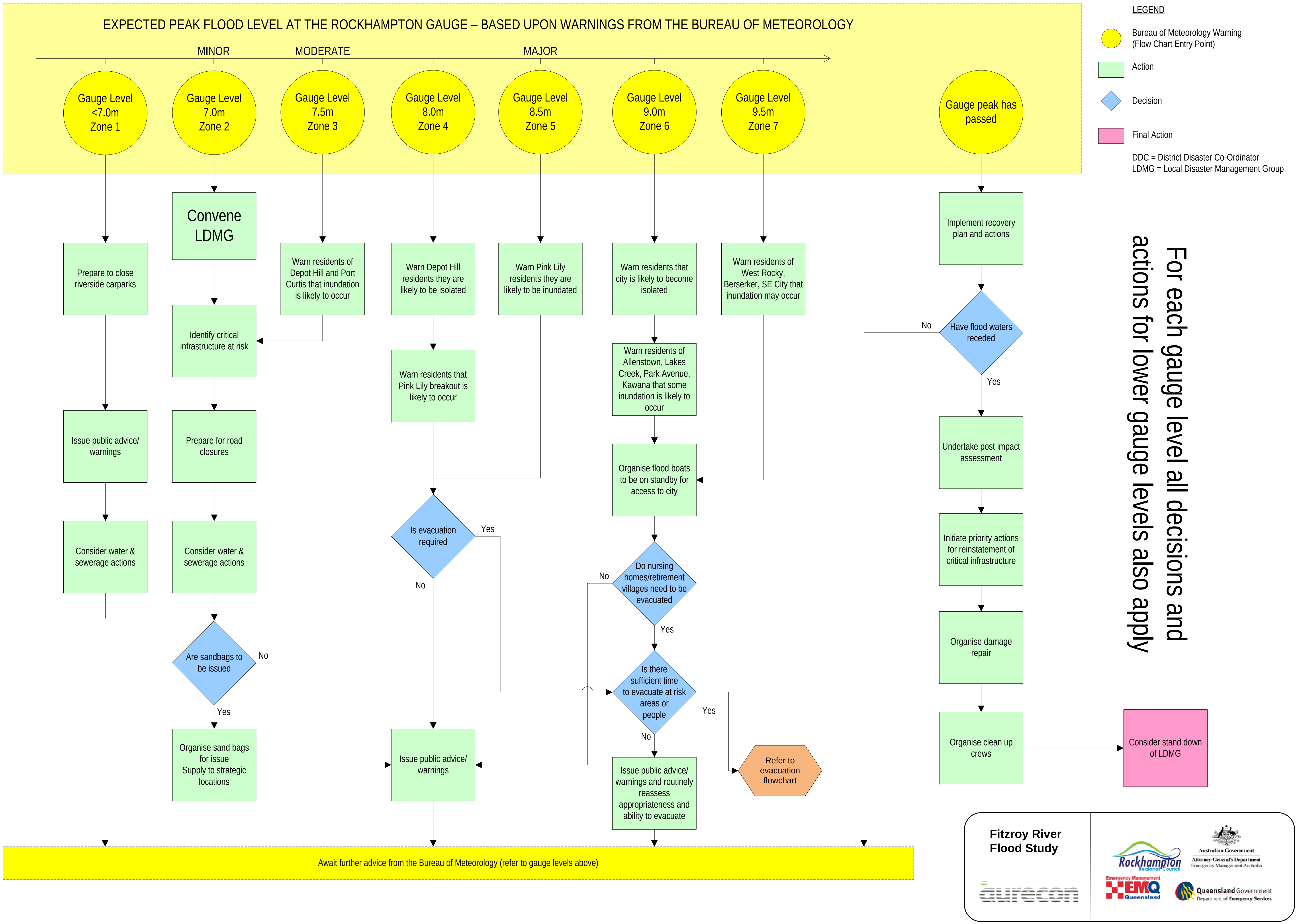
Road Name	Suburb	Road Section	GL7.0 Inundated Length	GL7.5 Inundated Length	GL8.0 Inundated Length	GL8.5 Inundated Length	GL9.0 Inundated Length	GL9.5 Inundated Length	GL10.0 Inundated Length	GL10.5 Inundated Length	GL11.0 Inundated Length	GL11.5 Inundated Length	PMF Inundated Length
Albert Street	Rockhampton City	Kent Street to Victoria Parade	-	-	-	-	-	-	-	-	Bolsover Street to Victoria Parade	Denison Street to Alma Street and Bolsover Street to Victoria Parade	Kent Street to Victoria Parade
Alexandra Street	Kawana	Hinchliff Street to Richardson Road	-	-	-	-	-	-	-	-	-	-	Hinchliff Street to Richardson Road
Berserker Street	Berserker	Lucas Street to Lakes Creek Road	-	-	Rodboro Street intersection	Charles Street to Lakes Creek Road	Charles Street to Lakes Creek Road	Charles Street to Lakes Creek Road	Charles Street to Lakes Creek Road	Charles Street to Lakes Creek Road	Charles Street to Lakes Creek Road	Charles Street to Lakes Creek Road	Lucas Street to Lakes Creek Road
Bolsover Street	Depot Hill Rockhampton City	North Street to O'Connell Street	-	-	Jane Street to O'Connell Street	Francis Street to O'Connell Street	Stanley Street to O'Connell Street	Derby Street to O'Connell Street	Derby Street to O'Connell Street	Cambridge Street to Archer Street and Market Lane to O'Connell Street	Cambridge Street to Fitzroy Street and Market Lane to O'Connell Street	North Street to Denham Street and Market Lane Street to O'Connell Street	North Street to O'Connell Street
Bridge Street	Berserker	Queen Elizabeth Drive to Lakes Creek Road	-	-	-	-	-	Queen Elizabeth Drive to Lakes Creek Road	Queen Elizabeth Drive to Lakes Creek Road	Queen Elizabeth Drive to Lakes Creek Road	Queen Elizabeth Drive to Lakes Creek Road	Queen Elizabeth Drive to Lakes Creek Road	Queen Elizabeth Drive to Lakes Creek Road
Bruce Highway	Allenstown Fairy Bower Port Curtis	Gladstone Road to Gavial Gracemere Road	-	-	-	Upper Dawson Road intersection	Gladstone Road to Edith Street	Gladstone Road to Edith Street and Gavial Creek crossing	Gladstone Road to Edith Street and Gavial Creek crossing	Gladstone Road to Edith Street and Whyte Road to Gavial Gracemere Road	Gladstone Road to Edith Street and Whyte Road to Gavial Gracemere Road	Gladstone Road to Edith Street and Whyte Road to Gavial Gracemere Road	Gladstone Road to Edith Street and Whyte Road to Gavial Gracemere Road
Burnett Highway	Bouldercombe Gracemere	Bruce Highway to Gavial Gracemere Road	-	-	-	-	Bruce Highway intersection	Bruce Highway intersection	Bruce Highway intersection	Bruce Highway intersection	Bruce Highway intersection	Bruce Highway to Gavial Gracemere Road	Bruce Highway to Gavial Gracemere Road
Canoona Road	West Rockhampton	Lion Creek Road to Hunter Street	-	-	-	-	Lion Creek Road to Hunter Street	Lion Creek Road to Hunter Street	Lion Creek Road to Hunter Street	Lion Creek Road to Hunter Street	Lion Creek Road to Hunter Street	Lion Creek Road to Hunter Street	Lion Creek Road to Hunter Street
Capricorn Highway	Fairy Bower Gracemere	McLaughlin Street to Bruce Highway	-	-	-	Fairy Bower Road to Bruce Highway	McLaughlin Street to Bruce Highway	McLaughlin Street to Bruce Highway	McLaughlin Street to Bruce Highway	McLaughlin Street to Bruce Highway	McLaughlin Street to Bruce Highway	McLaughlin Street to Bruce Highway	McLaughlin Street to Bruce Highway
Dean Street	Berserker	Elphinstone Street to Lakes Creek Road	-	-	Rodboro Street intersection	Mason Street to Peter Street	Bedford Street to Peter Street	Elphinstone Street to Lakes Creek Road	Elphinstone Street to Lakes Creek Road	Elphinstone Street to Lakes Creek Road	Elphinstone Street to Lakes Creek Road	Elphinstone Street to Lakes Creek Road	Elphinstone Street to Lakes Creek Road
Dooley Street	Park Avenue	Glenmore Road to Haynes Street	-	-	-	-	-	-	-	-	Glenmore Road to Robison Street	Glenmore Road to Tom Brady Street	Glenmore Road to Haynes Street
East Street	Depot Hill Rockhampton City	Archer Street to Broadway Street	-	-	Wood Street to Broadway Street	Francis Street to Broadway Street	Derby Street to Broadway Street	Market lane to Broadway Street	Denham Street to Broadway Street	Denham Street to Broadway Street	Archer Street to Royal Street and Bus Lane to Broadway Street	Archer Street to Royal Street and Bus Lane to Broadway Street	Archer Street to Broadway Street
Elphinstone Street	Berserker Koongal	Moores Creek to Ascot Lane	-	-	-	-	-	Part Street intersection	Part Street intersection	Moores Creek to Ascot Lane	Moores Creek to Ascot Lane and Craig Street to Rush Street	Moores Creek to Ascot Lane and Craig Street to Rush Street	Moores Creek to Ascot Lane and Craig Street to Rush Street
Emu Park Road	Lakes Creek	Dorly Street to Hartington Street	-	-	-	-	Dorly Street to Hartington Street	Dorly Street to Hartington Street	Dorly Street to Hartington Street	Dorly Street to Hartington Street	Dorly Street to Hartington Street	Dorly Street to Hartington Street	Dorly Street to Hartington Street
Fitzroy Street	Rockhampton City	George Street to Quay Street	-	-	-	-	-	-	-	Kent Street to Bolsover Lane	Campbell Street to Bolsover Street	Campbell Lane to East Street	George Street to Quay Street
Gavial Gracemere Road	Bouldercombe Gracemere Midgee	Watts Road to Bruce Highway	-	-	-	-	-	-	-	-	Breakspear Street intersection	Breakspear Street intersection	Breakspear Street intersection and Burnett Highway to Tipson Road
George Street	Rockhampton City	Fitzroy Street to Gladstone Street	-	-	-	-	-	-	Denham Street to Gladstone Street	Denham Street to Gladstone Street	Fitzroy Street to Gladstone Street	Fitzroy Street to Gladstone Street	Fitzroy Street to Gladstone Street

Road Name	Suburb	Road Section	GL7.0 Inundated Length	GL7.5 Inundated Length	GL8.0 Inundated Length	GL8.5 Inundated Length	GL9.0 Inundated Length	GL9.5 Inundated Length	GL10.0 Inundated Length	GL10.5 Inundated Length	GL11.0 Inundated Length	GL11.5 Inundated Length	PMF Inundated Length
Gladstone Road	Allenstown Rockhampton City	George Street to Lower Dawson Road	-	-	-	Prospect Street to Lower Dawson Road	Church Street to Lower Dawson Road	Caroline Street to Derby Street and Church Street to Lower Dawson Road	George Street to Margaret Street and Elizabeth Street to Lower Dawson Road	George Street to Lower Dawson Road	George Street to Lower Dawson Road	George Street to Lower Dawson Road	George Street to Lower Dawson Road
Glenmore Road	Park Avenue	Haynes Street to Moores Creek	-	-	-	-	Moores Creek Road to Moores Creek	Moores Creek Road to Moores Creek	McAlister Street to Highway Street and Moores Creek Road to Moores Creek	Haynes Street to Highway Street and Moores Creek Road to Moores Creek	Haynes Street to Moores Creek	Haynes Street to Moores Creek	Haynes Street to Moores Creek
Haynes Street	Park Avenue	Richardson Road to Dooley Street	-	-	-	-	Glenmore Road to Hogan Street	Glenmore Road to Hogan Street	Richardson Road to Churchill Street and Glenmore Road to Hogan Street and Underwood Street intersection	Richardson Road to Buckle Street	Richardson Road to Main Street	Richardson Road to Dooley Street	Richardson Road to Dooley Street
Hinchliff Street	Kawana	Farm Street to Alexandra Street	-	-	-	-	-	-	-	-	-	Near Munro Street intersection	Farm Street to Alexandra Street
Hunter Street	West Rockhampton	Canoona Road to Melbourne Street	-	-	-	-	-	Canoona Road to Gorle Street	Canoona Road to Gorle Street	Canoona Road to Fenlon Street	Canoona Road to Fenlon Street	Canoona Road to Fenlon Street	Canoona Road to Melbourne Street
Lakes Creek Road	Berserker Koongal Lakes Creek	Bridge Street to Dorly Street	Bryant Street to Stack Street	Bryant Street to Stack Street	Bryant Street to Stack Street	Tucker Street to Stack Street	Tucker Street to Stack Street and Hill Street to Dorly Street	Water Street to Stack Street and Mackay Street to Dorly Street	Bridge Street to Pilkington Street and Mackay Street to Dorly Street	Bridge Street to Pilkington Street and Fargher Street to Cooper Street and Mackay Street to Dorly Street	Bridge Street to Harbourne Street and Fargher Street to Cooper Street and Mackay Street to Dorly Street	Bridge Street to Harbourne Street and Fargher Street to Cooper Street and Mackay Street to Dorly Street	Bridge Street to Harbourne Street and Fargher Street to Cooper Street and Mackay Street to Dorly Street
Lion Creek Road	Wandal West Rockhampton	Lion Creek to North Street	-	-	-	Exhibition Road to North Street	Exhibition Road to North Street	Lion Creek to Wandal Road and Sheehan Avenue to Luck Avenue and Exhibition Road to North Street	Lion Creek to North Street	Lion Creek to North Street	Lion Creek to North Street	Lion Creek to North Street	Lion Creek to North Street
Lower Dawson Road	Allenstown	Upper Dawson Road to Gladstone Road	-	-	Ferguson Street intersection	Ferguson Street intersection	Upper Dawson Road to Gladstone Road	Upper Dawson Road to Gladstone Road	Upper Dawson Road to Gladstone Road	Upper Dawson Road to Gladstone Road	Upper Dawson Road to Gladstone Road	Upper Dawson Road to Gladstone Road	Upper Dawson Road to Gladstone Road
Main Street	Park Avenue	Fitzroy River to Bertram Street	-	-	-	-	-	-	Fitzroy River to Glenmore Road	Fitzroy River to Glenmore Road	Fitzroy River to Lloyd Street	Fitzroy River to Edgar Street	Fitzroy River to Bertram Street
Moores Creek Road	Park Avenue	Alexandra Street to Glenmore Road	-	-	-	-	-	-	-	-	-	Alexandra Street to Knight Street	Alexandra Street to Dowling Street and Welch Street intersection
Musgrave Street	Berserker	Queen Elizabeth Drive to Charles Street	-	-	-	-	-	-	-	-	Queen Elizabeth Drive to Armstrong Street	Queen Elizabeth Drive to Armstrong Street	Queen Elizabeth Drive to Charles Street
North Street	Rockhampton City Wandal	Campbell Street to Victoria Parade	-	-	-	-	-	-	Victoria Parade intersection	Victoria Parade intersection	Bolsover Street to Victoria Parade	Denison Street to Victoria Parade	Campbell Street to Victoria Parade
O'Connell Street	Depot Hill	Bolsover Street to Wharf Street	-	-	Bolsover Street to Quay Street	Bolsover Street to Wharf Street	Bolsover Street to Wharf Street	Bolsover Street to Wharf Street	Bolsover Street to Wharf Street	Bolsover Street to Wharf Street	Bolsover Street to Wharf Street	Bolsover Street to Wharf Street	Bolsover Street to Wharf Street
Port Curtis Road	Allenstown Port Curtis	Gladstone Road to Gavial Creek	Gavial Creek crossing	Gavial Creek crossing	Near Gladstone Road intersection and Jellicoe Street to Gavial Creek	Gladstone Road to Garden Street and Jellicoe Street to Gavial Creek	Gladstone Road to Gavial Creek	Gladstone Road to Gavial Creek	Gladstone Road to Gavial Creek	Gladstone Road to Gavial Creek	Gladstone Road to Gavial Creek	Gladstone Road to Gavial Creek	Gladstone Road to Gavial Creek
Queen Elizabeth Drive	Berserker	Bridge Street to Macaree Street	-	-	-	-	-	-	Bridge Street to Bernard Street	Bridge Street to Macaree Street	Bridge Street to Macaree Street	Bridge Street to Macaree Street	Bridge Street to Macaree Street

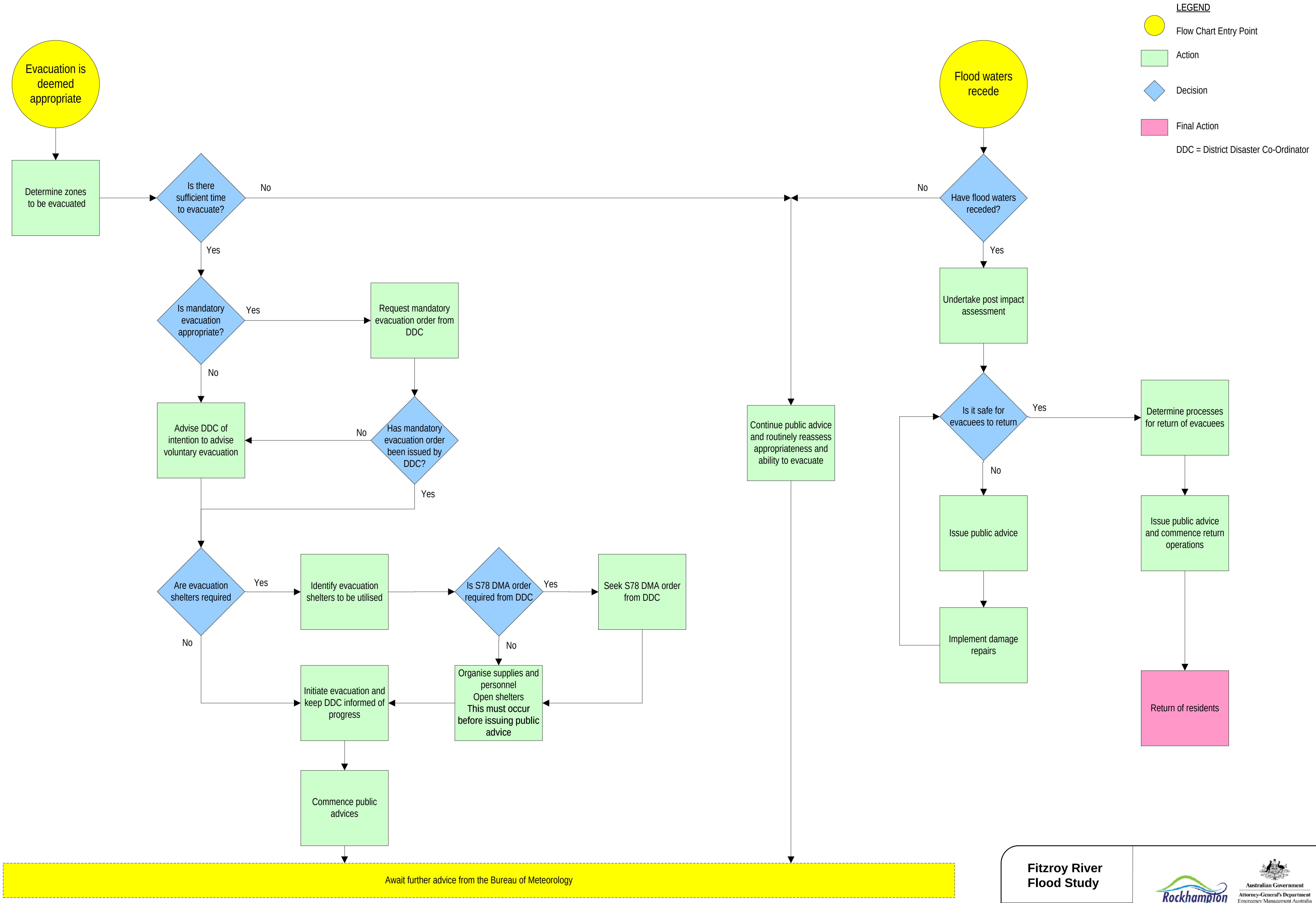
Road Name	Suburb	Road Section	GL7.0 Inundated Length	GL7.5 Inundated Length	GL8.0 Inundated Length	GL8.5 Inundated Length	GL9.0 Inundated Length	GL9.5 Inundated Length	GL10.0 Inundated Length	GL10.5 Inundated Length	GL11.0 Inundated Length	GL11.5 Inundated Length	PMF Inundated Length
Richardson Road	Kawana Park Avenue	Haynes Street to Alexandra Street	-	-	-	-	-	-	-	Haynes Street intersection	Haynes Street to Symons Street	Haynes Street to Alexandra Street	Haynes Street to Alexandra Street
Ridgelands Road	Alton Downs Pink Lily	Woodford Road to Lion Creek Road	-	-	Near Pink Lily Road intersection	Laurel Bank Road to Osborne Road	Woodford Road to Osborne Road	Woodford Road to Lion Creek Road	Woodford Road to Lion Creek Road	Woodford Road to Lion Creek Road	Woodford Road to Lion Creek Road	Woodford Road to Lion Creek Road	Woodford Road to Lion Creek Road
Rockhampton Emu Park Road	Nerimbera	Hartington Street to Black Creek Road	-	-	-	-	-	Barkers Road to Saint Christophers Chapel Road	Hartington Street to Saint Christophers Chapel Road	Hartington Street to Saint Christophers Chapel Road	Hartington Street to Saint Christophers Chapel Road	Hartington Street to Saint Christophers Chapel Road	Hartington Street to Black Creek Road
Thozet Road	Koongal	Grubb Street to Lakes Creek Road	-	-	Grubb Street to Lakes Creek Road	Grubb Street to Lakes Creek Road	Grubb Street to Lakes Creek Road	Grubb Street to Lakes Creek Road	Grubb Street to Lakes Creek Road	Grubb Street to Lakes Creek Road	Grubb Street to Lakes Creek Road	Grubb Street to Lakes Creek Road	Grubb Street to Lakes Creek Road
Upper Dawson Road	Allenstown	Canning Street to Gladstone Road	-	-	-	-	Nathan Street to Gladstone Road	Nathan Street to Gladstone Road	Nathan Street to Gladstone Road	Nathan Street to Gladstone Road	Nathan Street to Gladstone Road and Canning Street to MacDonald Street	Nathan Street to Gladstone Road and Canning Street to Caroline Street	Nathan Street to Gladstone Road and Canning Street to Glencoe Street
Wandal Road	Wandal	Lion Creek Road to Campbell Street	-	-	-	-	-	Lion Creek Road to Cran Street	Lion Creek Road to Bracher Street and Jardine Street to Oakley Street	Lion Creek Road to Naughton Street and Jardine Street to Birdwood Street	Lion Creek Road to Naughton Street and Jardine Street to Birdwood Street	Lion Creek Road Birdwood Street	Lion Creek Road to Campbell Street

Appendix C
Emergency planning decision support tool

ROCKHAMPTON REGIONAL COUNCIL FLOOD EMERGENCY PROCEDURES



ROCKHAMPTON REGIONAL COUNCIL FLOOD EVACUATION PROCEDURES



Fitzroy River Flood Study

Appendix D
Pre-written flood warnings

Appendix D – Pre-written flood warnings

Flood Warning Public Announcement Pro-Forma

Flood Warning Advice

Issued at __________ *(insert time)* on __________________________ *(insert day, date, month and year)*

The Rockhampton Local Disaster Management Group wishes to inform residents of:

- *(insert suburbs from third page depending upon expected peak flood level)*
-
-

that flooding is predicted to occur at Rockhampton and may affect parts of the above suburbs or areas.

