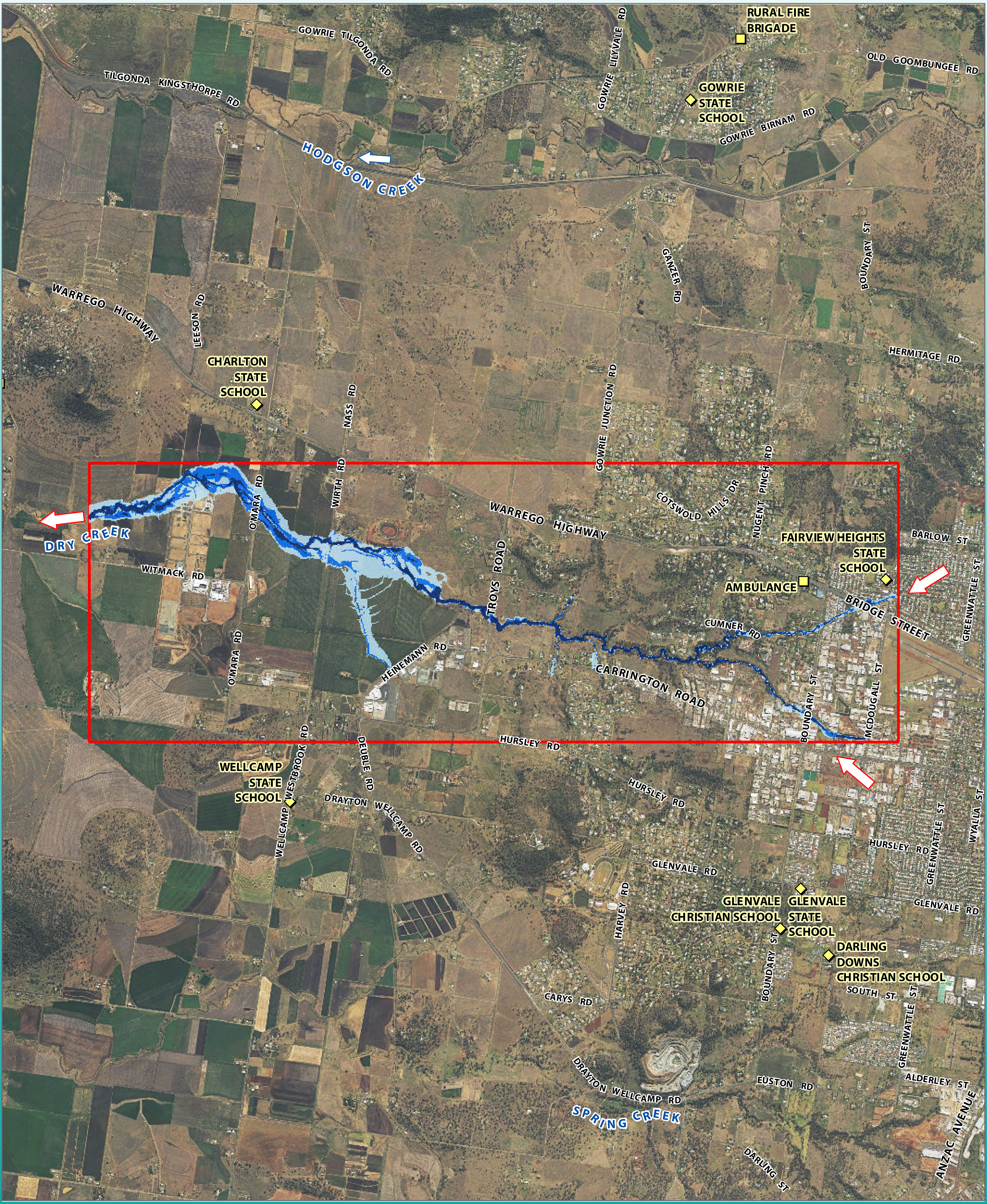
DRY CREEK



TOOWOOMBA REGIONAL COUNCIL

1:35,000 (at A3)

0 300 600 900 1,200
Metres

N

1% AEP FLOOD DEPTH RIVERINE

Water Depth (m)		
0 - 0.5		Model Extent
0.5 - 1		DirectionFlow
1+		Emergency Services
		School

Flood Studies

TOOWOOMBA REGION
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2D Flood Study for Dry Creek (Charlton and Torrington)

August 2014 • *Endorsed on 25 February 2015*

GENERAL NOTE

These reports/documents are a base source of information that will be continually refined over time.

DISCLAIMER

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REPORT TITLE: Work Package 8 – 2D Flood Study for Dry Creek (Charlton and Torrington), Final Report

CLIENT: Toowoomba Regional Council

REPORT NUMBER: 0965-03-D5

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DRAFT 1	6 February 2013	First Pass Results	MB/DS	TV/SM
DRAFT 2	25 March 2014	Draft Report	MB/DS	TV/SM
FINAL 1	1 May 2014	Final Report	MB/DS	TV/SM
FINAL 2	16 May 2014	Final Report (rev 1)	MB/DS	TV/SM
FINAL 3	21 August 2014	Final Report (rev 2)	MB/DS	TV/SM

For and on behalf of
WRM Water & Environment Pty Ltd

Sharmil Markar
Director

EXECUTIVE SUMMARY

Toowoomba Regional Council (TRC) has appointed WRM Water and Environment Pty Ltd (WRM) in association with DHI Water and Environment Pty Ltd (DHI) to carry out hydraulic investigations of flooding in the Dry Creek Catchment (Charlton and Torrington). The hydrologic modelling was undertaken using a XP-RAFTS model and the hydraulic modelling was undertaken using a coupled MIKE FLOOD 1D/2D hydrodynamic model.

The majority of the data for the construction of the hydraulic model was derived from a 1m LiDAR Digital Elevation Model (DEM) provided by TRC. A site visit was undertaken on September 4, 2013. The purpose of the site visit was to allow the project team to identify key drainage features within the catchment, survey structures with potential significant hydraulic impact and gain a general feel for the floodplain.

The validation data consisted of observed rainfall, one anecdotal peak flood spot level and two locations where flooding was observed (but not measured) during the January 2011 event. The XP-RAFTS and MIKE FLOOD models were validated to this event iteratively using a joint calibration approach. Flows from XP-RAFTS were adjusted and applied in the MIKE FLOOD model until a good match between the modelled and observed water level was achieved and areas of known flooding were reproduced by the model.

The hydraulic model results show that the Dry Creek catchment was not significantly affected by flooding during the January 2011 event. The flooding in the upstream part of the catchment was contained within the major overland flow paths and the Dry Creek channel. However, some rural areas in the downstream part of the catchment were inundated. Boundary Street, Wirth Road and O'Mara Road were cut off during the event.

Available design rainfall data and associated procedures to determine the design flood discharges for the Dry Creek area have been reviewed, and an appropriate methodology and design parameters for this study have been proposed. A comparison of the XP-RAFTS model design discharges against discharges estimated using the Rational Method for 10 year and 100 year Average Recurrence Interval (ARI) shows that the design discharges from the two methods are consistent.

Design flood discharges, flood levels, flood depths, flood velocities and flood hazards for design rainfall events ranging from 2 year ARI to 500 year ARI and for the Probable Maximum Flood (PMF) were predicted using the validated XP-RAFTS and MIKE FLOOD models. In addition, sensitivity analysis on predicted 100 year ARI flood behaviour was undertaken and used to assess the impacts of changes to adopted design discharges (±30%), hydraulic roughness (±30%) and hydraulic structure blockage (50%). Potential impacts of climate change (2ºC, 3ºC and 4ºC temperature increase by 2050, 2070 and 2100 respectively) on 100, 200 and 500 year ARI events were assessed.

The study results show that:

- The 500 year ARI design discharges at the O'Mara Road and Troys Road reporting locations are up to 7 times larger than the 2 year ARI discharges and peak flood levels are up to 1.02m higher;
- The 500 year ARI design discharges at the Cumners Road, Boundary Street and McDougall Street reporting locations are up to 5 time larger than the 2 year ARI discharges, while the peak flood levels are up to 0.7m higher;
- Design flood levels at the Carrington Road and Warrego Highway reporting locations vary significantly with ARIs up to the 500 year ARI. The 500 year ARI design discharges at

these locations are up to 5 times larger than the 2 year ARI discharges, while the peak flood levels are up to 2.8m higher;
- Most of the road crossings in the study area have low flood immunity. Four of the seven major road crossings modelled are overtopped in a 2 year ARI design event. The Warrego Highway crossing has flood immunity up to and including a 500 year ARI design event;
- Along the northern tributary of Dry Creek, fully-developed conditions have increased the degree of urbanisation. This has resulted in a more rapid runoff response. As a result, fully-developed conditions design discharges at locations 4, 6, 7 & 8 are 2% to 33% larger than the corresponding existing- development conditions design discharges. Peak flood levels at these locations are up to 0.16m higher than for the corresponding existing-development conditions;
- Along the upper reach of the southern tributary of Dry Creek, a small portion of the catchment south of Toowoomba Airport changes from commercial to residential land use. Along the remainder of the southern tributary, there is an increase in the degree of urbanisation. Fully-developed conditions design discharges at reporting location 5 are 2% to 28% larger than the corresponding existing-development conditions discharges, while peak flood levels are largely unchanged;
- Between the junction of the two Dry Creek tributaries and Troys Road, the catchment becomes more urbanised. Fully-developed conditions design discharges at location 3 are 38% to 75% larger and peak flood levels are up to 1.13m higher than for the corresponding existing-development conditions;
- As a result of the changes to runoff response times upstream and the resultant changes to the timing of discharge hydrographs, fully-developed conditions design discharges and peak flood levels at locations 1 & 2 are lower than for the corresponding existing-development conditions. Fully-developed conditions design discharges at locations 1 & 2 are up to 9% lower than the corresponding existing-conditions and peak flood levels are 0.02m to 0.11m lower.

Sensitivity analysis results for the 100 year ARI design event indicate the following:

- A 30% increase and decrease in design discharges results in peak flood levels increasing and decreasing by up to 0.17m and 0.25m respectively across the reporting locations. The exception being the upstream side of the Warrego Highway, where peak flood levels increase and decrease by 0.56m and 0.64m respectively;
- A 30% increase and decrease in roughness results in peak flood levels increasing and decreasing by up to 0.07m and 0.04m respectively; and
- A 50% blockage of structures results in the overtopping of the ‘Carrington Road 1’ and Warrego Highway crossings which were previously not overtopped. Design discharge at Boundary St, corner of Beacon Ct (reporting location 6) is reduced by 25% and peak flood level is reduced by 0.07m due to discharge attenuation caused upstream by the Warrego Highway crossing (reporting location 7) immediately upstream. Peak flood levels at the remaining reporting locations increased by up to 0.07m, while the peak discharge either decreased slightly or remained unchanged.

Climate change scenario results indicate the following:

- For all of the climate change scenarios, peak discharges increase at the reporting locations; and
- Peak flood levels for the 100 year, 200 year and 500 year ARI events increase by up to 0.44m, 0.48m and 0.54m respectively at the reporting locations.

Based on modelling results, the predicted design discharges and peak flood levels at some locations along the modelled lower reach of Dry Creek (e.g. at Troys Road) under full-developed conditions are lower than under existing conditions. When these results are used for future planning purposes, caution should be exercised before applying potentially reduced flood levels when considering proposed development within this catchment.

The study limitations and recommendations on how model predictions could be improved are also presented.

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1 INTRODUCTION

1.1 BACKGROUND

Toowoomba Regional Council (TRC) is a large local government area located in the Darling Downs part of Queensland, Australia. TRC comprises an area of nearly 13,000 km^2 with a population of approximately 172,000 people in 33 towns. In 2009 TRC commenced the Toowoomba Regional Planning Project (RPP) to develop one integrated planning scheme policy covering the entire Council area. Later that year TRC commissioned Water Technology Pty Ltd to collate and review the existing flood data in the region and provide advice on the applicability of the data for use in the Planning Scheme. One of the findings from the study was that only a small portion of the Council area is covered by high/medium quality flood mapping.

In 2012 the State Government approved Council adopting the Toowoomba Regional Planning Scheme with a set of conditions to be met to ensure the scheme was compliant with nominated State Planning Policies. To meet the conditions established by the State Government, a scoping study was completed by Council to identify the information required to meet the specified conditions. The study highlighted the need to investigate the flood behaviour and flood risk in several towns in the region.

WRM in association with DHI was commissioned by TRC to undertake a 2D flood study for the Dry Creek Catchment, which includes the townships of Charlton and Torrington. The 2D flood study which includes both historical and design event modelling will provide Council with information needed for land development control, infrastructure development and management, emergency planning, and emergency response in the study area.

