Pioneer River Flood Study

Mackay Regional Council

0500-47-I1, 22 October 2021

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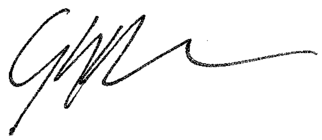

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1 Introduction

1.1 OVERVIEW

WRM Water & Environment Pty Ltd (WRM) was commissioned by Mackay Regional Council (MRC) to prepare a Floodplain Management Plan for the City of Mackay. The location of the study area and the key drainage characteristics of interest in this study are shown in Figure 1.1.

This report forms part of a series of reports to review and update the existing flood studies of the Pioneer River catchment to estimate design flood discharges and flood levels across Mackay using the latest techniques given in Australian Rainfall and Runoff (ARR) (Ball, et al. 2019). This report specifically investigates the flooding from the Pioneer River and updates a Pioneer River study completed in 2011 by WRM.

This report should be read in conjunction with the flood studies of Goosepond Creek (WRM, 2021a), Mackay CBD (WRM, 2021b) and Bakers Creek/Walkerston (WRM, 2021c) which investigates local catchment flooding from these sources together with overflow flooding from the Pioneer River.

1.2 ADOPTED APPROACH

The approach and methodology employed to achieve this phase of the study involved:

- the compilation and review of available flood related data;
- the review and recalibration of computer based hydraulic models for the Pioneer River;
- the update of the Pioneer River design flood discharges by:
    - using the ensemble methodology described in ARR and updated rainfalls to derive design discharge hydrographs; and
    - validating the design discharges from an annual series flood frequency analysis of the recorded flows
- the use of the computer model results to derive design flood extent maps and hydraulic flood hazard maps.

1.3 REPORT STRUCTURE

The report is structured as follows:

- Section 2 describes the background of the study, including the catchment characteristics, previous flood studies that have been undertaken in the Pioneer River catchment;
- Section 3 outlines the available data for the study;
- Section 4 outlines the configuration, calibration and verification of the Pioneer River hydrologic model;
- Section 5 outlines the configuration and calibration of the Pioneer River hydraulic model;
- Section 6 presents the design discharge estimates for the Pioneer River;
- Section 7 describes the design flood depths, levels and extents for the 10%, 5%, 2%, 1%, 0.5%, 0.2% annual exceedance probability (AEP) events and the Probable Maximum Flood;
- Section 8 discusses the effect of climate change;

- Section 9 describes the provisional hydraulic hazard categories for the study area;
- Section 10 is a list of references;
- Appendix A shows the Pioneer River regional flood mapping; and
- Appendix B provides hydraulic hazard classification maps for the Pioneer River.

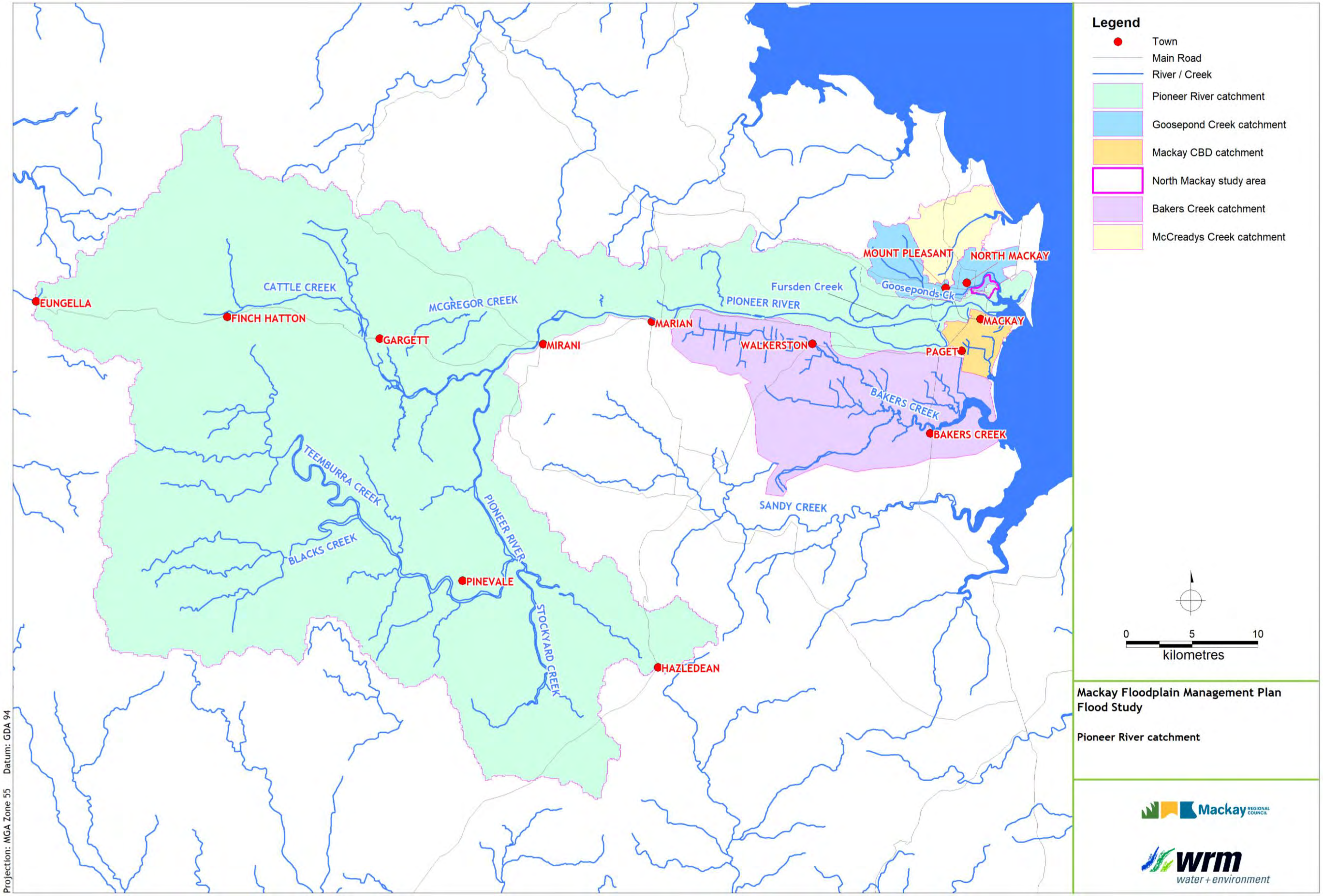

Figure 1.1 - Pioneer River catchment

2 Background

2.1 CATCHMENT CHARACTERISTICS

Figure 1.1 shows the key catchments and drainage features in the study area. The Study Area is drained by the following watercourses and drainage features:

- the Pioneer River;
- Janes Creek / Goosepond Creek / Vines Creek through Glenella, Mount Pleasant and North Mackay;
- Shellgrit Creek and Sandfly Creek within the Mackay CBD;
- Bakers Creek (south of the Pioneer River catchment); and
- McCreadys Creek (north of the Goosepond Creek catchment).

Brief descriptions of these catchments are given below.

2.1.1 Pioneer River

The main drainage feature in the study area is the Pioneer River. The Pioneer River catchment extends from the Connors Range to the west and is bordered by the Leila Creek and Murray Creek catchments to the north, the Bowen River catchment to the west and Sandy Creek, Bakers Creek and the Isaac River catchments to the south (see Figure 1.1). It includes the major tributaries of Cattle Creek, Teemburra Creek, Blacks Creek, Stockyard Creek and Macgregor Creek in the upper catchment and the floodplain channels of Fursden Creek, Goosepond Creek and Lagoon Creek in the lower catchment in the vicinity of Mackay. The total catchment area of the Pioneer River is approximately 1,560 km^2.

Near Mackay, the Pioneer River consists of a main channel that is some 400 m wide and 8 m to 10 m deep. It has a highly mobile sandy bed, and the water levels are controlled by the ocean tides during non-flood river flows. Major remnant channels of the Pioneer River exist across the lower floodplain with Fursden Creek located to the north and Lagoon Creek to the south. The Pioneer River overflows into these two remnant channels during moderate sized flood events and 'back flows' into the creeks during smaller events. Flood levees are currently in place to protect much of the Mackay CBD and North Mackay areas.

2.1.2 Janes Creek / Goosepond Creek / Vines Creek

Janes Creek and Goosepond Creek are tributaries of Vines Creek, which drains into the Pioneer River in an area known as the Bassett Basin. Janes Creek originates near Farleigh and (Upper) Goosepond Creek originates near Richmond both to the north-west of the Mackay CBD. The two channels converge to form Goosepond Creek at the Bruce Highway. Goosepond Creek drains through the suburbs of Glenella and Mount Pleasant before draining into Vines Creek in North Mackay. Much of Vines Creek and the lower section of Goosepond Creek are tidally affected. The combined catchment area of these three streams is approximately 35 km^2. The Pioneer River overflows to Goosepond Creek and Goosepond Creek overflows to the Pioneer River in Glenella during large flood events.

2.1.3 Mackay CBD

The Mackay CBD is drained via two urbanised creek catchments named Shellgrit Creek and Sandfly Creek. Sandfly Creek drains Mackay City and Mackay East to the northeast towards the Pioneer River. A gated pipe drains Sandfly Creek through a levee to the Pioneer River. Shellgrit Creek drains much of South and West Mackay to the southeast around the Mackay Airport to the Coral Sea. The lower reach of Shellgrit Creek is tidally affected and is not protected by a flood levee. However, tide gates are used to prevent high tides from draining into the city area channels.

Both catchments have been fully urbanised with runoff draining via a combination of stormwater pipes and constructed channels. Runoff in excess of the piped stormwater drainage system flows along the roadways.

2.1.4 North Mackay

North Mackay is surrounded by the Pioneer River to the south, Goosepond Creek to the north and Vines Creek to the east. Flood levels in the area are influenced by regional flooding mechanisms, or combination of these mechanisms including tide levels, Goosepond Creek flooding and Pioneer River flooding. North Mackay is protected from regional flooding by levee systems along the north-western and eastern sides of the area.

Runoff from North Mackay is drained via pit and pipe networks throughout the area before discharging into open drains in low lying areas adjacent to the levees surrounding North Mackay. Drainage through the levees (into the surrounding creeks and rivers) is provided at a number of outlets, some of which have backflow prevention devices installed. The open drains then pass beneath the levees via culverts (fitted with backflow prevention devices) into the surrounding creeks and rivers.

A more detailed description is provided in the North Mackay Drainage Study (WRM, 2019) report.

2.1.5 Bakers Creek

Bakers Creek drains the southern floodplain of the Pioneer River through the townships of Walkerston and Bakers Creek to the South Pacific Ocean about 8 km south of the Pioneer River mouth. The Bakers Creek catchment is topographically flat except for the areas in the vicinity of Mt Vince and Greenmount. The topographically flat sections of the Bakers Creek catchment are cropped for sugarcane area.

A more detailed description is provided in the Bakers Creek/Walkerston Flood Study (WRM, 2021c) report.

2.1.6 McCreadys Creek

The McCreadys Creek South catchment area encompasses the land in the Glenella, Mt Pleasant, Richmond and Beaconsfield suburbs of MRC. The McCreadys Creek South channel commences as a concrete lined channel within the suburb of Mount Pleasant and drains in a northerly direction, east of Mackay-Bucasia Road, to the Golf Club and then to McCreadys Creek. This region is relatively flat and low lying and, as a result, is flood prone. The golf course is situated in the downstream reaches of the catchment area within the low-lying flood prone region. McCreadys Creek downstream of Golflinks Road is tidally influenced.

A more detailed description is provided in the McCreadys Creek South Stormwater Trunk Infrastructure Study (WRM, 2017) report.

2.2 PREVIOUS FLOOD STUDIES

2.2.1 Pioneer River

WRM completed a flood study of the Pioneer River in 2011 for MRC. An URBS rainfall-runoff-routing model of the Pioneer River catchment was developed to estimate design discharges. The model was calibrated to six historical flood events (1958, 1970, 1990, 2000, 2007 and 2008) and then validated against annual series flood frequency analyses at five stream gauges throughout the catchment.

Design flood levels were estimated using a TUFLOW two-dimensional hydrodynamic model that extended from Mirani Weir to the Coral Sea. The model was calibrated to recorded water levels for four historical flood events (1958, 1970, 2007 and 2008). The main river channel upstream of the Dumbleton Weir was modelled in the one-dimensional domain and the downstream river and overbank areas were modelled within the two-dimensional domain using a 20 m grid. For all events, it was assumed that the flood event coincided with the HAT level of 3.64 mAHD.

This report represents an update of the WRM (2011) study to include the updated ARR (Ball et. al, 2019) hydrology and an update to the TUFLOW hydraulic model.

2.2.2 Goosepond/ Vines Creek

GHD (2012) was commissioned by MRC to undertake a flood study for Goosepond Creek, Janes Creek and Vines Creek in the North Mackay area. A XP-RAFTS rainfall-runoff-routing model was used to estimate design discharges and a MIKEFLOOD hydrodynamic model was used to estimate design flood levels. The models were calibrated to the February 2007 and February 2008 flood events.

The MIKEFLOOD model extended from the Richmond area upstream of the Mackay Harbour Railway line to the Bassett Basin between North Mackay and Mackay Harbour. The model was also used to assess a range of development scenarios and flood mitigation options.

The GHD study did not include the overflows into Goosepond Creek from the Pioneer River and as such potentially underestimated design flood levels along much of Goosepond Creek. In addition, the hydrodynamic model adopted by GHD is different to all other models used throughout the Mackay region.

WRM (2012) integrated the Pioneer River Flood Study (WRM, 2011) and Goosepond/Vines Creek Flood Study (GHD, 2012) to include the interaction of flood flows between Goosepond Creek and the Pioneer River. The integrated flood model was recalibrated to the February 2007 and February 2008 flood events along Goosepond Creek.

The Goosepond Creek / Vines Creek Flood study was updated by WRM (2021a) using the latest ARR (Ball, et al., 2019) techniques.

2.2.3 North Mackay

WRM completed a drainage study of North Mackay in 2019 for MRC. A TUFLOW two-dimensional hydrodynamic model was developed using the rain-on-grid approach to estimate design peak flood levels for North Mackay taking into consideration local rainfall, the piped drainage system and local stormwater drains. The TUFLOW model was validated to a limited number of surveyed peak flood levels available for the February 2008 event. This model is referred to in this report as the “North Mackay model”.

The North Mackay model was used to define peak flood levels and depths in North Mackay for local catchment events up to the 0.2% AEP event for existing conditions and four flood mitigation scenarios. The design discharges and levels were determined in accordance with the methodology recommended in ARR (Ball et al, 2019).

2.2.4 Shellgrit Creek

Cardno (QLD) Pty Ltd (2014) was commissioned by Mackay Regional Council to prepare a flood study of the Shellgrit Creek catchment. A rain-on-grid TUFLOW two-dimensional hydraulic model was developed for the Shellgrit Creek catchment in South Mackay to derive flood levels across the catchment and investigate relief drainage options.

The Shellgrit Creek model to the west of Paradise Street was defined using a 8 m grid and the area to the east of Paradise Street was represented using a 4 m grid. Underground pipes within Shellgrit Creek catchment were included as 1D elements in the Shellgrit Creek hydraulic model. An outflow boundary was included at the northern extent of the model (along Evan Street) to allow outflows into the Sandfly Creek catchment to the north. The Shellgrit Creek TUFLOW model was calibrated to the 2008 flood event at 8 locations.

The Shellgrit Creek model did not include interaction of flooding from the Sandfly Creek catchment and as such potentially underestimated design flood levels along the northern boundary of the model area. Also, the Shellgrit Creek model (Cardno, 2014) did not include the Pioneer River overflows which potentially has significant impacts on design flood levels during large flood event.

2.2.5 Mackay CBD

AECOM Australia Pty Ltd (2015) was commissioned by Mackay Regional Council and Queensland Government to prepare a flood study of the Mackay CBD area. A rain-on-grid TUFLOW two-dimensional hydraulic model was developed for the Sandfly Creek catchment in Mackay CBD to derive flood levels across the catchment and investigate structural mitigation options.

The Sandfly Creek model was defined using a 4 m grid size and covered Mackay CBD, East Mackay and part of West Mackay. An outflow boundary was included at the southern extent of the model (near McKenney Street) to allow outflows into the Shellgrit Creek catchment to the south. Underground pipes within Sandfly Creek catchment were included as 1D elements in the Sandfly Creek hydraulic model. The Sandfly Creek model was calibrated to the 2008 flood event at 44 surveyed locations.

The study includes the investigation of the Pioneer River overflows during 1% AEP flood event. However, the Sandfly Creek model did not include interaction of flooding from the Shellgrit Creek catchment and as such potentially underestimated design flood levels along the southern boundary of the model area.

WRM (2021b) updated the Mackay CBD study to include Shellgrit Creek. In effect, the WRM (2021b) study combined the AECOM (2015) and Cardno (2014) studies.

2.2.6 Mackay Storm Tide

BMT WBM Pty Ltd was commissioned by Mackay Regional Council to undertake a storm tide study in the Mackay region. The storm tide study involved a numerical modelling system to predict tropical cyclone generated storm tide inundation and estimate various AEP storm tide levels.

Based on the Mackay Storm Tide Study (2013), BMT WBM Pty Ltd (2017) also provided time series of surge plus tide levels for the 2%, 1%, 0.2%, 0.1% AEP and the future climate 1% AEP to determine storm tide flooding in the Mackay CBD.

2.2.7 Bakers Creek / Walkerston Flood Study

WRM completed a flood study of Bakers Creek in 2013 (WRM, 2013). Flood discharges within the Bakers Creek catchment were estimated using the XP-RAFTS runoff-routing model. The TUFLOW hydrodynamic model was used to simulate the flow behaviour of Bakers Creek from the eastern side of Marian to the mouth of the creek. The TUFLOW model includes the townships of Walkerston and Bakers Creek.

The XP-RAFTS and TUFLOW models were calibrated to the January 2007 and February 2008 flood events. The calibrated XP-RAFTS and TUFLOW models were used to estimate design discharges and peak flood levels in Bakers Creek for events up to the PMF.

WRM (2021c) updated the Bakers Creek / Walkerston Flood Study using the updated rainfalls and methodology recommended in ARR (Ball et al, 2019). The XP-RAFTS and TUFLOW models of Bakers Creek were refined and then calibrated to the Tropical Cyclone Debbie (TC Debbie) March 2017 event.

2.2.8 Bakers One Catchment Stormwater Trunk Drainage Study (WRM, 2015)

WRM (2015) prepared a stormwater trunk drainage infrastructure study for the Ooralea Development Area (ODA) located within the Bakers One catchment, a tributary of Bakers Creek. A runoff-routing model (XP-RAFTS) was used to estimate design flood discharges in the catchment. A two-dimensional unsteady flow hydraulic model (TUFLOW) was used to estimate flood levels in catchment. The models were calibrated to surveyed peak flood level data at various locations throughout the catchment.

The calibrated TUFLOW model was used to investigate flood behaviour for existing conditions (based on the 2015 catchment conditions) as well as the Ultimate Development Scenario for the ODA.

2.2.9 McCreadys Creek South

WRM (2017) prepared a stormwater trunk drainage infrastructure study for the Richmond Development Area (RDA) located within the McCreadys Creek catchment. A runoff-routing model (XP-RAFTS) was used to estimate design flood discharges in the catchment. A two-dimensional unsteady flow hydraulic model (TUFLOW) was used to estimate flood levels in McCreadys Creek. The models were calibrated to surveyed peak flood level data at various locations throughout the McCreadys Creek catchment.

The calibrated TUFLOW model was used to investigate flood behaviour in McCreadys Creek for existing conditions (based on the 2017 catchment conditions) as well as the Five Year Planning Scenario and Ultimate Development Scenario for the RDA.

2.3 DAMS AND WEIRS

There are a number of dams and weirs located within the Pioneer River catchment. The four major structures are Teemburra Dam, Mirani Weir, Marian Weir and Dumbleton Weir. Details of the weirs have been provided by Sunwater.

2.3.1 Teemburra Dam

Teemburra Dam is located on Teemburra Creek, some 40 km upstream of the Pioneer River confluence. Construction of the dam was completed in 1996/1997. The dam stores 147,500 ML and has a catchment area of approximately 60 km^2. Water stored in the dam is used for agricultural, industrial and domestic purposes (BOM, 2010).

2.3.2 Mirani Weir

The Mirani Weir is located on the Pioneer River, some 46 km upstream of the Pioneer River mouth. Construction of the weir was completed in 1987. The weir pool stores approximately 4,660 ML and the water stored in the weir pool is used for agricultural purposes (BOM, 2010). Figure 2.1 shows a photograph of Mirani Weir, taken in 2009.

2.3.3 Marian Weir

The Marian Weir is located on the Pioneer River, some 30 km upstream of the Pioneer River mouth. Construction of the weir was completed in 1952. The weir pool stores approximately 3,830 ML and the water stored in the weir pool is used for agricultural and industrial purposes. Figure 2.2 shows a photograph of Marian Weir, taken in 2009.

2.3.4 Dumbleton Weir

The Dumbleton Weir is located on the Pioneer River, some 16 km upstream of the Pioneer River mouth. Initial construction of the weir was completed in 1982, with Stage 2 construction completed in 1992. Stage 3, which consists of an inflatable bag was installed in 1998 but removed in 2007. The weir pool (at Stage 2) stores approximately 6,000 ML and the water stored in the weir pool is used for agricultural, industrial and domestic purposes. Figure 2.3 shows a photograph of Dumbleton Weir, taken in 2009.

Figure 2.1 - Mirani Weir looking upstream (taken from the right bank)

Figure 2.2 - Marian Weir, (taken from the right bank)

Figure 2.3 - Dumbleton Weir, looking upstream (taken from the left bank)

3 Available Data

3.1 GENERAL

Available data for the calibration of the hydrologic and hydraulic models consisted of:

- recorded rainfalls (daily and sub-daily records);
- recorded water levels at stream gauging stations within the catchment;
- rating curves to convert recorded water levels to discharges at the stream gauges; and
- topographic data.

A summary of the available data is provided in the following sections.

3.2 RAINFALL DATA

Table 3.1 provides details of the available rainfall stations within and in the vicinity of the Pioneer River and Bakers Creek catchments for seven historical floods from 1958 to 2017. The rainfall data was obtained from the Commonwealth Bureau of Meteorology (BOM), the Department of Regional Development, Manufacturing and Water (RDMW) and Mackay Regional Council (MRC). Locations of the rainfall stations are shown in Figure 3.1. The available rainfall data provides a reasonable coverage of the catchment-wide rainfalls for recent flood events. As shown in Table 3.1, the rainfall data coverage for the earlier flood events is poor.

3.3 STREAMFLOW DATA

Recorded water level data and rating curves for stream gauging stations were obtained from RDMW, Sunwater and BOM. Due to unavailability of stations, equipment malfunctions or other recording problems, recorded water level data was not available at all streamflow monitoring sites for all events.

Table 3.2 shows the streamflow data available for the various model calibration and verification events at key stations. The locations of the key streamflow gauges used in the model calibration and verification are shown in Figure 3.1.

3.4 RATING CURVES

3.4.1 Overview

Rating curves for key stations throughout the Pioneer River catchment were obtained from BOM, RDMW and Sunwater. These curves were reviewed and checked, where possible, against the actual stream gaugings and the hydraulic model results. Table 3.3 summarises the data available for the rating curve review.

3.4.2 Finch Hatton/Higham's Bridge

Figure 3.2 shows the RDMW and BOM rating curves for Cattle Creek at Finch Hatton/Higham Bridge (AWRC No. 129009) gauging station. This station has only been gauged to a height of 1.3m (GH) and the rating above this height is theoretical. The BOM rating curve has been determined by correlating recorded water levels and URBS hydrologic model results using the methodology given in Wright and Malone (2008) and has been adopted in this study.

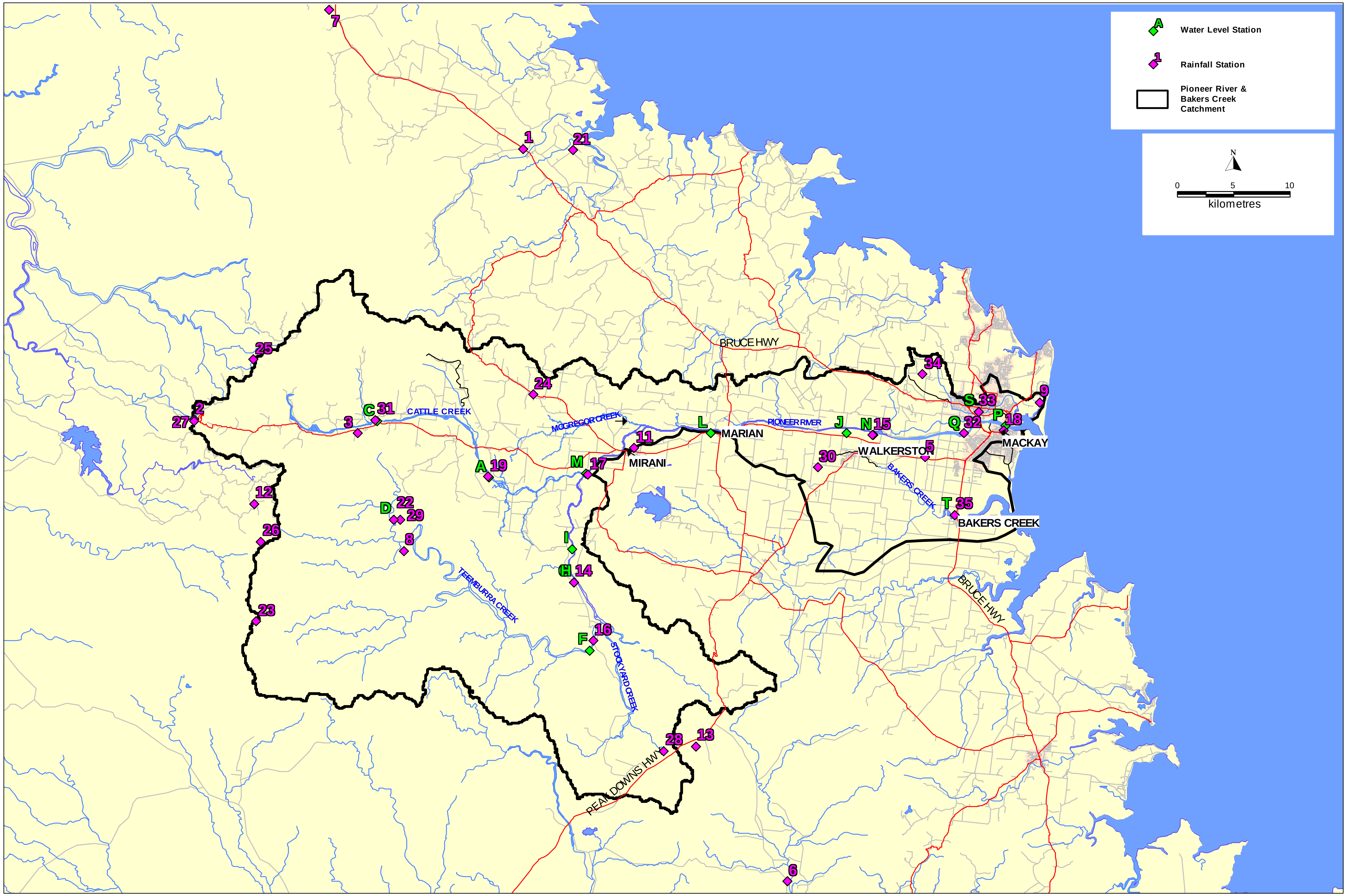

Figure 3.1 - Location of Water Level and Rainfall Stations

Table 3.1 - Rainfall Data Availability for Calibration & Verification Events

Station ID in Figure 3.1	Station No.	Station Name	Observation Interval	1958	1970	1990	2000	2007	2008	2017
1	33010	Calen Post Office	Daily	✓	x	x	x	x	x	x
2	33016	Dalrymple Heights	Daily	x	✓	✓	x	✓	✓	x
3	33026	Finch Hatton Cook St	Continuous	x	x	✓	x	x	x	x
4	33045	Mackay PO	-	x	x	x	x	✓	✓	x
5	33047	Te Kowai Exp Stn	Daily	x	✓	x	x	x	x	x
6	33087	Barnganal Blue	Continuous	x	✓	x	x	x	x	x
7	33091	Elaroo	Daily	✓	x	x	x	x	x	x
8	33099	Teemburra Ck Pluvio	Continuous	x	✓	x	x	x	x	x
9	33119	Mackay M.O	Continuous	x	✓	✓	x	✓	✓	x
10	33141	Finch Hatton	-	x	✓	x	x	x	x	x
11	33152	Mirani	Continuous	x	x	✓	x	x	x	x
12	33172	Crediton	Continuous	x	x	✓	x	x	x	x
13	33276	Doraville Stn	Continuous	x	x	✓	x	x	x	x
14	33299	Sarich's Alert	Continuous	x	x	x	✓	✓	✓	✓
15	33300	Dumbleton Rocks Alert	Continuous	x	x	x	✓	✓	✓	✓
16	33301	Whiteford's Alert	Continuous	x	x	x	✓	✓	✓	✓
17	33302	Mirani Weir Alert	Continuous	x	x	x	x	✓	✓	✓
18	33303	Mackay Alert	Continuous	x	x	x	✓	✓	✓	✓
19	33304	Gargett Alert	Continuous	x	x	x	✓	✓	✓	✓
20	33888	Sybil Creek*	-	✓	x	x	x	x	x	x
21	33999	Mt Pelion*	-	✓	x	x	x	x	x	x
22	533021	Teemburra Alert	Continuous	x	x	x	✓	x	x	x
23	533035	Plevna Alert	Continuous	x	x	x	✓	✓	✓	✓
24	533036	Dow's Ck Alert	Continuous	x	x	x	✓	✓	✓	✓
25	533037	Clarke Range Alert	Continuous	✓	x	x	✓	✓	✓	✓
26	533038	Ridgelands Alert	Continuous	x	x	x	✓	✓	✓	✓
27	533039	Eungella Alert	Continuous	x	x	x	✓	✓	✓	✓
28	533040	Hannaville Alert	Continuous	x	x	x	✓	✓	✓	✓
29	533041	Teemburra Dam Alert	Continuous	x	x	x	x	✓	✓	✓
30	533058	Greenmount Alert	Continuous	x	x	x	x	✓	✓	✓
31	533059	Finch Hatton Alert	Continuous	x	x	x	x	✓	✓	✓
32	533060	Hospital Br Alert	Continuous	x	x	x	x	✓	✓	✓
33	533061	Gooseponds Alert	Continuous	x	x	x	x	✓	✓	✓
34	533062	Rowallan Park Alert	Continuous	x	x	x	x	✓	x	x
35	533063	Bakers Ck Alert	Continuous	x	x	x	x	✓	✓	✓

× *Data unavailable or incomplete* ✓ *Data available* ** Location unknown*

Table 3.2 - Streamflow Data Availability for Calibration & Verification Events

Station ID in Figure 3.1	Station No.	Station Name	Stream	1958	1970	1990	2000	2007	2008	2017
A	125004A/B	Gargett	Cattle Creek	x	✓	✓	✓	✓	✓	✓
C	125009	Finch Hatton TM	Cattle Creek	x	x	x	P	✓	✓	✓
D	125912	Teemburra Dam Alert	Teemburra Creek	x	x	x	x	x	✓	✓
E	-	Teemburra Dam	Teemburra Creek	x	x	x	x	✓	✓	X
F	125005A	Whitefords	Blacks Creek	x	x	✓	✓	✓	✓	✓
G	125002	Sarich's TM	Pioneer River	✓	✓	✓	✓	✓	✓	✓
H	125909	Sarich's Alert	Pioneer River	x	x	x	x	✓	✓	✓
I	125902	Mia Mia	Pioneer River	x	x	x	P	x	x	x
J	125001C	Pleystowe	Pioneer River	x	x	x	✓	x	x	x
K	125001A	Pleystowe Mill	Pioneer River	✓	✓	x	x	x	x	x
L	125003A	Marian Weir	Pioneer River	x	✓	x	x	x	x	x
M	125008A	Mirani Weir HW	Pioneer River	x	x	x	✓	✓	✓	✓
N	125013A	Dumbleton Pump Stn	Pioneer River	x	x	x	✓	✓	✓	✓
O	-	Mirani Town	Pioneer River	✓	✓	x	✓	x	x	X
P	125903	Mackay	Pioneer River	✓	✓	P	✓	✓	✓	✓
Q	125914	Hospital Br Alert	Pioneer River	x	x	x	✓	✓	✓	✓
R	125905	Mackay Outer Harbour	Mackay Harbour	✓	✓	✓	x	x	x	✓
S	125915	Goosepongs Alert	Goosepongs	x	x	x	x	✓	✓	✓
T	125916	Bakers Ck Alert	Bakers Creek	x	x	x	x	✓	✓	✓

- Station No. Unknown × Data unavailable/ incomplete ✓ Data available P Peak Level only

Table 3.3 - Data Available for Stream Gauge Rating Table Review

URBS Gauging Station	Available Data		Maximum Gauged Discharge (m³/s)
	BOM Curve	RDMW/Sunwater Curve	
Finch Hatton	✓	✓	-
Gargett (125004a)	✓	✓	465
Gargett (125004b)	✓	✓	1,219
Whitefords	✓	✓	1,655
Sarichs	✓	✓	1,812
Mia Mia	x	✓	-
Mirani Headwater	✓	✓	-
Mirani Tailwater	✓	✓	3,145
Mirani Town	✓	x	-
Marian Weir	x	✓	4
Dumbleton HW	✓	✓	-
Dumbleton TW	x	✓	2,477
Pleystowe Recorder	x	✓	-
Pleystowe Mill	✓	✓	1,066
Hospital Bridge	✓	x	-
Mackay	✓	x	-

- No recorded gaugings

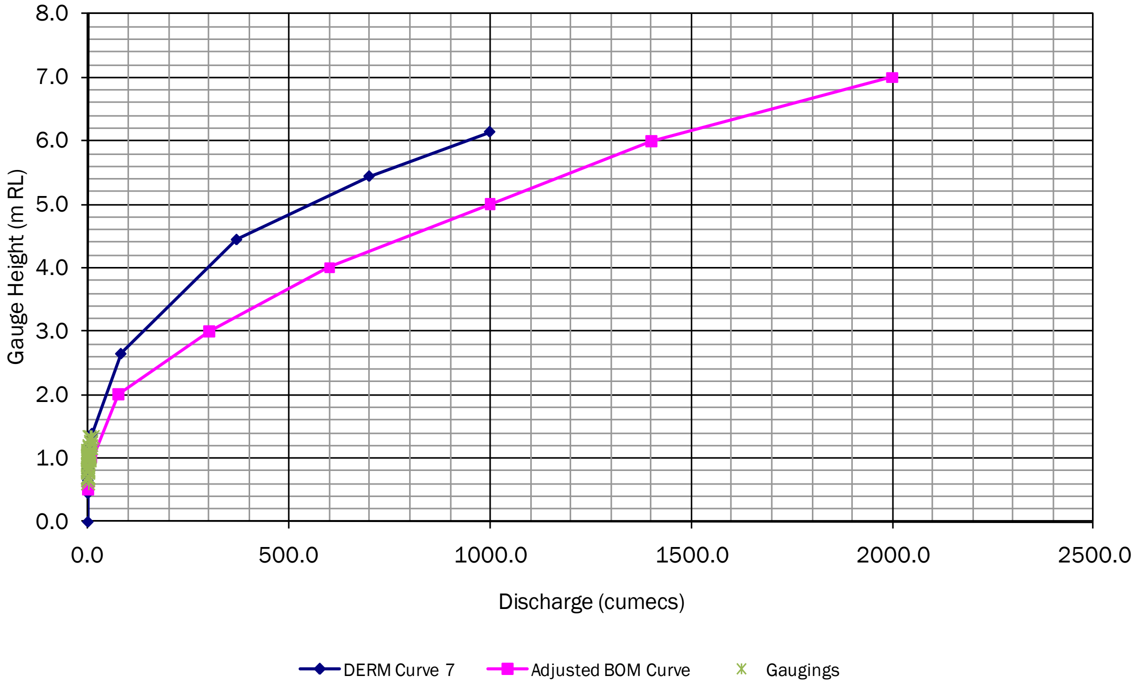

Figure 3.2 - Rating Curves and Recorded Gaugings, Cattle Creek at Finch **Hatton/Higham's Bridge**

3.4.3 Gargett, Gargett Bridge & D/S Gargett Bridge

Figure 3.3 shows the available rating curves for the gauging stations on Cattle Creek at Gargett (AWRC No. 125004a&b). A new low flow control was constructed in 1986 and the gauging station name was changed from 'a' to 'b' to signify the change. The RDMW high flow rating for the two stations are virtually unchanged.

The RDMW rating curves for Gargett are based on gauged data up to 1,219 m^3/s (7.12m GH). The rating curves have been extrapolated by RDMW beyond the gauged limits. The RDMW rating curves have been modified by BOM to provide discharges that are more consistent with discharges at upstream and downstream stations. However, the RDMW rating curves have been adopted in this study to be consistent with the gauged data.

3.4.4 Whitefords

Figure 3.4 shows the available BOM and RDMW rating curves together with recorded gaugings for the Whitefords (AWRC No. 125005a) gauging station on Blacks Creek. The RDMW rating curve is based on gauged data up to 1,655 m^3/s (7.102m GH) and has been adopted for this study.

3.4.5 Sarichs

Figure 3.5 shows the BOM and RDMW rating curves with recorded gaugings for the Sarichs (AWRC No. 125002c) gauging station on the Pioneer River. The RDMW rating curve for Sarichs is based on gauged data up to 1,812 m^3/s (9.63m GH). The rating curve has been extrapolated by RDMW beyond that discharge. The high flow component of the RDMW rating curve has been modified by BOM to provide high flows that are more consistent with high flows at upstream and downstream stations. The BOM curve has been adopted in this study as it appears to provide a better fit with the gauged data.

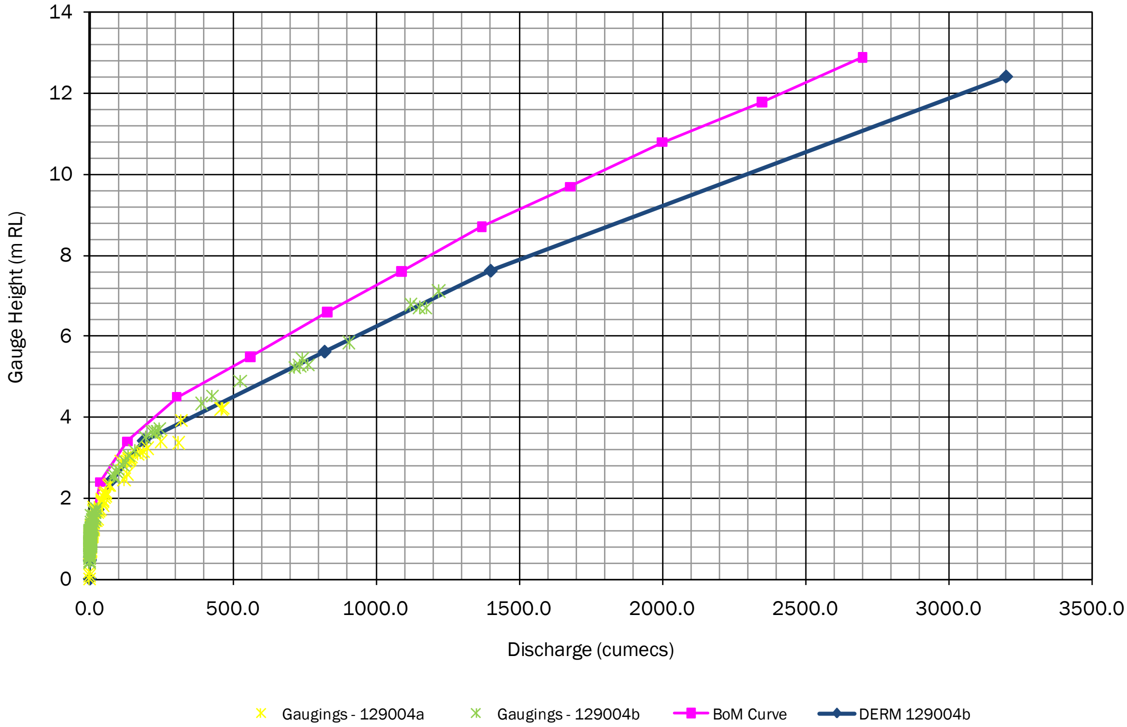

Figure 3.3 - Rating Curves and Recorded Gaugings, Cattle Creek at Gargett

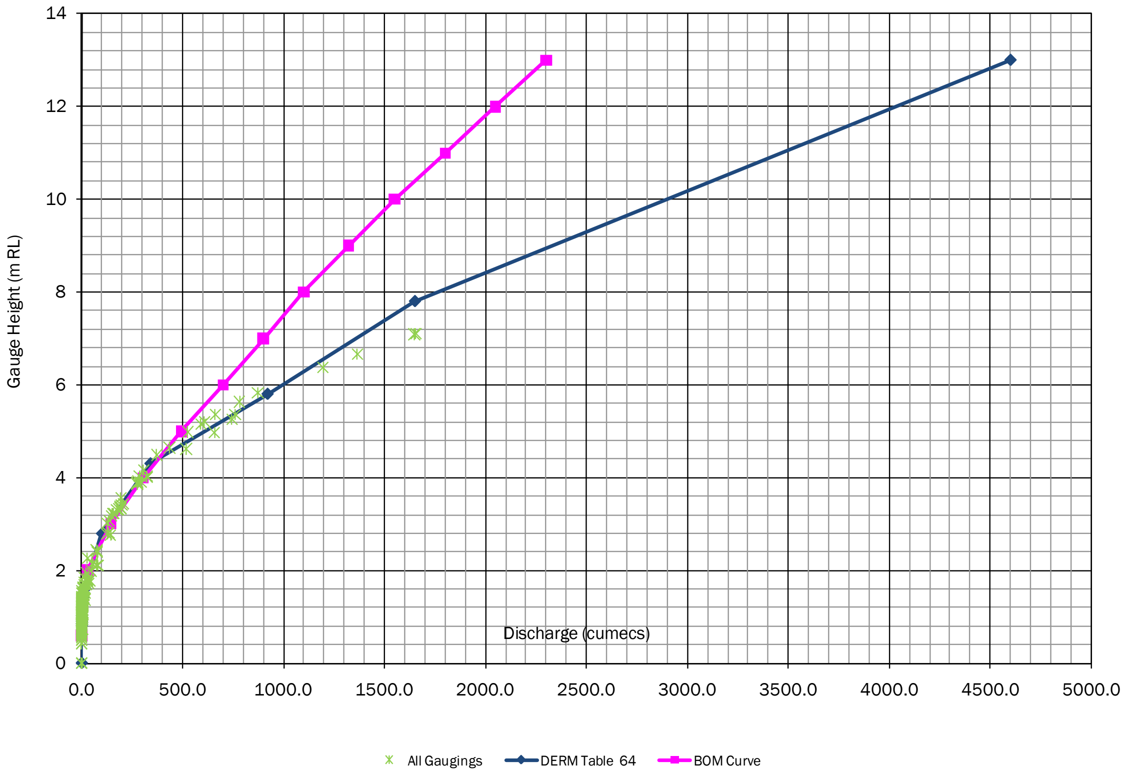

Figure 3.4 - Rating Curves and Recorded Gaugings, Blacks Creek at Whitefords

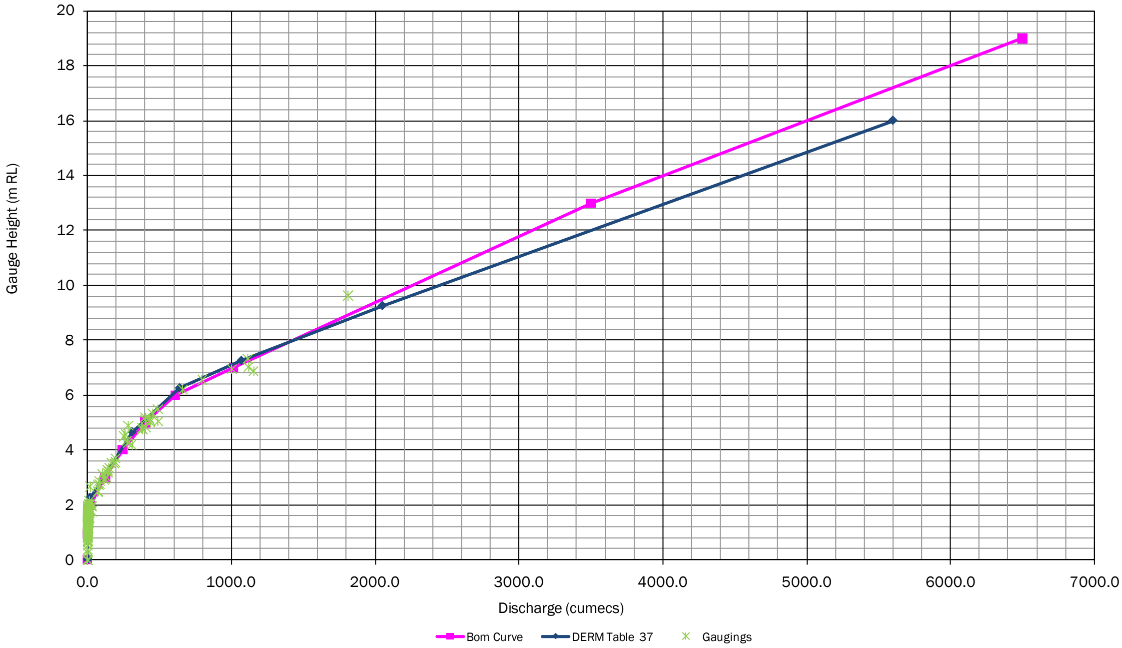

Figure 3.5 - Comparison of Rating Curves with Recorded Gaugings, Pioneer River at Sarichs

3.4.6 Mia Mia

Figure 3.6 shows the BOM curve for the Mia Mia (AWRC No. 125902) gauging station on the Pioneer River. This station has not been gauged and therefore this is a theoretical rating curve. A peak water level height is known for the 2000 flood at this station only. In the absence of better data, the BOM rating curve has been adopted in this study.

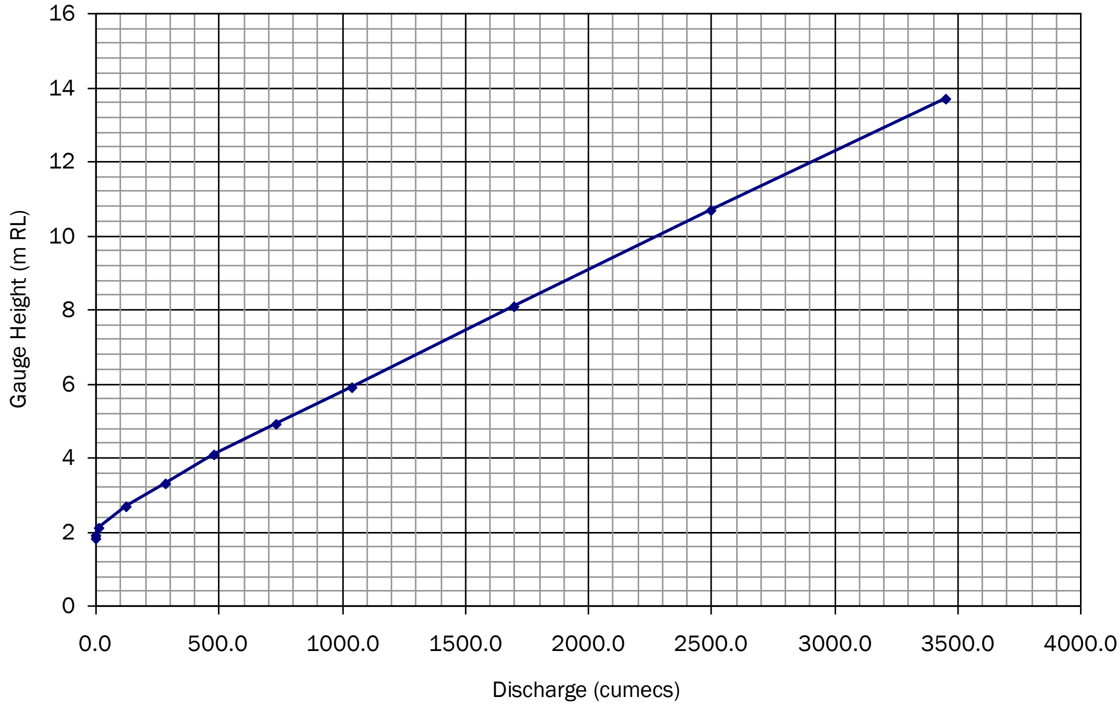

Figure 3.6 - Rating Curve, Pioneer River at Mia Mia

3.4.7 Mirani Weir Headwater

Figure 3.7 shows the BOM and RDMW rating curves for the Mirani Weir Headwater (AWRC No. 125008a) gauging station. The Mirani Weir Headwater rating curve is not based on gauging and is not used in this study.

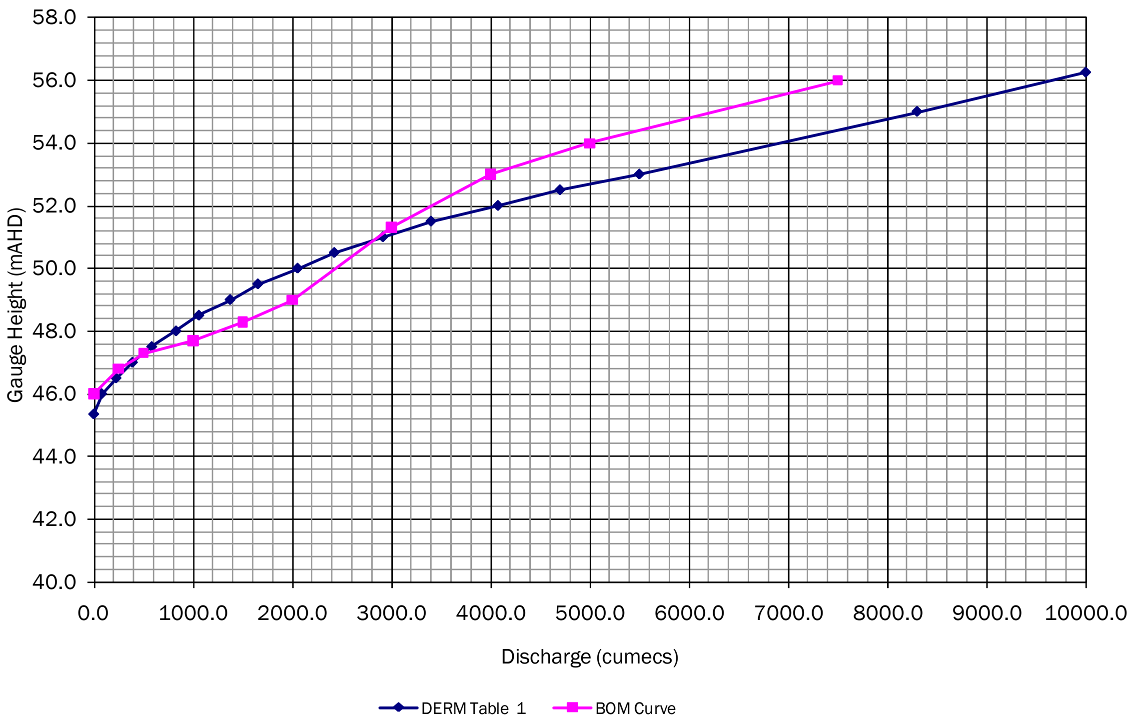

Figure 3.7 - Rating Curves, Pioneer River at Mirani Weir Headwater

3.4.8 Mirani Weir Tailwater

Figure 3.8 shows the BOM and RDMW rating curves with recorded gaugings for the Pioneer River at Mirani Weir Tailwater (AWRC No. 125007a) gauging station. The two curves effectively overlie each other. These ratings are based on gauged data up to 3,145 m^3/s (10.79m GH & 45.06m AHD). Also shown is the stage discharge relationship for the rising limb of the 1958 flood as estimated by the TUFLOW hydraulic model developed for this study. A description of the hydraulic model calibration is given in Section 5. There is an excellent correlation between the TUFLOW model results and the rating curves up to a flood depth of 15m GH (49m AHD). The TUFLOW model results deviate slightly above this depth. It is expected that the TUFLOW model curve would be more accurate for the higher flows, given that the BOM and RDMW curves are theoretical above this level. The TUFLOW rating curve has been adopted for this study.

3.4.9 Mirani Town

Figure 3.9 shows the BOM curve for the Mirani Town gauging station on the Pioneer River. There is no RDMW rating curve for Mirani Town station. Further, this station has not been gauged. BOM has developed this curve by correlating water levels at this station with water levels and discharges at Mirani Weir Tailwater station. Also shown is the stage discharge relationship for the rising limb of the 1958 flood as estimated by the TUFLOW hydraulic model. A description of the hydraulic model calibration is given in Section 5. The adopted curve, which is largely based on the hydraulic model results are also shown.

It is noted that the historical water levels at the Mirani Town Gauge are likely to be impacted by the road bridge, which was only upgraded in the late 1980s. Details of the old bridge were not available for this study. It is also possible that the water levels at the gauge are impacted by the McGregor Creek inflows downstream of the gauge.

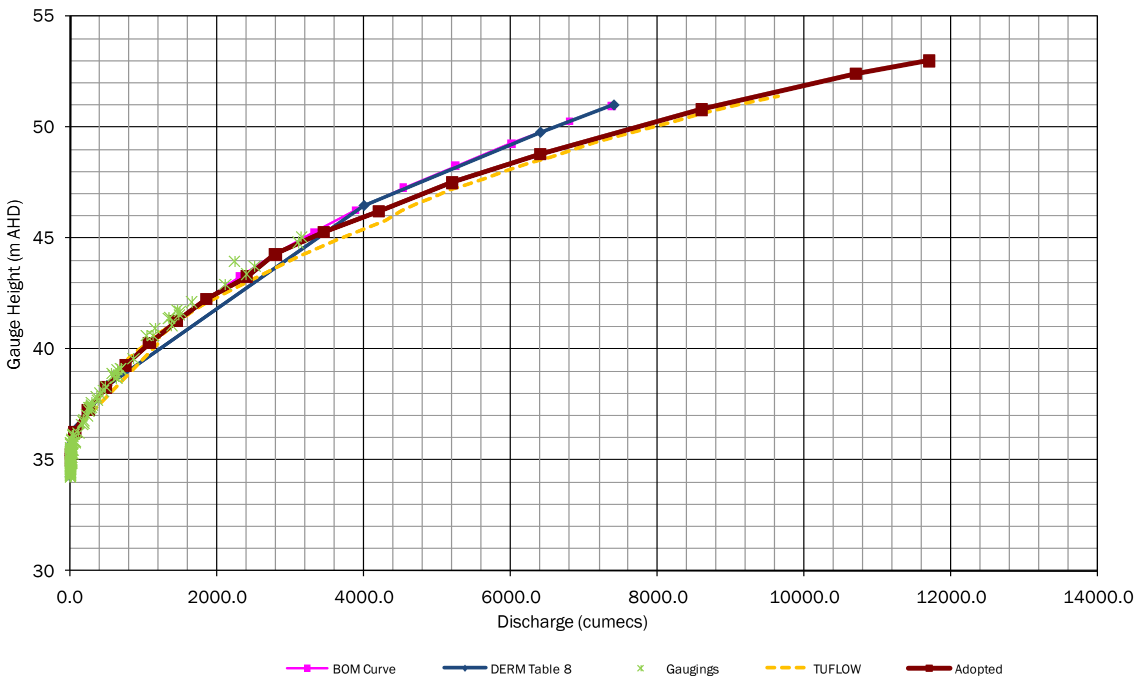

Figure 3.8 - Rating Curves and Recorded Gaugings, Pioneer River at Mirani Weir Tailwater

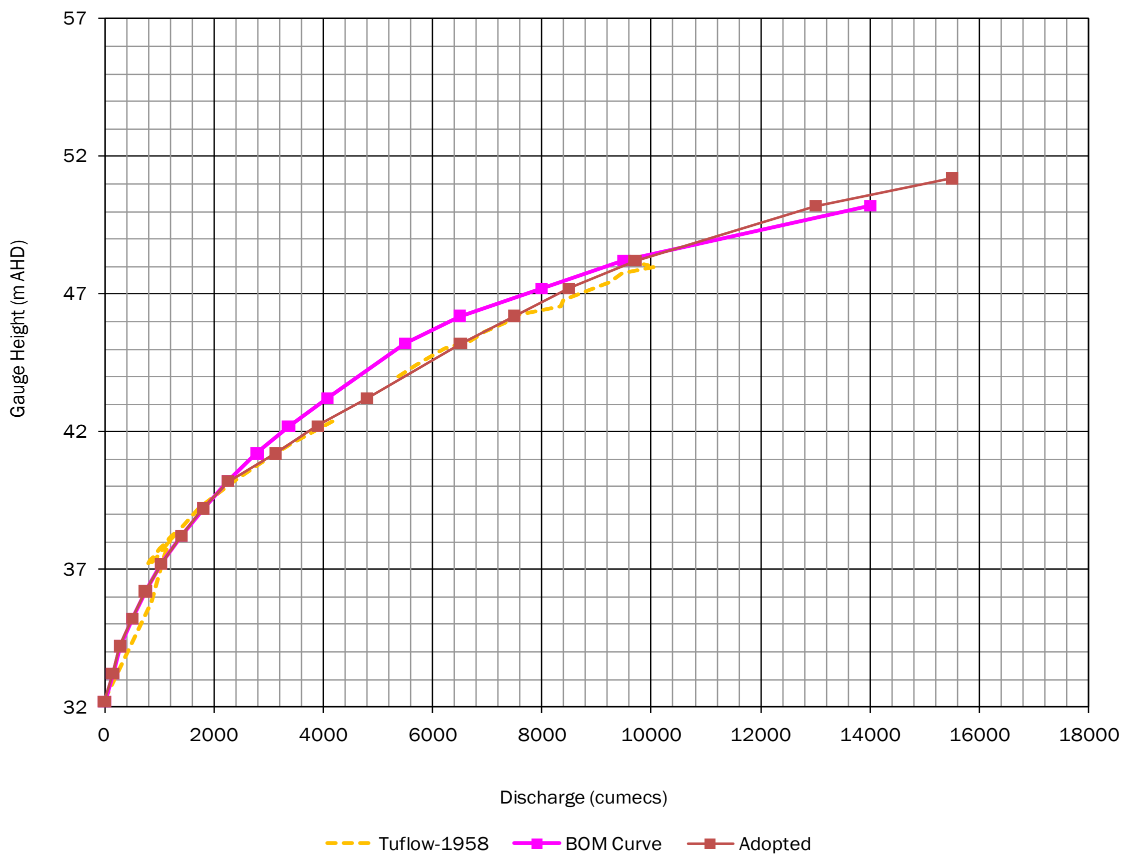

Figure 3.9 - Rating Curves, Pioneer River at Mirani Town

3.4.10 Marian Weir

Figure 3.10 shows the RDMW rating curves and recorded gaugings at the Marian Weir (Headwater) (RDMW No. 125003a) gauging station on the Pioneer River. Note that this station is gauged only up to 4.2 m^3/s (6.13m GH). There was no BOM rating curve for the Marian Weir gauging station. The TUFLOW stage discharge relationship for the 1958 flood event is also shown. The TUFLOW model results closely resemble the theoretical rating at Marian Weir and have been adopted for this study.

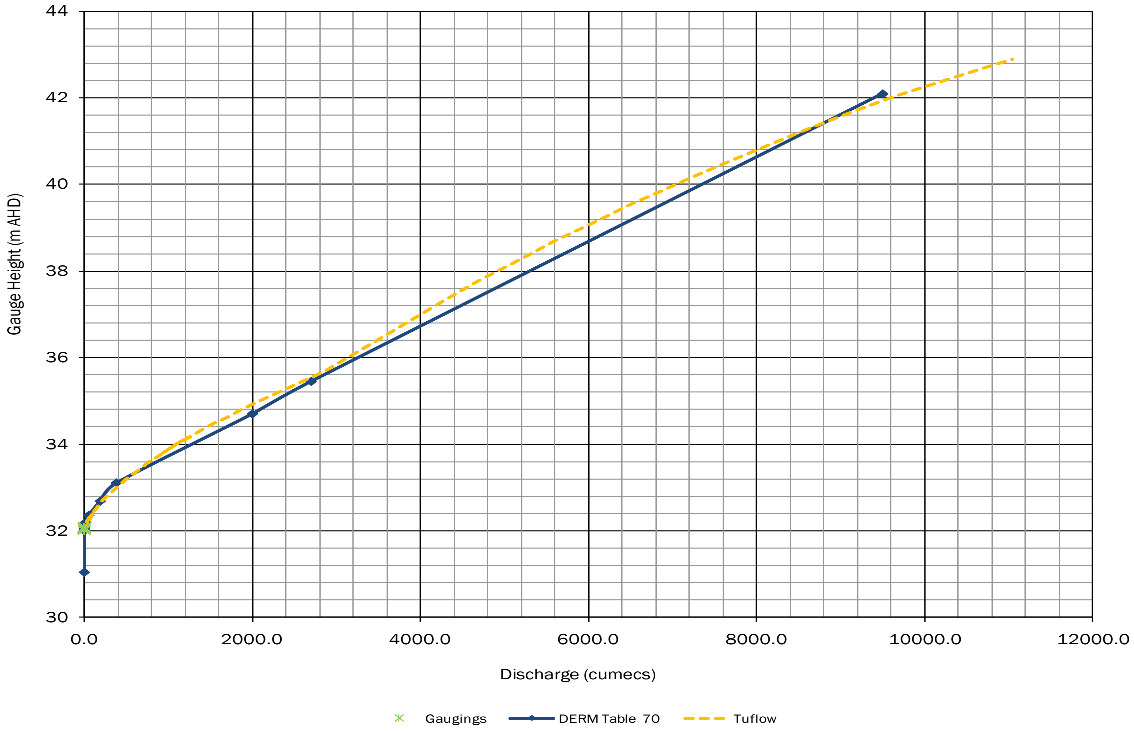

Figure 3.10 - Rating Curve & Recorded Gaugings, Pioneer River at Marian Weir

3.4.11 Dumbleton Weir Headwater

Figure 3.11 shows the BOM and RDMW rating curves for the Dumbleton Pump Station (RDMW No. 125013A & BOM No. 125013 (TM Station)) gauging station located in the Dumbleton Weir pool. This rating curve is not based on gaugings. BOM has modified the RDMW rating curve for this station to provide discharges more consistent with discharges at upstream and downstream stations. The stage discharge relationship at this station as derived by the TUFLOW hydraulic model for the February 2008 event is also shown. The TUFLOW model generally over-predicts peak flood levels at this location when compared to the theoretical rating curves. The TUFLOW derived curve has been adopted for this study.

3.4.12 Dumbleton Weir Tailwater

Figure 3.12 shows the RDMW rating curve and recorded gaugings for the Pioneer River at Dumbleton Tailwater (RDMW No. 125016a) gauging station. The RDMW rating curve is based on gauged data up to 2,477 m^3/s (13.78 mAHD). The latest RDMW curve was adopted for this study. The TUFLOW stage discharge relationship for the 1958 calibration event is also shown. A discussion of the differences between the TUFLOW derived curve and the RDMW rating curve is given in Section 4.4.

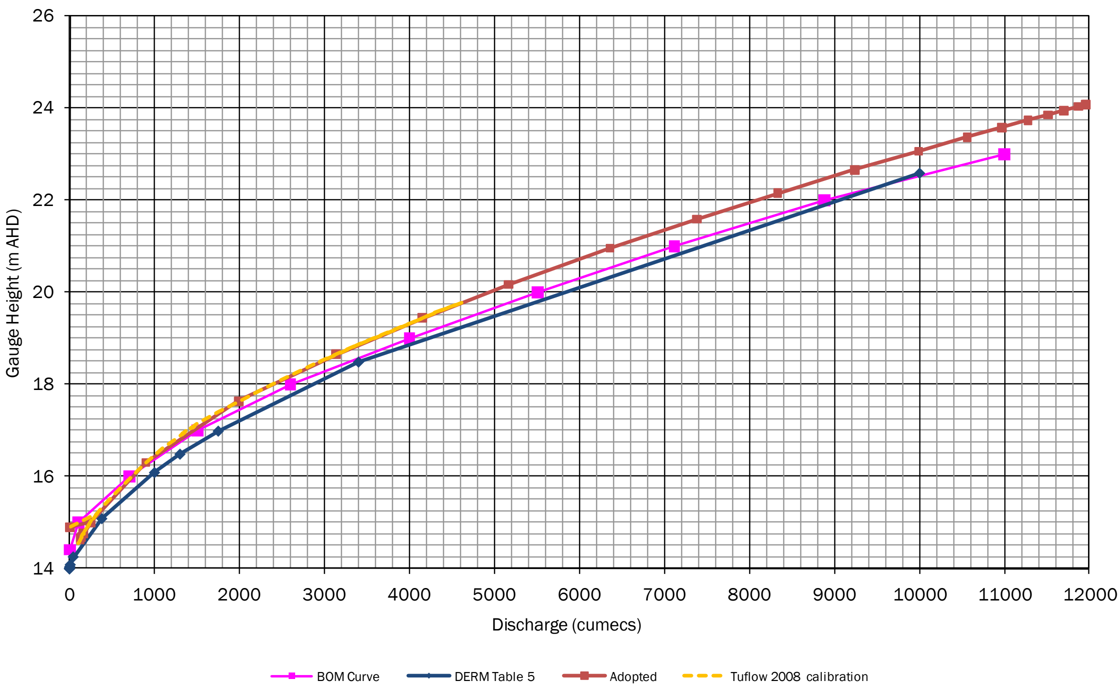

Figure 3.11 - Rating Curves, Pioneer River at Dumbleton Weir Headwater

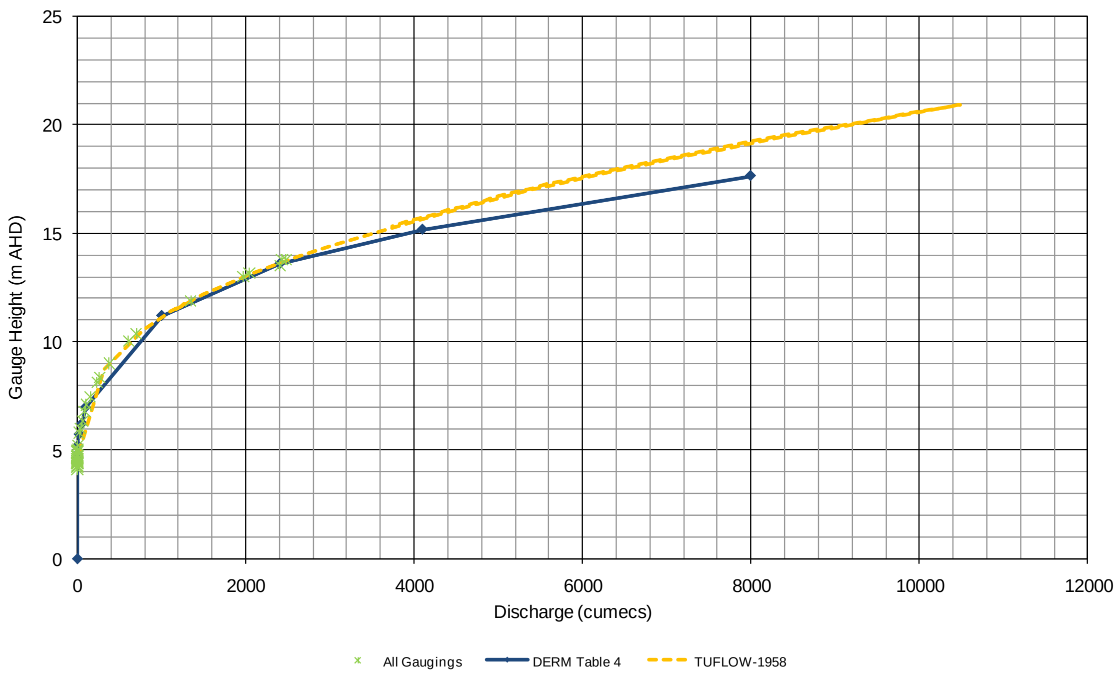

Figure 3.12 - Rating Curves & Recorded Gaugings, Pioneer River at Dumbleton Weir Tailwater

3.4.13 Pleystowe Mill & Recorder

Figure 3.13 shows the BOM and RDMW rating curves and recorded gaugings for the Pioneer River at Pleystowe Mill (AWRC No. 125001a) gauging station. The recorded gaugings at the Pioneer River at Pleystowe (AWRC No. 125001b) gauge, which is located some 200 m downstream, are also shown. The water level for each of the 125001b gaugings have been adjusted to correspond to the expected water level at the 125001a gauge using the hydraulic model results.

The RDMW rating curve is based on gauged data up to 4,664 m^3/s (11.567m GH & 19.135 mAHD) and is almost identical to the BOM curve. This station is located within the Dumbleton weir pool and as such is only relevant for historical flows prior to 1983. The TUFLOW stage discharge relationship for the rising limb of the 1956 flood at this station is also shown and has been adopted for this study.