Flood waters are expected to peak at ___________ *(insert BoM predicted flood peak)* metres on the Rockhampton Flood Gauge at ___________ *(insert time)* on _______________ *(insert day, date and month)*.

The Rockhampton Local Disaster Management Group recommends that all residents who live in these areas:

- Listen to Radio ABC Capricornia (837AM) or local radio stations for further updates and advice
- Consider the need to move vehicles and outdoor equipment to higher locations
- Consider the need to raise indoor items in case floodwater threatens your home
- Consider arrangements for pets and livestock, and
- Make preparations in the event you need to relocate from your property

Residents who decide to voluntarily relocate from their premises are requested to register with the Queensland Police on ____________ *(insert phone number)*.

Further advice and information is also available from the following websites;

- Rockhampton Regional Council – rrc.qld.gov.au
- Bureau of Meteorology – www.bom.gov.au

(Delete if not applicable) Residents requiring further advice or assistance can contact the Local Disaster Coordination Centre on ____________ *(insert phone number)*

Further advice and updates will be issued at ________________ *(insert time and date)*.

Example Media Release

Activation of Local Disaster Coordination Centre

The Chairperson of the Rockhampton Regional Council Local Disaster Management Group, Councillor _______________ *(insert Councillor's name)* has announced that the Local Disaster Co-Ordination Centre has now been activated in response to _______________ *(insert **impending flood, cyclone, earthquake etc)***.

Councillor _____________ *(insert Councillor's name)* said that any persons in the Rockhampton Region who require assistance or advice can telephone the centre on ***1 300 652 659.***

The Centre will be open _____________ *(insert opening hours eg **24 hours or 8.00 am to 5.00 pm etc)*** and will ensure residents receive prompt attention by relevant agencies for assistance or advice.

"We will endeavour to protect the community as much as possible and assist in the co-ordination of response and recovery measures as a result of this event" Councillor _____________ *(insert Councillor's name)* said.

Text to insert: Select range in which predicted peak gauge level falls and insert appropriate text into proforma

Gauge Level <7.0 m

Suburbs: Depot Hill, Fairy Bower, Gracemere, Koongal, Midgee, Port Curtis, The Common

Gauge Level 7.0 m – 7.5 m

Suburbs: Allenstown, Depot Hill, Fairy Bower, Gracemere, Koongal, Midgee, Port Curtis, The Common,

Gauge Level 7.5 m – 8.0 m

Suburbs: Allenstown, Berserker, Depot Hill, Fairy Bower, Gracemere, Kawana, Koongal, Midgee, Nine Mile, Pink Lily, Port Curtis, The Common, West Rockhampton

Gauge Level 8.0 m – 8.5 m

Suburbs: Allenstown, Alton Downs, Berserker, Depot Hill, Fairy Bower, Gracemere, Kawana, Koongal, Midgee, Nerimbera, Nine Mile, Park Avenue, Parkhurst, Pink Lily, Port Curtis, Rockhampton City, The Common, Wandal, West Rockhampton

Gauge Level 8.5 m – 9.0 m

Suburbs: Allenstown, Alton Downs, Berserker, Depot Hill, Fairy Bower, Gracemere, Kawana, Koongal, Lakes Creek, Midgee, Nerimbera, Nine Mile, Park Avenue, Parkhurst, Pink Lily, Port Curtis, Rockhampton City, The Common, Wandal, West Rockhampton

Gauge Level 9.0 m – 9.5 m

Suburbs: Allenstown, Alton Downs, Berserker, Depot Hill, Fairy Bower, Gracemere, Kawana, Koongal, Lakes Creek, Midgee, Nerimbera, Nine Mile, Park Avenue, Parkhurst, Pink Lily, Port Curtis, Rockhampton City, The Common, The Range, Wandal, West Rockhampton

Gauge Level 9.5 m – 10.0 m

Suburbs: Allenstown, Alton Downs, Berserker, Depot Hill, Fairy Bower, Gracemere, Kawana, Koongal, Lakes Creek, Midgee, Nerimbera, Nine Mile, Park Avenue, Parkhurst, Pink Lily, Port Curtis, Rockhampton City, The Common, The Range, Wandal, West Rockhampton

Appendix E
Flood zones

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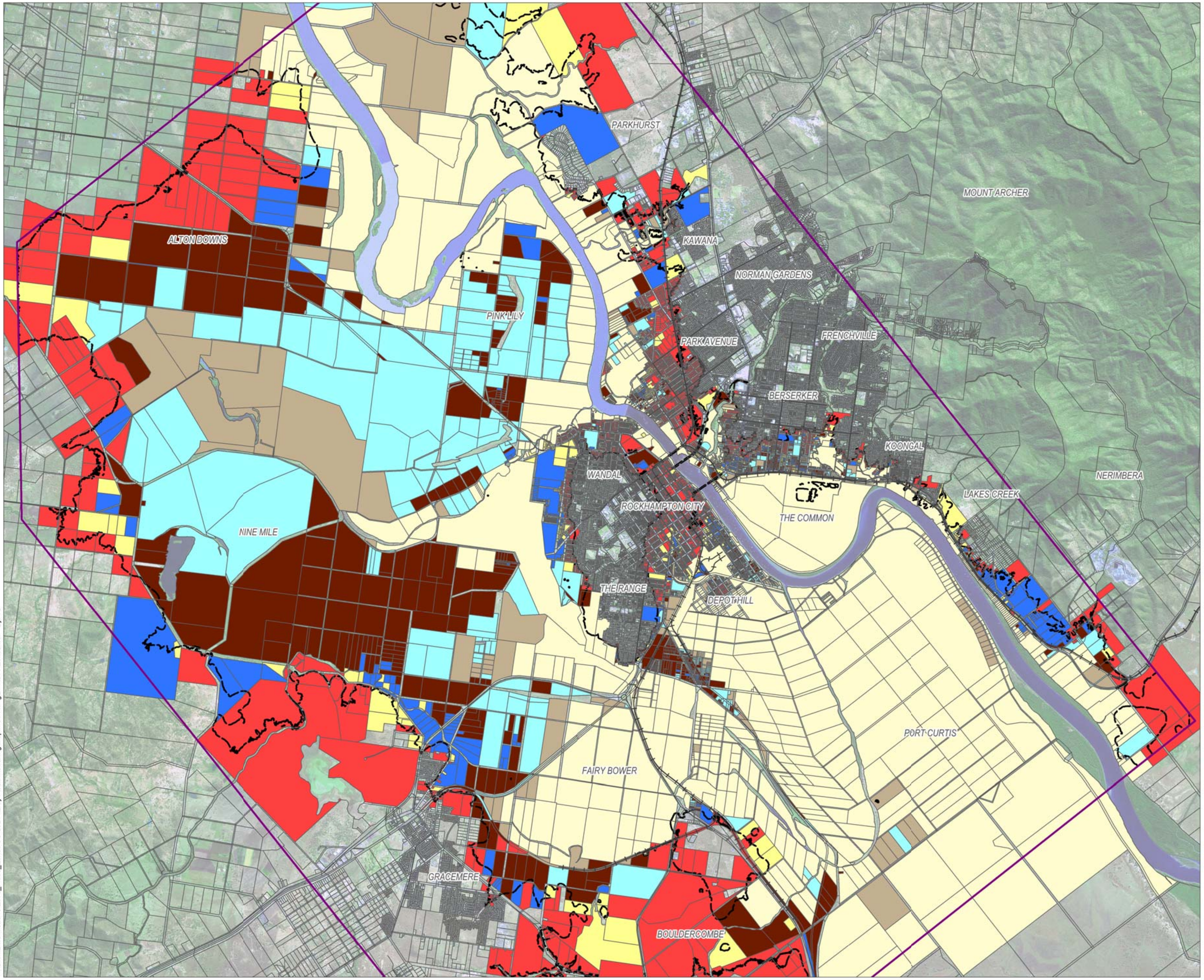
Rockhampton Regional Council

Australian Government
Attorney-General's Department
Emergency Management Australia

Emergency Management
EMQ
Queensland

Queensland Government
Department of Emergency Services



Legend

- Cadastre
- Major Road
- Railway Line
- TUFLOW Model Extents
- Probable Maximum Flood Extent

Flood Zone

- Zone 1 - Cream (<GL7.0)
- Zone 2 - Khaki (GL7.0 - 7.5)
- Zone 3 - Cyan (GL7.5 - 8.0)
- Zone 4 - Maroon (GL8.0 - 8.5)
- Zone 5 - Blue (GL8.5 - 9.0)
- Zone 6 - Yellow (GL9.0 - 9.5)
- Zone 7 - Red (>GL9.5)

Notes:

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4. This mapping shows inundation within the Fitzroy River Flood Study TUFLOW model extents only. Fitzroy River flood inundation continues beyond the upstream and downstream extents of this mapping.
5. Estimated equivalent Rockhampton gauge levels for each event are:

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10 year ARI = 6.65m AHD = 8.10m Gauge Datum
5 year ARI = 5.96m AHD = 7.41m Gauge Datum
2 year ARI = 4.20m AHD = 5.65m Gauge Datum

Date: 18/03/2011 Version: 1

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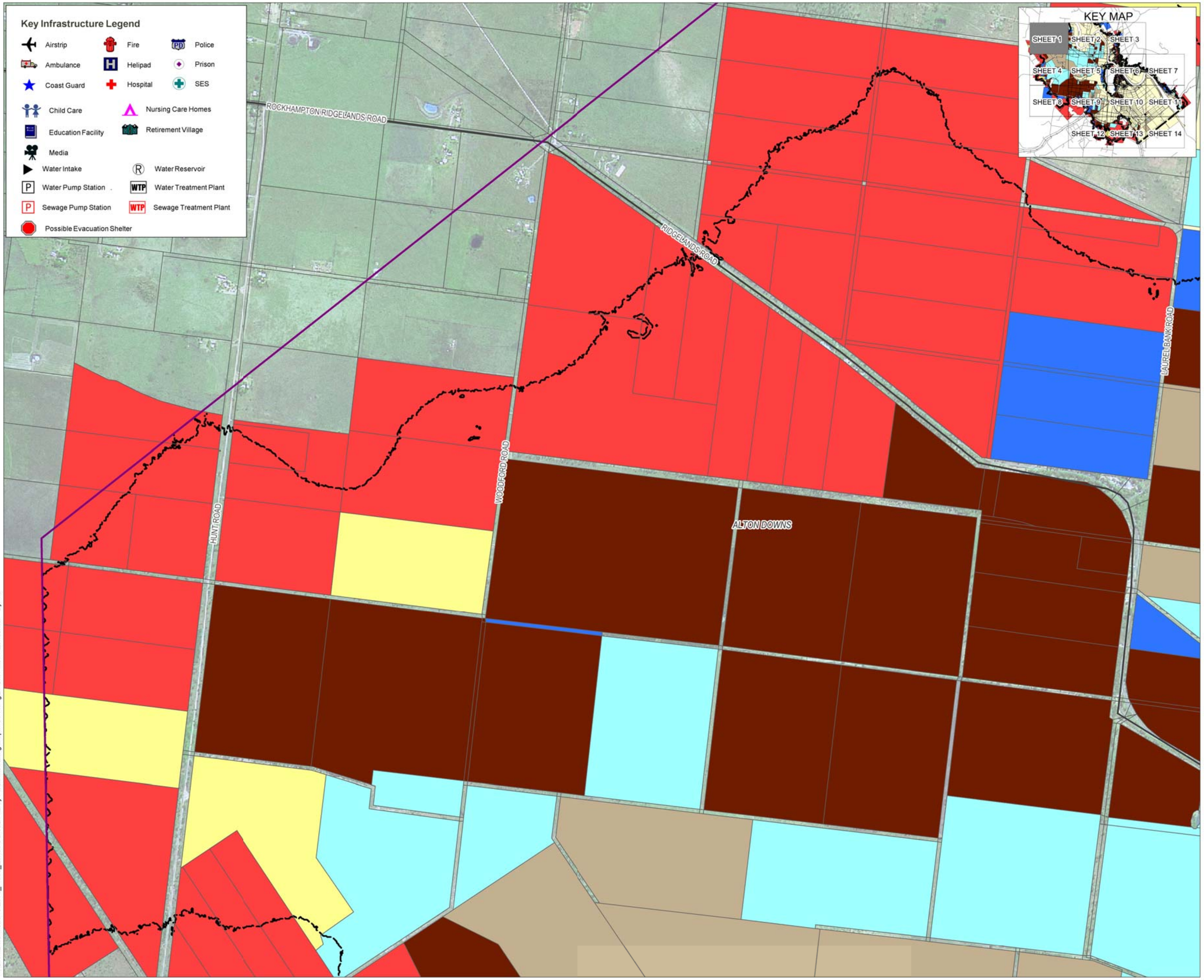
0 4000 (m)

Scale 1:80 000 (m) (@ A3 size)

Projection: MGA Zone 56

Fitzroy River Flood Study

Figure E1 - Flood Zones



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aurecon

Rockhampton Regional Council

Australian Government
Attorney-General's Department
Emergency Management Australia

Emergency Management EMQ Queensland

Queensland Government
Department of Emergency Services

Legend

- Cadastre
- Major Road
- Railway Line
- TUFLOW Model Extents
- Probable Maximum Flood Extent

Flood Zone

- Zone 1 - Cream (<GL7.0)
- Zone 2 - Khaki (GL7.0 - 7.5)
- Zone 3 - Cyan (GL7.5 - 8.0)
- Zone 4 - Maroon (GL8.0 - 8.5)
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Date: 18/03/2011 Version: 1

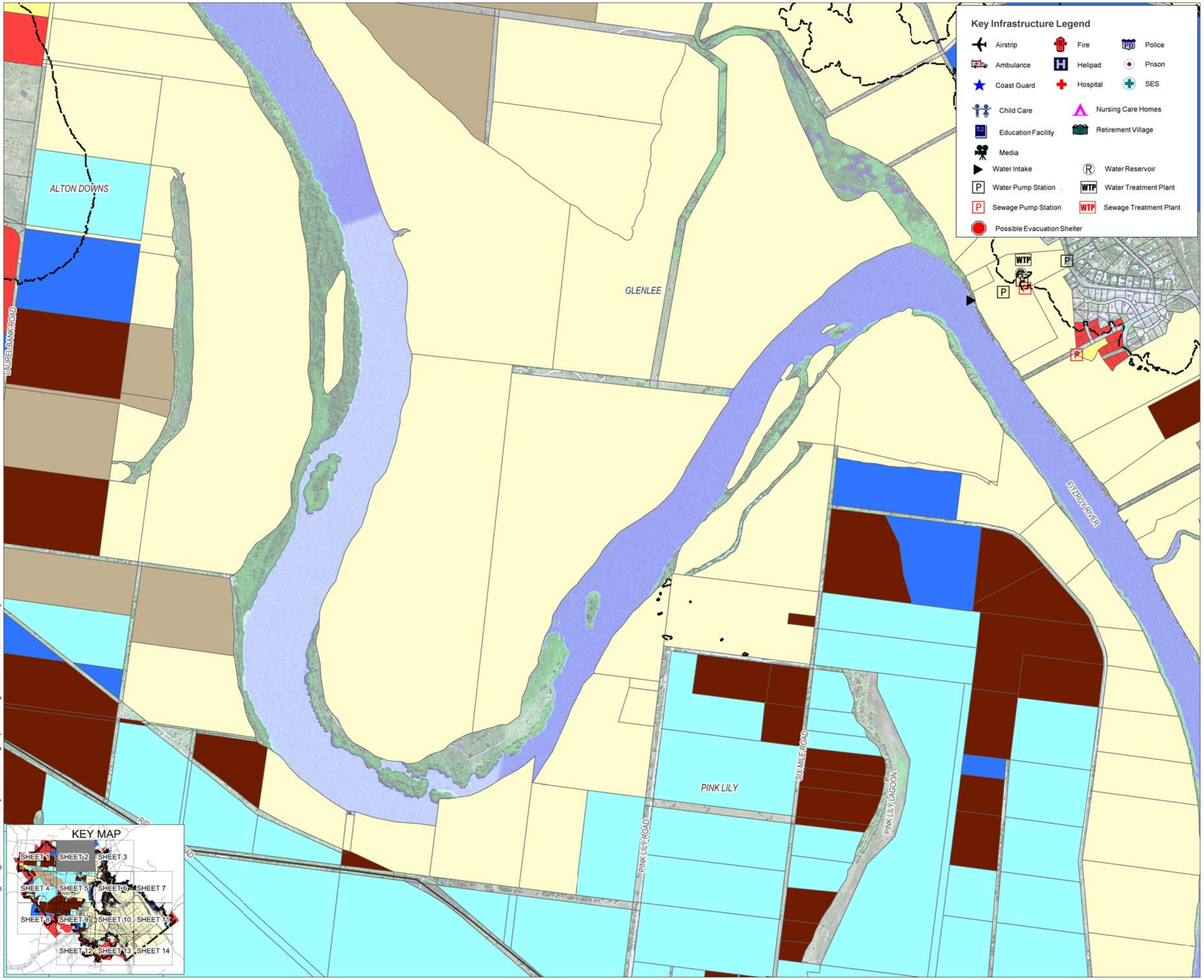
0 1000 (m)

Scale 1:20 000 (m) (@ A3 size)

Projection: MGA Zone 56

Fitzroy River Flood Study

Figure E1 - Sheet 1: Flood Zones



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aurecon

Rockhampton Regional Council

Australian Government Attorney-General's Department Emergency Management Australia

Emergency Management EMQ Queensland

Queensland Government Department of Emergency Services

Legend

- Cadastre
- Major Road
- Railway Line
- TUFLOW Model Extents
- Probable Maximum Flood Extent

Flood Zone

- Zone 1 - Cream (<GL7.0)
- Zone 2 - Khaki (GL7.0 - 7.5)
- Zone 3 - Cyan (GL7.5 - 8.0)
- Zone 4 - Maroon (GL8.0 - 8.5)
- Zone 5 - Blue (GL8.5 - 9.0)
- Zone 6 - Yellow (GL9.0 - 9.5)
- Zone 7 - Red (>GL9.5)

Notes:

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5 year ARI = 5.96m AHD = 7.41m Gauge Datum
2 year ARI = 4.20m AHD = 5.65m Gauge Datum

Date: 18/03/2011 Version: 1

0 1000 (m)

Scale 1:20 000 (m) (@ A3 size)

Projection: MGA Zone 56

Fitzroy River Flood Study

Figure E1 - Sheet 2: Flood Zones

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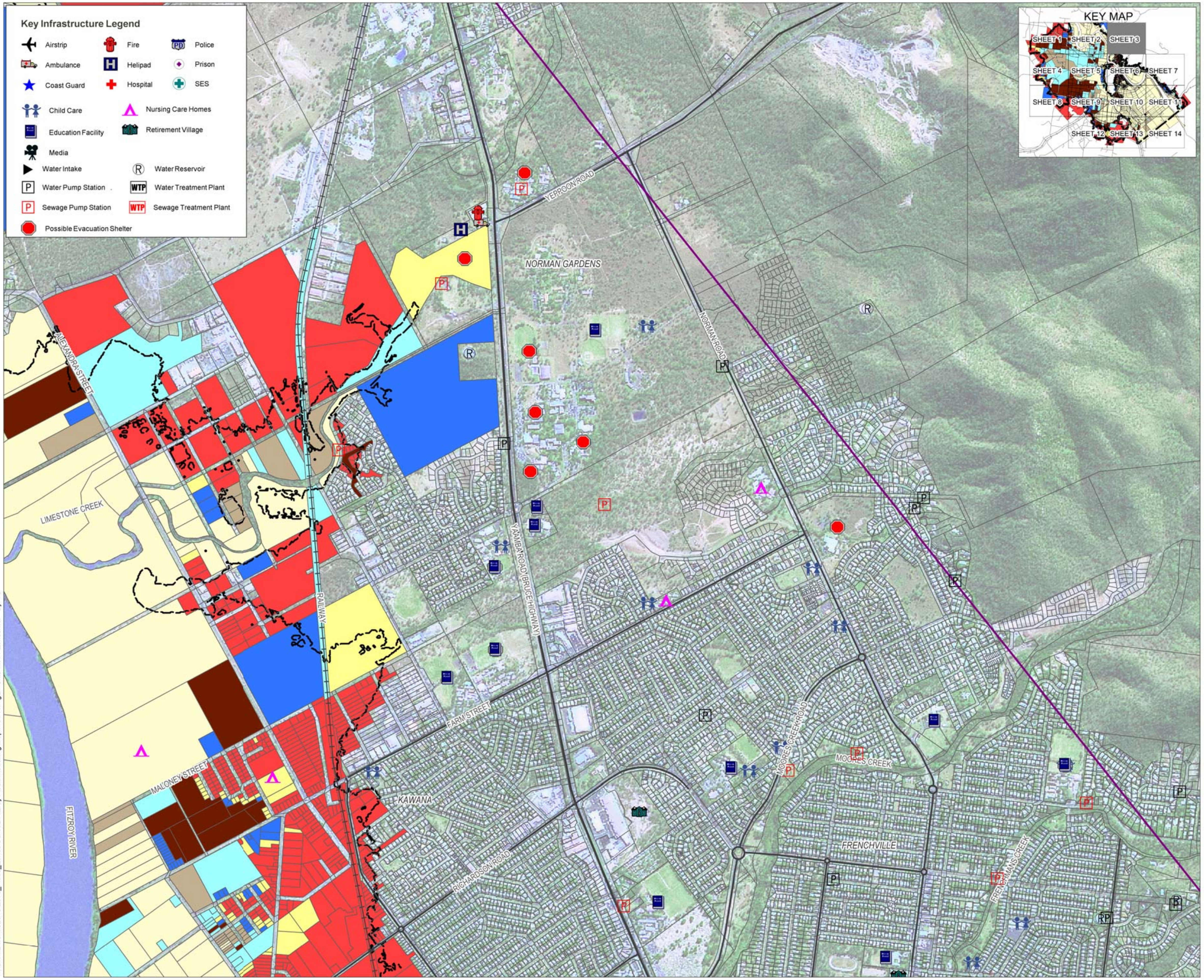
Rockhampton Regional Council