This report describes the methodology, available data, and development of hydrologic and hydraulic models for historical and design event simulations for the Dry Creek catchment. The report ends with concluding remarks and recommendations to further improve the model accuracy.

1.2 SCOPE OF PROJECT

The primary objective of this project was to define the nature and extent of flood behaviour in the Dry Creek study area to enable TRC to:

- "*Develop a Flood Risk Management Study and plan to address the flood hazards identified in the flood studies;* and
- *Amend the Toowoomba Regional Planning Scheme to appropriately reflect the flood requirements of State Planning Policy 1/03 and the recommendations of the Queensland Commission of Inquiry*" (TRC, 2013).

The project was divided into a number of phases. The scope of each phase is briefly outlined below.

Information Review and Project Start-Up

- Completion of project briefing;
- Development of stakeholder consultation strategy;
- Site visit; and
- Collection and review of available data.

Hydrologic Model Development

- Development of a XP-RAFTS hydrologic model.

MIKE FLOOD Model Development

- Development of a coupled 1D/2D MIKE FLOOD model; and
- Adjusting parameters to ensure model stability.

Model Validation

- Adjustment of flows from XP-RAFTS until a good match between modelled and observed water levels is achieved and areas of known flooding are reproduced by the MIKE FLOOD model (a joint calibration approach was used).

Deliverables

- Report detailing methodology and validation results including A3 flood maps for the validation event; and
- Handover of model setup and result files for the validation event.

1.3 STUDY AREA

The Dry Creek Catchment encompasses the townships of Charlton and Torrington located approximately 14 km and 8 km north-west of Toowoomba, respectively. The primary flood risk to the towns is from overland flow and local drainage issues. However roads within both townships can be cut off by flood water from Dry Creek; roads that do get cut off include Boundary Street in Torrington and O'Mara Road in Charlton.

Land use within the study area is primarily rural. Within the local areas of Charlton and Torrington the land use is predominantly residential, although there is light industrial development in the upstream parts of the catchment, and Toowoomba Airport straddles the upper catchment boundary. The study area is shown in Figure 1-1.

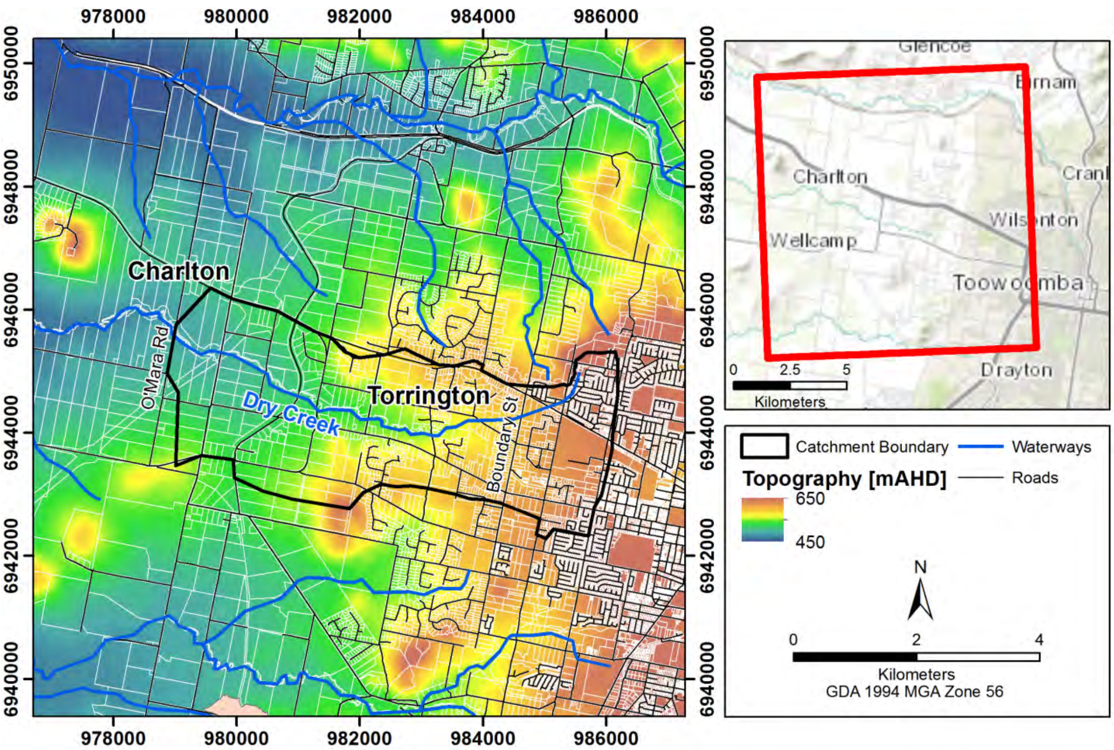

Figure 1-1 Study Area

2 AVAILABLE DATA

2.1 TOPOGRAPHIC DATA

Tiles of 1m LiDAR-derived gridded topographic data were provided by TRC. The 1m tiles were merged to create a seamless 1m Digital Elevation Model (DEM) of the study area, see Figure 2-1.

2.2 GIS LAYERS

The available GIS layers provided by TRC included:

- Aerial photography;
- Cadastral data;
- Road and rail network;
- Structures with a likely hydraulic impact (not including structure geometry, dimensions or levels);
- Land use data;
- Future planning scheme; and
- Location of emergency services.

2.3 SITE VISIT

A site visit was undertaken on September 4th, 2013. The purpose of the site visit was to allow the project team to identify key drainage features within the catchment, survey structures with potential significant hydraulic impact and gain a general feel for the floodplain. All information collected during the site visit including photos, structure geometry data and a GIS layer showing the location of the structures was delivered as part of the study.

No topographic survey of drainage structures or critical road or other threshold levels in the catchment was carried out during this project. Drainage structure information used in the study for model development is based on field measurements taken during the site visits.

2.4 HISTORICAL FLOOD INFORMATION

Historical pluviograph and daily rainfall data were available from TRC, Bureau of Meteorology (BOM) and the University of Southern Queensland (USQ) for a number of rainfall stations in the vicinity of the Dry Creek catchment. Rainfall data available for the January 2011 validation event is described in Section 3.2.3.

The available observed historical flood information was supplied by TRC and a Torrington resident. The available historical flood information was limited to the January 2011 flood event. No additional flood information was available from the stakeholder consultation undertaken prior to the site visit. The available validation data is summarised in Table 2.1 and shown in Figure 2-1. The flood level referred to as point 1 in Figure 2-1 is based on an interview with a local resident from Torrington. According to the local resident the water level reached the top of the side pipe in Figure 2-2 during the January 2011 event, corresponding to a water depth of approximately 0.6m. The water surface elevation of 599.65mAHD listed in Table 2.1 was estimated from the 1m LiDAR-dataset provided by TRC and the approximate water depth estimated during the site visit. The flood extents on O'Mara Road referred to as points 2 and 3 in Figure 2-1 are based on photographic evidence obtained from TRC, see Figure 2-3 and Figure 2-4. It should be noted that the accuracy of all three validation points is probably low.

Information used is the best information available at this time for the purposes of this study. Marks observed and other anecdotal information obtained after flood events have been obtained from a range of sources and have varying degrees of uncertainty.

Table 2.1 Historical Flood Event Data, January 2011 Event

ID	Location	Flood Reference	Elevation (m AHD)
1	Corner of Beacon Court and Boundary Street (overtopped side of pipe)	Flood level	599.65
2	O'Mara Road crossing over Dry Creek (North flood point)	Known flooding (no recorded depth or level)	-
3	O'Mara Road crossing over Dry Creek (South flood point)	Known flooding (no recorded depth or level)	-

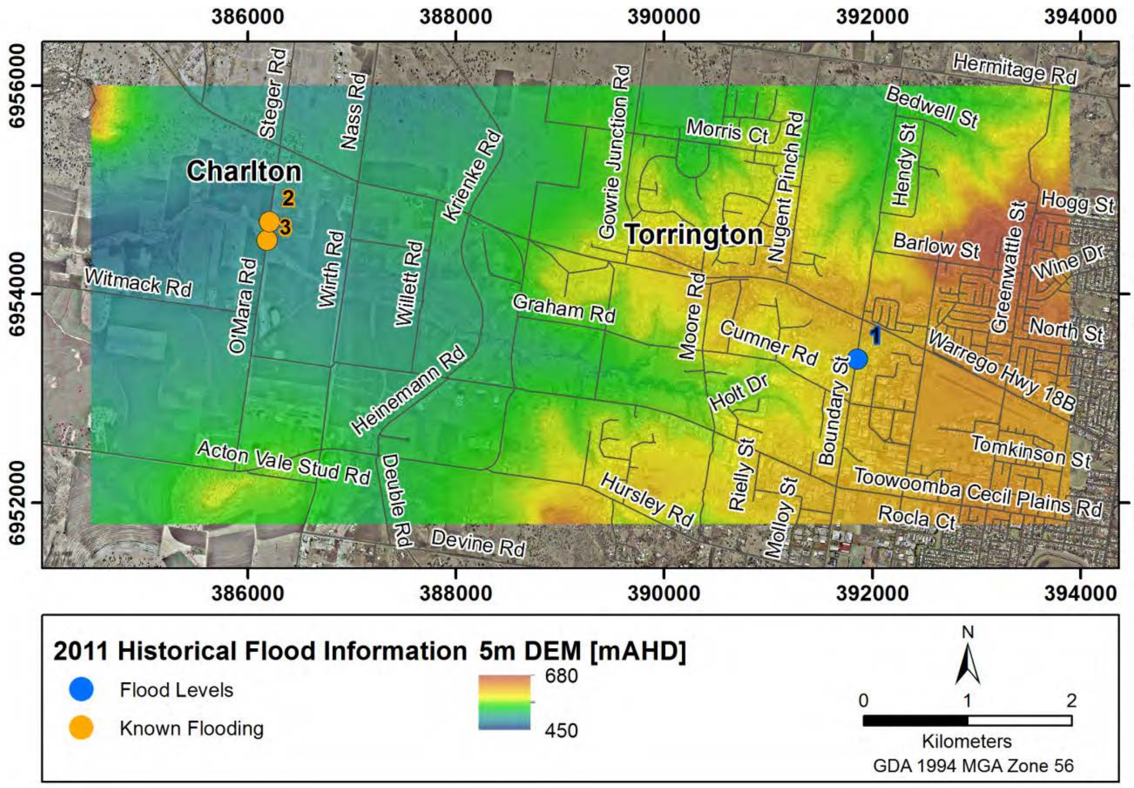

Figure 2-1 LiDAR-Derived DEM Extent and Available Historical Flood Information

Figure 2-2 January 2011 Flood Level at the Corner of Beacon Ct and Boundary St

Figure 2-3 Flooding on O'Mara Rd in January 2011 Looking North

Figure 2-4 Flooding on O'Mara Road in January 2011 Looking South

3 HYDROLOGIC MODEL DEVELOPMENT AND VALIDATION

3.1 OVERVIEW

Flood discharges within the Dry Creek catchment were estimated using the XP-RAFTS runoff-routing model (XP Software, 2009) for existing and ultimate development conditions. The Dry Creek catchment and the configuration of the XP-RAFTS model are shown in Figure 3-1.

- The existing-development conditions scenario was based on the Toowoomba Regional Council Zones and Precincts (Version 2) plan and the latest aerial photographs; and
- The ultimate-development conditions scenario assumed that the catchment was fully developed in accordance with the Toowoomba Regional Council Zones and Precincts plan (Version 2).

The existing-development conditions scenario model was initially validated against the Rational Method estimates at 6 locations within the catchment. The routing parameters of the model were then ‘fine-tuned’ via a joint calibration of the hydrologic and hydraulic models to observed water levels for the January 2011 event.

The following section presents the methodology and results of the hydrological model validation for the Dry Creek catchment.

3.2 MODEL VALIDATION DATA

3.2.1 Adopted Validation Event

The largest recent flood event (on 10 January 2011) at Dry Creek was selected for hydrologic and hydraulic model validation due to availability of rainfall and flood data.

The severe flooding in the Toowoomba region on the afternoon of 10 January 2011 was caused by intense rainfalls over the region delivered by a south-westerly tracking storm that originated when a low pressure system off Fraser Island moved north to combine with a monsoonal trough. During this event, the maximum 1 to 2 hour storm durations had an Average Recurrence interval (ARI) greater than 100 year in parts of Toowoomba (ICA, 2011).