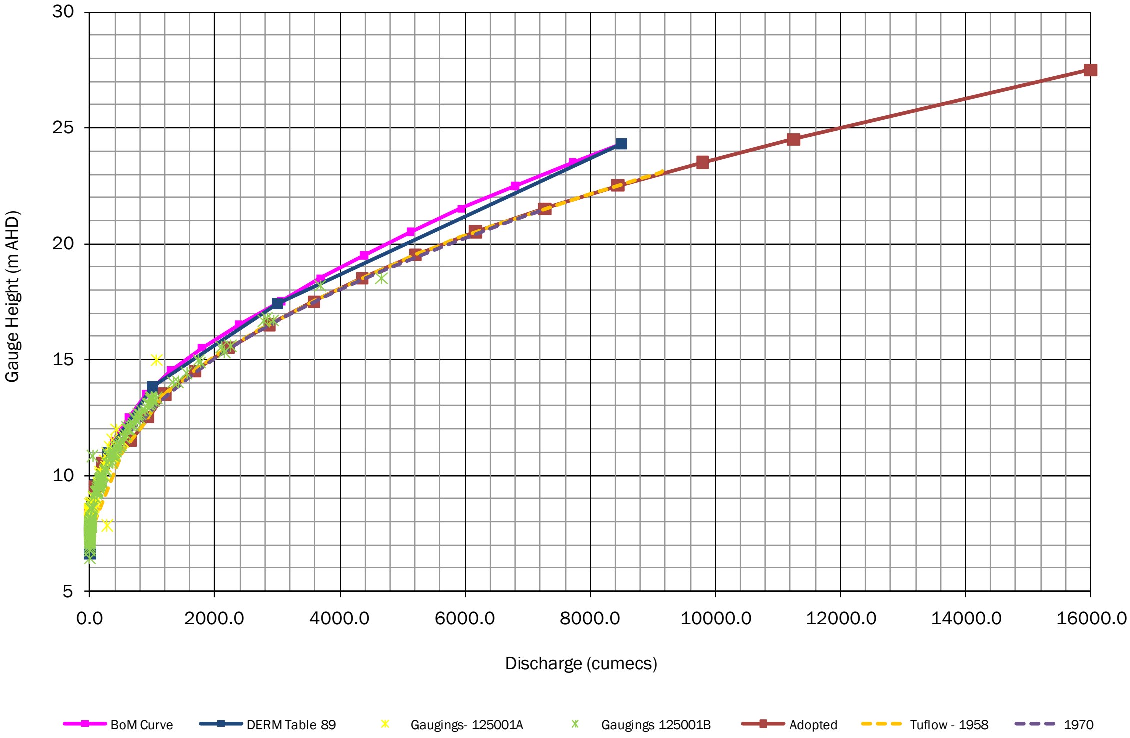

Figure 3.13 - Rating Curves & Recorded Gaugings, Pioneer River at Pleystowe Mill

3.4.14 Hospital Bridge

Figure 3.14 shows the BOM rating curves for the Pioneer River at Hospital Bridge (AWRC No. 125914) gauging station. Water levels at this station are influenced by tide levels at the river mouth. Hence, BOM has derived a set of downstream water level dependent rating curves for this station. The BOM rating curves have been adopted for this study. Note that there are significant uncertainties when using this rating curve, especially for small to medium discharges.

3.4.15 Mackay at Forgan Bridge

Figure 3.15 shows the BOM rating curve for the Pioneer River at Mackay (Forgan Bridge) (AWRC No. 125903) gauging station. There is no RDMW rating curve for this station. Water levels at this station are influenced by tide levels at the river mouth. Hence, BOM has derived a set of downstream water level dependent rating curves for this station. The BOM rating curves have been adopted for this study. Note that there are significant uncertainties when using this rating curve, especially for small to medium discharges.

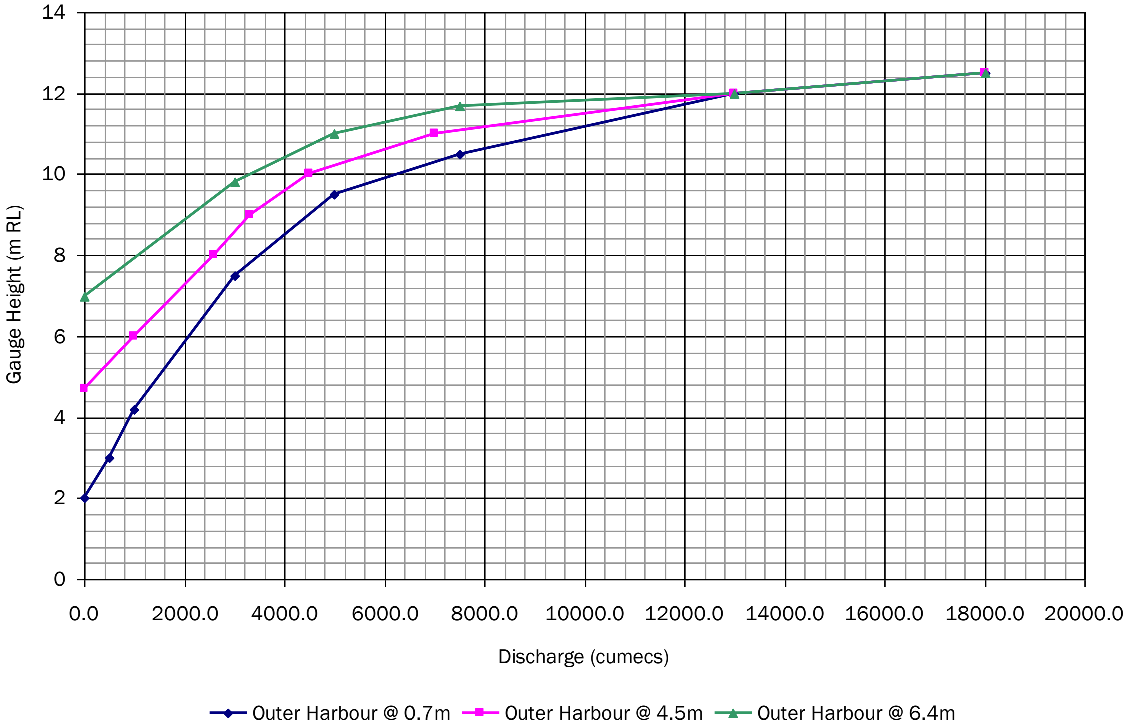

Figure 3.14 - BOM Rating Curve, Pioneer River at Hospital Bridge

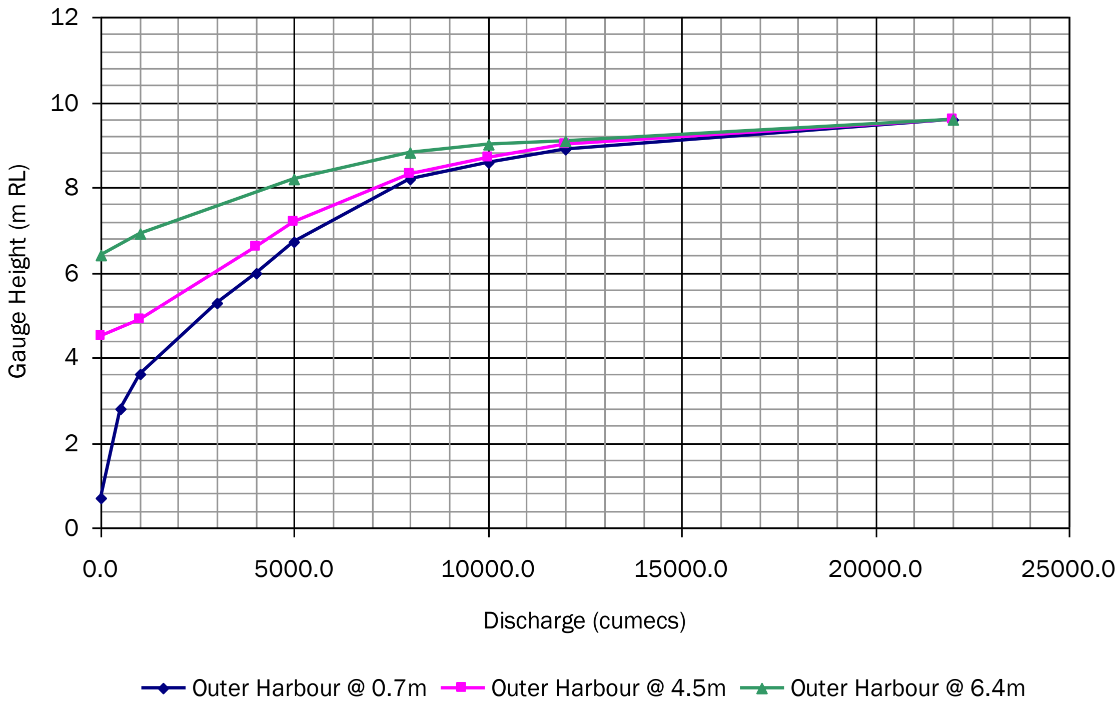

Figure 3.15 - BOM Rating Curve, Pioneer River at Mackay (Forgan Bridge)

3.5 STAGE-STORAGE-DISCHARGE RELATIONSHIPS

3.5.1 Teemburra Dam

Teemburra Dam is located in the upper Pioneer River catchment on Teemburra Creek. Figure 3.16 shows the water level-storage and water level-spillway discharge relationships obtained from BOM (Sunwater data was unavailable). The adopted dam storage capacity at spillway level (290m RL) is approximately 147,500 ML.

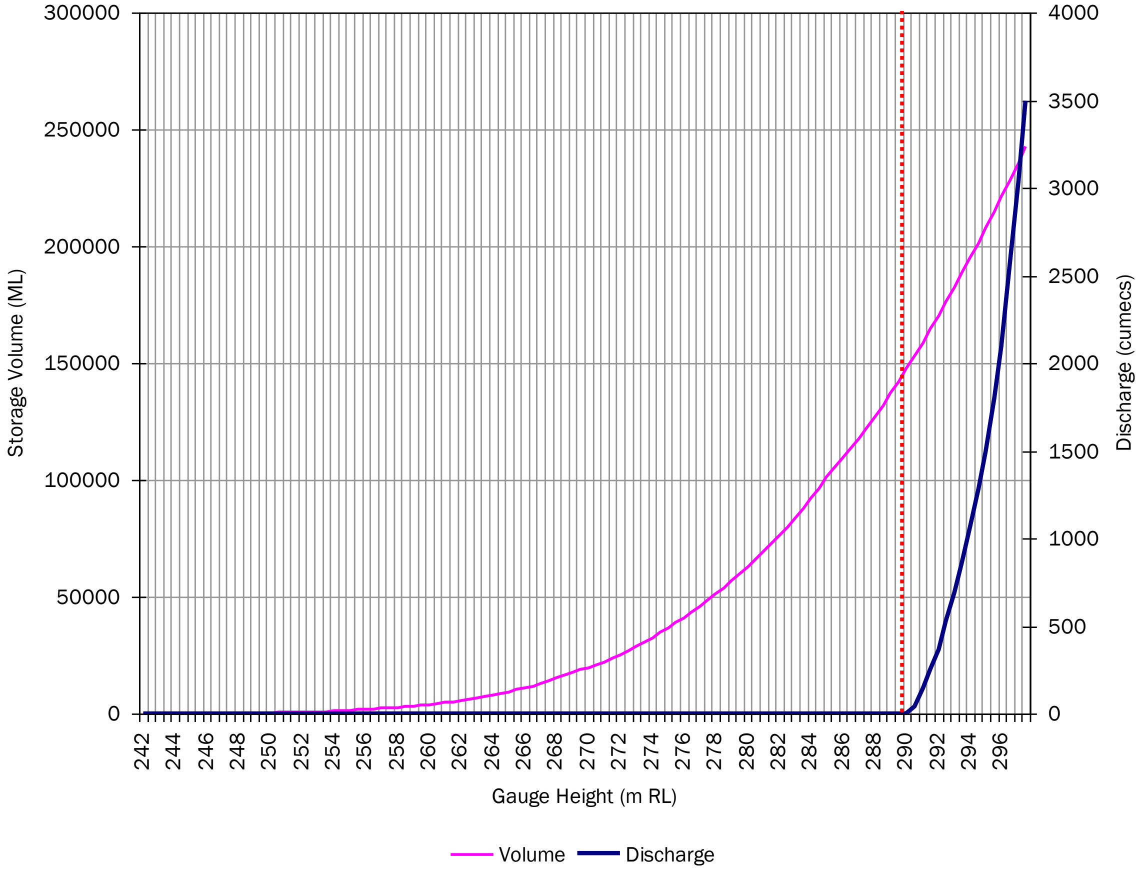

Figure 3.16 - Adopted Stage-Storage and Stage-Spillway Discharge Curves for Teemburra Dam

3.5.2 Mirani Weir

Figure 3.17 shows the water level-storage and water level-spillway discharge relationships for Mirani Weir obtained from RDMW. The adopted dam storage capacity at spillway level (47m RL) is approximately 4,660 ML.

3.5.3 Marian Weir

Figure 3.18 shows the water level-storage and water level-spillway discharge relationships for Marian Weir obtained from RDMW. The adopted dam storage capacity at spillway level (31.9m RL) is approximately 3,830 ML.

3.5.4 Dumbleton Weir

Figure 3.19 shows the water level-storage and water level-spillway discharge relationships for the Dumbleton Weir obtained from RDMW. The adopted dam storage capacity at spillway level (14.4m RL, Stage 2) is approximately 6,540 ML.

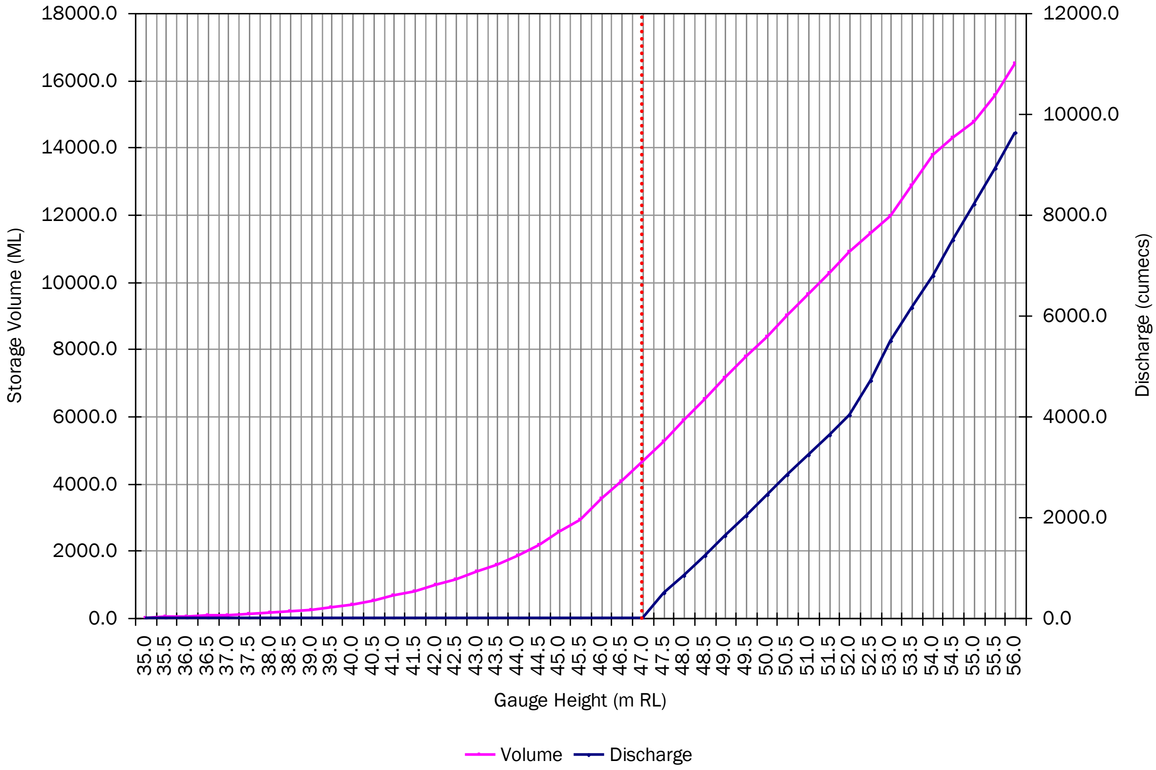

Figure 3.17 - Adopted Stage-Storage and Stage-Spillway Discharge Curves for Mirani Weir

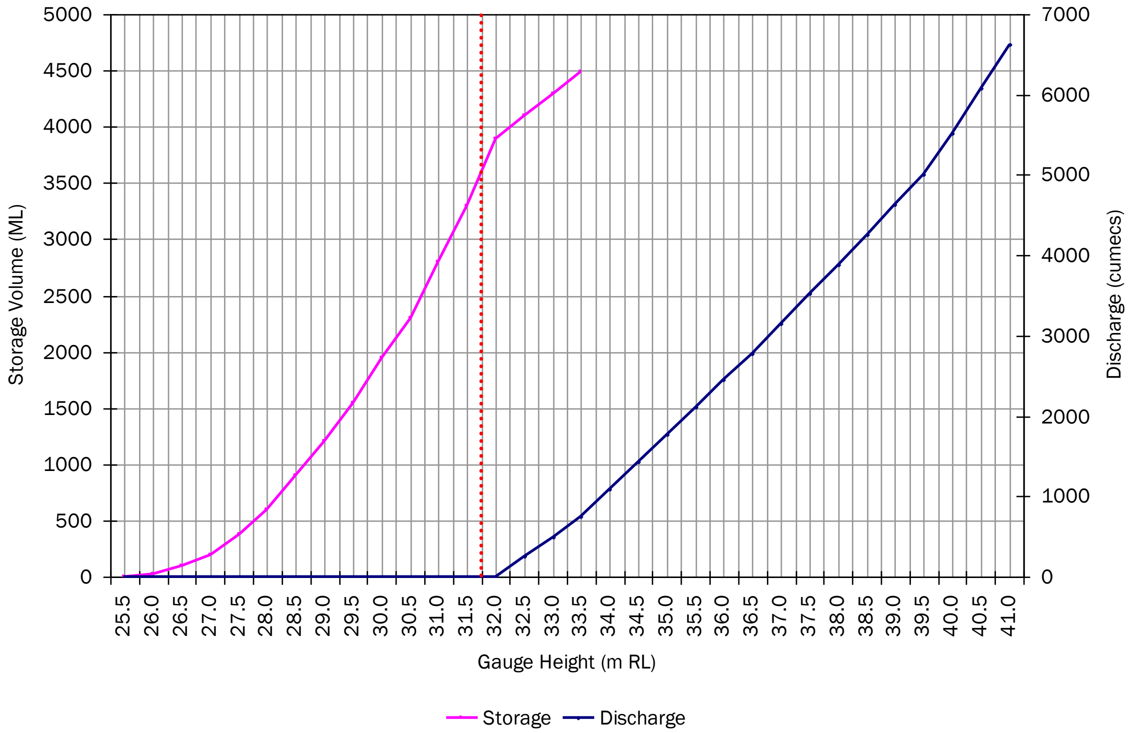

Figure 3.18 - Adopted Stage-Storage and Stage-Spillway Discharge Curves for Marian Weir

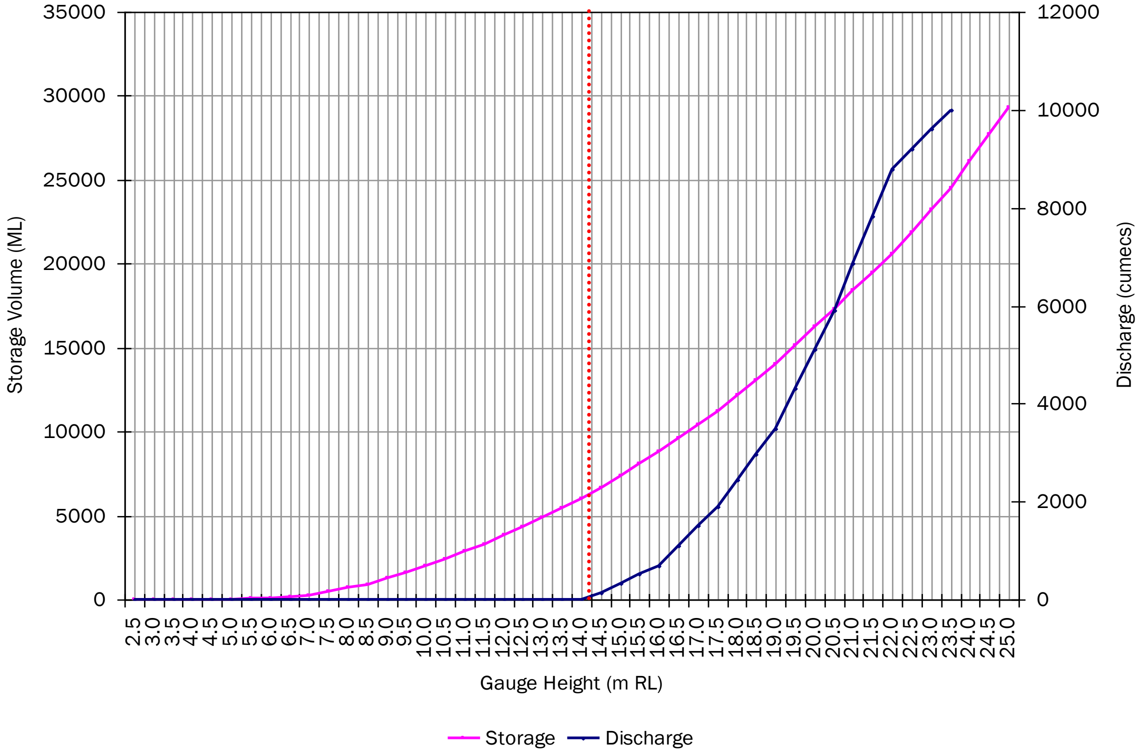

Figure 3.19 - Adopted Stage-Storage and Stage-Spillway Discharge Curves for Dumbleton Weir

3.6 TOPOGRAPHIC DATA

A digital terrain model (DTM) of the lower Pioneer River catchment was provided by Fugro Spatial Solutions Pty Ltd via MRC and the Queensland Department of Environment and Resource Management (DERM) and was obtained by LiDAR capture in July and December 2009 (referred as 2009 LiDAR). RPS Group Australia also provided bathymetry survey for the tidal reaches of the Pioneer River (downstream of the Dumbleton Weir) and Bakers Creek (downstream of the Bruce Highway crossing). The survey was captured during the first half of 2010. The 2009 LiDAR was used for the Pioneer River flood studies between 2011 to 2015.

The TUFLOW hydraulic model in this study was updated to use the LiDAR data captured in 2015 (except for calibration events prior to 2015). This data was commissioned by the Department of Natural Resources and Mines (DNRM) and was captured in August 2015 and has a vertical accuracy of 0.15 m (AAM, 2016). Updated bathymetry survey (undertaken in 2017) for the tidal reaches of the Pioneer River (downstream of the Dumbleton Weir) was also provided by MRC.

Figure 3.20 shows the ground level difference between 2015 LiDAR and 2009 LiDAR. The difference between the 2015 LiDAR and 2009 LiDAR are mostly within 0.15 m, except for isolated areas of sugarcane, a band near Marian and in the Pioneer River channel. The different survey levels in Marian are potentially due to sugarcane. The different LiDAR survey levels along Pioneer River are due to the different water levels at the time of survey. The Pioneer River channel is modelled using 1d cross sections and these sections are assumed to be unchanged.

The 2015 LiDAR data and the bathymetry data were combined to create the DTM used as the ground surface for the hydraulic model.

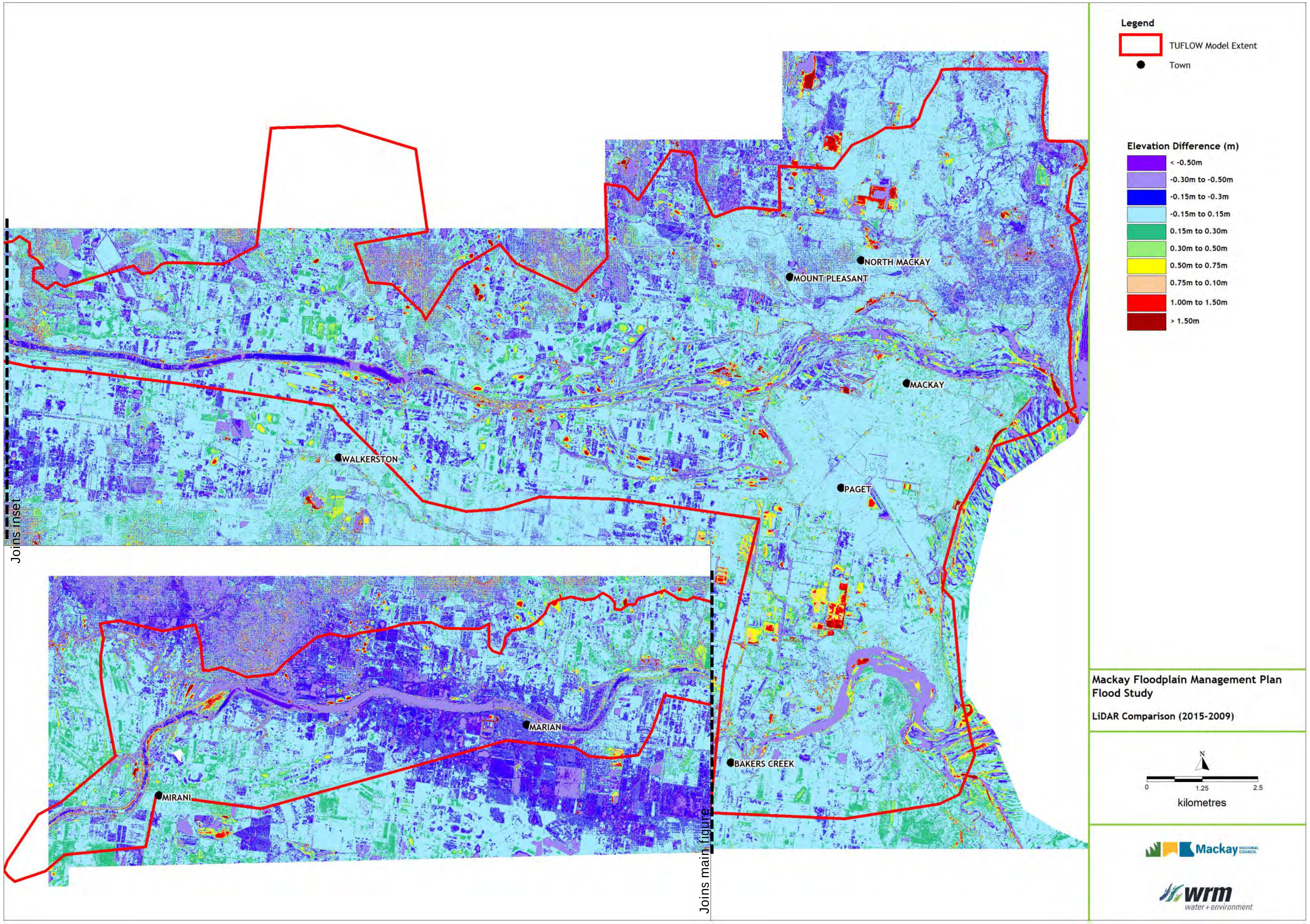

Figure 3.20 - LiDAR comparison

The following changes were made to the DTM:

- The LiDAR DTM was supplemented with ground survey provided Mackay Regional Council of the existing flood protection levees. Survey was available for the following levees.
  - The Mackay City Levee from Shakespeare St along the southern bank of the Pioneer River to Lluka Park adjacent to Binnington Esplanade.
  - The Gooseponds Creek levee between Harrington St and Malcomson St in North Mackay.
  - The Gooseponds Creek levee from Evans Ave to Sapphire Ct in North Mackay.
  - The Vines Creek levee in North Mackay along Grendon St and from Shinn St along Harbour Rd to Vine St.
  - The river training wall between the old Hospital Bridge and the Ron Camm Bridge.
  - The levee around the Valetta Gardens Estate in Glenella.
  - The Gordon Street upgrade roadworks near the Bruce Highway.
- Bathymetry data of the Pioneer River channel within the Marian Weir and Dumbleton Weir pools was interpolated from cross sections of the river provided by Sunwater. The weir pool cross sections were surveyed as part of a siltation study undertaken by Sunwater from the late 1980s to the early 1990s. More recent bathymetry data of the weir pools was not available.
- The Mackay Ring Road from Racecourse to Glenella was completed in 2020 and was captured in the LiDAR data acquired in June 2021 (referred as 2021 LiDAR). The road embankments of the Mackay Ring Road were included in the hydraulic model using the 2021 LiDAR.

4 Hydrologic model configuration and calibration

4.1 OVERVIEW

The Pioneer River design discharges have been estimated using the URBS rainfall runoff routing model (Carroll, 2004) developed as part of the Pioneer River Flood Study (WRM, 2011). The configuration of the rainfall runoff model has not changed since the completion of the Goosepond Creek (including Pioneer River) Flood Study (WRM, 2012).

The following section describes the model configuration, model calibration and verification results (mostly from the 2011 flood study) and the additional verification of the 2017 TC Debbie event.

4.2 SELECTION OF CALIBRATION

The URBS model was calibrated against recorded stream flows within the catchment for the following historical flood events:

- February 1958
- January 1970
- December 1990
- February 2000
- January 2007
- February 2008, and
- March 2017.

The selected events cover a wide range of discharges across the catchment. The main goal of the model calibration was to achieve the best possible fit between the predicted and recorded discharge hydrographs at key stations along the main streams of the Pioneer River catchment for each of the calibration events. For these stations, the calibration attempted to match the predicted and recorded flood peaks and volumes, and also the shape of the hydrographs. The calibrated model was then verified by comparing the model predictions against the discharge hydrographs recorded at various gauging stations for the selected verification events.

Due to the lack of detailed rainfall data for most events, the URBS models cannot be expected to accurately reproduce flood behaviour for all events and at all gauging stations. As such, calibration emphasis was placed more on large events, as the accuracy of small events are impacted significantly by spatial and temporal variation in rainfall. A single set of model parameters was adopted for each of the URBS sub-models (except for rainfall losses) and maintained for all calibration events. The model parameters were adjusted to achieve the best calibration across all events, resulting in a compromise between model accuracy and model simplicity. It is noted that calibration of the models for individual events can be improved by adopting a different set of model parameters for each of the different events.

4.3 MODEL CONFIGURATION

4.3.1 Model sub-catchments

The adopted URBS sub-models of the Pioneer River catchment are based on an URBS model originally developed by the Bureau of Meteorology (BOM). The BOM model consists of 61 sub-catchments. Catchment subdivisions for the BOM model have been determined using the CatchmentSIM program (Ryan, 2004), and a Digital Elevation Model derived from the NASA Shuttle Radar Topographic Mission (SRTM) data. The BOM model configuration was refined using more accurate topographical data available for the catchment.

Figure 4.1 shows the adopted URBS model configuration for this study. The adopted URBS models consist of 70 sub-catchments. Table 4.1 lists the sub-catchment numbers and areas adopted in the Pioneer River URBS model.

Table 4.1 - Adopted URBS Model Catchment Areas

Catchment Number	Area (km²)	Catchment Number	Area (km²)	Catchment Number	Area (km²)
1	4.93	25	26.76	49	23.17
2	30.84	26	14.87	50	38.21
3	26.08	27	19.98	51	18.23
4	3.17	28	30.85	52	17.89
5	23.79	29	11.93	53	25.09
6	65.39	30	28.45	54	7.78
7	7.62	31	6.34	55	16.83
8	1.17	32	38.28	56	32.75
9	43.37	33	42.17	57	15.2
10	49.48	34	37.04	58	42.05
11	21.97	35	12.35	59	25.35
12	62.78	36	8.85	60	8.95
13	2.74	37	53.86	61	11.8
14	26.7	38	37.86	62	2.9
15	14.43	39	40.01	63	4.48
16	18.15	40	7.01	64	6.36
17	1.55	41	51.06	65	11.14
18	22.34	42	44.64	66	6.75
19	20.15	43	23.9	67	10.82
20	23.33	44	16.38	68	3.61
21	35.3	45	33.93	79^	5.78
22	7.3	46	21.49	80^	11.63
23	39.54	47	11.59		
24	23.63	48*	8.31		

^ Mackay CBD catchment excluded in this study

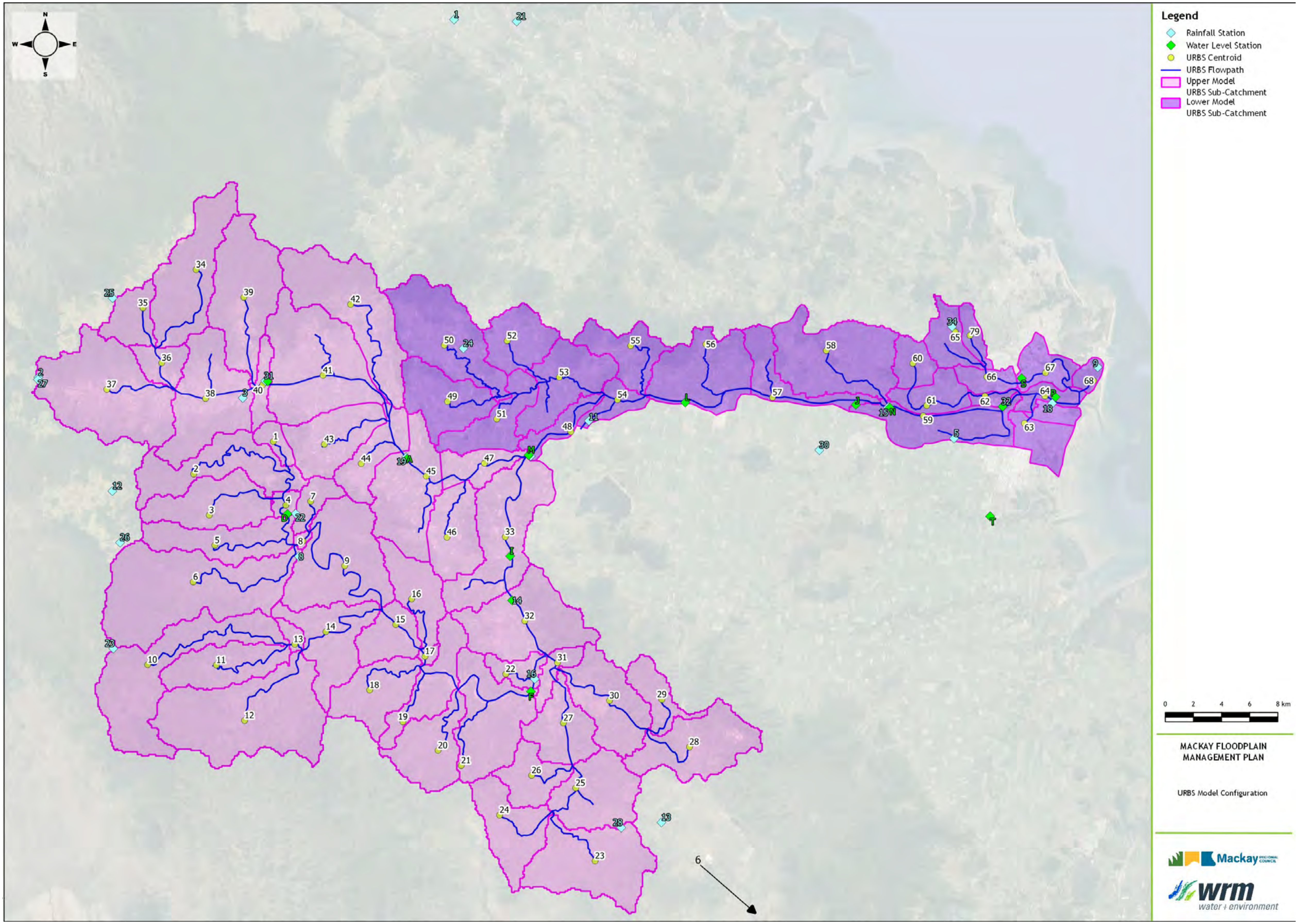

Figure 4.1 - Adopted URBS Model Configuration

The refinements made to the BOM URBS model are summarised below:

- The catchment boundaries were improved using the latest available topographic data, such as 1:100,000 topographic maps and a Digital Elevation Model derived from LiDAR Airborne Laser Survey (ALS) data.
- The catchments were renumbered so that the catchment numbers were in general ascending order as the model progressed downstream.
- The catchment areas for Fursden Creek, Janes Creek and Goosepond Creek were subdivided in order to improve model representation of flood discharges in these catchments.

4.3.2 Breakout flows to Sandy Creek and Bakers Creek catchments

Under extreme flow situations in the Pioneer River, floodwater may break out and flow into Sandy and/or Bakers Creeks (depending on the location of the breakout). Given the complexity of flow behaviour in this area, the flood discharges along the Pioneer River downstream of Mirani Weir were determined using the TUFLOW hydraulic model, described in Section 5.

4.3.3 Assignment of total rainfalls and temporal patterns

Total event rainfalls for each sub-catchment of the URBS sub-models were estimated by weighting recorded data (both daily and pluviograph stations) based on the square of the inverse distance from the centroid of each sub-catchment to the nearest four rainfall stations, using the method described by Malone (2000). The rainfall temporal pattern for each sub-catchment was then obtained by applying the temporal rainfall distribution derived from the nearest pluviograph station. Note that some of the earlier calibration and verification events had relatively limited coverage by pluviograph stations, resulting in substantial reliance on daily rainfalls in some areas of the catchment.

4.3.4 Initial storage levels in Teemburra Dam

Teemburra Dam is located in the upper Pioneer River catchment on Teemburra Creek. The starting storage level in the dam at the commencement of the calibration events is not known. Therefore, the staring storage level was estimated by trial and error to match recorded discharges from the dam. Table 4.2 shows the adopted starting storage level in Teemburra Dam for each of the calibration and verification events.

Table 4.2 - Adopted Teemburra Dam Starting Storage Level for Calibration & Verification Events

Event	Adopted Starting Storage (ML)
1958	-
1970	-
1990	-
2000	5,000
2007	112,800
2008	199,000
2017	0

- Not constructed during these events

4.3.5 Initial storage volumes in Mirani, Marian and Dumbleton weir pools

The three weirs along the Pioneer River are unlikely to have a significant impact on flood behaviour in the Pioneer River system. The adopted weir pool storage capacities at spillway level for each of the 3 weirs are as follows:

- Mirani Weir: 4,660 ML at 47m RL;
- Marian Weir: 3,830 ML at 31.9m RL; and
- Dumbleton Weir: 6,540 ML at 14.4m RL (Stage 2).

The storage volumes below the full supply level in the above weirs at the commencement of the calibration and verification events were estimated using the available gauging station data. Table 4.3 shows the adopted storage volumes below full supply level in the weir pools for each of the calibration events based.

Table 4.3 - Adopted Weir Pool Starting Storage Volume below full supply level for Calibration & Verification Events

Event		Adopted Starting Storage Volume below full supply level (ML)		
		Mirani Weir	Marian Weir	Dumbleton Weir
Calibration	2008	100*	0	0
	2007	100*	0	0
	2000	100*	0	0
Verification	2017	100*	0	0
	1990	100*	0	0
	1970	100*	0	0
	1958	100*	0	0

** Nominal available storage volume*

4.3.6 Adopted URBS model parameters

Table 4.4 shows the adopted model parameters for the URBS sub-models for the calibration events. The ß parameter for the downstream of Mirani Weir sub-model reflects the higher density of sugar cane, which appears to significantly affect catchment flows.

Table 4.4 - Adopted URBS Model Parameters for Calibration Events

Parameter	Value	
	U/S Mirani Sub-model	D/S Mirani Sub-model
α (channel lag parameter)	0.15	0.15
ß (catchment lag parameter)	1.00	3.10
m (catchment non-linearity parameter)	0.80	0.80

Table 4.5 shows the adopted initial loss and continuing loss rates for the Pioneer River catchment for the different calibration and verification events. It is of note that the losses across the events were adjusted to produce the best calibration, and as such the amount and quality of available rainfall data will have some effect on the adopted initial and continuing losses. Note that different continuing loss rates were adopted for the upstream and downstream sub-models for the 2008 event to improve the calibration.

Table 4.5 - Adopted Initial and Continuing Losses for Calibration & Verification Events

Event	Initial Loss (mm)	Continuing Loss (mm/hr)
1958	200	2.0
1970	140	1.0
1990	70	1.0
2000	25	1.5
2007	30	1.2
2008	15	3.0[a]/1.0[b]
2017	50	1.5

[a] *upstream sub-model*
[b] *downstream sub-model*

4.4 MODEL CALIBRATION RESULTS

4.4.1 February 1958

Figure 4.2 to Figure 4.5 show comparisons of predicted and recorded flood discharge hydrographs at Sarichs, Mirani Town, Pleystowe Mill and Mackay for the February 1958 event. Data was not available for this event at other gauging stations in the catchment.

The rainfall data coverage for this event is very poor and hence model calibration is poor. It is likely that much lower rainfall occurred in the upper catchment than the available rainfall data is suggesting. Nevertheless, the flood timing is satisfactorily reproduced.

To validate the model at the downstream stations, the model was run using the recorded discharges at Mirani Town (i.e. assuming the model accurately predicts recorded discharges at this station). The results show that, if upper catchment discharges are predicted accurately, the lower catchment predicted discharges at Pleystowe Mill and Mackay can be improved. Again, the BOM rating curves were unable to provide reasonable estimates of recorded flow at Mackay. However, the shape and timing of the predicted hydrograph at Mackay is reasonable.

4.4.2 January 1970

Figure 4.6 to Figure 4.11 show comparisons of predicted and recorded flood discharge hydrographs at Gargett, Sarich's, Mirani Town, Marian Weir, Pleystowe Mill and Mackay for the January 1970 event. Data was not available for this event at other gauging stations in the catchment.

The rainfall data coverage for this event is poor and as such, the model was unable to accurately predict the peak discharges in the upper catchment at Sarichs and Mirani Town, as shown by Figure 4.7 and Figure 4.8. To validate the model at the downstream stations, the model was run using the recorded discharges at Mirani Town (i.e. assuming the model accurately predicts recorded discharges at this station). The results show that, if upper catchment discharges are predicted accurately, the lower catchment discharges at Marian Weir and Pleystowe Mill are predicted accurately by the model as shown by Figure 4.9 and Figure 4.10. At Mackay, the BOM rating curves were unable to provide reasonable estimates of recorded flow that are consistent with the upstream flows. However, the shape and timing of the predicted hydrograph at Mackay is reasonable, as shown in Figure 4.11.

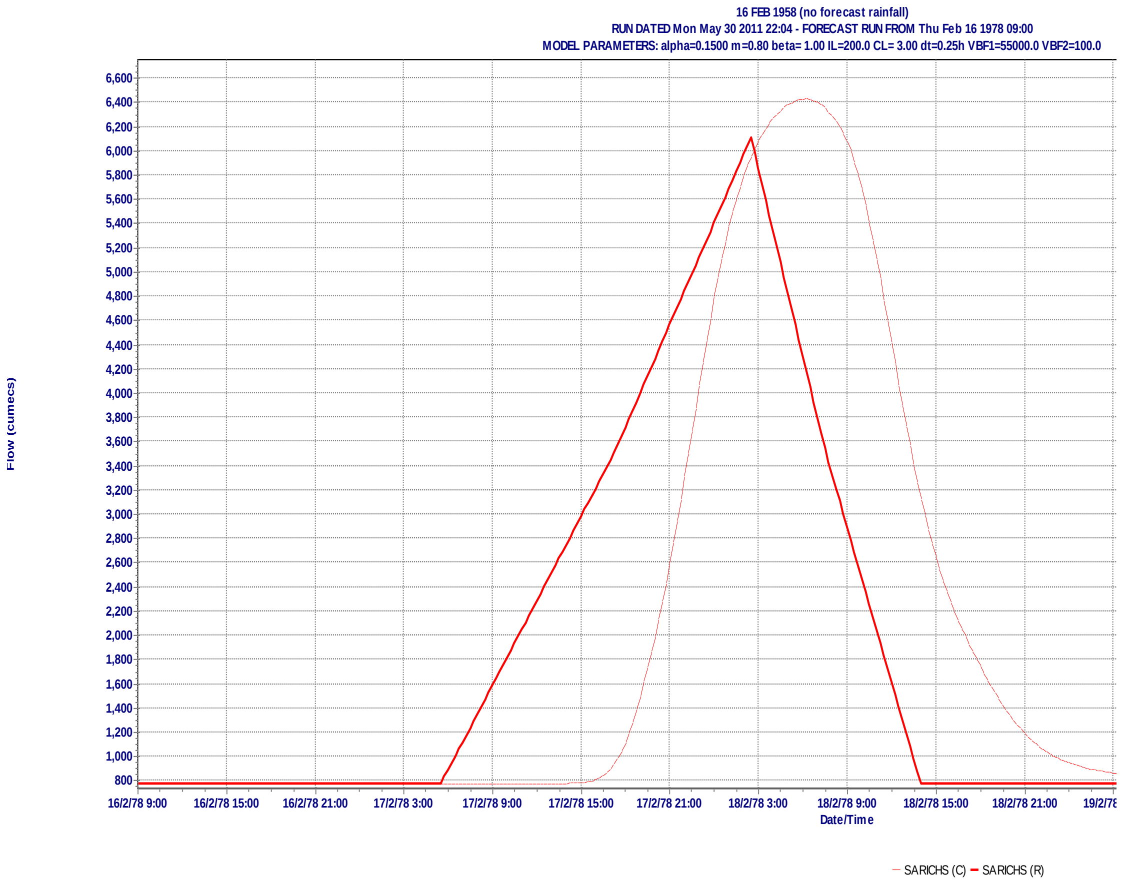

Figure 4.2 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Sarichs, 1958

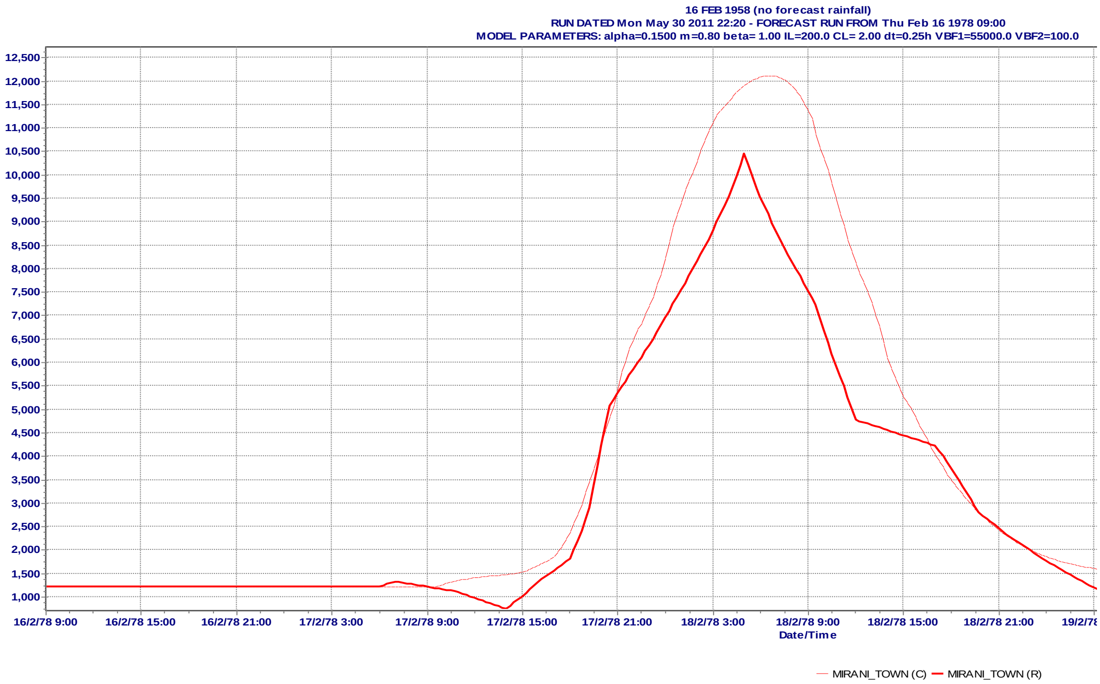

Figure 4.3 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Mirani Town, 1958 (Matched Flows)

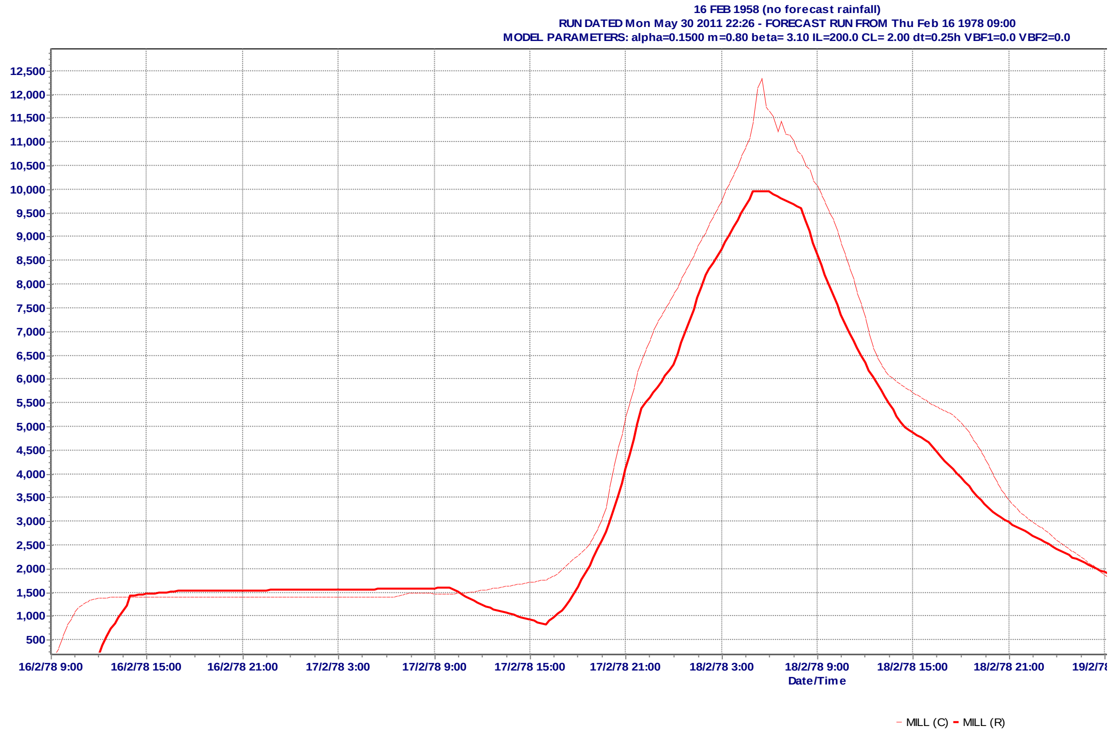

Figure 4.4 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs (Using Matched U/S inflows at Mirani Town), Pioneer River at Pleystowe Mill, 1958

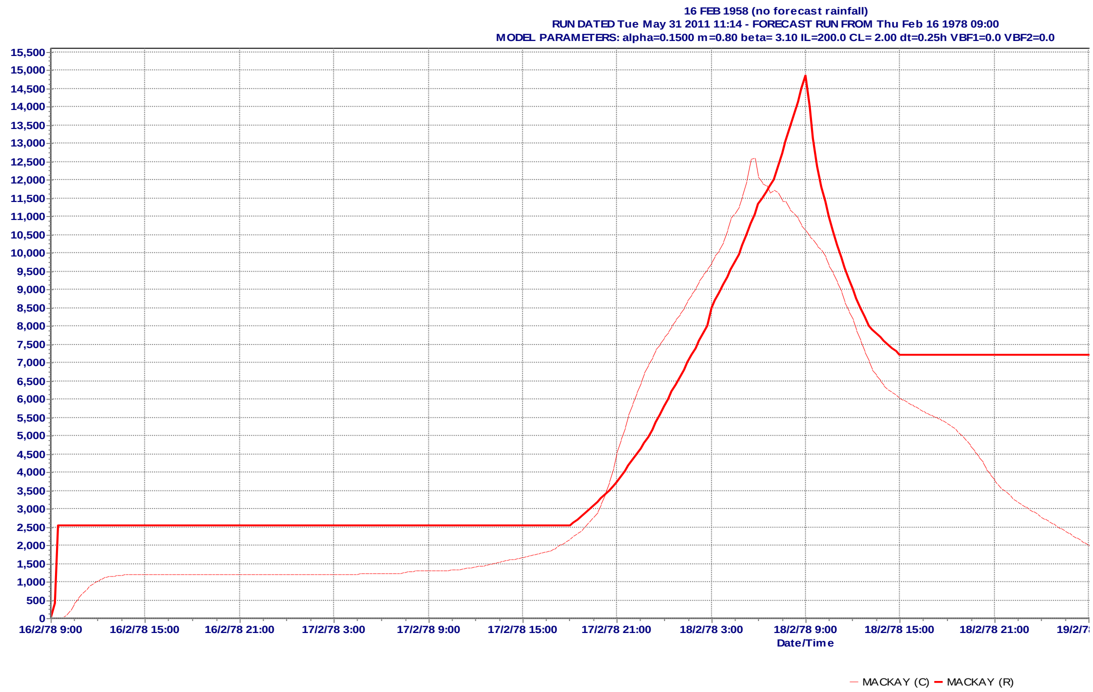

Figure 4.5 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs (Using Matched U/S inflows at Mirani Town), Pioneer River at Mackay, 1958

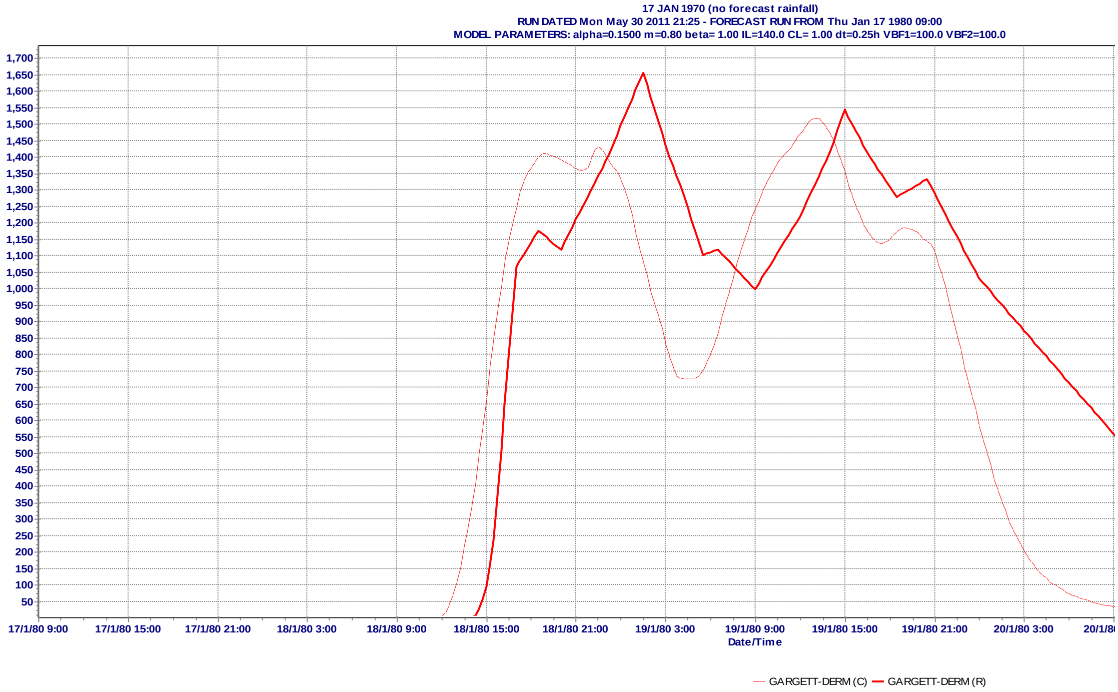

Figure 4.6 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Cattle Creek at Gargett, 1970

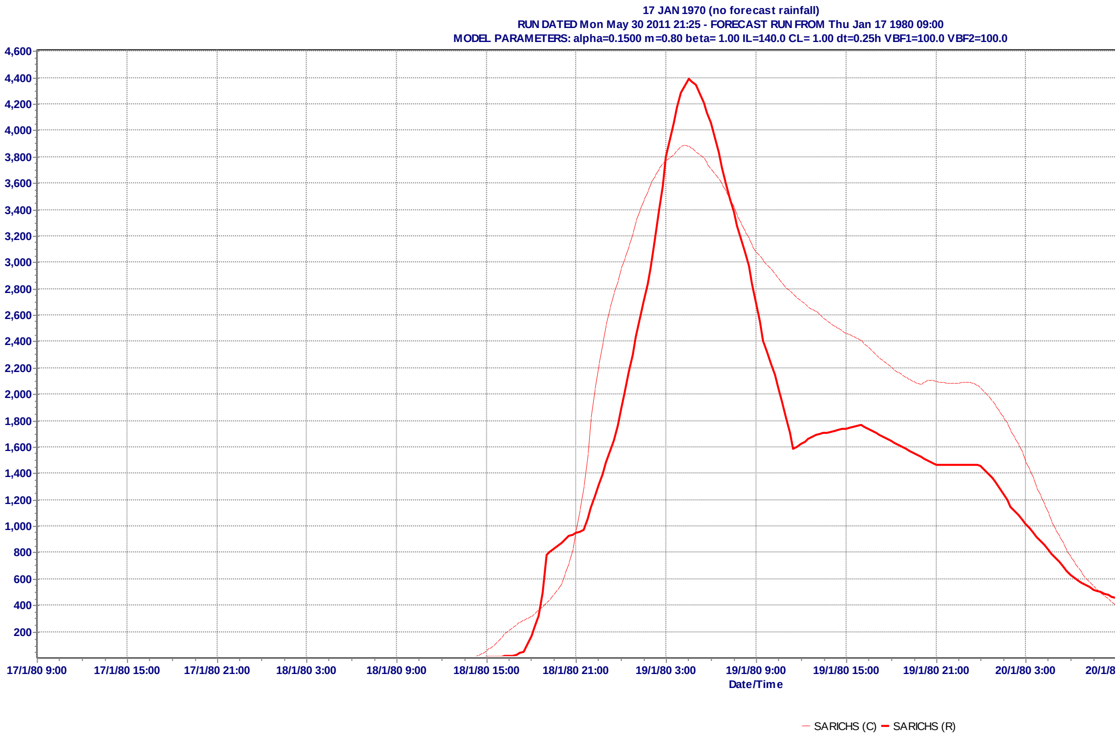

Figure 4.7 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Sarichs, 1970

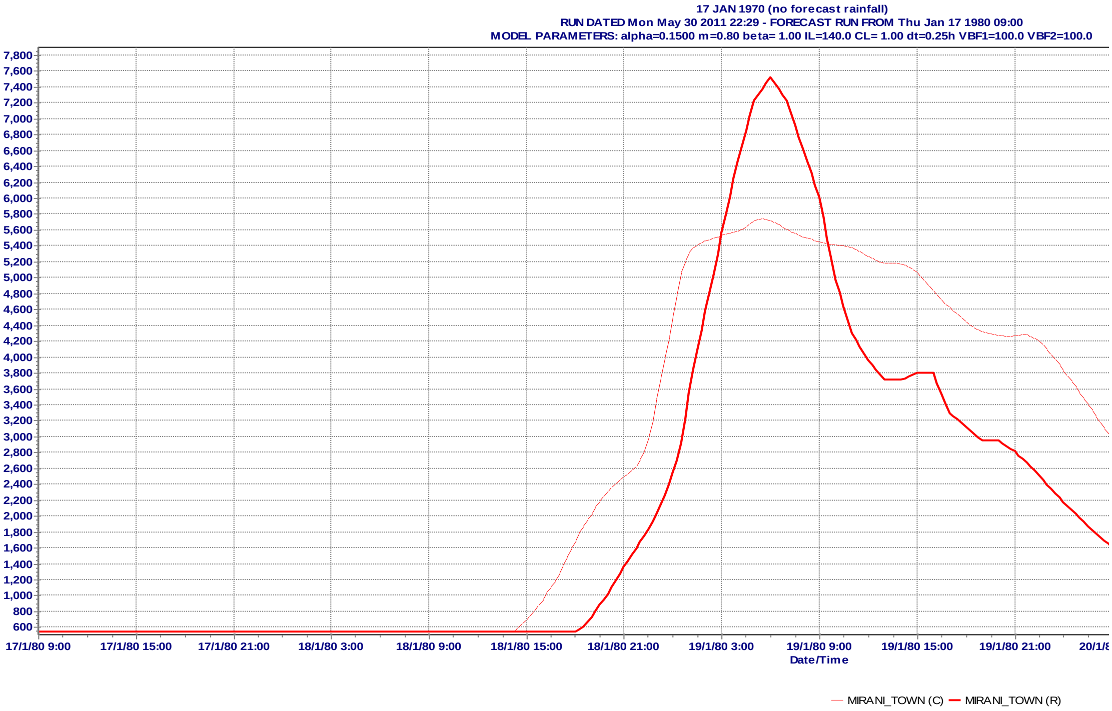

Figure 4.8 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Mirani Town, 1970

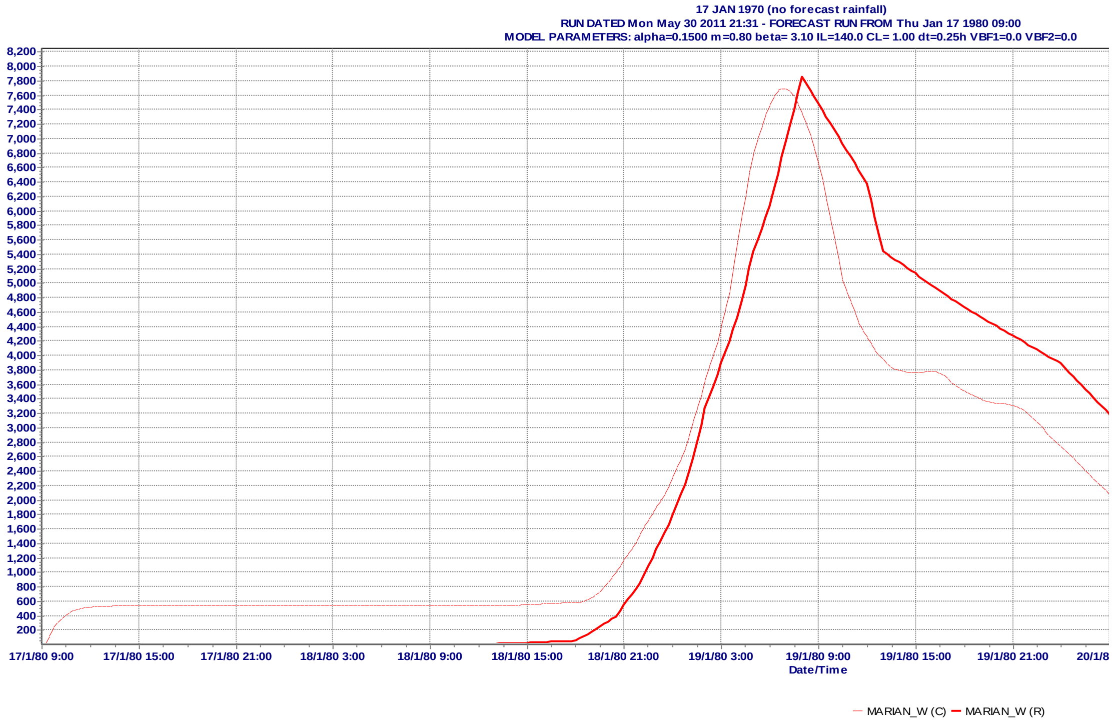

Figure 4.9 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, (Using Matched U/S inflows at Mirani Town) Pioneer River at Marian Weir, 1970

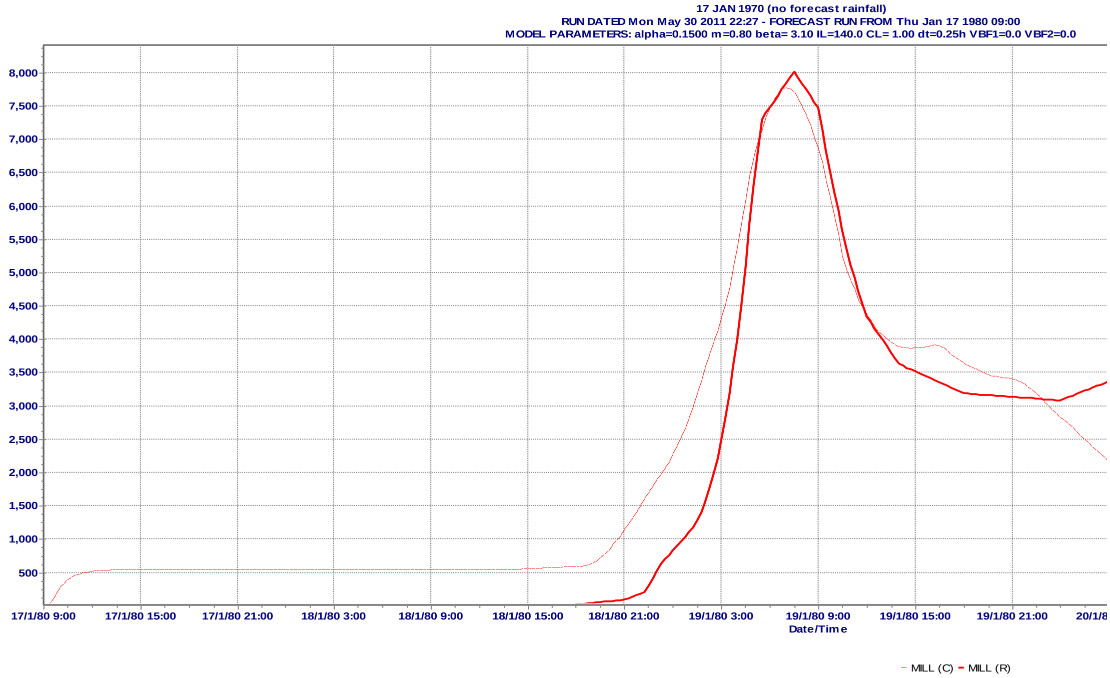

Figure 4.10 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs (Using Matched U/S inflows at Mirani Town), Pioneer River at Pleystowe Mill, 1970

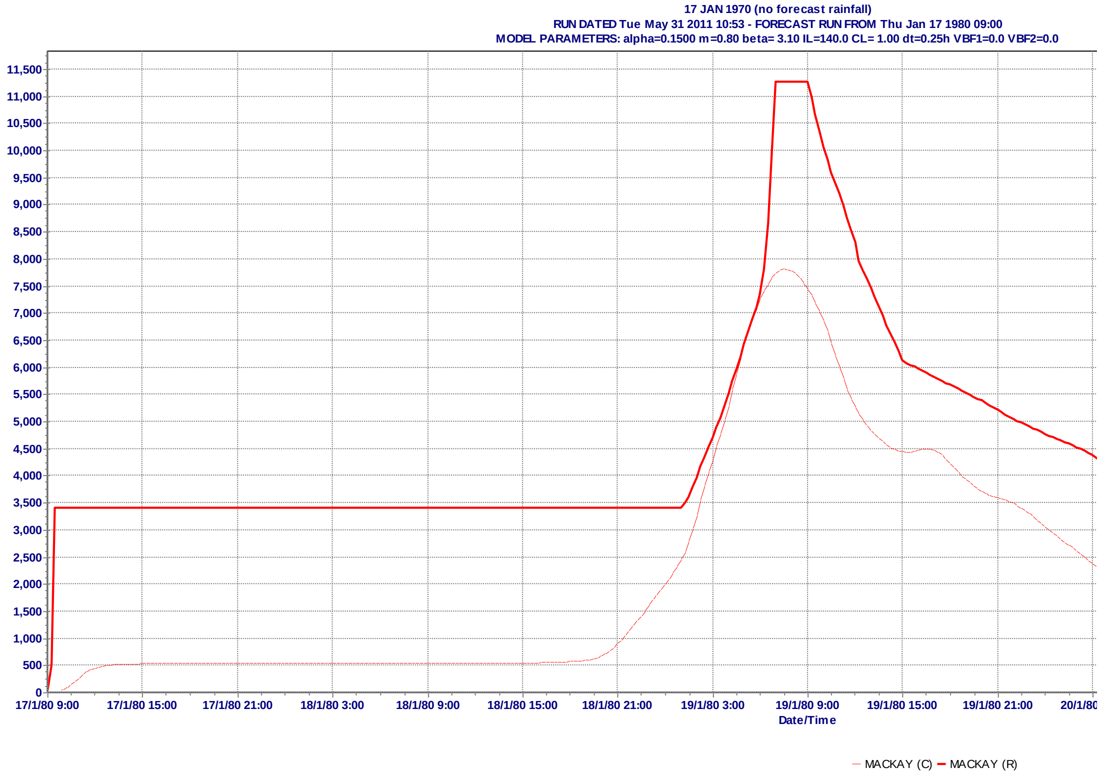

Figure 4.11 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs (Using Matched U/S inflows at Mirani Town), Pioneer River at Mackay, 1970

4.4.3 December 1990

Figure 4.12 to Figure 4.16 show comparisons of predicted and recorded flood discharge hydrographs at Gargett, Whitefords, Sarichs, Mirani Weir and Mackay for the December 1990 event. Data was not available for this event at other gauging stations in the catchment.

The rainfall data coverage in the upper catchment for this event is poor and hence a good calibration of the model was not possible. To validate the model at the downstream stations, the model was run using the recorded discharges at Whitefords and Gargett stations (i.e. assuming the model accurately predicts recorded discharges at these stations). The results show that, if upper catchment discharges are predicted accurately, the lower catchment discharges at Sarichs, Mirani Weir and Mackay are predicted accurately by the model.

4.4.4 February 2000

Figure 4.17 to Figure 4.26 show comparisons of predicted and recorded flood discharge hydrographs at Finch Hatton, Gargett, Whitefords, Sarichs, Mia Mia, Mirani Weir, Mirani Town, Dumbleton Weir HW, Hospital Bridge and Mackay for the February 2000 event. Data was not available for this event at other stream gauging stations in the catchment.