Australian Government
Attorney-General's Department
Emergency Management Australia

Emergency Management EMQ Queensland

Queensland Government
Department of Emergency Services



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Legend

- Cadastre
- Major Road
- Railway Line
- TUFLOW Model Extents
- Probable Maximum Flood Extent

Flood Zone

- Zone 1 - Cream (<GL7.0)
- Zone 2 - Khaki (GL7.0 - 7.5)
- Zone 3 - Cyan (GL7.5 - 8.0)
- Zone 4 - Maroon (GL8.0 - 8.5)
- Zone 5 - Blue (GL8.5 - 9.0)
- Zone 6 - Yellow (GL9.0 - 9.5)
- Zone 7 - Red (>GL9.5)

Notes:

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Date: 18/03/2011 Version: 1

0 1000 (m)

Scale 1:20 000 (m) (@ A3 size)

Projection: MGA Zone 56

Fitzroy River Flood Study

Figure E1 - Sheet 3: Flood Zones

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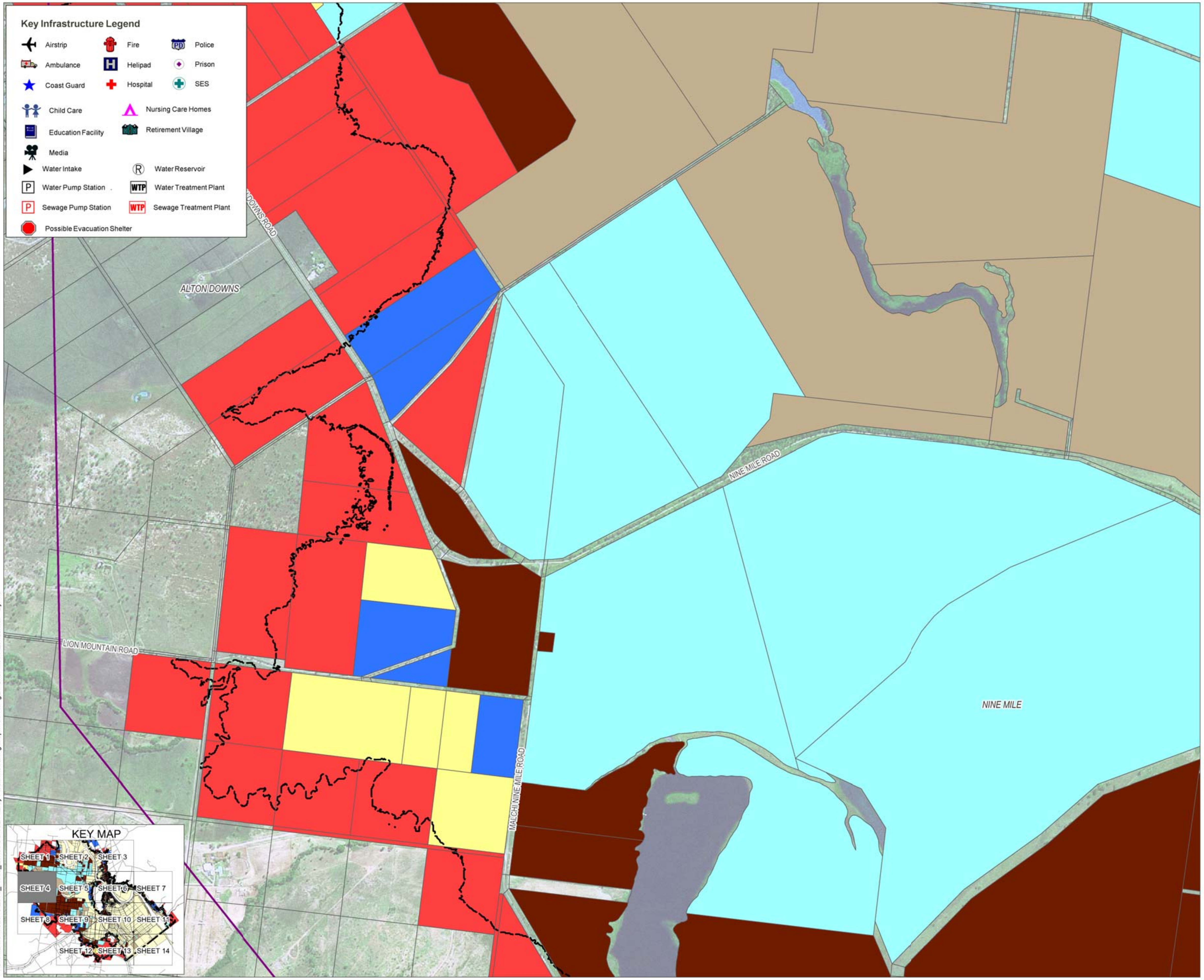
Rockhampton Regional Council

Australian Government
Attorney-General's Department
Emergency Management Australia

Emergency Management EMQ Queensland

Queensland Government
Department of Emergency Services



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Legend

- Cadastre
- Major Road
- Railway Line
- TUFLOW Model Extents
- Probable Maximum Flood Extent

Flood Zone

- Zone 1 - Cream (<GL7.0)
- Zone 2 - Khaki (GL7.0 - 7.5)
- Zone 3 - Cyan (GL7.5 - 8.0)
- Zone 4 - Maroon (GL8.0 - 8.5)
- Zone 5 - Blue (GL8.5 - 9.0)
- Zone 6 - Yellow (GL9.0 - 9.5)
- Zone 7 - Red (>GL9.5)

Notes:

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2 year ARI = 4.20m AHD = 5.65m Gauge Datum

Date: 18/03/2011 Version: 1

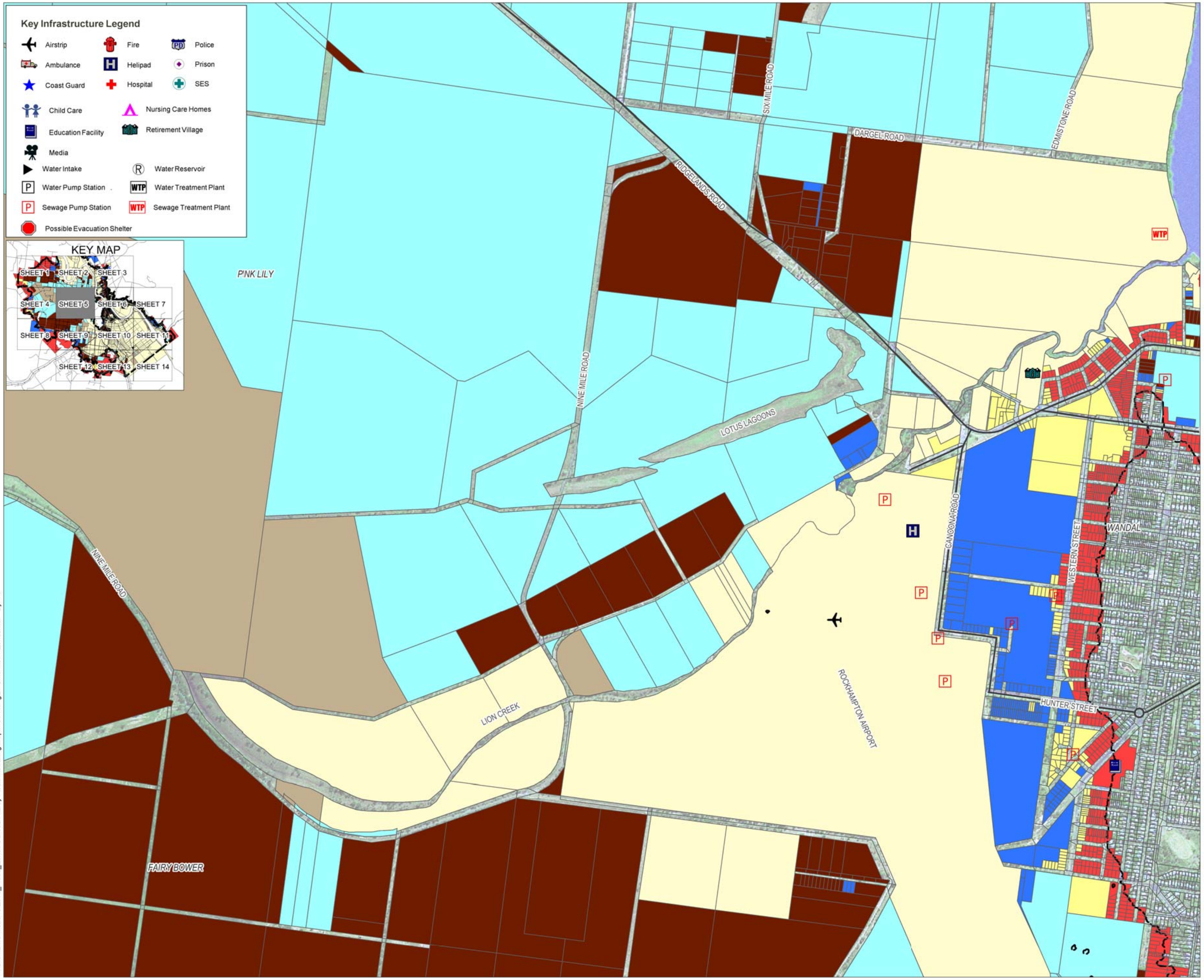
0 1000 (m)

Scale 1:20 000 (m) (@ A3 size)

Projection: MGA Zone 56

Fitzroy River Flood Study

Figure E1 - Sheet 4: Flood Zones



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Legend

- Cadastre
- Major Road
- Railway Line
- TUFLOW Model Extents
- Probable Maximum Flood Extent

Flood Zone

Zone 1 - Cream	(<GL7.0)
Zone 2 - Khaki	(GL7.0 - 7.5)
Zone 3 - Cyan	(GL7.5 - 8.0)
Zone 4 - Maroon	(GL8.0 - 8.5)
Zone 5 - Blue	(GL8.5 - 9.0)
Zone 6 - Yellow	(GL9.0 - 9.5)
Zone 7 - Red	(>GL9.5)

Notes:

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   10 year ARI = 6.65m AHD = 8.10m Gauge Datum
   5 year ARI = 5.96m AHD = 7.41m Gauge Datum
   2 year ARI = 4.20m AHD = 5.65m Gauge Datum

Date: 18/03/2011 Version: 1

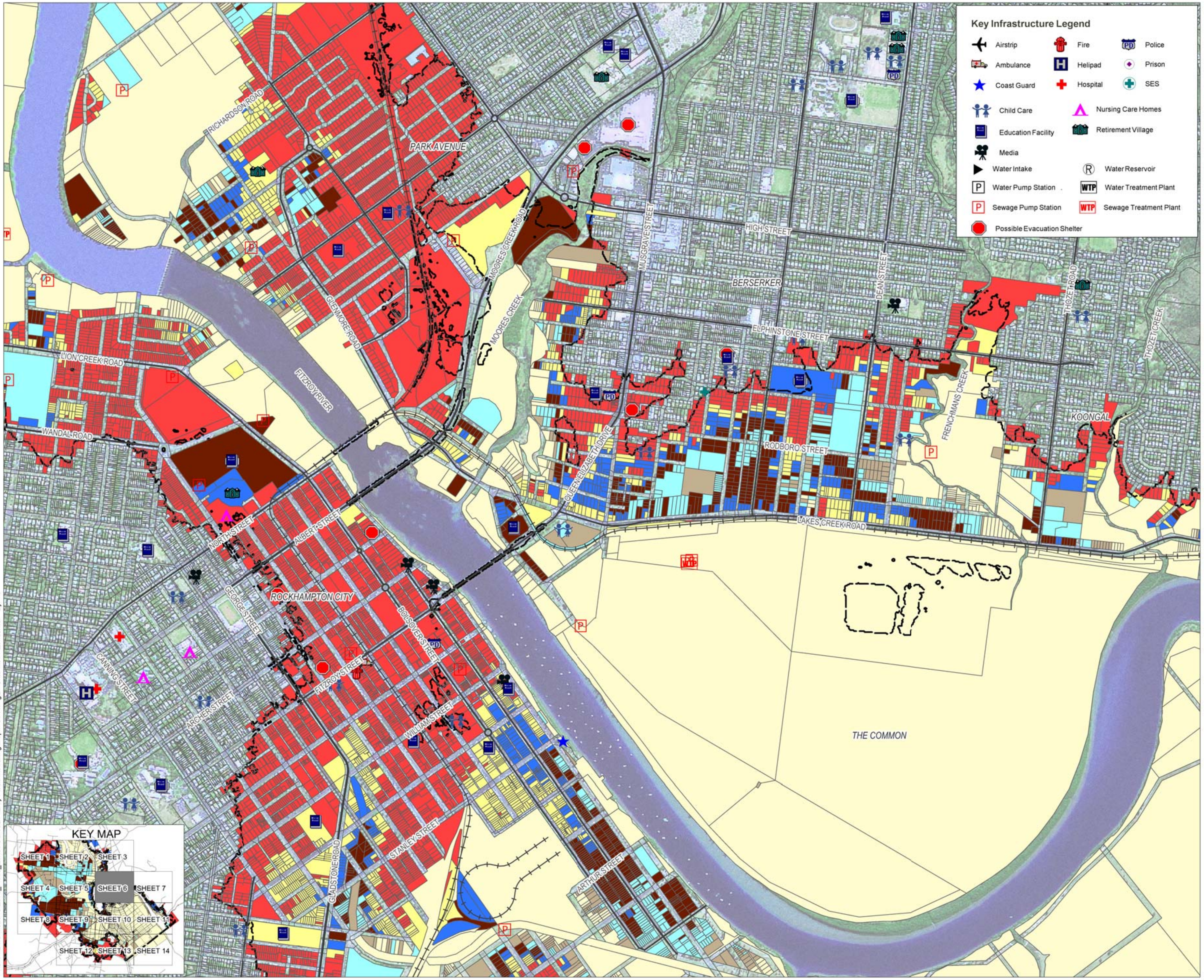
0 1000 (m)

Scale 1:20 000 (m) (@ A3 size)

Projection: MGA Zone 56

Fitzroy River Flood Study

Figure E1 - Sheet 5: Flood Zones



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aurecon

Rockhampton Regional Council

Australian Government Attorney-General's Department Emergency Management Australia

Emergency Management EMQ Queensland

Queensland Government Department of Emergency Services

Legend

- Cadastre
- Major Road
- Railway Line
- TUFLOW Model Extents
- Probable Maximum Flood Extent

Flood Zone

- Zone 1 - Cream (<GL7.0)
- Zone 2 - Khaki (GL7.0 - 7.5)
- Zone 3 - Cyan (GL7.5 - 8.0)
- Zone 4 - Maroon (GL8.0 - 8.5)
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   20 year ARI = 7.23m AHD = 8.68m Gauge Datum
   10 year ARI = 6.65m AHD = 8.10m Gauge Datum
   5 year ARI = 5.96m AHD = 7.41m Gauge Datum
   2 year ARI = 4.20m AHD = 5.65m Gauge Datum

Date: 18/03/2011 Version: 1

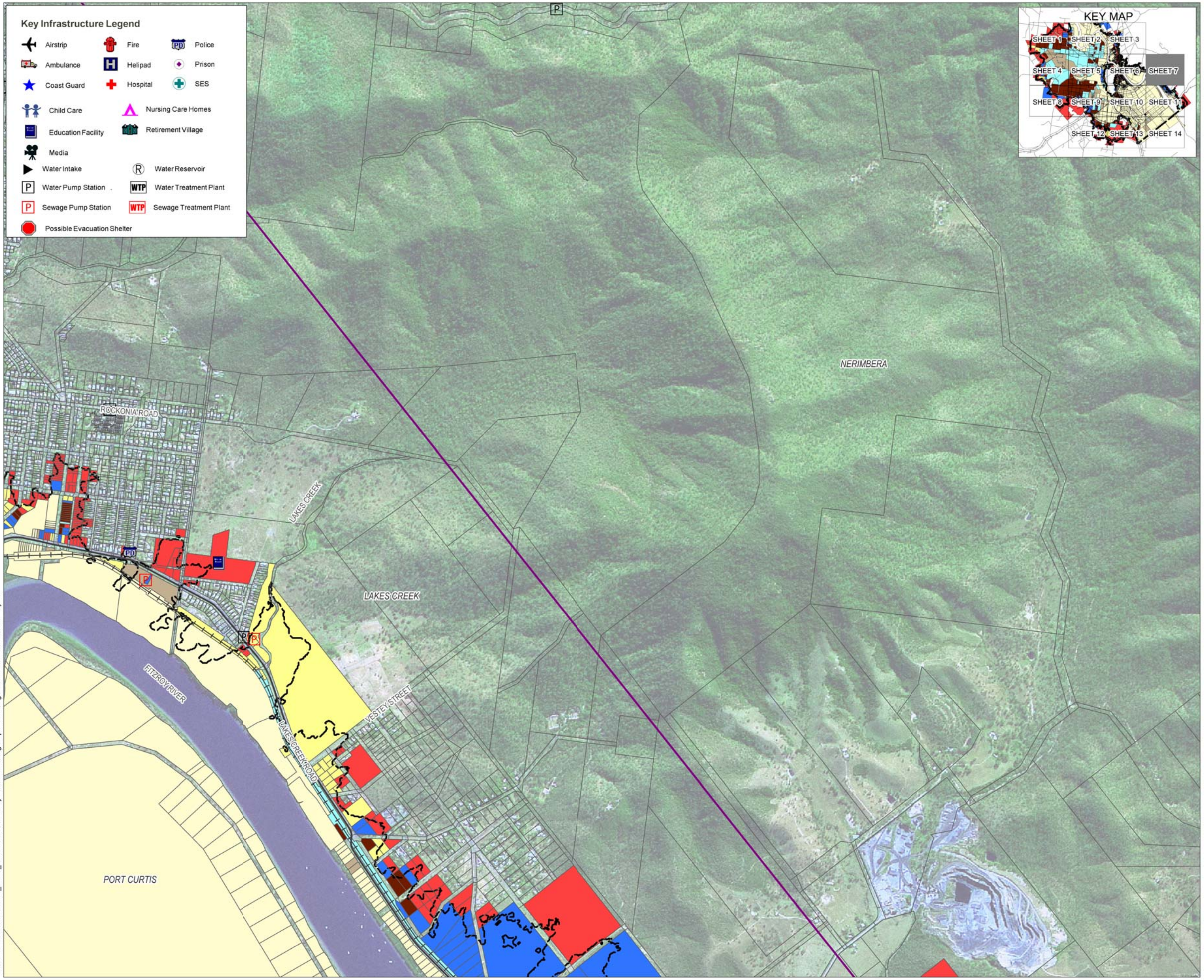
0 1000 (m)

Scale 1:20 000 (m) (@ A3 size)

Projection: MGA Zone 56

Fitzroy River Flood Study

Figure E1 - Sheet 6: Flood Zones



P:\SWM2\work\32513 E070_Flood_Zones CC\002 Fitzroy Flood Modelling\MapInfo\FR-FigE1-Sht7-Rev1-Zones.wor By: TC

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Queensland Government
Department of Emergency Services

Legend

- Cadastre
- Major Road
- Railway Line
- TUFLOW Model Extents
- Probable Maximum Flood Extent

Flood Zone

Zone 1 - Cream	(<GL7.0)
Zone 2 - Khaki	(GL7.0 - 7.5)
Zone 3 - Cyan	(GL7.5 - 8.0)
Zone 4 - Maroon	(GL8.0 - 8.5)
Zone 5 - Blue	(GL8.5 - 9.0)
Zone 6 - Yellow	(GL9.0 - 9.5)
Zone 7 - Red	(>GL9.5)

Notes:

1. This map must not be used without consideration of, or reference to, the Explanatory Notes and Disclaimers which are provided on the Fitzroy River Flood Study Figure 1 so as to understand the important limitations and conditions on such use.
2. All level information is expressed in metres AHD. Rockhampton Gauge Datum = AHD plus 1.448m
3. This mapping considers Fitzroy River flooding only. No consideration of local catchment flooding has been made.
4. This mapping shows inundation within the Fitzroy River Flood Study TUFLOW model extents only. Fitzroy River flood inundation continues beyond the upstream and downstream extents of this mapping.
5. Estimated equivalent Rockhampton gauge levels for each event are:

100 year ARI = 7.93m AHD = 9.38m Gauge Datum
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20 year ARI = 7.23m AHD = 8.68m Gauge Datum
10 year ARI = 6.65m AHD = 8.10m Gauge Datum
5 year ARI = 5.96m AHD = 7.41m Gauge Datum
2 year ARI = 4.20m AHD = 5.65m Gauge Datum