3.2.2 Rainfall Data

Figure 3-1 shows the Dry Creek catchment and the locations of the two rainfall stations with data suitable for model validation. The Toowoomba Airport Automatic Weather Station (AWS) records rainfall continuously whereas the Moyola station records rainfall on a daily basis. Table 3.1 shows the daily rainfall data recorded at these stations for the January 2011 event.

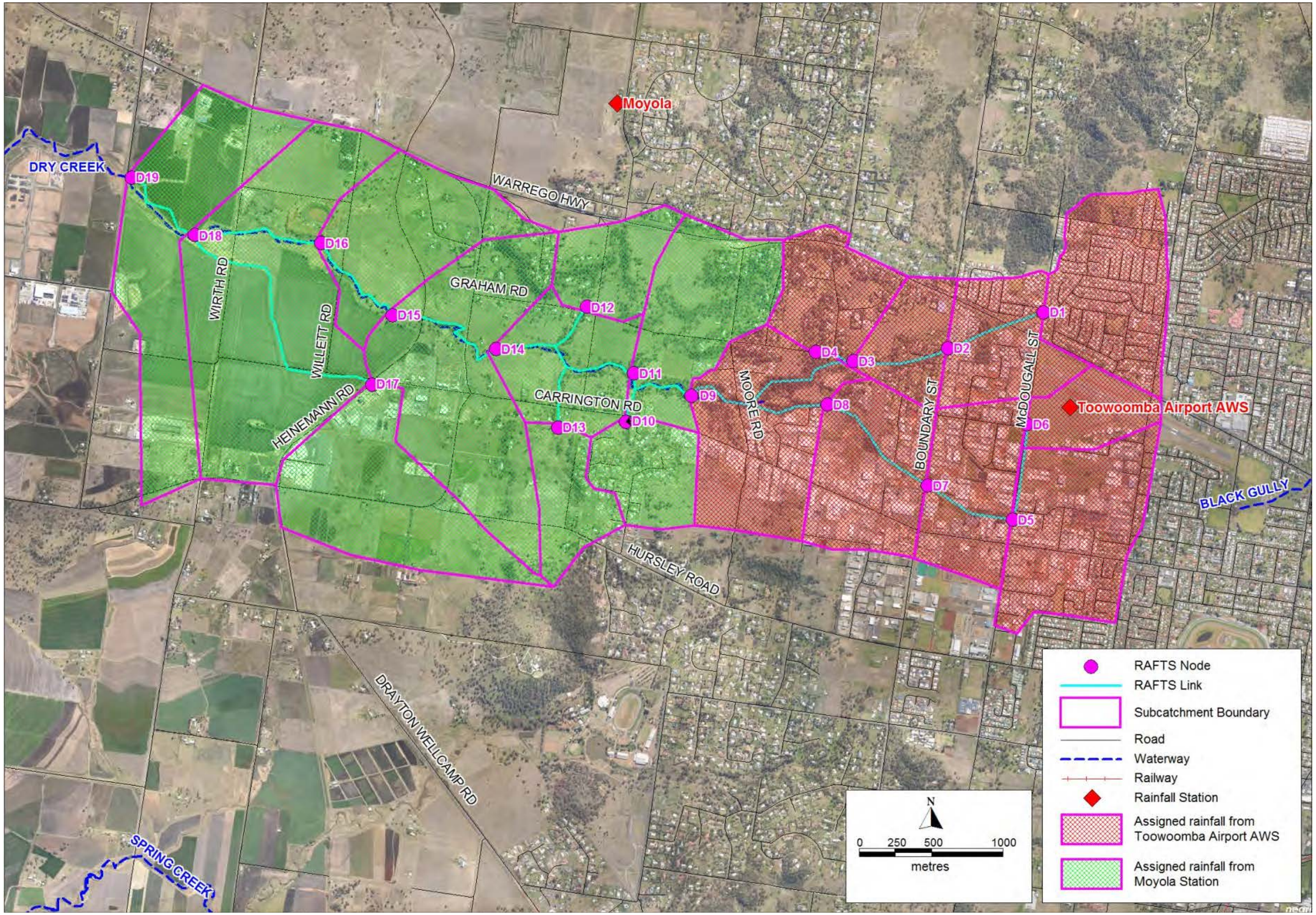

Figure 3-1 XP-RAFTS Model Configuration and sub-catchment Rainfall Assignment

Table 3.1 Dry Creek Pluviograph and Daily Rainfall Data, 10th and 11th January 2011

Station Name	Rainfall Station Type	Station No.	24-hour Rainfall to 0900 hours (mm)	
			10th Jan	11th Jan
Toowoomba Airport AWS	Pluviograph	41529	83.6	108.0
Moyola	Daily	041369	55.6	82.4

Figure 3-2 shows the recorded cumulative rainfall at the Toowoomba Airport AWS for the January 2011 flood event. The Moyola data was disaggregated across the days using the Toowoomba AWS temporal pattern.

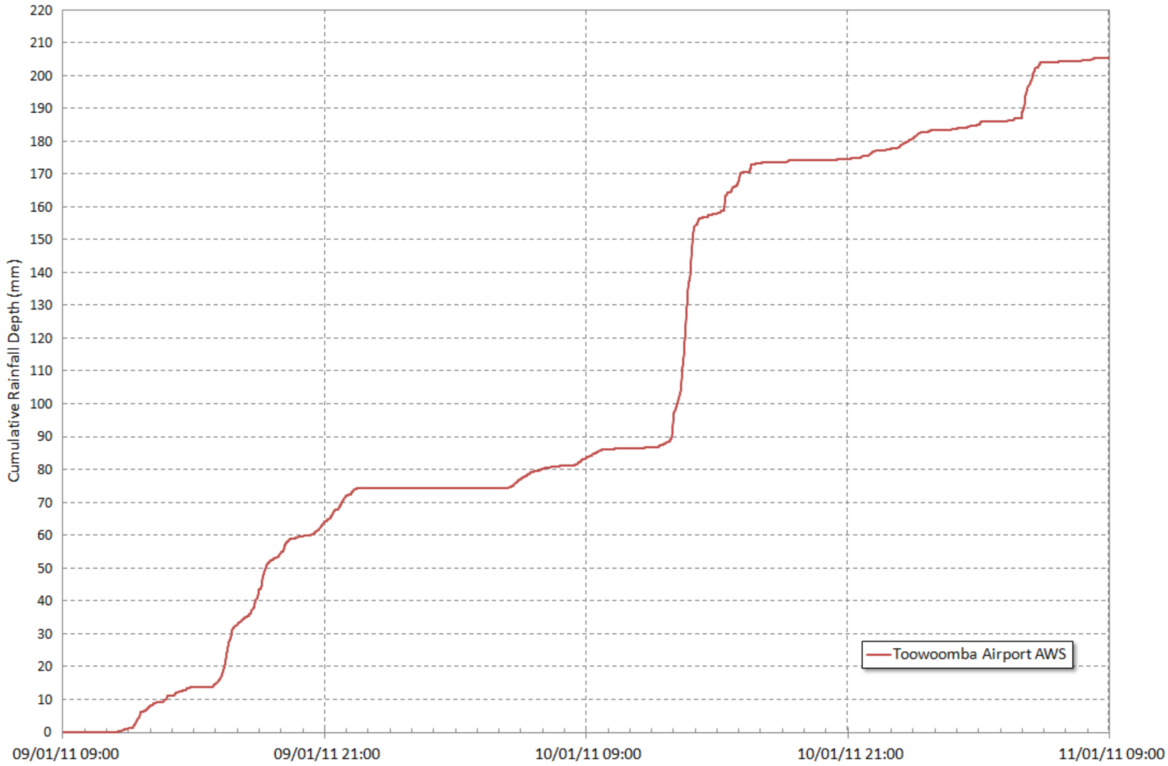

Figure 3-2 Cumulative Rainfall at Toowoomba AWS, January 2011 Event

3.2.3 Streamflow Data

There is no streamflow data available within the catchment.

3.2.4 Existing and Ultimate Conditions Land Use

Figure 3-3 shows the current land uses within the Dry Creek catchment. Figure 3-4 shows the ultimate development conditions land uses within the Dry Creek catchment.