The overall calibration of the model for the February 2000 flood event is considered satisfactory with respect to the peak discharge, flood volume and the timing and shape of the discharge hydrographs. The model appears to under predict the peak discharge in the river reaches downstream of Dumbleton Weir. This appears to be due to the adopted rating curve for the downstream gauges that are strongly affected by tide levels, particularly for this event.

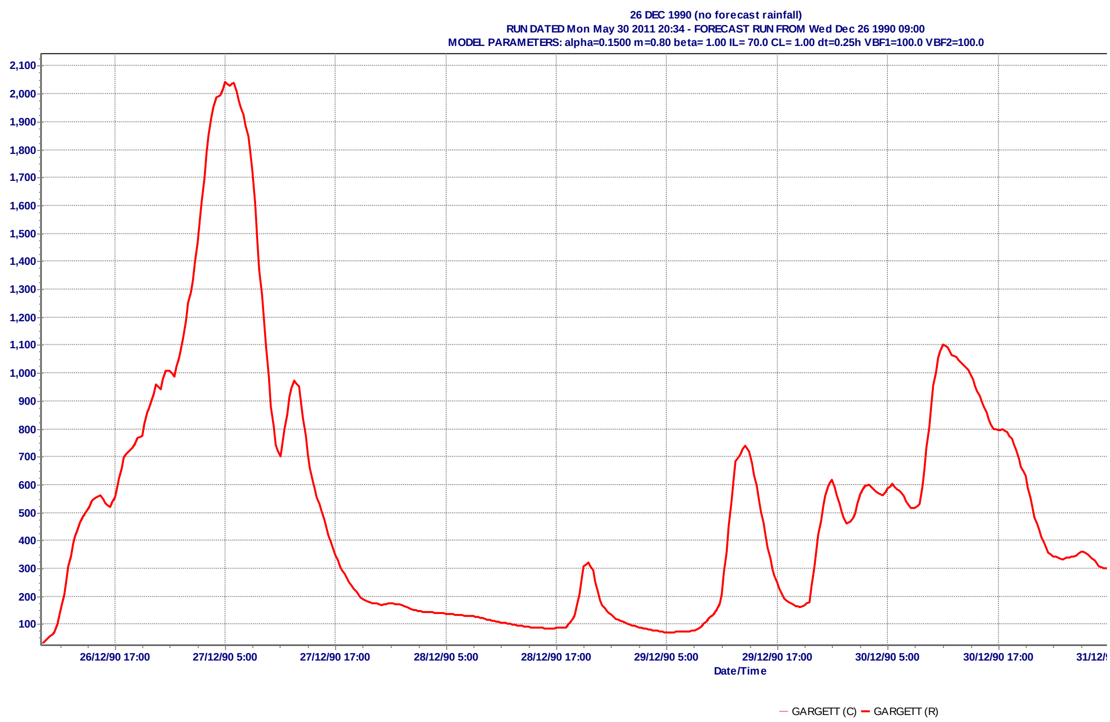

Figure 4.12 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Cattle Creek at Gargett, 1990 (Matched Flows)

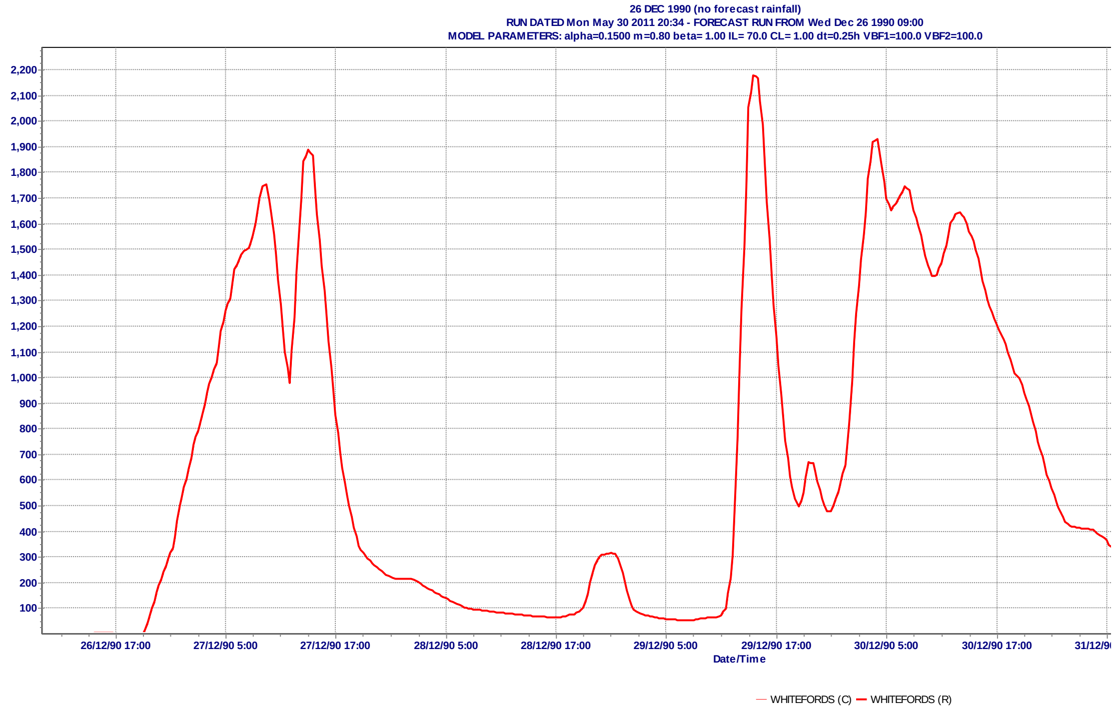

Figure 4.13 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Blacks Creek at Whitefords, 1990 (Matched Flows)

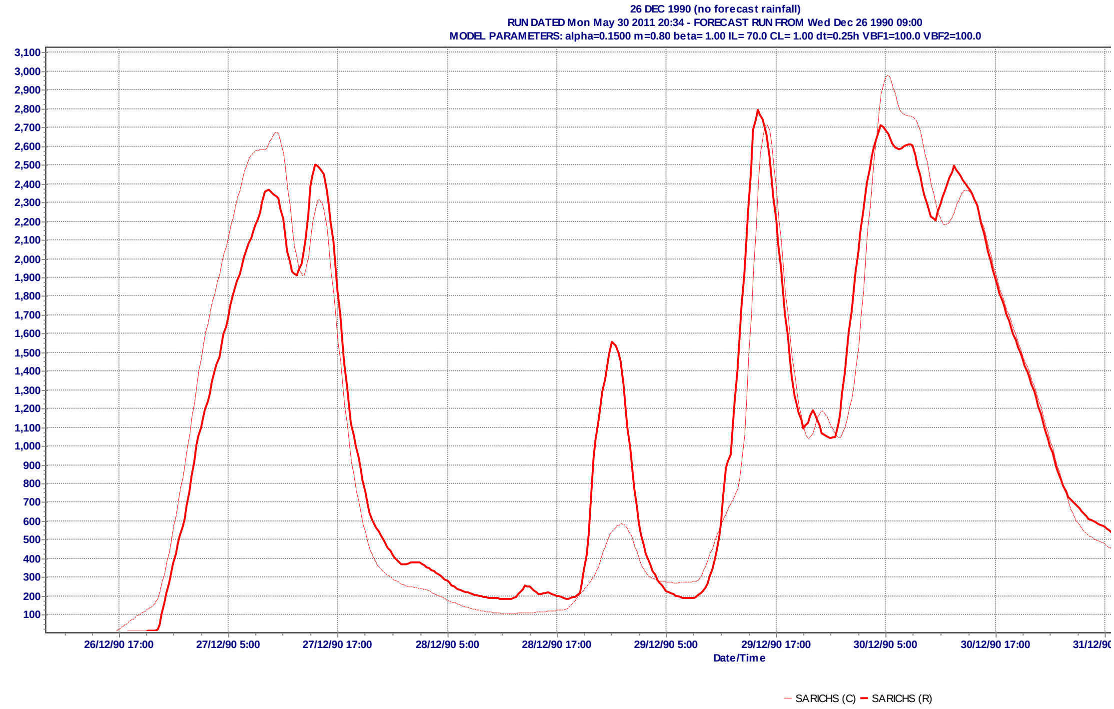

Figure 4.14 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Sarichs, 1990 (Matched Flows at Whitefords)

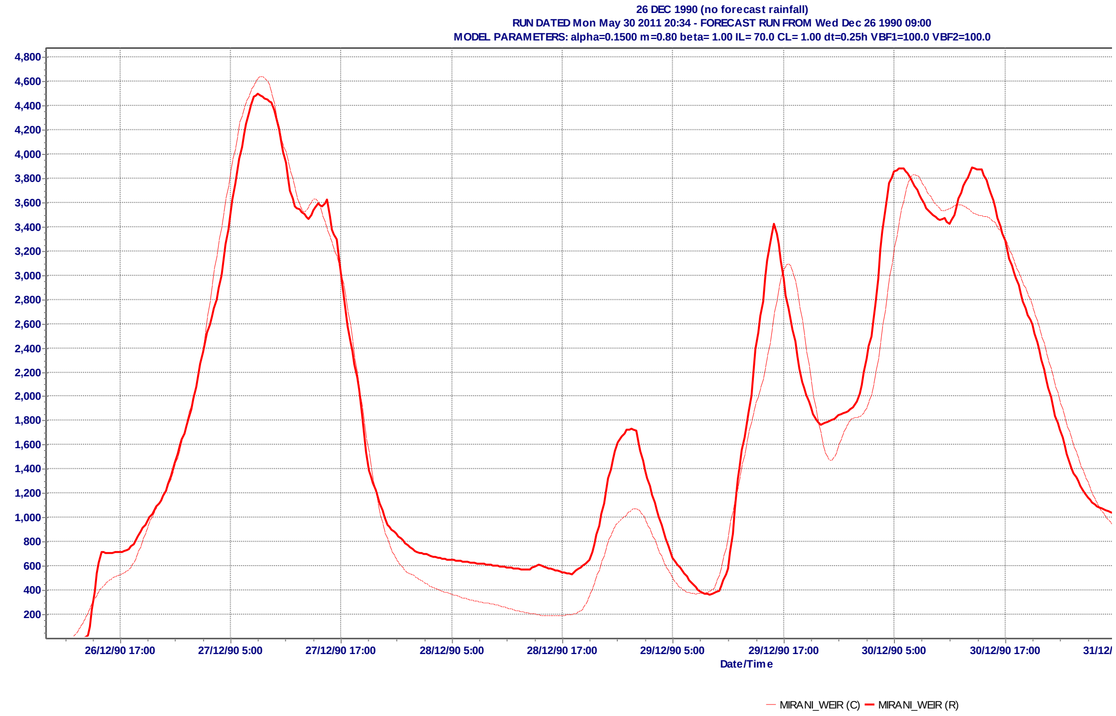

Figure 4.15 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Mirani Weir, 1990 (Matched Flows at Gargett and Whitefords)

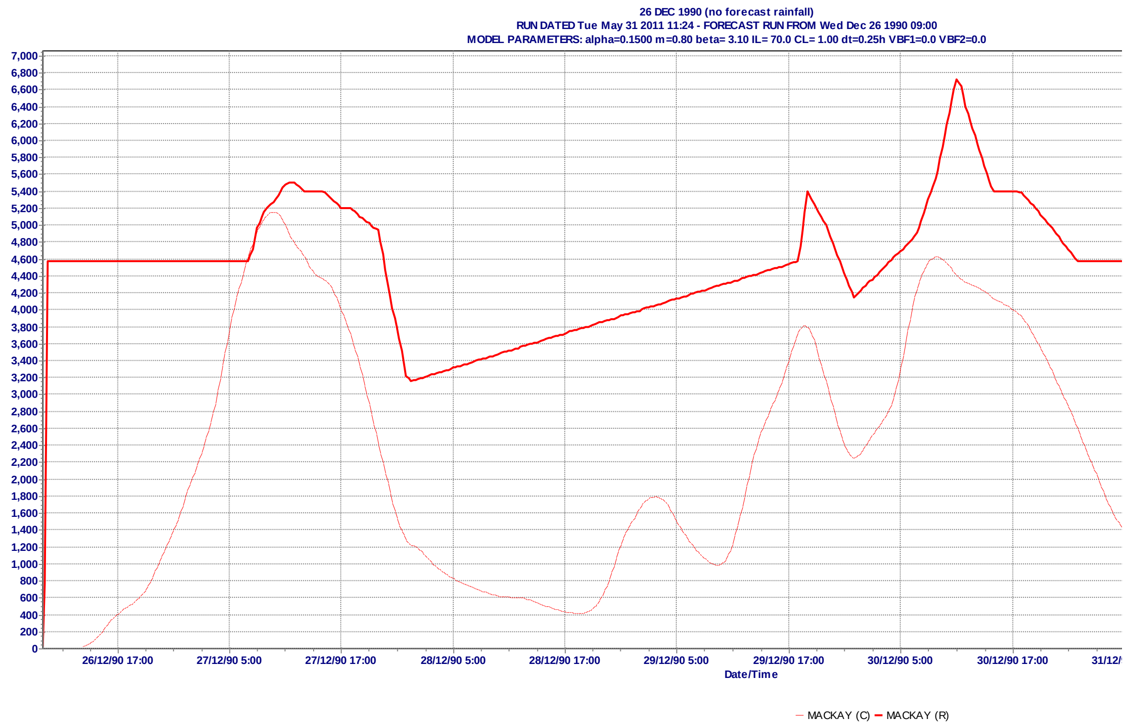

Figure 4.16 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Mackay, 1990 (Matched Flows at Gargett and Whitefords)

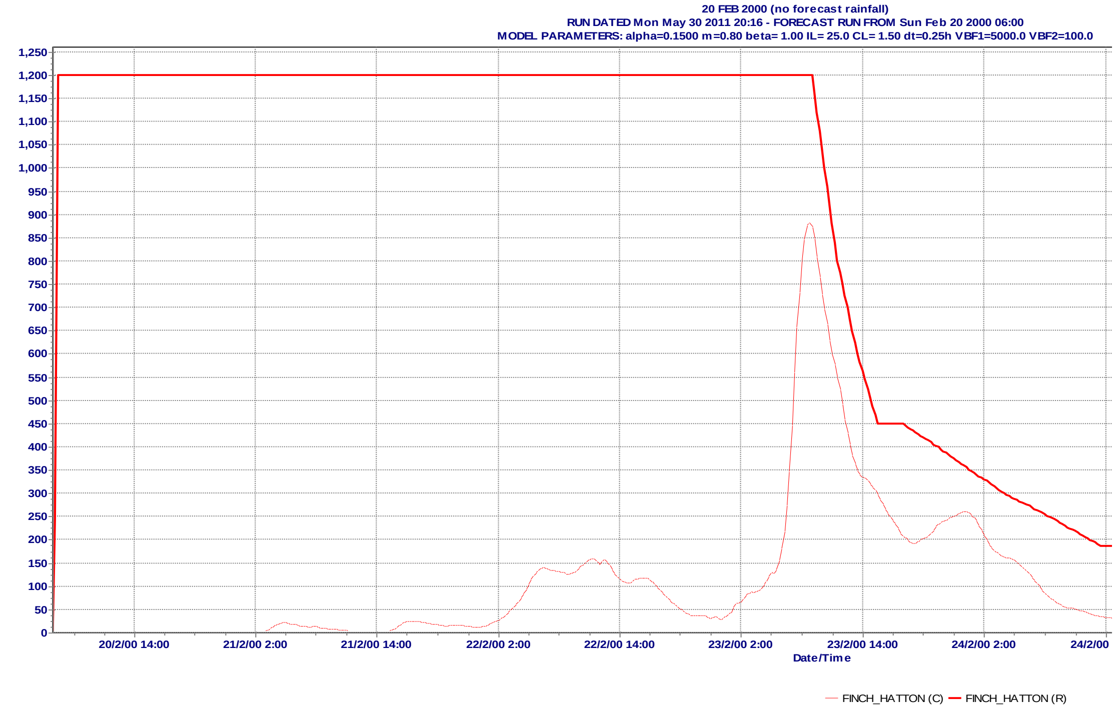

Figure 4.17 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Cattle Creek at Finch Hatton, 2000

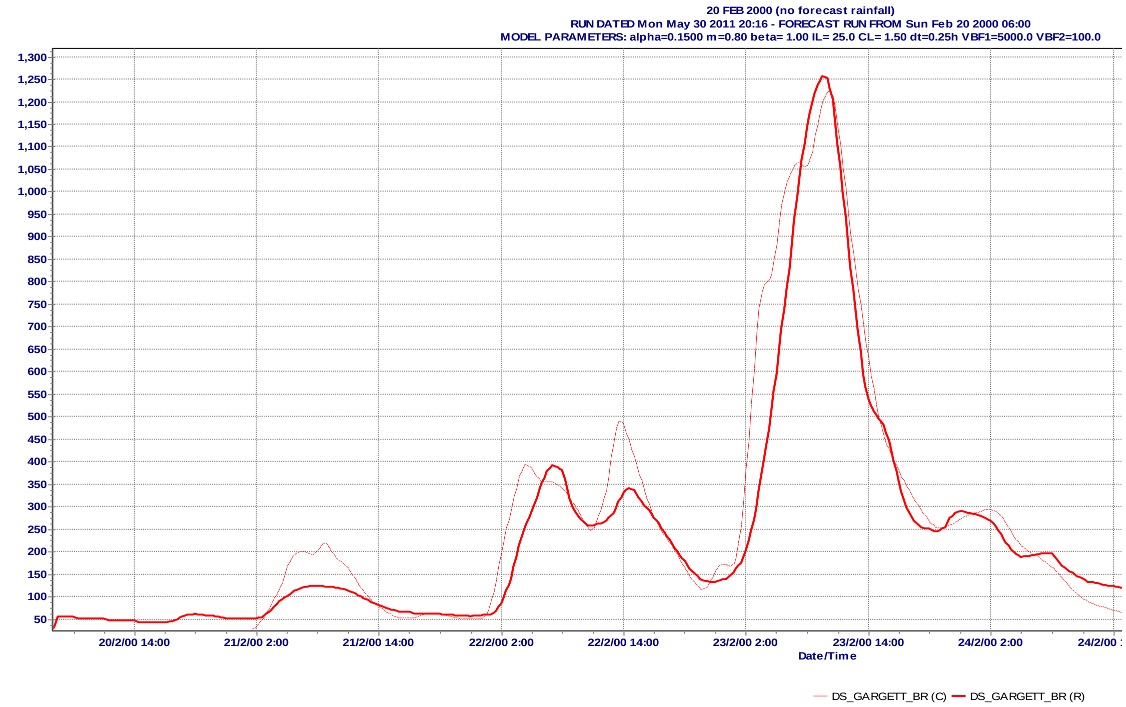

Figure 4.18 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Cattle Creek at Gargett, 2000

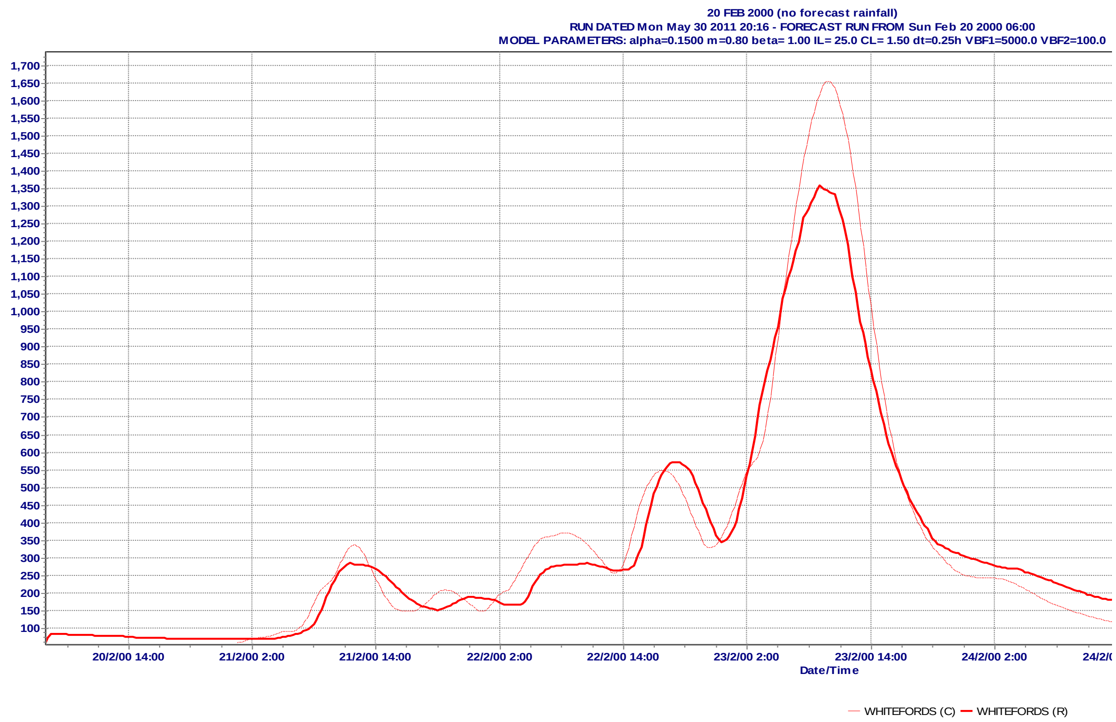

Figure 4.19 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Blacks Creek at Whitefords, 2000

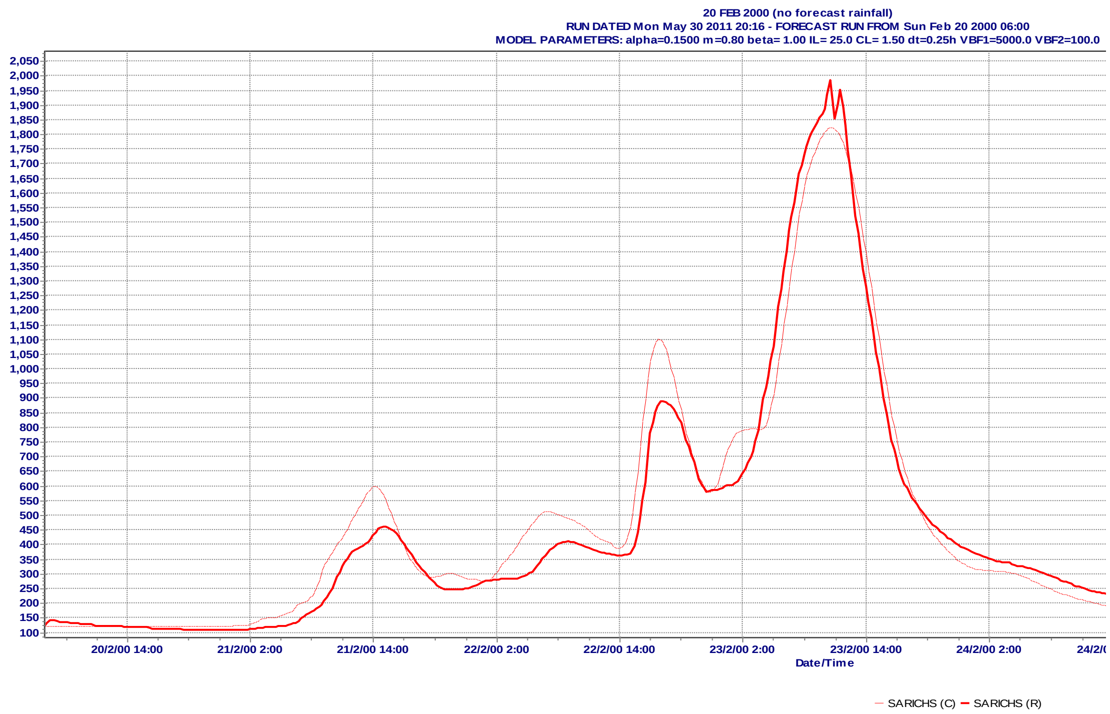

Figure 4.20 - Comparison of Calculated (C) and Recorded (R) Water Discharge **Hydrographs, Pioneer River at Sarich's, 2000**

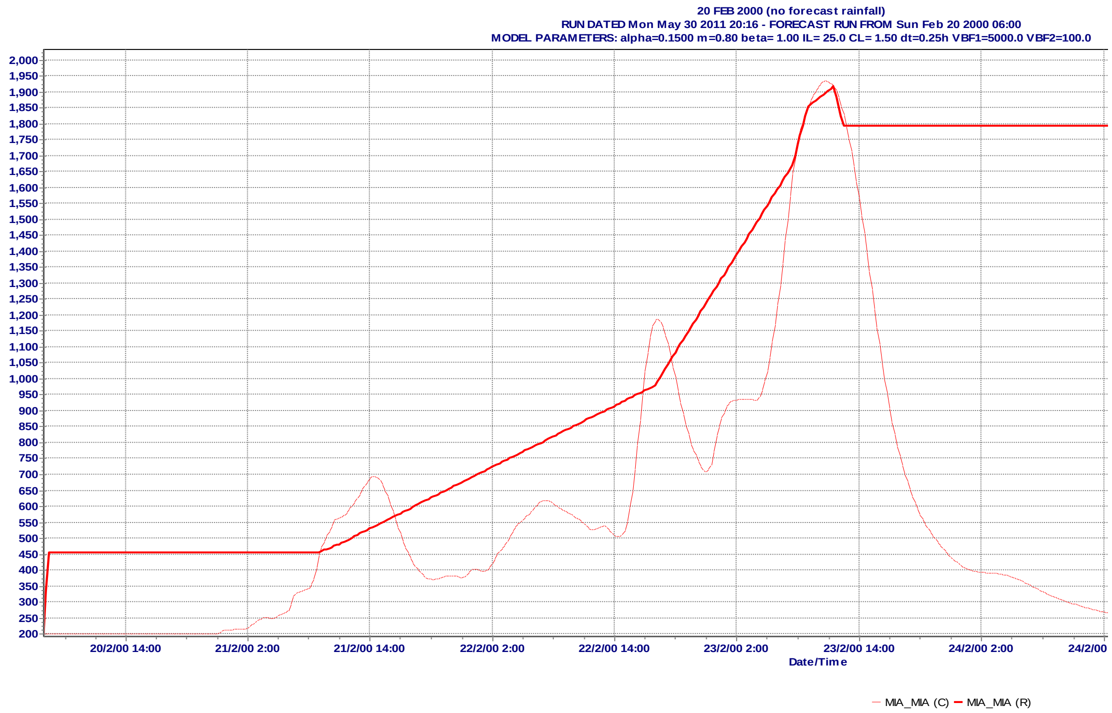

Figure 4.21 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Mia Mia, 2000

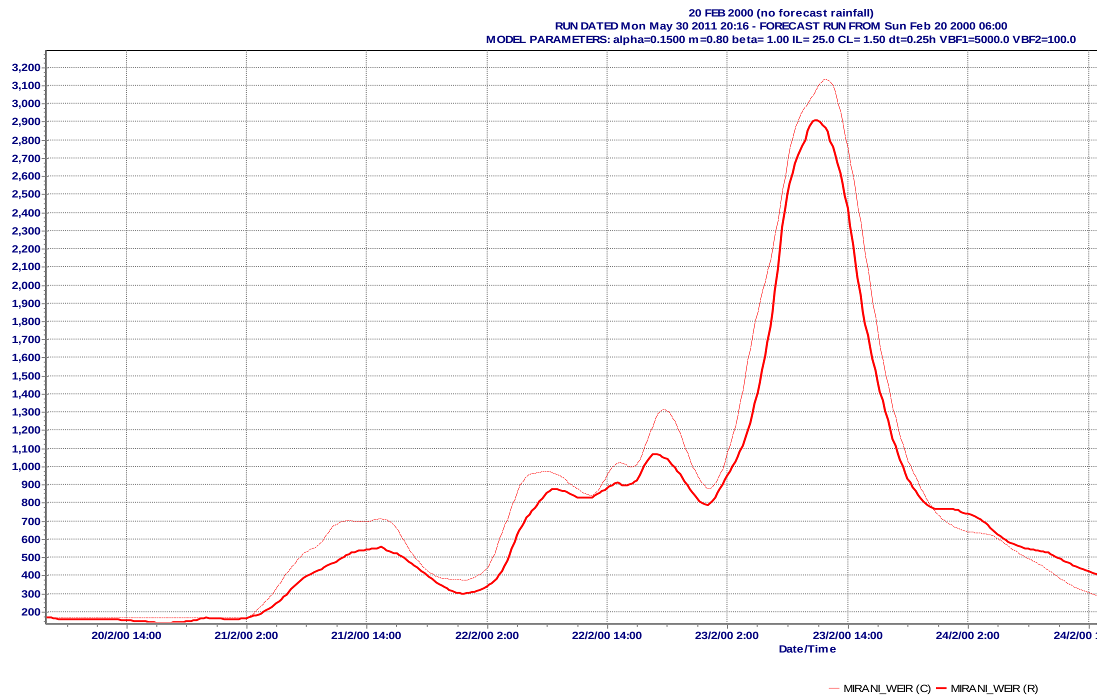

Figure 4.22 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Mirani Weir Tailwater, 2000

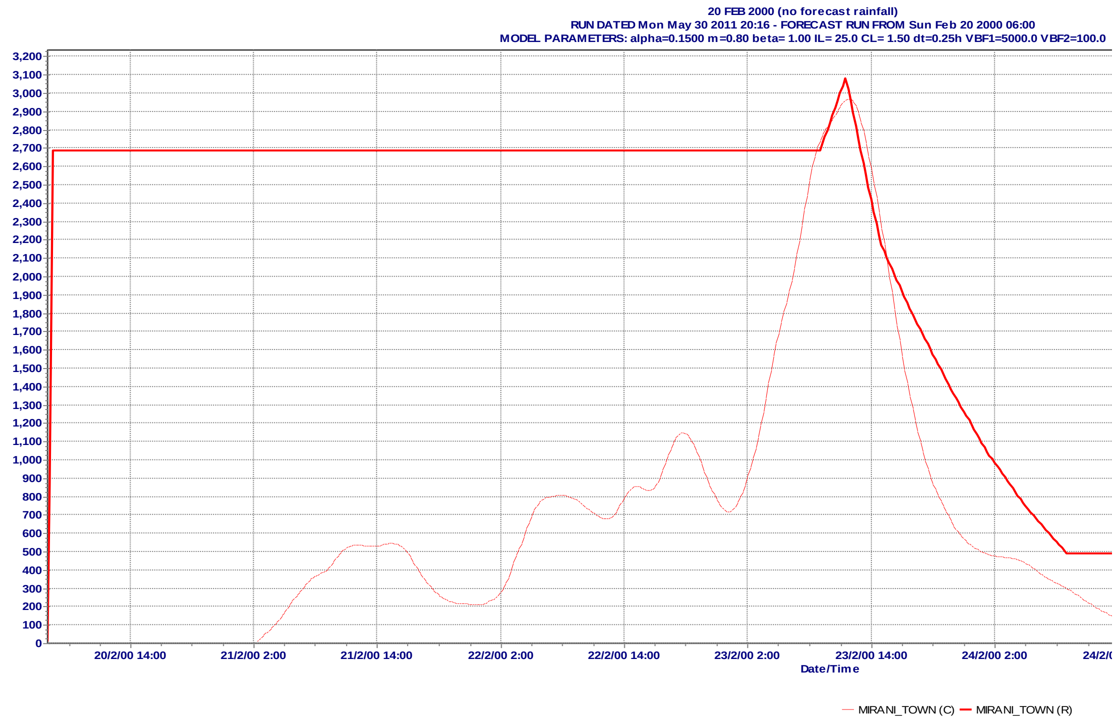

Figure 4.23 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Mirani Town, 2000

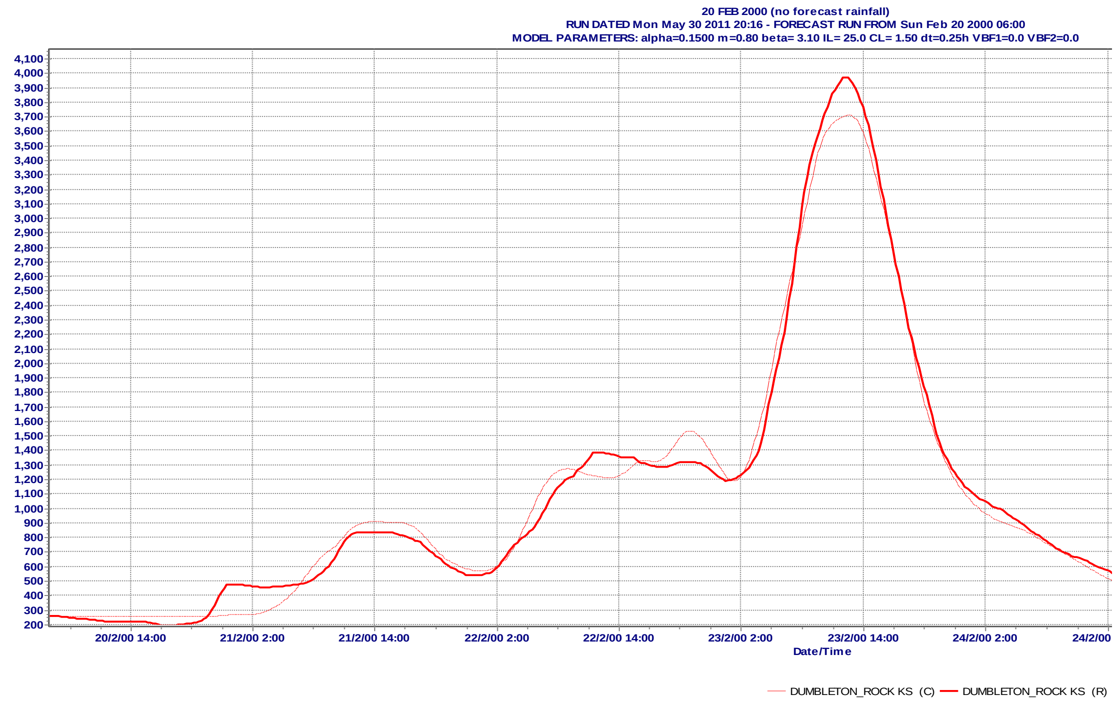

Figure 4.24 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Dumbleton Weir Headwater, 2000

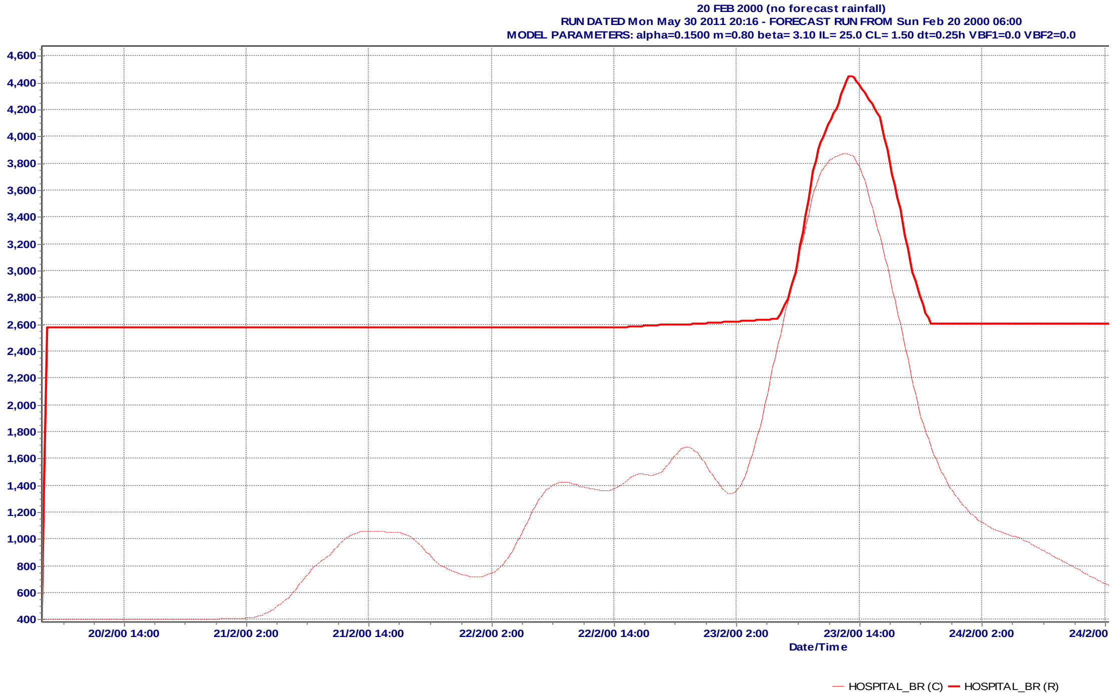

Figure 4.25 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Hospital Bridge, 2000

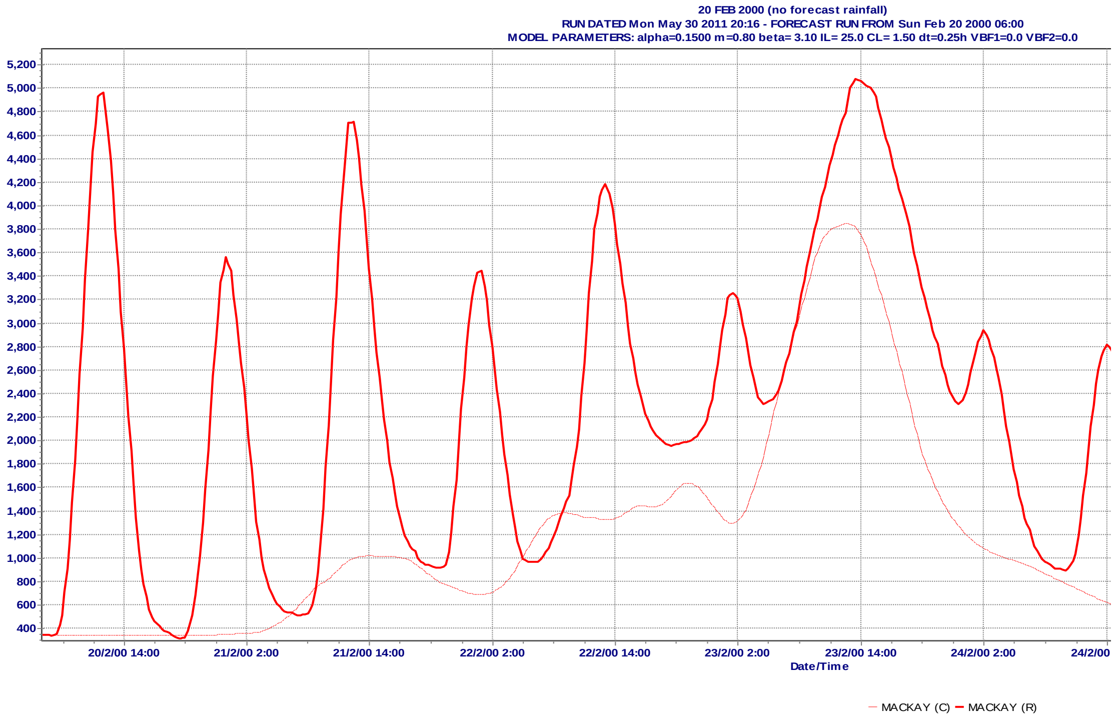

Figure 4.26 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Mackay, 2000

4.4.5 January 2007

Figure 4.27 to Figure 4.34 show comparisons of predicted and recorded flood discharge hydrographs at Finch Hatton, Gargett, Whitefords, Sarichs, Mirani Weir, Dumbleton Weir Headwater, Dumbleton Weir Tailwater, Hospital Bridge and Mackay for the January 2007 event. Data was not available for this event at other gauging stations in the catchment.

The calibration is generally acceptable, with respect to the flood peaks, flood volumes and the timing and shape of hydrographs at all stations, except Whitefords and Mirani Weir. It appears that the water level recorded at Mirani Weir malfunctioned during this event. The reason for the discrepancy at Whitefords is not clear, given the downstream flood peaks at Sarich's compare well to the recorded data.

The predicted flood peak at Dumbleton Weir is over estimated when compared to the recorded flows. Further discussion on the validity of the rating at this station is given in Section 5.4.1. The predicted flows are marginally overestimated at the Hospital Bridge Gauge and marginally underestimated at the Mackay Gauge. The rating curves of the tidally affected gauges are not considered reliable at these flows.

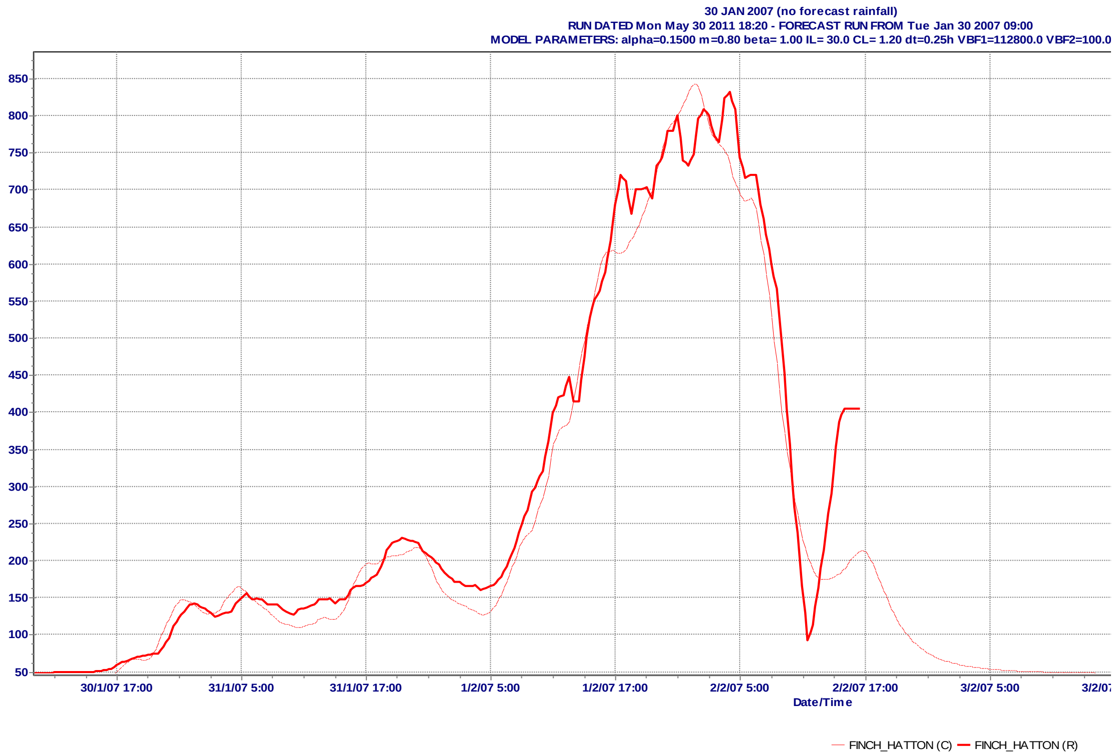

Figure 4.27 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Cattle Creek at Finch Hatton, 2007

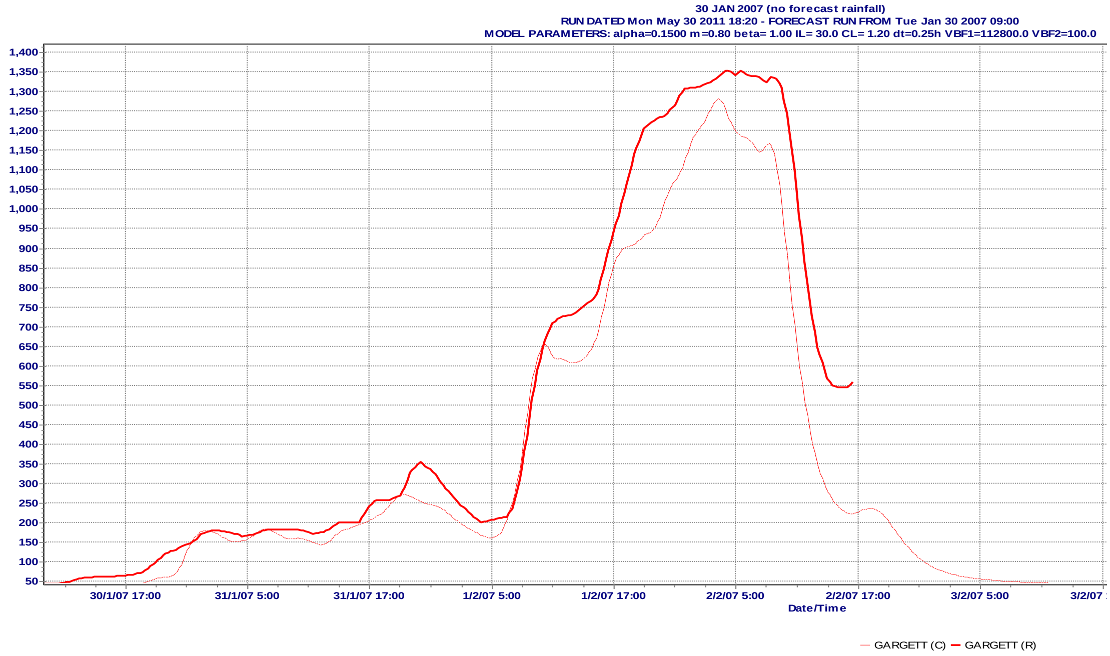

Figure 4.28 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Cattle Creek at Gargett, 2007

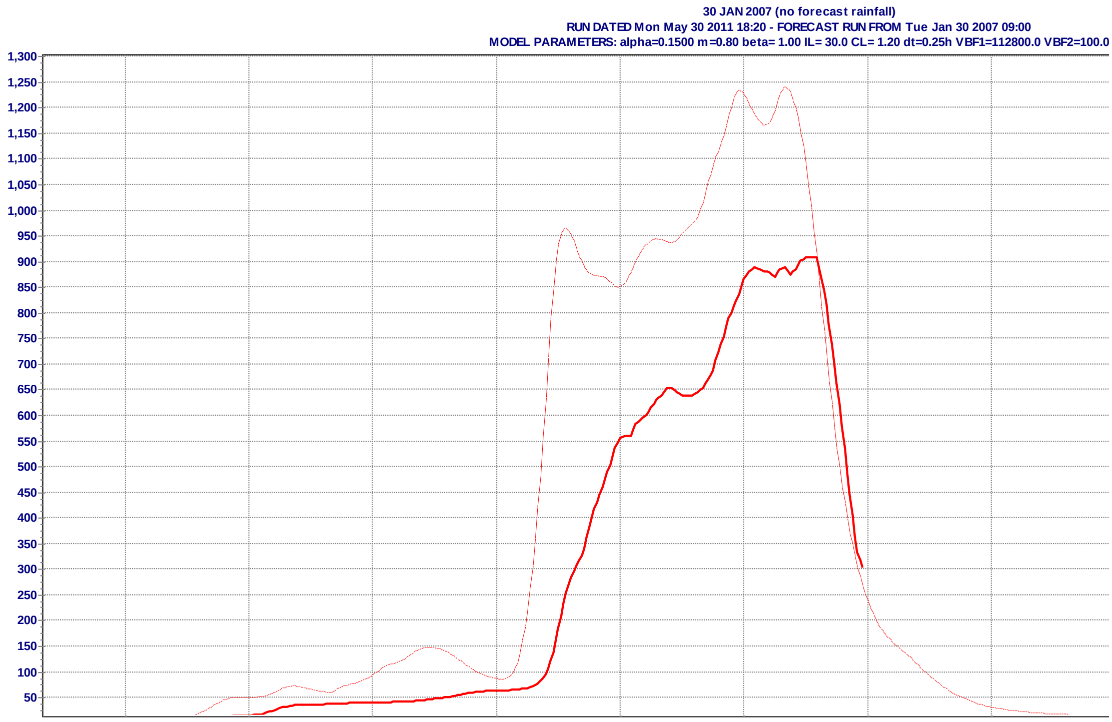

Figure 4.29 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Blacks Creek at Whitefords, 2007

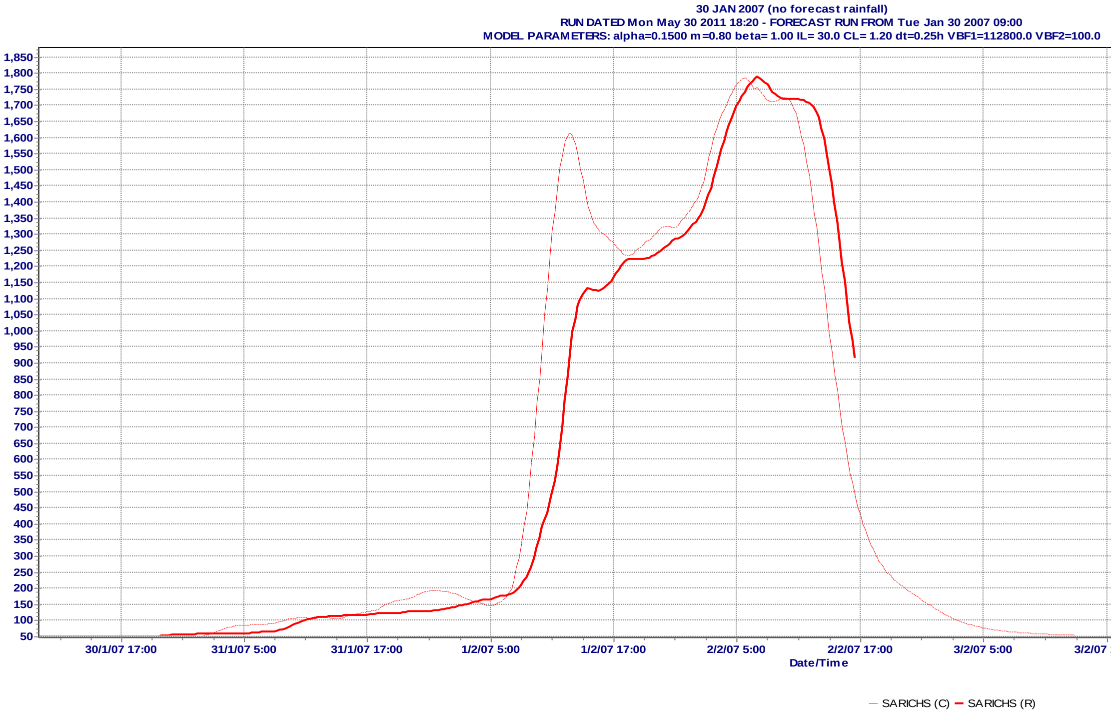

Figure 4.30 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Sarichs, 2007

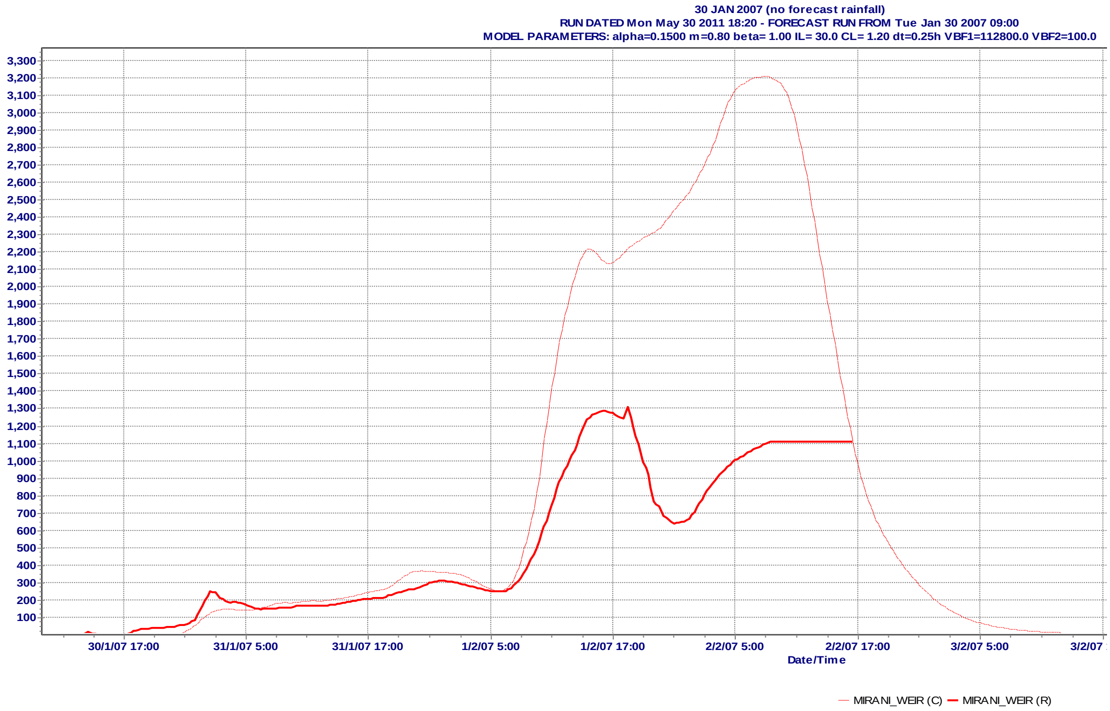

Figure 4.31 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Mirani Weir Tailwater, 2007

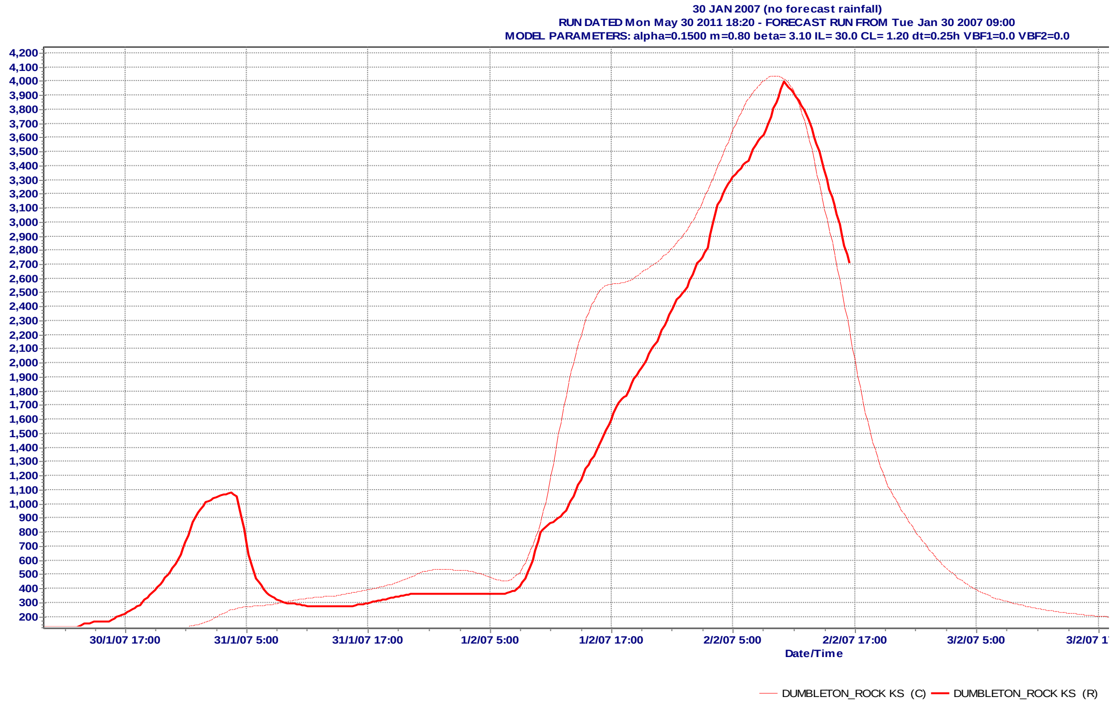

Figure 4.32 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Dumbleton Weir Headwater, 2007

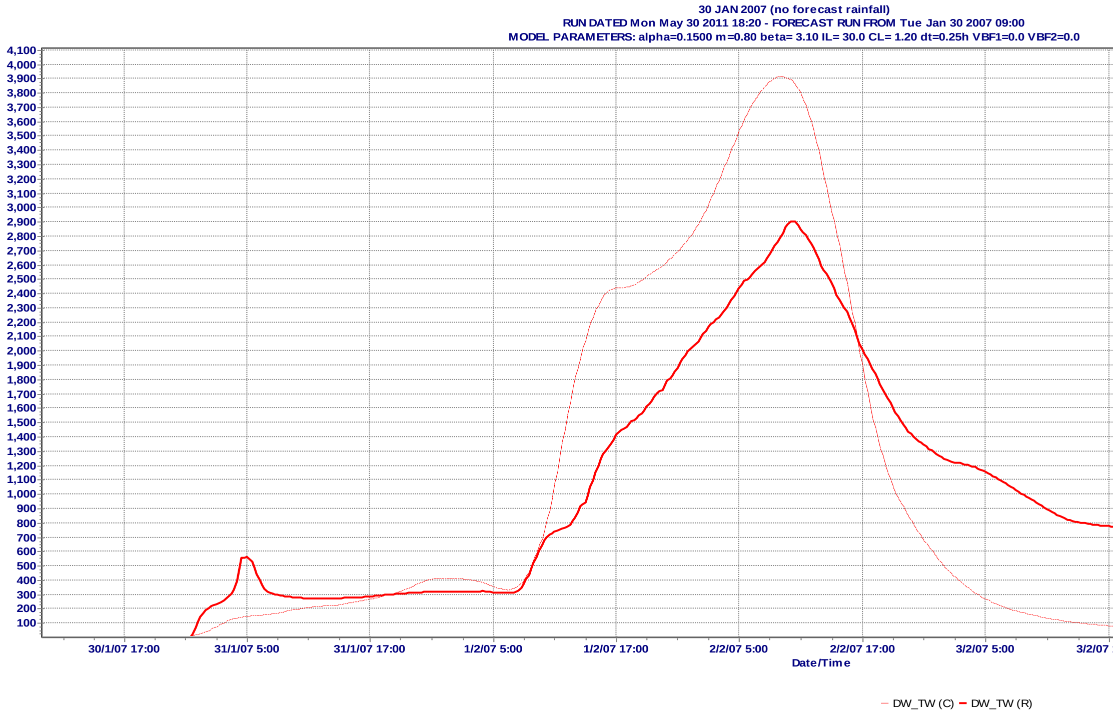

Figure 4.33 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Dumbleton Weir Tailwater, 2007

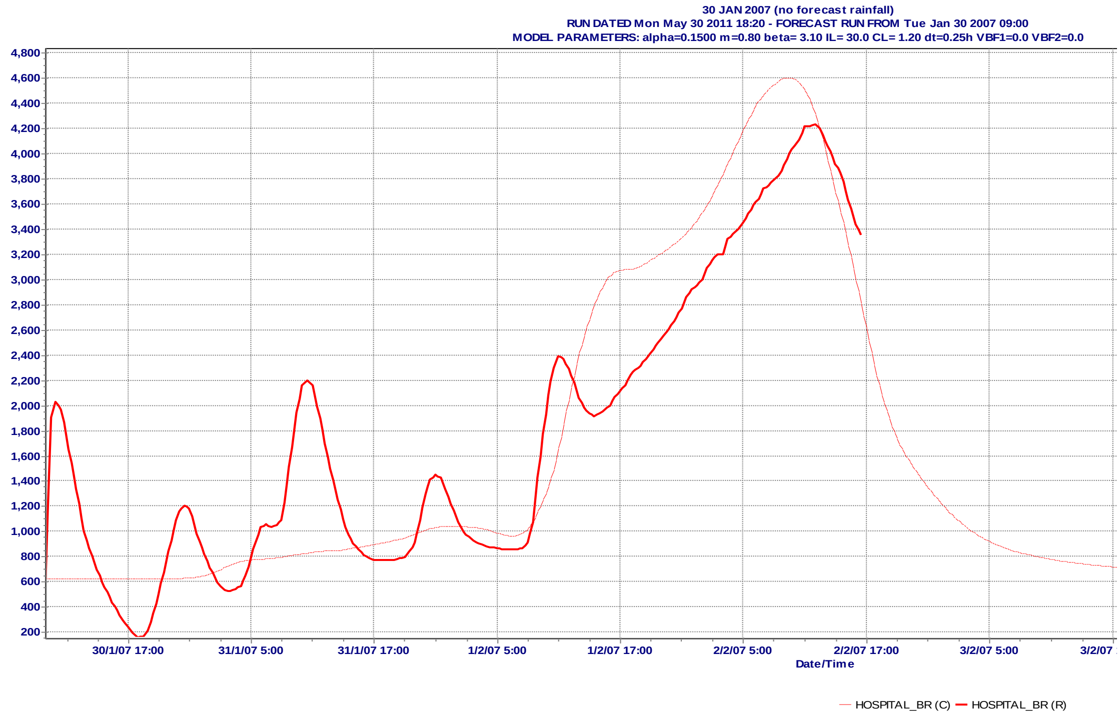

Figure 4.19 Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Hospital Bridge, 2007

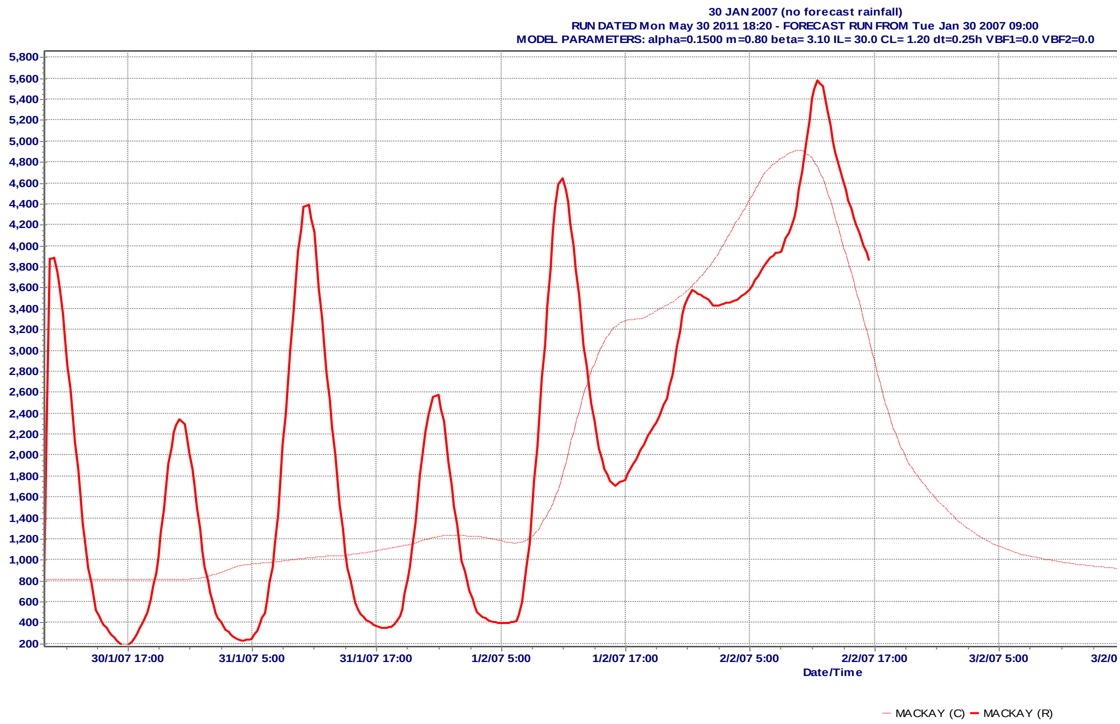

Figure 4.34 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Mackay, 2007

4.4.6 February 2008

Figure 4.35 to Figure 4.43 show comparisons of predicted and recorded flood discharge hydrographs at Finch Hatton, Gargett, Whitefords, Sarichs, Mirani Weir, Dumbleton Weir Headwater, Dumbleton Weir Tailwater, Hospital Bridge and Mackay for the February 2008 event. Data was not available at other gauging stations in the catchment for this event.

A good calibration was achieved in the upstream catchment to Mirani for this event as well as at the Hospital Bridge and Mackay, with the URBS models satisfactorily responding to the flood peaks, flood volumes and the timing and shapes of the hydrographs. The predicted flood peaks at the Dumbleton Weir tailwater gauge are significantly underestimated when compared to the recorded flows. However, the recorded flows at this station estimated using both the RDMW and adopted rating curves appears inconsistent with the other gauges in the catchment. Further discussion on the Dumbleton Weir stations is given in Section 5.4.1.