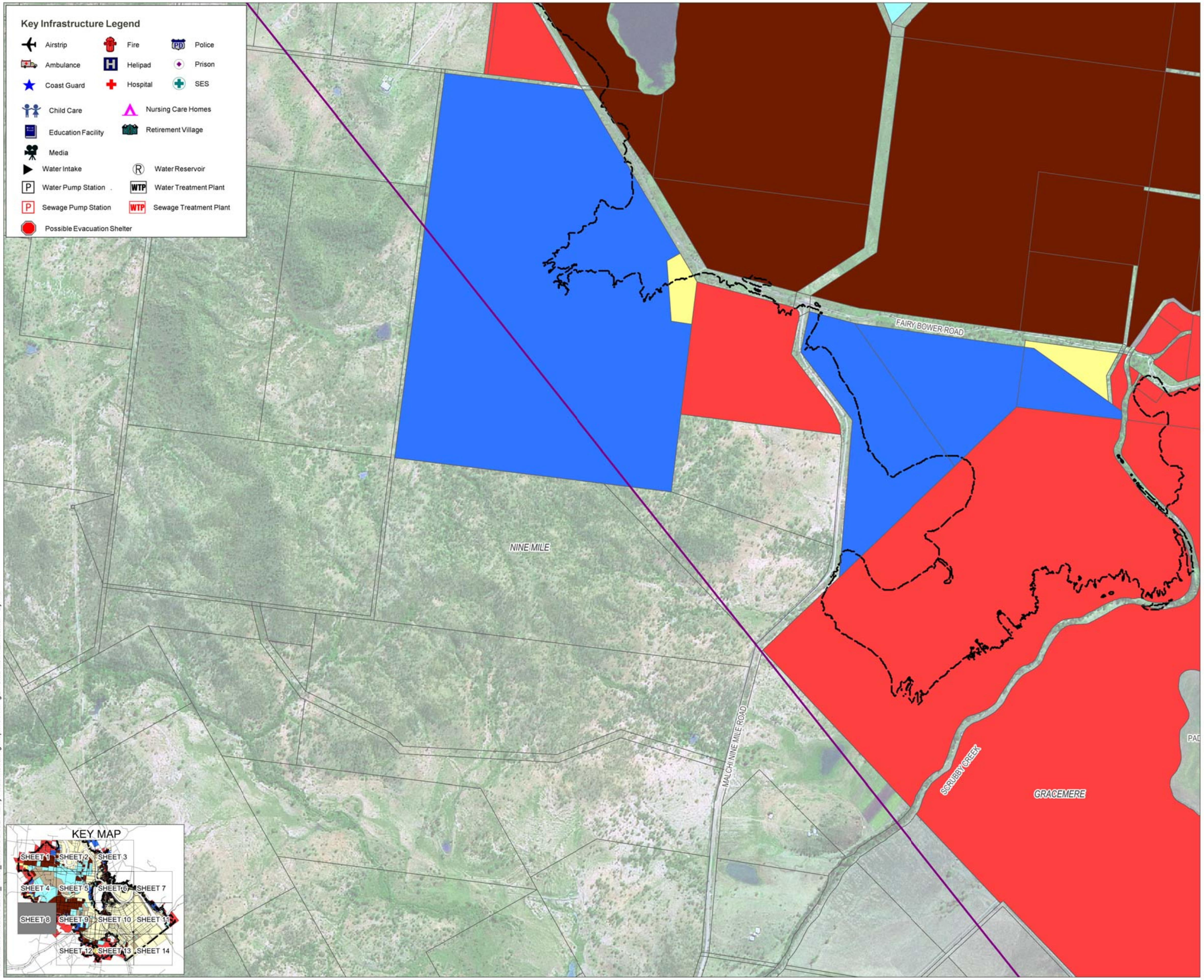
Date: 18/03/2011 Version: 1

0 1000 (m)
Scale 1:20 000 (m) (@ A3 size)

Projection: MGA Zone 56

Fitzroy River Flood Study

Figure E1 - Sheet 7: Flood Zones



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Attorney-General's Department
Emergency Management Australia

Emergency Management Queensland

Queensland Government
Department of Emergency Services

Legend

- Cadastre
- Major Road
- Railway Line
- TUFLOW Model Extents
- Probable Maximum Flood Extent

Flood Zone

- Zone 1 - Cream (<GL7.0)
- Zone 2 - Khaki (GL7.0 - 7.5)
- Zone 3 - Cyan (GL7.5 - 8.0)
- Zone 4 - Maroon (GL8.0 - 8.5)
- Zone 5 - Blue (GL8.5 - 9.0)
- Zone 6 - Yellow (GL9.0 - 9.5)
- Zone 7 - Red (>GL9.5)

Notes:

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10 year ARI = 6.65m AHD = 8.10m Gauge Datum
5 year ARI = 5.96m AHD = 7.41m Gauge Datum
2 year ARI = 4.20m AHD = 5.65m Gauge Datum

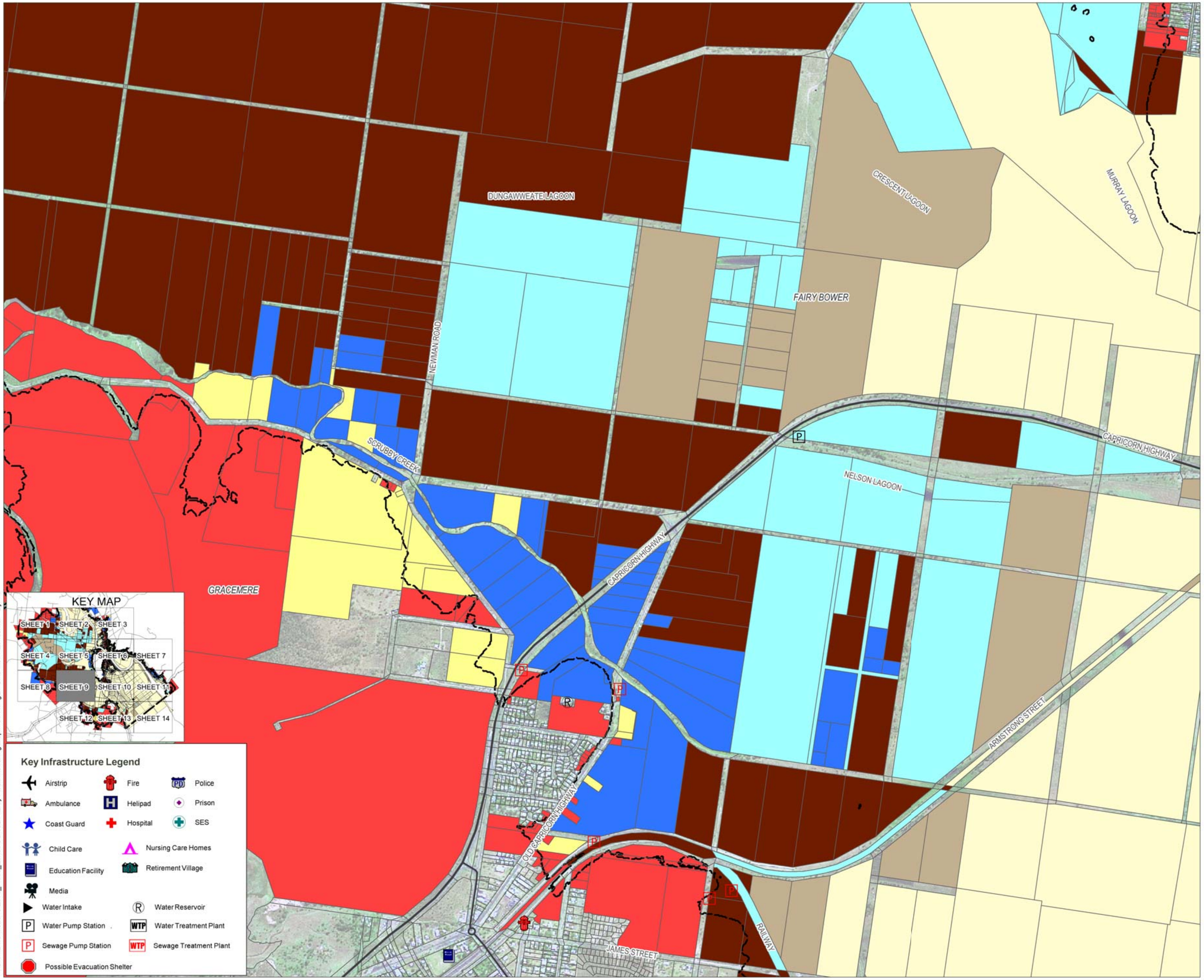
Date: 18/03/2011 Version: 1

0 1000 (m)
Scale 1:20 000 (m) (@ A3 size)

Projection: MGA Zone 56

Fitzroy River Flood Study

Figure E1 - Sheet 8: Flood Zones



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Legend

- Cadastre
- Major Road
- Railway Line
- TUFLOW Model Extents
- Probable Maximum Flood Extent

Flood Zone

- Zone 1 - Cream (<GL7.0)
- Zone 2 - Khaki (GL7.0 - 7.5)
- Zone 3 - Cyan (GL7.5 - 8.0)
- Zone 4 - Maroon (GL8.0 - 8.5)
- Zone 5 - Blue (GL8.5 - 9.0)
- Zone 6 - Yellow (GL9.0 - 9.5)
- Zone 7 - Red (>GL9.5)

Notes:

1. This map must not be used without consideration of, or reference to, the Explanatory Notes and Disclaimers which are provided on the Fitzroy River Flood Study Figure 1 so as to understand the important limitations and conditions on such use.
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4. This mapping shows inundation within the Fitzroy River Flood Study TUFLOW model extents only. Fitzroy River flood inundation continues beyond the upstream and downstream extents of this mapping.
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10 year ARI = 6.65m AHD = 8.10m Gauge Datum
5 year ARI = 5.96m AHD = 7.41m Gauge Datum
2 year ARI = 4.20m AHD = 5.65m Gauge Datum

Date: 18/03/2011 Version: 1

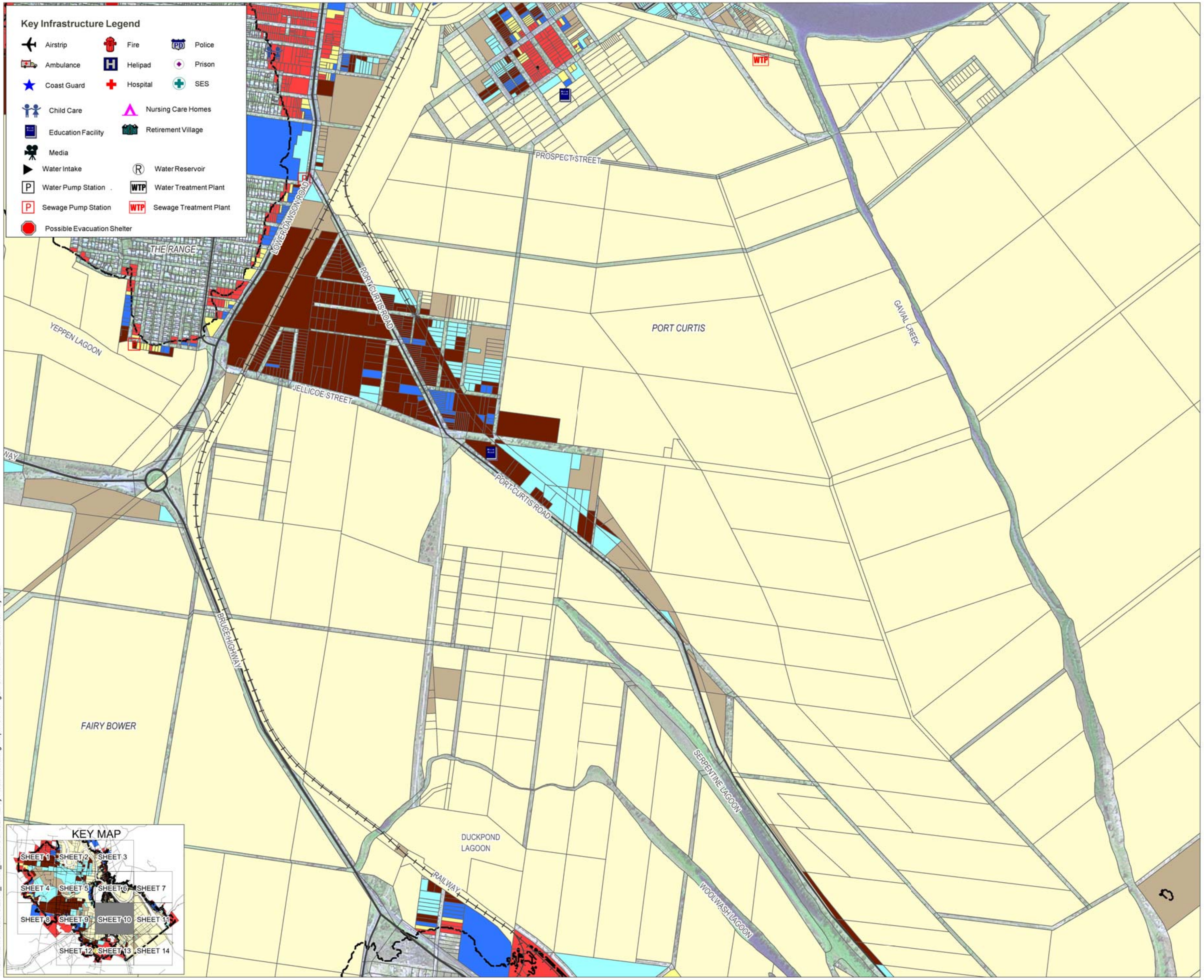
0 1000 (m)

Scale 1:20 000 (m) (@ A3 size)

Projection: MGA Zone 56

Fitzroy River Flood Study

Figure E1 - Sheet 9: Flood Zones



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Department of Emergency Services

Legend

- Cadastre
- Major Road
- Railway Line
- TUFLOW Model Extents
- Probable Maximum Flood Extent

Flood Zone

- Zone 1 - Cream (<GL7.0)
- Zone 2 - Khaki (GL7.0 - 7.5)
- Zone 3 - Cyan (GL7.5 - 8.0)
- Zone 4 - Maroon (GL8.0 - 8.5)
- Zone 5 - Blue (GL8.5 - 9.0)
- Zone 6 - Yellow (GL9.0 - 9.5)
- Zone 7 - Red (>GL9.5)

Notes:

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   10 year ARI = 6.65m AHD = 8.10m Gauge Datum
   5 year ARI = 5.96m AHD = 7.41m Gauge Datum
   2 year ARI = 4.20m AHD = 5.65m Gauge Datum

Date: 18/03/2011 Version: 1

0 1000 (m)

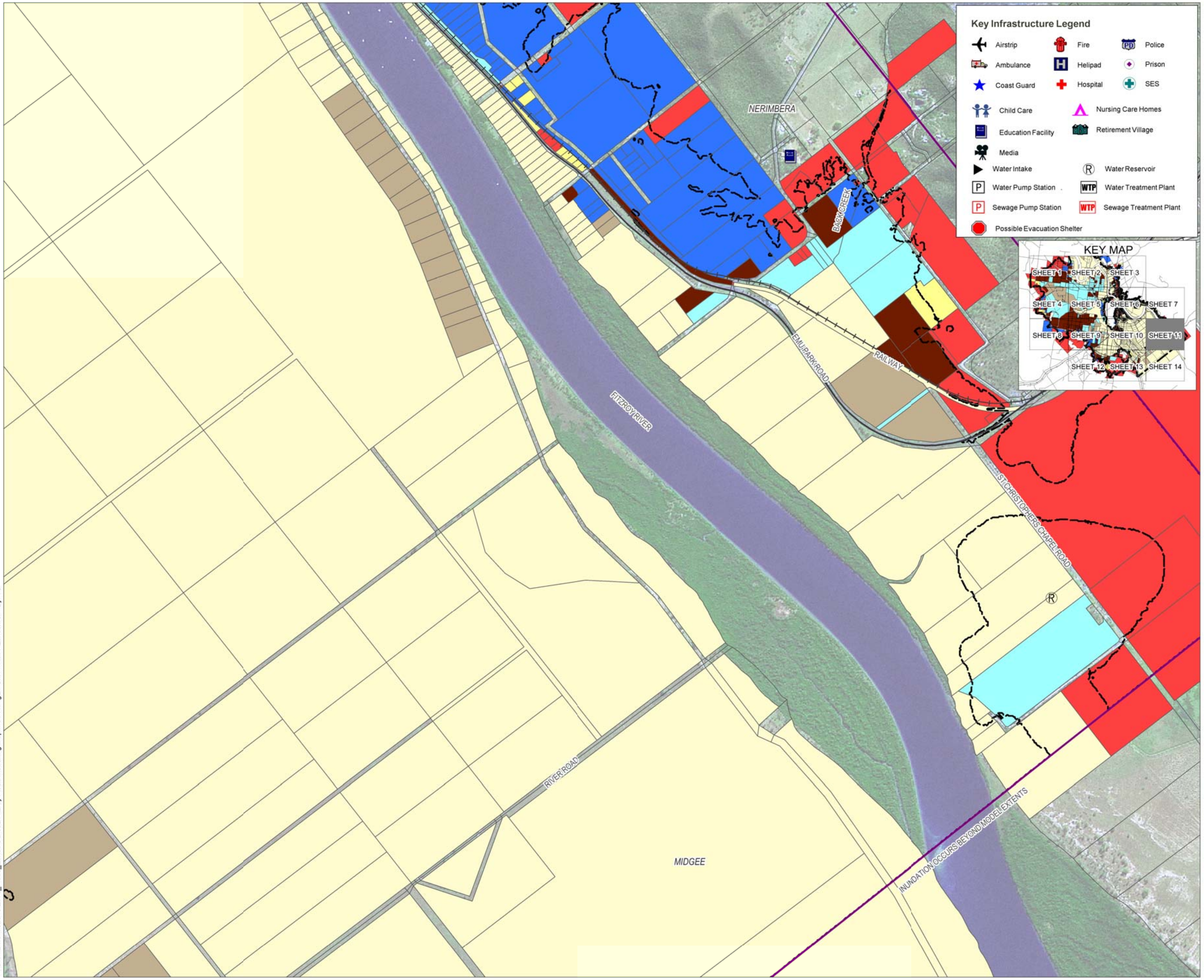
Scale 1:20 000 (m) (@ A3 size)

Projection: MGA Zone 56

Fitzroy River Flood Study

Figure E1 - Sheet 10: Flood Zones

P:\SWM2\work\32513 E070_Flood_Zones CC\002 Fitzroy Flood Modelling\MapInfo\FR-FigE1-Sht11-Rev1-Zones.wor By: TC



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Emergency Management EMQ Queensland

Queensland Government
Department of Emergency Services

Legend

Cadastre

Major Road

Railway Line

TUFLOW Model Extents

Probable Maximum Flood Extent

Flood Zone

Zone 1 - Cream	(<GL7.0)
Zone 2 - Khaki	(GL7.0 - 7.5)
Zone 3 - Cyan	(GL7.5 - 8.0)
Zone 4 - Maroon	(GL8.0 - 8.5)
Zone 5 - Blue	(GL8.5 - 9.0)
Zone 6 - Yellow	(GL9.0 - 9.5)
Zone 7 - Red	(>GL9.5)

Notes:

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4. This mapping shows inundation within the Fitzroy River Flood Study TUFLOW model extents only. Fitzroy River flood inundation continues beyond the upstream and downstream extents of this mapping.
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20 year ARI = 7.23m AHD = 8.68m Gauge Datum
10 year ARI = 6.65m AHD = 8.10m Gauge Datum
5 year ARI = 5.96m AHD = 7.41m Gauge Datum
2 year ARI = 4.20m AHD = 5.65m Gauge Datum

Date: 18/03/2011 Version: 1

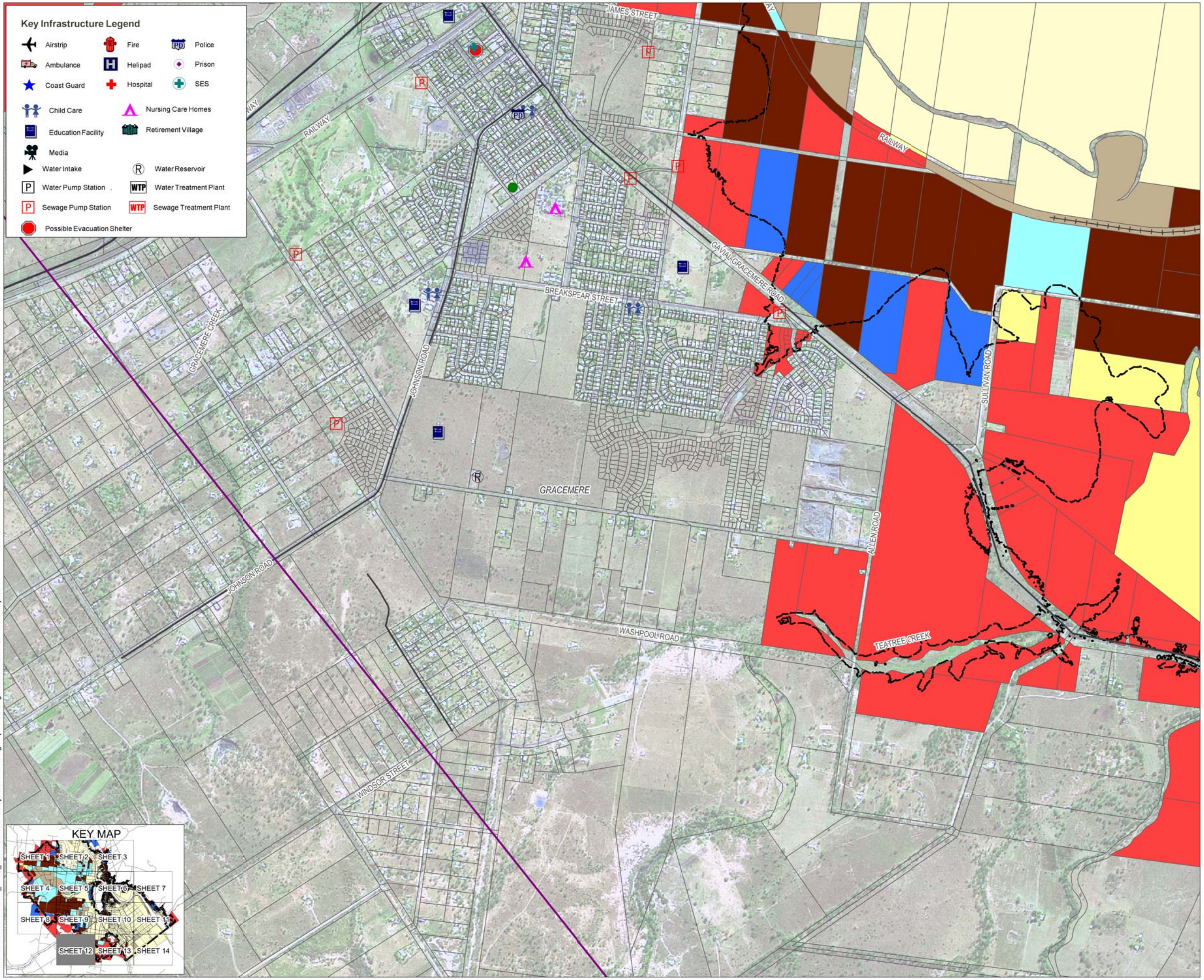
0 1000 (m)

Scale 1:20 000 (m) (@ A3 size)

Projection: MGA Zone 56

Fitzroy River Flood Study

Figure E1 - Sheet 11: Flood Zones



P:\SWM2\work\32513 E070_Flood_Zones CC002 Fitzroy Flood Modelling\Mapinfo\FR-FigE1-Sht12-Rev1-Zones.wor By: TC