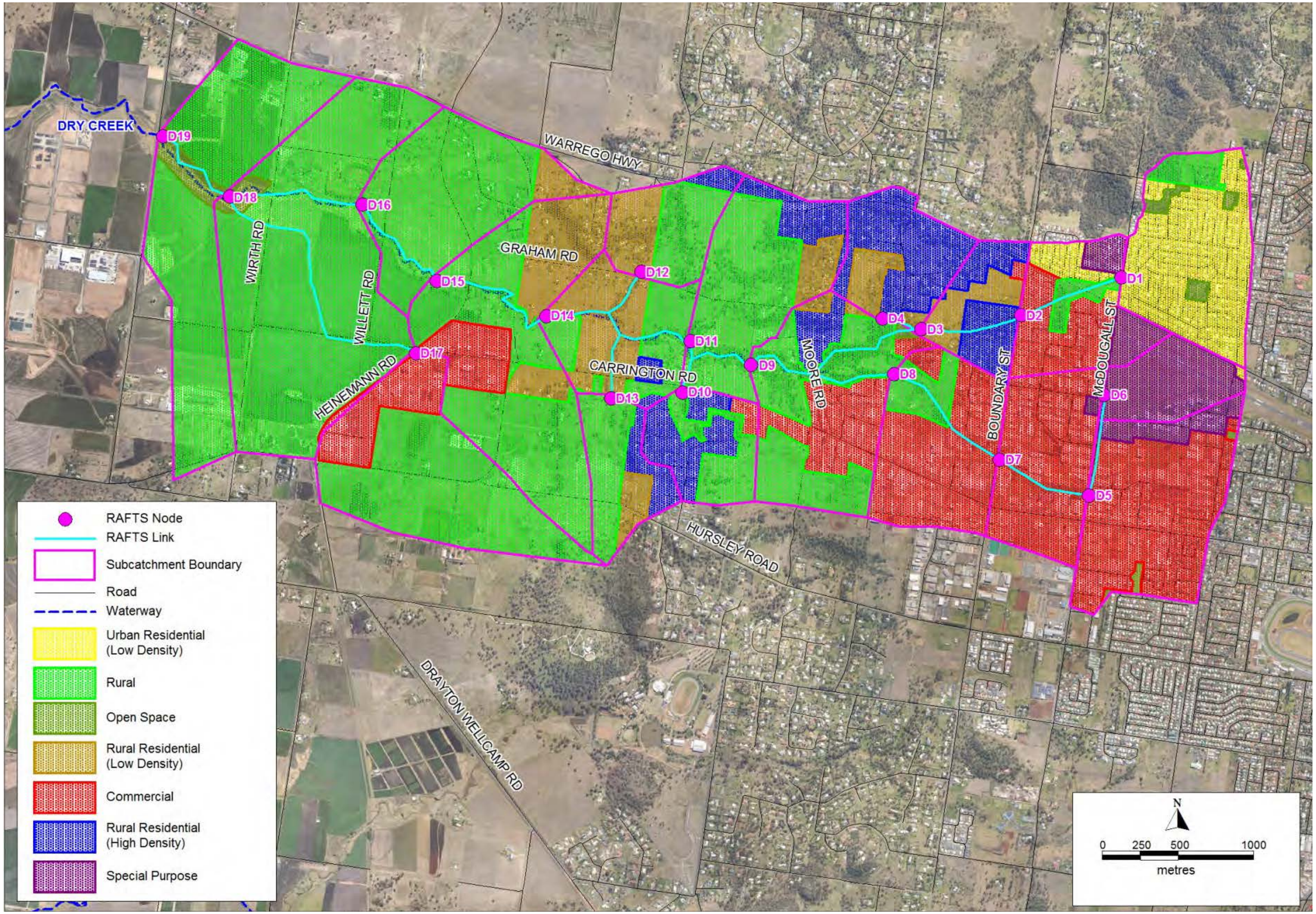

Figure 3-3 Dry Creek Land Use – Existing Conditions

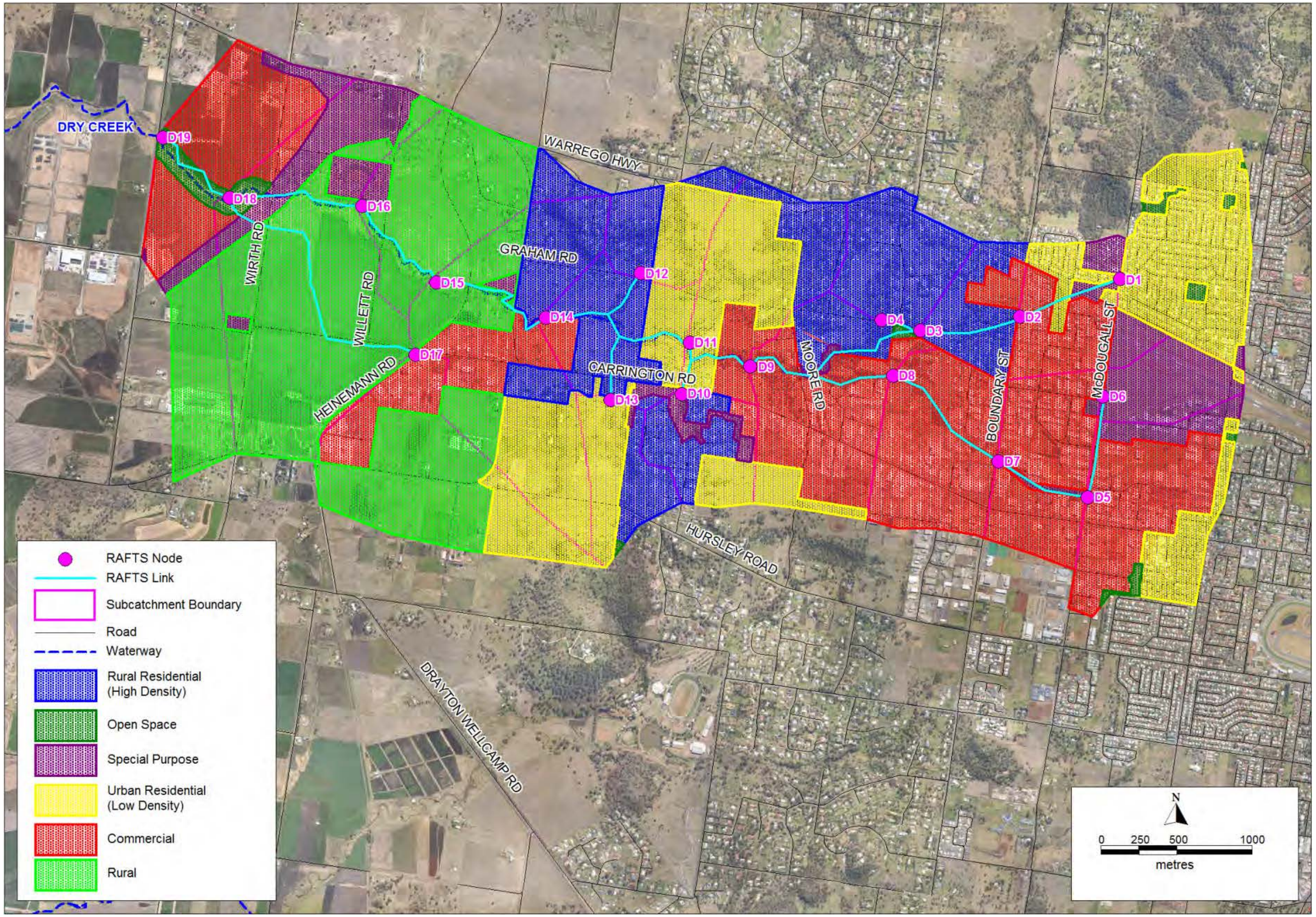

Figure 3-4 Dry Creek Land Use – Ultimate Development Conditions

3.3 HYDROLOGIC MODEL CONFIGURATION

3.3.1 General

Figure 3-3 shows the existing-conditions Dry Creek XP-RAFTS model configuration, consisting of 19 sub-catchments areas totalling 1732 ha in area (D1 to D19).

XP-RAFTS sub-catchment boundaries were delineated using the available LiDAR data, land use planning information and the available road and stormwater drainage network.

3.3.2 RAFTS Model Parameters

Table 3.2 and Table 3.3 show the adopted XP-RAFTS parameters for each land use in the existing and ultimate conditions Dry Creek XP-RAFTS model. Table 3.2 also shows the adopted fraction impervious for each land use based on the Queensland Urban Drainage Manual (QUDM, 2013) recommendations. The XP-RAFTS model percentage impervious values and catchment PERN 'n' values, which represent the average sub-catchment roughness, were used as a calibration parameter.

Table 3.4 shows the adopted sub-catchment parameters for the existing and ultimate development conditions Dry Creek XP-RAFTS models. Where there was more than one land use in each sub-catchment, the percentage impervious and PERN 'n' was factored in proportion to catchment area.

A global 'Bx' factor of 1.0 was adopted. The adopted channel routing parameters were assigned based on the physical channel characteristics including channel length and slope. A channel velocity was assigned to each link based on the MIKE FLOOD model results.

Table 3.2 Adopted Land Use Parameters, Dry Creek XP-RAFTS Model

Land Usage	Typical Lot Size (ha)	Fraction Impervious (f_i)	Adopted RAFTS Parameters	
			Percent Impervious (%)	Catchment PERN 'n'
Commercial/Industrial	Varies	0.90	70	0.020
Special Purpose	Varies	0.75	55	0.030
Urban Residential	0.04 to 0.2	0.70	50	0.035
Rural Residential (High Density)	0.2 to 1.0	0.40	30	0.040
Rural Residential (Low Density)	1.0 to 10	0.20	15	0.045
Rural	>10	0.05	5	0.060
Open Space	Varies	0.00	0	0.070

Table 3.3 Initial and Continuing Losses, Dry Creek XP-RAFTS Model

Percentage Impervious	2 - 5 year ARI		10 year ARI		20 - 100 year ARI		> 100 year ARI	
(%)	IL (mm)	CI (mm)	IL (mm)	CI (mm)	IL (mm)	CI (mm)	IL (mm)	CI (mm)
< 25	20	2.5	15	2.5	15	2.5	0	2.5
25 to 40	20	1.5	10	1.5	10	1.5	0	1.5
> 40	20	1	10	1	5	1	0	1

Table 3.4 Adopted XP-RAFTS Sub-Catchment Parameters, Existing and Ultimate Conditions

Sub-catchment	Catchment Area (ha)	Existing Conditions			Ultimate Conditions		
		Catchment Slope (%)	Percent Imp. (%)	'PERN' 'n'	Catchment Slope (%)	Percent Imp. (%)	'PERN' 'n'
D1	94.19	4.6	43.1	0.039	4.6	47.5	0.037
D2	64.44	4.4	56.6	0.029	4.4	61.5	0.026
D3	41.48	5.0	25.9	0.041	5.0	37.9	0.036
D4	56.00	5.9	26.9	0.041	5.9	30.0	0.040
D5	108.26	2.5	66.7	0.022	2.5	62.1	0.026
D6	37.54	1.8	55.0	0.030	1.8	55.0	0.030
D7	74.18	2.8	69.8	0.020	2.8	69.2	0.021
D8	86.97	4.0	59.6	0.026	4.0	70.0	0.020
D9	113.54	6.1	28.8	0.045	6.1	59.4	0.026
D10	47.20	6.3	22.8	0.047	6.3	41.6	0.036
D11	94.36	6.5	10.5	0.055	6.5	47.9	0.034
D12	46.31	6.6	11.1	0.052	6.6	40.4	0.037
D13	43.16	8.0	12.7	0.053	8.0	41.5	0.037
D14	70.48	6.7	11.8	0.051	6.7	40.0	0.036
D15	164.43	5.9	15.2	0.051	5.9	35.0	0.041
D16	99.24	3.8	5.8	0.059	3.8	9.0	0.057
D17	121.43	4.4	19.6	0.051	4.4	27.9	0.046
D18	224.01	2.7	5.3	0.060	2.7	17.8	0.052
D19	144.51	3.2	4.7	0.061	3.2	43.6	0.037

3.4 XP RAFTS MODEL VALIDATION AGAINST RATIONAL METHOD

3.4.1 General

The existing-conditions Dry Creek XP-RAFTS model was validated against the Rational Method at 6 locations using the methodology recommended in QUDM (2013) for rural and urban catchments. The model was validated at the following locations (see Figure 3.3 for locations):

- Sub-catchment D1;
- Sub-catchment D6;
- Sub-catchment D8;
- Sub-catchment D9;
- Sub-catchment D14; and
- Sub-Catchment D19.

3.4.2 Design Rainfalls and Temporal Patterns

Design rainfalls and temporal patterns were derived for the Dry Creek catchment in accordance with Australian Rainfall and Runoff (Pilgrim, 1998). The adopted design rainfalls are presented in Section 6.

3.4.3 Rational Method Estimates

Table 3.5 shows the Rational Method estimates of 10 year and 100 year ARI design discharges at the above 6 locations. The Rational Method discharges were calculated assuming the following:

- A catchment-weighted fraction impervious and catchment slope based on existing conditions land uses (see Table 3.4);
- A catchment-weighted C_{10} value was assigned to each catchment based on the values recommended in QUDM (2013). The adopted 10 year ARI 1-hour duration rainfall intensity for Dry Creek is 47.5mm/hr;
- A C_{10} value of 0.49 was assigned to predominantly rural catchments (with a catchment weighted fraction impervious of 20% or less);
- The stream velocity was calculated as follows:
  - For rural catchments, the stream velocity was selected based on the MIKE FLOOD model results; and
  - For urban upper catchments, a standard inlet time of 5mins, pipe velocity of 3.0m/s and open channel flow velocity based on the MIKE FLOOD model results.

3.4.4 Comparison of Rational Method and XP-RAFTS Estimates

Table 3.6 compares the 10 year and 100 year ARI peak discharges estimated using the Rational Method with XP-RAFTS model predicted peak discharges at each of the 6 locations. The comparison shows that the XP-RAFTS peak discharges for sub-catchments D1, D6, D8, D9, D14 and D19 (Outlet) match reasonably well with the Rational Method discharges and that the differences are generally less than 20% for all design events up to and including the 100 year ARI event.

Table 3.5 Rational Method 10 Year and 100 Year ARI Design Discharges

Parameter	Sub-catchment ID					
	D1	D6	D8	D9	D14	D19
Catchment Area (ha)	94	38	307	677	978	1732
Travel Time						
Standard Inlet Time (mins)	5	5	5	5	5	5
Stream Length (km)	0.6	0.6	2.7	3.8	5.0	7.5
Stream Velocity (m/s)	3.0 [a]	3.0 [a]	3.0 [b]	3.0 [b]	3.5 [b]	3.5 [b]
Time of Concentration (mins)	**8.3**	**8.3**	**20.0**	**26.1**	**28.8**	**40.7**
Rainfall Intensity						
10 Year ARI event (mm/hr)	136.1	136.1	89.2	78.6	74.0	63.2
100 Year ARI event (mm/hr)	207.6	207.6	133.0	116.5	109.2	93.0
Coefficient of Discharge						
Fraction Impervious (%)[c]	60	75	83	64	50	33
C_{10} (no units)	0.70	0.78	0.81	0.72	0.66	0.54
C_{100} (no units)	0.84	0.94	0.97	0.86	0.79	0.65
10Year ARI Discharge (m^3/s)	**24.9**	**11.1**	**61.6**	**106.4**	**132.6**	**164.1**
100 Year ARI Discharge (m^3/s)	**45.6**	**20.3**	**110.2**	**189.2**	**235.0**	**289.8**

[a] Assumed Pipe/Channel Velocity
[b] Based on MIKE FLOOD 100 year ARI results
[c] Different to XP-RAFTS Percent Impervious. These values are based on Table 3.2

Table 3.6 Comparison of Rational Method and XP-RAFTS Model Peak Discharges

Inflow Location	10 Year ARI Peak Discharge (m^3/s)		100 Year ARI Peak Discharge (m^3/s)	
	RM	XP-RAFTS	RM	XP-RAFTS
D1	24.9	23.7	45.6	43.4
D6	11.1	10.3	20.3	18.5
D8	61.6	61.0	110.2	97.1
D9	106.4	111.9	189.2	180.4
D14	132.6	139.6	235.0	230.0
D19	164.1	174.1	289.8	292.9

3.5 XP-RAFTS MODEL JANUARY 2011 RESULTS

3.5.1 Assignment of Total Rainfalls and Temporal Patterns

Total rainfalls from pluviograph and daily stations were assigned to each sub-catchment based on the nearest rainfall station. The nearest available pluviograph temporal pattern (at Toowoomba Airport AWS) was applied to the Moyola rainfall station as well. This approach ensures all the available data are used. Figure 3-1 shows the locations of the available daily and pluviograph rainfall stations within and adjacent to the catchment. Sub-catchments assigned rainfall from the Toowoomba AWS are shaded red and those assigned rainfall from Moyola are shaded green. Table 3.7 shows a summary of the adopted rainfall assignment.