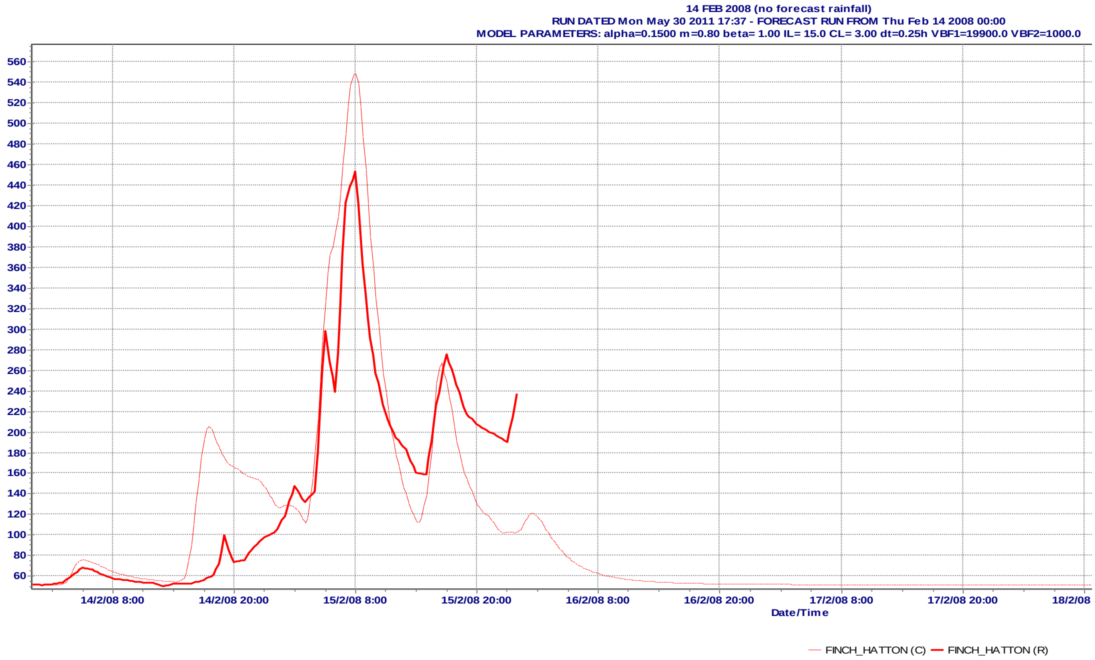

Figure 4.35 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Cattle Creek at Finch Hatton, 2008

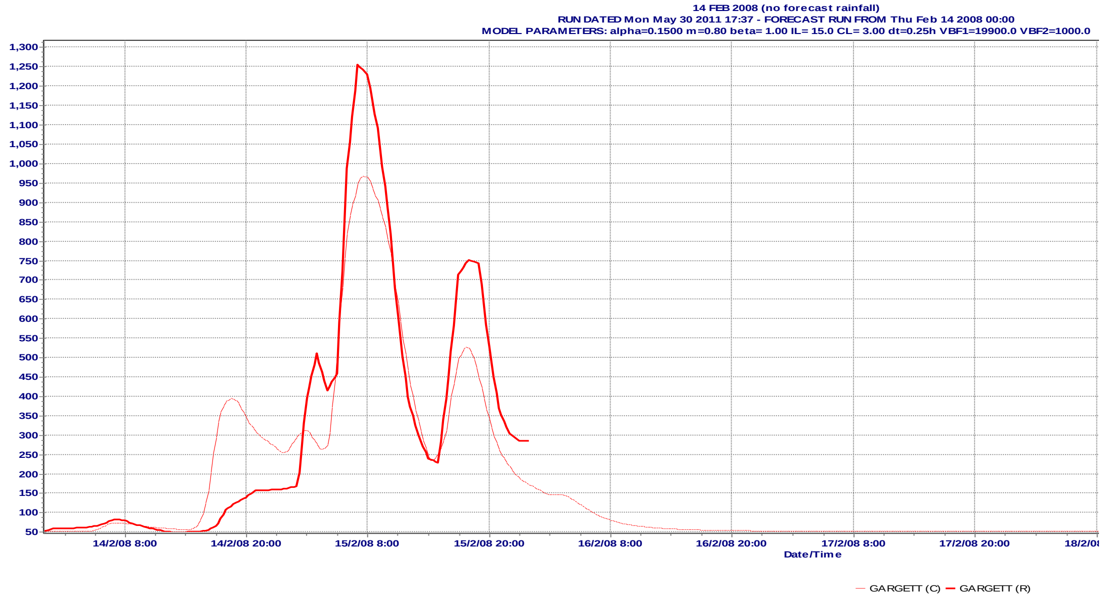

Figure 4.36 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Blacks Creek at Gargett, 2008

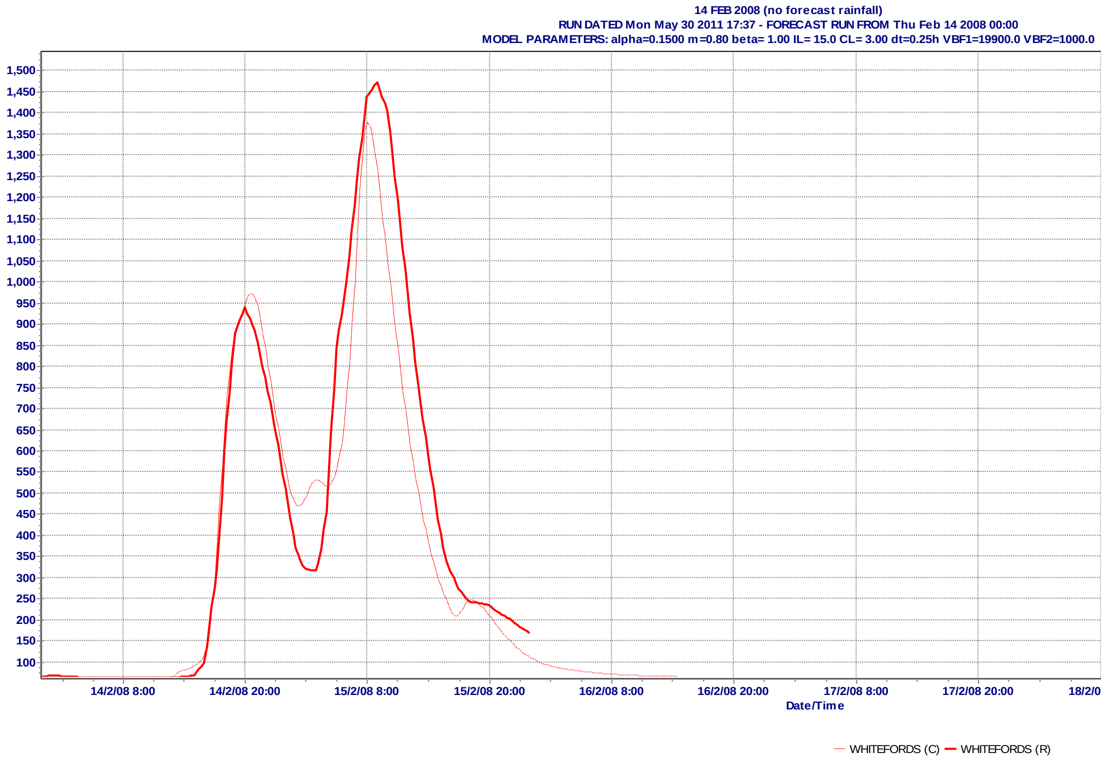

Figure 4.37 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Blacks Creek at Whitefords, 2008

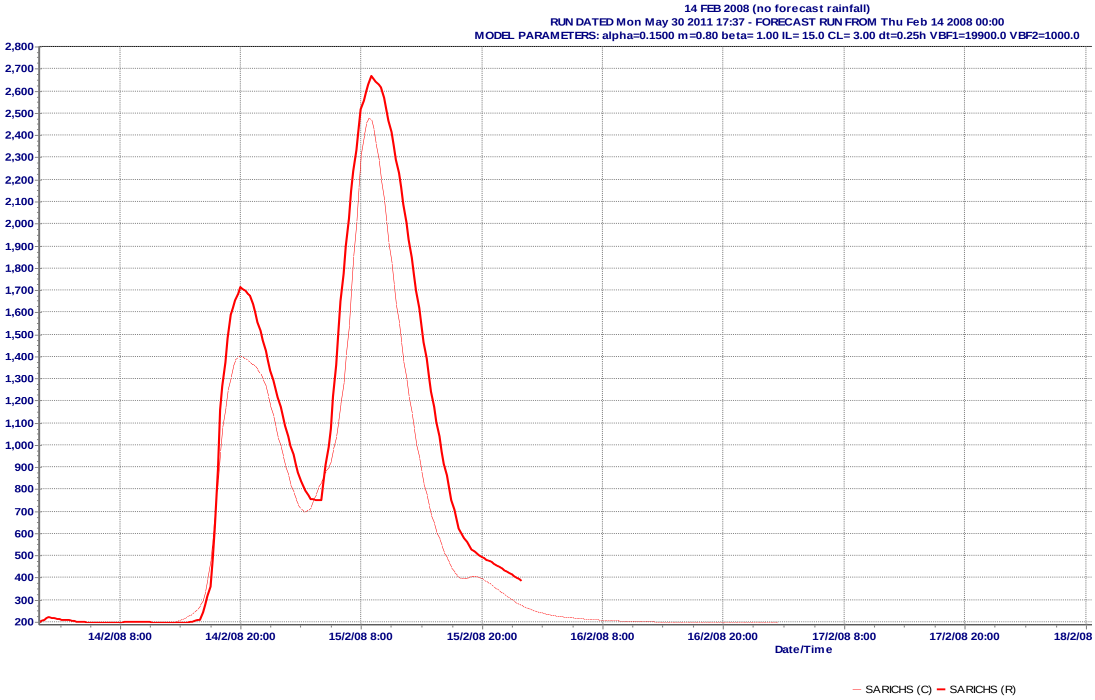

Figure 4.38 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Sarichs, 2008

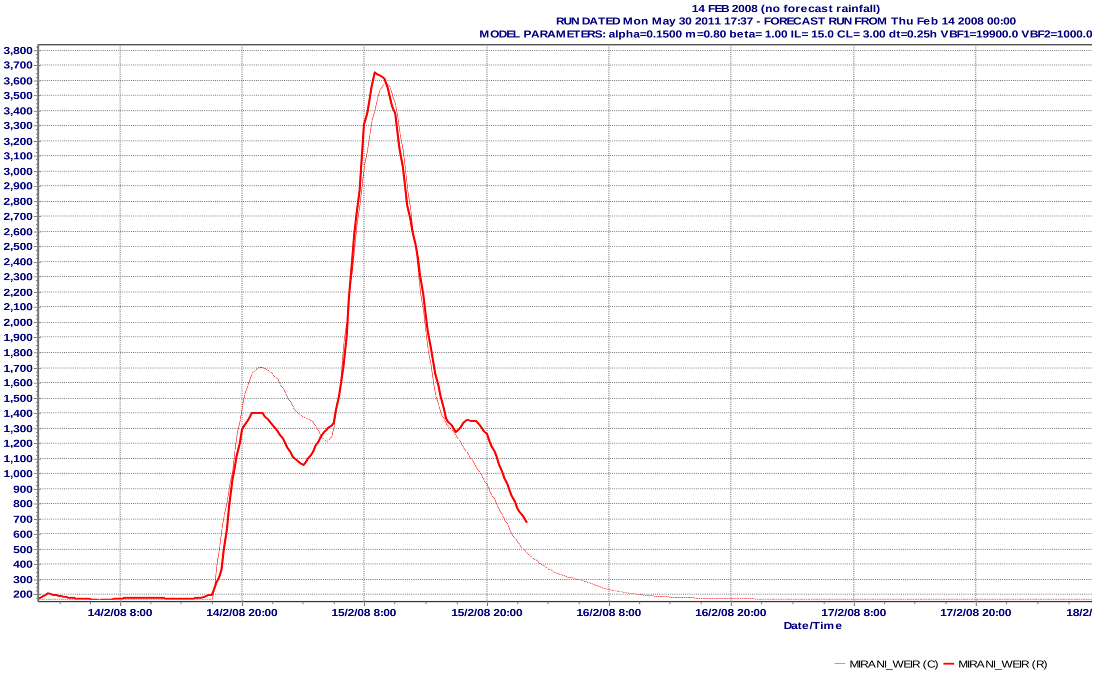

Figure 4.39 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Mirani Weir Tailwater, 2008

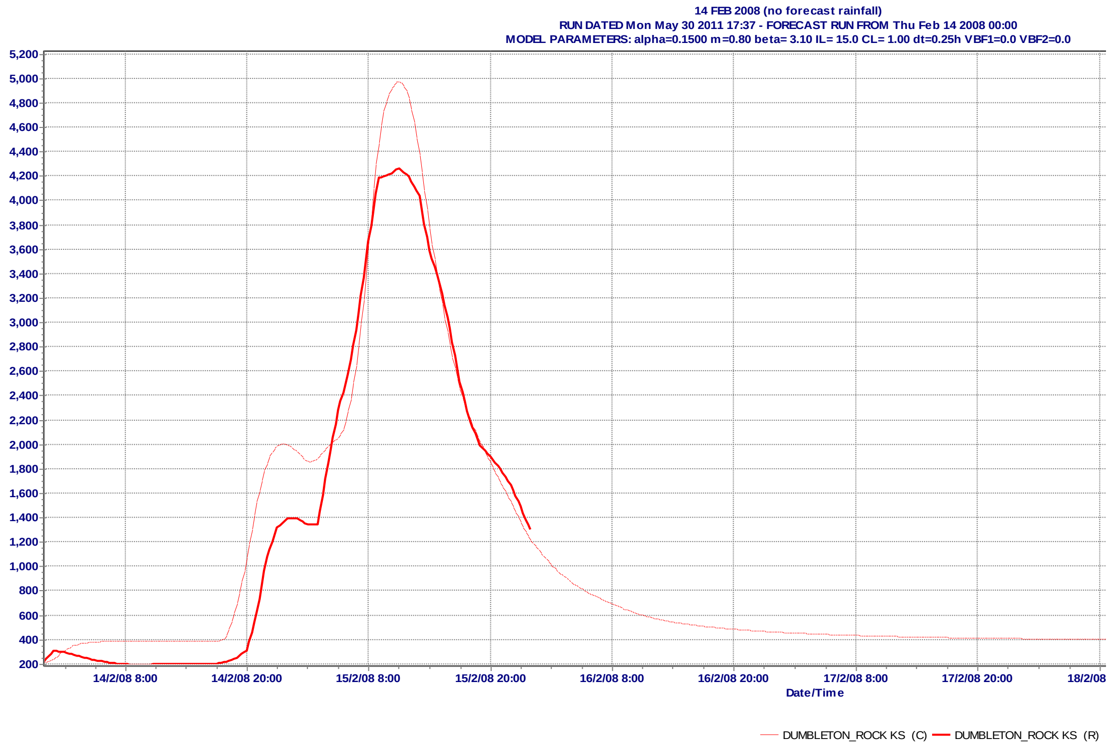

Figure 4.40 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Dumbleton Weir Headwater, 2008

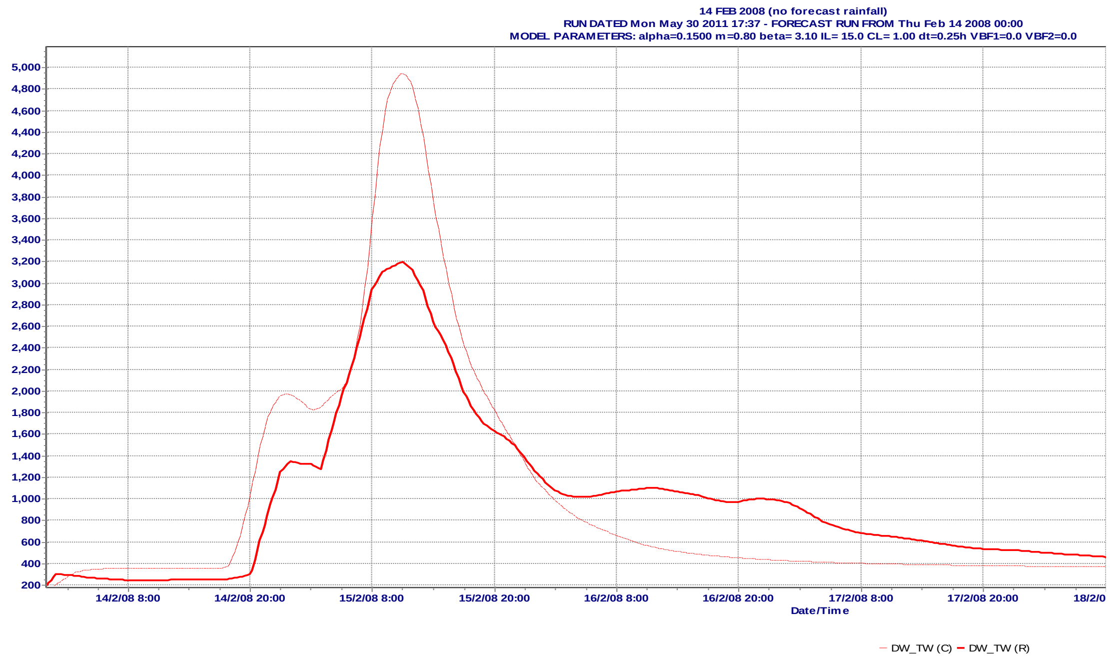

Figure 4.41 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Dumbleton Weir Tailwater 2008

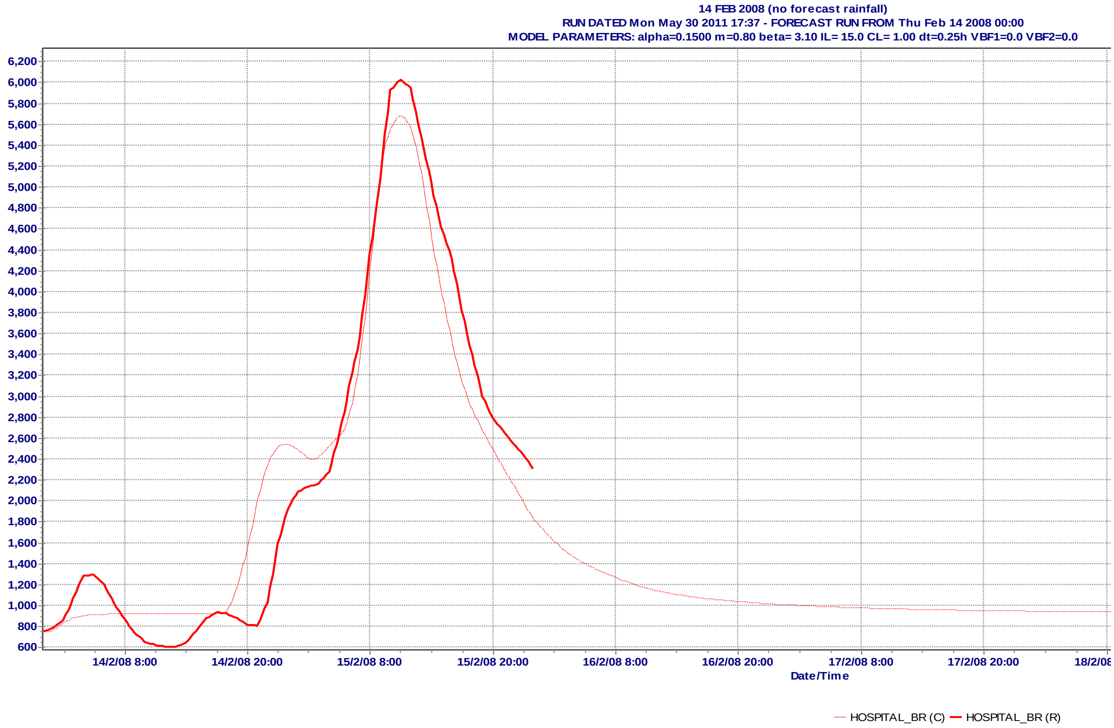

Figure 4.42 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Hospital Bridge, 2008

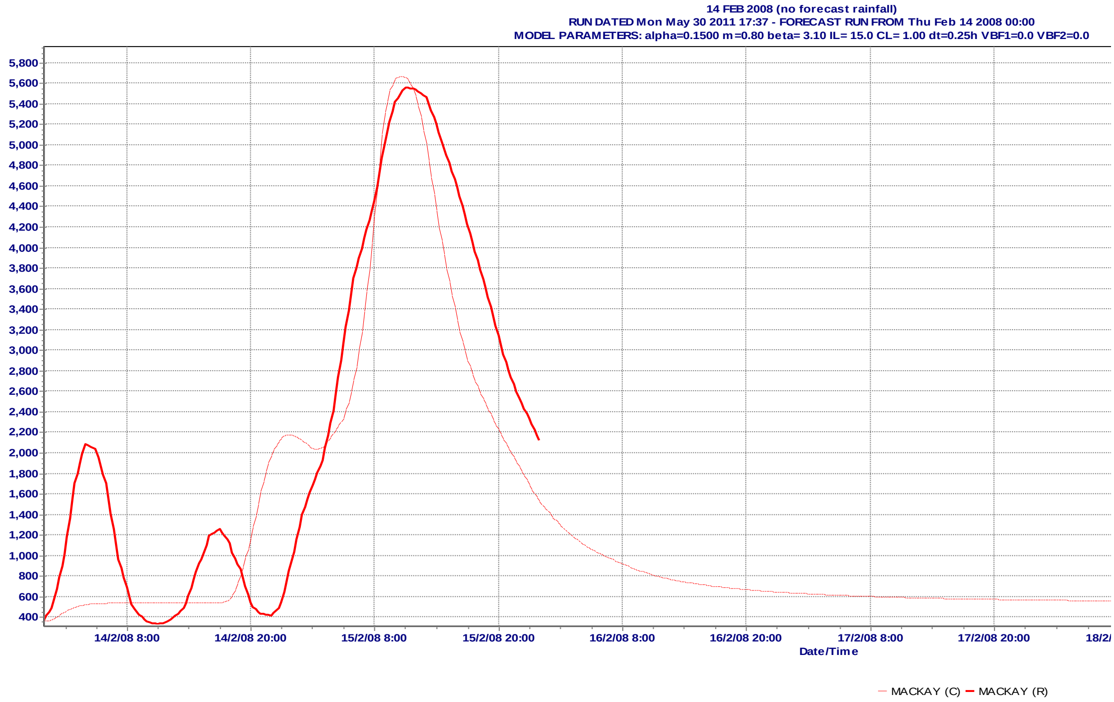

Figure 4.43 - Comparison of Calculated (C) and Recorded (R) Discharge Hydrographs, Pioneer River at Mackay, 2008

4.4.7 TC Debbie (March 2017) flood

TC Debbie formed in the Coral Sea on 24 March and made landfall around midday on 28 March 2017 near Airlie Beach as a Category 4 system. It weakened after landfall and was downgraded to a tropical low on the morning of 29 March approximately 170 km west of Mackay.

Figure 4.44 shows the cumulative rainfalls recorded across the Pioneer River catchment during the event. The locations of the rainfall stations are shown in Figure 4.1. The rainfall within the Pioneer River catchment started during the evening of 26 March 2017 and continued through to 29 March 2017. The majority of the rain fell on 28 and 29 March 2017. From 0900 hours on 26 March to 0900 hours on 31 March 2017, the highest rainfalls were recorded at the Clark Range gauge (1,025 mm) with moderately lower (but still significant) rainfalls occurring across the remainder of the catchment.

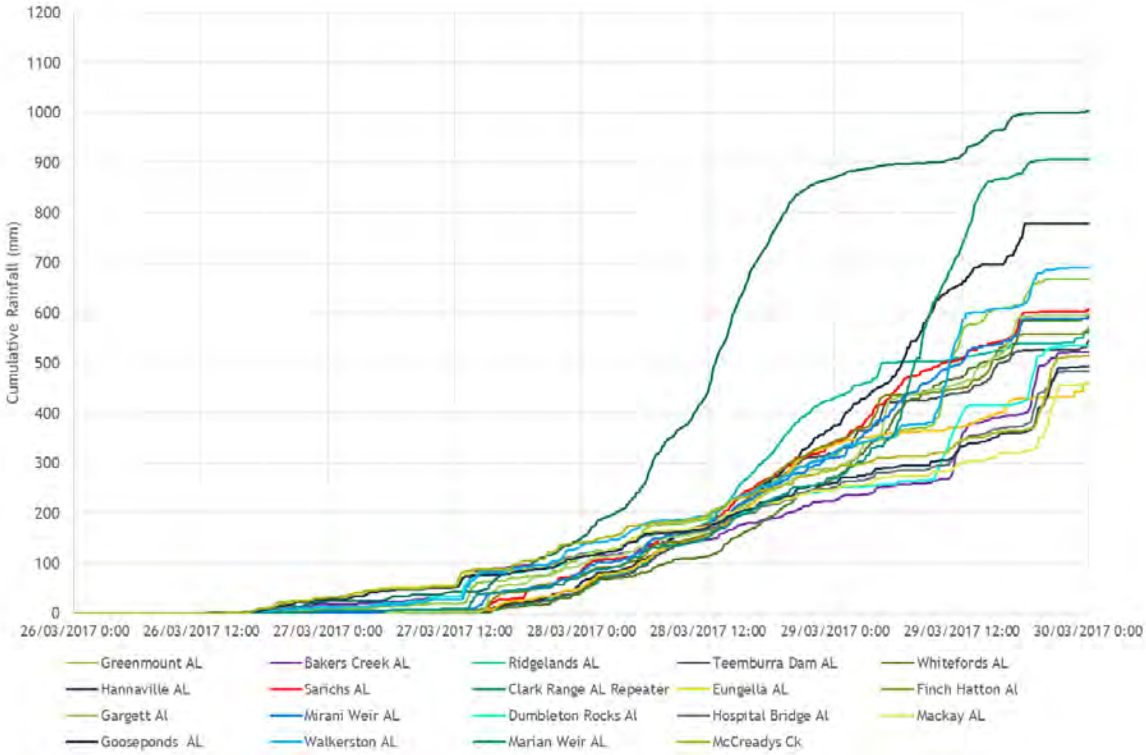

Figure 4.44 - Recorded Pioneer River catchment cumulative rainfalls, TC Debbie event

A comparison of recorded rainfalls with design rainfall intensities suggests that 12 to 36 hour rainfalls mostly had an AEP between 10% and 5% in the upper Pioneer River catchment. Recorded rainfall near Clark Range exceeded 1% AEP for this event. In the lower Pioneer River catchment near Mackay, the 12 to 36 hour rainfalls were between 39% AEP (2 year ARI) and 18% AEP (5 year ARI).

Figure 4.45 to Figure 4.48 shows the recorded and predicted discharges at the stream gauges at Pioneer River at Sarichs (Station No. 125002), Cattle Creek at Gargett (Station No. 125004), Pioneer River at Mirani Weir Tailwater (Station No. 125007) and Pioneer River at Dumbleton Weir HW (Station No. 125013) for the event.

The two predicted peak discharges at the Sarichs gauge are lower than the two recorded peak discharges. The lower flood volume suggests that this may be due to the lack of recorded rainfall data in the Blacks Creek and lower Teemburra Creek catchments upstream of Whitefords. The closest rainfall data is used for these catchments, which may be lower than the actual rainfall received during the event. It is of note that the Sarichs gauge failed at around 1000 hours on 29 March and the gauge levels after this time were estimated by the DNRM.

The first and highest peak discharge predicted at Gargett is slightly higher than recorded peak discharge. This peak corresponds to the severe rainfall burst recorded at the Clark Range Station. It is possible that the extent of this rainfall burst was not as broad as what has been assumed. The peak discharge and timing of the predicted second and third peaks at Gargett generally match the recorded data.

At Mirani Weir TW gauge, the model under predicts the peak discharge. This is partly due to the under predicted discharges at Sarichs gauge. It is of note that the gauge failed at approximately 1030 hours on 29 March before the flood peak. The gauge levels after this time were estimated by DNRM.

The Dumbleton Weir is a key location for model validation because it captures most of the Pioneer River catchment upstream of Mackay. The predicted flood peak at Dumbleton Weir is slightly lower than the recorded peak. However, the shape and timing of the predicted hydrograph is reasonable.

Overall, the predicted results compare well with the upstream and downstream gauges with discharges slightly over predicted in the Cattle Creek catchment and slightly under predicted in the Blacks Creek catchment.

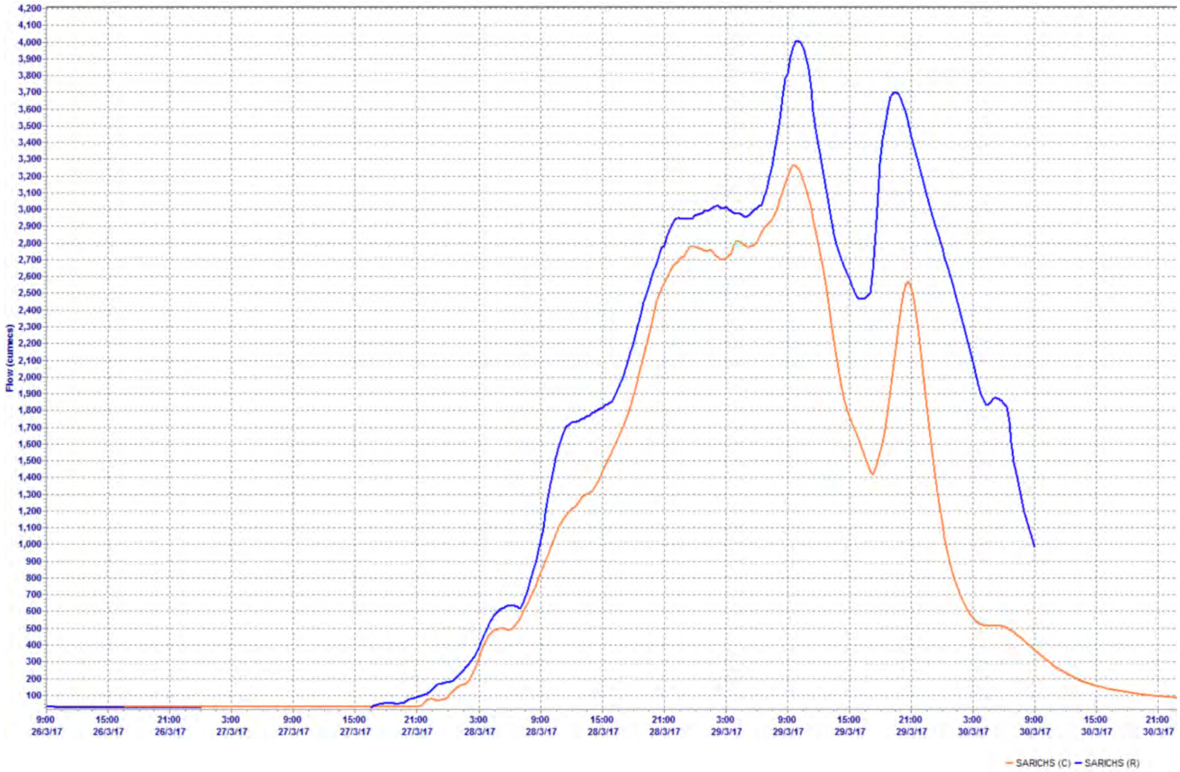

Figure 4.45 - Comparison of recorded and URBS model predicted discharges, Pioneer River at Sarichs, March 2017 event

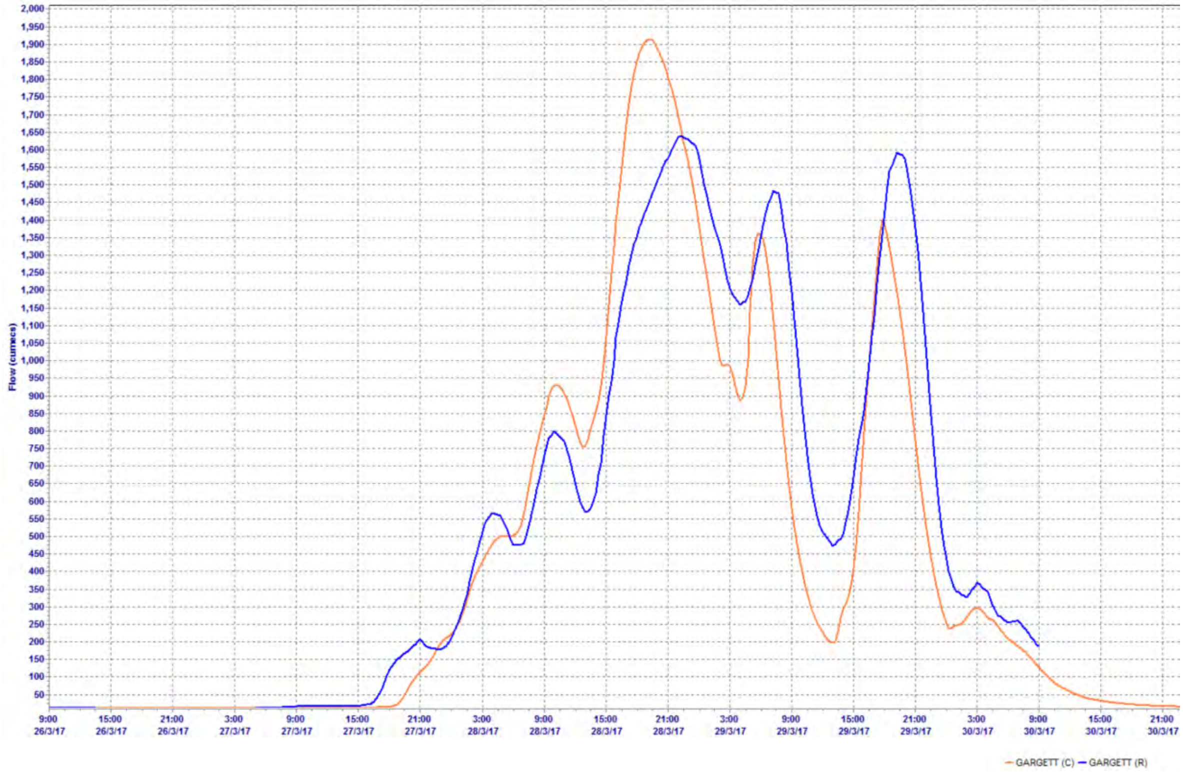

Figure 4.46 - Comparison of recorded and URBS model predicted discharges, Cattle Creek at Gargett, March 2017 event

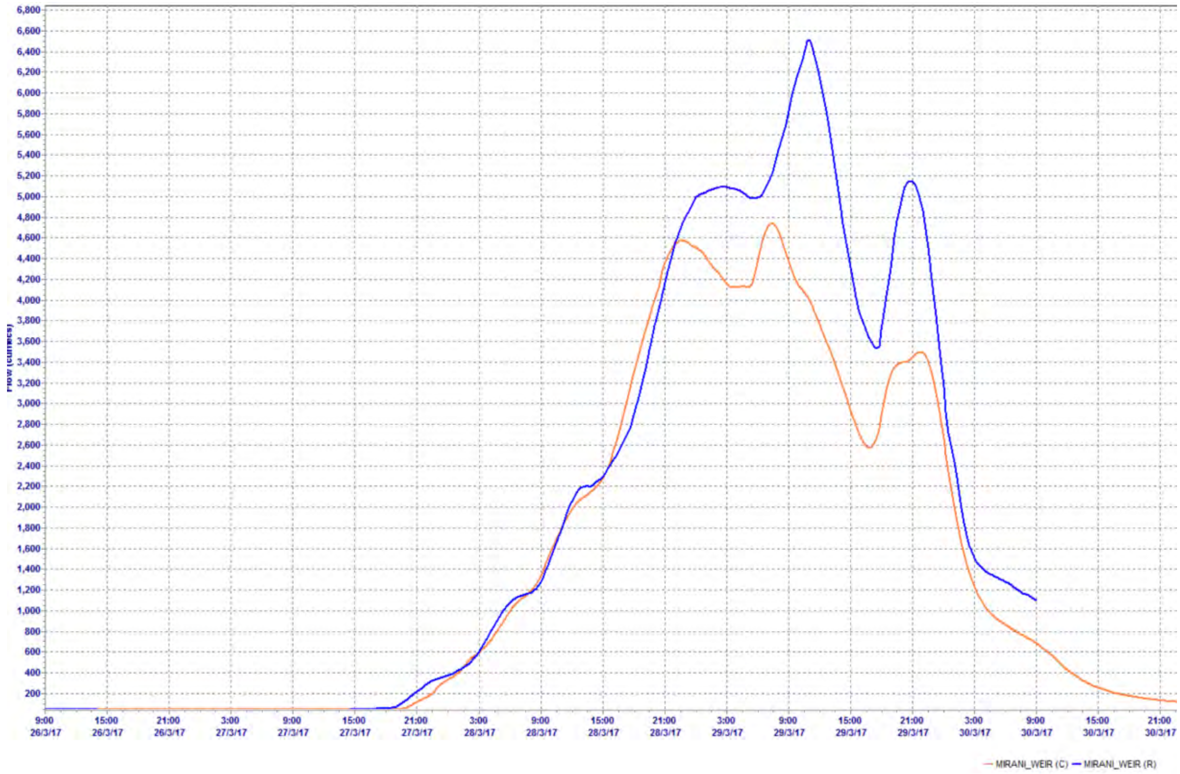

Figure 4.47 - Comparison of recorded and URBS model predicted discharges, Pioneer River at Mirani Weir Tailwater, March 2017 event

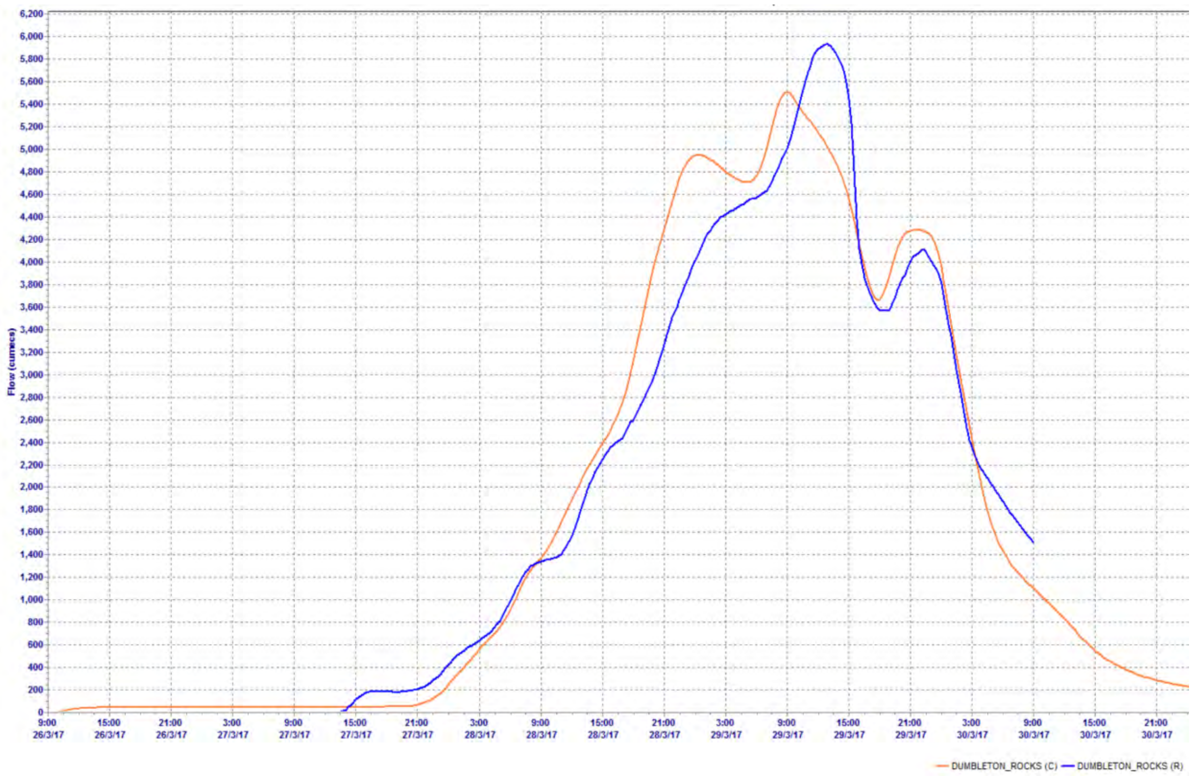

Figure 4.48 - Comparison of recorded and URBS model predicted discharges, Pioneer River at Dumbleton HW, March 2017 event

5 Hydraulic model development and calibration

5.1 OVERVIEW

The TUFLOW hydrodynamic model was used to simulate the flow behaviour of the Pioneer River channel and floodplain (including Goosepond Creek) from Mirani Weir to the mouth of the river at Mackay. TUFLOW represents hydraulic conditions on a fixed grid by solving the full two-dimensional depth averaged momentum and continuity equations for free surface flow. The model automatically calculates breakout points and flow directions within the study area. The Pioneer River channel from Mirani Weir to downstream of Dumbleton Weir was modelled as a one-dimensional channel (using cross sections) as no bathymetric data was available for the weirs. The overbank areas and the Pioneer River downstream of Dumbleton Weir were modelled within the two-dimensional domain.

The Pioneer River TUFLOW model was run using the HPC solver (2020-10-AB) and 5 m grid. The TUFLOW model was also updated to incorporate recent developments since the LiDAR survey undertaken in 2015, including the Mackay Ring Road. The model configuration and calibration results are provided in the following sections.

5.2 MODEL CALIBRATION

The TUFLOW model was calibrated against the recorded water levels (and recorded gaugings, where possible) for the following historical flood events:

- February 1958
- January 1970
- January 2007
- February 2008; and
- March 2017.

Note that not all events adopted for the hydrologic model calibration and verification were adopted for the calibration and verification of the TUFLOW hydraulic model. The events adopted for the hydraulic were chosen based on the quality of water level data available for calibration and the magnitude of the event. The March 2017, February 2008 and January 2007 events have the most data and the February 1958 event is the largest event on record for the Pioneer River. Model calibration was not undertaken for the January 1990 and February 2000 events because limited calibration data was available for the 1990 event downstream of Mirani Weir and the 2000 flood event was smaller than the 2007 and 2008 events that have more calibration data.

TUFLOW model calibration was undertaken using the recorded discharges at Mirani Weir for the 2017, 2008 and 2007 events and the recorded discharges Mirani Town for the 1970 and 1958 events at the upstream boundary of the model, and the URBS model discharges at interval boundaries along the downstream reach.

5.3 HYDRAULIC MODEL CONFIGURATION

5.3.1 Model extent

Figure 5.1 shows the extent of the Pioneer River TUFLOW model. The main channel of the Pioneer River from the Mirani Weir to immediately downstream of the Dumbleton Weir was modelled using one-dimensional cross sections. The Pioneer River downstream of the Dumbleton Weir and the Pioneer River floodplain were modelled using a two-dimensional 5 m grid.

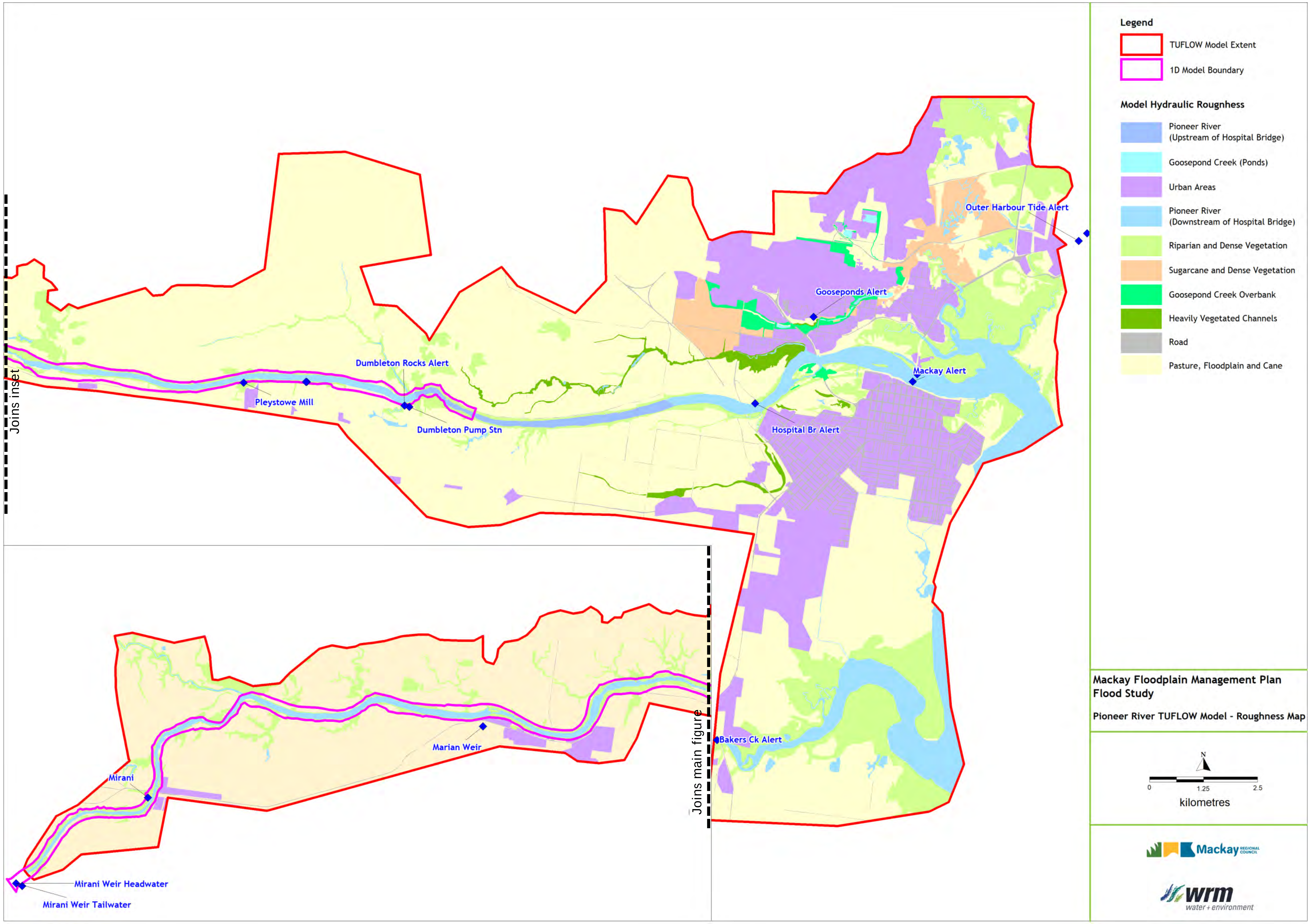

Figure 5.1 - Pioneer River model **Manning's roughness map**

5.3.2 Adopted Manning's 'n' values

The TUFLOW model uses Manning's 'n' values to represent hydraulic resistance (notionally channel or floodplain roughness). Discrete regions of continuous vegetation types and land uses were mapped, and an appropriate roughness values assigned to each region. The mapped areas are shown in Figure 5.1.

The adopted Manning's 'n' values for each mapped area are shown in Table 5.1 and are mostly unchanged from the Pioneer River Flood Study (WRM, 2011). The Manning's 'n' values were selected during model calibration and were applied to all model scenarios.

Table 5.1 - Adopted Manning's 'n' parameters

Location	Adopted Manning's 'n'
2D Area	
- Pasture, Floodplain, Cane	0.070
- Riparian and Dense Vegetation	0.090
- Urban Areas	0.100
- Roads	0.020
- Pioneer River - Upstream Hospital Bridge	0.035
- Pioneer River - Downstream Hospital Bridge	0.035
- Heavily Vegetated Creek Channels	0.100
- Goosepond Creek Overbank	0.050
- Goosepond Creek Ponds	0.030
- Sugarcane and Dense Vegetation	0.120
1D Area (Pioneer River Channel)	
- Mirani Weir to Mirani	0.048
- Marian and Dumbleton Weir pools	0.035
- Marian Weir to Dumbleton Weir Pool	0.042
- Dumbleton Weir to end of 1D	0.100 (to 10m deep) 0.065 (>14m deep)

5.3.3 Inflow and outflow boundaries

Table 5.2 shows the inflow and outflow boundaries used in the TUFLOW model. The primary inflow at the upstream boundary of the model corresponds to the recorded discharges at the Mirani Weir tailwater gauge. Residual catchment inflows correspond to the various URBS sub-catchment discharges downstream of Mirani as shown in Figure 4.1. The Mackay Outer Harbour tidal gauge record was adopted as the downstream boundary for the Pioneer River for the calibration runs.

The inflow boundaries for Goosepond Creek (except for the 1958 and 1970 events) were obtained from the Goosepond Creek XP-RAFTS model. Details of the Goosepond Creek (XP RAFTS model configuration and calibration are given in the Goosepond Creek Flood Study (WRM, 2021a).

5.3.4 Hydraulic structures

Table 5.3 shows the locations of the road and rail bridges in the TUFLOW model. The approximate date of construction of each structure is also given. For model calibration, only the bridges constructed at the time of the event were included in each model. Details of the bridges were obtained from 'as-constructed' drawings supplied by Department of Transport and Main Roads and Queensland Rail.

Table 5.2 - Inflow and Outflow Boundaries

Boundary Name	Location
Inflow	
US_Mirani	Mirani Weir Tailwater
McGregor	McGregor Creek
Sub_48L	Pioneer River
Sub_54L	Pioneer River
Sub_55L	Devereaux Creek
Sub_56L	Marian Town
Sub_57L	Balnagowan Creek
Sub_58L	Tin Pot Creek
Sub_60L	Fursden Creek
Sub_61L	Fursden Creek
Sub_62L	Fursden Creek
Sub_59L	Pioneer River (West Mackay)
Sub_63_64L	Mackay City
Sub_68L	Pioneer River Estuary (Bassett Basin)
ToSub_66L	Jane Creek
Sub_67L	Goosepond Creek (North Mackay)
Outflow	
DS_Tidal	Mackay Outer Harbour
Sandy_out (1,2&3)	Pioneer River overflows to Sandy Creek between Mirani and Marian
Bakersout (1,2,3&4	Pioneer River overflows to Bakers Creek

Hydraulic structures such as weirs, channel crossings, levees and sea training walls were included in the TUFLOW models as 1D weir and bridge channels, 2D Z-Shapes and Layered 2D-flow constrictions. Marian and Dumbleton Weirs were modelled within the 1D domain using weir crest data supplied by Sunwater.

Details of the minor channel crossings and the levees were obtained from survey data collected by MRC in 2009. The details of the sea training walls were estimated from the LIDAR and bathymetry data supplied by MRC. Details of the Mackay Ring Road bridges and overpasses were provided by MRC in 2021.

Table 5.3 - Road and Rail Bridges

Structure	Location	Date of Construction
Mackay Eungella Rd Bridge	Mirani	1985
Finch Hatton Branch Rail	Mirani	1897
Marian Hampden Rd	Marian	1990
North Coast Rail	West Mackay	
Hospital Bridge (New)	Mackay	2007
Hospital Bridge (Old)	Mackay	1876
Bruce Highway Bridge	Mackay	1999
Forgan Smith Bridge (old)	Mackay	1938
Forgan Smith Bridge (new)	Mackay	2010
Mackay Bypass	Fursden Creek	1967
MRR Peak Downs Highway Overpass	Racecourse	2020
MRR Lagoon Creek Bridge	Racecourse	2020
MRR Gibsons Road Overpass	Racecourse	2020
MRR Pioneer River Bridge	Racecourse	2020
MRR Fursden Creek Overflow Bridge	Foulden	2020
MRR Fursden Creek Bridge	Foulden	2020
MRR North Coast Rail and Sugarshed Road Overpass	Glenella	2020

5.4 MODEL CALIBRATION RESULTS

5.4.1 February 1958

Figure 5.2 to Figure 5.4 show comparisons of predicted and recorded water level hydrographs at Mirani Town, Pleystowe Mill and Mackay gauges for the February 1958 event. February 1958 was the largest flood on record causing significant flooding throughout Mackay. The recorded and predicted flood levels are in good agreement at all three locations.

Figure 5.5 show the predicted longitudinal profile of the peak water levels along the river and compares them to recorded peak water levels surveyed from debris marks. The results show there is a good agreement between the predicted levels and the surveyed flood debris marks. Peak flood levels along the city reach of the river are over-predicted by up to 0.9 m at the mouth of the river and by about 0.5 m between the Forgan and Hospital Bridges.

It is understood that there has been considerable changes to both the Pioneer River channel and floodplain following the 1958 flood. EPA (2004) states that some 620,000 m^3 of sand was dredged from the Pioneer River to reclaim the Caneland Shopping Centre in 1978. An average of 100,000 m^3 per annum have been extracted from the lower reaches of the Pioneer River over the past two decades. It is also likely that some scour of the river would have occurred during large floods, although this did not appear to be experienced during the 1970 flood. Given the bathymetry of the Pioneer River during the 1958 flood is not known, the calibration of the model to the 1958 flood appears reasonable.

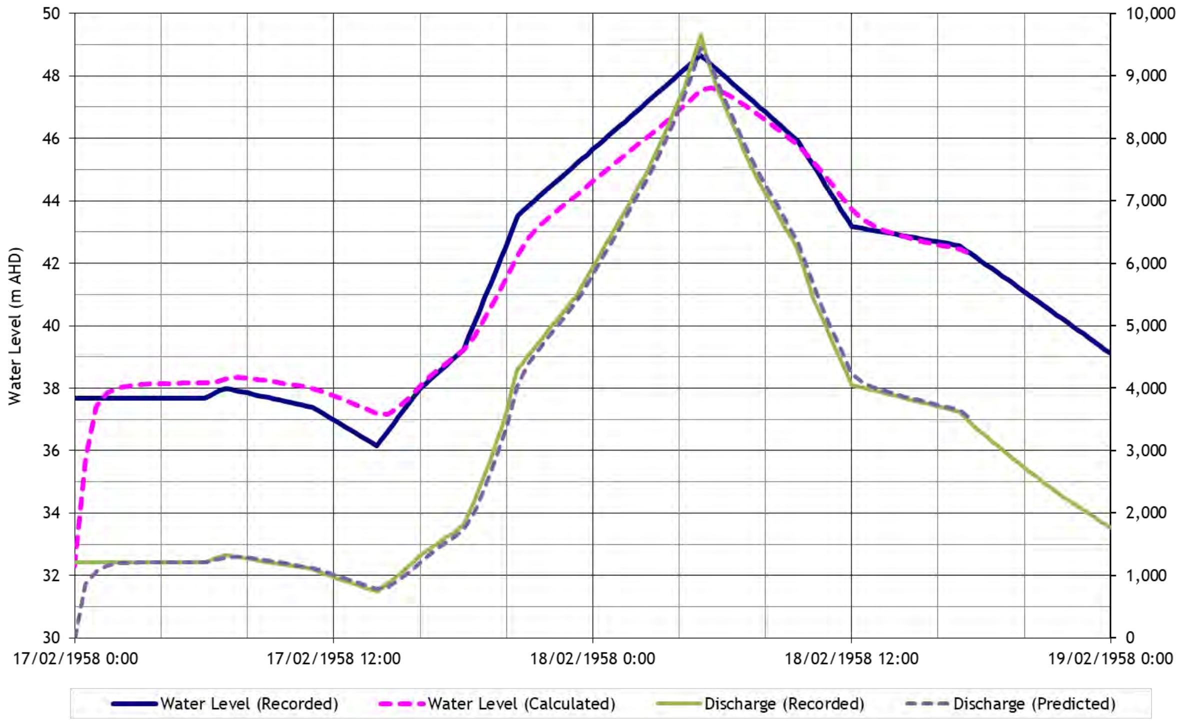

Figure 5.2 - Predicted and Recorded Water Level and Discharge Hydrographs, Pioneer River at Mirani Town, 1958

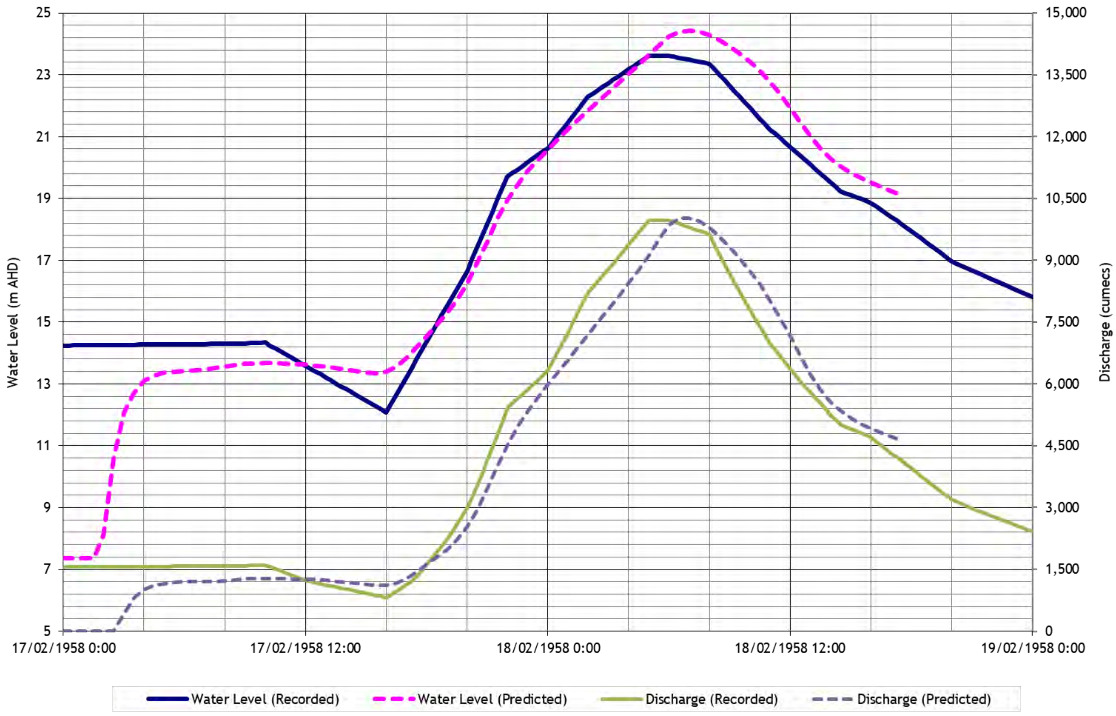

Figure 5.3 - Predicted and Recorded Water Level and Discharge Hydrographs, Pioneer River at Pleystowe Mill, 1958

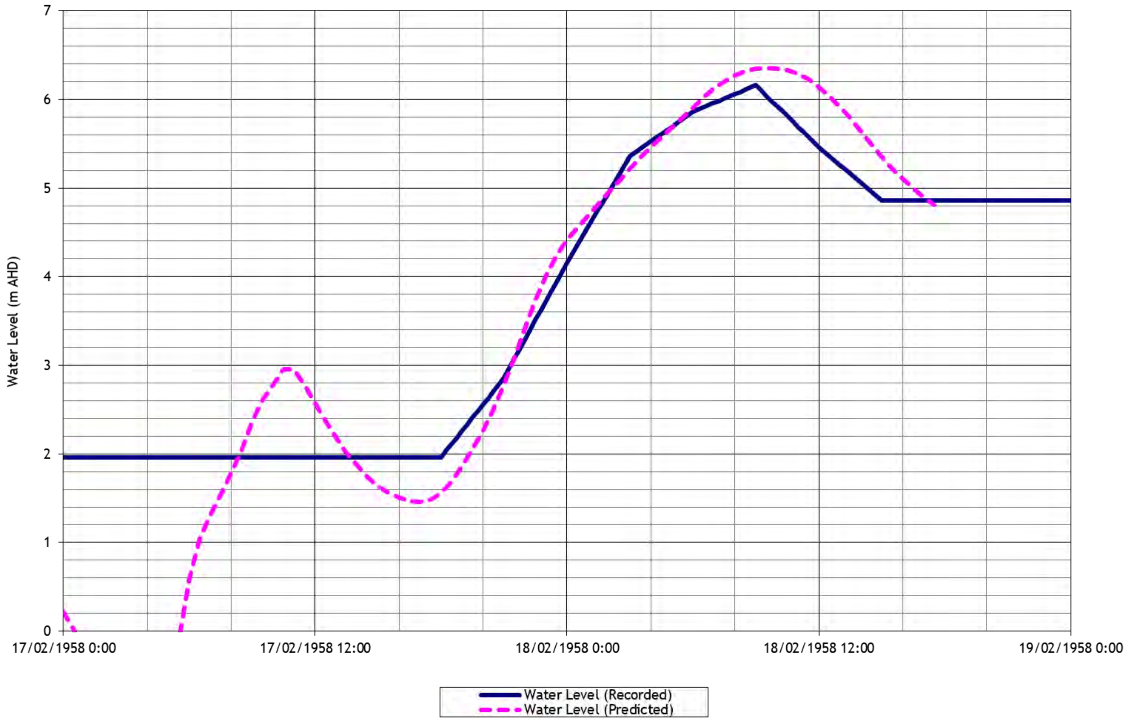

Figure 5.4 - Predicted and Recorded Water Level and Discharge Hydrographs, Pioneer River at Mackay, 1958

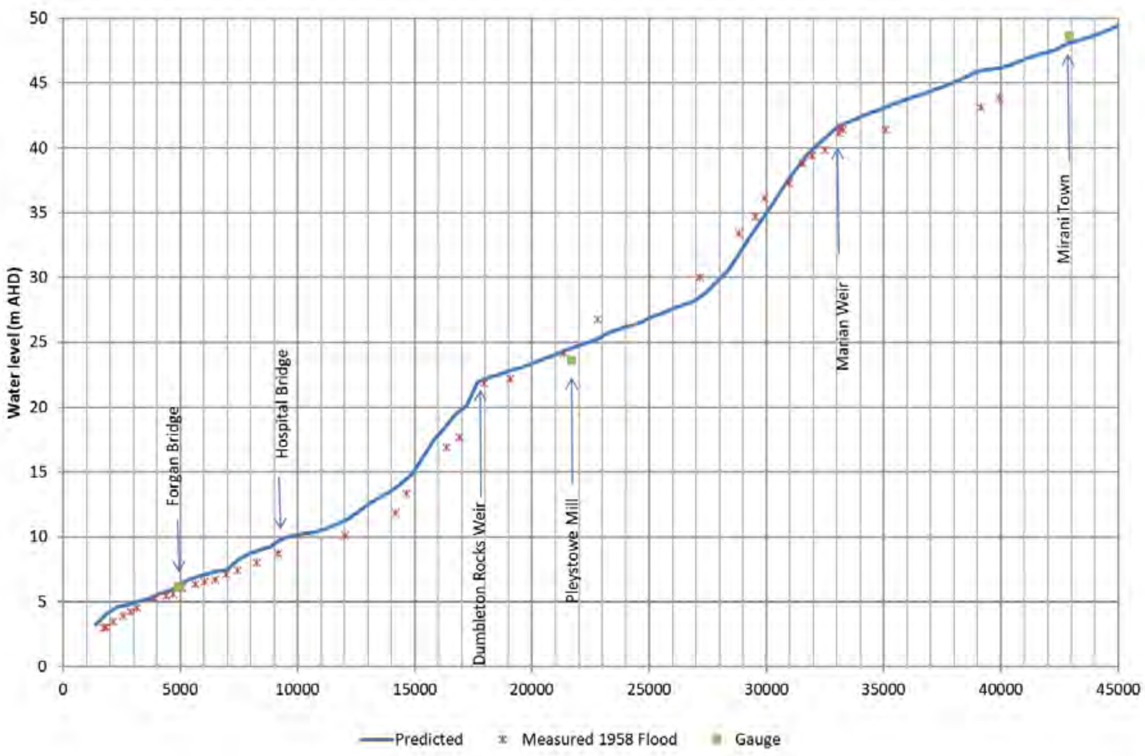

Figure 5.5 - Predicted Pioneer River Peak Water Level Longitudinal Profile and Peak Recorded Water Levels, 1958 Event

5.4.2 January 1970

Figure 5.6 to Figure 5.9 show comparisons of predicted and recorded water level and discharge hydrographs at Mirani town, Marian Weir, Pleystowe Mill and Mackay for the January 1970 flood event. The recorded discharges at Mirani Town (estimated using the BOM curve) (see Figure 3.7) were used to represent the inflows at Mirani Weir for this scenario. Dumbleton weir had not been constructed at this time.

The predicted peak flood levels and discharges at Mirani town, Marian Weir and Pleystowe Mill are in good agreement with the recorded data. The predicted flood levels at Mackay are some 0.5 m lower than the recorded levels.

Figure 5.10 shows the predicted longitudinal profile of the water levels along the river and compares them to recorded water levels measured from debris marks. The debris mark data was obtained from MRC. The results show that there is a good agreement between the predicted levels and the surveyed flood marks near the Mackay Gauge. It is understood that some debris had built up on the Forgan Bridge during the 1970 event, which may have affected the gauge water levels.

Figure 5.10 also shows that the model under-predicted the debris mark levels upstream of the Dumbleton Weir location by some 0.9 m. Given that the Pleystowe Weir levels correspond well, it is likely that the debris mark chainages may be slightly offset from what is shown in Figure 5.10.

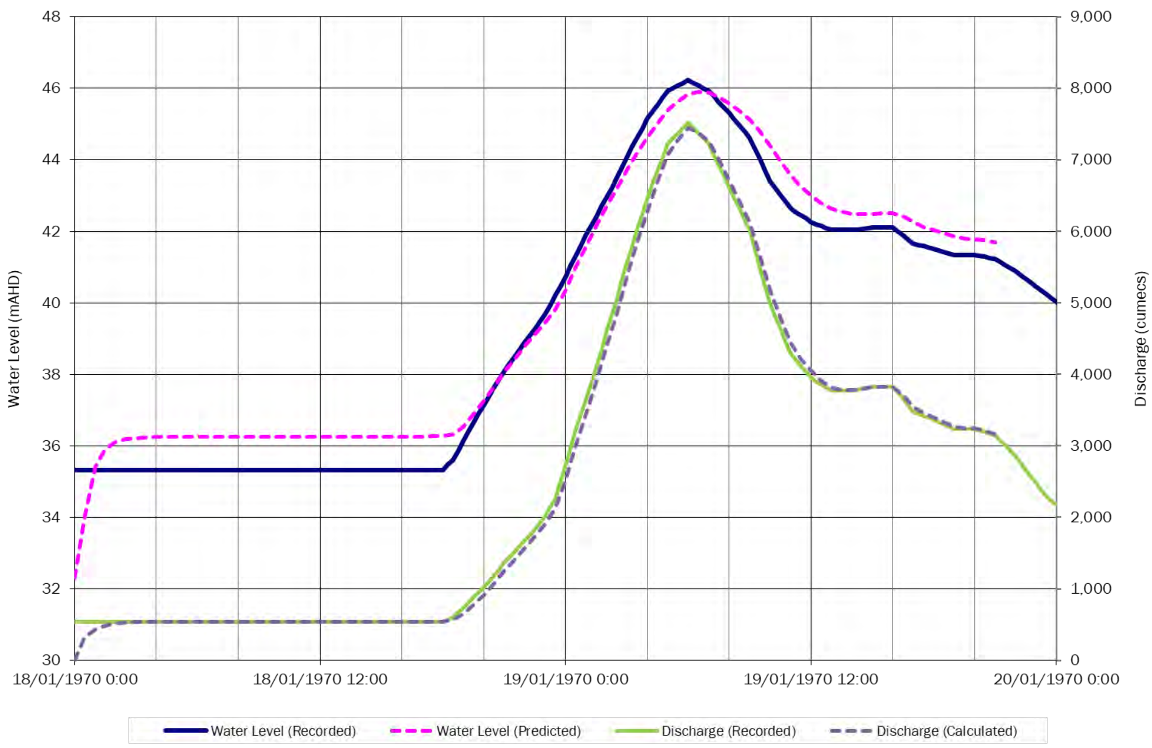

Figure 5.6 - Predicted and Recorded Water Level and Discharge Hydrographs, Pioneer River at Mirani Town, 1970

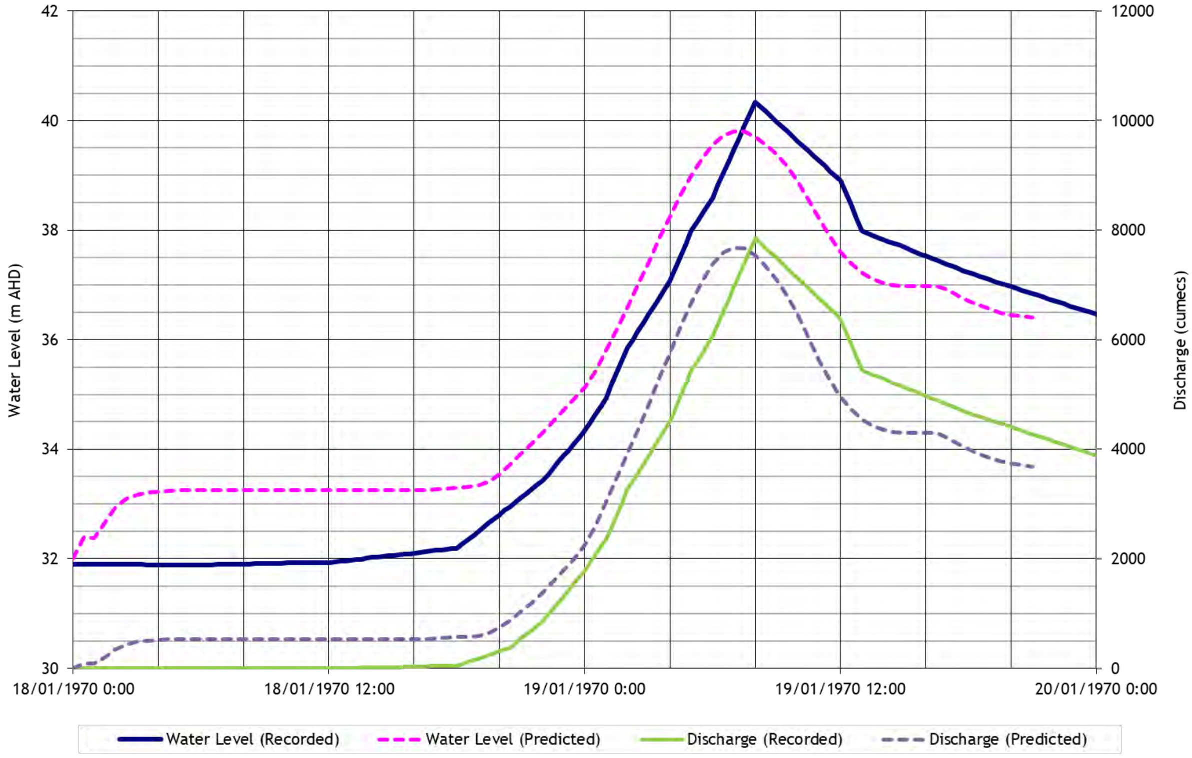

Figure 5.7 - Predicted and Recorded Water Level and Discharge Hydrographs, Pioneer River at Marian Weir, 1970

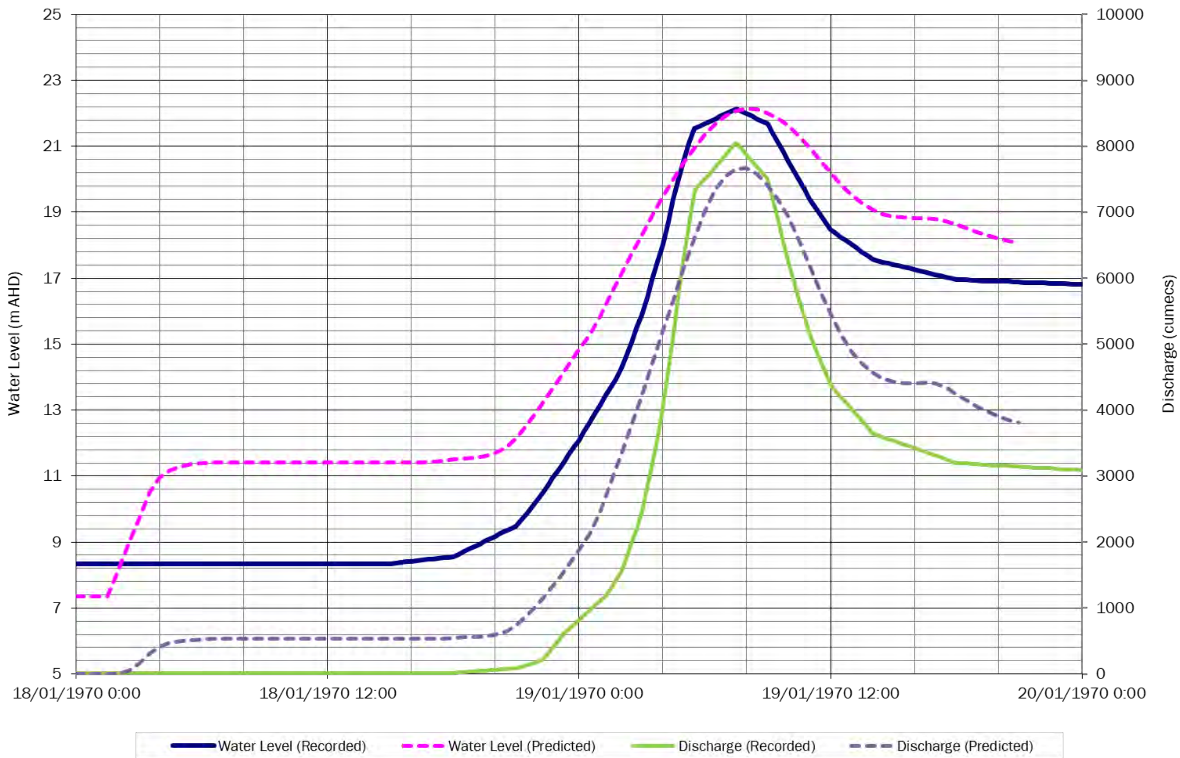

Figure 5.8 - Predicted and Recorded Water Level and Discharge Hydrographs, Pioneer River at Pleystowe Mill, 1970

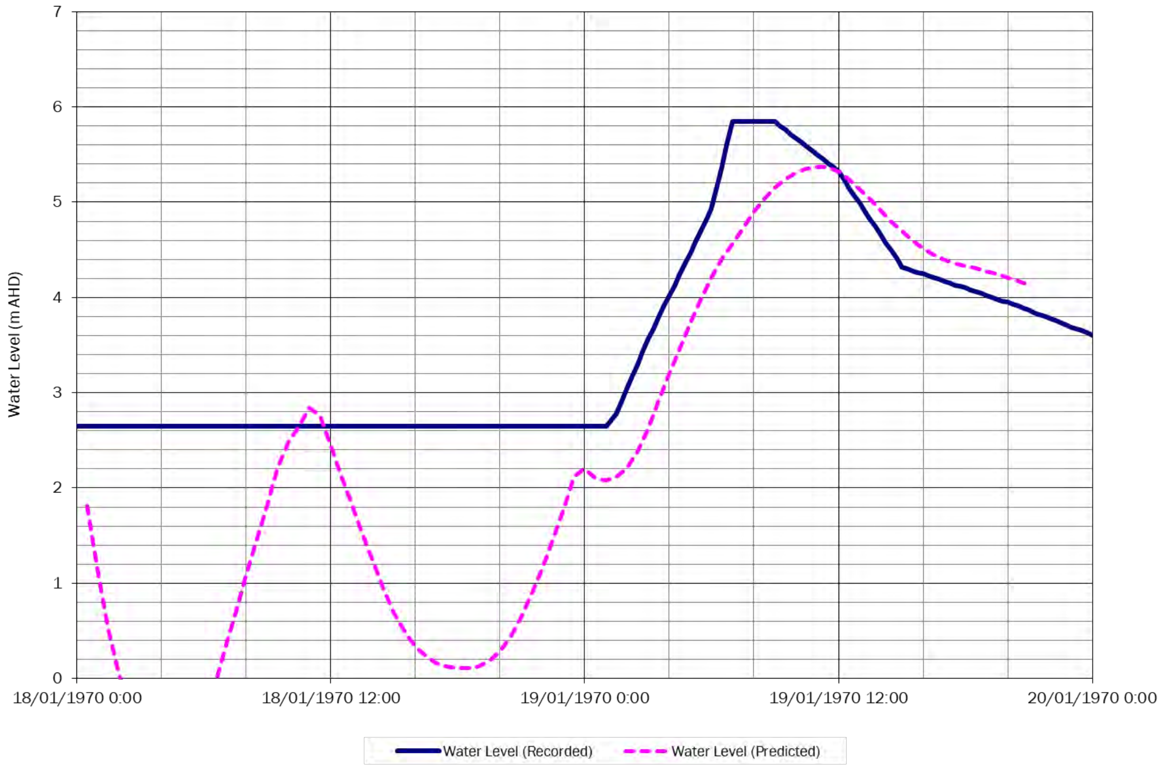

Figure 5.9 - Predicted and Recorded Water Level and Discharge Hydrographs, Pioneer River at Mackay, 1970

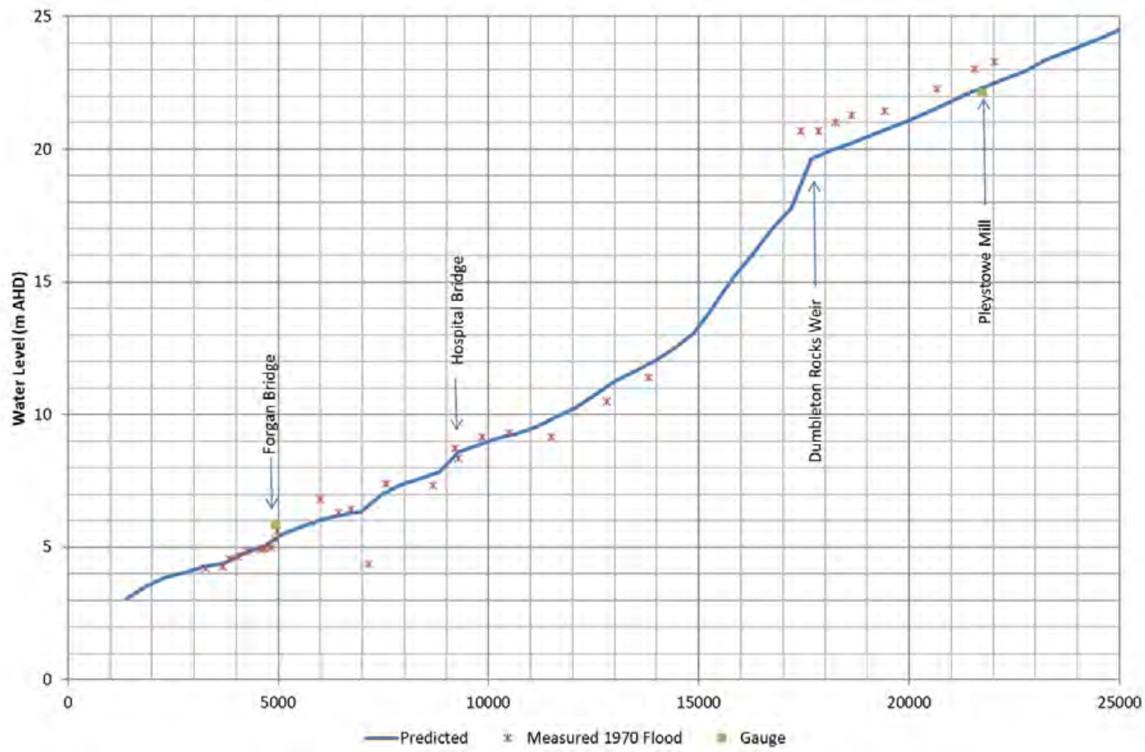

Figure 5.10 - Predicted Pioneer River Peak Water Level Longitudinal Profile and Recorded Peak Water Levels, 1970 Event

5.4.3 January 2007

Figure 5.11 to Figure 5.15 show comparisons of predicted and recorded water level hydrographs at Mirani Weir, Dumbleton Weir Headwater, Dumbleton Weir Tailwater, Hospital Bridge and Mackay gauges for the January 2007 event. The recorded and predicted discharge hydrographs at Dumbleton Weir is also shown. As noted in Section 4.4.5, the water level recorder at Mirani appears to have malfunctioned during this event and as such the URBS model discharges were also adopted for the upstream boundary of the model.