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Queensland Government
Department of Emergency Services

Legend

- Cadastre
- Major Road
- Railway Line
- TUFLOW Model Extents
- Probable Maximum Flood Extent

Flood Zone

- Zone 1 - Cream (<GL7.0)
- Zone 2 - Khaki (GL7.0 - 7.5)
- Zone 3 - Cyan (GL7.5 - 8.0)
- Zone 4 - Maroon (GL8.0 - 8.5)
- Zone 5 - Blue (GL8.5 - 9.0)
- Zone 6 - Yellow (GL9.0 - 9.5)
- Zone 7 - Red (>GL9.5)

Notes:

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20 year ARI = 7.23m AHD = 8.68m Gauge Datum
10 year ARI = 6.65m AHD = 8.10m Gauge Datum
5 year ARI = 5.96m AHD = 7.41m Gauge Datum
2 year ARI = 4.20m AHD = 5.65m Gauge Datum

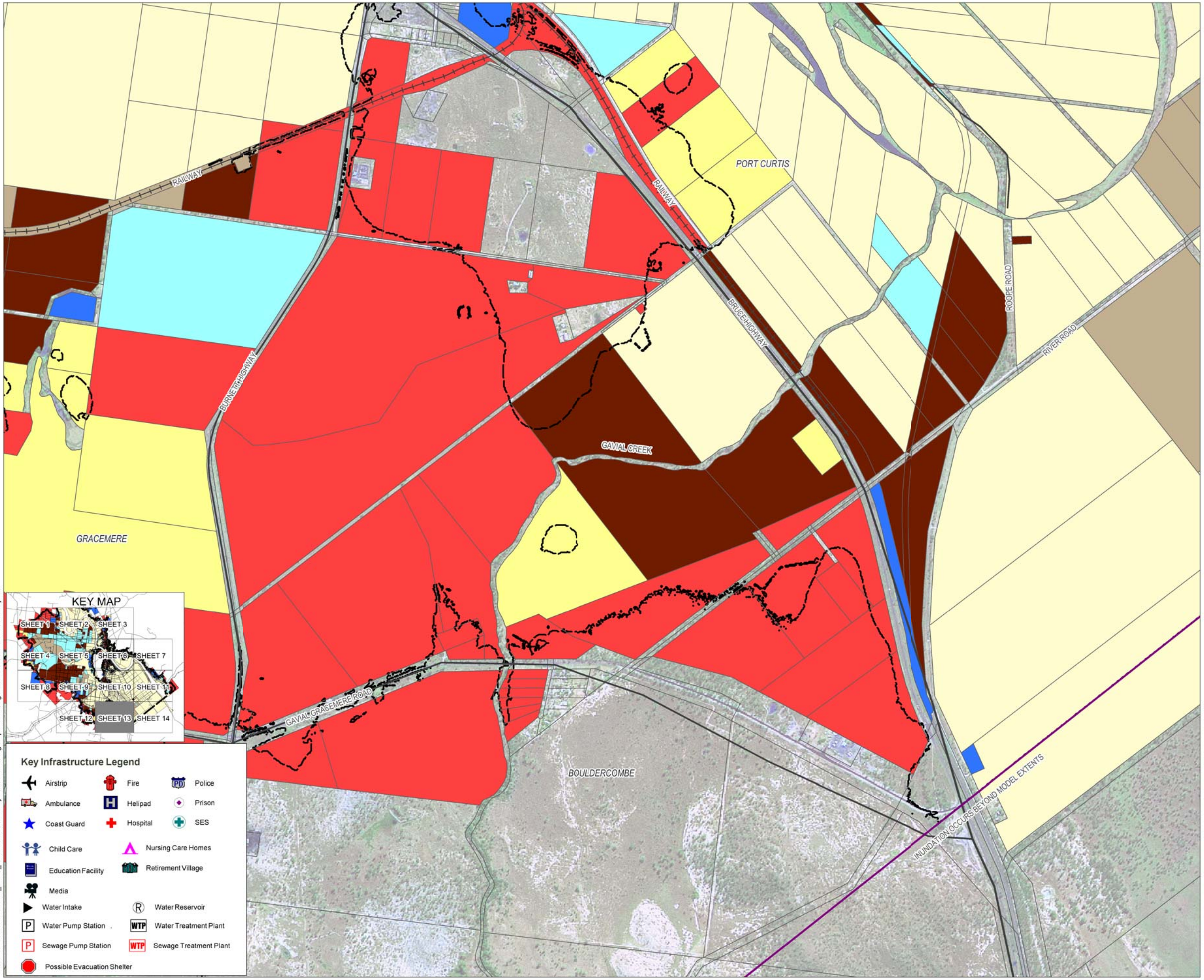
Date: 18/03/2011 Version: 1

0 1000 (m)
Scale 1:20 000 (m) (@ A3 size)

Projection: MGA Zone 56

Fitzroy River Flood Study

Figure E1 - Sheet 12: Flood Zones



P:\SWM2\work\32513 E070_Flood_Zones CC002 Fitzroy Flood Modelling\MapInfo\FR-FigE1-Sht13-Rev1-Zones.wor By: TC

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Queensland Government
Department of Emergency Services

Legend

- Cadastre
- Major Road
- Railway Line
- TUFLOW Model Extents
- Probable Maximum Flood Extent

Flood Zone

- Zone 1 - Cream (<GL7.0)
- Zone 2 - Khaki (GL7.0 - 7.5)
- Zone 3 - Cyan (GL7.5 - 8.0)
- Zone 4 - Maroon (GL8.0 - 8.5)
- Zone 5 - Blue (GL8.5 - 9.0)
- Zone 6 - Yellow (GL9.0 - 9.5)
- Zone 7 - Red (>GL9.5)

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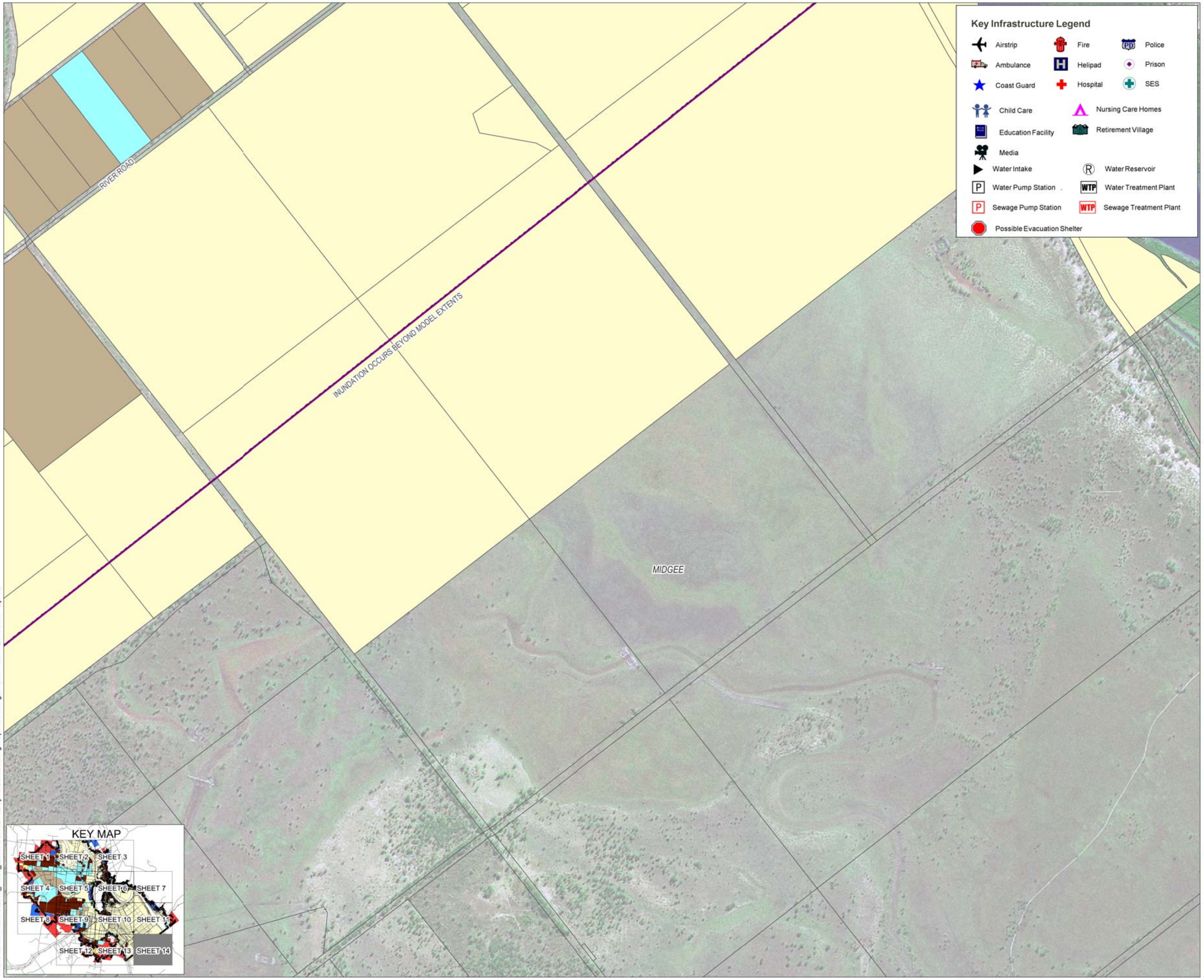
10 year ARI = 6.65m AHD = 8.10m Gauge Datum
5 year ARI = 5.96m AHD = 7.41m Gauge Datum
2 year ARI = 4.20m AHD = 5.65m Gauge Datum

Date: 18/03/2011 Version: 1

0 1000 (m)
Scale 1:20 000 (m) (@ A3 size)
Projection: MGA Zone 56

Fitzroy River Flood Study

Figure E1 - Sheet 13: Flood Zones



P:\SWM2\work\32513 E070_Flood_Zones CC\002 Fitzroy Flood Modelling\MapInfo\FR-FigE1-Sht14-Rev1-Zones.wor By: TC

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Emergency Management EMQ Queensland

Queensland Government
Department of Emergency Services

Legend

- Cadastre
- Major Road
- Railway Line
- TUFLOW Model Extents
- Probable Maximum Flood Extent

Flood Zone

- Zone 1 - Cream (<GL7.0)
- Zone 2 - Khaki (GL7.0 - 7.5)
- Zone 3 - Cyan (GL7.5 - 8.0)
- Zone 4 - Maroon (GL8.0 - 8.5)
- Zone 5 - Blue (GL8.5 - 9.0)
- Zone 6 - Yellow (GL9.0 - 9.5)
- Zone 7 - Red (>GL9.5)

Notes:

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10 year ARI = 6.65m AHD = 8.10m Gauge Datum
5 year ARI = 5.96m AHD = 7.41m Gauge Datum
2 year ARI = 4.20m AHD = 5.65m Gauge Datum

Date: 18/03/2011 Version: 1

0 1000 (m)

Scale 1:20 000 (m) (@ A3 size)

Projection: MGA Zone 56

Fitzroy River Flood Study

Figure E1 - Sheet 14: Flood Zones

Appendix F
Community brochure text

Appendix F – Community brochure text

Floods

Floods occur when water temporarily covers land which is normally dry. They may result from prolonged or very heavy rainfall, severe thunderstorms, monsoonal (wet season) rains in the tropics or tropical cyclones. People who live near rivers or in low-lying coastal areas live with the greatest threat of floods.

Flash flooding results from relatively short, intense bursts of rainfall, often from thunderstorms. It can occur in almost all parts of Australia and poses the greatest threat of loss of life.

The primary effects of flooding are physical damage to property, infrastructure, people or livestock and disruption to regular way-of-life. Floods can be very dangerous and people are often swept away after entering floodwaters on foot or in vehicles. Deciding to remain in your home or business when it is surrounded by floodwaters or when you have over floor flooding can be dangerous. It may become a refuge for vermin, snakes or spiders. There may be no water, sewerage, power, telephone or other services for long periods of time and emergency service personnel may not be able to help you.

Rockhampton flooding

Floods in Rockhampton can occur from flash flooding, local creek flooding or Fitzroy River flooding. This brochure is intended to provide information regarding Fitzroy River flooding.

The Fitzroy River at Rockhampton contains water from the Dawson, Mackenzie, Comet, Nogoa, Connors and Isaac river systems. Rockhampton floods can come from any of these rivers. The Fitzroy River catchment is one of the largest in Australia and floods in Rockhampton can last for weeks.

Since the recording of flood information in Rockhampton began in 1859, many damaging floods have occurred. The last major flood occurred in 2011 (9.20 m). Other recent, but much less severe, floods occurred in 2008 (7.55 m and 7.75 m). Major floods also occurred in 1928 (8.70 m), 1954 (9.40 m) and 1991 (9.30 m). The most significant flood on record occurred in 1918 (10.11 m) and lasted more than six weeks. Every flood behaves differently and it is impossible to know exactly what will occur in a flood.

Rockhampton Regional Council has undertaken a flood study of the Fitzroy River and the area surrounding Rockhampton to identify the potential impact of flooding on the region. This study may provide information in relation to the risk of flooding in your area. Information is available from Rockhampton Regional Council Customer Service on 1300 22 55 77 or via Council's website www.rockhamptonregion.qld.gov.au.

Flood behaviour

The following description of the way floods behave in Rockhampton is typical for all floods. It is important to note that the levels at which inundation occurs can vary from flood to flood based upon many factors (previous drought/flooding, rainfall intensity and duration etc).

Floods start at The Common and in Port Curtis where water breaks out of the River. Floodwaters travel back up Gavial Creek into Yeppen and parts of Fairy Bower. Floodwaters also start to travel back up Lion Creek. At approximately 7.8 m at the gauge, floodwaters break out at Pink Lily, join with floodwaters in Lion Creek and travel around the western side of the Airport to join floodwaters at Yeppen.

At approximately 8.0 m at the gauge the Capricorn Highway is inundated at Fairy Bower. By 8.5 m most of Pink Lily, Fairy Bower and Port Curtis are inundated. At approximately 8.6 m the Bruce Highway, Railway and Airport are all inundated. At 9.0 m many of the lower areas on the eastern side of the river are inundated (eg lower parts of Kawana, Park Avenue, Berserker, Koongal, Lakes Creek and Nerimbera).

Flood zones

As part of the above flood study, Council has adopted a system of flood zones. All properties which have the potential to be fully or partially inundated by Fitzroy River flooding have been assigned a zone. These zones identify the likely gauge level at which a property starts to be inundated. This is determined by the ground levels of the properties, not by the floor levels.

A series of maps have been prepared to show which flood zone each property sits in. It is important to know the zone your property is in and we encourage you to view these maps via Councils website (www.rockhamptonregion.qld.gov.au) or contacting Council Customer Service on 1300 22 55 77.

Flood warning

Flood warnings for the Rockhampton area, are issued by the Bureau of Meteorology (BoM) based on the likely flood level at the Rockhampton flood gauge.

If the level is predicted to be above 7.0 m warnings are issued to the Local Disaster Management Group and to local radio stations. The Bureau aims to provide at least 60 hours warning for flood heights above 7.0 m and the forecasts are updated at least once each day.

To communicate the severity of flooding to emergency managers, local governments, other agencies and the community, a simple classification of severity levels has been devised.

Minor flooding

Causes inconvenience. Low-lying areas next to watercourses are inundated which may require the removal of stock and equipment. Minor roads may be closed and low-level bridges submerged.

Moderate flooding

In addition to the above, the evacuation of some houses may be required. Main traffic routes may be covered. The area of inundation is substantial in rural areas requiring the removal of stock.

Major flooding

In addition to the above, extensive rural areas and/or urban areas are inundated. Properties and towns are likely to be isolated and major traffic routes likely to be closed. Evacuation of people from flood affected areas may be required.

If necessary, Council's Local Disaster Management Group will provide local information to the media and the community. This information will include the flood zones likely to be affected and estimations of expected flood behaviour including which key roads may be cut.

What to do in a flood

In order to be adequately prepared, individuals need to be aware of the risk of flooding to their environment.

Individuals are responsible for their own safety and as such should:

- Be aware of the risk of flooding where they live (eg on a floodplain, close to a river, creek, lake or sea, in low lying areas that are easily inundated; or in floodways and flood paths where water velocities may be high)
- Ensure that their properties and structures are adequately maintained as poorly maintained structures are more susceptible to direct flood damage, including structural failures
- Be aware of the meaning of flood warning systems and flood categories in place for their area
- Prepare a Household Emergency Plan

If flooding is predicted

- Listen to your radio (ABC Capricornia 83.7AM or your normal radio station) for updates and advice
- Heed all warnings and advice
- Move as many household items as possible (including cardboard boxes and newspaper items) to the highest point possible
- Pile furniture on beds, benches or tables and place personal and electrical items on top. Remove all drawers from built-ins
- Secure loose items in your yard to prevent them floating away
- Protect items of value that cannot be removed by enclosing them in waterproof covers or coating them in grease for protection
- Relocate waste containers, chemicals and poisons to the highest point possible and ensure all chemicals that may react with water are within a waterproof container
- Gas cylinders and gas bottles should be disconnected and tied down or removed above flood height
- Close the main water valve
- If driving be sure of the depth of water before driving through them. Remember that cars float even in very shallow depths of water
- Be prepared to evacuate immediately if you are advised to do so

If flooding occurs

- Collect your emergency kit and listen to the radio
- Switch off electricity and gas if you leave home
- Don’t drink floodwaters
- Avoid entering floodwaters on foot or in a vehicle. Water may be deeper or faster flowing than you think and contain hidden snags or debris
- Do not attempt to cross a flowing stream if water is above your knees

After the flood

- If you had to evacuate don’t return home until advised, then use the route recommended
- Don’t eat food which has been in contact with floodwaters. Boil all tap water until supplies have been declared safe
- Do not use gas or electrical appliances which have been flood affected until they have been checked by qualified personnel
- Beware of vermin, snakes and spiders which may have taken refuge in your home or business
- Avoid wading, even in shallow water, as it may be contaminated
- If you must enter floodwater wear solid shoes and check the depth with a stick
- Check with the police for safe routes before driving anywhere

Household emergency plan

It’s important to plan ahead and be prepared so that during an emergency you and your household know what to do, where to go, how to keep in touch with each other and how to contact emergency services as required.

Information on how to develop a household emergency plan is available on the web at www.emergency.qld.gov.au

Develop your emergency plan with as many household members as possible, to ensure everyone understands the risks and appropriate actions to take in an emergency. Once completed, make copies of your Emergency Plan for:

- Your household members
- Your family, friends and neighbours
- Display on the fridge or notice board
- Your Emergency Kit

Critical gauge levels

Zone 1 < 7.0	• Riverside car parks are inundated	5.5
	Minor flood level	**7.0**
Zone 2 7.0 – 7.5	• The Common is almost completely inundated • Low-lying areas of Port Curtis, Depot Hill, Fairybower and Gracemere are inundated • Lakes Creek Road is inundated	7.0
	Moderate flood level	**7.5**
Zone 3 7.5 – 8.0	• Depot Hill is almost isolated	7.5
	2008 Flood Peak	7.75
	• Pink Lily breakout occurs	7.9
Zone 4 8.0 – 8.5	• Depot Hill is isolated • Port Curtis is almost completely inundated • Ridgelands Road is inundated Inundation occurs in: • Western Pink Lily • Low-lying parts of Berserker • Koongal between Frenchmans Creek and Thozet Creek	8.0
	1988 Flood Peak	8.4
	Major flood level	**8.5**
Zone 5 8.5 – 9.0	Inundation occurs in • Most of Fairy Bower and Pink Lily • Berserker, between Rodboro Street and Lakes Creek Road • Low-lying parts of Allenstown • The upper end of Splitters Creek in Kawana	8.5
	• Airport is closed	8.7
	• Bruce Highway and Railway are cut	8.8
Zone 6 9.0 – 9.5	• Only the higher eastern parts of Pink Lily remain dry Inundation occurs in • Lakes Creek to the west of the railway • Nerimbera near Black Creek • Western Park Avenue • The lower parts of the City • Most of the area between Splitters Creek and the Fitzroy River in Kawana	9.0
	2011 Flood Peak	9.2
	1991 Flood Peak	9.3
	1954 Flood Peak	9.4
Zone 7 > 9.5	• Pink Lily is almost completely inundated Inundation spreads into • West Rockhampton • The lower parts of the City	9.5
	1918 Flood Peak	10.11

Appendix G
Example flood affected area codes

Part 7 Codes
Division 3 Constraint Codes
Chapter 8 Flood Affected Areas

1.0 Purpose

To ensure that, where premises within flood affected areas are to be developed, adequate measures are taken to:

- ensure that the development does not cause, or have the cumulative potential to cause, real damage (as defined below);
- provide standards for development in these areas that will ensure that the runoff from land and/or premises does not create any adverse environmental impacts.

Key objectives include:

a) avoiding, if practicable, or otherwise lessening, the adverse impacts of flooding;

b) maintaining or improving the City's counter disaster response efforts during a flood emergency;

c) equitably sharing development constraints and development potential within a single river catchment and its sub catchments;

d) equitably sharing the costs and benefits of flood mitigation infrastructure within a river catchment and its sub-catchments;

e) protecting the flood storage function of the City's flood plains;

f) protecting the flood discharge capacity of the City's rivers, streams and canals;

g) achieving and maintaining a best practice approach to flood plain management;

h) protecting ocean beaches and the shores and banks of estuaries, lakes, canals, rivers, streams and other waterbodies from erosion.

This code seeks to manage the effects of flooding on flood prone land, where it relates to new and existing development, infrastructure and ecosystems, by requiring:

- certified engineering hydraulic management plans or studies;
- specific design criteria for certain types of land uses.

All such proposals for development will be fully evaluated against the following criteria:

- real damage: whether the development is likely to cause damage that would adversely affect land and/or premises to an extent likely to be actionable;
- cumulative impact: whether the cumulative impact of development is likely to cause real damage;
- flood hazard: whether the development is likely to cause or worsen flood hazard;
- risks: whether the risks associated with the development are fully known, quantifiable and capable of being dealt with to Council's satisfaction, without any uncertainties; and
- flood mitigation: whether flood mitigation works, intended to reduce flood risk, hazard and damage, do so without adversely impacting upon other land and/or premises.

2.0 Application

2.1 This code applies to development that is indicated as self, code or impact assessable in the Table of Development to the domain or Local Area Plan (LAP) within which the development is proposed. In particular, this code applies to any site that is located within a Flood Affected Area*, defined as follows:

- flood prone land; or
- premises where access would be adversely affected during a range of floods, up to and including the designated flood.