Table 3.7 Adopted Rainfall Assignment

Rainfall source	Sub-Catchments Assigned
Toowoomba Airport AWS	D1 - D9
Moyola	D10 - D19

3.5.2 Initial and Continuing Losses

Each sub-catchment was assigned losses based on the catchment percentage impervious. The same initial and continuing losses were adopted for the validation event as were adopted for the 20 to 100 year ARI events shown in Table 3.3. These loss rates are based on the recommended design loss rates for Eastern Queensland (Pilgrim, 1998). Note that the flood peaks are not overly sensitive to lower initial losses, which would have been expected given the very wet conditions experienced prior to this event. The adopted initial loss removes the pre-storm and pre-burst rainfall only.

3.5.3 Peak Discharges

Table 3.8 shows a summary of the total upstream catchment (external) and local residual catchment (internal) peak discharges at each hydrodynamic (MIKE FLOOD) model inflow location estimated using the XP-RAFTS model.

Table 3.8 Peak Discharges at Inflow Hydrograph Locations to Hydrodynamic Model

Sub-catchment ID	Peak Discharge (m^3/s)	
	Local (Internal)	Total (External)
D1	23.8	23.8
D2	16.8	38.0
D3	10.2	54.7
D4	13.9	13.9
D5	28.3	37.0
D6	9.6	9.6
D7	20.0	54.0
D8	22.8	69.4
D9	27.0	143.9
D10	7.2	7.2
D11	12.3	160.2
D12	6.3	6.3
D13	6.1	6.1
D14	9.6	176.4
D15	21.8	187.6
D16	9.1	192.8
D17	16.3	16.3
D18	13.0	213.5
D19	10.0	220.9

4 HYDRODYNAMIC MODEL DEVELOPMENT

4.1 OVERVIEW

The following section documents the development and validation of the hydrodynamic model, selection of key model parameters and assumptions made. The hydrodynamic model was developed in the MIKE FLOOD Release 2012 (Service Pack 2), which was the most recent version available at the time of the project. MIKE FLOOD is a software program that allows coupling of a MIKE 11 (1D) model and a MIKE 21 (2D) model to run together in parallel. The fundamental principle of MIKE FLOOD is that features smaller than the MIKE 21 grid resolution (e.g. small channels and structures) can be represented in MIKE 11, with linkages (couples) that transfer water levels and discharges between MIKE 11 and MIKE 21 at each time step.

The MIKE FLOOD model schematisation (DHI, 2013) was proposed and agreed with TRC prior to the commencement of model development. The original assessment was to model the main overland flood channels in MIKE 11 and couple these laterally to the out-of-bank floodplain flows. However, once initial model results were analysed, it became apparent that a 2D representation of the overland flow paths would be sufficient as they are wide and their conveyance and geometry is adequately represented by the 2D grid spacing used. In addition, the initial modelling results showed that out-of-bank flooding would not occur for the majority if not all modelled events (this is demonstrated in Figure 4-1 by an example cross-section with the modelled 100 year ARI peak water level based on preliminary 100 year ARI XP-RAFTS flow estimates).

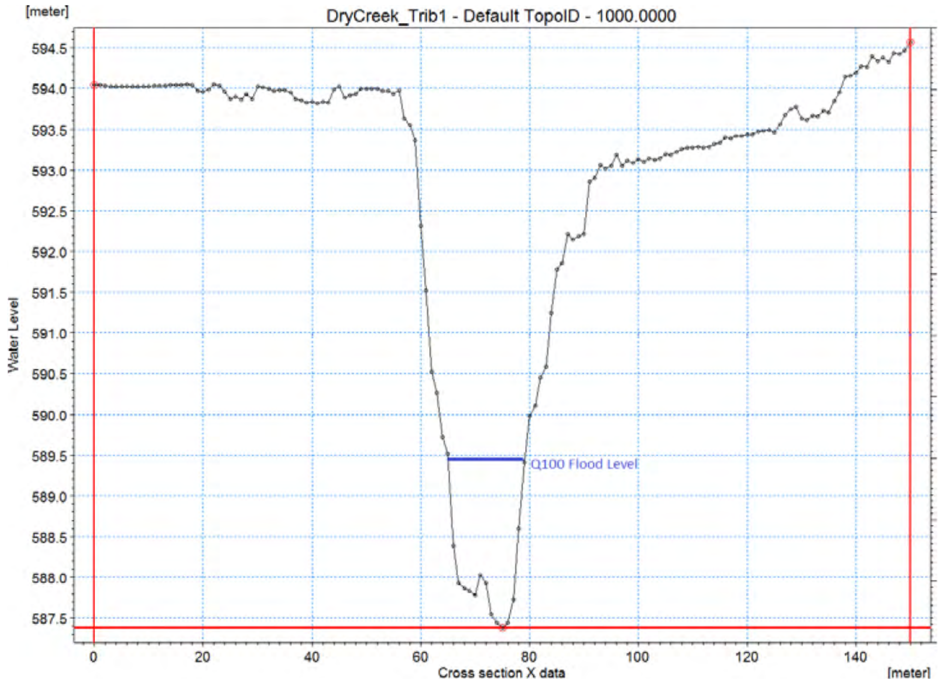

Figure 4-1 Example Cross-Section with Modelled 100 Year ARI Water Level

It is noted that the model developed for this study does not include the stormwater pipe network system in the upper parts of the catchment between Toowoomba Airport and Torrington.

4.2 MIKE 21 MODEL

The 2D model domain for the Dry Creek catchment extends from east of Greenwattle Street to west of O'Mara Road as shown in Figure 4-2. The model domain is approximately 9.4km by 4.2km.

4.2.1 Bathymetry

The MIKE 21 model incorporates a detailed elevation model (bathymetry) of the ground surface. The DEM used in this model was created from the 1 m DEM supplied by TRC. The DEM was then re-sampled to a 5 m grid resolution.

Small flow structures and crossings on secondary flow paths were implemented as they were represented in the source DEM data. These structures were not incorporated as 1D elements, and the 2D bathymetry was not adjusted to reflect any geometry or associated control levels. This implies that most small culverts and structures were assumed to be 100% blocked during a flood, thus producing a conservative estimate of the flood extent.

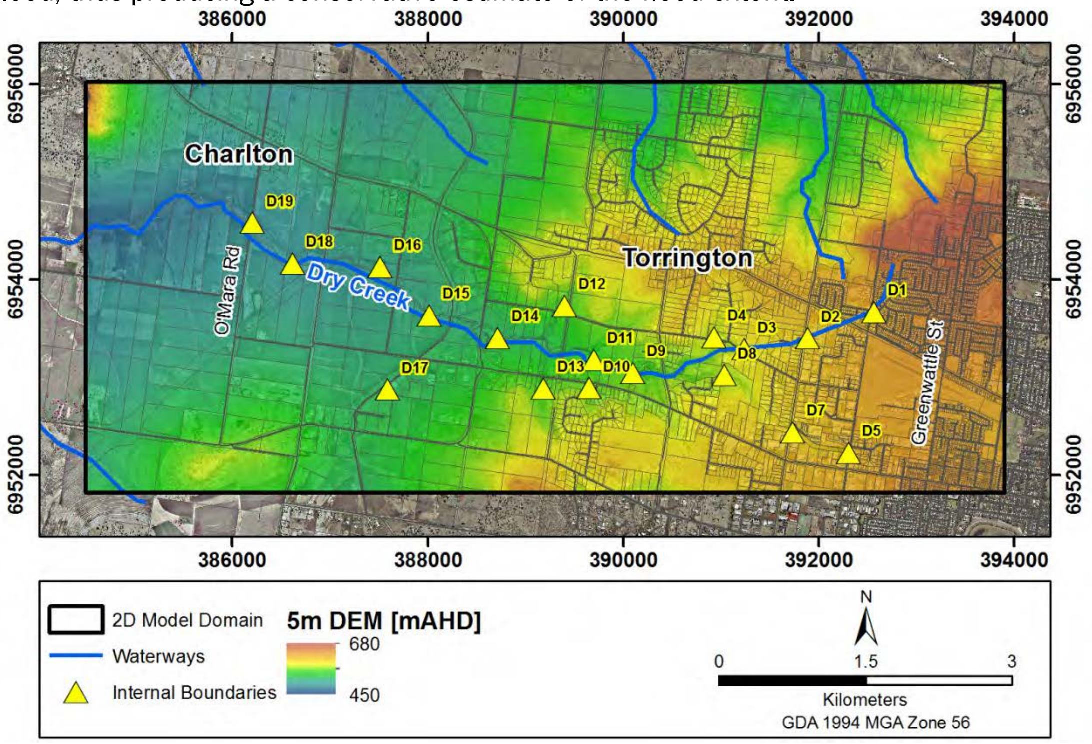

Figure 4-2 MIKE FLOOD Model Setup

4.2.2 Hydraulic Roughness

MIKE21 models require the specification of hydraulic roughness to be applied in each cell, either as a constant value or in the form of a map (grid) of roughness values. A spatially distributed roughness map for the model domain was created based on the land uses classes provided by TRC as well as vegetation coverage identified from the aerial photography, also supplied by TRC. Six distinct land use classes were identified within the study area.

The adopted hydraulic roughness values (Manning's 'n') for each class are shown in Table 4.1. These values were based on DHI's previous experience in Queensland, whilst also taking into account the Australian Rainfall and Runoff (ARR) Revision Project's valid Manning's 'n' ranges for different land use types (Smith and Wasko, 2012). It should be noted that the adopted Manning's 'n' value for 'Developed Areas' is slightly lower than the ARR recommended range of roughness values for this land use type. This is due to the coarse delineation of 'Developed Areas' based on land use classes, resulting in a Manning's 'n' value of 0.083 being applied to buildings as well as some open pervious areas. The spatial distribution of roughness is presented in Figure 4-3.

Table 4.1 Adopted Hydraulic Roughness Values in MIKE FLOOD

Land Use	Manning's 'n'	Range of Manning's 'n' Values[a]
Floodplain	0.04	0.03 – 0.05
Roads	0.025	0.02 – 0.03
Developed Areas	0.083	0.10 – 0.20
Waterways	0.033	0.02 – 0.04
Dense Vegetation	0.10	0.07 – 0.12
Vegetated Waterways	0.05	0.04 – 0.10

Notes: [a] (Smith and Wasko, 2012)

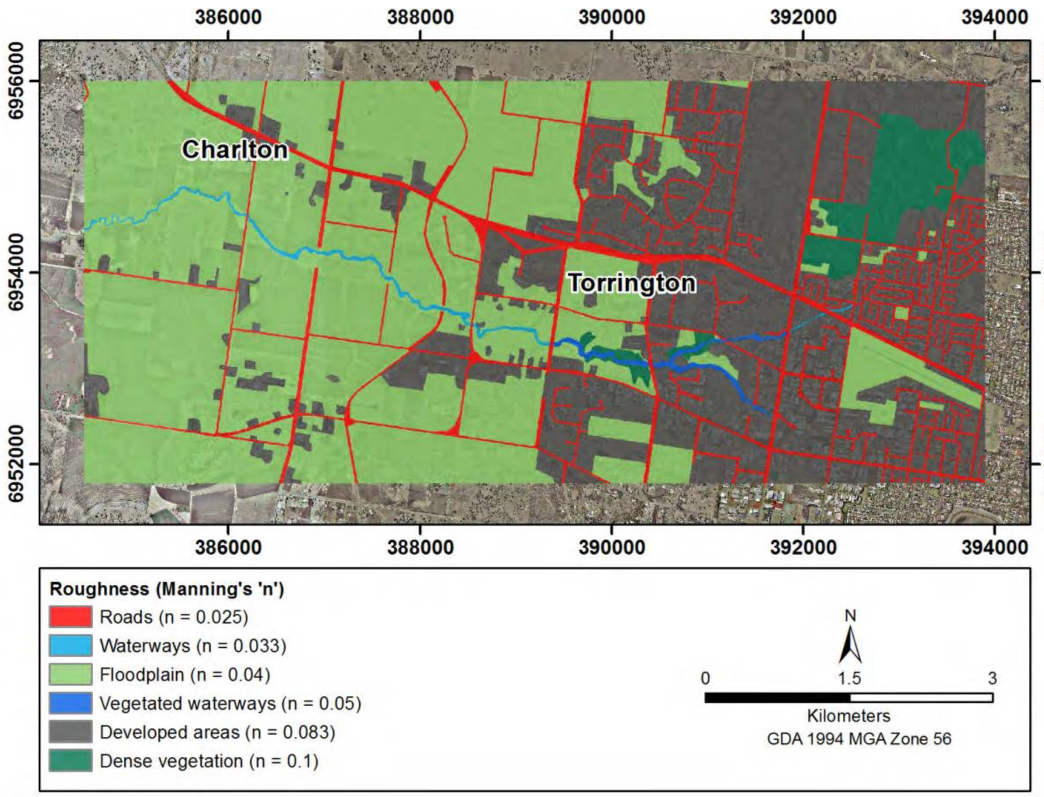

Figure 4-3 Spatial Distribution of Roughness

4.2.3 Flooding and Drying Depths

In the MIKE FLOOD Release 2012, there is a new 'Inland Flooding' option available which results in much improved mass balances in urban flooding and floodplain applications. Continuity is fully preserved during the flooding and drying process, as the water depths at the points which are dried out are saved and then reused when the point becomes flooded again. A flooding depth of 0.05 m and a drying depth of 0.02 m were adopted in this study.