There is a good agreement between recorded and predicted water levels at Dumbleton Weir Headwater. However, predicted water levels and discharges downstream of the weir are much higher than the recorded values. Predicted water levels at the Hospital Bridge gauge are some 0.6 m higher than recorded values and some 0.2 m higher at Mackay.

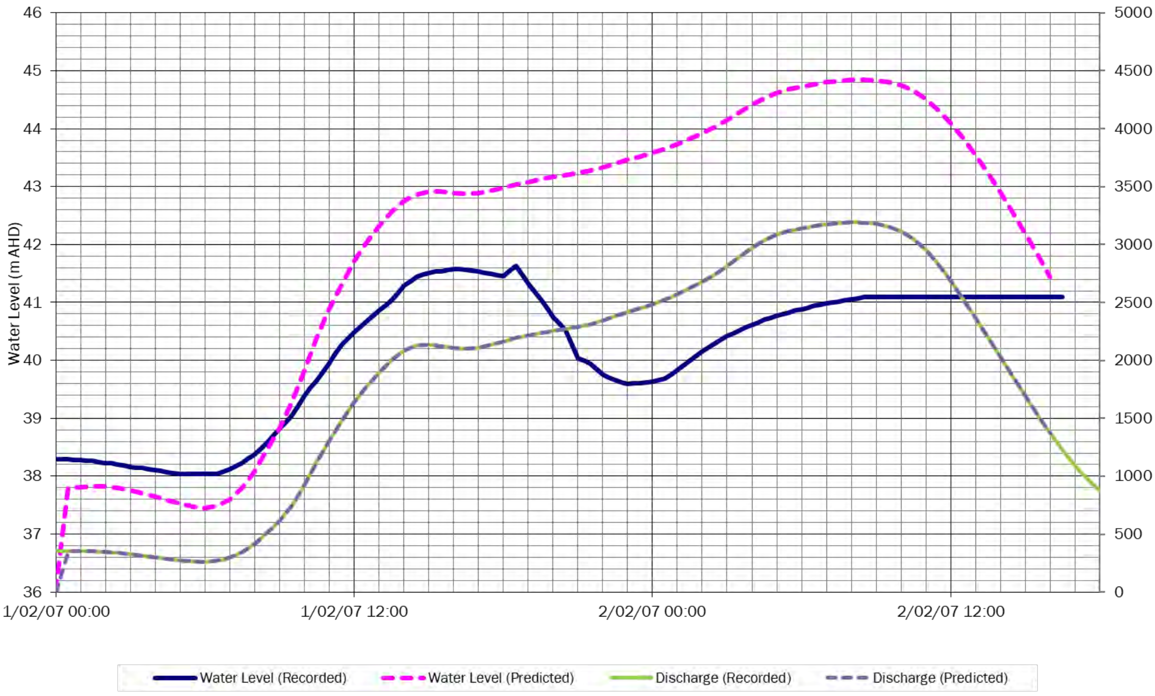

Figure 5.11 - Comparison of Predicted and Recorded Water Level Hydrographs, Pioneer River at Mirani Weir Tailwater, 2007

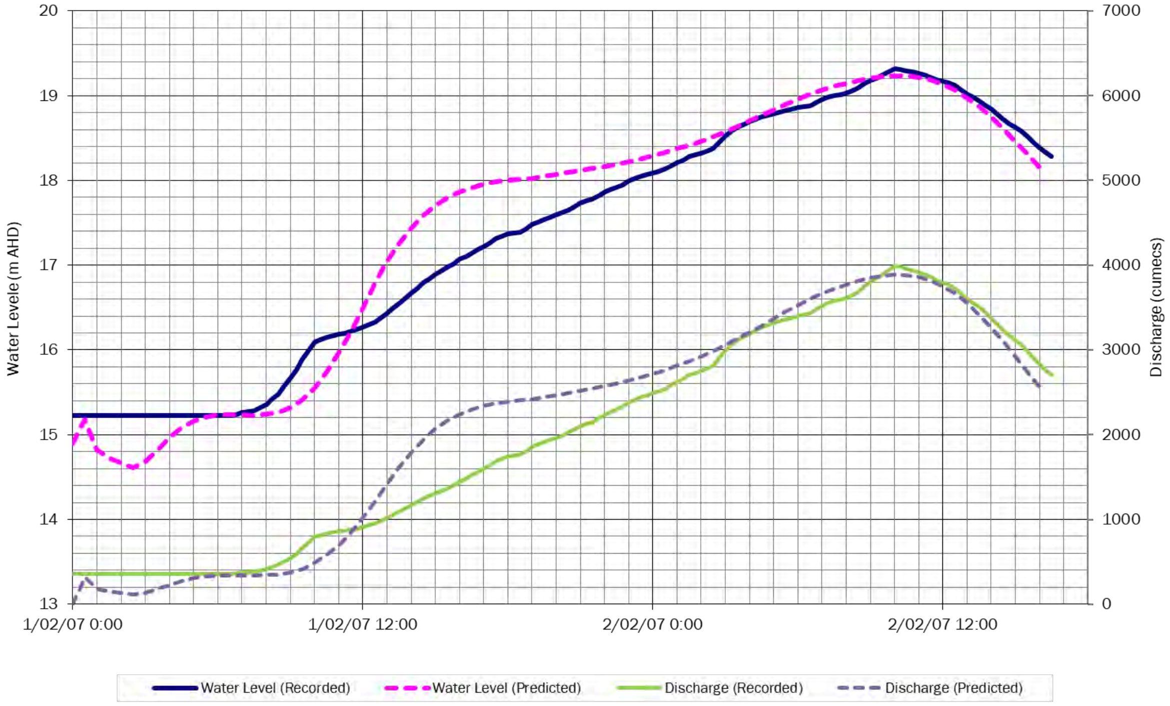

Figure 5.12 - Comparison of Predicted and Recorded Water Level Hydrographs, Pioneer River at Dumbleton Weir Headwater, 2007

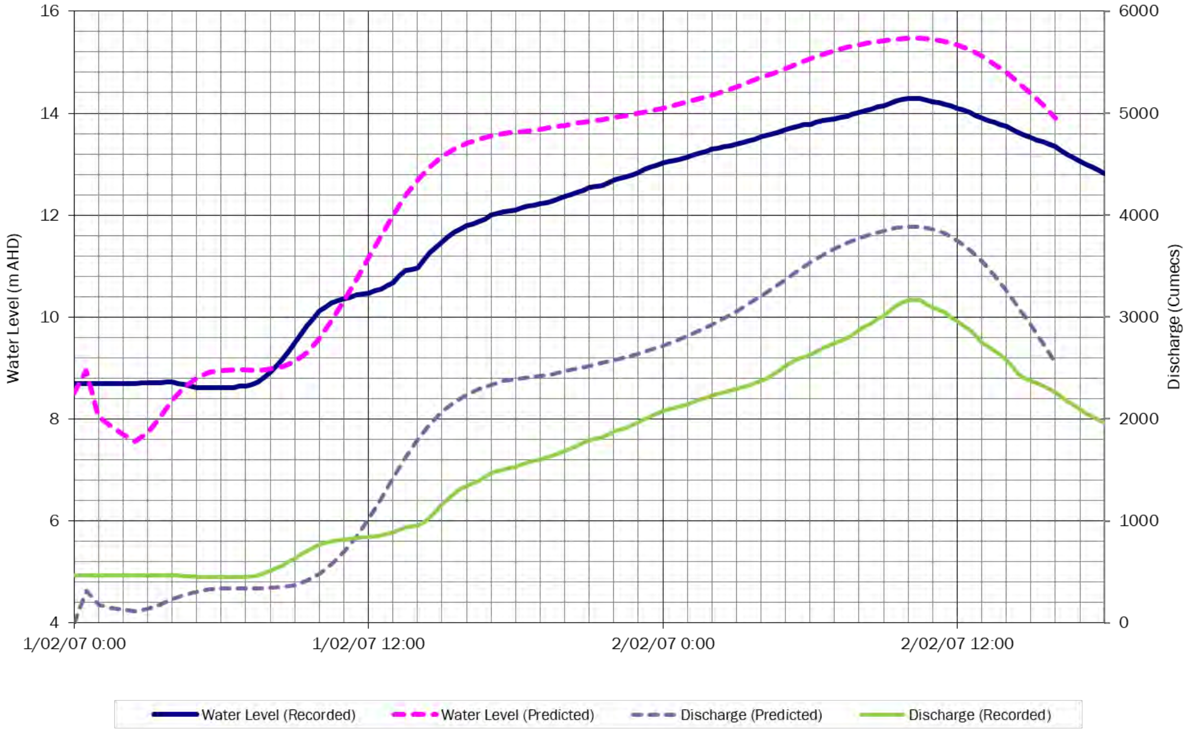

Figure 5.13 - Comparison of Predicted and Recorded Water Level Hydrographs, Pioneer River at Dumbleton Weir Tailwater, 2007

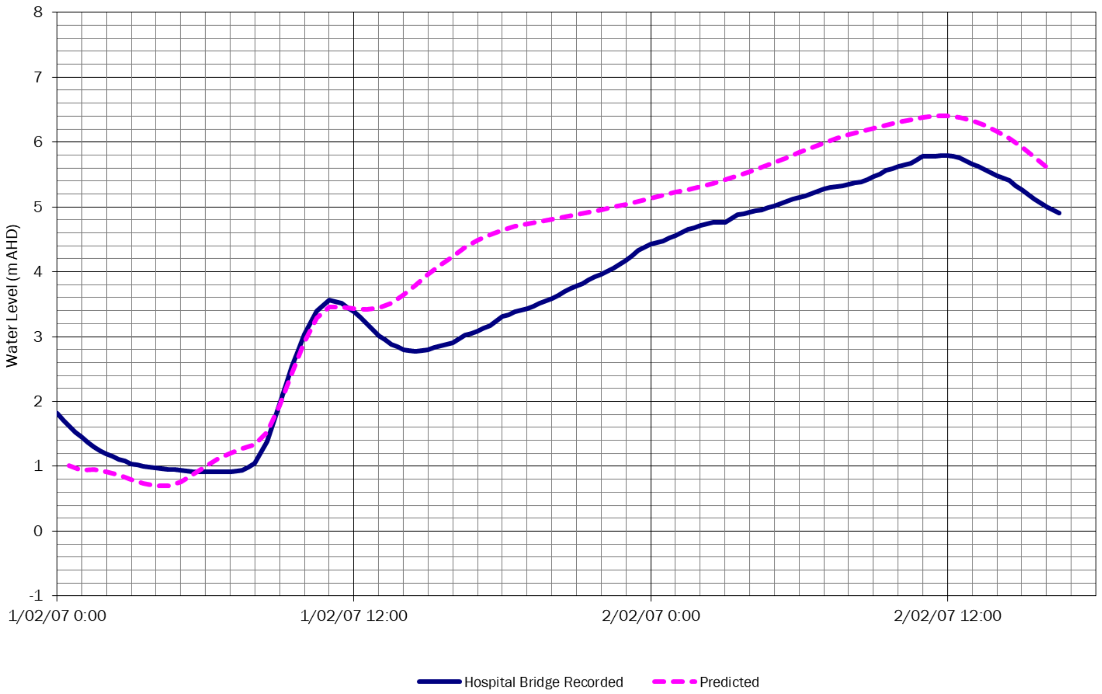

Figure 5.14 - Comparison of Predicted and Recorded Water Level Hydrographs, Pioneer River at Hospital Bridge, 2007

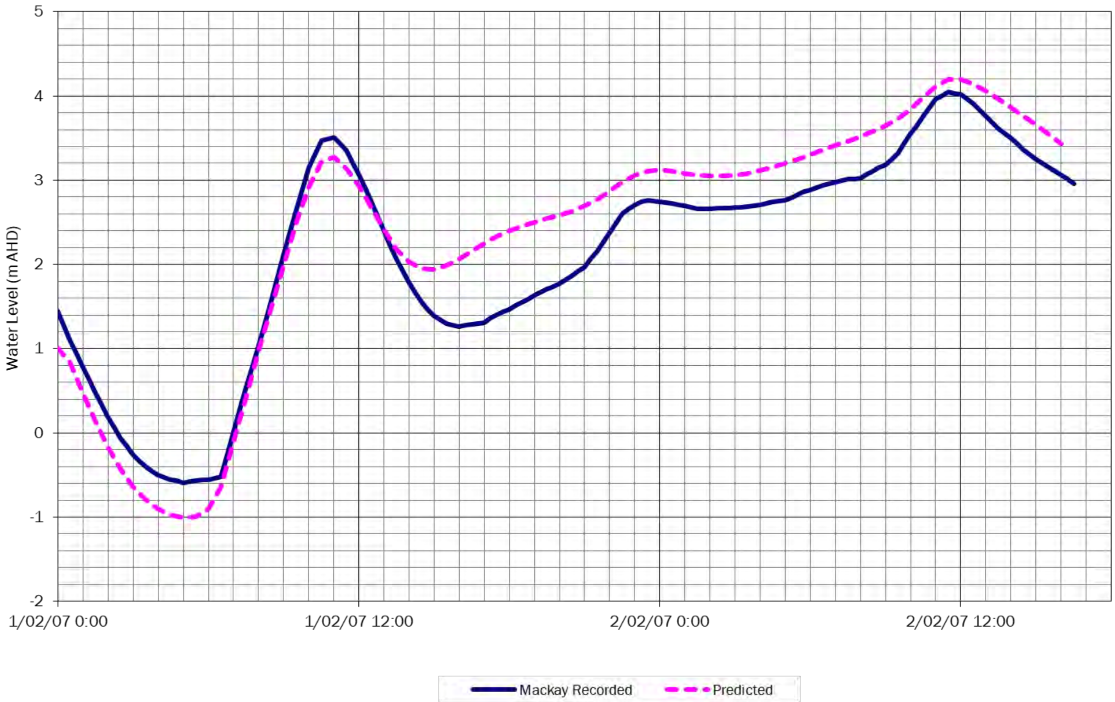

Figure 5.15 - Comparison of Predicted and Recorded Water Level Hydrographs, Pioneer River at Mackay, 2007

5.4.4 February 2008

Figure 5.16 to Figure 5.20 show comparisons of recorded and predicted water level hydrographs at Mirani Weir, Dumbleton Weir Headwater, Dumbleton Weir Tailwater, Hospital Bridge and Mackay gauges for the February 2008 event. The comparison of recorded and predicted discharge hydrographs at Dumbleton Weir is also shown.

The model accurately predicts peak flood levels at all stream gauges with all predicted peak levels within 0.4 m of recorded levels except at the Dumbleton Weir tailwater gauge. The reason for the differences at the Dumbleton Weir tailwater gauge is not clear. The water levels and predicted discharges at the tailwater gauge are inconsistent with the other gauges along the river. In particular, the peak discharge is some 10% higher at the Dumbleton Weir headwater gauge for this event using the adopted rating curves. It is noted that the modelling predicts that the storage effects of the weir do not impact on peak flood flows for any of the calibration events.

Figure 3.12 shows that the TUFLOW model achieved a good calibration against the stream gaugings and the rating curve at the tailwater gauge, although a very high channel roughness value of n=0.1 was required to achieve this calibration. A high channel roughness was required to calibrate the model to the other historical events as described in 5.4.2 and 5.4.1. It is possible that the siting of the water level recorder at the tailwater gauge may be the cause of the inconsistency. The section of the river immediately downstream of the weir is very steep with average velocities up to 3.5 m/s for this event. It is possible that there is a difference in velocity head at the water level recorder, which is located in a zero velocity zone behind the northern abutment of the weir, and the cross section averaged velocities used by TUFLOW. The difference in velocity head could translate to a water level difference of up to 0.6 m.

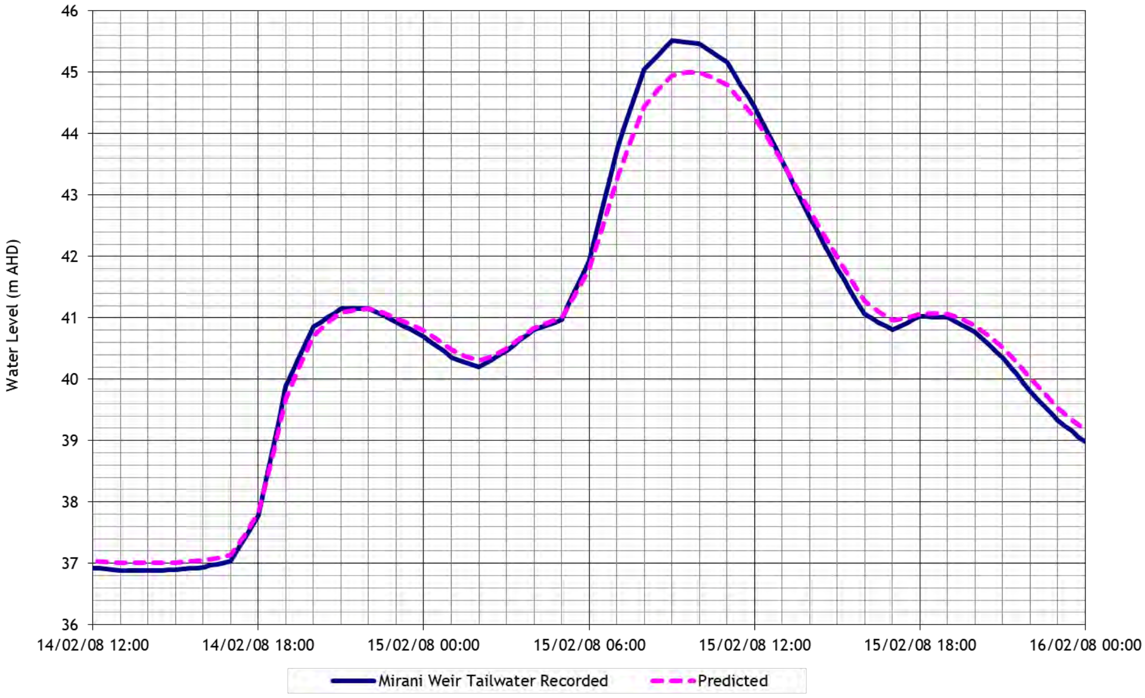

Figure 5.16 - Comparison of Recorded and Predicted Water Level Hydrographs, Pioneer River at Mirani Weir Tailwater, 2008

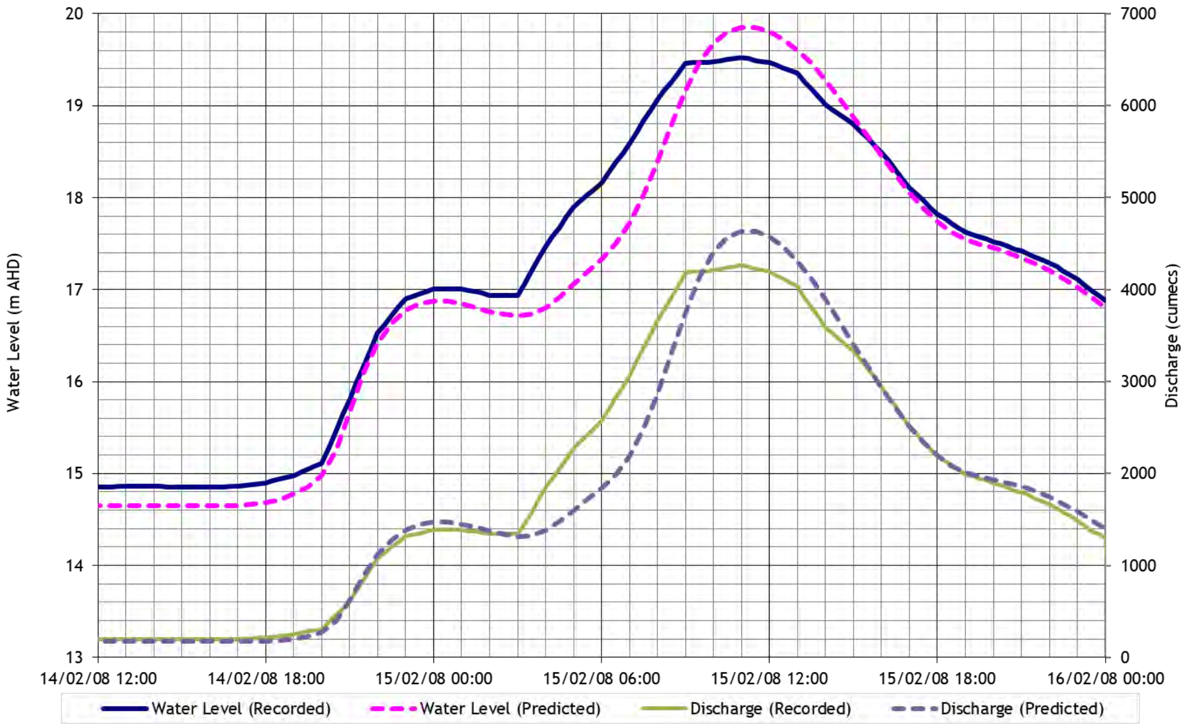

Figure 5.17 - Comparison of Predicted and Recorded Water Level Hydrographs, Pioneer River at Dumbleton Weir Headwater, 2008

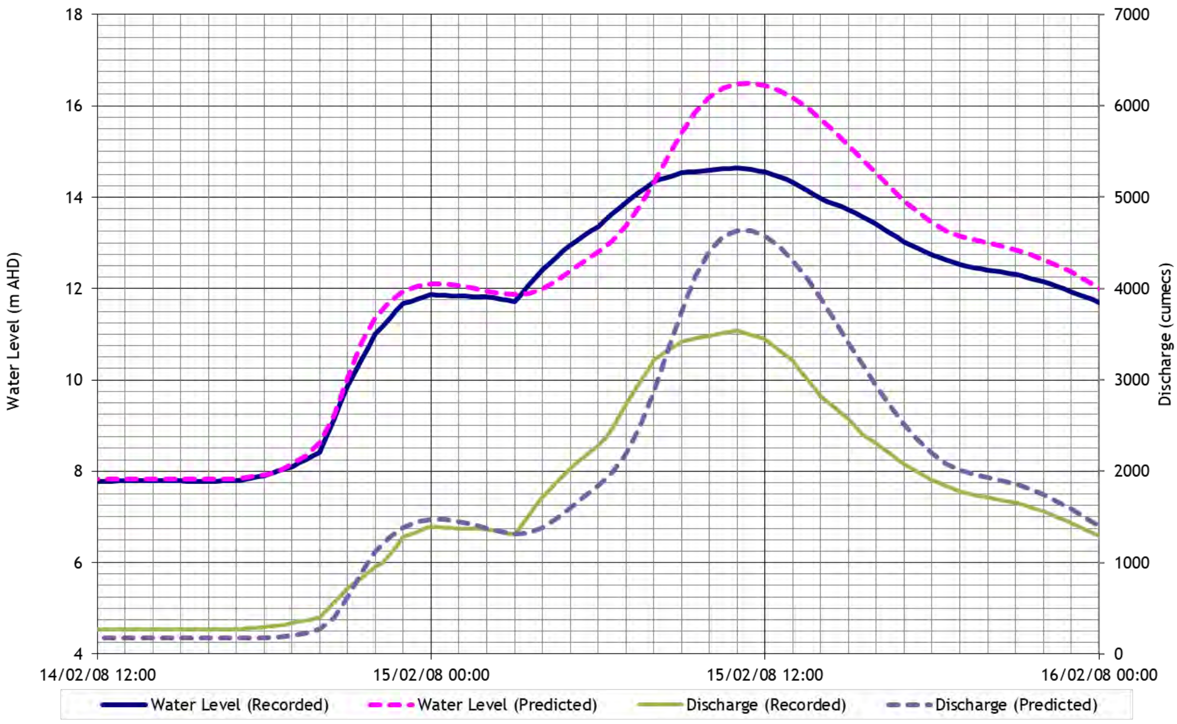

Figure 5.18 - Comparison of Recorded and Predicted Water Level and Discharge Hydrographs, Pioneer River at Dumbleton Weir Tailwater, 2008

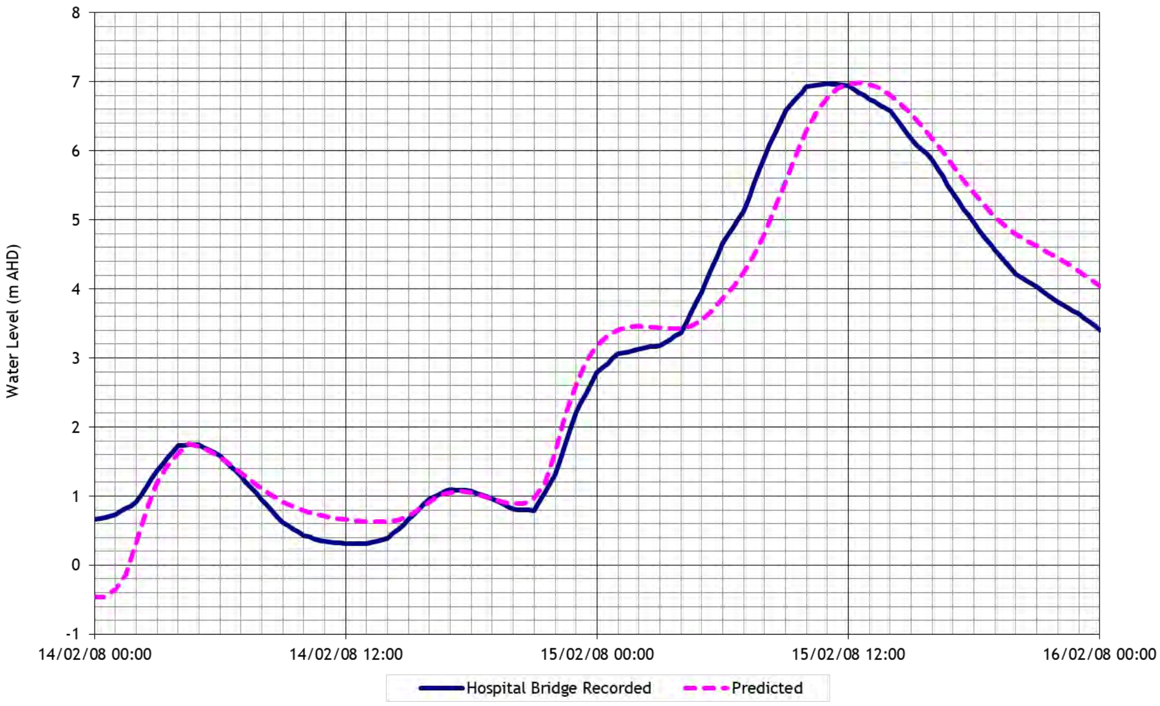

Figure 5.19 - Comparison of Predicted and Recorded Water Level Hydrographs, Pioneer River at Hospital Bridge, 2008

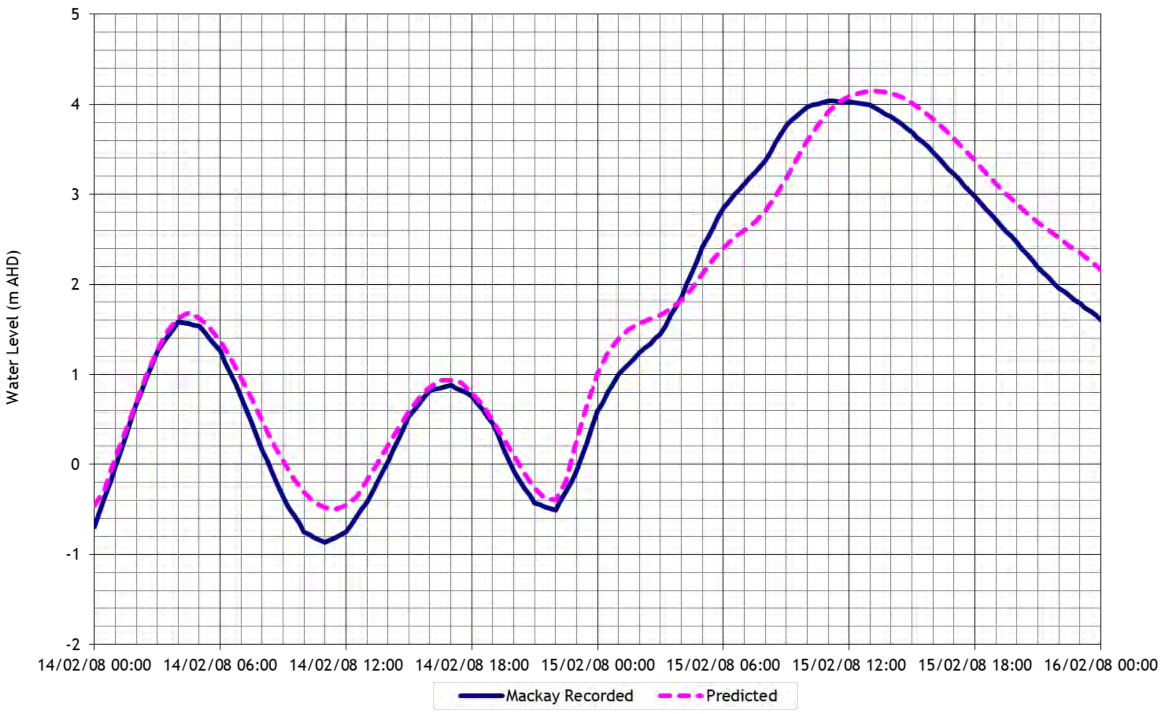

Figure 5.20 - Comparison of Predicted and Recorded Water Level Hydrographs, Pioneer River at Mackay, 2008

5.4.5 March 2017 TC Debbie

Figure 5.21 to Figure 5.25 show the recorded and predicted water levels at Mirani Weir Tailwater, Dumbleton Headwater, Dumbleton Tailwater, Hospital Bridge and Mackay gauges for the March 2017 TC Debbie event. A comparison of surveyed and predicted peak flood levels near Mackay is shown in Table 5.4. The predicted peak flood depths and extents together with the locations of the surveyed flood levels are shown in Figure 5.26. The following is of note:

- The predicted peak level is some 2 m lower than the recorded value at Mirani Weir TW gauge (155007A, DNRM), but is similar to the recorded value provided MRC at Mirani Alert (33302). It is of note that both gauges failed near the flood peak. The recorded levels at Mirani Weir TW gauge (155007A, DNRM) were estimated after 1030 hours on 29 March.
- The predicted peak level is 0.73 m lower than the recorded value at the Dumbleton Weir Alert (33300) provided by MRC but is only 0.16 m lower than the Dumbleton Weir Headwater gauge (125013A), which is located at a similar location. A post-flood survey confirmed that the Dumbleton Headwater gauge was accurate during the event.
- The predicted peak water level is about 0.5 m higher than the recorded peak water level at the downstream gauges at Dumbleton Weir TW.
- The predicted peak water level at the Hospital Bridge gauge is 0.4 m lower than the recorded value. It is possible that flood debris may have accumulated upstream of the hospital bridge fishing pier to elevate water levels at Hospital Bridge gauge during the event. The pier was significantly damaged during the event.
- The predicted peak water level matches the recorded peak water level at Mackay Alert.

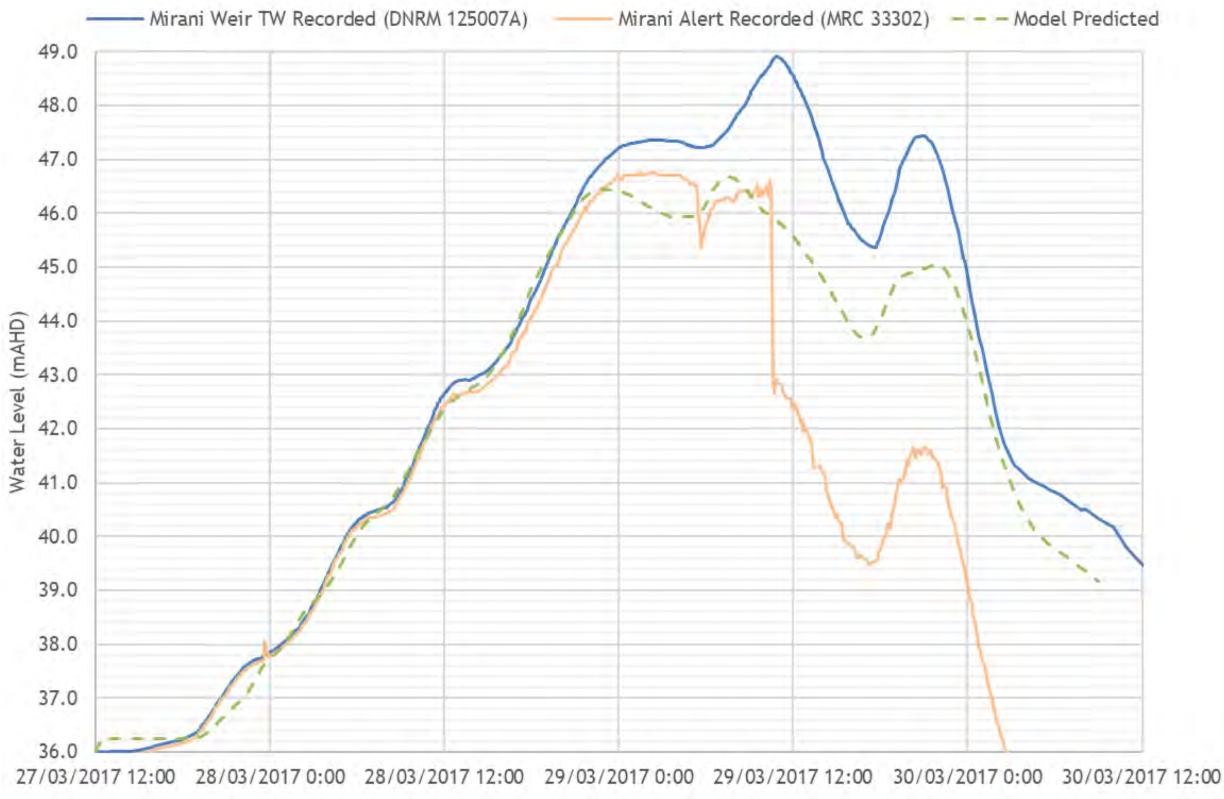

Figure 5.21 - Comparison of recorded and predicted water level hydrographs, Pioneer River at Mirani Weir Tailwater, 2017

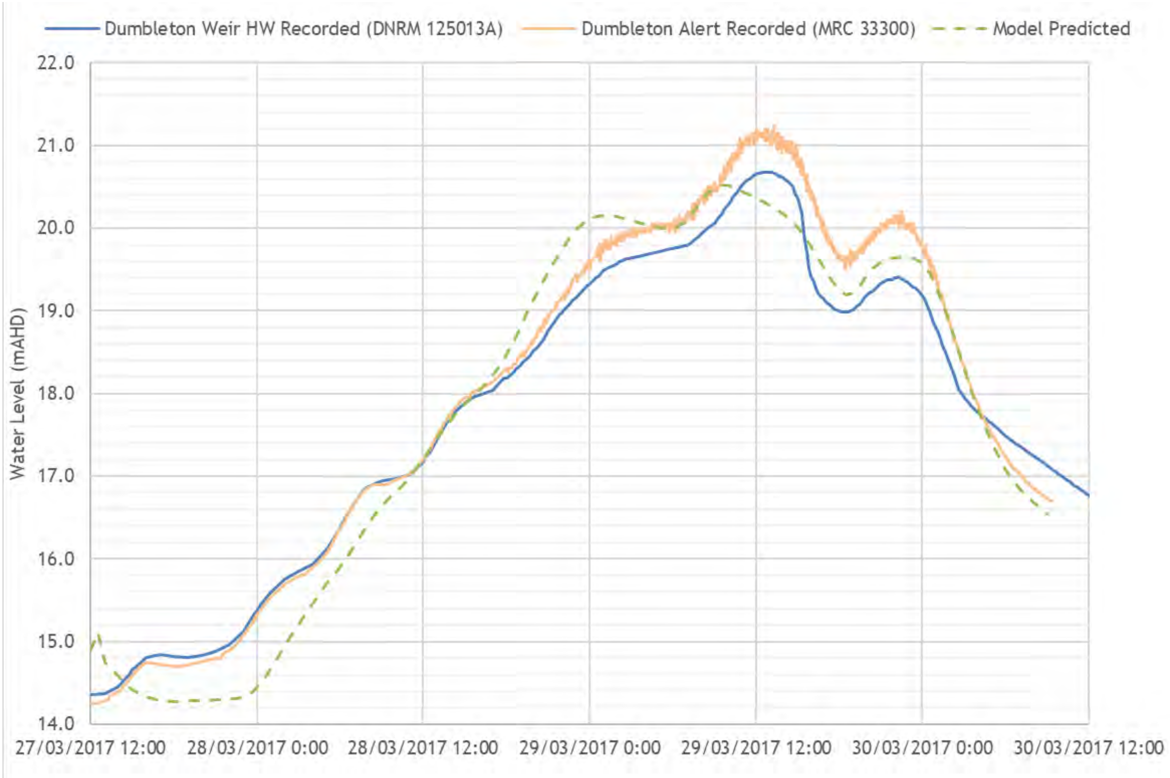

Figure 5.22 - Comparison of recorded and predicted water level hydrographs, Pioneer River at Dumbleton Weir Headwater, 2017

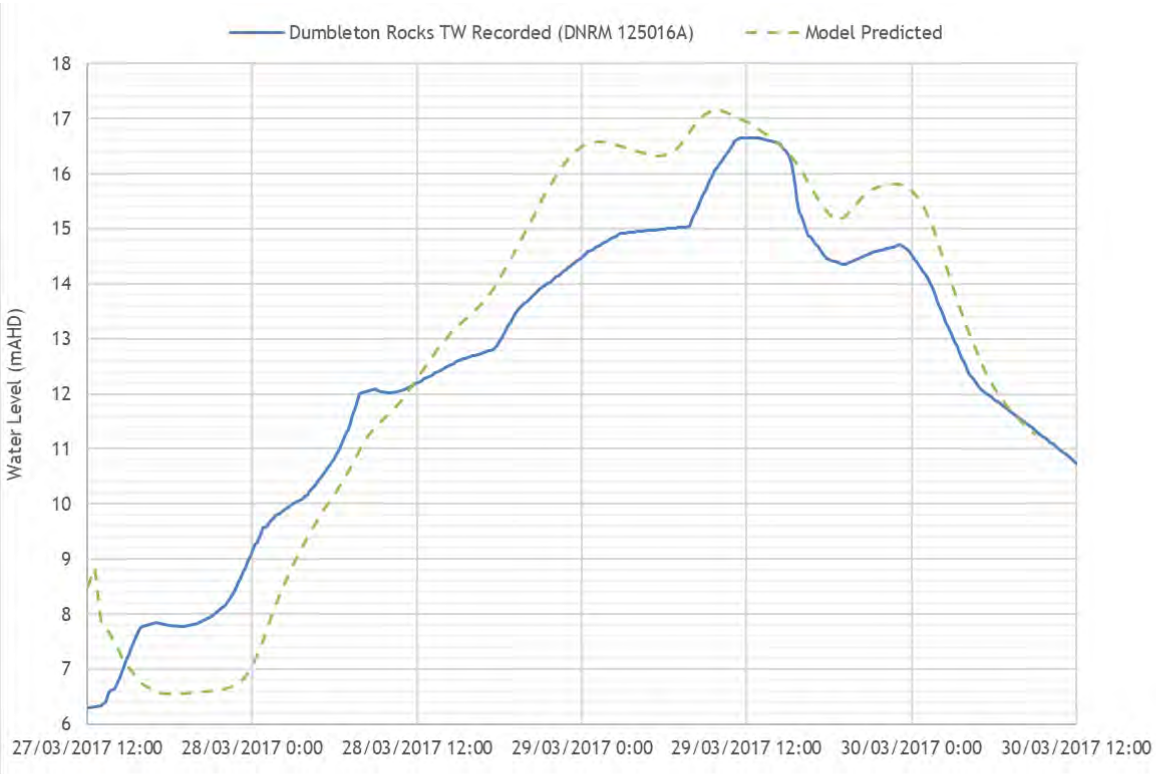

Figure 5.23 - Comparison of recorded and predicted water level hydrographs, Pioneer River at Dumbleton Weir Tailwater, 2017

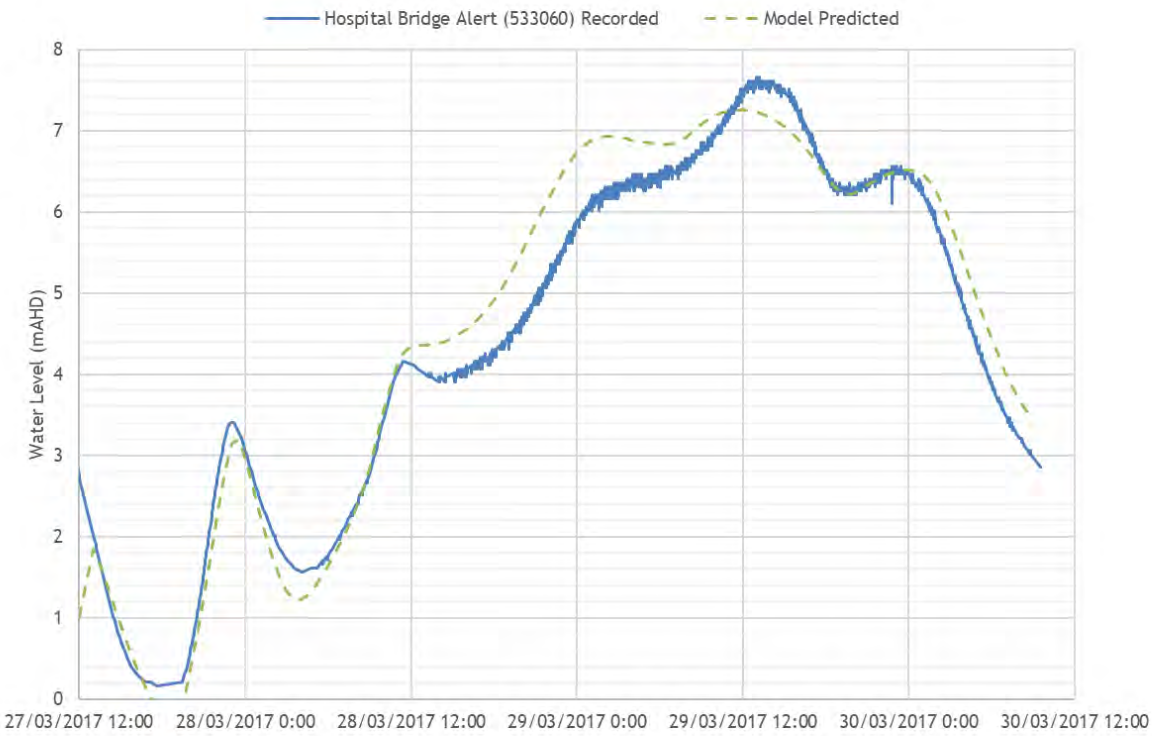

Figure 5.24 - Comparison of recorded and predicted water level hydrographs, Pioneer River at Hospital Bridge Alert, 2017

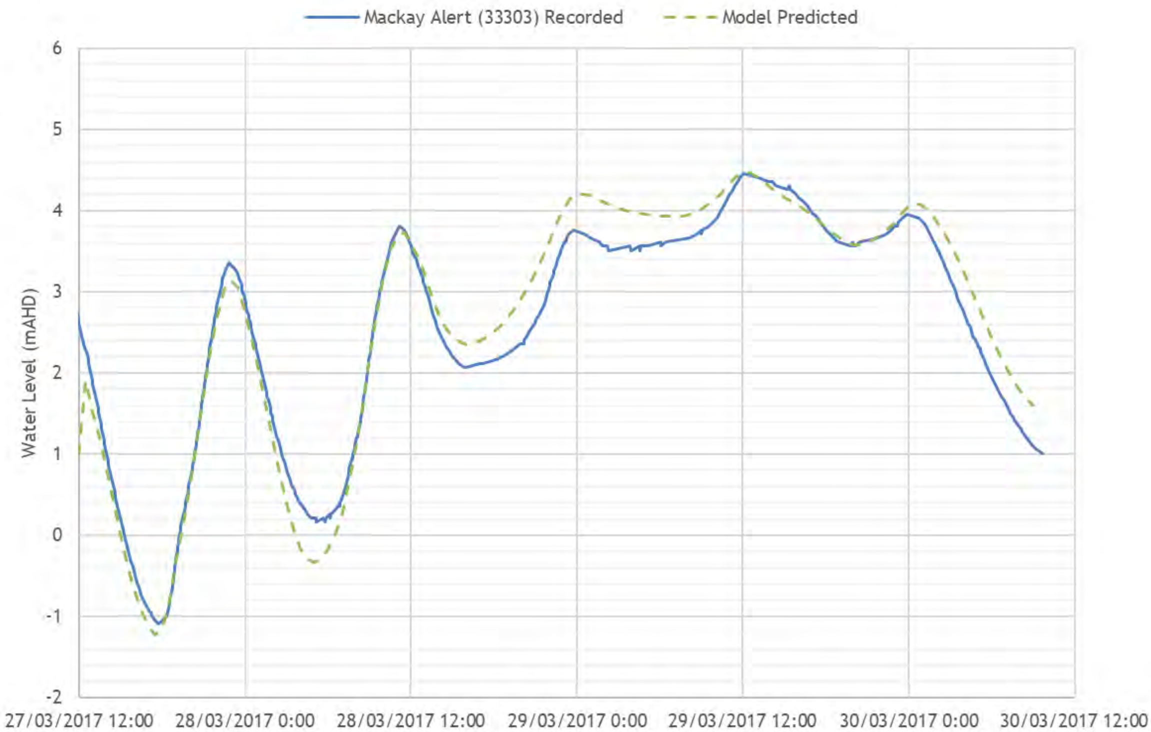

Figure 5.25 - Comparison of recorded and predicted water level hydrographs, Pioneer River at Mackay Alert, 2017

Table 5.4 - Surveyed and predicted peak water levels, 2017 Cyclone Debbie event

Location ID	Peak Water Level (mAHD)		Difference (m) (Predicted - Surveyed)
	Surveyed	Predicted	
1	7.93	7.69	-0.23
2	7.51	7.28	-0.23
3	5.75	5.88	0.13
4	5.61	5.55	-0.06
5	5.41	5.37	-0.04
6	4.53	5.37	0.84
7	5.86	6.55	0.69
8	5.60	6.54	0.94
9	5.47	5.55	0.08
10	4.23	4.04	-0.19
11	4.11	3.85	-0.26
12	6.98	7.46	0.48
13	5.62	6.03	0.41
14	4.70	4.90	0.20

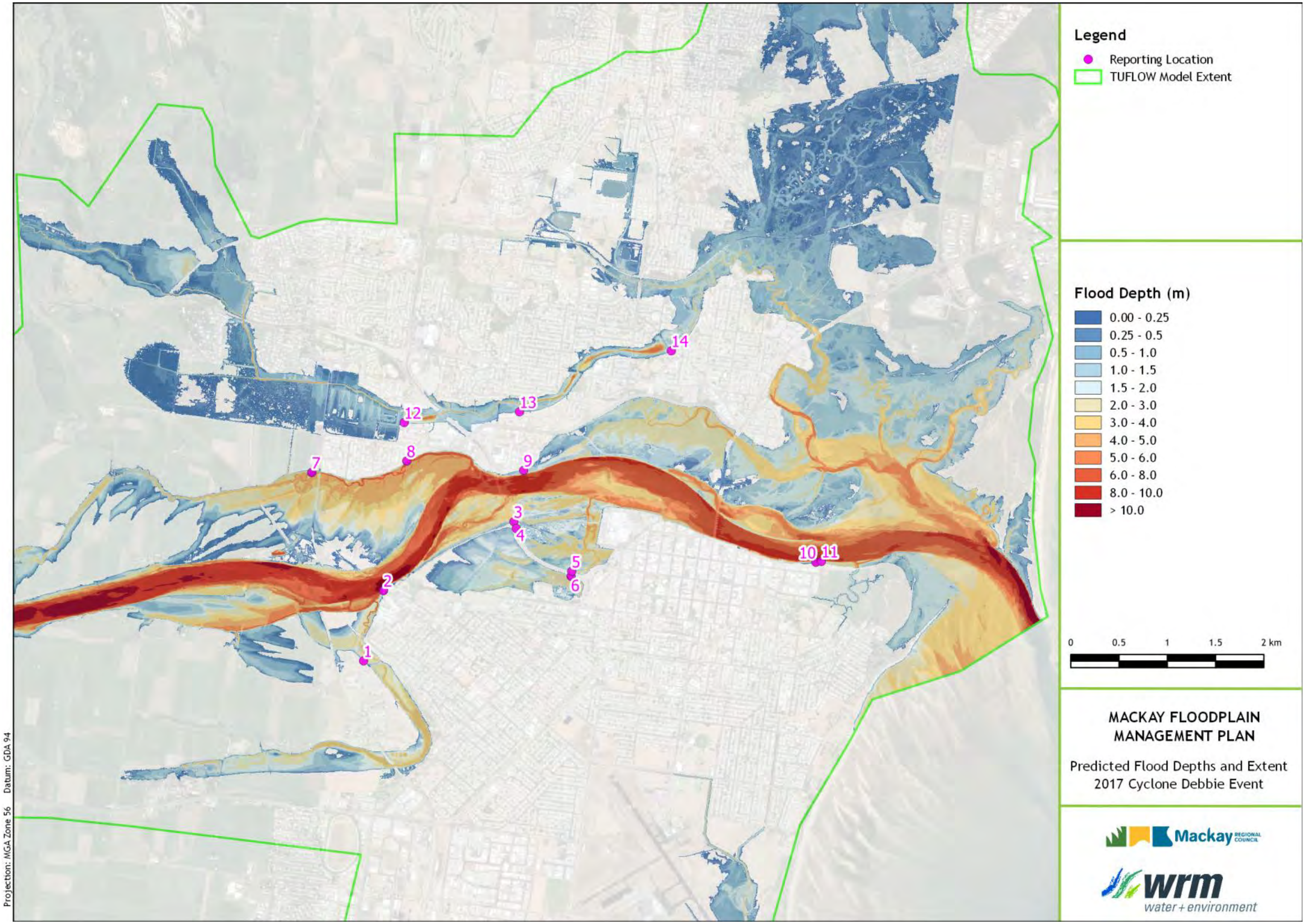

Figure 5.26 - Predicted flood depths and extent, 2017 event

- The predicted peak flood levels at the survey locations are generally within 0.2 m of the surveyed levels with the exception of both Fursden Creek and Goosepond Creek.
    - Predicted Fursden Creek levels are substantially higher than the surveyed levels. The surveyed levels are also much lower than the surveyed levels in the Pioneer River immediately downstream of the Fursden Creek confluence. A review of the model results suggest that the river level overtops the natural levee between the Pioneer River and Fursden Creek by only 0.2 m to 0.3 m at some locations. Minor variations in the overtopping depth will impact on the Fursden Creek levels for this level of flooding in the Pioneer River.
    - Predicted Goosepond Creek levels are moderately higher than the surveyed levels. A comparison of recorded rainfalls with design rainfall intensities suggests that the AEP in the Goosepond Creek catchment of the event is approximately 18% (5 year ARI). A further description of the Goosepond Creek calibration for the March 2017 event is given in the Goosepond Creek Flood Study report (WRM, 2021a).

6 Design discharges

6.1 OVERVIEW

Pioneer River design discharges were estimated using both the URBS model and TUFLOW model. The URBS model was used to generate upper catchment discharges and subcatchment discharges within the boundary of the TUFLOW model. These discharges were routed through the TUFLOW model to estimate design flood discharges in the Pioneer River at Mackay. The design discharges were verified against design discharges estimated from an annual series flood frequency analysis (FFA) of the recorded flows at the combined Pleystowe Mill (Station No. 125001) and Dumbleton Weir (Station No. 125013) gauges.

The design discharges were determined in accordance with the methodology recommended in ARR (Ball et al., 2019), replacing ARR 1987 (Pilgrim, 1987). The major changes between ARR 2016 and ARR 1987 include:

- the use of new rainfall Intensity-Frequency-Duration (2016 IFDs), which are based on a more extensive data base, with more than 30 years of additional rainfall data and data from extra rainfall stations;
- the use of an ensemble of 10 temporal patterns to derive the design discharges (the temporal pattern that gives the peak discharge closest to the mean is used), compared to using single temporal pattern in ARR 1987; and
- modified areal reduction factors (ARFs).

6.2 PIONEER RIVER DESIGN DISCHARGES

6.2.1 Design rainfalls

Design rainfall depths were obtained from the Commonwealth Bureau of Meteorology (BOM, 2016) for the 10%, 5%, 2%, 1%, 0.5% and 0.2% AEP design events. The Probable Maximum Precipitation (PMP), which is used to define the Probable Maximum Flood (PMF), was determined using the Generalised Tropical Storm Method revised (GTSMR) (BOM, 2005) methodology.

The Pioneer River catchment was divided into five sub-areas. Rainfall depths were obtained at the centroid of each sub-areas and the areal reduction factors (ARFs) of the total Pioneer River catchment were applied to the design rainfall depths. Further discussion on ARFs are provided in Section 6.2.2. The adopted rainfall depths for the various sub areas (with ARFs applied) for the 12 hour to 72 hour storm durations are given in Table 6.1.

Table 6.1 also provides comparisons of the 2016 rainfall depths to the previously adopted CRC-Forge rainfall depths (both with ARFs applied) used for the previous study (WRM, 2011). The following is of note:

- The 10% AEP, 5% AEP and PMP were not provided in the previous study and as such have not been compared.
- The 2%, 1%, 0.5% and 0.2% AEP 2016 rainfall depths are generally lower for the 12 hour and 18 hour storm durations but are generally higher for the longer duration events with the exception of the Teemburra Creek catchment.

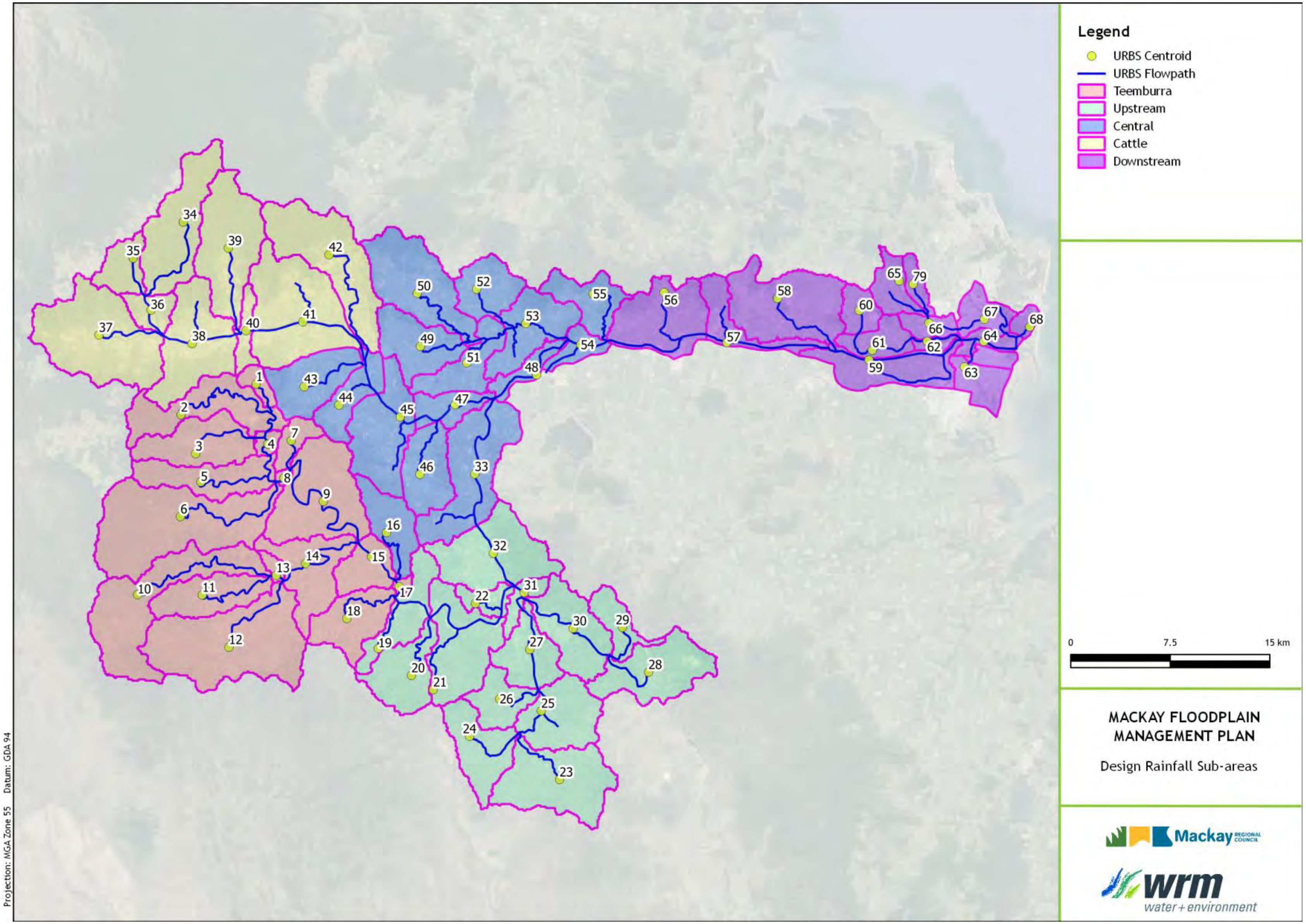

Figure 6.1 - Design rainfall sub-areas

Table 6.1 - Pioneer River catchment design rainfall depths (with areal reduction factors applied) and comparison to CRC-Forge rainfall depths

Storm Duration	Rainfall Depth (mm)				
	Teemburra	Upstream	Cattle	Central	Lower
10% AEP					
12 hour	191	168	222	190	220
18 hour	243	211	288	244	278
24 hour	288	251	348	293	329
36 hour	349	308	428	365	401
48 hour	395	352	487	420	456
72 hour	459	419	569	502	536
5% AEP					
12 hour	229	200	266	227	259
18 hour	296	255	352	294	332
24 hour	354	307	428	356	397
36 hour	433	380	530	447	490
48 hour	490	439	604	519	561
72 hour	573	526	706	623	664
2% AEP					
12 hour	280	242	325	275	312
18 hour	367	316	437	363	407
24 hour	445	384	537	446	494
36 hour	547	482	668	566	617
48 hour	622	559	760	661	713
72 hour	727	674	883	798	852
1% AEP					
12 hour	319	276	371	313	353
18 hour	425	364	506	419	467
24 hour	520	448	627	519	574
36 hour	644	567	781	665	725
48 hour	733	661	889	780	842
72 hour	858	800	1,033	950	1,015
0.5% AEP					
12 hour	360	311	419	353	398
18 hour	481	413	574	474	529
24 hour	595	515	718	598	666
36 hour	741	657	894	770	842
48 hour	850	771	1,017	908	980
72 hour	1,004	939	1,188	1,114	1,188
0.2% AEP					
12 hour	419	362	487	410	463
18 hour	562	482	671	555	618
24 hour	711	616	857	714	794
36 hour	893	794	1,067	928	1,015
48 hour	1,032	941	1,213	1,104	1,195
72 hour	1,222	1,157	1,415	1,369	1,460
PMP					
12 hour	1,480	1,290	1,540	1,300	1,350
24 hour	1,910	1,680	2,000	1,680	1,770
36 hour	2,300	2,030	2,420	2,030	2,150
48 hour	2,660	2,360	2,810	2,360	2,510
72 hour	3,310	2,940	3,510	2,940	3,140

2016 rainfalls vs CRC-Forge Rainfalls

Diff < -10%

-10% < Diff < -5%

-5% < Diff < 5%

5% < Diff < 10%

Diff > 10%

Not Available for comparison

6.2.2 Areal reduction factor

Table 6.2 shows the adopted ARFs for the Pioneer River catchment. The ARFs for the Pioneer River catchment were estimated in accordance with recommendations of Chapter 4 in ARR (Ball et al., 2019). The Pioneer River catchment is within the East Coast North zone.

Table 6.2 - Pioneer River areal reduction factors

Storm Duration	Aerial reduction factors per AEP					
	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP
12	0.827	0.819	0.808	0.800	0.792	0.781
18	0.858	0.853	0.846	0.841	0.836	0.829
24	0.889	0.887	0.884	0.882	0.880	0.877
36	0.905	0.903	0.901	0.899	0.897	0.894
48	0.916	0.914	0.911	0.909	0.908	0.905
72	0.928	0.926	0.924	0.922	0.921	0.919

6.2.3 Rainfall losses

An initial loss of 0 mm and a continuing loss of 1 mm/hr were adopted in the URBS model for all design events. These losses were derived through verification against FFA design discharge estimates.

6.2.4 Temporal patterns

The temporal patterns define the variability of rainfall across an event. The ensemble event approach described in ARR (Ball et al., 2019) has been used for this analysis. This approach uses an 'ensemble' of 10 temporal patterns for each storm duration to derive a range of estimated flood peaks for each AEP up to the 1% AEP event. The magnitude of the design flood is then estimated from the weighted average of the flood peaks, where the weighting applied to each result reflects the relative likelihood of the selected input occurring. For design event rarer than 1% AEP and up to PMF, the GTSMR temporal patterns (BOM, 2005) were adopted.

The temporal patterns of relevance to the Pioneer River (Wet Tropics areal rainfall temporal patterns) were obtained from the ARR Data Hub[1]. Due to the catchment size, the Areal Temporal pattern set for this region (for a Standard Area of 1,000 km^2) were adopted for events up to and including 1% AEP.

6.2.5 URBS model design discharges

The design rainfalls for each of the five sub-areas within the Pioneer River catchment along with the Wet Tropic areal temporal patterns and regional ARFs were incorporated in the Pioneer River URBS model to estimate the design discharges.