*Refer to **Overlay Map OM17 – Natural Hazard (Flood) Management Areas** sheets 1-35.

2.2 This code does not apply to Class 1 or Class 10 buildings as defined in the **Building Code of Australia**, except where Council has declared an area to be flood liable under **Section 53** of the **Queensland Building Regulations**. However, this code provides recommendations for minimum floor levels for Class 1 and Class 10 buildings within flood prone land.

2.3 Note that where Operational Work is being undertaken within flood affected areas that results in a disturbance to the surface of the land, **Specific Development Code 11 – Changes to Ground Level and Creation of New Waterbodies** and **Constraint Code 14 – Sediment and Erosion Control** are also relevant.

2.4 Performance Criteria PC1-PC14 apply to all code and impact assessable development subject to this code. For development identified as self assessable in the relevant domain or LAP, only the acceptable solutions to Performance Criteria PC1-PC4 apply.

3.0 Development Requirements

Performance Criteria	Acceptable Solutions
Development that is Self Assessable, Code Assessable or Impact Assessable	
Flood Storage	
PC1 All development activity conducted on land below the designated flood level must not detrimentally affect the flood storage capacity of the catchment and the drainage regime.	AS1 The flood storage volume on the site is maintained up to the Designated Flood Level. ***Note:*** ***The Designated Flood Level can be obtained from Council's Flood Search.***
Building Floor Levels	
PC2 Building floor levels of habitable rooms must be raised to provide an allowance for the hydraulic gradient above the main floodway, so as to meet the requirements of the Standard Building Regulation and **Building Code of Australia**. ***Note:*** ***Performance criteria for setting building floor levels are set out in the Standard Building Regulation and Building Code of Australia. However, it should be noted that Designated Flood Levels provided by Council relate to mainstream flood flow paths and do not include allowances for the hydraulic gradients from residential areas to the main floodway.***	AS2.1.1 An allowance of at least 300mm is added to the Designated Flood Level for habitable rooms, or other allowance amount specified in a Local Area Plan. OR AS2.1.2 Damaged residential buildings are reconstructed to have a Design Floor Level at or above the level that existed prior to the building's damage, provided that the building work is limited to reinstatement. AS2.2 Where the building has been destroyed by flood, the reconstructed floor level accords with **AS2.1.1**.
PC3 Building floor levels of garages and non habitable rooms must be constructed at a height that reflects an acceptable flood risk for their purpose. ***Note:*** ***PC3 does not apply to:*** a) ***extensions to existing buildings;*** b) ***structures detached from a dwelling, for which the use is ancillary to that of a dwelling, provided that use is not listed in column 1 of Table to Acceptable Solution AS7.1.***	AS3.1 Building floor levels of garages and non habitable rooms, constructed at approximately the same level as, and attached to, the main dwelling, is constructed at a height above the Designated Flood Level, except where the dwelling has a suspended floor, constructed one metre or more above ground, or where the building is to be constructed within a Rural Domain. AS3.2 Non-habitable rooms and garages, detached from the fabric but within the curtilage of a building, that are not for the storage of goods are constructed above or below the Designated Flood Level.
Overland Flow	
PC4 Building work must not provide obstructions to the free passage of stormwater through a property.	AS4 Overland flowing stormwater is allowed free passage between the street and any waterway at the rear of the property, in accordance with the provisions of the **Building Code of Australia**.

Performance Criteria	Acceptable Solutions
Development that is Code Assessable or Impact Assessable	
Flooding Risk	
PC5 Development in flood affected areas must not cause, or have the cumulative potential to cause, real damage, must not increase the level of risk to life, or be to the detriment of flood evacuation procedures.	AS5 Development does not: a) increase the number of people calculated to be at risk from flooding; b) increase the number of people likely to need evacuation; c) shorten flood warning times; d) impact on the ability of traffic to use evacuation routes, or unreasonably increase traffic volumes on evacuation routes, or as identified within Council's Counter Disaster Plan (flooding); e) place additional burdens on Council's resources or emergency services; f) increase the duration of flooding, unless that increase is part of a Council approved flood mitigation strategy.
Flood Storage and Conveyance	
PC6 Development with plans for earthworks in a floodplain on or over a water body or within a flood affected area below the Designated Flood Level must allow for the maintenance of flood storage, and flood conveyance of flood and drainage channels and overland flow paths.	AS6.1 Provide flood storage calculations that demonstrate that flood storage volume, over the site below the Designated Flood Level, is maintained or increased. AS6.2 A certified hydraulic study (and, if necessary, a hydrologic study) is prepared by a suitably qualified and experienced engineer to investigate the hydraulic characteristics of both the undeveloped and developed site and make comparisons between them. Proposed developments in, on or over a water body, or within a flood affected area, must be tested for: a) the 50%, 20%, 10%, 5%, 2% and 1% Annual Exceedance Probability (AEP) for local flood events; b) the 5%, 2%, and 1% AEP floods and the designated flood and design flood AEP (as specified in **Table to Acceptable Solution AS7.1**) for riverine flood events, c) any resultant afflux or increase in flood velocities sufficient to cause real damage to premises. The Assessment Manager may also require the development to be assessed against rarer floods. AS6.3 The Assessment Manager may decide that a hydraulic and/or hydrological study is not necessary if in the Assessment Manager's opinion: a) a relevant study, that is not outdated, demonstrates there are no significant flooding impacts that were not covered in the relevant study; or b) the flooding impact of the approval, in relation to the development, is minor, c) in which event the Assessment Manager must provide a written notice to that effect to the applicant.

Performance Criteria	Acceptable Solutions
Development for Certain Purposes	
PC7 Development listed in **Table to Acceptable Solution AS7.1** must allow for flood events and be constructed at a level above most floods.	AS7.1 Development is designed for the Design Flood AEP, as specified in **Table to Acceptable Solution AS7.1**. ***Note:*** ***The designated flood level for residential buildings in general is a 1% flood level except for:*** a) ***Broadwater – the 1% AEP storm surge level, plus an allowance of 0.27 metres, to account for sea level rise resulting from climate change;*** b) ***Logan and Albert Rivers – the designated flood is based, in part, on rainfall that occurred during the January 1974 flood and assumptions made regarding the ultimate level of development, in accordance with the relevant local planning instruments; and*** c) ***Historical flood level is the only information available to be specified designated flood level.*** AS7.2 Development is constructed at or above the Design Flood Reclamation Level, shown in the **Table to Acceptable Solution AS7.1**, where the Designated Flood is the 1% AEP flood event, except as follows: a) Broadwater: the 1% AEP storm surge level, plus an allowance of 0.27 metres, to account for sea level rise resulting from climate change; b) Logan and Albert Rivers: the designated flood is based, in part, on rainfall that occurred during the January 1974 flood and assumptions made regarding the ultimate level of development, in accordance with the relevant local planning instruments; and c) Coomera River: the designated flood is based on the modelled 1% AEP flood event or historic levels, whichever is the higher.
PC8 Development must consider hydrologic and hydraulic impacts of development in flood affected areas with regard to future climate change.	AS8 No acceptable solution provided. ***Note:*** ***As part of a Hydrologic and hydraulic impact assessment, investigation has been undertaken to determine the impacts of future climate change. The findings of the investigation may be used to modify modelling parameters and boundary conditions used in modelling the hydrologic and hydraulic impacts of development in flood affected areas.***

Table to Acceptable Solution AS7.1

Land Use	Design Flood
Disaster management facilities	0.2% AEP
Hospitals	0.2% AEP
Major electrical switchyards, power stations, water treatment plants	0.2% AEP
Fire/police stations	0.5% AEP
Places of refuge	0.5% AEP
Electricity substations	0.5% AEP
Sewage treatment plants	0.5% AEP

Land Use	Design Flood
Homes for the aged, hospice	0.5% AEP
Regional fuel storage	0.5% AEP
Food storage warehouses	0.5% AEP
Hotel residential	Designated flood
Educational facilities	Designated flood
Residential buildings	Designated flood
Camping grounds, caravan parks and relocatable homes reclamation levels	Designated flood
Commercial	Designated flood
Light industrial/warehousing	Designated flood
Theme parks	Not specified, but users should not be subjected to any more than high hazard conditions in the designated flood, as specified in **AS10.1**
Clubs/non-habitable buildings associated with enjoyment of public open space	Not specified, but users should not be subjected to any more than high hazard conditions in the designated flood, as specified in **AS10.1**
Car parking below buildings	Not specified, but users should not be subjected to any more than high hazard conditions in the designated flood, as specified in **AS10.1**
Open space	Not specified, but ancillary structures are subject to appropriate hazard conditions in the designated flood, as specified in **AS10.1**
Rural	Not specified

Performance Criteria	Acceptable Solutions
Hazard Considerations for Development	
PC9 Development listed in the **Table to Acceptable Solution AS9** below must be designed and constructed to avoid causing exposure to undue flood hazard.	AS9 Development is to be designed and constructed so that users are not exposed to a greater degree of hazard than shown in **Table to Acceptable Solution AS9** for the range of flows specified in **AS7.1**.

Table to Acceptable Solution AS9

Land-Use	Appropriate Degree of Hazard				
	Nil	Low	Medium	High	Extreme
Public open space/recreation	✓	✓	✓	✓	✓
Theme parks	✓	✓	✓	✓	
Clubs/non-habitable buildings associated with enjoyment of public open space	✓	✓	✓	✓	
Commercial/industrial	✓	✓	✓		
Residential	✓	✓	✓		
Public institutions	✓	✓	✓		
Car parking below buildings	✓	✓	✓	✓	
Caravan parks	✓	✓	✓		
Council offices	✓	✓			
Schools	✓	✓			
Homes for the elderly	✓	✓			
Hospitals	✓	✓			
SES	✓	✓			
Police/fire stations	✓	✓			
Museums/libraries/archives/ infrastructure plan repositories	✓				
Telephone exchanges	✓				

Note: ✓ ***Indicates an appropriate land use.***

The above table examines the appropriateness of land use decisions from the aspect of flood hazard only. As such, it does not confer any land use rights or provide any indication that Council will reject or favourably consider various uses in particular areas. Such consideration will be dealt with appropriately, in the context of the Planning Scheme, and based upon full consideration of all relevant issues.

Performance Criteria	Acceptable Solutions
Access Criteria with Respect to Hazard	
PC10 All proposed development must demonstrate that sufficient access or egress will be available to enable evacuation during a range of floods, up to and including the designated flood.	AS10.1 Development, not including underground car parks, must ensure that evacuation opportunities exist in accordance with the minimum levels of exposure outlined in **Table to Acceptable Solution AS10.1**, where means of access or egress may be: a) an access route that is below the level of the designated flood, provided that route is classed as a low hazard, as defined in **Table to Acceptable Solution AS10.1**; or b) an access route that is not the main access route. However, it must remain effective for the duration of a range of flood events, up to and including the designated flood; or c) a temporary access arrangement, provided that access can be gained without significant preparation time being required; The access or egress must: a) in the event of a designated flood: ▪ not expose users to undue risk; ▪ not cause, or have the cumulative potential to cause, real damage to land and/or premises; ▪ not interrupt or materially change the surface water drainage from or onto adjoining land; b) not create, in the event of a flood, a sudden change in flow distributions, flood level or velocity that could result in: ▪ the breaking of a levee; or ▪ the establishment of blockage of a breakout; or ▪ excessive scour; or ▪ sedimentation; or ▪ increased flood hazard.

Table to Acceptable Solution AS10.1

Criteria	Degree of Flood Hazard			
	Low	**Medium**	**High**	**Extreme**
Wading ability	If necessary children and the elderly could wade. (Generally, safe wading velocity depth product is less than 0.25.)	Fit adults can wade. (Generally, safe wading velocity depth product is less than 0.4.)	Fit adults would have difficulty wading. (Generally, where wading velocity depth product is less than 0.6.)	Wading is not an option.
Evacuation distances	< 200 metres	200 – 400 metres	400 – 600 metres	> 600 metres
Maximum flood depths	< 0.3 metres	< 0.6 metres	< 1.2 metres	> 1.2 metres
Maximum flood velocity	< 0.4 metres per second	< 0.8 metres	< 1.5 metres	> 1.5 metres
Typical means of egress	Sedan	Sedan early, but 4WD or trucks later	4WD or trucks only in early stages, boats or helicopters	Large trucks, boats or helicopters
Timing **Note: This category cannot be implemented until evacuation times have been established in the Counter Disaster Plan (flooding).**	Ample for flood forecasting. Warning and evacuation routes remain passable for twice as long as evacuation time.	Evacuation routes remain trafficable for 1.5 times as long as the evacuation time.	Evacuation routes remain trafficable for only up to minimum evacuation time.	There is insufficient evacuation time.

Note: ***The evacuation times for various facilities or areas would (but not necessarily) be included in the Counter Disaster Plan (flooding).***

Generally, safe wading conditions assume even walking surfaces with no obstructions, steps, soft underfoot, etc.

<table>
<tr><th>Performance Criteria</th><th>Acceptable Solutions</th></tr>
<tr><td colspan="2">Filling, Excavation and Contouring</td></tr>
<tr><td>PC11
Any change to ground level, by way of filling, excavation or contouring, must not result in real damage, flood hazard or impediment to any Counter Disaster Plan, measure or create unreasonable change in the exposure to flood hazard.</td><td>AS11.1.1
Changes to ground level, by way of filling, excavating or contouring, comply with a hydraulic master plan approved by Council.
OR
AS11.1.2
A flood study is prepared in accordance with the requirements set out in AS6.1 and AS6.2, is approved by Council, and it is established that the development complies with, or does not impede, any Counter Disaster Plan measure.</td></tr>
<tr><td>PC12
Filling, excavation or contouring must not cause sedimentation, erosion or adverse impact on the City's drainage network.</td><td>AS12
No acceptable solution provided. For guidance, please refer to Constraint Code 14 – Sediment and Erosion Control.</td></tr>
<tr><td colspan="2">Landscaping</td></tr>
<tr><td>PC13
Landscaping must not impede a natural watercourse, a flood channel or an overland flow path.</td><td>AS13.1.1
Landscaping complies with a hydraulics master plan approved by Council.
OR
AS13.1.2
A flood study, allowing for the landscaping, is prepared in accordance with the requirements of AS6.2, and is approved by the Assessment Manager.</td></tr>
<tr><td colspan="2">Building Floor Levels</td></tr>
<tr><td>PC14
Buildings that are to be constructed on flood prone land shall not be inundated by floodwaters during a designated flood event.</td><td>AS14.1
Development is constructed at or above the Specified Minimum Flood AEP plus the Minimum Design Freeboard, as set out in column 2 of the Table to Acceptable Solution AS14.1.
AS14.2
Where a proposed land use does not reasonable apply to any land use listed in the Table to Acceptable Solution AS14.1, the applicant is to submit:
a) the proposed minimum flood AEP for building floor levels;
b) the proposed design freeboard above the specified flood level; and
c) a flood hazard and flood risk assessment for the proposed development, assessing the effects on costs, safety, access and potential losses.
AS14.3
It is noted that PC14 does not apply to:
a) garages below residential buildings;
b) garages below commercial premises; and
c) garages below industrial premises, provided there are suitable means to restrict motor vehicles being washed away during a flood event.</td></tr>
</table>

Table to Acceptable Solution 14.1

Land Use	Specified Minimum Flood AEP Plus Minimum Design Freeboard
Disaster management facilities	0.2% AEP + 500mm
Hospitals	0.2% AEP + 500mm
Major electrical switchyards, Power stations, Water treatment plants[1]	0.2% AEP + 500mm
Fire and Police stations[2]	0.5% AEP + 400mm
Places of refuge	0.5% AEP + 400mm
Electricity Substations[1]	0.5% AEP + 400mm
Sewage Treatment Plants[3]	0.5% AEP + 400mm
Homes for the aged, Hospice[4]	0.5% AEP + 400mm
Regional fuel storage	0.5% AEP + 400mm
Food storage warehouses	0.5% AEP + 400mm
Hotel residential	Designated flood + 300mm
Educational facilities[5]	Designated flood + 300mm
Residential buildings	Designated flood + 300mm
Camping grounds, Caravan parks and Relocatable homes reclamation levels	Designated flood + 300mm
Commercial[6]	Designated flood
Light Industrial / Warehousing[6]	Designated flood
Theme Parks	Not specified, but ancillary structures are subject to medium hazard considerations at the designated flood.
Clubs/ Non-habitable buildings associated with enjoyment of public open space	Not specified, but ancillary structures are subject to medium hazard considerations at the designated flood.
Car parking below buildings	Not specified, but ancillary structures are subject to medium hazard considerations at the designated flood.
Open space	Not specified, but ancillary structures are subject to appropriate hazard considerations at the designated flood.
Rural	Not specified

Note: ***AEP is the Annual Accedence Probability***

Notes for Table of AS14.1

1. ***Applies to switchyard components necessary for the operation of the facility during a flood emergency. This shall be determined by Powerlink.***
2. ***Excludes 'shop front' facilities and those not likely to be utilised during a flood emergency.***
3. ***Specifically, bunds, electrical and mechanical equipment necessary for the continued operation of a sewage treatment plant shall not be at risk of inundation during a flood emergency.***
4. ***The flood immunity specified is to meet the objective of not adding to the burden of flood emergency services.***
5. ***It is not necessary that all rooms within an education facility be above the 1% AEP level. However, there should be sufficient space to accommodate the whole of the school population during a flood event.***
6. ***Freeboard is not specified, as it is considered that commercial risk provisions should apply. If such land is developed to a flood immunity less than 1% AEP (as may be permitted by any local planning instrument), Council may endorse rates notices accordingly.***

Increasing Queensland's resilience to inland flooding in a changing climate:

Policy options for incorporating climate change into the flood risk management framework in Gaydah (North Burnett Regional Council)

A joint project of:

Department of Environment and Resource Management

Department of Infrastructure and Planning

Local Government Association of Queensland

Prepared by:

Department of Environment and Resource Management

Department of Infrastructure and Planning

Local Government Association of Queensland

November 2010

#29528

Contents

Background

In response to advice requested by the Local Government Association of Queensland (LGAQ), the Minister for Climate Change and Sustainability and the Minister for Planning and Infrastructure jointly established the State Government/LGAQ Inland Flooding Study. The purpose of the Inland Flooding Study was to deliver:

1. An improved methodology for assessing inland flooding risk that considers how to take account of climate change.
2. Specific policy options for improved flood risk management in the case study area, namely the Gayndah township in the North Burnett Regional Council (NBRC).
3. General policy options for consideration as part of the review of State Planning Policy 1/03 Mitigating the Adverse Impacts of Flood, Bushfire and Landslide (SPP 1/03).

This paper addresses the second deliverable above and provides recommended policy options to improve flood risk management in Gayndah township for consideration by the NBRC.

Context

SPP 1/03 is intended to ensure that flooding is adequately considered when making decisions about development.

SPP 1/03 does not provide detailed guidance to assist local governments incorporate climate change science and potential impacts into their planning schemes.

The proposed planning policy options and associated constraint code presented in this document are intended to provide interim options and guidance for the Gayndah area for consideration by NBRC. Although the outcomes of the study are specific to Gayndah, this case study and its recommendations will be of interest to other local governments in Queensland. The recommended options align with SPP 1/03 to the fullest extent possible. Any measures that NBRC adopts outside of the SPP 1/03 may leave them liable to litigation.

The Queensland Climate Change Centre of Excellence (QCCCE) has developed a climate change factor for increased rainfall intensity for incorporation into flood studies. This approach provides guidance to local governments on a benchmark for factoring climate change considerations into flooding risk assessments, specifically a five per cent increase in potential rainfall intensity per degree of global warming.

This climate change factor has been developed using the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4) high (A1FI) greenhouse gas emissions scenario. The A1FI scenario assumes continued dependence on fossil fuels. This emissions scenario is recommended by the Queensland Office of Climate Change as the most appropriate scenario for land use planning as current global emissions are tracking at this level. Revised global emissions scenarios will be provided in the release of the IPCC Fifth Assessment Report in 2013. Any implications of changes to global emission scenarios on rainfall intensity and flooding impacts will be considered as part of the Australian Rainfall and Runoff review due to be released in 2014.

Overlay maps and planning horizons

It is recommended that overlay maps for flood affected areas are identified in the NBRC planning scheme consistent with the Queensland Planning Provision.

Two options are presented below to provide different means of incorporating the potential impacts of climate change into Gayndah's flood risk management framework. These options are intended to provide planners with transitionary arrangements while the SPP 1/03 is being reviewed.

The proposed policy options enable development to be conditioned differently depending on whether or not there is a development commitment in place.

For proposals already subject to a development commitment, conditions will ensure that development is subject to stringent design and evacuation standards. To achieve this, development either has to be consistent with appropriate land uses for specific flood hazard areas, or development must be designed and constructed to appropriate flood level and height of habitable rooms. In addition, evacuation routes must be maintained to specific flood levels.

For land that is not already subject to a development commitment, the policy options are intended to steer development to areas of lowest flood risk based on the proposed land use by requiring that new development be built above specific flood levels, and that evacuation routes must also be maintained to specific flood levels.

Two policy options are being provided for Gayndah, recognising that there is more than one pathway for considering climate change in the NBRC planning scheme.