4.2.4 Eddy Viscosity

Eddy viscosity is used to represent sub-grid scale turbulence to provide the modeller with the opportunity to enhance or retard the natural generation of flow eddies in the solution scheme for the purpose of matching observed flow phenomena. A velocity based eddy viscosity formulation was applied, and this is the recommended approach in floodplain applications.

Values for eddy viscosity can be calculated using a number of empirical formulas related to grid size and time step. Selecting an eddy viscosity value that is too high will result in the modelled flow having a more uniform velocity distribution tending to distribute more of the total flow to the floodplain. Selecting an eddy viscosity value that is too low can result in significant variability in the velocity field, formation of large modelled eddies in areas of no physical manifestation of this hydraulic phenomenon and contribute to model instability.

In this study, the eddy viscosity was set to 0.5 m^2/s, which is consistent with the model resolution and based on DHI's previous experience with selection of secondary model parameters. At a small number of locations associated with 1D/2D couples an eddy viscosity of 5 m^2/s was used to improve model stability.

4.2.5 Model Boundaries

Catchment flows from the XP-RAFTS model were applied to the MIKE 21 model at eighteen internal boundaries (source points), see Figure 4-2. A Q-h rating was used at the downstream model boundary. The rating curve was derived from a cross-section extracted from the 1m DEM at the location of the MIKE 21 downstream boundary. The cross-section width was set to match the width of the MIKE 21 boundary. An average bed slope of 4.05 m/km derived from the LIDAR data and a Manning's 'n' of 0.04 representative of the channel conditions, were used to derive the rating curve. The model boundary was positioned as far downstream of the area of interest as possible to minimise backwater effects on areas of interest to the study from assumptions made at the boundary location.

4.2.6 Time Step and Save Step

A 0.5 second time step was used in the Dry Creek model based on Courant number considerations. The save step in MIKE 21 was set to 10 minutes.

4.3 MIKE 11 MODEL

4.3.1 Network and Structures

The MIKE 11 network consists of sixteen branches used to model structures with potential significant hydraulic impact, see Figure 4-4. MIKE 11 was not used to model open overland flow paths as had been originally planned during the project inception, as during model development it was decided a 2D representation was sufficient to represent flow path conveyance and geometry.

Structure dimensions were implemented based on the measurements taken during the site visit. Invert levels of structures and their waterway length were estimated from the 1m DEM and aerial photography, respectively. Bridge or culvert headwall railing has not been considered in the structure definition, i.e. it was assumed no blockage of rails occurred during the validation flood event.

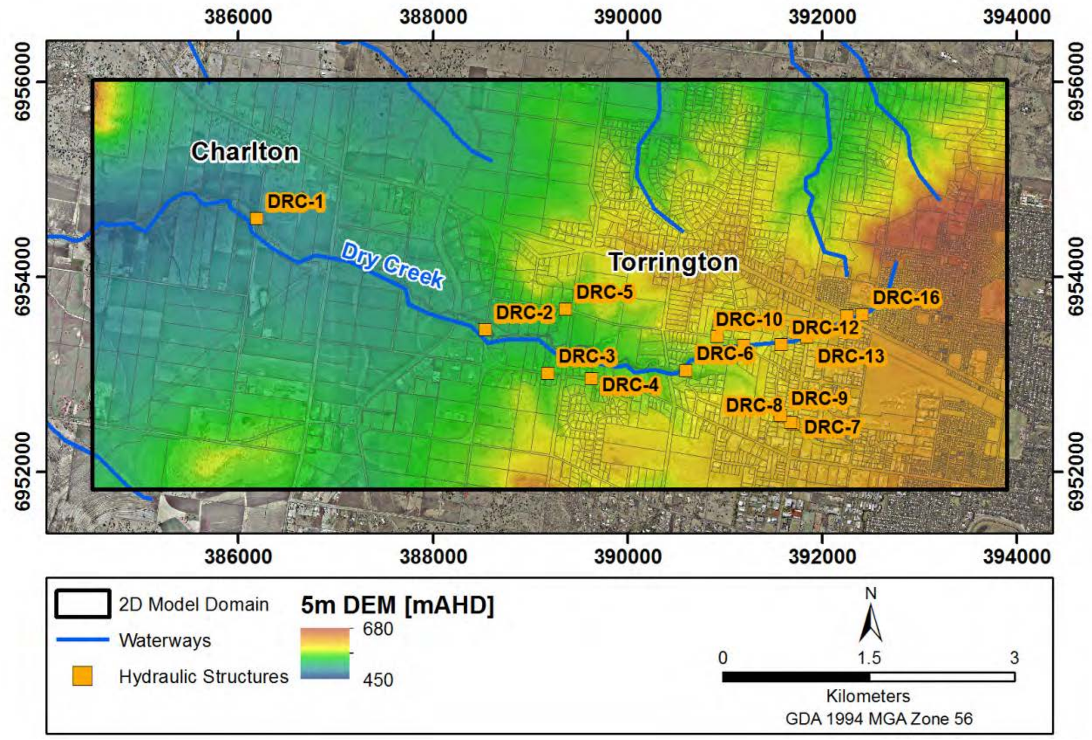

Figure 4-4 Modelled Structures

4.3.2 Cross-Sections

The cross-sections defined at the upstream and downstream ends of each MIKE 11 branch were extracted from the 1 m DEM. Cross-sections upstream and downstream of structures were enlarged if they were smaller than the structure dimensions. This is necessary to ensure a realistic head loss across the structure.

4.3.3 Time Step and Save Step

When MIKE 11 and MIKE 21 models are coupled, MIKE 11 is forced to use the same time step as MIKE 21. The MIKE 11 results were saved every 5 minutes.

4.4 MIKE FLOOD MODEL

A total of sixteen coupling points were implemented in the MIKE FLOOD model. The structures and couple types are listed in Table 4.2; photographs of the structures taken during the site visit are shown in Appendix A. Structures with a waterway length greater than two MIKE 21 grid cells (10m) were modelled using the 'Standard' link type, where structure submergence and overtopping is modelled in MIKE 11 and MIKE 21, respectively. In a 'Structure' link the upstream and downstream linked MIKE 21 cells must be adjacent. This link type was therefore applied to structures with a waterway length of 10 m or less. Structure submergence and overtopping are both modelled in MIKE 11 for this link type.

Table 4.2 Structures Implemented in MIKE FLOOD

Structure	Link Type	Modelled Structure	Height/Width or Diameter	Comments
DRC-1	Structure	Culvert/weir	2.38 m/0.91 m	3 rectangular culverts
DRC-2	Standard	Culvert	1.72 m	4 circular culverts
DRC-3	Standard	Culvert	1.51 m	2 circular culverts
DRC-4	Standard	Culvert	1.05 m	2 circular culverts
DRC-5	Standard	Culvert	1.52 m	1 circular culvert
DRC-6	Structure	Culvert/weir	-	Geometry was specified by a Cross-section
DRC-7	Standard	Culvert	3.05 m/1.23 m	2 rectangular culverts
DRC-8	Structure	Culvert/weir	1.2 m/0.9 m	4 rectangular culverts
DRC-9	Structure	Culvert/weir	0.9 m	2 circular culverts
DRC-10	Standard	Culvert	1.83 m	1 circular culvert
DRC-11	Standard	Culvert	-	5 rectangular culverts of varying dimensions (see Appendix A for more details)
DRC-12	Structure	Culvert/weir	1.48 m	1 circular culvert
DRC-13	Standard	Culvert	0.38 m	2 circular culverts
DRC-14	Structure	Culvert/weir	0.7 m	7 circular culverts
DRC-15	Standard	Culvert	1.82 m	3 circular culverts
DRC-16	Structure	Culvert/weir	1.2 m/0.9 m	3 rectangular culverts

4.4.1 Standard/Structure Link Options

The standard/structure link parameters adopted in the MIKE FLOOD model are summarised in Table 4.3. The momentum factor was set to 1 at all explicit links. An exponential smoothing factor of 0.2 was adopted; however, 0.1 was adopted at two structures to promote stability.

Table 4.3 Adopted Standard/Structure Link Parameters

Parameter	Value/Option
Momentum factor	1
Extrapolation factor	0
Add/Replace Flow	Replace
Depth Adjustment	Yes
Exponential Smoothing Factor	0.1/0.2

5 ASSESSMENT OF MODEL PERFORMANCE

The XP-RAFTS and MIKE FLOOD models were validated for the January 2011 flood event using a joint calibration approach. The fit between modelled and observed flooding is summarised in Table 5.1 and presented in Appendix C.

Table 5.1 Observed and Modelled Flooding

ID	Location	Observed Flood Level (m AHD)	Modelled Flood Level (m AHD)	Difference (m)
1	Corner of Beacon Court and Boundary Street (overtopped side of pipe)	599.65	599.57	-0.08
2	O'Mara Road crossing over Dry Creek (North flood point)	Flooded	Flooded	-
3	O'Mara Road crossing over Dry Creek (South flood point)	Flooded	Flooded	-

The fit between the modelled and observed spot water level (point 1) is very good. For points 2 and 3 where photographs confirm inundation occurred during the January 2011 flood, the model also shows these locations as flooded.

The predicted head losses at the hydraulic structures are shown in Appendix B, Table B.1. Note that the head losses have been calculated as the difference between upstream and downstream peak water levels extracted from either MIKE 11 or MIKE 21 results. At structures coupled to one grid cell as well as structures modelled using the 'Standard' link type, where structure overtopping is modelled in MIKE 21, the 2D results are often more representative of the actual head loss across the structure than the 1D results.

6 DESIGN FLOOD ESTIMATION

6.1 ESTIMATION OF DESIGN DISCHARGES

6.1.1 Overview

The validated XP-RAFTS model was used to estimate design flood discharges in Dry Creek. The XP-RAFTS model design discharge estimates were compared against Rational Method estimates at 6 sub-catchments for consistency.

The following sections detail the design rainfall data (IFD data, temporal patterns, areal reduction factors, rainfall spatial distribution and design rainfall losses) that have been adopted for the Dry Creek catchment. Design flood discharge hydrographs were estimated for a range of storm durations up to 12 hours for the 2, 5, 20, 50, 100, 200 and 500 year Average Recurrence Interval (ARI) and the Probable Maximum Precipitation (PMP) events.

6.1.2 Design Rainfalls for Events up to 100 Year ARI

Rainfall Depth Estimation

Design rainfall intensities for storms of varying durations (15 minutes to 12 hours) for all ARI events up to and including the 100 year ARI were determined at the centroid of the catchment using BOM's AR&R87 IFDs tool (BOM, 2014). Adopted design rainfall intensities are provided in Table 6.1.

Table 6.1 Intensity-Frequency-Duration Data (mm/hour)

Duration	Average Recurrence Interval (years)					
(Hours)	2	5	10	20	50	100
0.25	74.9	92.5	103.3	118.4	139.1	155.4
0.5	53.4	65.1	72.2	82.4	96.1	106.9
1	35.6	43.1	47.7	54.2	63.1	70.0
1.5	27.2	33.0	36.4	41.4	48.1	53.4
2	22.3	27.0	29.8	33.9	39.4	43.7
3	16.6	20.2	22.3	25.3	29.4	32.7
6	10.0	12.1	13.5	15.3	17.9	19.8
9	7.4	9.1	10.1	11.5	13.5	15.0
12	6.1	7.5	8.3	9.5	11.1	12.4

Areal Reduction Factors

An areal reduction factor of 1 was adopted for all design events up to and including the 100 year ARI. This will result in slightly conservative results.

Temporal Patterns

Temporal patterns for design storm events for durations from 15 minutes to 12 hours for design events up to and including the 100 year ARI were adopted from *Australian Rainfall and Runoff*: *A Guide to Flood Estimation* (Pilgrim, 1998).