Figure 6.2 shows the distribution of 1% AEP peak discharges estimated from the ensemble of 10 temporal patterns for each storm duration at Dumbleton Weir. The distribution is represented as a box and whisker plot, which is a standardised way of presenting the distribution of data. For each duration, the rectangle box represents the 25%ile and 75%ile (1st and 3rd quartile, the interquartile range or IQR) bound of the estimate. The black horizontal line (whiskers) represents the upper and lower estimates for 1.5 times of the IQR. The values outside the whiskers are considered outliers. There are two outliers for the 1% AEP 72 hour duration storms. The red horizontal line within the box is the median

[1] https://data.arr-software.org

value and the red dot represents the mean value. The box plots for the other AEP's are given in Figure 6.3 to Figure 6.7

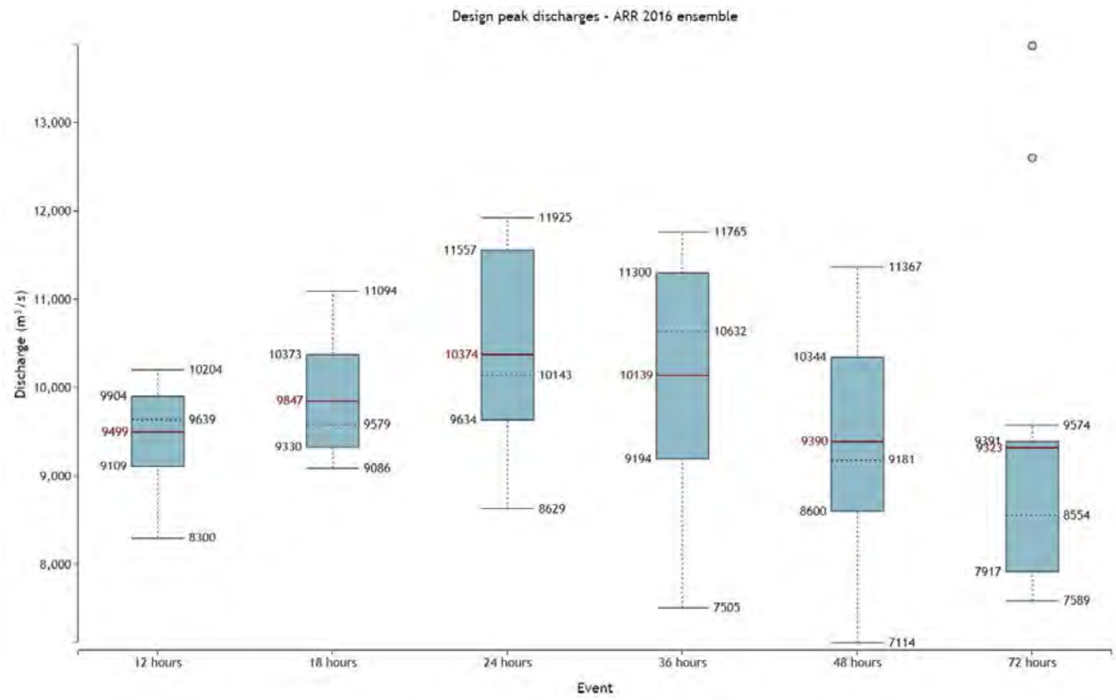

Figure 6.2 - Box plots of design discharges at Dumbleton Weir, 1% AEP design event

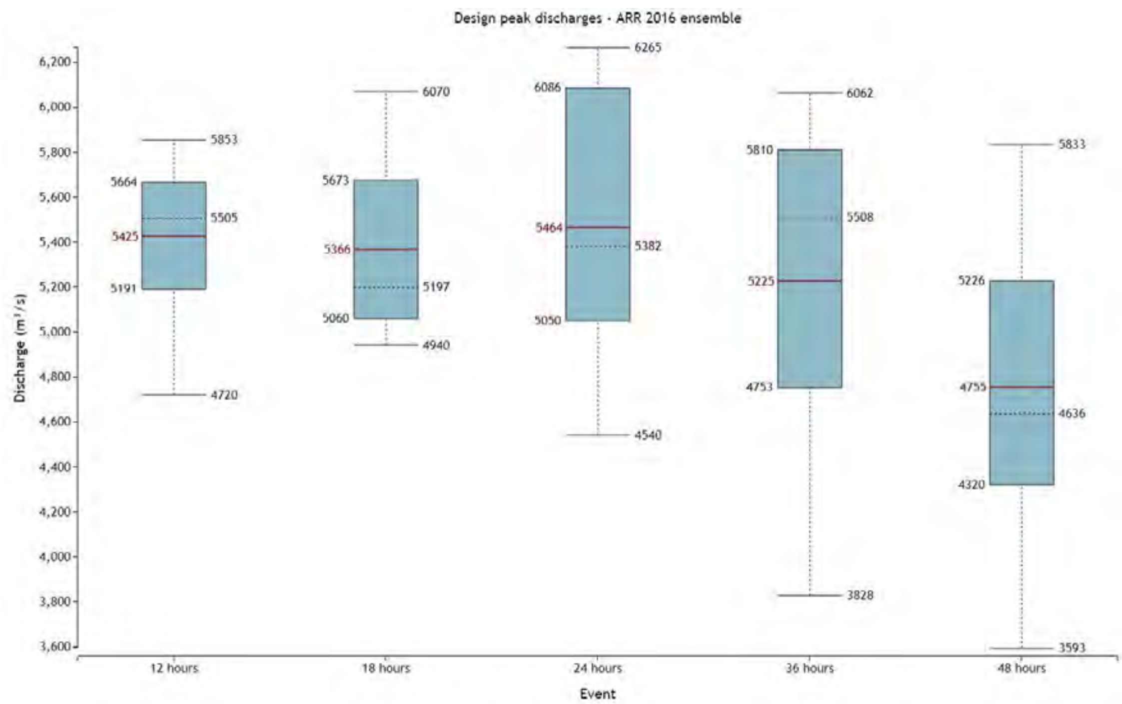

Figure 6.3 - Box plots of design discharges at Dumbleton Weir, 10% AEP design event

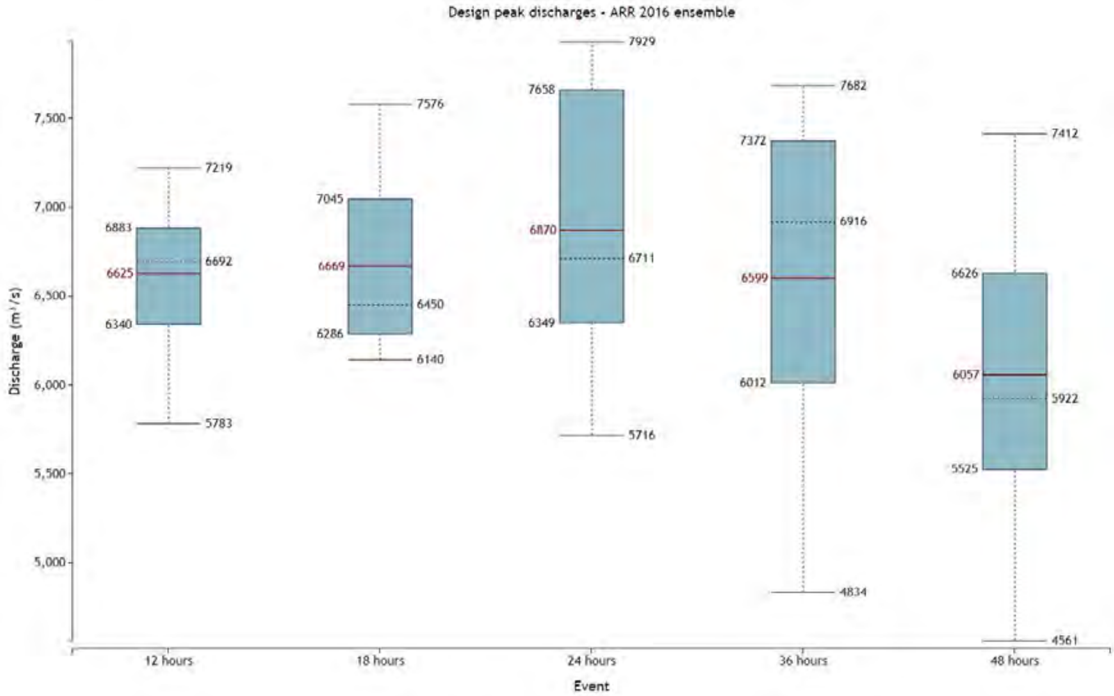

Figure 6.4 - Box plots of design discharges at Dumbleton Weir, 5% AEP design event

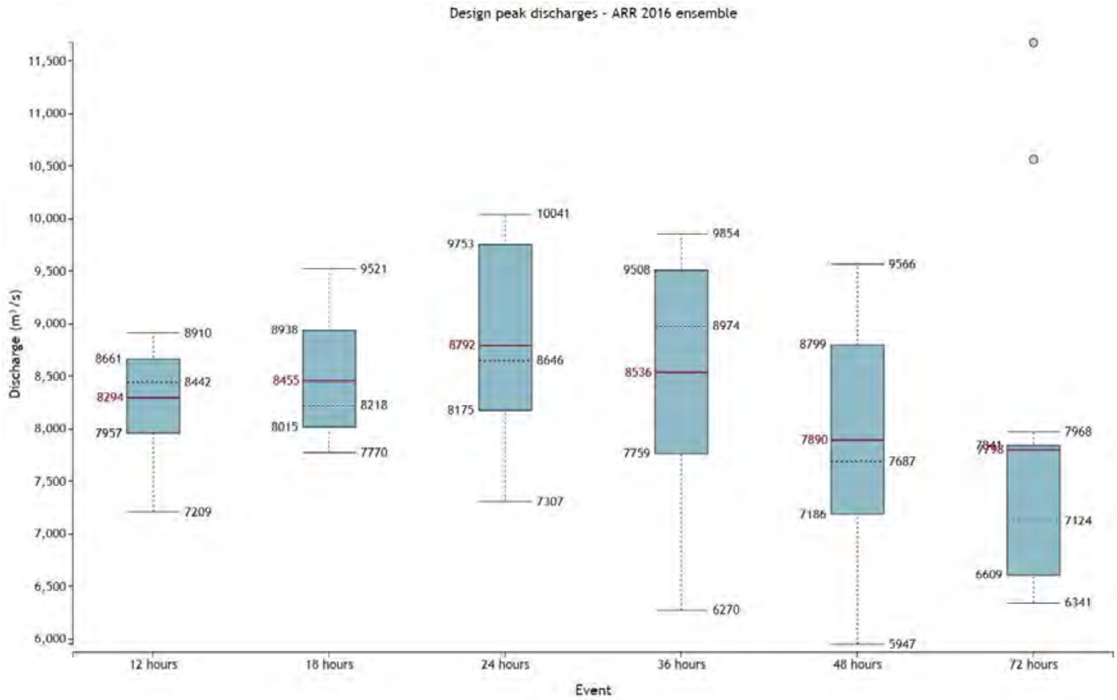

Figure 6.5 - Box plots of design discharges at Dumbleton Weir, 2% AEP design event

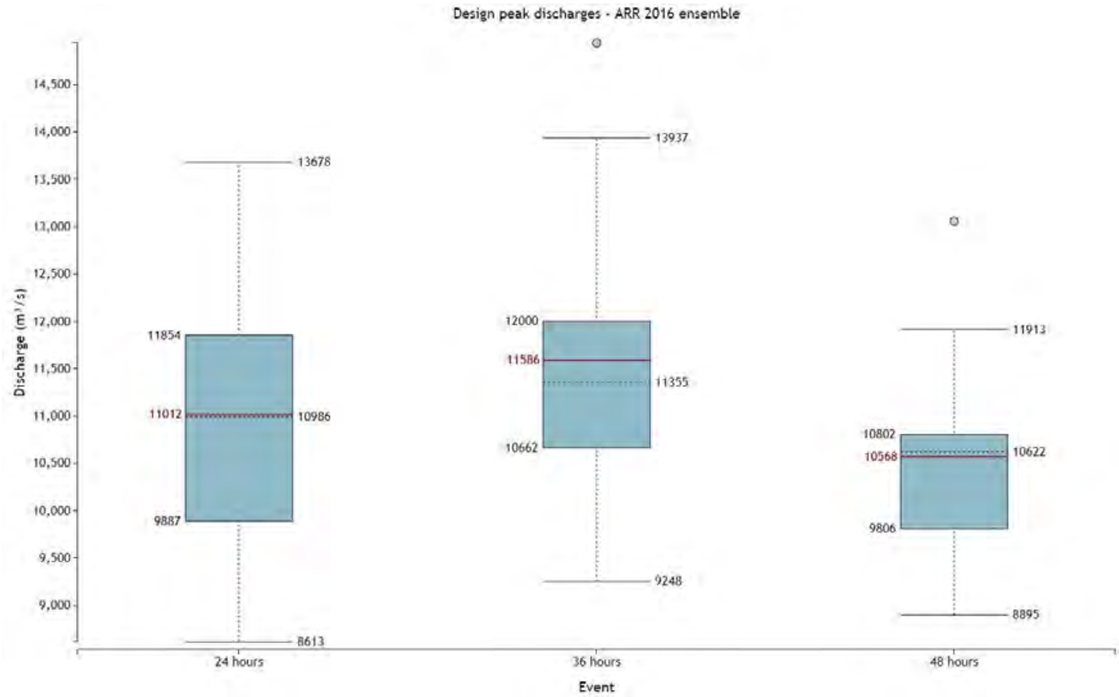

Figure 6.6 - Box plots of design discharges at Dumbleton Weir, 0.5% AEP design event

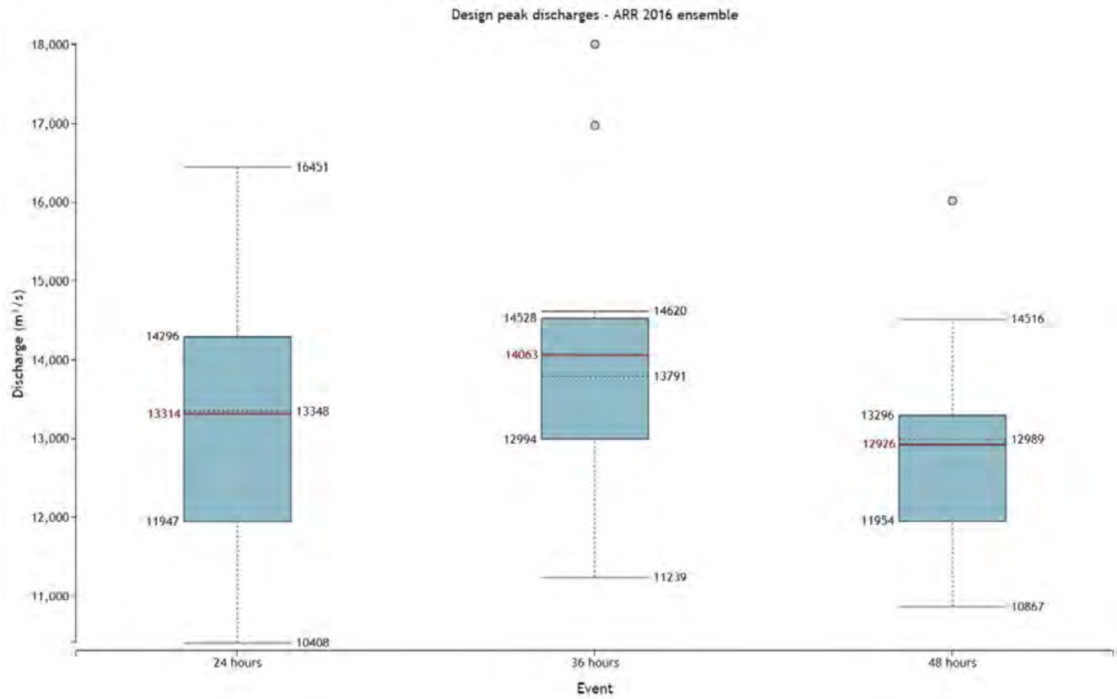

Figure 6.7 - Box plots of design discharges at Dumbleton Weir, 0.2% AEP design event

For each event, a single representative design storm (design temporal pattern) was selected, based on the design storm which produces a peak discharge closest and above the mean peak discharge from the 10 temporal patterns for each event at Dumbleton Weir. For the 1% AEP event, the 24 hour duration storm (temporal pattern 5) has been adopted as the representative design storm. Table 6.3 summarises the representative design storms (design temporal patterns) selected for each event.

Table 6.3 - Representative design storm (temporal pattern) selected for each event

Design Event (AEP)	Critical duration (hours)	Representative temporal pattern number	URBS model temporal pattern designation
10%	24	5	E04
5%	24	5	E04
2%	24	5	E04
1%	24	5	E04
0.5%	36	2	E01
0.2%	36	2	E01
PMF	36	2	E01

6.2.6 Flood frequency analysis

The flood frequency analysis (FFA) was updated by using the Bayesian inference methodology recommended in the ARR (Ball et al., 2019) using the FLIKE software for five gauging stations in the Pioneer River catchment. Table 6.4 shows the period of record for the five stations. The recorded peak annual flood discharges up until 2017 at all five stations were used for the flood frequency analysis.

Table 6.4 - Pioneer River gauging stations, period of record

Station Location	Station Number	Stream Name	Period of Record
Whitefords	125005A	Blacks Creek	1973 - Current
Gargett	125004A/B	Cattle Creek	1967 - Current
Sarichs	125002C	Pioneer River	1958 - Current
Mirani Weir Tailwater	125007A	Pioneer River	1977 - Current
Pleystowe Mill*	125001A/B/C	Pioneer River	1916 - 1988

**Dumbleton Weir record was used from 1982 to 2017*

The flood frequency analysis (FFA) results, including the 10% and 90% confidence limits for a range of design discharges are given in Table 6.5 and Figure 6.8 to Figure 6.12. The following is of note:

- Historical discharges at the Mirani and Pleystowe gauges were adjusted to be consistent with rating curves derived during TUFLOW model calibration.
- The Whitefords, Sarich's and Mirani Weir FFA results are to be used with caution because they include periods both before and after the construction of Teemburra Dam. No attempt has been made to determine pre and post Teemburra Dam FFA results because the period of record is too short.
- The Pleystowe gauge has the longest period of record of any of the gauges and the data set is not significantly affected by the construction of upstream dams. Dumbleton Weir was constructed in 1982 and effectively has the same catchment area as the old Pleystowe Mill gauge. The Pleystowe Mill gauge recorded data from 1916 to 1981 and Dumbleton Weir Headwater gauge data recorded data from 1982 to 2017 provides a 100 year combined dataset for the analysis. Therefore, the Pleystowe Mill/Dumbleton Weir data is expected to provide reasonable estimates of design discharges up to and including the 1% AEP event at that location.

Table 6.5 - Pioneer River Catchment, FFA Results

Station Location	Design Discharge (m³/s)								
	10% AEP			2% AEP			1% AEP		
	10%	Expected Quantile	90%	10%	Expected Quantile	90%	10%	Expected Quantile	90%
Whitefords	1,832	2,357	3,062	2,912	3,881	6,320	3,220	4,439	8,297
Gargett	1,516	1,886	2,491	2,074	2,802	4,913	2,250	3,195	6,377
Sarichs	3,041	3,674	4,522	4,474	5,328	7,493	4,842	5,808	8,652
Mirani Weir Tailwater	3,606	4,529	3,606	5,384	6,736	5,384	5,881	7,464	5,881
Pleystowe Mill / Dumbleton Weir	4,864	5,682	6,726	7,711	8,928	10,846	8,601	10,009	12,463

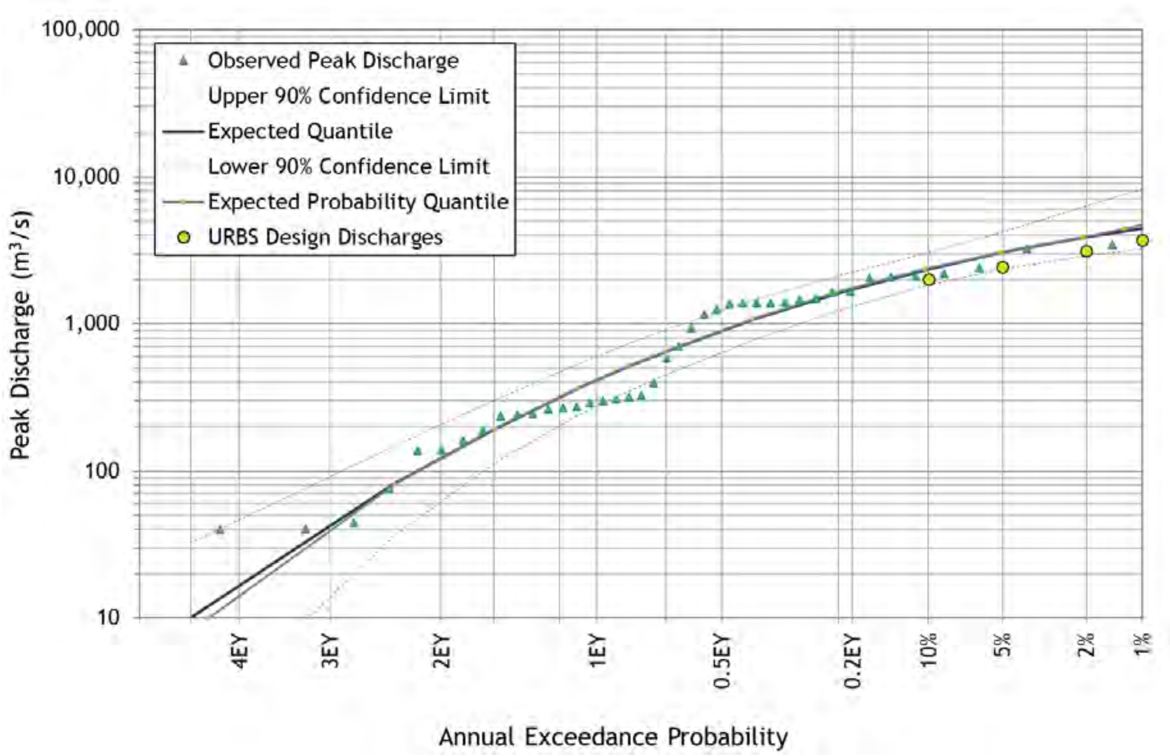

Figure 6.8 - LP III distribution of adjusted recorded flows at Blacks Creek at Whitefords, compared with URBS estimated peak discharges

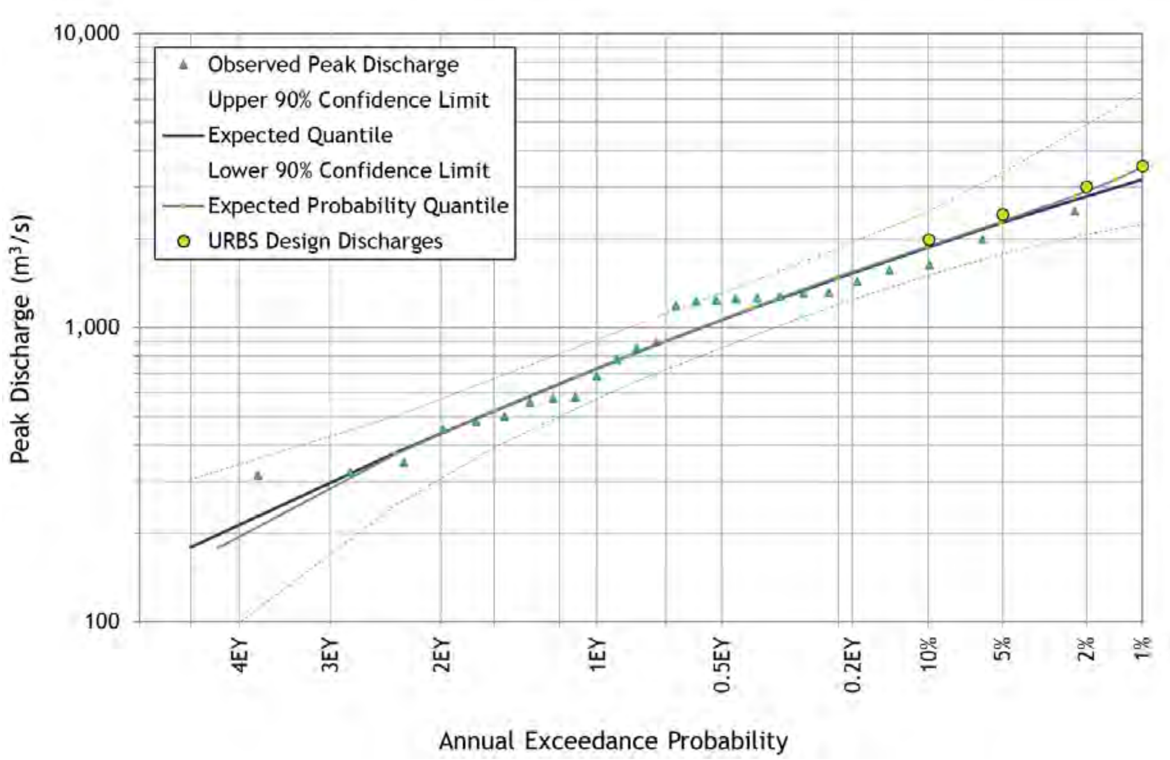

Figure 6.9 - LP III distribution of adjusted recorded flows at Cattle Creek at Gargett, compared with URBS estimated peak discharges

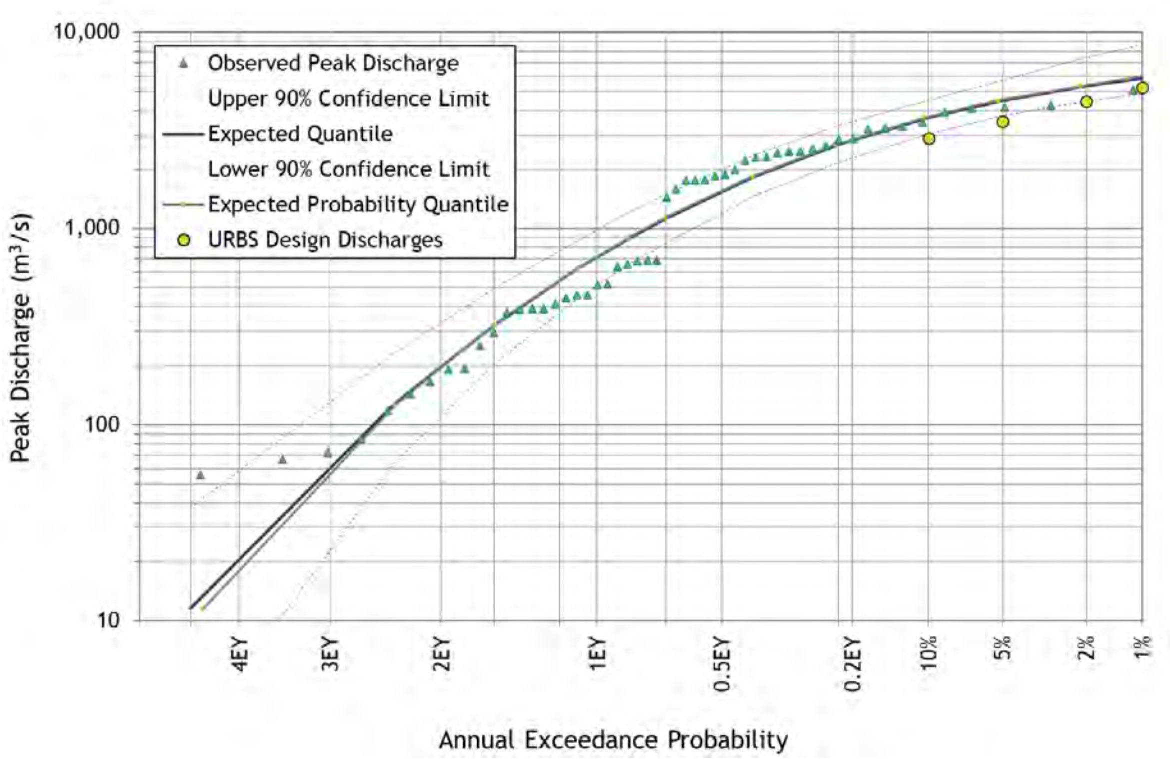

Figure 6.10 - LP III distribution of adjusted recorded flows at Pioneer River at Sarichs, compared with URBS estimated peak discharges

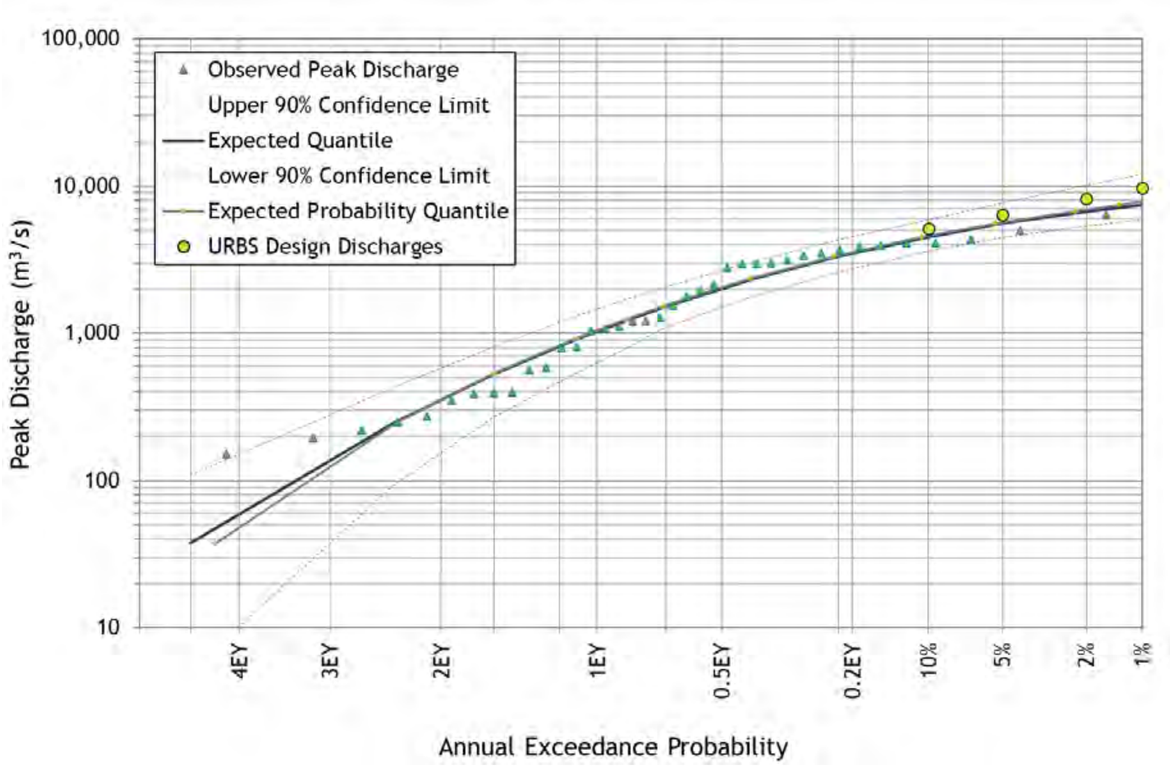

Figure 6.11 - LP III distribution of adjusted recorded flows at Mirani Weir Tailwater, compared with URBS estimated peak discharges

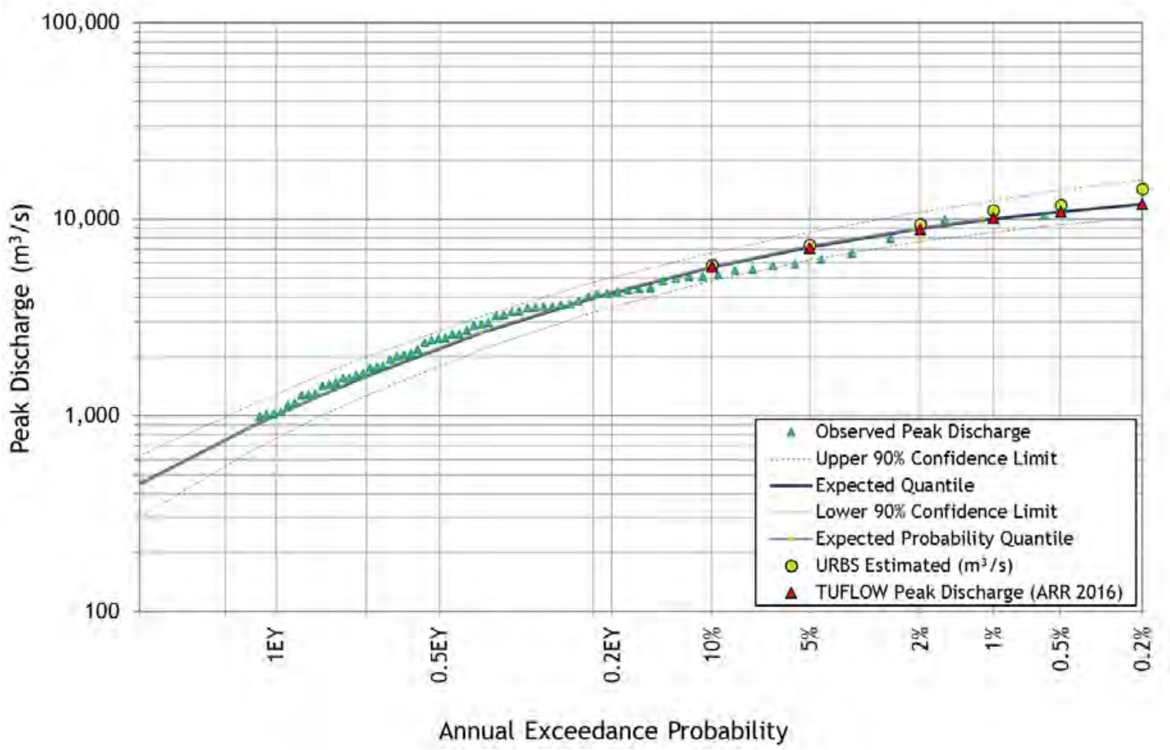

Figure 6.12 - LP III distribution of adjusted recorded flows at Pleystowe Mill/Dumbleton Weir, compared with URBS and TUFLOW estimated peak discharges

6.2.7 Adopted design discharges

Comparisons of URBS model and FFA design discharges at Whitefords, Gargett, Sarichs, Mirani Weir Tailwater and Pleystowe Mill/Dumbleton Weir gauges are shown graphically in Figure 6.8 to Figure 6.12. The URBS design discharges are lower than the FFA results at Whitefords and Sarichs gauges but are generally within the 90% confidence limits. The URBS design discharges at Gargett, Mirani Weir Tailwater and Pleystowe Mill/Dumbleton Weir gauges are generally consistent with or slightly higher the FFA results.

Table 6.6 also shows the Pioneer River design discharges at Dumbleton Weir estimated from the FFA analysis, the URBS model as well as using the TUFLOW model (using the routed URBS model flows). The results are shown graphically in Figure 6.12. The following is of note:

- The URBS model design discharges generally match the FFA estimates (within 10%) for events up to the 1% AEP event.
- Design discharges derived using the TUFLOW model (with the URBS inflows) are slightly lower than the URBS model design discharges. The TUFLOW model design discharges generally match the FFA estimates (within 1%) for events up to the 1% AEP event.
- The URBS model discharges are higher than the TUFLOW estimates for the 0.5% and 0.2% AEP design events because the TUFLOW model excludes the overflows from the Pioneer River into the Sandy Creek and Bakers Creek catchments that occur for these events.

Given the consistency of results, the design discharges derived using the TUFLOW model (with the URBS inflows) have been adopted for the study.

Table 6.6 - LP III distribution of adjusted recorded flows at Pleystowe Mill/Dumbleton Weir, compared with URBS and TUFLOW estimated peak discharges

Design Event (AEP)	FFA (m^3/s)	URBS (m^3/s)	Difference (URBS vs. FFA)	TUFLOW (m^3/s)	Difference (TUFLOW vs. FFA)
10%	5,682	5,831	3%	5,767	1%
5%	7,209	7,373	2%	7,141	-1%
2%	8,928	9,427	6%	8,913	0%
1%	10,009	11,059	10%	10,156	1%
0.5%	10,919	11,779	8%	10,994	0%
0.2%	11,897	14,250	20%	12,094	2%

6.2.8 Comparison to previous estimates

Table 6.7 compares the FFA, URBS and TUFLOW design discharge estimates from those given in the Pioneer River Flood Study (WRM, 2011). The following is of note:

- The 10% AEP and 5% AEP peak discharges at Pleystowe Mill/Dumbleton Weir estimated using the Bayesian Inference FFA methodology and tool (FLIKE) are similar to the previous FFA estimates.
- The 1% AEP peak discharge from updated FFA is 19% lower than the previous FFA estimate. The Bayesian inference methodology provides better fit to the recorded data, particularly for the larger events than the previous FFA, which used L-moment techniques. The additional 6 years of data also improves the FFA estimate for large events.
- The revised design discharges estimated using the TUFLOW model (with the URBS inflows) are between 5% and 8% lower for all events up to the 1% AEP event.

The design discharges adopted for this study are consistently lower than the previous (WRM, 2011) estimates, however they are considered appropriate. These estimates have been derived using the latest techniques that are more robust and based on more data including the 2017 event.

Table 6.7 - FFA, URBS and TUFLOW design discharge comparison at Pleystowe Mill/Dumbleton Weir, ARR 1987 versus ARR 2019

Design Event (AEP)	FFA Discharge (m³/s)			URBS Discharge (m³/s)			TUFLOW Discharge (m³/s)		
	ARR 1987	ARR 2019	Difference	ARR 1987	ARR 2019	Difference	ARR 1987	ARR 2019	Difference
10%	5,513	5,725	4%	6,283	5,831	-7%	6,184	5,767	-7%
5%	7,445	7,267	-2%	7,875	7,373	-6%	7,485	7,141	-5%
2%	10,228	9,005	-12%	10,573	9,427	-11%	9,659	8,913	-8%
1%	12,501	10,099	-19%	12,604	11,059	-12%	10,793	10,156	-5%
0.5%	n/a	11,021	n/a	13,460	11,779	-12%	11,567	10,994	-5%
0.2%	n/a	12,012	n/a	15,486	14,250	-8%	12,109	12,094	0%

7 Design flood levels

7.1 OVERVIEW

The Pioneer River TUFLOW model was used to estimate the peak flood levels, depths and extents for the 10% to 0.2% AEP design events and for the PMF for Pioneer River flooding. Results provided along Goosepond Creek and in Mackay City are based on Pioneer River catchment rainfalls, which may not produce the highest peak flood levels in these areas.

Separate flood reports have been prepared to define local catchment flooding from Goosepond Creek (WRM, 2021a) and within the Mackay City (WRM, 2021b). For these locations, local catchment flooding dominates flood levels for events up to the 2% AEP event. The models were run independently to determine the potential for flooding from each source.

7.2 ADOPTED TAILWATER CONDITIONS

Design flood levels along the lower reach of the Pioneer River are impacted by storm tide levels. BMT WBM (2013) investigated the likelihood of concurrent storm surge and freshwater flooding at Mackay as part of the Mackay Storm Tide Study. A Monte Carlo simulation was used to derive a joint probability distribution of flow and concurrent tailwater for use in future Pioneer River flood modelling in the Mackay Region. The joint probability distribution of the random high tide level and the 100,000 years of synthetic storm tide data is shown graphically in Figure 7.1.

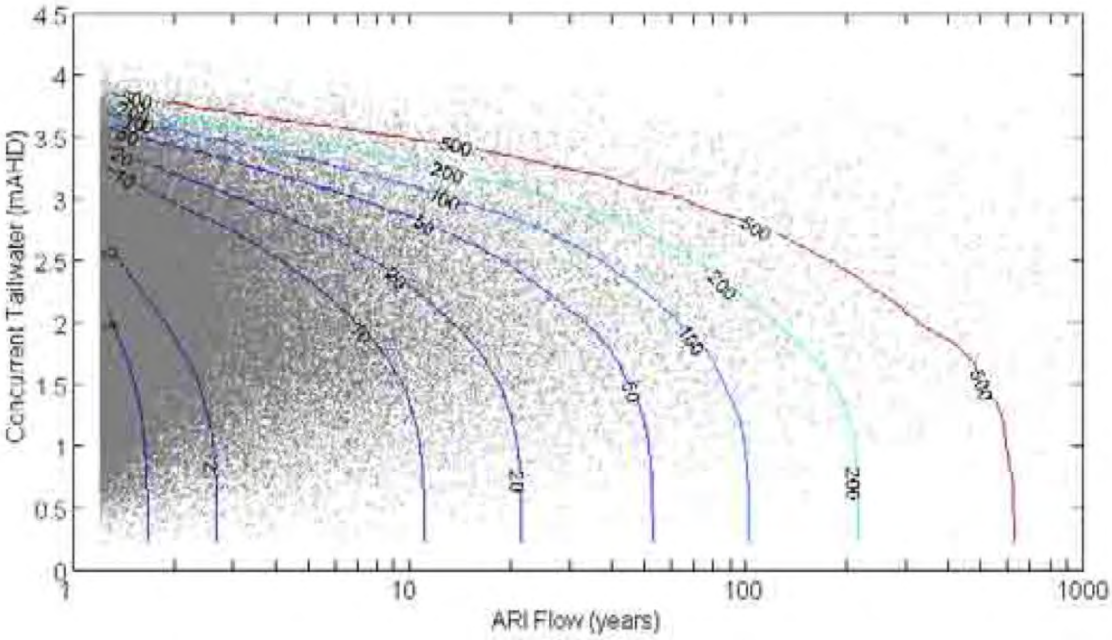

Figure 7.1 - Joint Probability Distribution, Freshwater Flow ARI and Ocean Tailwater Level (BMT WBM, 2013)

Figure 7.1 also shows the contours of equal probability of flow and concurrent tide level. The results suggest that a 100 year ARI (1% AEP) design flood level at the downstream reach of the river would be achieved from a 1% AEP design flood coinciding with a tide level varying from 0 m to 1 mAHD. In contrast, the same level would be achieved using a 10 year ARI (10% AEP) flood and a tide level of about 3.2 mAHD. BMT WBM advised that these results are preliminary and could be improved by combining the flow+surge+tide statistics with the surge + tide only statistics. The analysis was also undertaken for tide data at the Mackay Outer Harbour, which produces lower design tide levels than at the Pioneer River mouth.

For the Pioneer River Flood Study (WRM, 2011), design flood levels were determined from the design flood corresponding to the highest astronomical tide (HAT) of 3.64 mAHD. Figure 7.1 would suggest that this is equivalent to a 500 year ARI (0.2% AEP) water level along the lower reach of the river but was considered a reasonable assumption for determining design flood levels for planning purposes.

For this study, the mean high water spring (MHWS) tide level of 2.35 mAHD was adopted as the downstream boundary for all AEP's. Although not AEP neutral, it provides conservative flood level estimates along the flood protection levees and overcome some of the uncertainties described in the BMT WBM (2013) study.

Figure 7.2 shows the differences in 1% AEP peak flood levels when using HAT and MHWS tide levels along the lower Pioneer River. The results show that the adoption of HAT as the downstream boundary rather than MHWS would increase peak flood levels in the Bassett Basin area of Vines Creek and further downstream by between 0.2 m and 0.3 m. Peak flood levels between the Bassett Basin and the Caneland Central shopping centre would increase between 0.1 m and 0.3 m. In other words, Pioneer River peak flood levels are not overly sensitive to varying tailwater levels at the key overtopping locations upstream of the Caneland Central shopping centre for Mackay CBD and in Glenella to the north.

7.3 RON CAMM BRIDGE TRAINING WALL

Geotechnical investigations undertaken of the Ron Camm Bridge training wall, located on the southern bank of the Pioneer River upstream of the Ron Camm Bridge, found that it was susceptible to failure during flood events (AECOM, 2016). Previous hydraulic modelling of the failure mechanisms showed that design flood levels, including the susceptibility of flooding within the Mackay City area would be increased if the training wall breached. As a result, design flood levels have been determined assuming that the training wall would fail when the water level reached the 2% AEP flood, which is close to the crest level of the levee. A longitudinal section of the levee including the expected breach location is shown in Figure 7.3.

Limited design, geotechnical or as construction details of the training wall are available to determine the likely failure mechanism. For this assessment, the following extent and rate of failure have been adopted for the Ron Camm Bridge training wall:

- For the 2% and 1% AEP events, a piping failure with a final breach width of 180 m occurring at a rate (horizontal) 100 m/hr was adopted. The piping failure is assumed to initiate at a flood level of approximately 8.2 mAHD, representing 2 m flood depth against the training wall and about 0.5 m below the crest level.
- For events that overtop the wall, an overtopping failure with a final breach width of 180 m occurring in 10 minutes was adopted. The breach was initiated when water level reaches the top of the wall at the location shown in Figure 7.3.

7.4 DESIGN FLOOD LEVELS, DEPTHS AND EXTENTS

7.4.1 Downstream of Dumbleton Weir

Figure A.1 to Figure A.6 in Appendix A show the 10% AEP to 0.2% AEP design flood levels, depths and extents. Figure A.7 shows the design flood levels, depths and extents for the PMF.

Note that the Mackay City area drains via an extensive pipe network. The flood mapping of Mackay City for the Pioneer River overtopping events has been determined by the Mackay City TUFLOW model (WRM, 2021b) using the overflow discharges derived by the Pioneer River TUFLOW model.

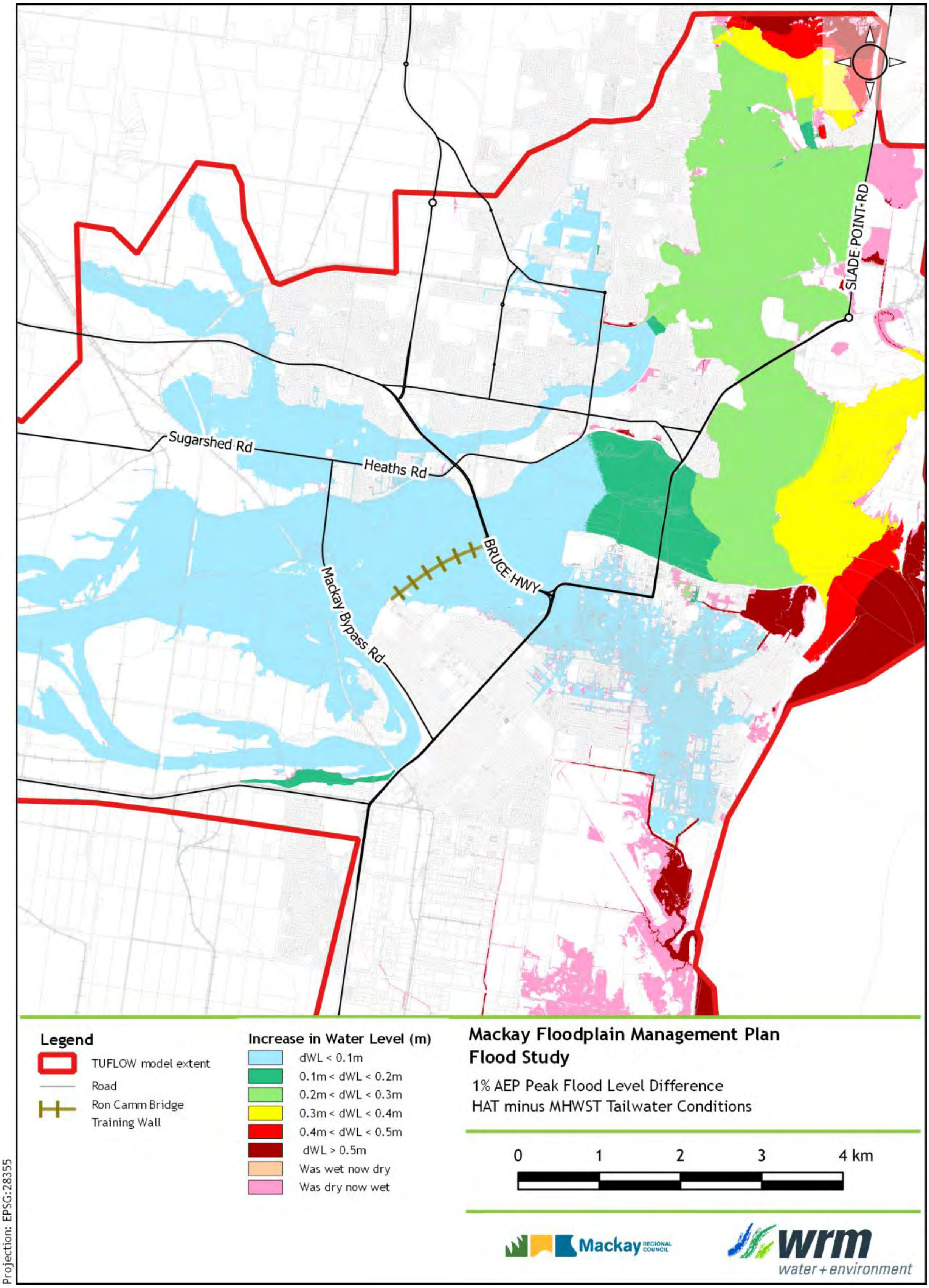

Figure 7.2 - 1% AEP Peak Flood Level Difference HAT and MHWST Tailwater Conditions

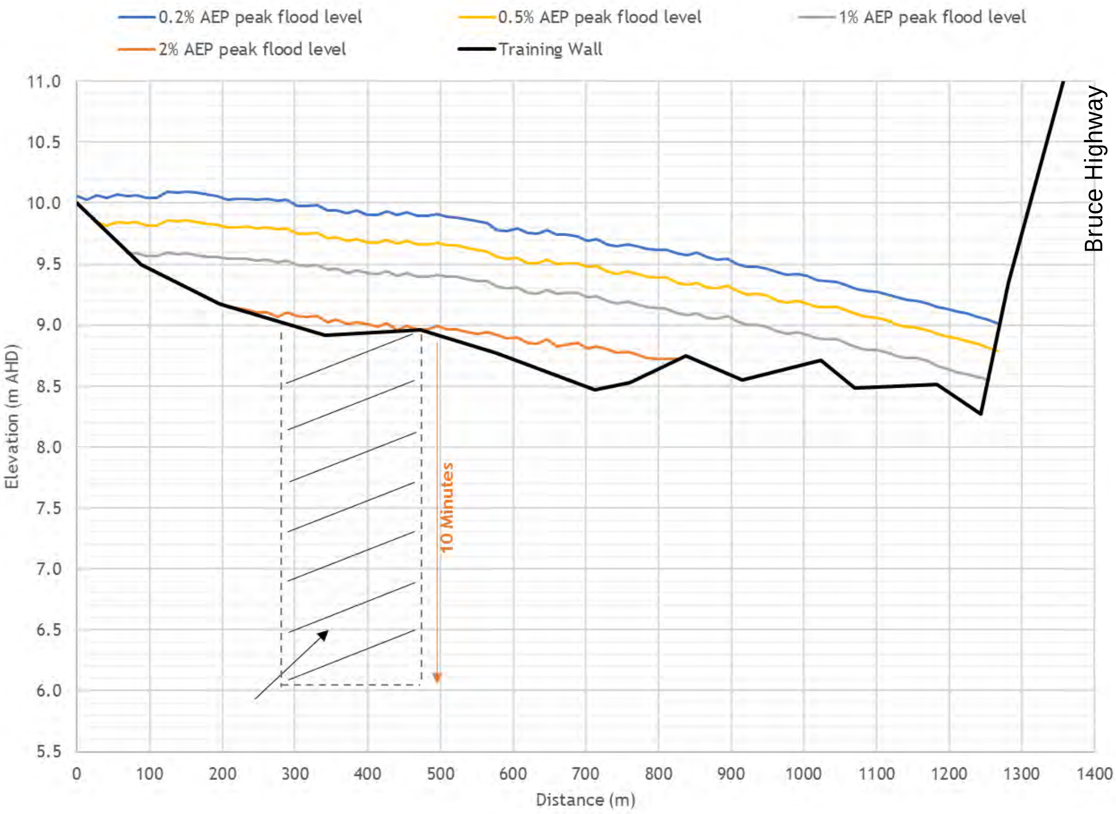

Figure 7.3 - Ron Camm Bridge training wall longitudinal section and adopted breach location

The following is of note:

- For the 10% and 5% AEP floods,
  - floodwater is generally contained within the banks of the Pioneer River and Goosepond Creek between the constructed flood levees;
  - significant overbank ponding occurs along Fursden Creek and Gooseponds Creek for these events;
  - the Pioneer River does not overflow to Goosepond Creek or Mackay City for these events; and
  - Gooseponds Creek drains into Fursden Creek to the west of Glenella Road.
- For the 2% AEP flood,
  - the levee protecting Mackay City along Shakespeare Street is just overtopped due to the breach of the Ron Camm Bridge training wall. The peak discharges draining into Mackay City is not significant at 10 m^3/s;
  - floodwater does not overflow to Goosepond Creek for this event;
  - significant overbank flooding occurs along Fursden Creek, Goosepond Creek and the Cremorne area for this event; and
  - Goosepond Creek drains into Fursden Creek to the west of Glenella Road.
- For the 1% AEP flood,
  - the levee protecting Mackay City is overtopped due to the breach of the Ron Camm Bridge training wall. The peak discharge draining into Mackay City is not significant at 77 m^3/s;

- Goosepond Creek overflows to the Pioneer River near Glenella Road and the Pioneer River overflows into Mount Pleasant upstream of the Bruce Highway; and
  - the floodwater along Goosepond Creek downstream of the Bruce Highway is generally contained within the levees.
- For the 0.5% AEP flood,
  - a peak discharge of about 240 m^3/s drains into Mackay City upstream of the Bruce Highway. There are no overflows downstream of the Bruce Highway;
  - some urban areas in Glenella and Mount Pleasant are inundated, mostly from the Pioneer River overflows upstream of the Bruce Highway;
  - minor inundation occurs in North Mackay around Carr Street to the south of Harbour Road; and
  - a peak discharge of about 376 m^3/s overflows from the Pioneer River to the Bakers Creek catchment upstream of Dumbleton Weir inundating parts of Walkerston.
- For the 0.2% AEP floods,
  - a peak discharge of about 562 m^3/s drains into Mackay City upstream and downstream of the Bruce Highway;
  - the majority of the overflows occurring upstream of the Bruce Highway and across the Ron Camm Bridge offramp to Gordon street. The levee to the east of Sydney Street is also overtopped (as shown in Figure A.6 in Appendix A);
  - almost the entire urban area between the Pioneer River and Goosepond Creek and much of Mackay City area would be inundated;
  - peak flood depths in the urban area exceed 1.5 m in Mackay City and 2 m in north Mackay; and
  - substantial overflows to Bakers Creek and to Sandy Creek occur from the Pioneer River.
- For the PMF,
  - Almost all levees along the Pioneer River and Goosepond Creek are overtopped; and
  - Substantial urban areas of Mackay, North Mackay, Mount Pleasant and Glenella are inundated.

7.4.2 Upstream of Dumbleton Weir

Figure A.8 to Figure A.13 in Appendix A show the 10% AEP to 0.2% AEP design flood levels, depths and extents along the upper reach of the Pioneer River from Mirani Weir to Walkerston. Figure A.14 shows the design flood levels, depths and extents for the PMF. The following is of note:

- For events up to the 0.5% AEP, there is no out-of-bank Pioneer River flooding between Mirani Weir and Pleystowe Mill;
- The Pioneer River overflows upstream of Dumbleton Weir for the 2% AEP event, but the overflows do not drain further south of Mackay Eungella Road;
- For the 1% AEP event, the Pioneer River overflows to Bakers Creek upstream of Dumbleton Weir. The peak discharge draining into Bakers Creek is approximately 71 m^3/s;
- For the 0.2% AEP flood, there is no out-of-bank flooding at Mirani. The Pioneer River overflows at Marian Weir to inundate the western areas of Marian before draining to Sandy Creek. Approximately 41 m^3/s overtops the Pioneer River at Marian resulting a peak flood depth of approximately 0.7 m in the urban areas of Marian.

- For the PMF, there will be significant overflow from the Pioneer River to Sandy Creek and Bakers Creek to cause significant inundation of the urban areas in Mirani, Marian and Walkerston.

7.5 STORM TIDE FLOODING

BMT WBM (2017) provided further advice on the storm tide levels specific for the Pioneer River. These levels, together with the tide planes for Mackay (MSQ, 2017), are given in Table 7.1. The results show 1% AEP design tide levels are much higher than HAT. However, they are lower than the Pioneer River design flood levels at all locations with the exception of the areas within and adjacent to the Bassett Basin.

Further to this, design storm tide levels do not overtop the Pioneer River or the Goosepond Creek/Vines Creek levees for any of the design events modelled with the exception of the 0.01% AEP event, which may just overtop the Shinn Street levee in North Mackay. This assumes temporary levees will be placed across Harbour Road in North Mackay. This is in contrast to the storm tide flood mapping prepared by BMT WBM (2013), which likely did not fully consider the impact of the existing flood levees. Notwithstanding this, design storm tide mapping along the Pioneer River (and Goosepond Creek) has not been undertaken for this assessment.

Table 7.1 - Predicted tide planes and design tide levels for Pioneer River

Tide Plane / AEP	Predicted Tide Level (mAHD)
2%[a]	4.27
1%[a]	4.34
0.2%[a]	4.48
0.1%[a]	4.81
0.01%[b]	5.58
Highest Astronomical Tide (HAT)	3.64
Mean High Water Springs (MHWS)	2.35
Mean High Water Neaps (MHWN)	1.13
Mean Low Water Neaps (MLWN)	-0.98
Mean Low Water Springs (MLWS)	-2.2
Lowest Astronomical Tide (LAT)	-2.94

[a]BMT WBM (2017) [b]BMT WBM (2013)

8 Effects of climate change

8.1 GENERAL

The Local Government Association of Queensland (LGAQ) and the Queensland Government (Qld Govt, 2010) have established a framework to provide Queensland local governments with advice on how to account for climate change in assessing flood risk. The study recommends a 'climate change factor' be included into flood studies in the form of a 5% increase in rainfall per degree of global warming. For the purposes of applying the climate change factor, the study outlines the following temperature increases and planning horizons:

- 2°Celsius by 2050;
- 3°Celsius by 2070; and
- 4°Celsius by 2100.

These increases in temperature equate to a 10% increase in rainfall depth by 2050, and 15% increase in rainfall depth by 2070 and a 20% increase in rainfall depth by 2100 (Qld Govt, 2010).

Book 1 Chapter 6 of ARR (Ball et al., 2019) also provides interim guideline on climate change considerations. The climate change design rainfall depth was increased by a factor of 1.2 (20% increase) in accordance with guidelines in Book 1 Chapter 6 of the ARR (Ball et al, 2019). The adopted multiplication factor is based on a planning horizon of year 2090 and a projected warming of more than 3.0 degrees Celsius. The 20% increase in rainfall depth using the interim climate change guideline in Book 1 Chapter 6 of ARR is generally consistent with the Qld Govt (2010) findings.

The ARR Data Hub also provides interim climate change factors that can be extracted for any point location within Australia. Recent inspection of the ARR Data Hub indicates that the projected temperature increase for the 2090 planning horizon for Mackay is 3.124 degrees Celsius (based on RCP 8.5). This corresponds to a 15.6% increase in rainfall, which differs to the Qld Govt (2010) guidelines and to the guideline in Book 1 Chapter 6 of ARR.

A sensitivity analysis was undertaken to assess the differences in design peak flood levels along the Pioneer River and Goosepond Creek between adopting a 20% and 15.6% increase in rainfall. Details of the methodology and results of this sensitivity analysis are documented in a memorandum prepared for MRC (WRM, 2020).

Following discussions with Mackay Regional Council, the climate change that would be expected to occur in 2100, a 20% increase in rainfall, has been adopted to assess the climate change design events.

In addition to increased rainfall, climate change has the potential to increase sea levels. A sea level rise of 0.8 m is expected by 2100. The MHWS and HAT levels at the downstream boundary has been increased by 0.8 m to 3.15 mAHD and 4.44 mAHD, respectively, for the design events.

8.2 ADOPTED DESIGN RAINFALL AND BOUNDARY CONDITIONS

The 10%, 1% and 0.2% AEP design rainfall depths presented in Section 6.2.1 for the Pioneer River catchment were increased by 20% to account for the effects of climate change.

A fixed water level of 3.15 mAHD was adopted for the Pioneer River and Mackay City models, representing a sea level rise of 0.8 m on the MHWS. A fixed water level of 4.44 mAHD was adopted for the Goosepond Creek model, representing a sea level rise of 0.8 m on the HAT.

8.3 MODEL RESULTS

Figure A.15 to Figure A.17 in Appendix A show the 10%, 1% and 0.2% AEP climate change design flood levels, depths and extents for the Pioneer River flooding. The following is of note with respect to the increased flooding due to climate change:

- For the 10% AEP climate change event:
  - Peak flood levels increase by between 0.6 m and 1.2 m along the Pioneer River;
  - Peak flood levels increase by 0.1 m and 0.5 m along Goosepond Creek; and
  - The climate change scenario remains within the banks of the Pioneer River.
- For the 1% AEP climate change event:
  - Peak water levels along the Pioneer River are increased by up to 1 m;
  - Peak flood levels are increased by 0.5 m and 0.4 m at the Hospital Bridge and Mackay gauges respectively. The levee protecting Mackay City is overtopped upstream of the Bruce Highway during this event. The model predicts that 268 m^3/s overtops the levee at the peak of the flood;
  - Some properties in Mount Pleasant and Glenella will be inundated during this event; and
  - Some 572 m^3/s overflows the Pioneer River channel to Bakers Creek for this event.
- For the 0.2% AEP climate change event:
  - Peak flood levels increase by 0.5 m at Dumbleton Weir. Greater volumes of Pioneer River floodwater overflows to Bakers Creek. At the peak, some 1,800 m^3/s overflows to Bakers Creek for this event;
  - Peak flood levels are increased by 0.35 m and 0.25 m at the Hospital Bridge and Mackay gauges respectively;
  - The levee protecting Mackay City is overtopped during this event. The model predicts that 918 m^3/s overtops the levee upstream of the Caneland Central shopping centre and that 146 m^3/s overtops the levee to the east of Sydney Street at the peak of the flood; and
  - Significant areas of North Mackay, Mount Pleasant and Glenella are inundated as water overflows all of the northern levees.

Figure A.18 to Figure A.20 in Appendix A show the 10%, 1% and 0.2% AEP climate change design flood levels, depths and extents along the upper reach of the Pioneer River from Mirani Weir to Walkerston. The following is of note:

- For the 10% AEP climate change event, peak flood levels increase by between 1.0 m and 1.2 m between Marian and Mirani. There is no out-of-bank flooding at Mirani and Marian.
- For the 1% AEP climate change event, peak flood levels increase by between 1.4 m and 1.5 m between Mirani and Marian. There is no out-of-bank flooding at Mirani and Marian.
- For the 0.2% AEP climate change event, peak flood levels increase by up to 1.5 m at Mirani. There is no out-of-bank flooding at Mirani. The overflow from the Pioneer River to Marian peaks at approximately 1,280 m^3/s and the peak flood levels are increased by up to 0.9 m in Marian when compared to the 0.2% AEP event.

9 Provisional hydraulic hazard classification

9.1 FLOOD HAZARD CLASSIFICATION

As part of the floodplain management study, the initial categorisation of flood prone land has been defined using the depth and velocity of the floodwaters calculated using the flood model. Each area is then assigned a provisional classification using the categories given in Australian Disaster Resilience Guideline 7-3 Flood Hazard (AIDR, 2017) and shown in Figure 9.1.

The flood hazard curves shown in Figure 9.1 set hazard thresholds that relate to the vulnerability of the community when interacting with floodwaters. Table 9.1 shows the 6 flood hazard classifications and Table 9.2 provides the depth and velocity limits for each of the classifications.

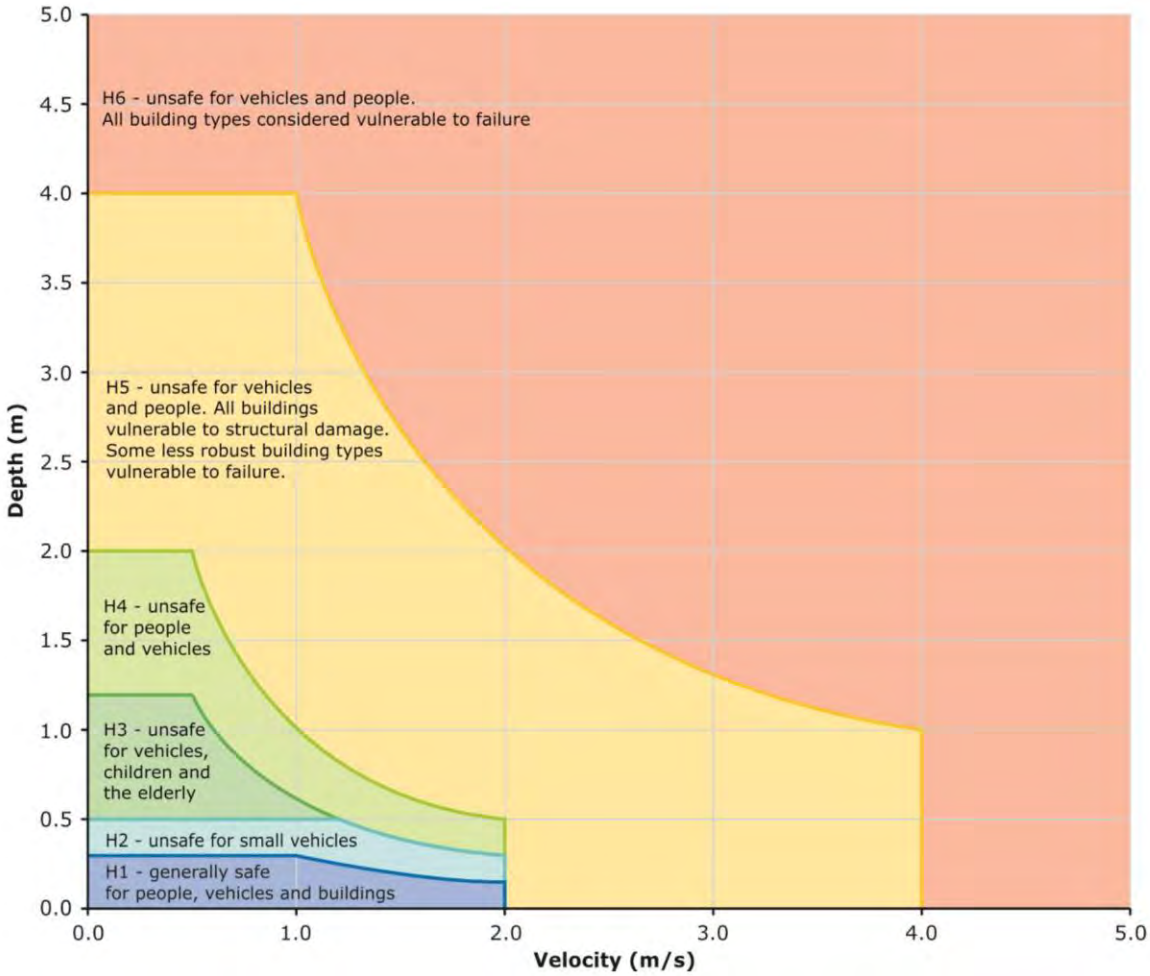

Figure 9.1 - General flood hazard vulnerability curves (Source: AIDR, 2017)

Table 9.1 - Combined hazard curves - vulnerability thresholds

Hazard Vulnerability Classification	Description
H1	Generally safe for people, vehicles and buildings
H2	Unsafe for small vehicles.
H3	Unsafe for vehicles, children and the elderly
H4	Unsafe for vehicles and people.
H5	Unsafe for vehicles and people. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure.
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.

Table 9.2 - Combined hazard curves - vulnerability thresholds classification limits

Hazard Vulnerability Classification	Classification limit (D and V in combination) m^2/s	Limiting still water depth (D) m	Limiting velocity (V) m/s
H1	$D*V \le 0.3$	0.3	2
H2	$D*V \le 0.6$	0.5	2
H3	$D*V \le 0.6$	1.2	2
H4	$D*V \le 1.0$	2	2
H5	$D*V \le 4.0$	4	4
H6	$D*V > 4.0$	-	-

9.2 FLOOD HAZARD MAPPING

Appendix B shows the flood hazard mapping for the Pioneer River for a range of design flood events. The following is of note for the Pioneer River:

- Unsafe flood hazard zones are mostly within the channels for events up to 1% AEP.
- For rarer flood events of 0.5% and 0.2% AEP, significant areas in Mackay, North Mackay and along Goosepond Creek will be within unsafe flood hazard zones.
- For the PMF, almost the entire Mackay City and areas between the Pioneer River and Goosepond Creek will be in unsafe flood hazard zones.