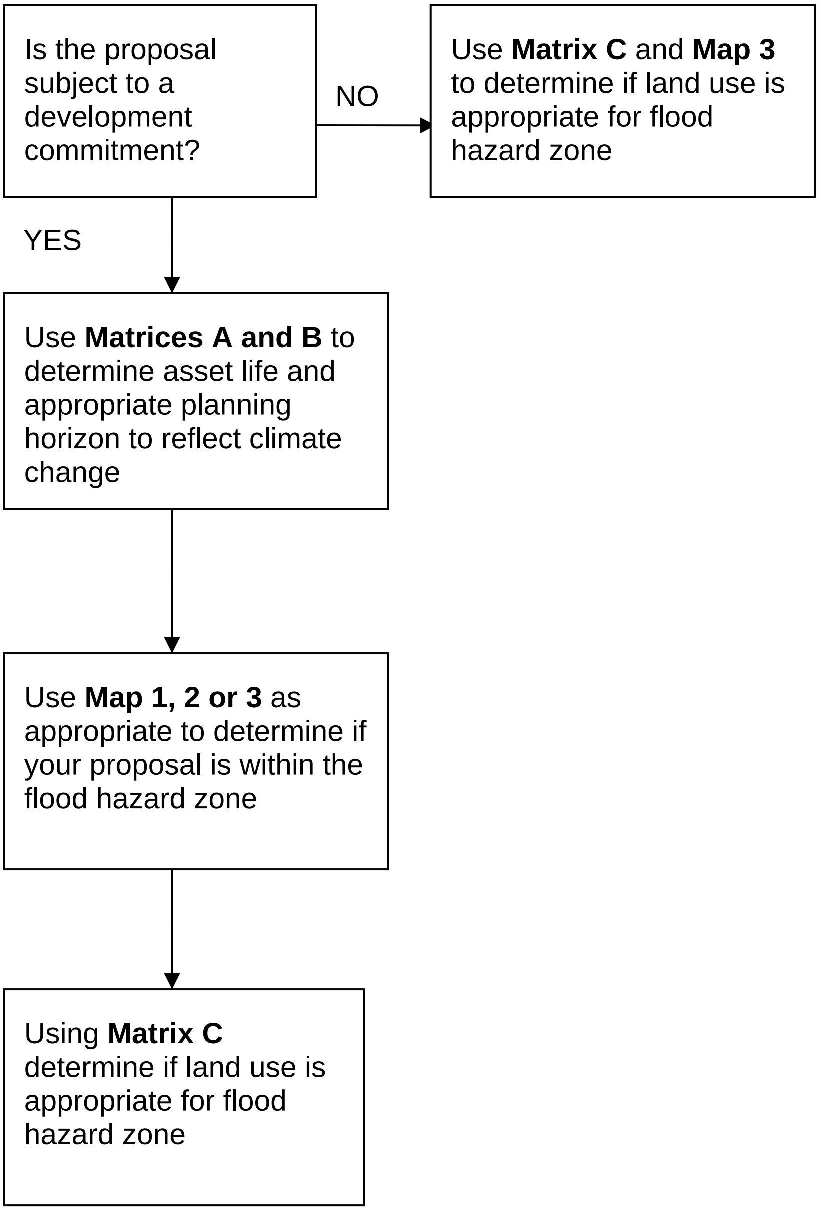
Option 1: New flood maps incorporating climate change in 2050, 2070 and 2100

Option 1 is based on four hazard areas mapped to incorporate the climate change factor[1] over three planning horizons: 2050, 2070 and 2100. Development is constrained based on the anticipated asset life of the development.

	Proposals not subject to a development commitment **(non urban or non-specific urban zone, e.g. future urban)**	**Proposals subject to a development commitment** **(existing urban zone)**
Maps	Use map 3 (where flood levels incorporate climate change for the 2100 planning horizon).	Consider development against appropriate planning horizon based on anticipated asset life (see Matrix A and B below). Use maps 1, 2 and 3 (where flood levels incorporate climate change for 2050, 2070 and 2100).
Outcomes	Development is steered to areas of lowest flood hazard based on land use (i.e. residential, commercial, industrial above 1% AEP + cc factor and community infrastructure above 0.5% AEP or 0.2% AEP as appropriate).	Development approval subject to stringent design and evacuation standards.
Acceptable solutions	Development is consistent with appropriate land uses for flood hazard areas based on climate in 2100 (see Matrix C below) AND Evacuation routes are maintained (e.g. situated above flood levels).	Development is consistent with appropriate land uses for flood hazard areas (see Matrix C below) OR Development is constrained through construction to appropriate flood level and freeboard (e.g. designed to be above flood waters) AND Evacuation routes are maintained (e.g. situated above flood levels).

[1]The climate change factor is determined by increasing rainfall intensity for the 1 per cent, 0.5 per cent, and 0.2 per cent AEP flood levels by 5 per cent per degree increase in global mean temperature.

Option 1—decision tree



Matrix A—Planning period for proposals subject to a development commitment [2]

Type of development	Planning period based of anticipated asset life	Relevant map
Short term tourist accommodation (i.e. campgrounds and caravan parks)	40 years	Map 1. Flood extents in future climate scenario— 2050
Residential dwelling (less than 7 units)	50 years	Map 2. Flood extents in future climate scenario—2070
Residential dwelling (7 or more units)	60 years	Map 3. Flood extents in future climate scenario—2100
Residential and multi-use developments	80 years +	Map 3. Flood extents in future climate scenario—2100
Industrial building	40 years	Map 1. Flood extents in future climate scenario—2050
Commercial building (single storey)	40 years	Map 1. Flood extents in future climate scenario—2050
Commercial building (multiple storeys)	60 years	Map 3. Flood extents in future climate scenario—2100

Matrix B—Anticipated asset life and appropriate planning horizon

Type of development	Asset life 40 years Map 1. Flood extents in future climate scenario—2050	Asset life 50 years Map 2. Flood extents in future climate scenario—2070	Asset life 60 years + Map 3. Flood extents in future climate scenario—2100
Existing development infill/re-development	If development proposed is within the mapped area, assess against the draft flood constraint code. If development is outside the mapped area, no assessment is required.	If development proposed is within the mapped area, assess against the draft flood constraint code. If development is outside the mapped area, no assessment is required.	If development proposed is within the mapped area, assess against the draft flood constraint code. If development is outside the mapped area, no assessment is required.
Greenfield/new urban – no existing structures but with development commitment	No residential, commercial or industrial subdivision (development commitment is beyond 40 years).	No residential subdivision. Commercial/industrial subdivision assessed against the draft flood constraint code.	All development assessed against the draft flood constraint code.

[2] These planning periods are consistent with those presented in other state planning policy.

Matrix C—Option 1—Appropriate land uses for flood hazard areas

		Very low hazard area	Low hazard area	Moderate hazard area	High hazard area
Development status	Land use	Area above the 0.2% AEP year level, including climate change factor	Area between 0.5% AEP year and 0.2% AEP year level, including climate change factor	Area between 1% AEP year and 0.5% AEP year level, including climate change factor	Area below 1% AEP year level, including climate change factor
		Hazard maps incorporate climate change factor			
Constrain development in committed and uncommitted areas based upon anticipated asset life and associated planning horizon	Group 1a Critical community infrastructure	Land use appropriate	Code assessable (see Schedule 1)	Code assessable (see Schedule 1)	Code assessable (see Schedule 1)
	Group 1b Essential community infrastructure	Land use appropriate	Land use appropriate	Code assessable (see Schedule 1)	Code assessable (see Schedule 1)
	Group 2a Essential industrial or commercial use	Land use appropriate	Subject to special conditions*	Subject to special conditions	Code assessable (see Schedule 1)
	Group 2b Residential, commercial development	Land use appropriate	Land use appropriate	Land use appropriate	Code assessable (see Schedule 1)
	Group 3 Open space and rural activities	Land use appropriate	Land use appropriate	Land use appropriate	Subject to special conditions

*Subject to special conditions: Council may wish to develop a special code to assess certain industrial, commercial and rural uses that pose a higher risk in flooding situations.

Strengths of Option 1

The following strengths have been identified in Option 1, it:

- takes account of the asset life of the development through the use of multiple planning horizons (2050, 2070 and 2100)
- achieves climate change outcomes directly by mapping the revised flood extents taking account of climate change
- considers proposals with and without development commitments over different planning horizons.

Limitation of Option 1

The following limitation has been identified for Option 1:

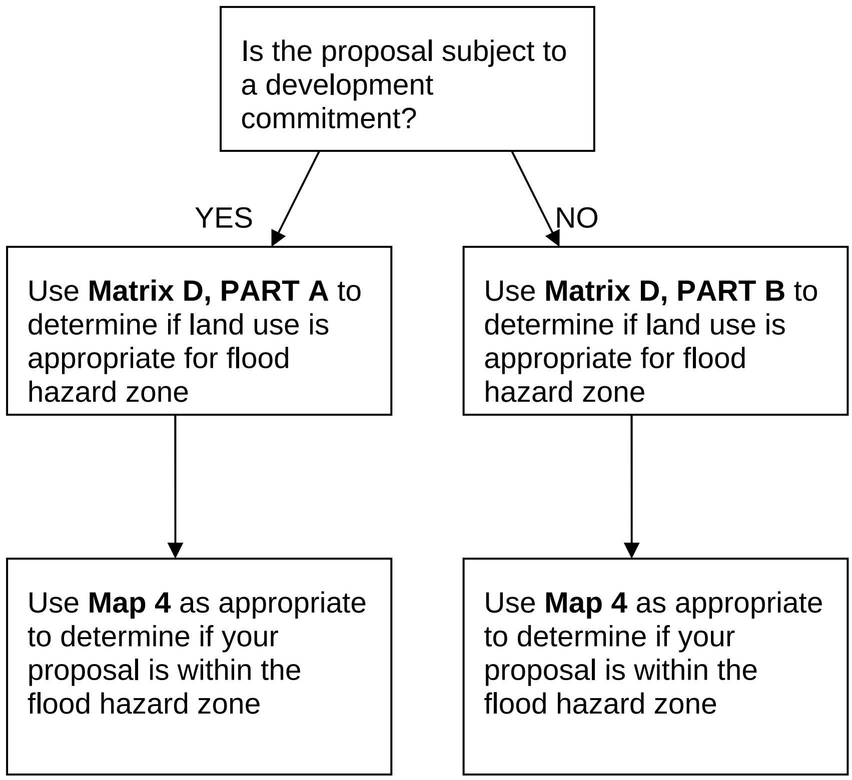
- Flood hazard areas reflecting climate change may move after AR&R method is released, which could cause confusion.

Option 2: Existing flood maps approximate climate change in 2050 and 2100

Option 2 is based on four hazard areas mapped to reflect the current climate at 2010. Climate change is addressed by increasing the level of constraint on planning proposals to:

- approximate the 2050 flood levels (including climate change factor) for assessing development in committed areas
- approximate the 2100 flood levels (including climate change factor) for assessing development in uncommitted areas.

Option 2—decision tree



Matrix D—Option 2—Appropriate land uses for flood hazard areas shown on Map 4

		Very low hazard area	Low hazard area	Moderate hazard area	High hazard area
Development status	Land use	Area between 0.2% AEP year level and PMF	Area between 0.5% AEP year and 0.2% AEP year level	Area between 1% AEP year and 0.5% AEP year level	Area below 1% AEP year level
PART A		Hazard maps based on current climate in 2010 (i.e. no climate change factor in mapping)			
Proposals subject to a development commitment (future built development outside current urban areas) – approximate climate change to 2050	Group 1a Critical community infrastructure	Land use appropriate	Code assessable (see Schedule 1)	Code assessable (see Schedule 1)	Code assessable (see Schedule 1)
	Group 1b Essential community infrastructure	Land use appropriate	Code assessable (see Schedule 1)	Code assessable (see Schedule 1)	Code assessable (see Schedule 1)
	Group 2a Essential industrial or commercial use	Land use appropriate	Subject to special conditions	Code assessable (see Schedule 1)	Code assessable (see Schedule 1)
	Group 2b Residential, commercial development	Land use appropriate	Land use appropriate	Code assessable (see Schedule 1)	Code assessable (see Schedule 1)
	Group 3 Open space and rural activities	Land use appropriate	Land use appropriate	Subject to special conditions	Subject to special conditions
PART B		Hazard maps based on current climate in 2010 (i.e. no climate change factor in mapping)			
Proposals not subject to a development commitment (development inside committed urban areas) – approximate climate change to 2100	Group 1a Critical community infrastructure	Land use appropriate	Code assessable (see Schedule 1)	Code assessable (see Schedule 1)	Code assessable (see Schedule 1)
	Group 1b Essential community infrastructure	Land use appropriate	Code assessable (see Schedule 1)	Code assessable (see Schedule 1)	Code assessable (see Schedule 1)

	Group 2a Essential industrial or commercial use	Land use appropriate	Code assessable (see Schedule 1)	Code assessable (see Schedule 1)	Code assessable (see Schedule 1)
	Group 2b Residential, commercial development	Land use appropriate	Code assessable (see Schedule 1)	Code assessable (see Schedule 1)	Code assessable (see Schedule 1)
	Group 3 Open space and rural activities	Land use appropriate	Land use appropriate	Subject to special conditions	Subject to special conditions

*Subject to special conditions: Council may wish to develop a special code to assess certain industrial, commercial and rural uses that pose a higher risk in flooding situations.

Strengths of Option 2

The following strengths have been identified in Option 2, it:

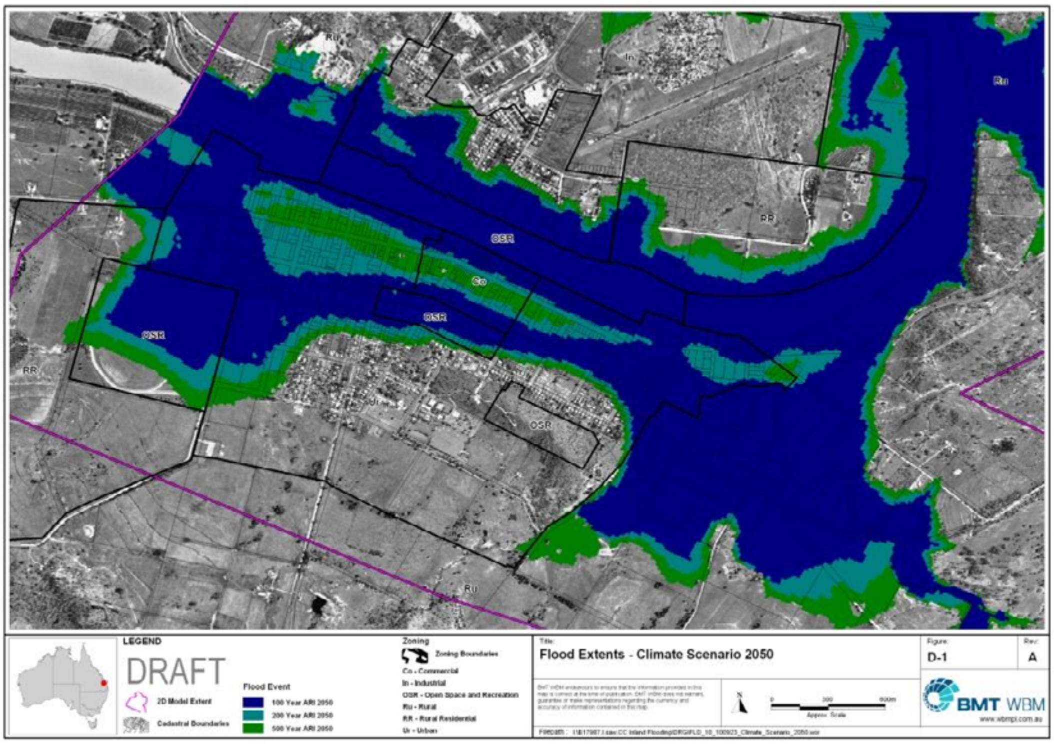
- adopts a conservative/incremental approach
- constrains proposals with and without development commitments over different planning horizons
- allows Council to review constraints in currently committed areas in the future without shifting the flood level zones represented in the overlay maps
- uses shorter planning horizon (to 2050) in recognition of need to balance existing commitments with consideration of climate change
- establishes a firm basis for flood levels based on current climate – may have better community acceptance
- provides interim approach that leaves flood hazard areas in stable location until AR&R method is released.

Limitations of Option 2

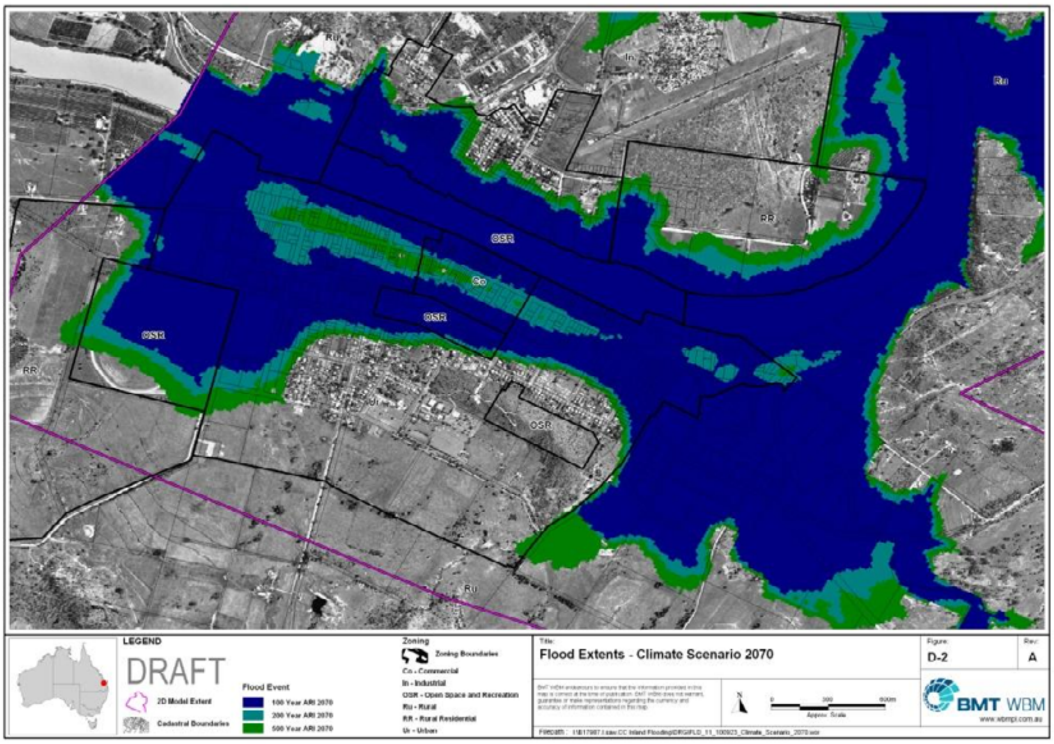
The following limitations have been identified in Option 2, it:

- achieves climate change outcomes indirectly via constraints, not changing the flood hazard maps
- imprecisely allocated constraints under climate change (may under constrain development in 0.2 per cent AEP + zone)
- does not take into account asset life of development.

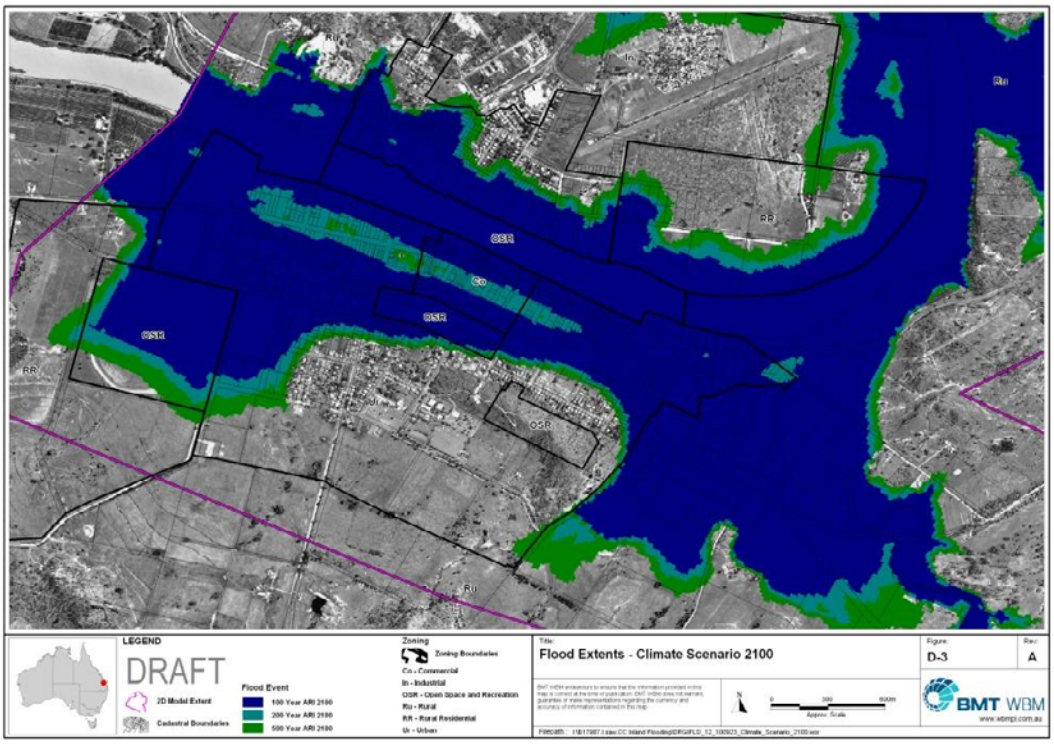
MAP 1: Flood levels in 2050



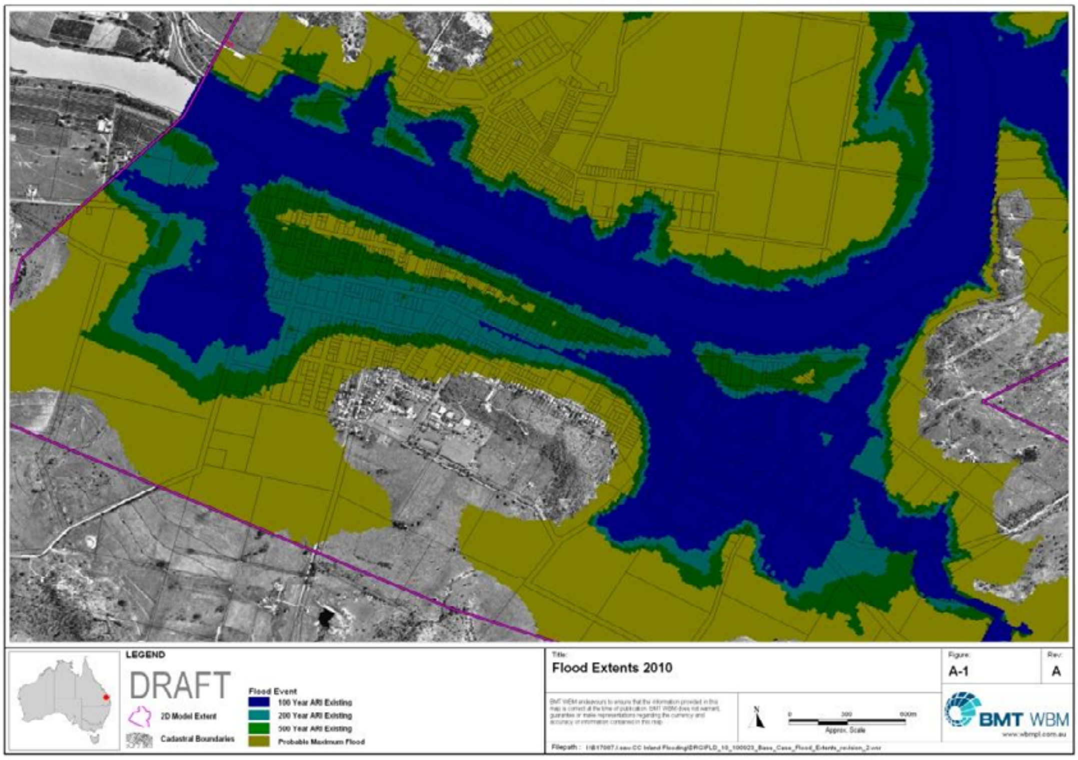
MAP 2: Flood levels in 2070



MAP 3: Flood levels in 2100



MAP 4: Flood levels in 2010



Schedule 1—Draft flood constraint code for flood affected areas in Gaydah

Purpose

The purpose of this code is to assess development in flood affected areas according to levels of risk so that:

- property damage is limited
- safety is increased and lives are protected
- cumulative impacts of flooding are reduced.