The Dry Creek catchment is within the transition zone between Zone 2 and Zone 3. For storm durations of 1 hour or less, the temporal patterns for Zones 2 and 3 are identical. Of the events modelled in this study, only the 2 and 5 year ARI events had critical storm durations longer than 1 hour. In this study, Zone 3 temporal patterns were adopted, as the nature of the weather systems that result in large floods in the study area tend to be rainfall from ex-tropical cyclone activity.

Spatial Distribution

The design rainfalls for durations from 15 minutes to 12 hours for all ARIs up to and including the 100 year ARI were estimated at the centroid of the catchment using standard procedures (Pilgrim, 1998), and assumed to be uniform across the catchment.

Rainfall Losses

The initial loss (IL) / continuing loss (CL) method of accounting for rainfall losses was adopted for this study. Book II, Section 3 of *Australian Rainfall and Runoff*: *A Guide to Flood Estimation* (Pilgrim, 1998) recommends design initial loss rates of 15-35mm and a median continuing loss of 2.5mm/h for eastern Queensland, up to and including the 100 year ARI event.

For all design events up to and including the 100 year ARI, initial and continuing losses have been adopted based on the relationship with percentage impervious in Table 3.3. This is consistent with the losses adopted for the January 2011 model validation event (refer Section 3.5.2), and provides results consistent with the Rational Method.

6.1.3 Design Rainfalls for 200 and 500 Year ARI Events

Rainfall Depth Estimation

Design rainfall depths for the 200 and 500 year ARI events were estimated using the approach recommended in *Australian Rainfall and Runoff*: *A Guide to Flood Estimation* (Pilgrim, 1998). CRC-Forge rainfall (DNRM, 2005) was also considered for design rainfalls for the 200 and 500 years ARI events. The CRC-Forge rainfall intensities were found to be 10-15% lower than the ARR rainfall intensities. The higher ARR rainfall intensities were adopted to produce conservative discharge estimates.

The adopted design rainfalls are provided in Table 6.2.

Table 6.2 Intensity-Frequency-Duration Data (mm/hour)

Duration (hours)	Average Recurrence Interval (years)	
	200	500
0.25	175	207
0.5	120	142
1	79	93
1.5	60	71
2	49	59
3	37	44
6	23	27

Areal Reduction Factors

Similar to the methodology for design rainfall events up to the 100 year ARI, an areal reduction factor of 1 was adopted for the 200 year and 500 year ARI design events.

Temporal Patterns

The temporal patterns for the 200 and 500 year ARI design events for all durations up to and including 6 hours were obtained from The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method (BOM, 2003).

Spatial Distribution

The design rainfalls for durations from 15 minutes to 6 hours for the 200 and 500 year ARI events were estimated at the centroid of the catchment using standard procedures (Pilgrim, 1998), and assumed to be uniform across the catchment.

Rainfall Losses

The initial loss rate adopted for the 200 and 500 year ARI design events is 0 mm. The continuing loss rate was not changed.

6.1.4 Probable Maximum Precipitation (PMP) Rainfall Estimates

Rainfall Depth Estimation

PMP rainfall depth estimates for durations up to 6 hours were obtained using the methodology given in The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method (BOM, 2003). The notional AEP of the estimated PMP design event is 1×10^{-7} (or 1 in 10,000,000) (BOM, 2003.

The PMP initial mean rainfall depths and intensities (unadjusted) for durations up to 6 hours are shown in Table 6.3. Design spatial distribution was then applied to the values shown in Table 6.3 using the ellipse methodology described in BOM (2003). A spatially averaged design PMP estimate was then applied uniformly across the catchment.

Table 6.3 PMP Estimates - Initial Mean Rainfall Depths and Intensities

Duration (hours)	PMP Estimate* mm	mm/h
0.25	160	640
0.5	240	480
1	360	360
1.5	460	307
2	540	270
3	650	217
6	870	145

Notes: *Initial Mean Rainfall Depth

Areal Reduction Factors

Areal reduction factors are incorporated in the BOM (2003) PMP rainfall estimation methodology, and as such no ARFs were applied to the rainfalls estimated for the catchment using this method.

Temporal Patterns

Temporal patterns for the PMP design storm events for durations up to 6 hours were obtained from The Estimation of Probable Maximum Precipitation in Australia: Generalised Short Duration Method (BOM, 2003).

Spatial Distribution

Spatial distribution of rainfall is accounted for in the BOM (2003) PMP rainfall estimation methodology.

Rainfall Losses

The initial loss rate adopted for the PMP event is 0 mm. The continuing loss rate was not reduced.

Terrain Category

A roughness fraction of 1 (i.e. 100% roughness) was adopted, based on the topographical data available.

Catchment Elevation Adjustment

An elevation adjustment factor of 1 was adopted based on the mean elevation of the catchment.

Moisture Adjustment

A moisture adjustment factor of 0.808 was adopted based on guidelines given in the BOM (2003) PMP rainfall estimation methodology.

6.1.5 Design Flow Comparison Using Alternative Methods

Design discharges estimated using the XP-RAFTS model were compared against design discharges estimated using the Rational Method for the 10 and 100 year ARIs, at 6 locations in the Dry Creek catchment (refer Figure 3-3 for the locations). Table 3.6 shows the comparison of the XP-RAFTS model and Rational Method peak discharges. Results indicate differences of no more than 20% for the two design events.

6.2 FULLY-DEVELOPED CATCHMENT FLOOD BEHAVIOUR

The validated XP-RAFTS and MIKE FLOOD models were modified to reflect the fully-developed catchment conditions, based on the TRC regional planning scheme (refer Figure 3-4).

- The validated XP-RAFTS model was modified to reflect the developed conditions fraction impervious and catchment PERN 'n' as shown in Table 3.4. All other parameters remained unchanged. The modified XP-RAFTS model was then used to estimate 2 to 100 year ARI design discharges for fully-developed conditions.

- The validated MIKE FLOOD model was modified to reflect the fully-developed conditions hydraulic roughness and design event inflows at the external and internal boundaries. All other model parameters remained unchanged, including bathymetry, flooding and drying depths, eddy viscosity, downstream model boundary, time step and save step; and hydraulic structure setup. The modified MIKE FLOOD model was then used to estimate design peak flood surface elevation, peak water depths and velocities in the Dry Creek catchment for 2 to 100 year ARI design events.

6.3 ESTIMATION OF DESIGN FLOOD LEVELS, DEPTHS AND VELOCITIES

6.3.1 Methodology

The validated MIKE FLOOD model was used to estimate design peak flood surface elevation, peak water depths and velocities in the Dry Creek catchment for the nominated design events for both existing and developed catchment conditions. The validated model was modified to reflect the design event inflows at the external and internal boundaries.

All other model parameters remained unchanged, including bathymetry, hydraulic roughness, flooding and drying depths, eddy viscosity, downstream model boundary, time step and save step; and hydraulic structure setup.

6.3.2 Design Flood Levels and Extents

The XP-RAFTS model was run for a range of storm durations up to 12 hours and the critical durations within the hydraulic model extent were found to be 90 minutes for the 2 and 5 year ARIs. The critical duration for the 10 year ARI was found to be 60 minutes with the exception of the reach upstream of node D1, where it was found to be 25 minutes. The critical duration of the 20, 50 and 100 year ARIs was also found to be 60 minutes, with the exception of the reaches upstream of node D2, where it was found to be 25 minutes. Because the 25 minute critical duration was only for a very small portion of the hydraulic model extent the hydraulic modelling for the 10, 20, 50 and 100 year ARI events was undertaken only for the 60 minutes storm duration.

Maps of predicted flood levels and flood depths for the following design events for the existing-catchment conditions are provided in Appendix D:

- 10 year ARI
- 50 year ARI
- 100 year ARI
- 200 year ARI
- 500 year ARI
- PMP

Tables B4-B10 in Appendix B shows the predicted affluxes at hydraulic structures for the above events.

Hazard category and flood hydraulic category maps for the 100 year ARI and PMP events for the existing-catchment conditions are provided in Appendix F.

6.3.3 Peak Flood Levels and Design Discharges at Representative Locations

Table 6.5 shows predicted peak flood levels and discharges at eight representative locations within the study area for both existing and fully developed catchment conditions. Table 6.4 and Figure 6-1 show details of the reporting locations. Note that most reporting locations coincide with hydraulic structure locations. Water levels at the reporting locations are extracted from MIKE 21. Water levels at hydraulic structures shown in Appendix B are extracted from either MIKE 11 or MIKE 21 as described in Section 5. Water levels extracted from MIKE 11 may differ slightly from those extracted from MIKE 21.

Table 6.4 Details of Reporting Locations

Reporting Location	Description
1	O'Mara Rd.
2	Troys Rd.
3	Carrington Rd.
4	Cumners Rd.
5	Boundary St, corner of Gardner Ct.
6	Boundary St, corner of Beacon Ct.
7	Warrego Highway
8	McDougall St.

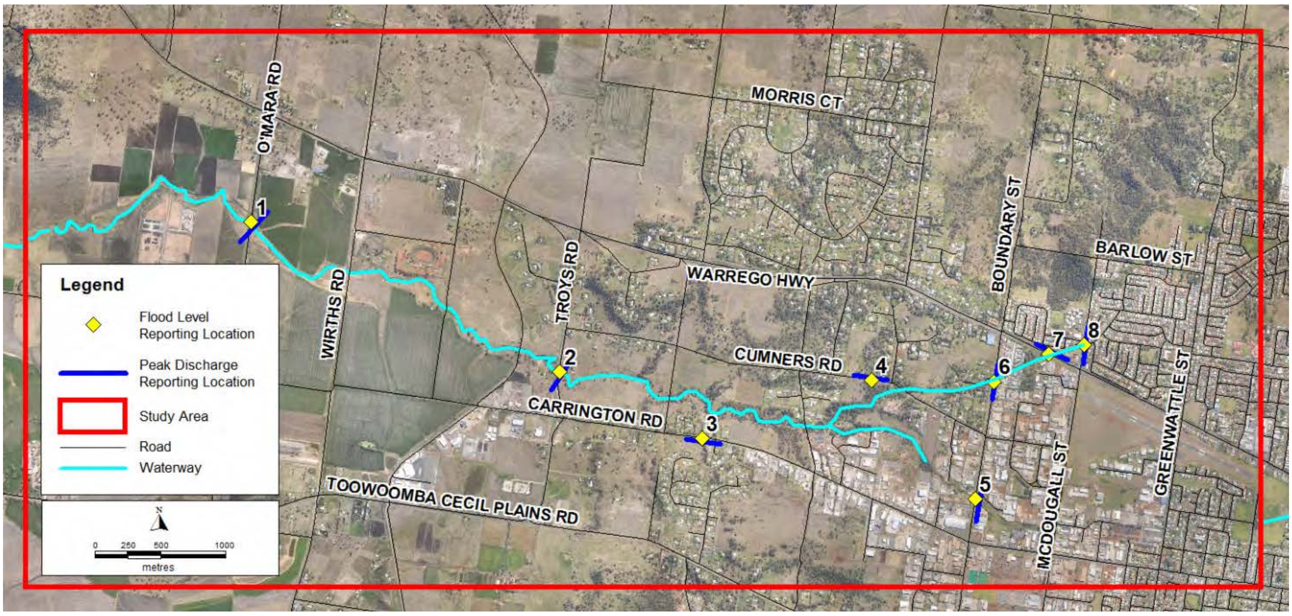

Figure 6-1 Reporting Locations for Peak Flood Levels and Discharges

Modelling of the existing- development conditions design events showed that:

- Design flood levels at all locations (refer Figure 6-1) increase with ARIs up to the 500 year ARI;
- The 500 year ARI design discharges at locations 1 & 2 are 6 to 7 times larger than the 2 year ARI discharges and peak flood levels are 0.90m to 1.02m higher. The 500 year ARI design discharges at locations 4, 5, 6 & 8 are 4 to 5 time larger than the 2 year ARI discharges, while the peak flood levels are 0.3m to 0.7m higher. The flow cross-sections at these locations are shallow and wide and therefore, the peak flood levels increase with increasing design discharges are relatively small;
- Design flood levels at locations 3 & 7 vary significantly with ARIs up to the 500 year ARI. The 500 year ARI design discharges at locations 3 & 7 are 5 and 4 times larger than the 2 year ARI discharges respectively, while the peak flood levels are up to 2.8m and 1.7m higher respectively. This is due to the narrow nature of the channel at these locations, where increasing discharges result in larger increases in peak flood levels; and
- Most of the road crossings in the study area have low flood immunity. Four of the seven major road crossings modelled (i.e. reporting locations 1, 2, 5 and 6) are overtopped in a 2 year ARI design event. The Warrego Highway crossing has flood immunity up to and including a 500 year ARI design event.