10 References

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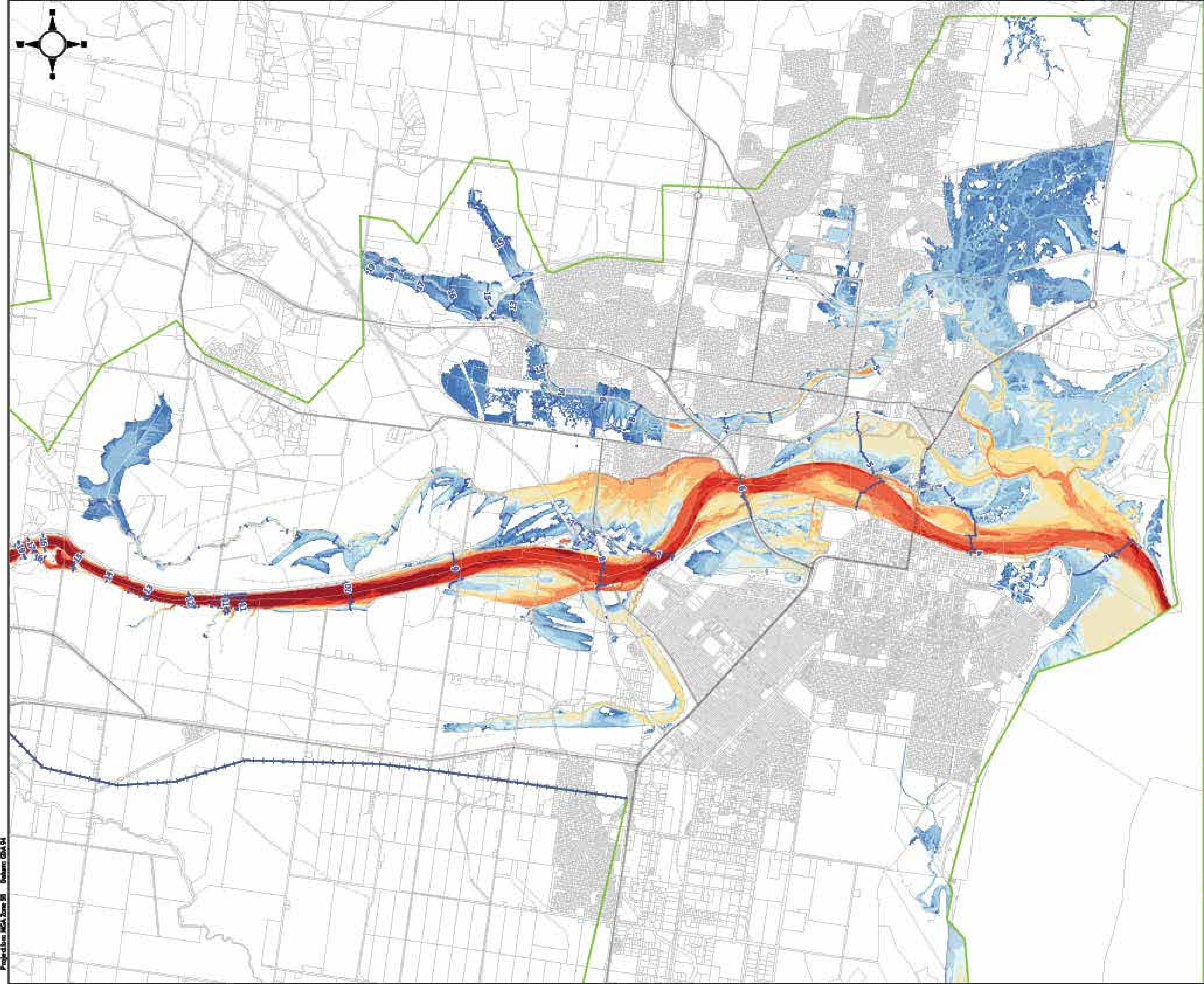
Appendix A - Pioneer River flood mapping



Legend

- Railway
- Main road
- Cadastral boundary
- TUFLOW model extent
- Overflow boundary
- Water level contour (1m interval)

Flood Depth (m)

- 0.00 - 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 8.0
- 8.0 - 10.0
- > 10.0

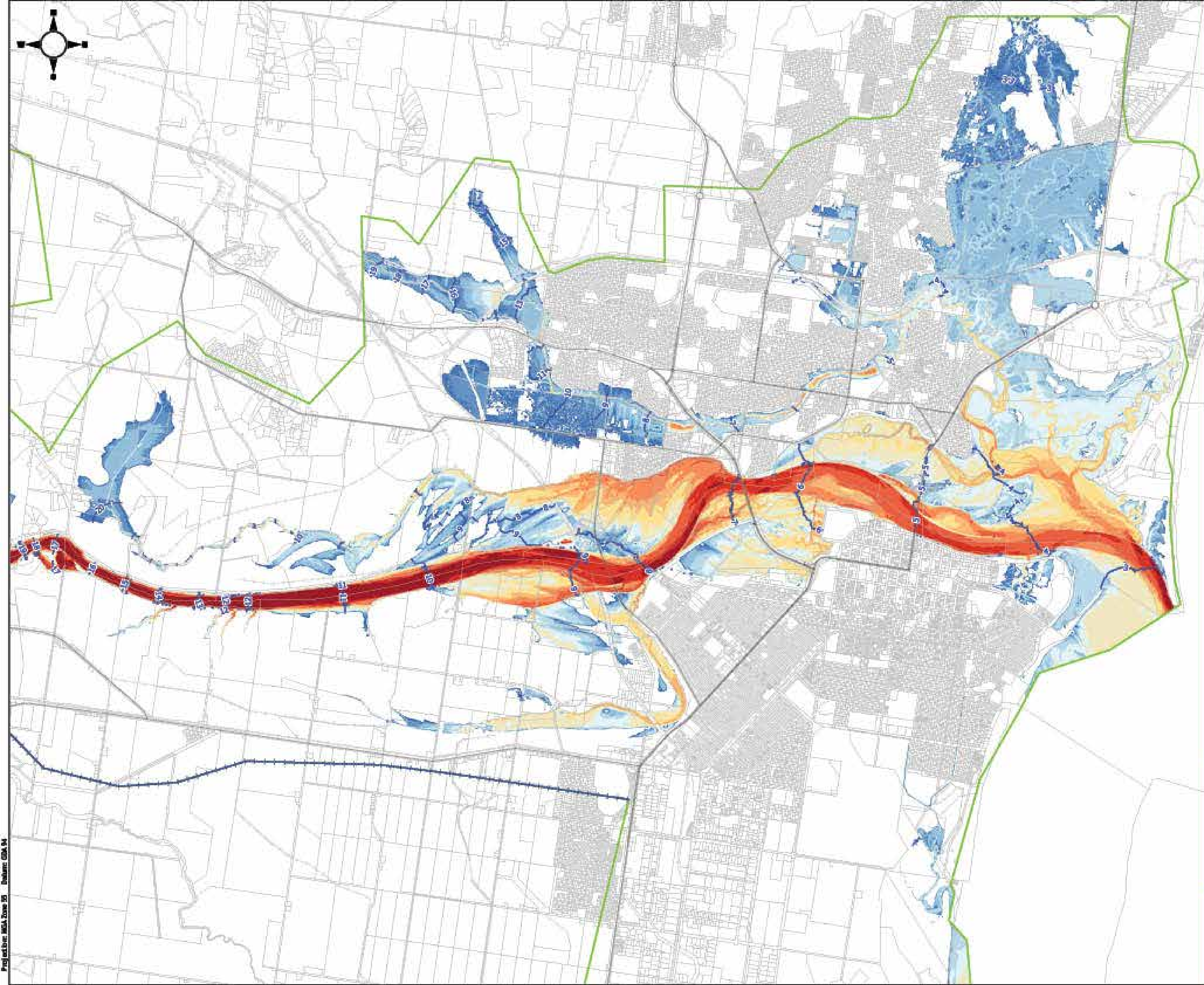
0 0.5 1 1.5 2 km

MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure A.1
Flood Depths, Levels and Extent
10% AEP Event

Mackay REGIONAL COUNCIL

wrm water + environment



Legend

- Railway
- Main road
- Cadastral boundary
- TUFLOW model extent
- Overflow boundary
- Water level contour (1m interval)

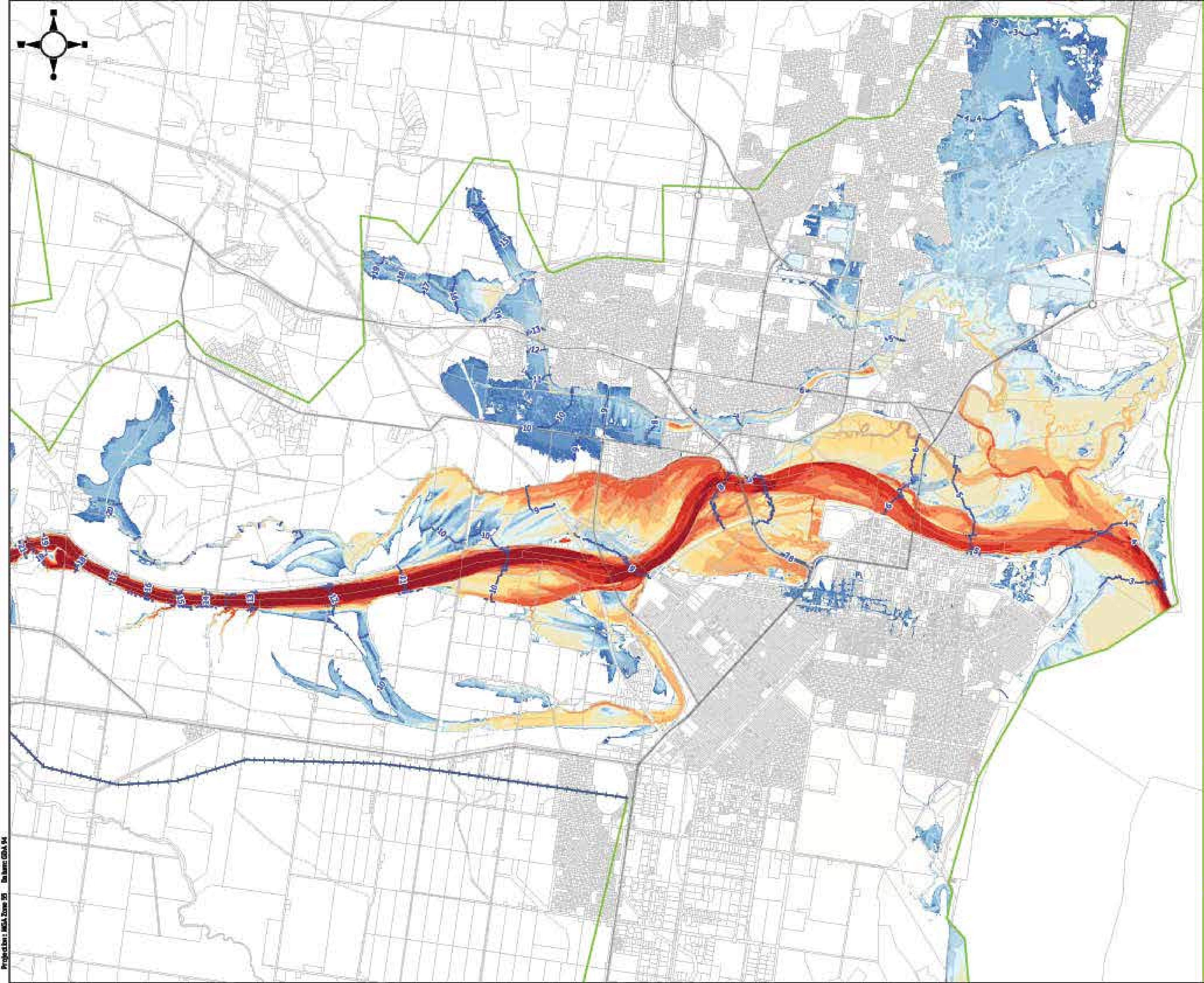
Flood Depth (m)

- 0.00 - 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 8.0
- 8.0 - 10.0
- > 10.0

0 0.5 1 1.5 2 km

MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure A.2
Flood Depths, Levels and Extent
5% AEP Event



Legend

- Railway
- Main road
- Cadastral boundary
- TUFLOW model extent
- Overflow boundary
- Water level contour (1m interval)

Flood Depth (m)

- 0.00 - 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 8.0
- 8.0 - 10.0
- > 10.0

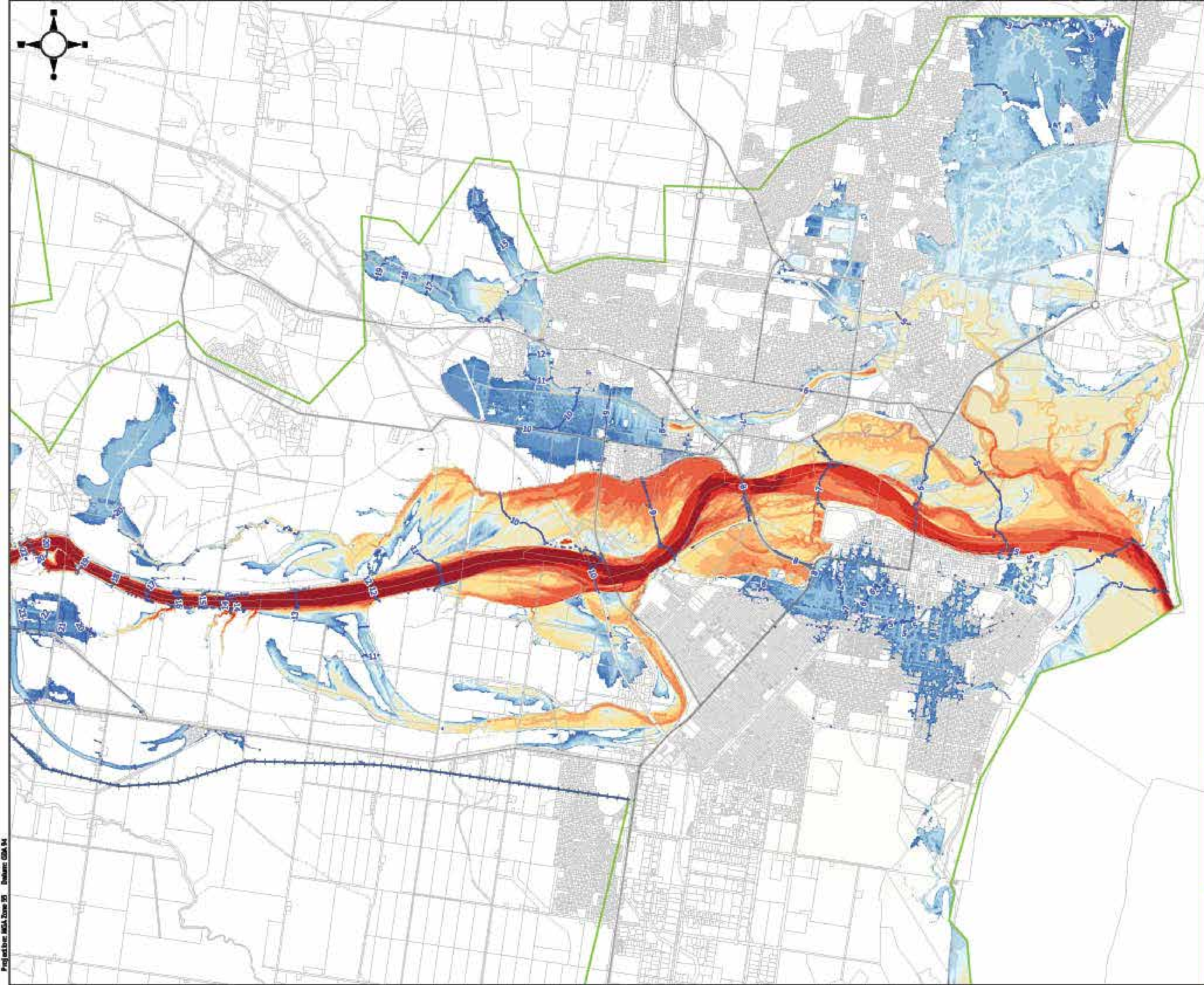
0 0.5 1 1.5 2 km

MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure A.3
Flood Depths, Levels and Extent
2% AEP Event

Mackay Regional Council

wrm water + environment



Legend

- Railway
- Main road
- Cadastral boundary
- TUFLOW model extent
- Overflow boundary
- Water level contour (1m interval)

Flood Depth (m)

- 0.00 - 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 8.0
- 8.0 - 10.0
- > 10.0

0 0.5 1 1.5 2 km

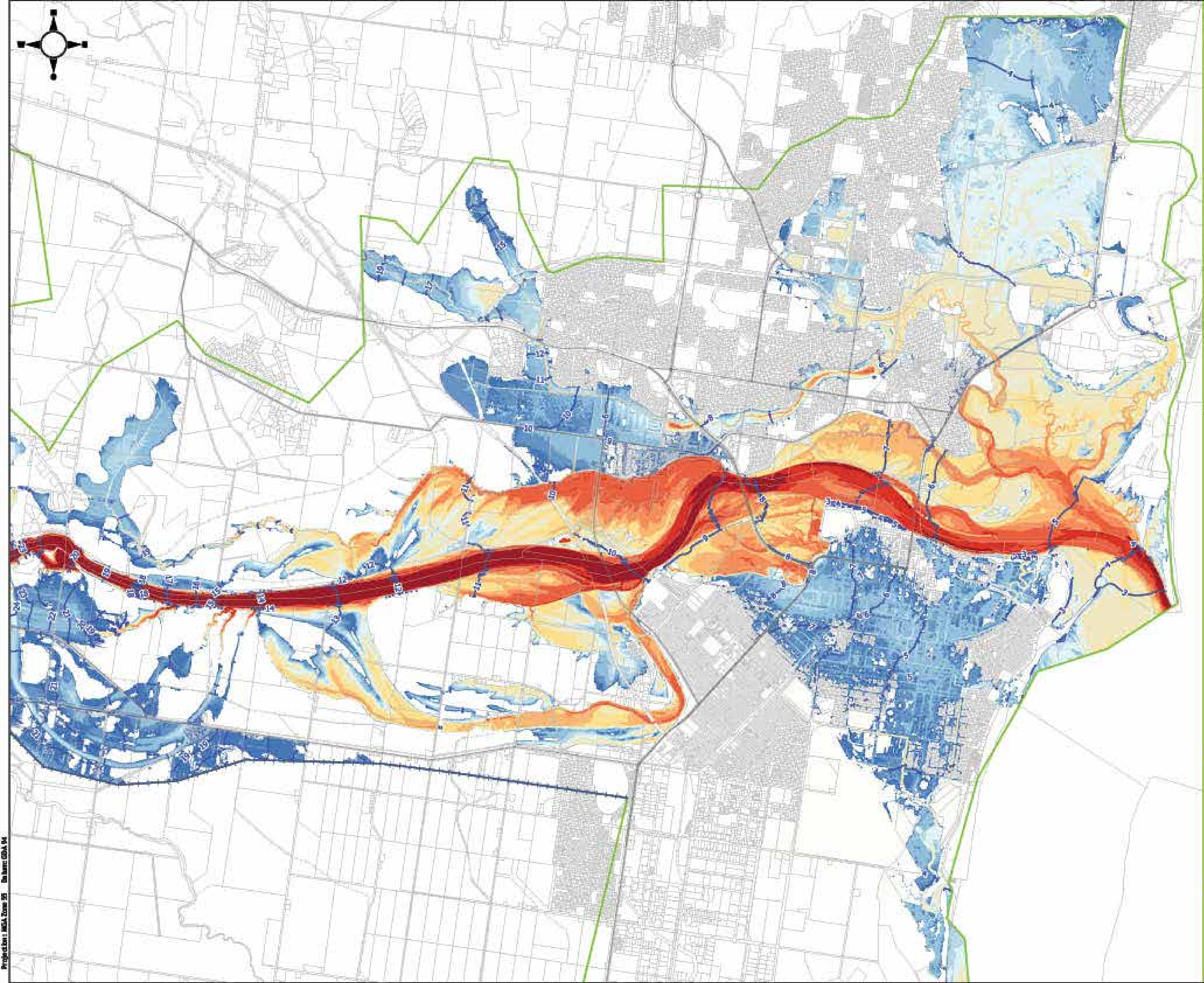
MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure A.4
Flood Depths, Levels and Extent
1% AEP Event

Mackay

wrm water + environment

Projection: MGA Zone 55 Datum: GDA 94

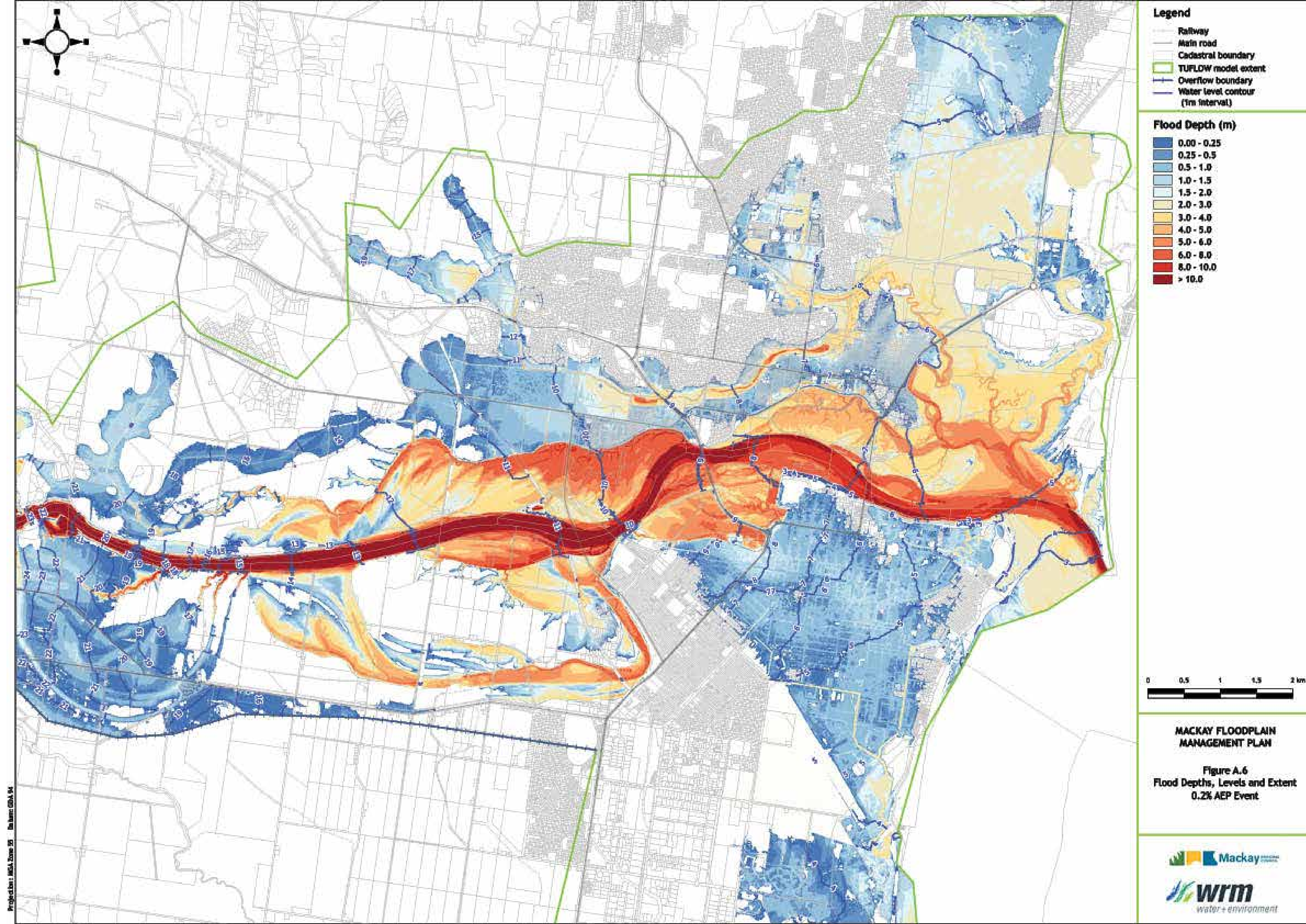


MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure A.5
Flood Depths, Levels and Extent
0.5% AEP Event

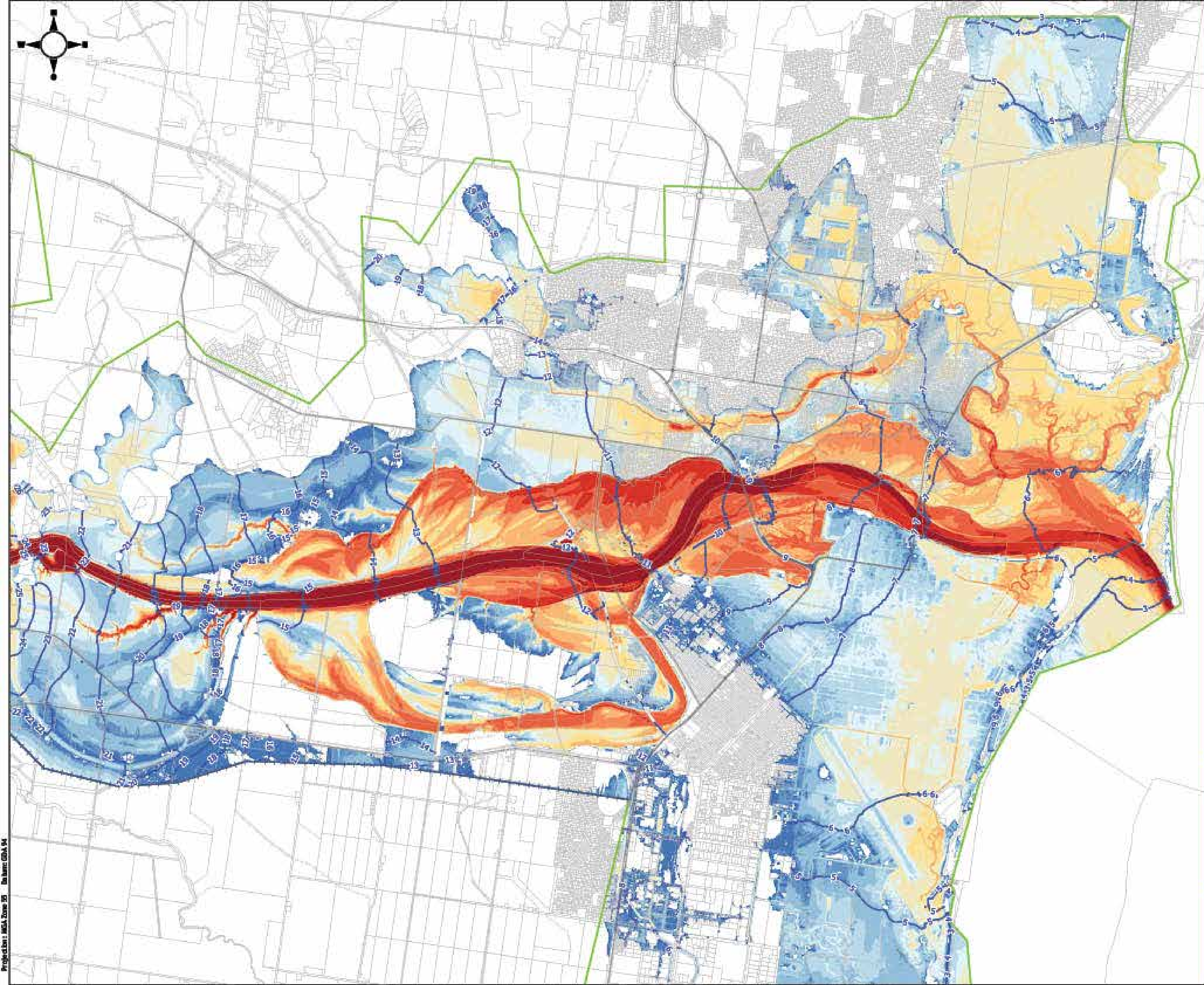
Mackay Regional Council

wrm water + environment



MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure A.6
Flood Depths, Levels and Extent
0.2% AEP Event



Legend

- Railway
- Main road
- Cadastral boundary
- TUFLOW model extent
- Overflow boundary
- Water level contour (1m interval)

Flood Depth (m)

- 0.00 - 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 8.0
- 8.0 - 10.0
- > 10.0

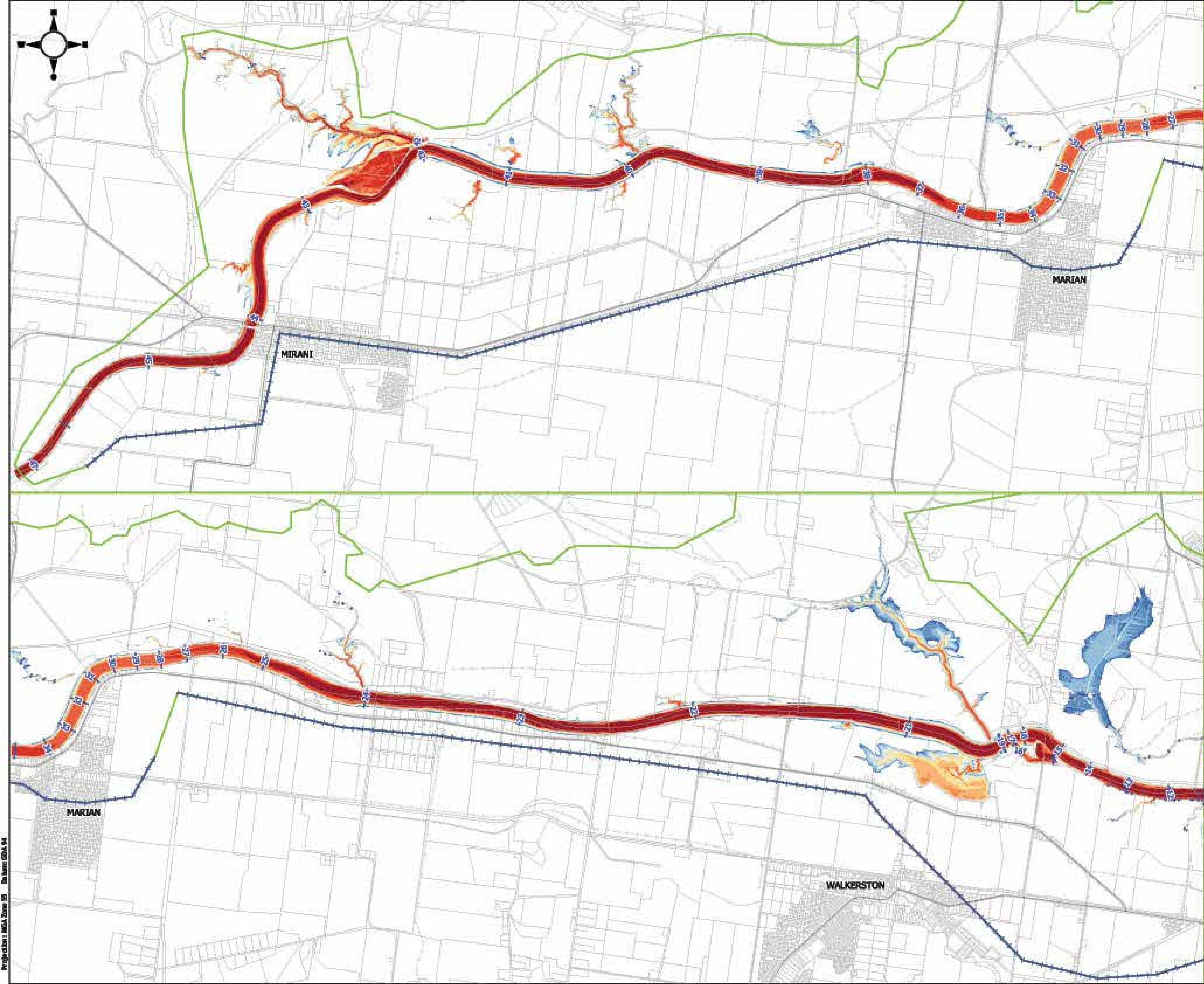
0 0.5 1 1.5 2 km

MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure A.7
Predicted Flood Depths, Levels and Extent
PMF Event

Mackay Regional Council

wrm water + environment



Legend

- Railway
- Main road
- Cadastral boundary
- TUFLOW model extent
- Overflow boundary
- Water level contour (1m interval)

Flood Depth (m)

- 0.00 - 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 8.0
- 8.0 - 10.0
- > 10.0

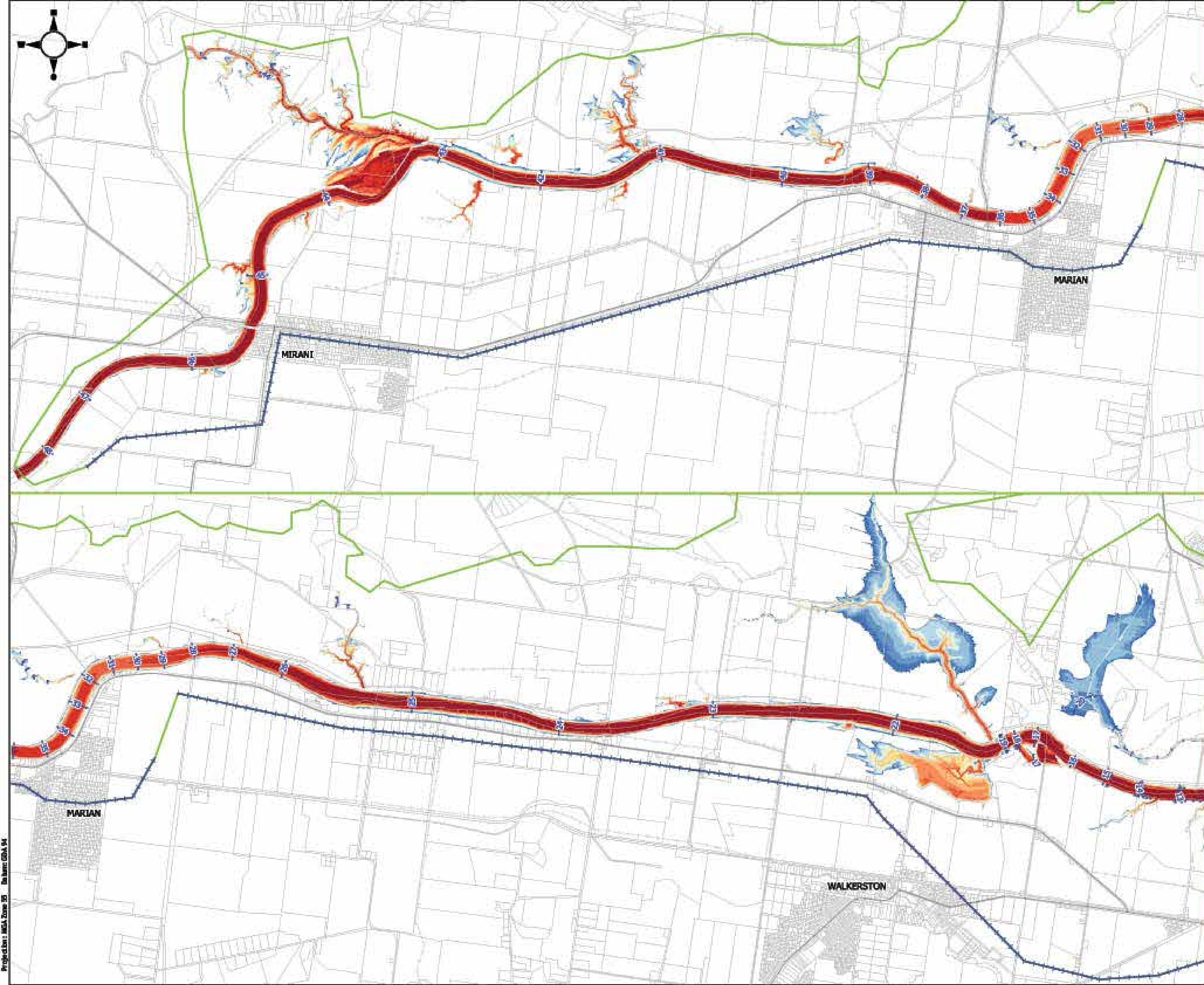
0 0.5 1 1.5 2 km

MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure A.8
Flood Depths, Levels and Extent
10% AEP Event

Mackay Regional Council

wrm water + environment



Legend

- Railway
- Main road
- Cadastral boundary
- TUFLOW model extent
- Overflow boundary
- Water level contour (1m interval)

Flood Depth (m)

- 0.00 - 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 8.0
- 8.0 - 10.0
- > 10.0

0 0.5 1 1.5 2 km

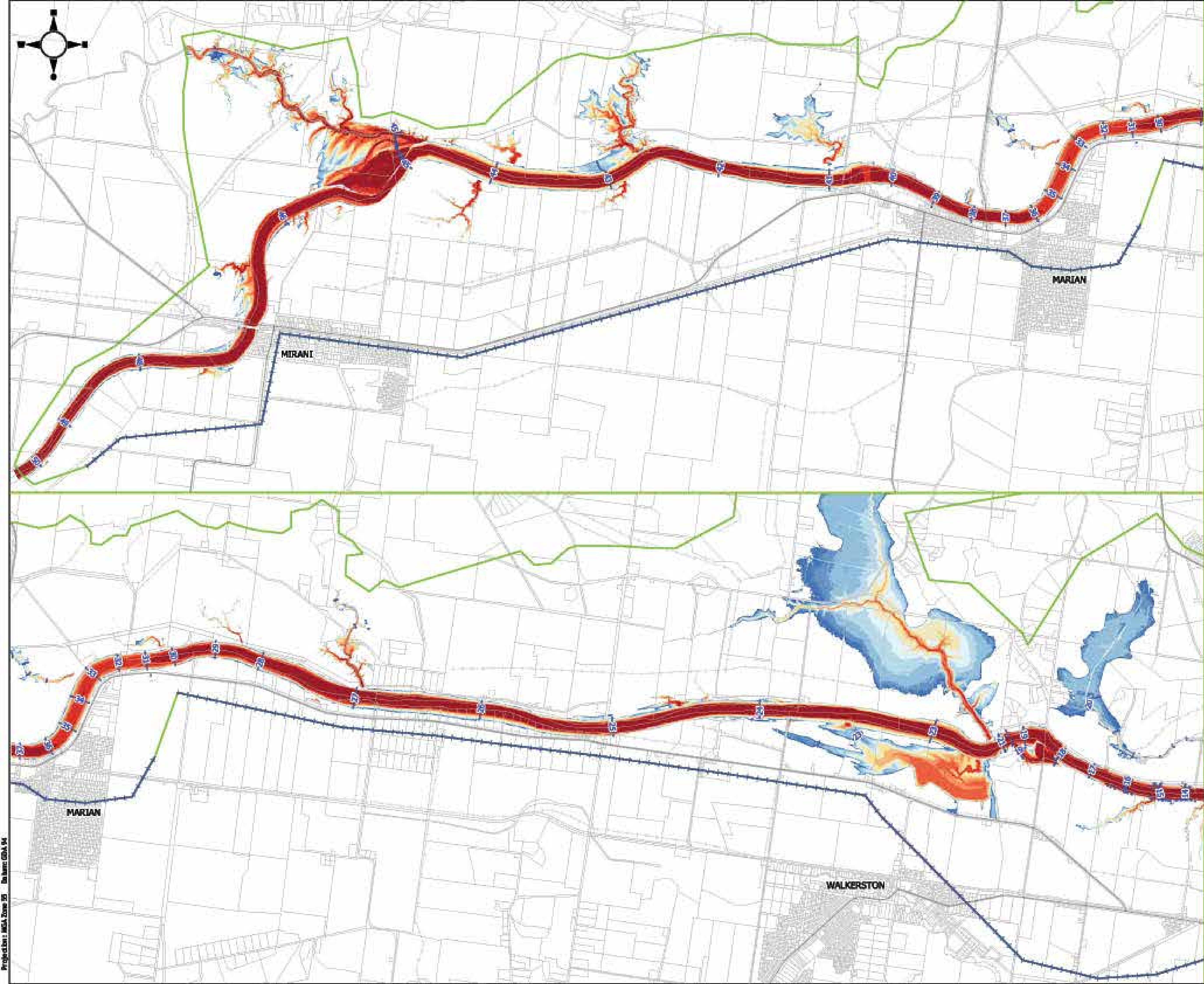
MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure A.9
Flood Depths, Levels and Extent
5% AEP Event

Mackay Regional Council

wrm water + environment

Projection: MGA Zone 55 Datum: GDA 94



Legend

- Railway
- Main road
- Cadastral boundary
- TUFLOW model extent
- Overflow boundary
- Water level contour (1m interval)

Flood Depth (m)

- 0.00 - 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 8.0
- 8.0 - 10.0
- > 10.0

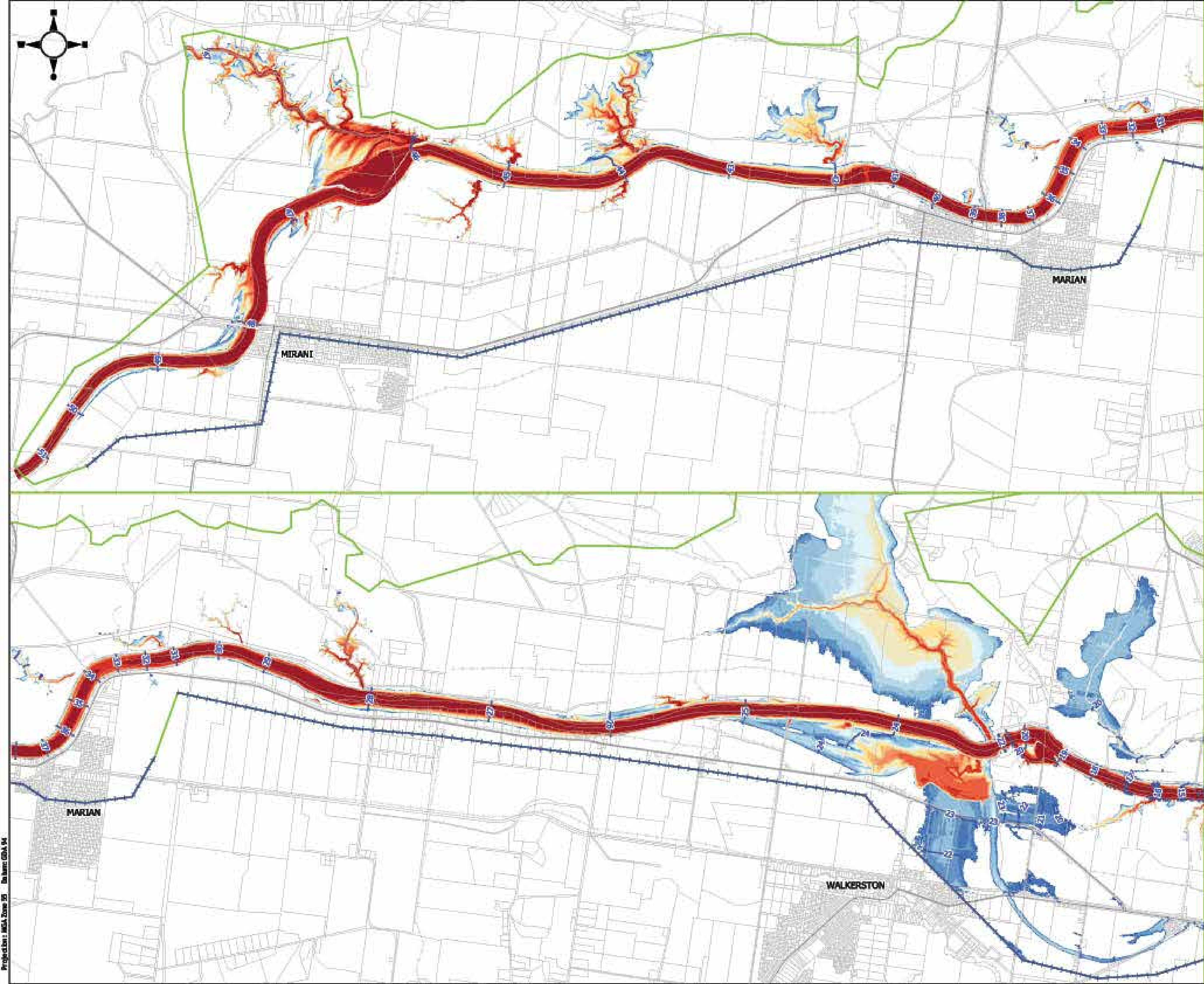
0 0.5 1 1.5 2 km

MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure A.10
Flood Depths, Levels and Extent
2% AEP Event

Mackay Regional Council

wrm water + environment



Legend

- Railway
- Main road
- Cadastral boundary
- TUFLOW model extent
- Overflow boundary
- Water level contour (1m interval)

Flood Depth (m)

- 0.00 - 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 8.0
- 8.0 - 10.0
- > 10.0

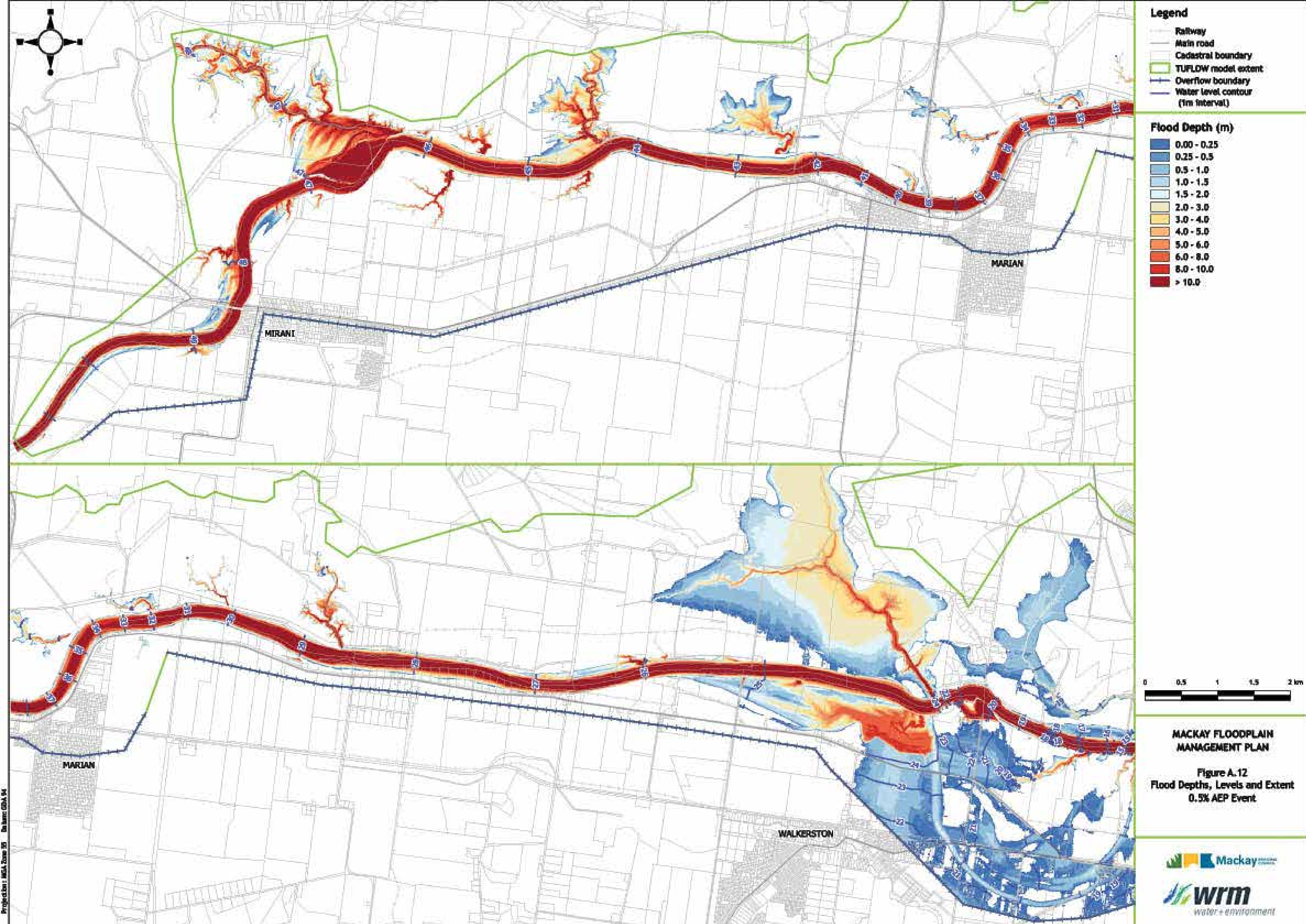
0 0.5 1 1.5 2 km

MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure A.11
Flood Depths, Levels and Extent
1% AEP Event

Mackay Regional Council

wrm water + environment

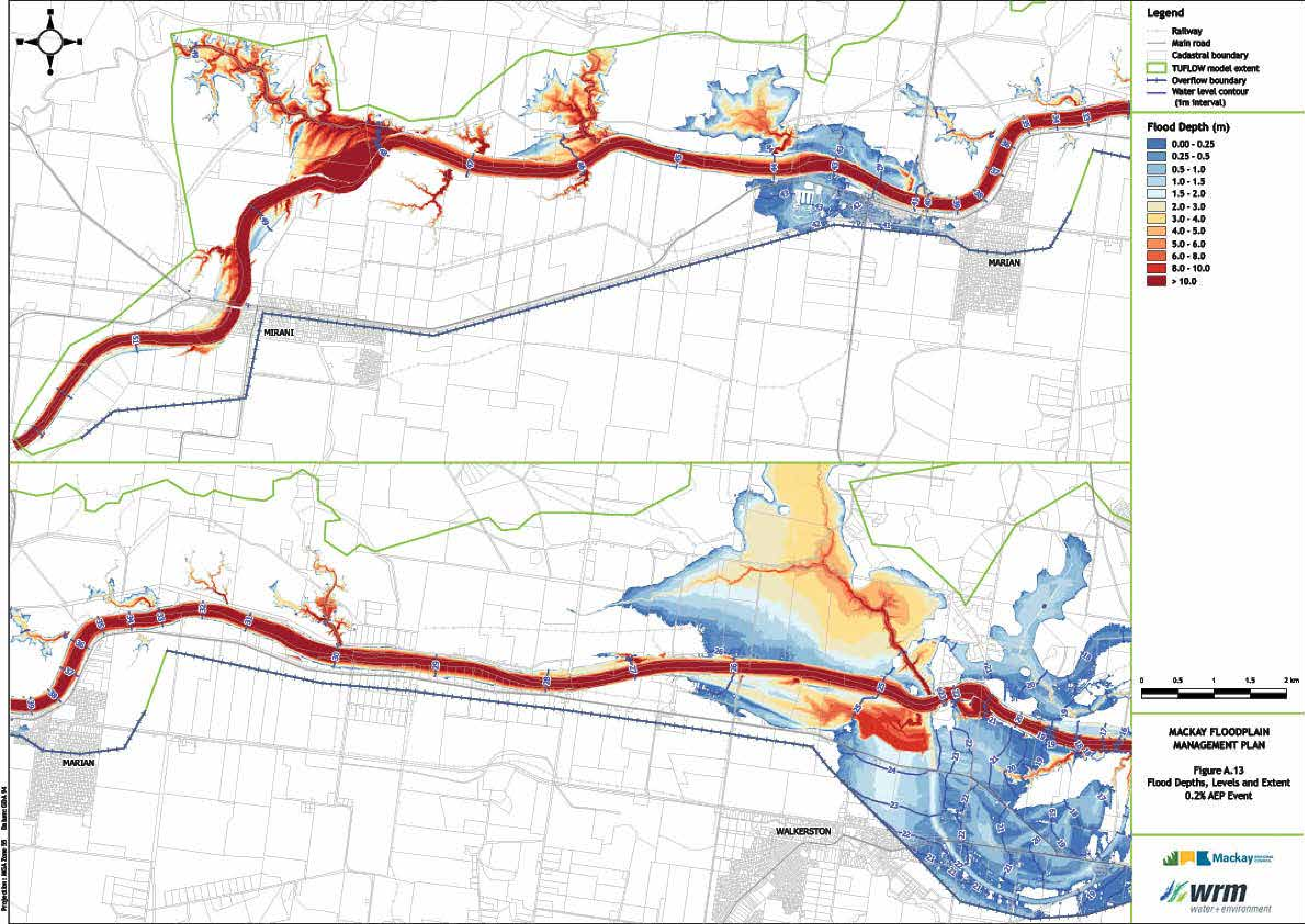


MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure A.12
Flood Depths, Levels and Extent
0.5% AEP Event

Mackay Regional Council

wrm water + environment

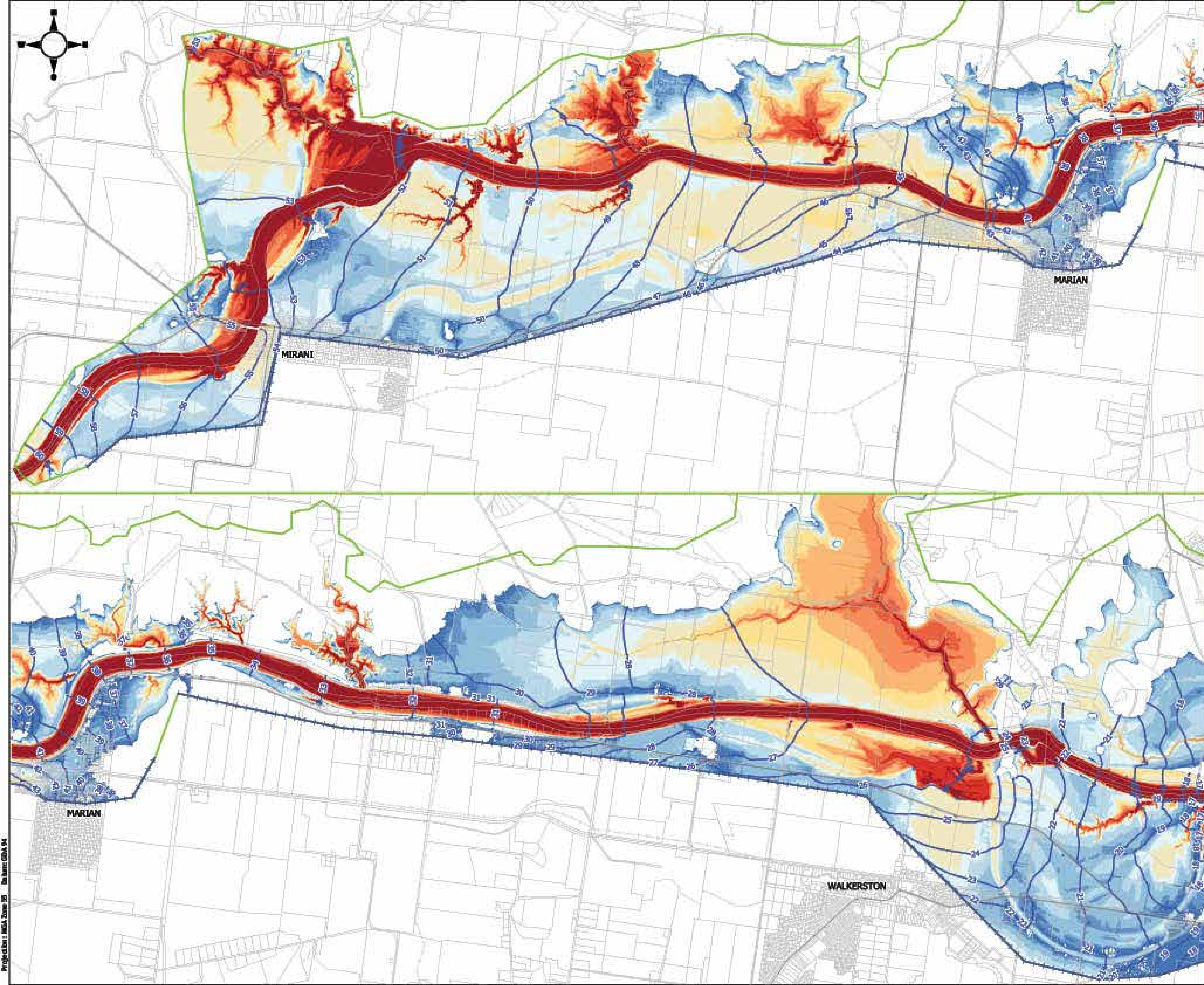


MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure A.13
Flood Depths, Levels and Extent
0.2% AEP Event

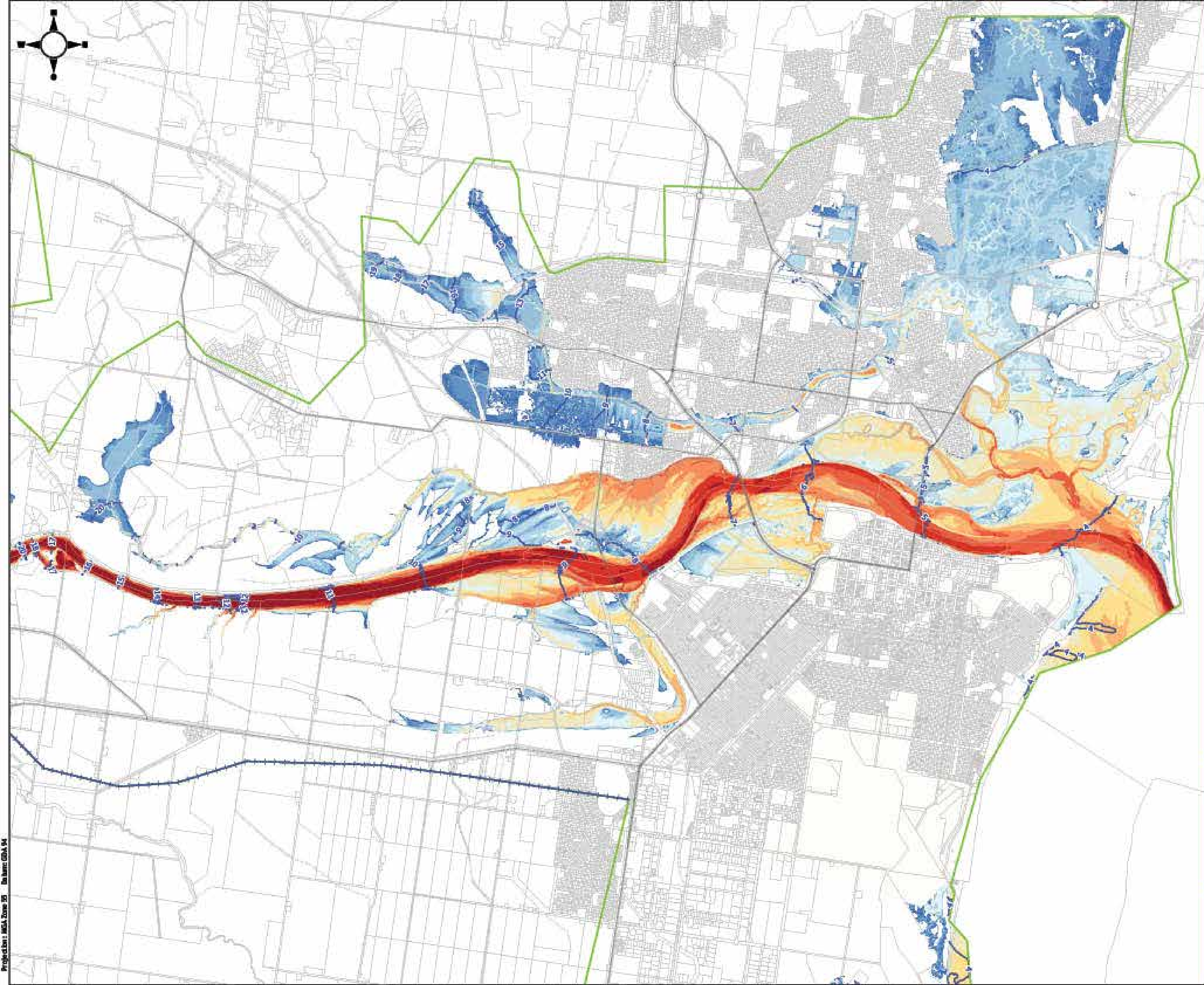
Mackay Regional Council

wrm water + environment



MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure A.14
Predicted Flood Depths, Levels and Extent
PMF Event



Legend

- Railway
- Main road
- Cadastral boundary
- TUFLOW model extent
- Overflow boundary
- Water level contour (1m interval)

Flood Depth (m)

- 0.00 - 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 8.0
- 8.0 - 10.0
- > 10.0

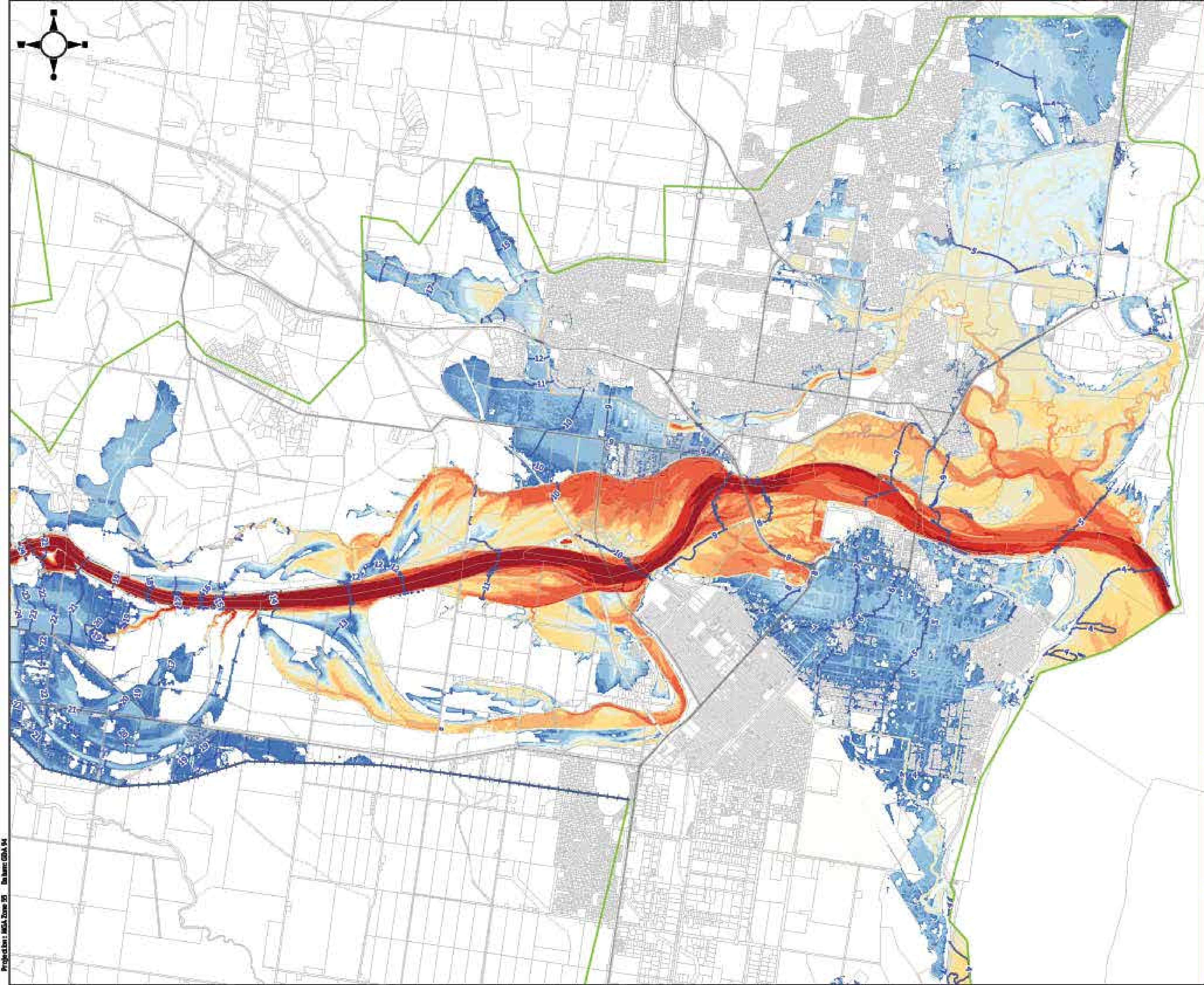
0 0.5 1 1.5 2 km

MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure A.15
Flood Depths, Levels and Extent
10% AEP Event
with climate change

Mackay

wrm water + environment



Legend

- Railway
- Main road
- Cadastral boundary
- TUFLOW model extent
- Overflow boundary
- Water level contour (1m interval)

Flood Depth (m)

- 0.00 - 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 8.0
- 8.0 - 10.0
- > 10.0

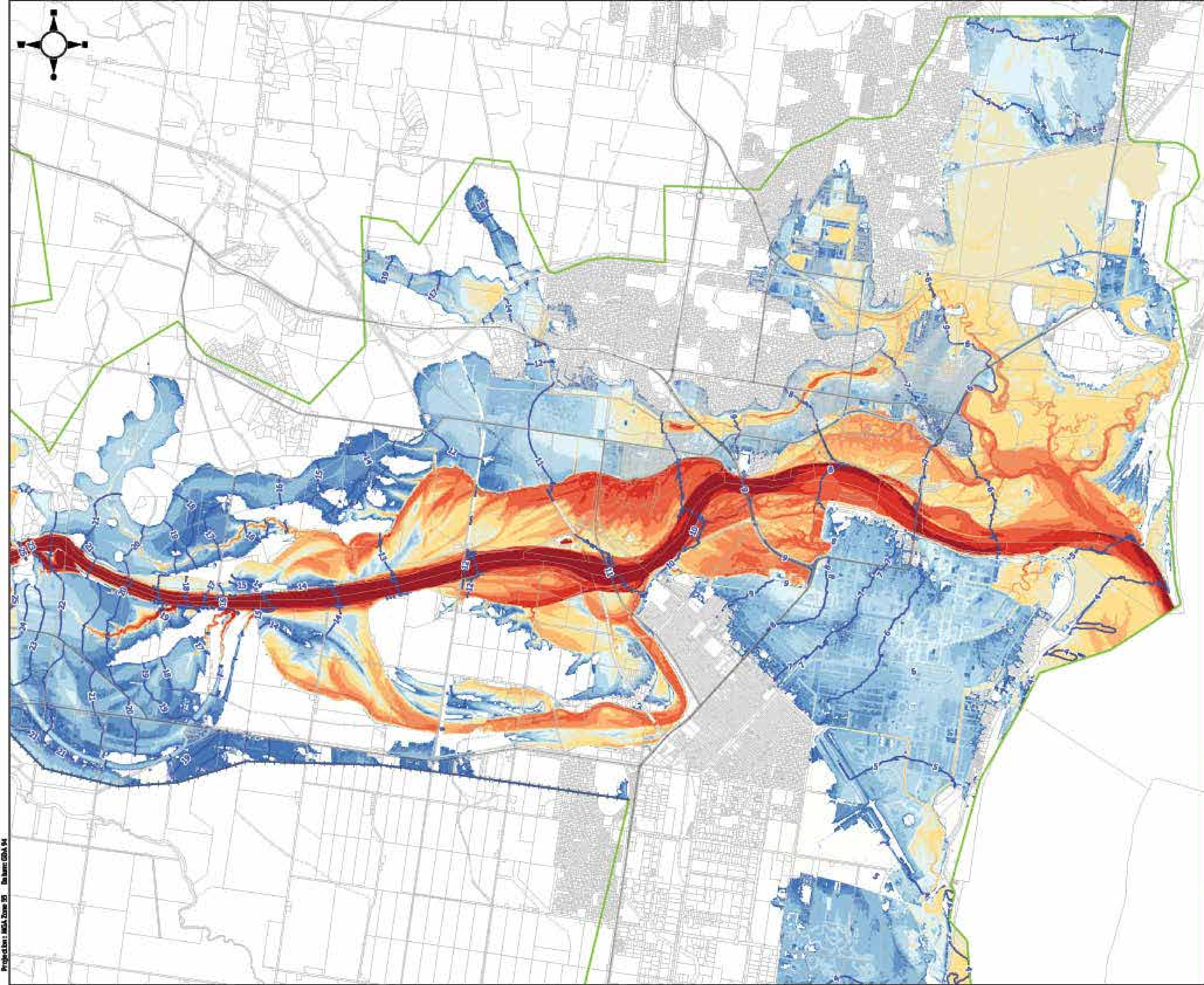
0 0.5 1 1.5 2 km

MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure A.16
Flood Depths, Levels and Extent
1% AEP Event
with climate change

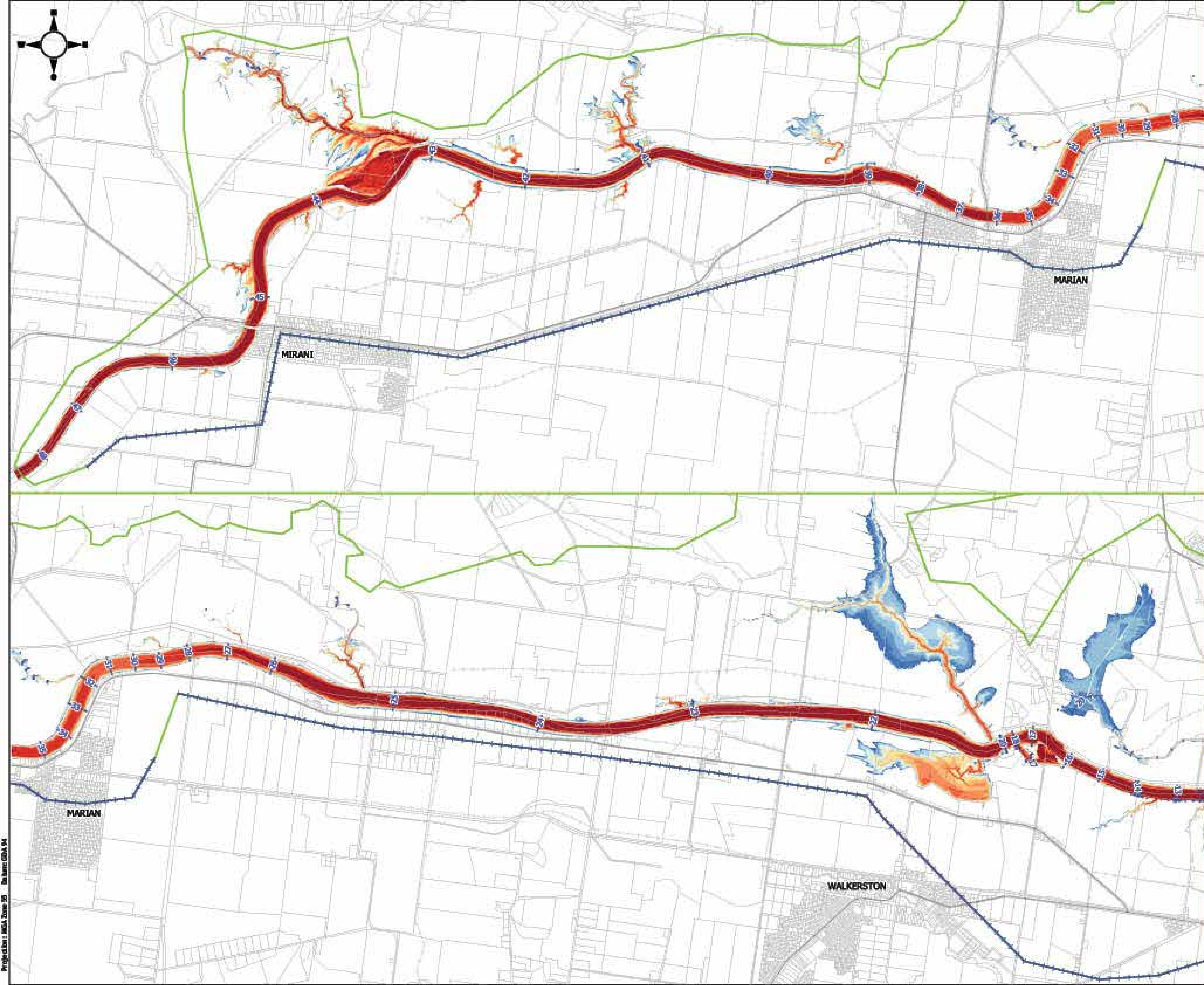
Mackay Regional Council

wrm water + environment



MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure A.17
Flood Depths, Levels and Extent
0.2% AEP Event
with climate change



Legend
- Railway
- Main road
- Cadastral boundary
- TUFLOW model extent
- Overflow boundary
- Water level contour (1m interval)

Flood Depth (m)
- 0.00 - 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 8.0
- 8.0 - 10.0
- > 10.0