Outcomes

The application of this code is to achieve the following outcomes:

- minimise the addition of risk in flood affected areas
- lessen the adverse impacts of flooding
- facilitate development in low probability flooding areas
- maintain local flood plain processes (water storage and flows, river discharge and capacity, banks of river, streams and water bodies are protected from erosion)
- maintain a network of evacuation routes
- maintain critical emergency infrastructure and services during flood events
- maintain functionality of community infrastructure during and immediately following flood events
- reduce the overall level of flood risk through the layout and form of the development and building design and construction.

Application

This code applies to land that is located within the identified flood hazard areas on overlay maps for flood affected areas. In this constraint code, the Defined Flood Event (DFE) is the 1 per cent AEP plus climate change factor.

The Local Disaster Management Group is to use the maps, identified flood levels and scheme solutions to inform preparation of local disaster management plans.

This code applies to development that is:

- building or other work that involves any physical alteration to a watercourse or floodway including vegetation clearing, or involves net filling exceeding 50 cubic metres; and
- material changes of use and reconfigurations of a lot that:
    - increase the number of people living or working in a flood hazard area (e.g. residential development, shopping centres, tourist facilities, industrial or commercial uses) except where the premises are occupied on a short term or intermittent basis); or
    - involve institutional uses where evacuating people may be particularly difficult (e.g. hospitals, schools, aged care, nursing homes, correctional centres); or
    - involve the manufacture or storage of hazardous materials in bulk; or
    - would involve the building or other work described in (a) as an intrinsic element of the development proposal.

The code does not apply to Class 1 buildings as defined in the Building Code of Australia, except where Council has declared an area to be flood prone under Section 13 of the Building Regulation 2006. However, this code designates minimum floor levels of buildings with habitable rooms within flood prone land.

Performance criteria and acceptable solutions for development that is self assessable, code assessable or impact assessable

Performance criteria	Acceptable solutions
Flooding risk	
PC1 Development does not result in unacceptable risk to people or property.	AS1.1 For development not subject to a development commitment, the proposed use is consistent with the uses and flood level in Table 1. OR AS1.2 For development subject to a development commitment, the development is consistent with Table 2.
Building floor levels	
PC2 Habitable rooms have acceptable levels of flood immunity.	AS2.1 Where the lot is subject to a resolution about minimum floor levels of habitable rooms under the Building Regulation, the floor level of all new rooms satisfy the level determined in the resolution. OR AS2.2 Where the residential building is on floodable land, but the lot is not subject to a resolution about minimum floor levels of habitable rooms under the Building Regulation, the floor level of all habitable rooms is not less than those set out in Table 2. AS2.3 Where a building has been destroyed and is being re-built, the reconstructed floor level accords with Table 2.
Disaster management	
PC3 Development in flood affected areas must not increase the level of risk to life or be to the detriment of flood evacuation procedures.	AS3.1 Development does not: • increase the number of people calculated to be at risk from flooding • increase the burden on disaster management operations • increase traffic volumes on evacuation routes • adversely impact on the ability of traffic to use evacuation routes. AND

	AS3.2 Evacuation access in accordance with Tables 3 and 4 is provided. Note: Compliance with this acceptable solution can be demonstrated by the submission of a report identifying that where there is an increase in the number of people, the disaster management burden is taken into account in Council's disaster management plan.
PC4 Access or egress to and from the site is available to enable evacuation during flooding.	AS4.1 Evacuation routes are in accordance with Tables 3 and 4.
Flood processes	
PC5 The development must not directly, indirectly or cumulatively cause an increase in flood level or velocity or negatively impact drainage resulting in the potential to cause real damage to upstream, downstream or adjacent properties.	AS5.1 Where the development is located within a high flood hazard area or moderate flood hazard area (as defined in Table 1), a hydraulic and hydrology report is provided from a Registered Professional Engineer of Queensland (using the flood mapping methodology developed by QCCCE) that demonstrates there are no increased flooding impacts on upstream, downstream or adjacent properties.
PC6 Filling, excavation, physical alteration to a watercourse, floodway or flow path must not directly, indirectly or cumulatively cause an increase in flood level or velocity, or negatively impact drainage resulting in the potential to cause real damage to upstream, downstream or adjacent properties.	AS6.1 No filling, excavation or physical alteration to a watercourse, floodway or flow path is located within the 100 year ARI extent. OR AS6.2 A report is provided from a Registered Professional Engineer of Queensland that demonstrates the following is achieved: • Filling and excavation do not cause ponding to any adjoining site and land upstream and down stream • Changes to flooding due to filling and excavation will not adversely affect the safety or use of any adjoining site and land upstream and downstream • Any changes to run-off characteristics resulting from filling for storm events, up to at least the two year ARI design storm, are minimised in an ecologically sensitive manner.

PC7 Development does not reduce the flood storage capacity of the catchment.	AS7.1 The flood storage volume on the site is maintained for flood levels up to the DFE.
Overland Flow	
PC8 Building work must not provide obstructions to the free passage of water through a property.	AS8.1 Water is allowed free passage across a property, in accordance with the provisions of the Building Code of Australia and the Queensland Urban Drainage Manual.

Note: Tables 1 to 3 reflect land uses identified in the North Burnett Regional Council Planning Scheme and types of community infrastructure identified in SPP1/03 Guideline Appendix 9 [3]

[3] Updates to Tables 1 to 3 should reflect the land uses identified in the Queensland Planning Provisions and the relevant local planning scheme.

Table 1 for use with planning horizons Option 1--Appropriate land uses for flood hazard areas				
Land Use	Very low hazard area	Low hazard area	Moderate hazard area	High hazard area
	Area between 0.2% AEP year level and probable maximum flood +climate change factor	Area between 0.5% AEP year and 0.2% AEP year level +climate change factor	Area between 1% AEP year and 0.5% AEP year level +climate change factor	Area below 1% AEP year level +climate change factor
Group 1a				
Disaster management facilities	✓			
Hospitals and associated facilities	✓			
Major electrical switchyards, power stations and substations	✓			
Group 1b				
Fire and police stations	✓	✓		
Emergency shelters	✓	✓		
Public utility (including water and sewage treatment plants)	✓	✓		
Retirement village, homes for the aged, hospice	✓	✓		
Community oriented activities (including child care centres, educational establishment, places of worship)	✓	✓		
Group 2a				
Regional fuel storage	✓	subject to special conditions	subject to special conditions	
Food storage warehouses	✓	subject to special conditions	subject to special conditions	
Group 2b				
Camping grounds, caravan parks	✓	✓	✓	
Residential activities (including detached house,	✓	✓	✓	

home business, and multiple dwelling (except retirement village), bed and breakfast premises, caretaker's residence, and visitor accommodation)				
Commercial activities (including hotels, professional offices and shops)	✓	✓	✓	
Clubs/ non-habitable buildings associated with enjoyment of public open space	✓	✓	✓	
Industrial activities	✓	✓	✓	
Group 3				
Open space, recreation, and conservation	✓	✓	✓	Subject to appropriate land assessment and planning
Rural activities (including agriculture, grazing, intensive animal husbandry)	✓	✓	✓	Some intensive rural uses may not be appropriate in this area and may only be acceptable with special conditions

*Subject to special conditions: Council may wish to develop a special code to assess certain industrial, commercial and rural uses that pose a higher risk in flooding situations.

Table 1 for use with planning horizons Option 2—Appropriate land uses for flood hazard areas PROPOSALS SUBJECT TO A DEVELOPMENT COMMITMENT				
Land use	Very low hazard area	Low hazard area	Moderate hazard area	High hazard area
	Area above 0.2% AEP year level (based on 2010 climate)	Area between 0.5% AEP year and 0.2% AEP year level (based on 2010 climate)	Area between 1% AEP year and 0.5% AEP year level (based on 2010 climate)	Area below 1% AEP year level (based on 2010 climate)
Group 1a				
Disaster management facilities	✓			
Hospitals and associated facilities	✓			
Major electrical switchyards, power stations and substations	✓			
Group 1b				
Fire and police stations	✓			
Emergency shelters	✓			
Public utility (including water and sewage treatment plants)	✓			
Retirement village, homes for the aged, hospice	✓			
Community oriented activities (including child care centres, educational establishment, places of worship)	✓			
Group 2a				
Regional fuel storage	✓	Subject to special conditions	Subject to special conditions	
Food storage warehouses	✓	Subject to special conditions	Subject to special conditions	
Group 2b				
Camping grounds, caravan parks	✓	✓		

Residential activities (including detached house, home business, and multiple dwelling (except retirement village), bed and breakfast premises, caretaker’s residence and visitor accommodation)	✓	✓		
Commercial activities (including hotels, professional offices and shops)	✓	✓		
Clubs/ non-habitable buildings associated with enjoyment of public open space	✓	✓		
Industrial activities	✓	✓		
Group 3				
Open space, recreation, and conservation	✓	✓	Subject to appropriate land assessment and planning	Subject to appropriate land assessment and planning
Rural activities (including agriculture, grazing, intensive animal husbandry)	✓	✓	Some intensive rural uses may not be appropriate in this area and may only be acceptable with special conditions	Some intensive rural uses may not be appropriate in this area and may only be acceptable with special conditions

**Subject to special conditions: Council may wish to develop a special code to assess certain industrial, commercial and rural uses that pose a higher risk in flooding situations.*

Table 1 for use with planning horizons Option 2—Appropriate land uses for flood hazard areas PROPOSALS NOT SUBJECT TO A DEVELOPMENT COMMITMENT				
Land use	Very low hazard area	Low hazard area	Moderate hazard area	High hazard area
	Area above 0.2% AEP year level (based on 2010 climate)	Area between 0.5% AEP year and 0.2% AEP year level (based on 2010 climate)	Area between 1% AEP year and 0.5% AEP year level (based on 2010 climate)	Area below 1% AEP year level (based on 2010 climate)
Group 1a				
Disaster management facilities	✓			
Hospitals and associated facilities	✓			
Major electrical switchyards, power stations and substations	✓			
Group 1b				
Fire and police stations	✓			
Emergency shelters	✓			
Public utility (including water and sewage treatment plants)	✓			
Retirement village, homes for the aged, hospice	✓			
Community oriented activities (including child care centres, educational establishment, places of worship)	✓			
Group 2a				
Regional fuel storage	✓			
Food storage warehouses	✓			
Group 2b				
Camping grounds, caravan parks	✓			
Residential activities (including detached house, home business, and multiple dwelling (except retirement village), bed and breakfast premises, caretaker’s residence and visitor accommodation)	✓			
Commercial activities (including hotels, professional offices and shops)	✓			

Clubs/ Non-habitable buildings associated with enjoyment of public open space	✓			
Industrial activities	✓			
Group 3				
Open space, recreation, and conservation	✓	✓	Subject to appropriate land assessment and planning	Subject to appropriate land assessment and planning
Rural activities (including agriculture, grazing, intensive animal husbandry)	✓	✓	Some intensive rural uses may not be appropriate in this area and may only be acceptable with special conditions	Some intensive rural uses may not be appropriate in this area and may only be acceptable with special conditions

**Subject to special conditions: Council may wish to develop a special code to assess certain industrial, commercial and rural uses that pose a higher risk in flooding situations.*

Table 2. Minimum design freeboard for development subject to a development commitment	
Land use	Minimum design freeboard
Disaster management facilities	0.2% AEP + cc factor + 300 mm
Hospitals and associated facilities	0.2% AEP + cc factor + 300 mm
Major electrical switchyards, power stations and substations	0.2% AEP + cc factor + 300 mm
Fire and police stations	0.5% AEP + cc factor + 300 mm
Emergency shelters	0.5% AEP + cc factor + 300 mm
Public utility (including water and sewage treatment plants)	0.5% AEP + cc factor + 300 mm
Retirement village, homes for the aged, hospice	0.5% AEP + cc factor + 300 mm
Community oriented activities (including child care centres, educational establishment, places of worship)	0.5% AEP + cc factor + 300 mm
Camping grounds, caravan parks	1% AEP + cc factor + 300 mm
Residential activities (including detached house, home business, and multiple dwelling (except retirement villages), bed and breakfast premises, caretaker's residence, and visitor accommodation)	1% AEP + cc factor + 300 mm
Commercial activities (including hotels, professional offices and shops)	1% AEP+ cc factor
Industrial activities	1% AEP+ cc factor
Regional fuel storage	subject to special conditions
Food storage warehouses	subject to special conditions
Clubs/non-habitable buildings associated with enjoyment of public open space	1% AEP+ cc factor
Open space and recreation activities/conservation	not specified
Rural activities (including agriculture, grazing, intensive animal husbandry)	not specified

**Subject to special conditions: Council may wish to develop a special code to assess certain industrial, commercial and rural uses that pose a higher risk in flooding situations.*

Table 3. Maximum degree of flood hazard for emergency routes	
Land use	Maximum degree of flood hazard for evacuation routes
Disaster management facilities	low
Hospitals and associated facilities	low
Major electrical switchyards, power stations and substations	low
Fire and police stations	low
Emergency shelters	low
Public utility (including water and sewage treatment plants)	low
Retirement village, homes for the aged, hospice	low
Community oriented activities (including child care centres, educational establishment, places of worship)	low
Camping grounds, caravan parks	medium
Residential activities (including detached house, home business, and multiple dwelling (except retirement villages), bed and breakfast premises, caretaker's residence, and visitor accommodation)	medium
Commercial activities (including hotels, professional offices and shops)	high
Industrial activities	high
Regional fuel storage	high
Food storage warehouses	high
Clubs/non-habitable buildings associated with enjoyment of public open space	high
Open space and recreation activities/conservation	extreme
Rural activities (including agriculture, grazing, intensive animal husbandry)	extreme

Table 4. Flood hazard criteria for emergency routes				
Criteria	Degree of flood hazard			
	Low	Medium	High	Extreme
Wading ability	If necessary children and the elderly could wade (generally, safe wading velocity depth product is less than 0.25.)	Fit adults can wade (generally, safe wading velocity depth product is less than 0.4.)	Fit adults would have difficulty wading (generally, where wading velocity depth product is less than 0.6.)	Wading is not an option
Evacuation distances	< 200 m	200 – 400 m	400 – 600 m	> 600 m
Maximum flood depths	< 0.3 m	< 0.6 m	< 1.2 m	> 1.2 m
Maximum flood velocity	< 0.4 m/sec	< 0.8 m	< 1.5 m	> 1.5 m
Typical means of egress	Sedan	Sedan early, but 4WD or trucks later	4WD or trucks only in early stages, boats or helicopters	Large trucks, boats or helicopters
Timing	Ample for flood forecasting. Warning and evacuation routes remain passable for twice as long as evacuation time.	Evacuation routes remain trafficable for 1.5 times as long as the evacuation time	Evacuation routes remain trafficable for only up to minimum evacuation time	There is insufficient evacuation time
Note: The evacuation times for various facilities or areas would be included in the local disaster management plan (flooding). Generally, safe wading conditions assume even walking surfaces with no obstructions, steps, soft underfoot, etc.				

Definitions

Critical community infrastructure includes disaster management facilities; hospitals and associated facilities; major electrical switchyards, power stations and substations.

Development is any of the following (as defined in s7 and s10 *Sustainable Planning Act 2009*) —

- carrying out building work
- carrying out plumbing or drainage work
- carrying out operational work
- reconfiguring a lot
- making a material change of use of premises

Development commitment means any of the following:

- development with a valid preliminary approval or development that arises from and is necessary to give effect to a valid approval; or
- development that is:
  - consistent with a relevant statutory regional plan or any applicable State Planning Regulatory Provision; and
  - explicitly anticipated by and consistent with the specific relevant zone (or equivalent), all applicable codes, and any other requirements of the relevant planning scheme
- development that is located within a State development area and is consistent with the development scheme prepared for the State development area
- development consistent with a designation for community infrastructure.

Essential community infrastructure includes fire and police stations; emergency shelters; public utility including water treatment plants and sewage treatment plants; retirement village, homes for the aged, and hospices; community oriented activities (including child care centres, educational establishments and places of worship).

Evacuation route means a path of travel from:

- any place in the development, through a final exit of the development to a place of safety outside the flood affected area; or
- a common area of the development to a place of safety outside the flood affected area.

Urban area means an area allocated under a planning scheme for an urban or rural residential purpose and the allocation is consistent with any applicable State planning regulatory provisions and statutory regional plan.

Appendix H
Hydraulic category maps

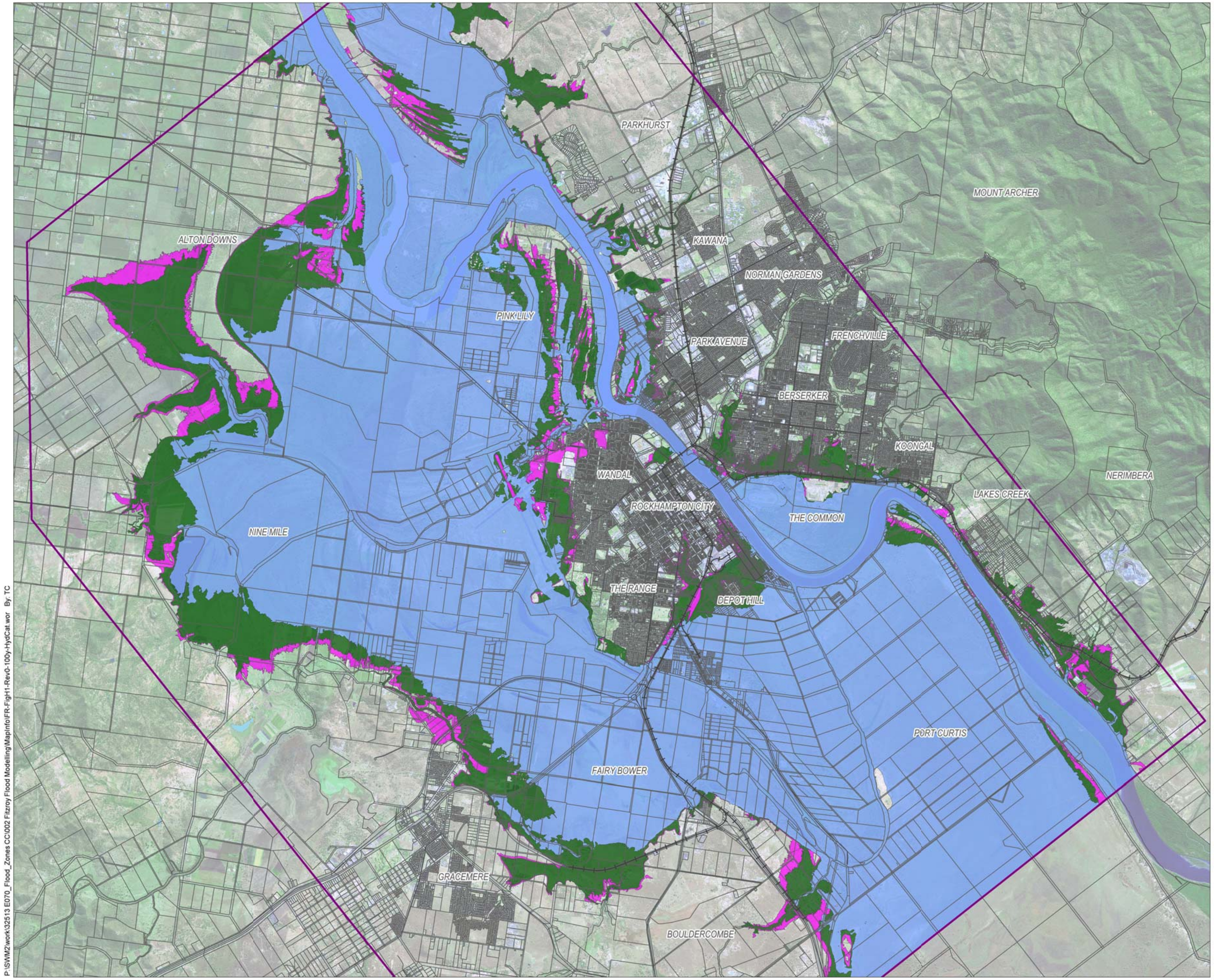
aurecon

Rockhampton Regional Council

Australian Government
Attorney-General's Department
Emergency Management Australia

Emergency Management EMQ Queensland

Queensland Government
Department of Emergency Services



Legend

- Cadastre
- Major Road
- Railway Line
- TUFLOW Model Extents

Hydraulic Category

- Floodway
- Flood Storage
- Flood Fringe

Notes:

1. This map must not be used without consideration of, or reference to, the Explanatory Notes and Disclaimers which are provided on the Fitzroy River Flood Study Figure 1 so as to understand the important limitations and conditions on such use.
2. All level information is expressed in metres AHD. Rockhampton Gauge Datum = AHD plus 1.448m
3. This mapping considers Fitzroy River flooding only. No consideration of local catchment flooding has been made.
4. This mapping shows inundation within the Fitzroy River Flood Study TUFLOW model extents only. Fitzroy River flood inundation continues beyond the upstream and downstream extents of this mapping.
5. Estimated equivalent Rockhampton gauge levels for each event are:

   100 year ARI = 7.93m AHD = 9.38m Gauge Datum
   50 year ARI = 7.59m AHD = 9.04m Gauge Datum
   20 year ARI = 7.23m AHD = 8.68m Gauge Datum
   10 year ARI = 6.65m AHD = 8.10m Gauge Datum
   5 year ARI = 5.96m AHD = 7.41m Gauge Datum
   2 year ARI = 4.20m AHD = 5.65m Gauge Datum

Date: 18/03/2011 Version: 1

0 4000 (m)

Scale 1:80 000 (m) (@ A3 size)

Projection: MGA Zone 56

Fitzroy River Flood Study

Figure H1 - Hydraulic Categories

Appendix I
List of figures

Appendix I – List of figures