0 0.5 1 1.5 2 km

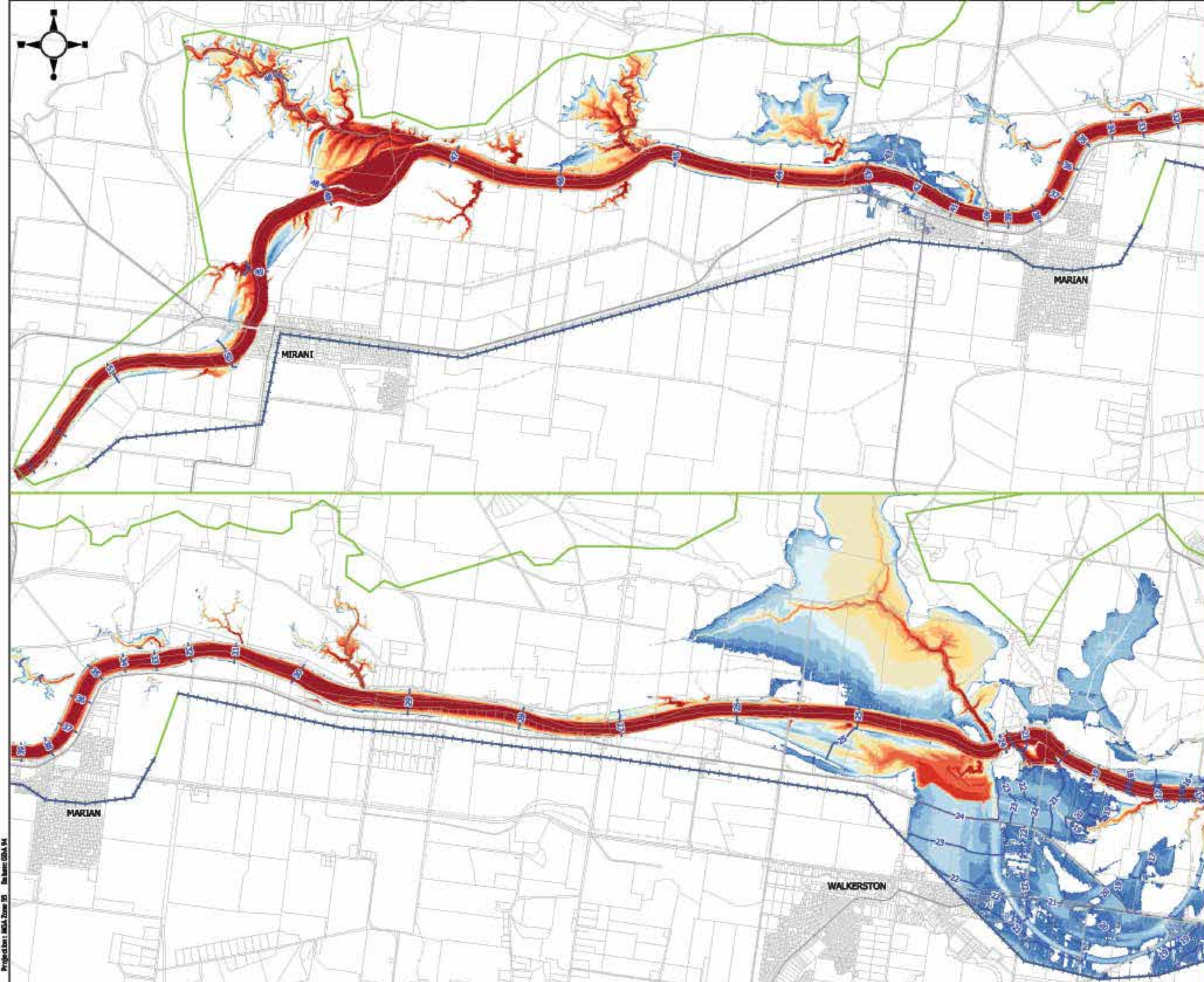
MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure A.18
Flood Depths, Levels and Extent
10% AEP Event
with climate change

Mackay

wrm water + environment

Projection: MGA Zone 55 Datum: GDA 94



Legend

- Railway
- Main road
- Cadastral boundary
- TUFLOW model extent
- Overflow boundary
- Water level contour (1m interval)

Flood Depth (m)

- 0.00 - 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 3.0
- 3.0 - 4.0
- 4.0 - 5.0
- 5.0 - 6.0
- 6.0 - 8.0
- 8.0 - 10.0
- > 10.0

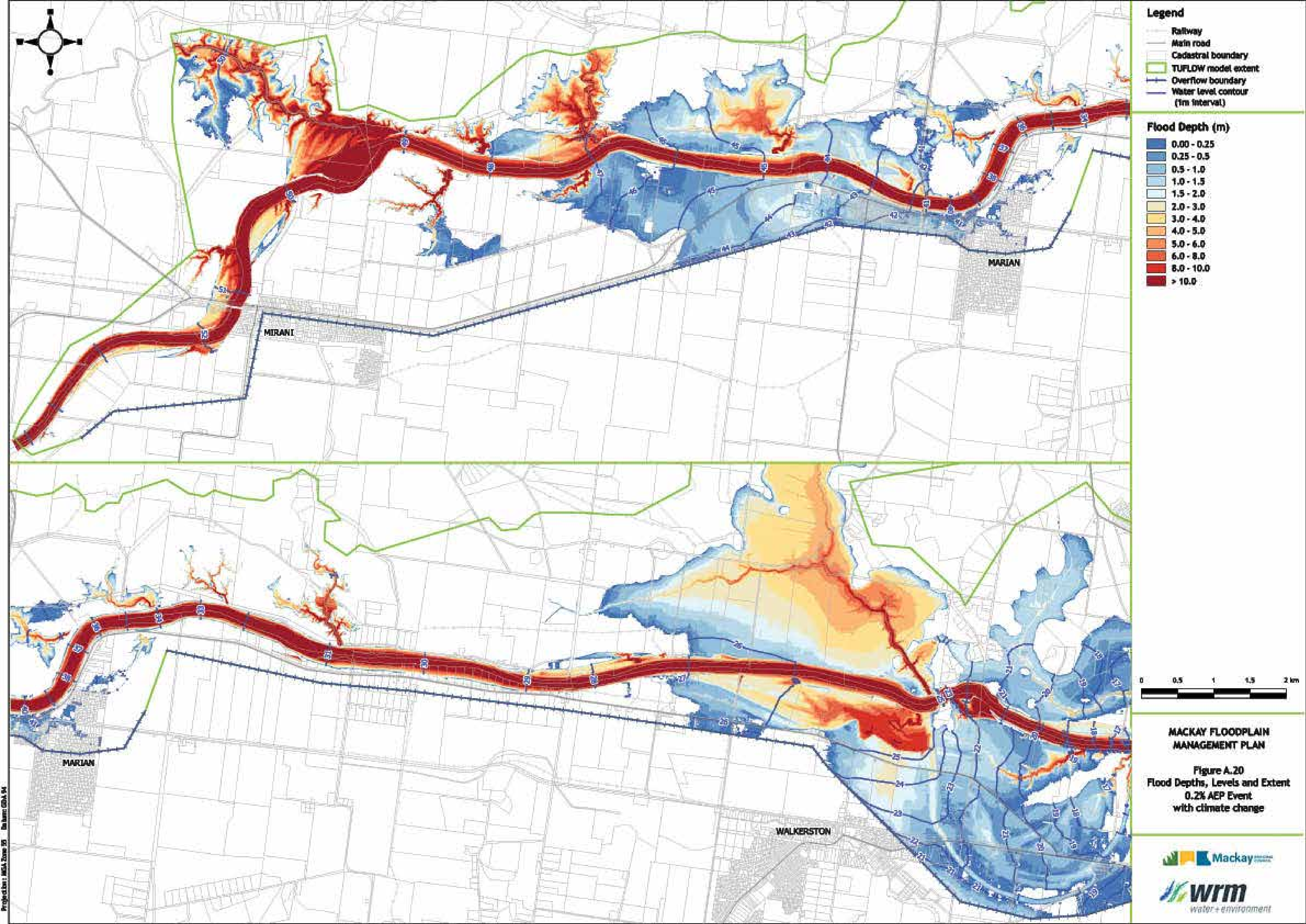
0 0.5 1 1.5 2 km

MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure A.19
Flood Depths, Levels and Extent
1% AEP Event
with climate change

Mackay Regional Council

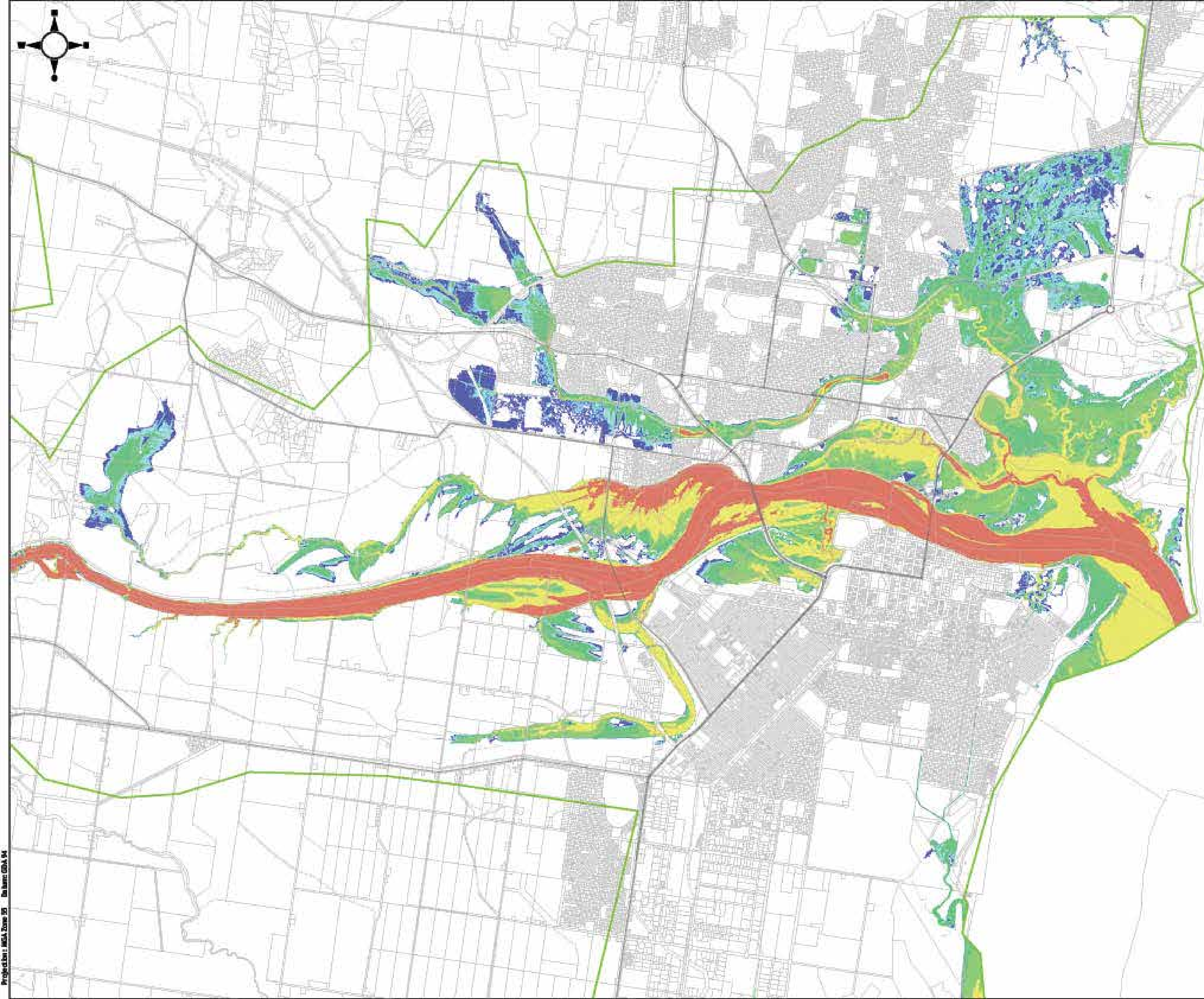
wrm water + environment



Legend
Railway
Main road
Cadastral boundary
TUFLOW model extent
Overflow boundary
Water level contour
(1m interval)
Flood Depth (m)
0.00 - 0.25
0.25 - 0.5
0.5 - 1.0
1.0 - 1.5
1.5 - 2.0
2.0 - 3.0
3.0 - 4.0
4.0 - 5.0
5.0 - 6.0
6.0 - 8.0
8.0 - 10.0
> 10.0
0 0.5 1 1.5 2 km
MIRANI
MARIAN
WALKERSTON
MACKAY FLOODPLAIN MANAGEMENT PLAN
Figure A.20
Flood Depths, Levels and Extent
0.2% AEP Event
with climate change
Mackay
wrm
water + environment

Pioneer River Flood Study

Appendix B – Provisional flood hazard classifications for the Pioneer River



Legend

- Railway
- Main road
- Cadastral boundary
- TUFLOW model extent

Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

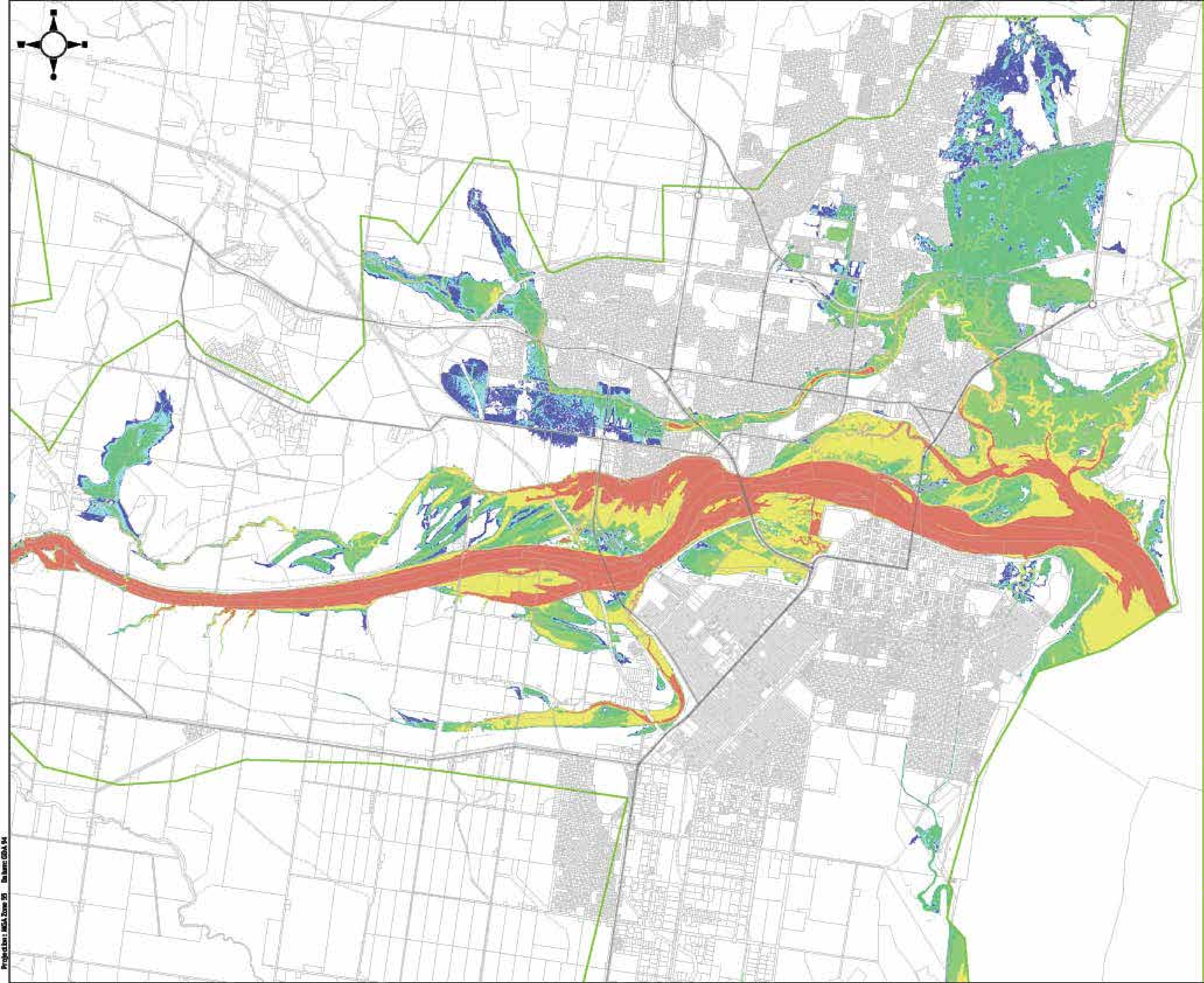
0 0.5 1 1.5 2 km

MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure 8.1
Flood Hazard
10% AEP Event

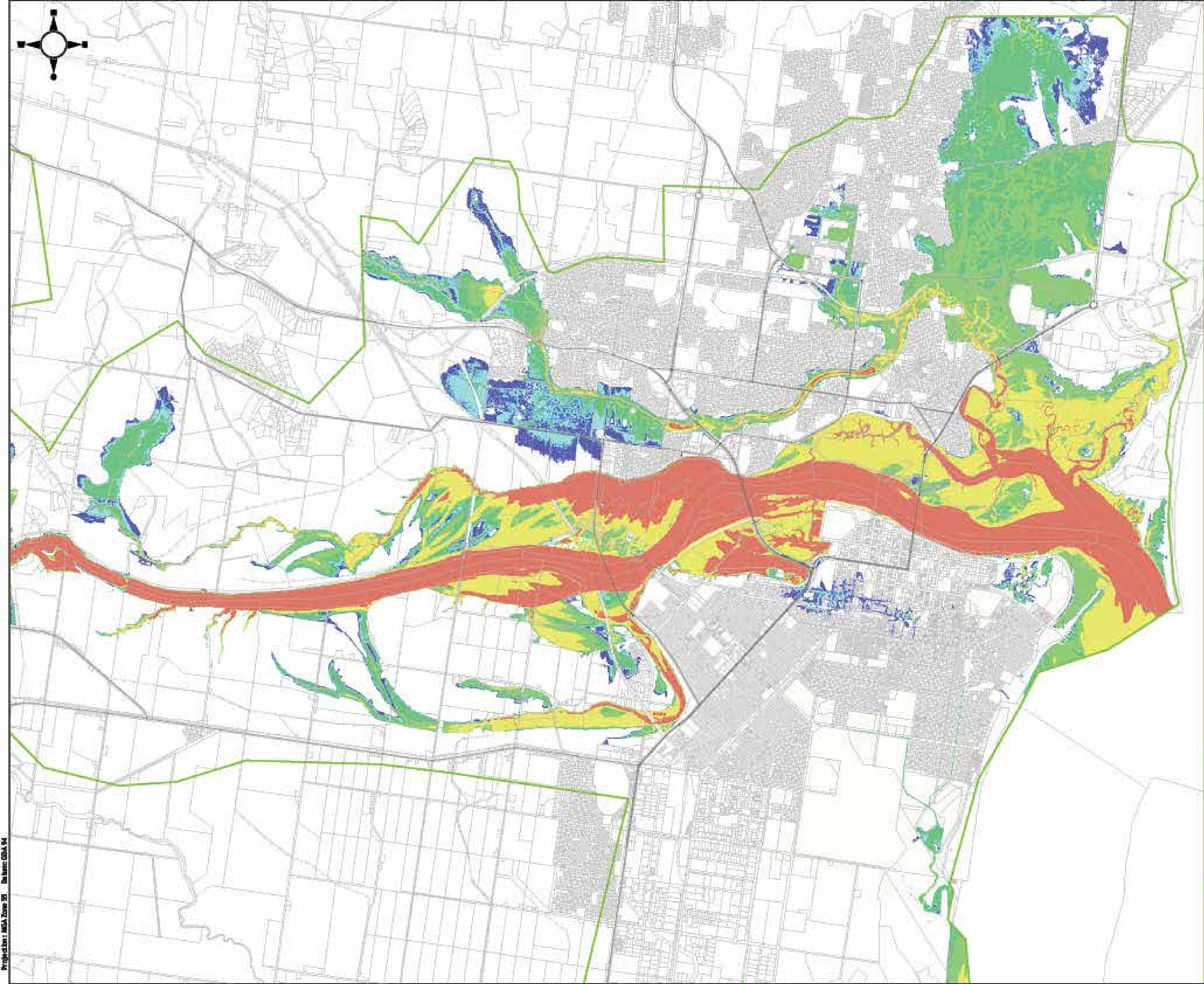
Mackay Regional Council

wrm water + environment



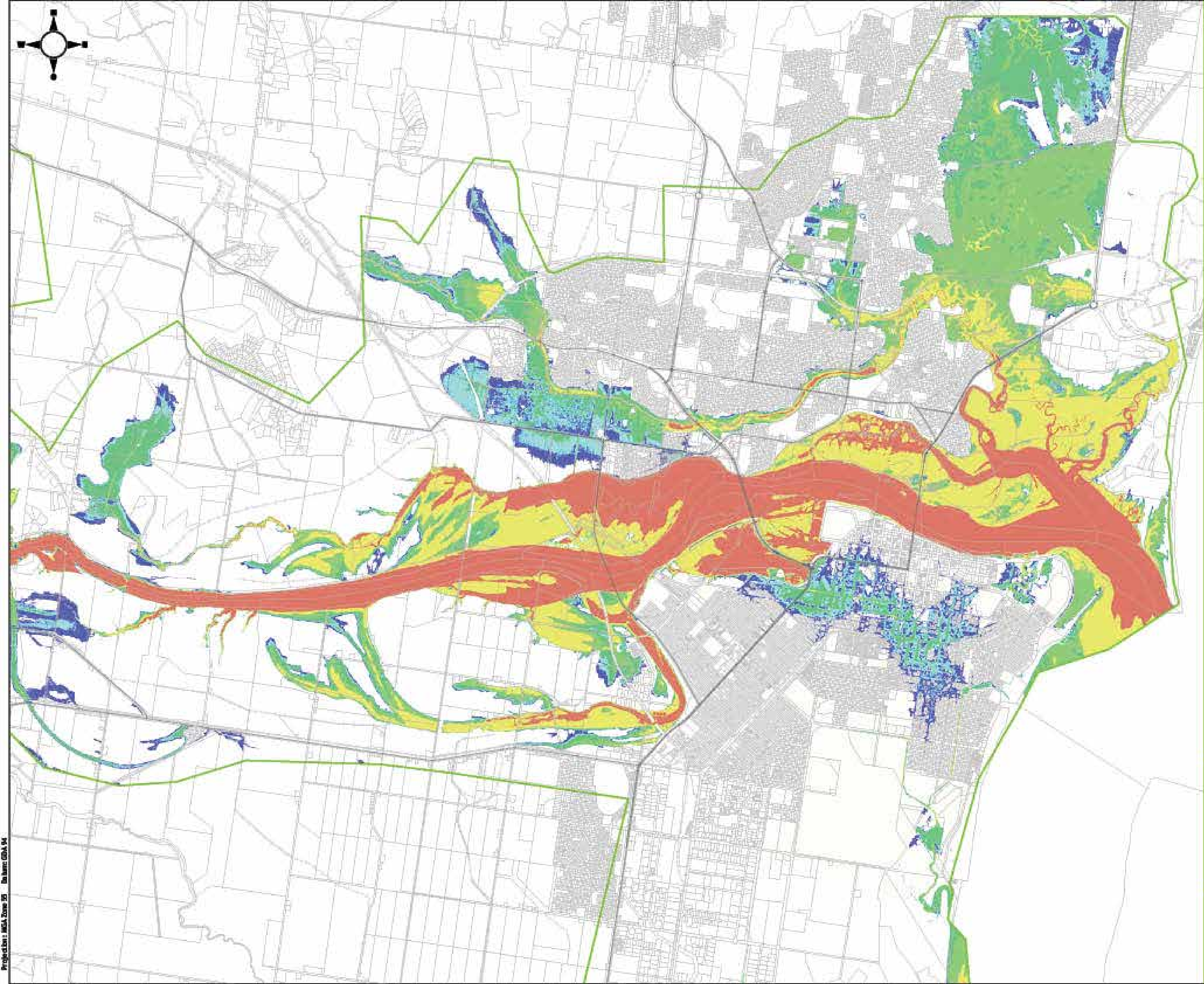
MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure B.2
Flood Hazard
5% AEP Event



MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure B.3
Flood Hazard
2% AEP Event



Legend

- Railway
- Main road
- Cadastral boundary
- TUFLOW model extent

Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

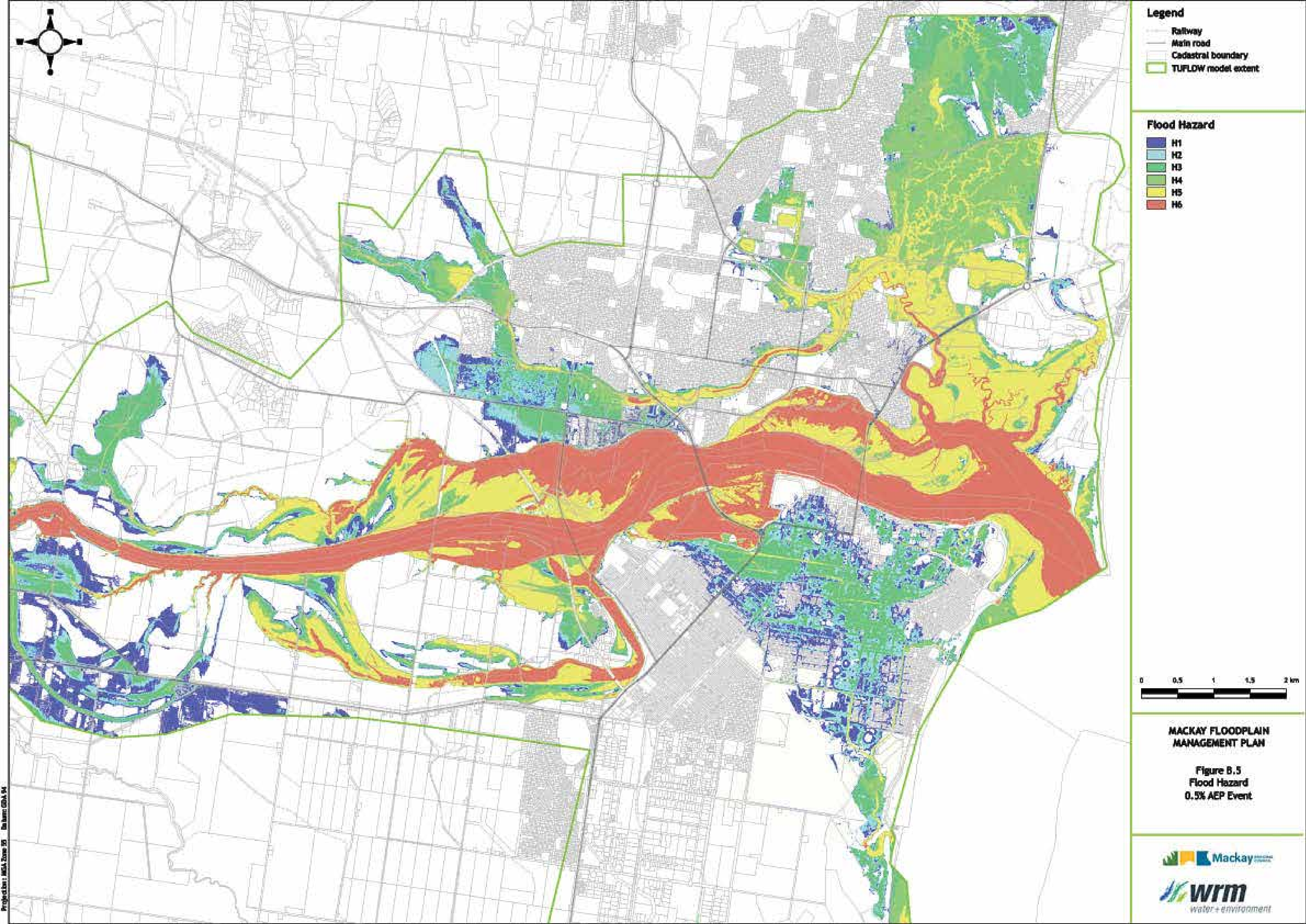
0 0.5 1 1.5 2 km

MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure B.4
Flood Hazard
1% AEP Event

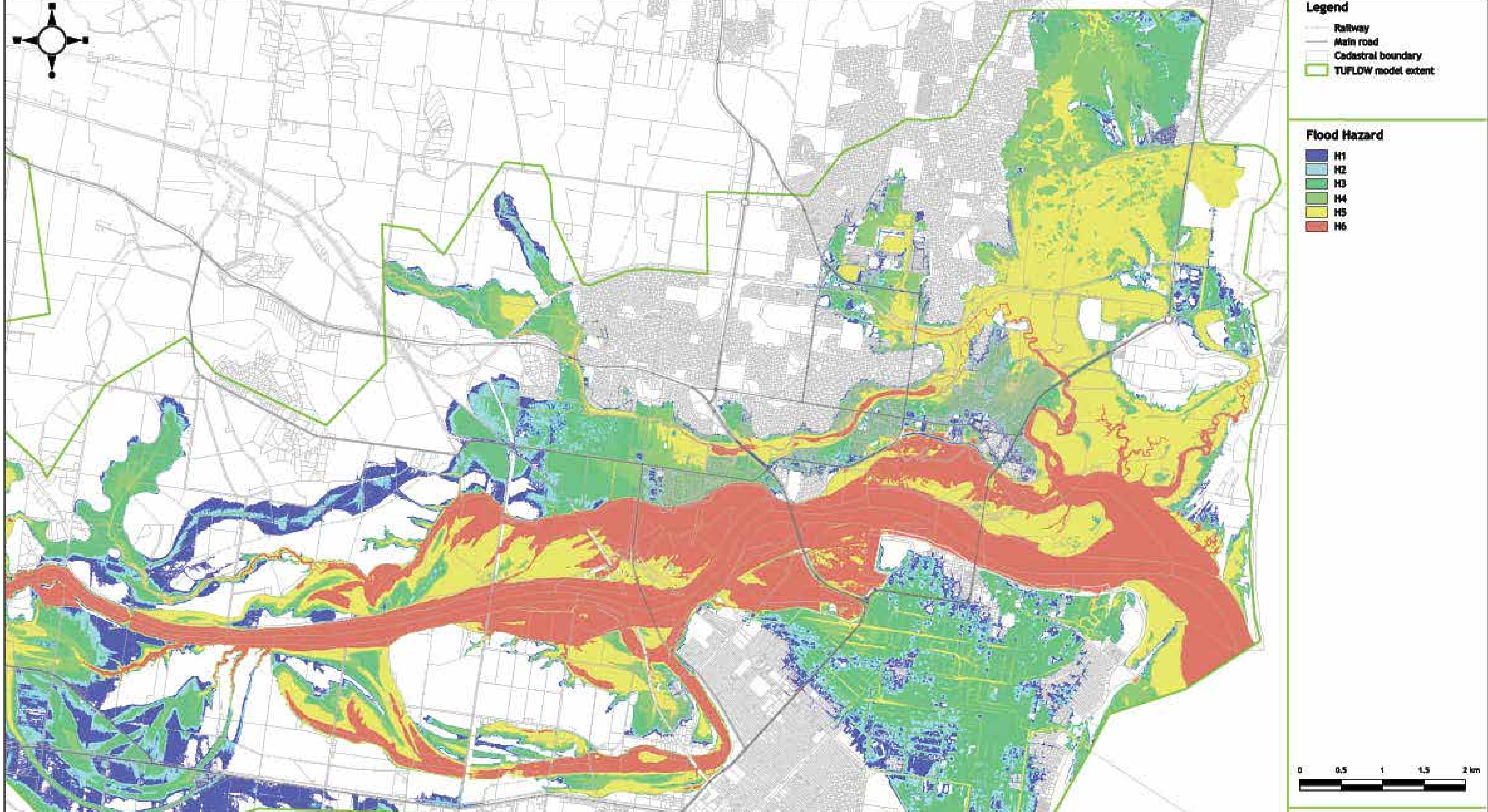
Mackay Regional Council

wrm water + environment



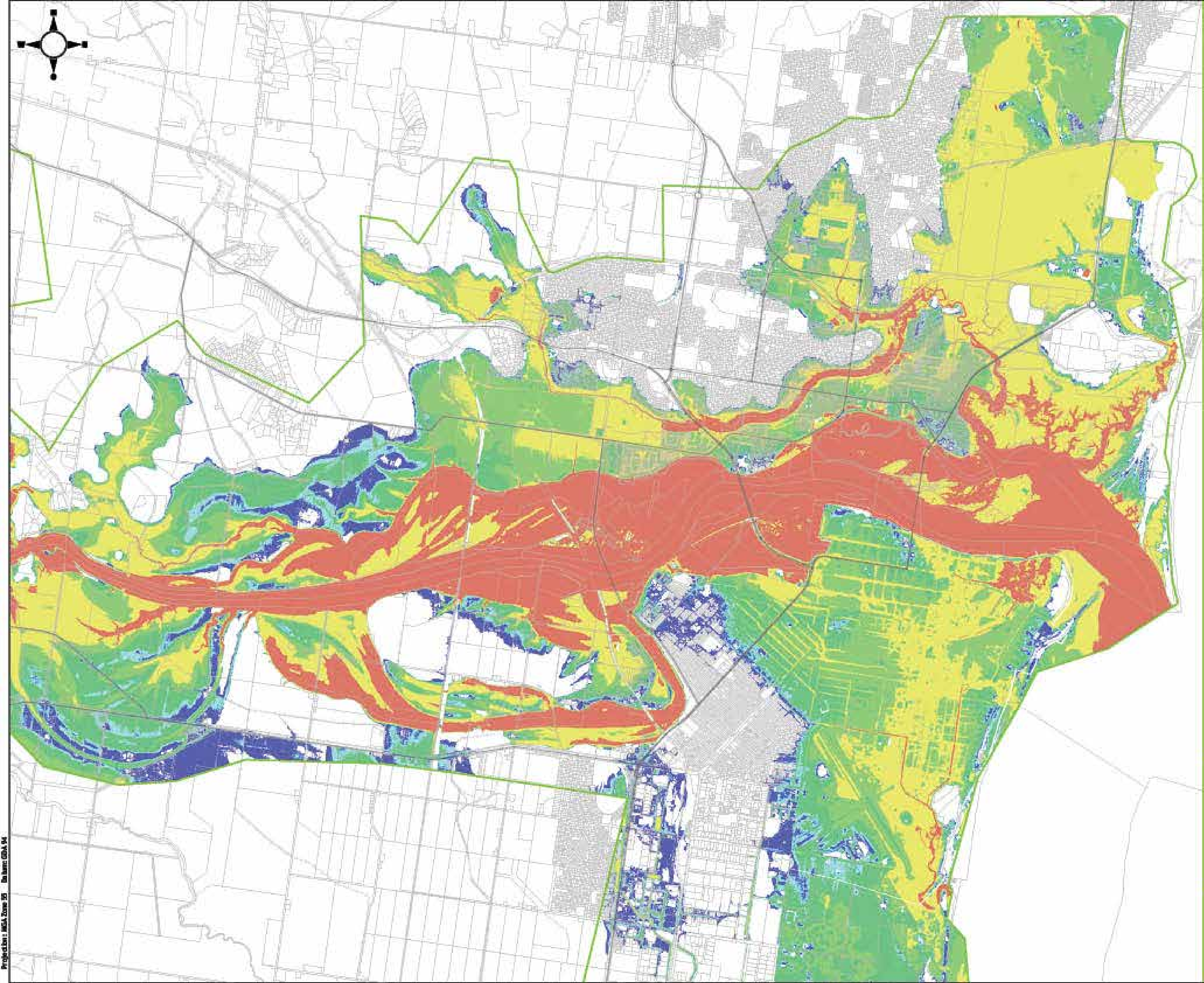
MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure 8.5
Flood Hazard
0.5% AEP Event



MACKAY FLOODPLAIN MANAGEMENT PLAN

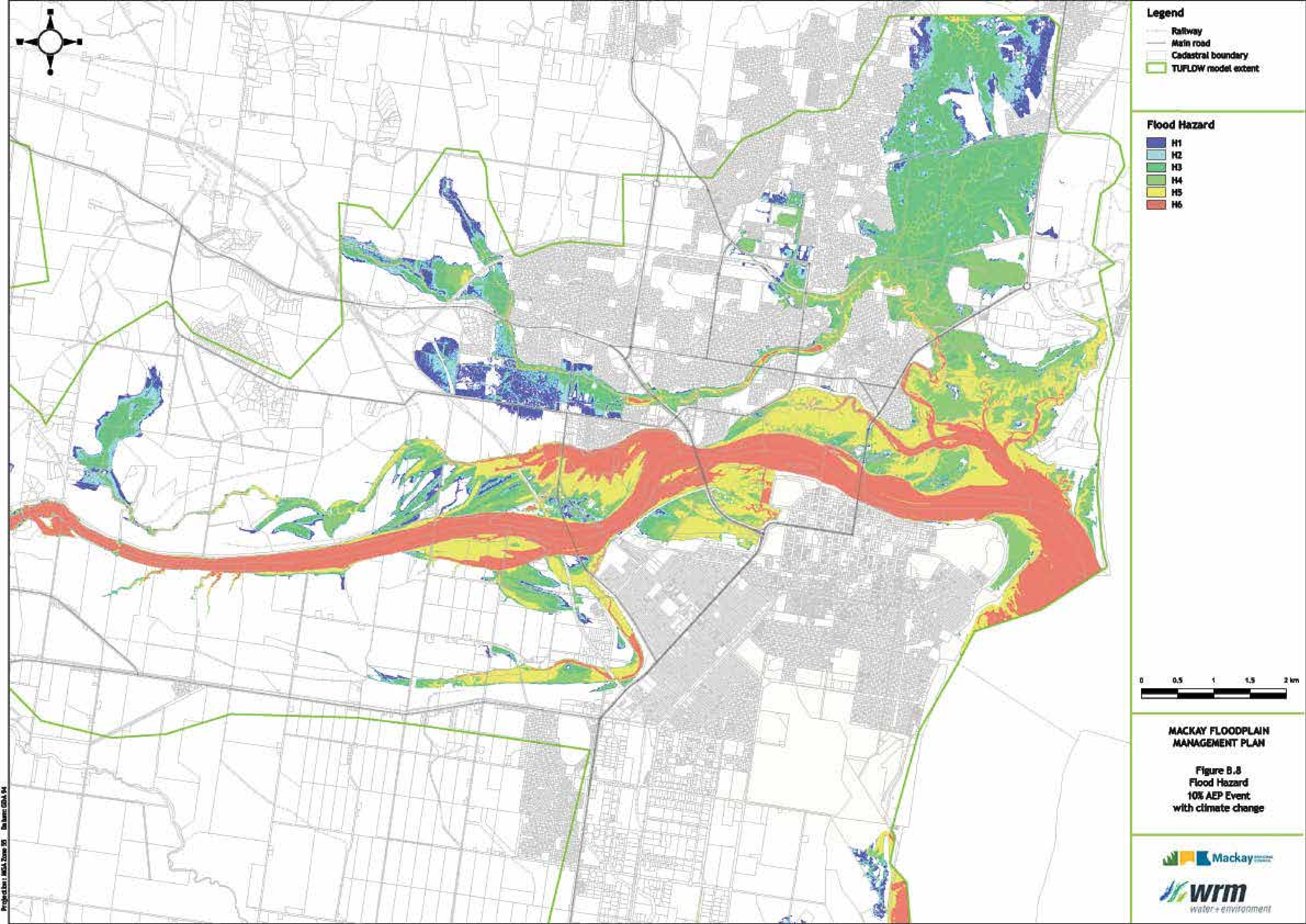
Figure B.6
Flood Hazard
0.2% AEP Event



MACKAY FLOODPLAIN MANAGEMENT PLAN

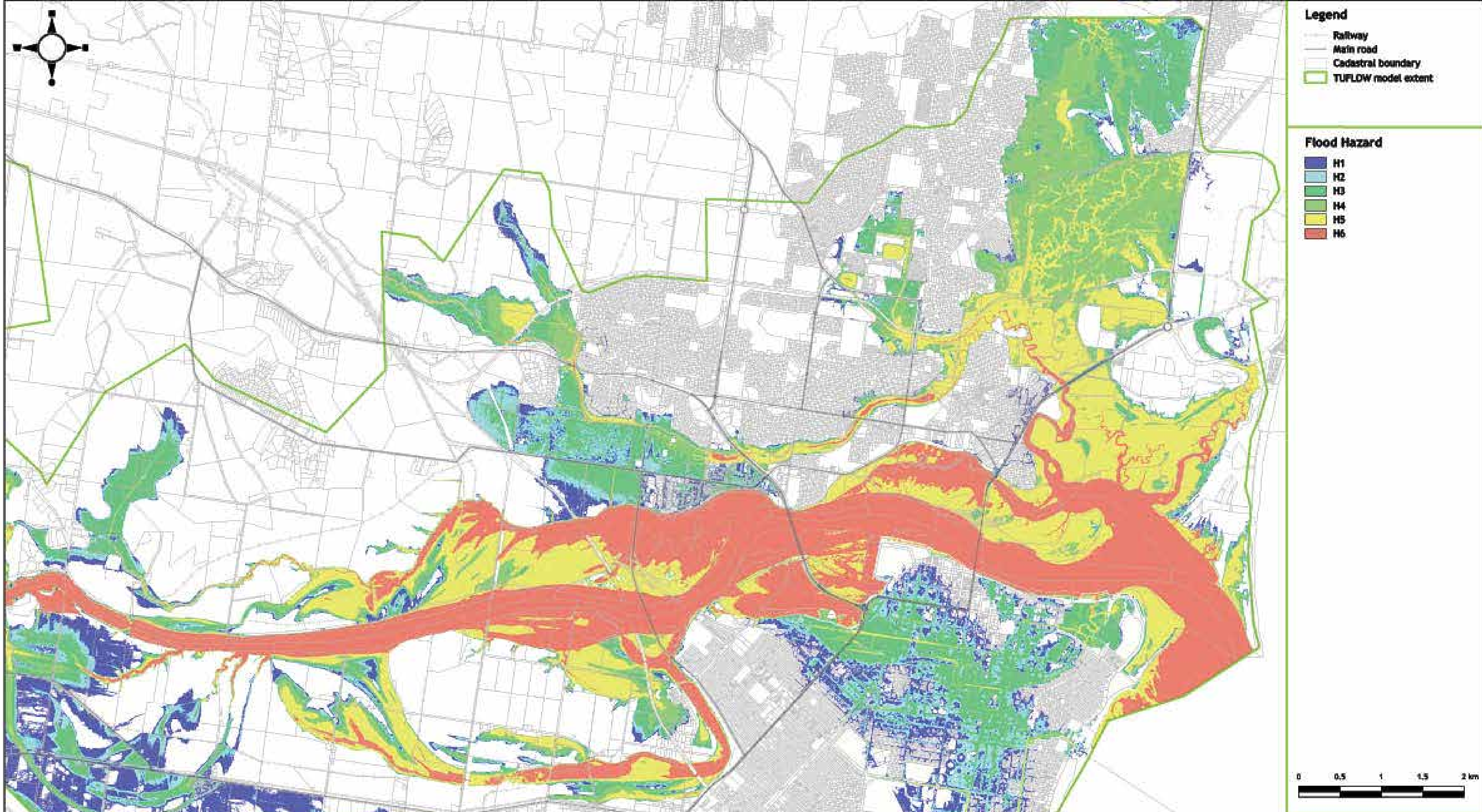
Figure B.7
Flood Hazard
PMF Event

Mackay
wrm water+environment



MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure B.8
Flood Hazard
10% AEP Event
with climate change

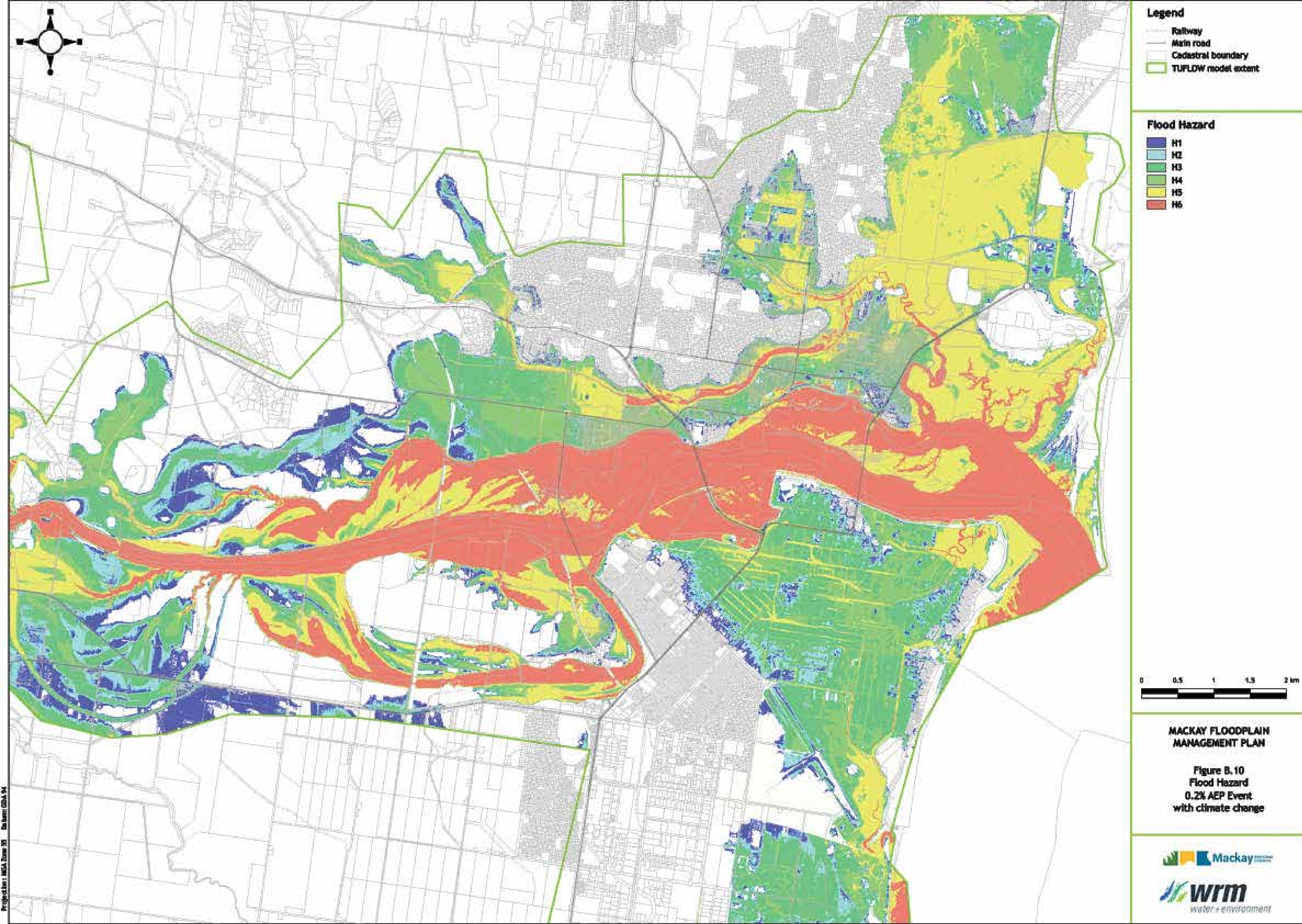


MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure B.9
Flood Hazard
1% AEP Event
with climate change

Mackay Regional Council

wrm water + environment



MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure B.10
Flood Hazard
0.2% AEP Event
with climate change

MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure B.11
Flood Hazard
10% AEP Event

Mackay

wrm water + environment

Legend

- Railway
- Main road
- Cadastral boundary
- TUFLOW model extent

Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

0 0.5 1 1.5 2 km

MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure B.12
Flood Hazard
5% AEP Event

Mackay Regional Council

wrm water + environment

Legend

- Railway
- Main road
- Cadastral boundary
- TUFLOW model extent

Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

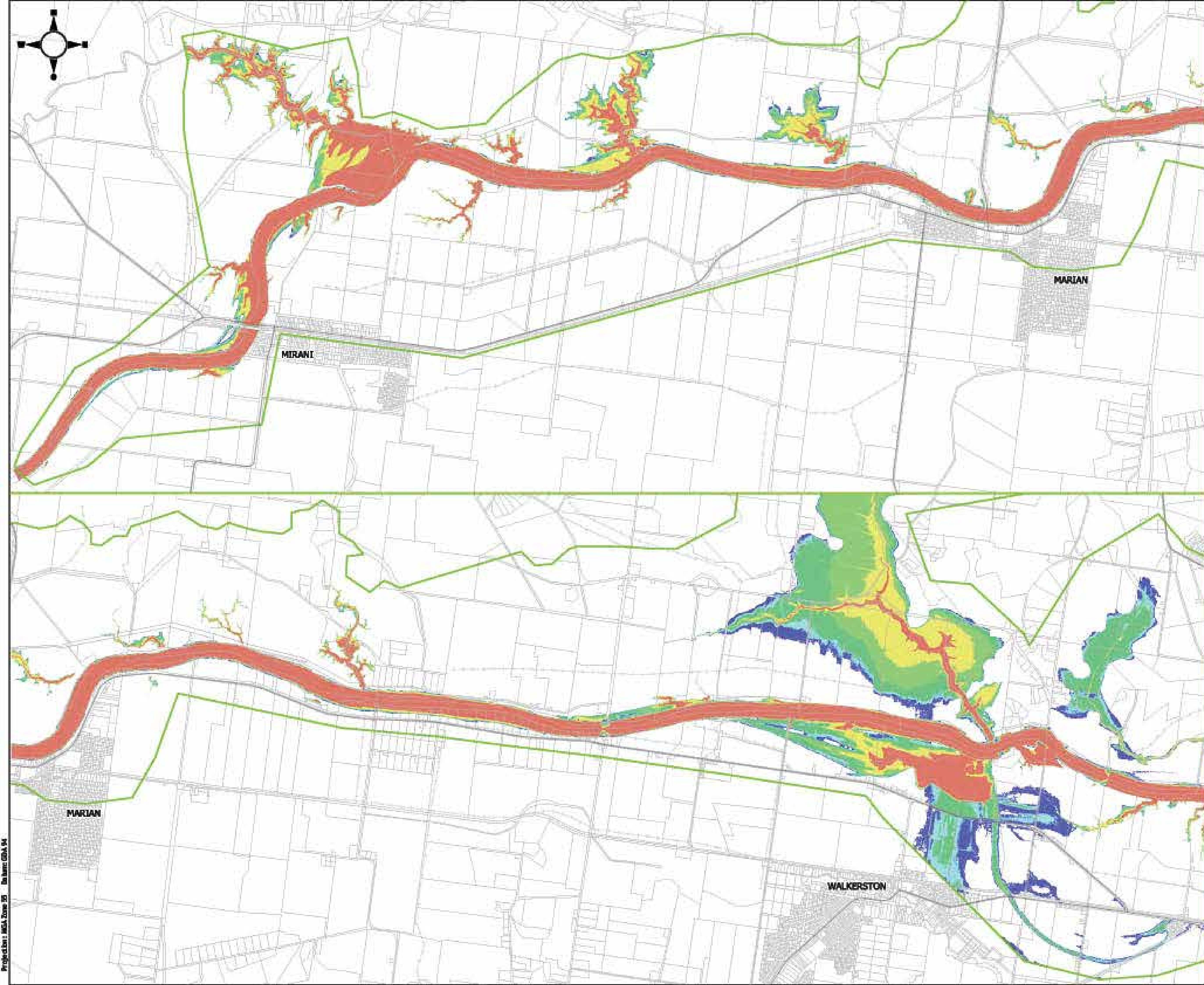
MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure B.13
Flood Hazard
2% AEP Event

Mackay Regional Council

wrm water + environment

Projection : MGA Zone 55 Datum : GDA 94

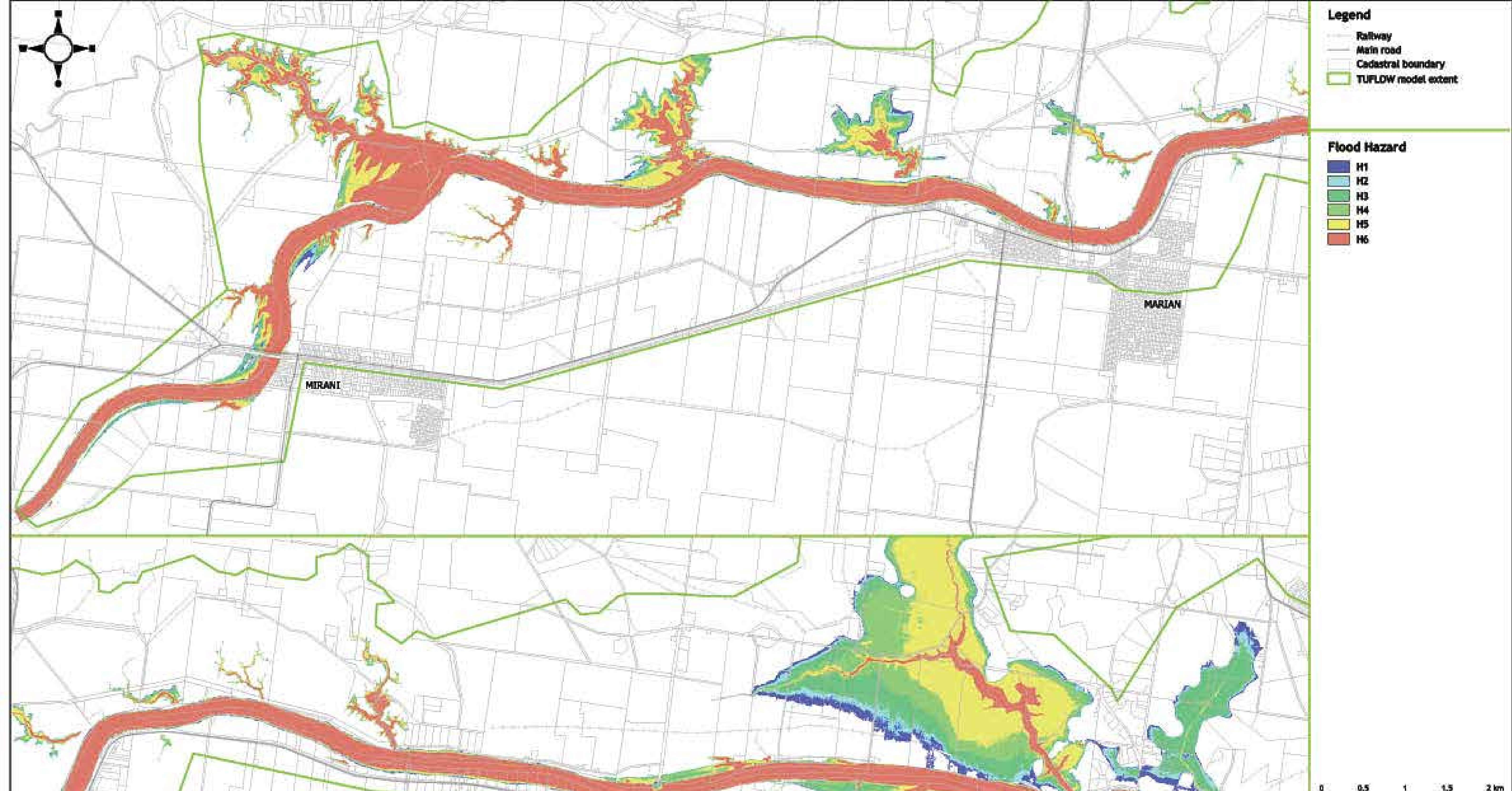


MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure B.14
Flood Hazard
1% AEP Event

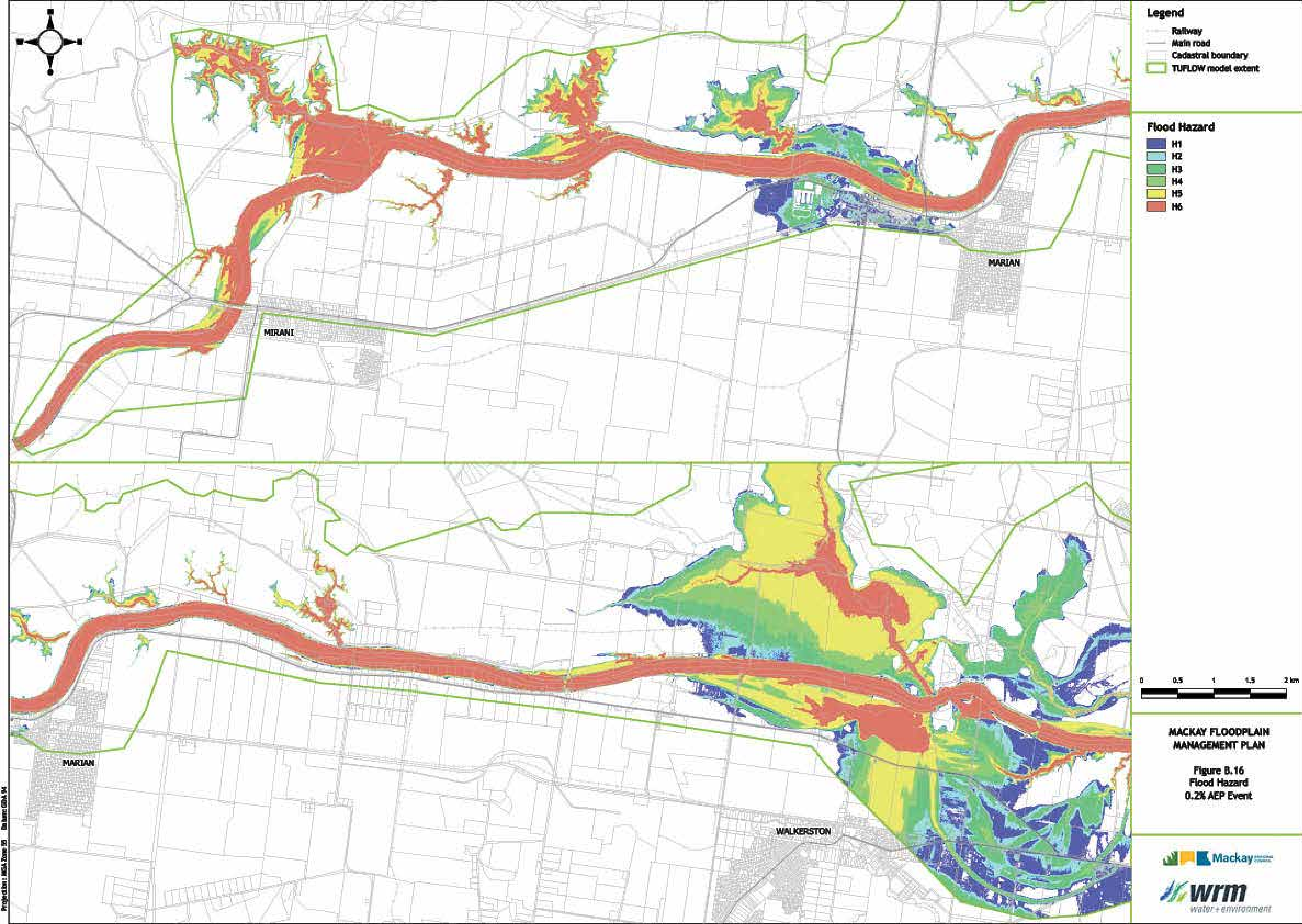
Mackay Regional Council

wrm water + environment



MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure B.15
Flood Hazard
0.5% AEP Event

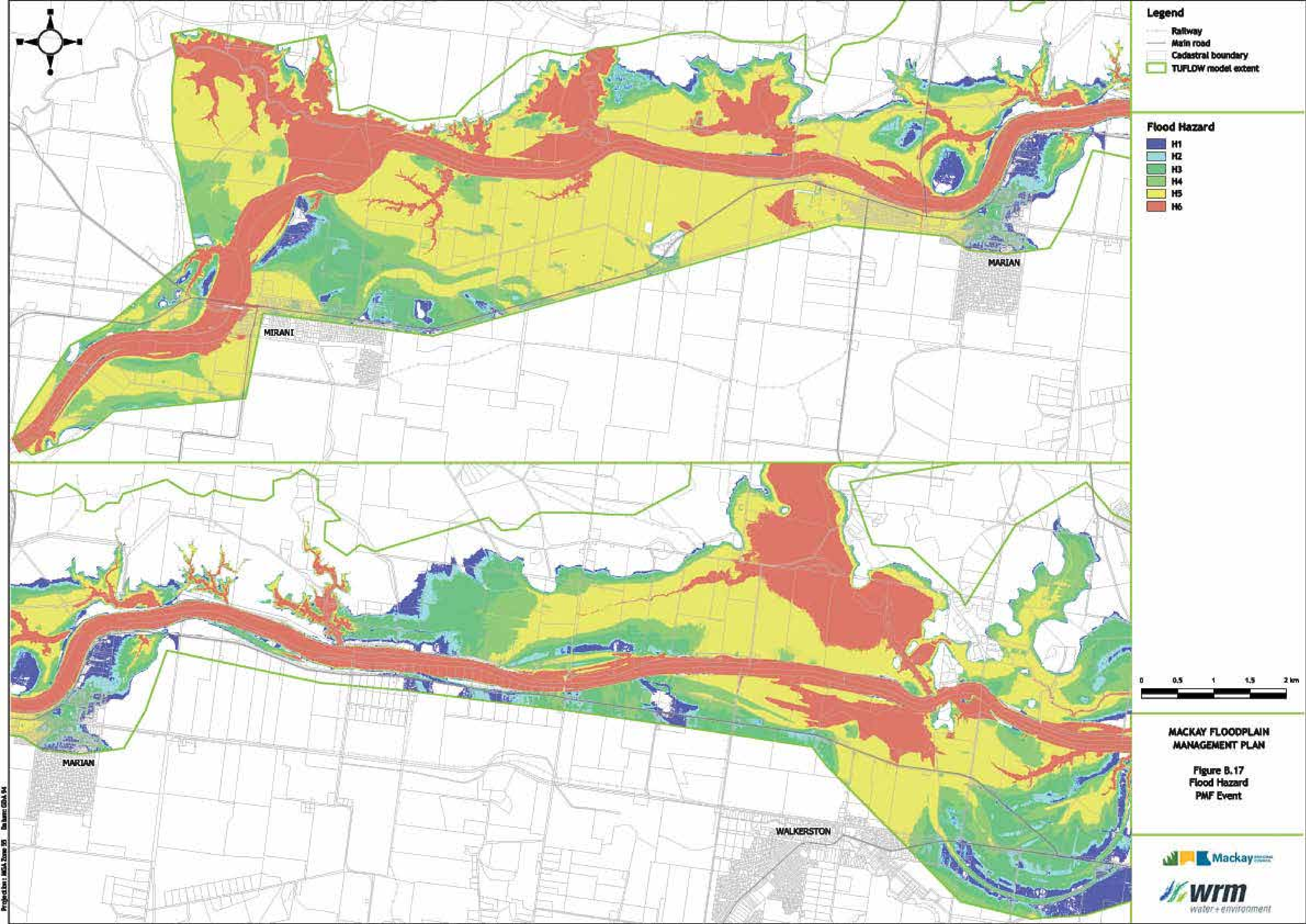


MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure B.16
Flood Hazard
0.2% AEP Event

Mackay Regional Council

wrm water + environment

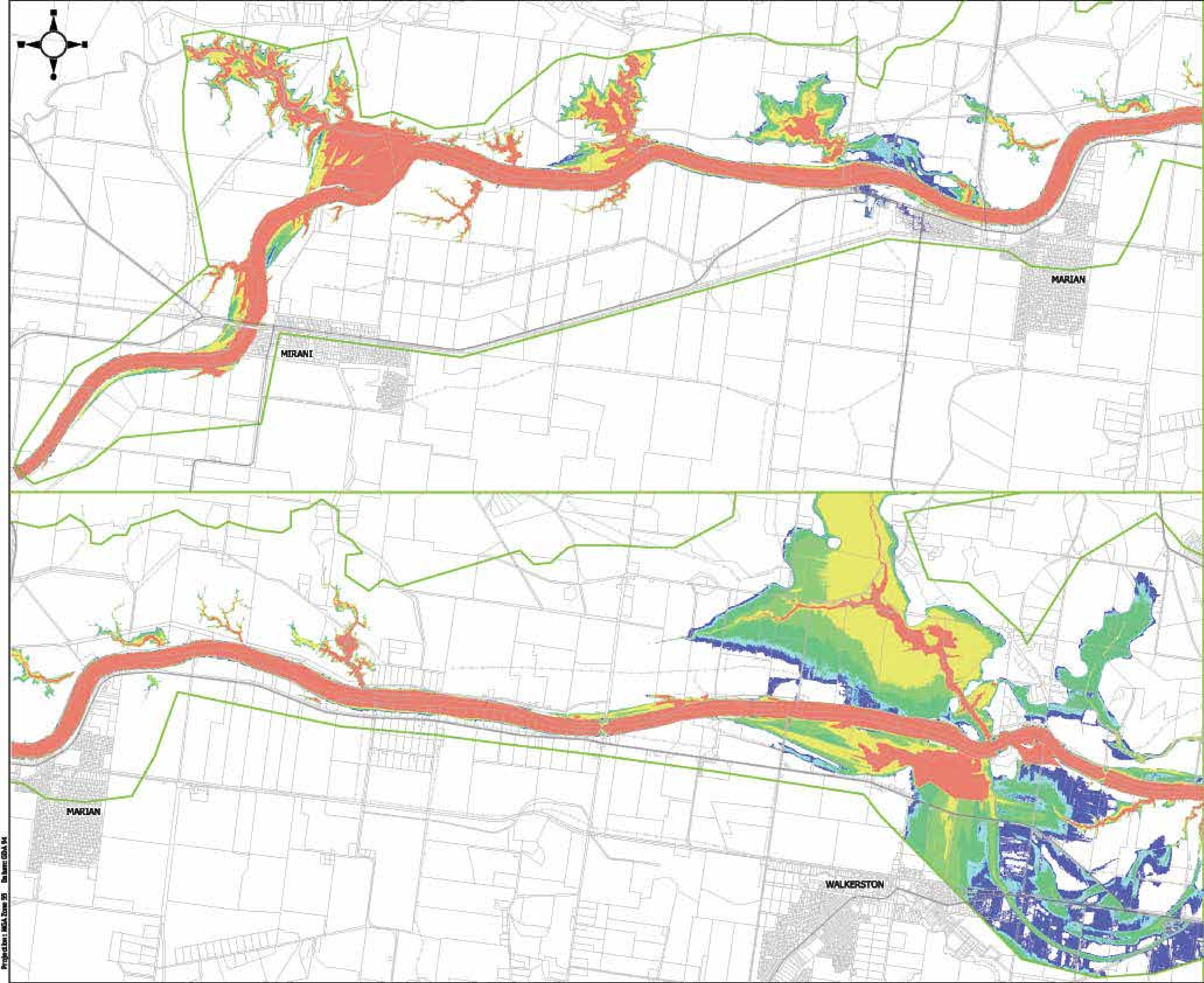


MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure B.17
Flood Hazard
PMF Event

MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure B.18
Flood Hazard
10% AEP Event
with climate change

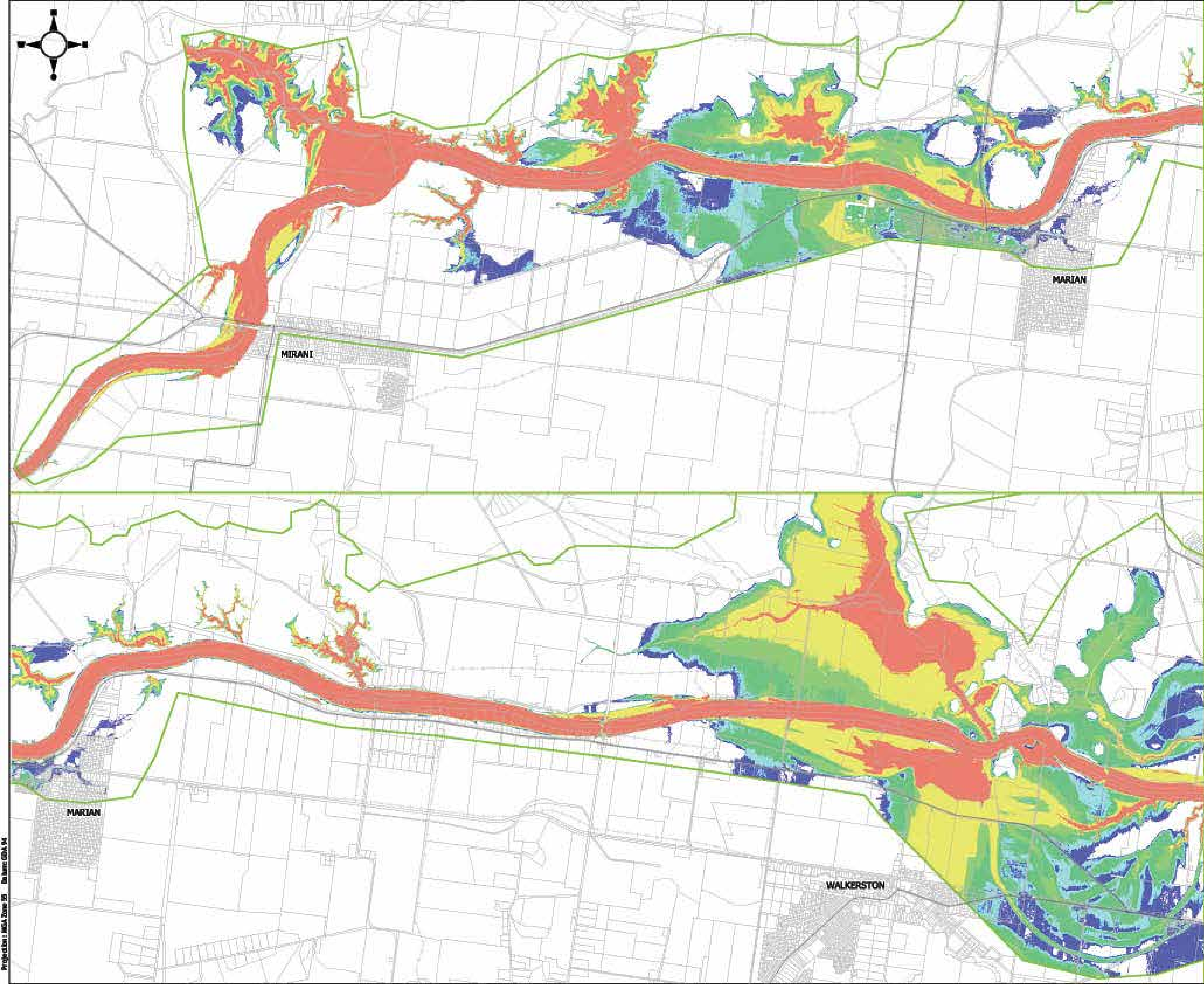


MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure B.19
Flood Hazard
1% AEP Event
with climate change

Mackay Regional Council

wrm water + environment



Legend

- Railway
- Main road
- Cadastral boundary
- TUFLOW model extent

Flood Hazard

- H1
- H2
- H3
- H4
- H5
- H6

0 0.5 1 1.5 2 km

MACKAY FLOODPLAIN MANAGEMENT PLAN

Figure B.20
Flood Hazard
0.2% AEP Event
with climate change

Mackay Regional Council

wrm water + environment