Modelling of the fully-developed conditions design events showed that:

- Along the northern tributary of Dry Creek (reporting locations 4, 6, 7 & 8, refer Figure 6-1), fully-developed conditions have increased the degree of urbanisation. This has resulted in a more rapid runoff response. As a result, fully-developed conditions design discharges at locations 4, 6, 7 & 8 are 2% to 33% larger than the corresponding existing-development conditions design discharges. Peak flood levels at these locations are up to 0.16m higher than for the corresponding existing-development conditions;
- Along the upper reach of the southern tributary of Dry Creek (reporting location 5, refer Figure 6-1), a small portion of the catchment south of Toowoomba Airport changes from commercial to residential land use. Along the remainder of the southern tributary, there is an increase in the degree of urbanisation. Fully-developed conditions design discharges at reporting location 5 are 2% to 28% larger than the corresponding existing-development conditions discharges, while peak flood levels are largely unchanged;

- Between the junction of the two Dry Creek tributaries and Troys Road (including at reporting location 3, refer Figure 6-1), the catchment becomes more urbanised. Fully-developed conditions design discharges at location 3 are 38% to 75% larger and peak flood levels are up to 1.13m higher than for the corresponding existing-development conditions; and
- As a result of the changes to runoff response times upstream and the resultant changes to the timing of discharge hydrographs, fully-developed conditions design discharges and peak flood levels at locations 1 & 2 (refer Figure 6-1) are lower than for the corresponding existing-development conditions. Figure 6-2 shows the 100 year ARI existing and full development conditions discharges at location 2. Fully-developed conditions design discharges at locations 1 & 2 are up to 9% lower than the corresponding existing-conditions and peak flood levels are 0.02m to 0.11m lower.

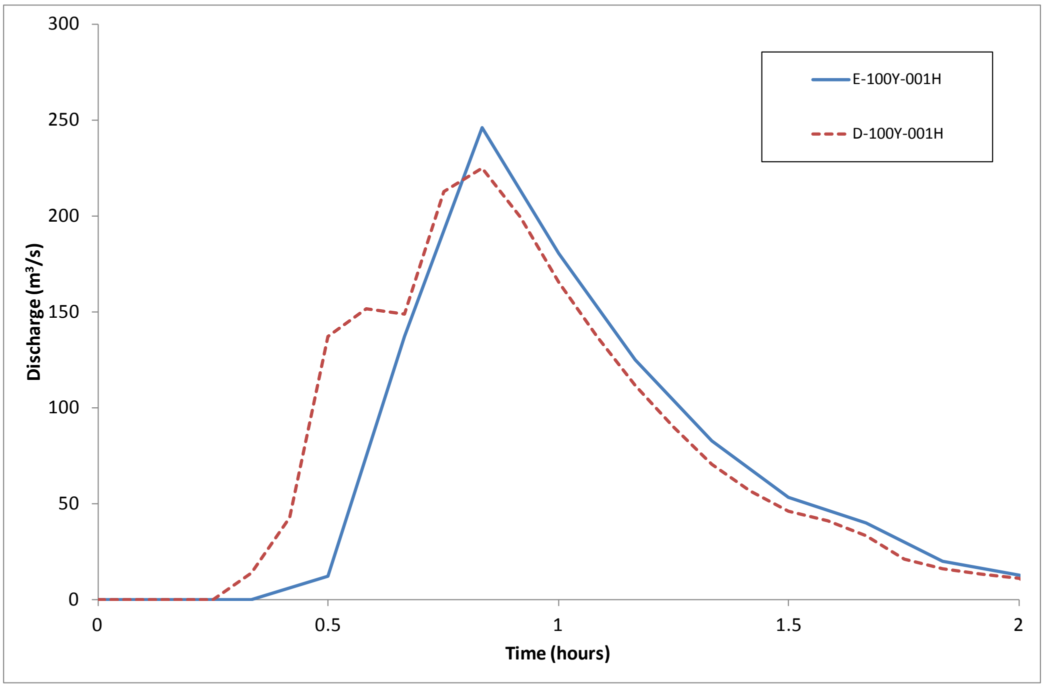

Figure 6-2 Existing and Full Development Conditions Discharges at Reporting Location 2

Table 6.5 Predicted Peak Flood Levels and Discharges at Reporting Locations

ARI (year)	Case Identifier	Reporting Location															
		1 –O'Mara Rd.		2 –Troys Rd.		3 –Carrington Rd.		4 –Cumner Rd.		5 –Boundary St., cnr Gardner Ct.		6 –Boundary St., cnr Beacon Ct.		7 –Warrego Highway		8 –McDougall St.	
		Flood Level (mAHD)	Discharge (m^3/s)	Flood Level (mAHD)	Discharge (m^3/s)	Flood Level (mAHD)	Discharge (m^3/s)	Flood Level (mAHD)	Discharge (m^3/s)	Flood Level (mAHD)	Discharge (m^3/s)	Flood Level (mAHD)	Discharge (m^3/s)	Flood Level (mAHD)	Discharge (m^3/s)	Flood Level (mAHD)	Discharge (m^3/s)
								January 2011 Validation Event									
	DRC-V03-E-Jan2011	486.73	243	521.20	194	553.11	6.8	574.51	13.8	600.94	53.9	599.42	36.7	613.81	21.8	619.89	23.6
								Existing-Development Cases									
2	DRC-V03-E-002Y-090M	486.13	59.4	520.47	49.6	551.40	3.5	573.93	4.4	600.56	18.8	599.23	13.0	613.05	8.0	619.67	7.6
5	DRC-V03-E-005Y-090M	486.33	103	520.74	81.3	552.28	5.2	574.28	6.1	600.66	24.2	599.29	18.7	613.17	12.3	619.77	14.5
10	DRC-V03-E-010Y-001H	486.54	162	521.00	132	553.47	7.5	574.49	12.7	600.93	52.4	599.39	31.6	613.76	21.6	619.87	21.8
20	DRC-V03-E-020Y-001H	486.66	216	521.18	187	554.02	9.7	574.54	14.8	600.99	61.7	599.44	38.4	614.14	25.1	619.91	25.3
50	DRC-V03-E-050Y-001H	486.78	265	521.28	222	554.13	12.3	574.58	16.6	601.03	68.3	599.45	41.6	614.35	27.0	619.94	28.1
100	DRC-V03-E-100Y-001H	486.84	291	521.35	246	554.17	14.5	574.61	18.4	601.07	75.6	599.47	44.9	614.57	28.9	619.97	31.0
200[a]	DRC-V03-E-200Y-001H	486.93	359	521.36	249	554.16	13.5	574.58	16.8	601.01	64.8	599.46	42.4	614.31	25.8	619.94	28.5
500	DRC-V03-E-500Y-001H	487.04	427	521.49	297	554.20	16.3	574.64	20.1	601.08	77.3	599.50	48.3	614.76	29.3	619.99	33.9
PMP	DRC-V03-E-PMP-001H	488.24	1996	523.13	1352	554.74	71.5	575.31	84.6	601.88	337	600.33	245	616.32	145	620.43	142
								Ultimate-Development Cases									
2	DRC-V03-D-002Y-090M	486.02	58.9	520.42	47.7	551.99	5.4	573.98	4.6	600.56	19.1	599.23	13.7	613.07	9.1	619.70	9.3
5	DRC-V03-D-005Y-090M	486.24	97.6	520.71	79.3	553.41	7.9	574.27	8.1	600.68	31.0	599.29	21.0	613.33	15.1	619.79	15.8
10	DRC-V03-D-010Y-001H	486.47	158	520.96	130	554.10	13.1	574.50	13.9	600.92	50.5	599.39	32.2	613.85	22.3	619.91	25.2
20	DRC-V03-D-020Y-001H	486.64	215	521.16	177	554.13	16.2	574.54	16.7	600.99	63.0	599.43	41.9	614.20	25.8	619.96	30.4
50	DRC-V03-D-050Y-001H	486.73	260	521.24	203	554.15	17.9	574.58	19.2	601.03	70.9	599.45	46.8	614.42	27.7	619.99	33.7
100	DRC-V03-D-100Y-001H	486.78	297	521.31	228	554.17	20	574.61	21.7	601.07	79.9	599.47	51.4	614.66	29.5	620.02	37.5

a. Differences between ARR and GSDM temporal patterns result in lower flood level and peak flows in the upper catchment when comparing the 100 and 200 year ARI events.
NOTE: These values are based on results output at 10minute intervals. For some locations or events, the exact peak values may have occurred between reporting intervals.

6.4 DESIGN FLOOD LEVEL SENSITIVITY ANALYSIS

6.4.1 Case 1: Variation in Discharge

Two scenarios investigating a variation in design discharge were modelled for the existing-development conditions for the 100 year ARI, critical duration (60 minute) design event only, as follows:

- A 30% increase in all inflow hydrographs to the hydrodynamic model; and
- A 30% decrease in all inflow hydrographs to the hydrodynamic model.

6.4.2 Case 2: Variation in Roughness

Two scenarios investigating a variation in hydraulic roughness were modelled for the existing-development conditions, 100 year ARI critical duration (60 minute) design event only, as follows:

- A 30% increase in the hydraulic roughness (Manning's 'M'); and
- A 30% decrease in the hydraulic roughness (Manning's 'M').

6.4.3 Case 3: Hydraulic Structure Blockage

One scenario investigating a 50% blockage of hydraulic structures was modelled for the existing development conditions, 100 year ARI critical duration (60 minute) design event only, as follows:

- The width of rectangular culverts was halved while maintaining the existing invert and obvert levels;
- The cross-sectional area of circular culverts was halved by reducing the diameter;
- The pier blockage factor was set to 0.5 for bridge openings;
- Bridge handrails were treated as fully blocked. The blockage of handrails was modelled by raising the road level in the MIKE 21 bathymetry file; and
- Culvert headwall railings were not considered strong enough to withstand a flood debris load (refer photographs in Appendix A) and so were not treated as blocked.

6.4.4 Sensitivity Analysis Results

Table 6.6 shows the peak flood level and discharges estimated in the sensitivity analysis runs at the eight reporting locations (refer Figure 6-1).

Sensitivity analysis results for the variation of the 100 year ARI design discharges showed that:

- A 30% increase in design discharges results in peak flood levels increasing by 0.05m to 0.17m across the reporting locations. The exception being the upstream side of the Warrego Highway, where peak flood levels increase by 0.56m; and
- A 30% decrease in design discharges results in peak flood levels decreasing by 0.06m to 0.25m. Peak flood levels on the upstream side of the Warrego Highway decrease by 0.64m.

Sensitivity analysis results for the variation of hydraulic model roughness for the 100 year ARI design event showed that:

- A 30% increase in roughness results in an increase in peak flood level of up to 0.07m; and
- A 30% decrease in roughness results in a decrease in peak flood level of up to 0.04m.

Sensitivity analysis results for the blockage of hydraulic structures for the 100 year ARI design event showed that:

- A 50% blockage of structures results in the overtopping of the 'Carrington Road 1' and Warrego Highway crossings which were previously not overtopped;
- Design discharge at reporting location 6 (refer Figure 6-1) is reduced by 25% and peak flood level is reduced by 0.07m due to discharge attenuation caused upstream by the Warrego Highway crossing (reporting location 7) immediately upstream ; and
- Peak flood levels at the remaining reporting locations increased by up to 0.07m, while the peak discharge either decreased slightly or remained unchanged.

6.5 CLIMATE CHANGE ANALYSIS

Three scenarios investigating climate change effects were modelled for the existing development conditions for each of the 100, 200 and 500 year critical duration (60 minute) design events, as follows:

- A 2ºC temperature increase by 2050;
- A 3ºC temperature increase by 2070; and
- A 4ºC temperature increase by 2100.

The effects of climate change were simulated assuming a 5% increase in rainfall intensity per degree of global warming.

Table 6.6 shows the peak flood level and discharges estimated in the climate change analysis at the eight reporting locations (refer Figure 4-4). Maps of predicted flood level for the following climate change analysis events are provided in Appendix E:

- 100 year ARI
- 200 year ARI
- 500 year ARI

Results of the climate change scenario analysis showed that:

- For the 100 year ARI climate change scenarios, peak discharges at the reporting locations increase by between 13% and 32%. Peak flood levels increased by up to 0.12m for most reporting locations while peak flood levels upstream of the Warrego Highway increased by up to 0.44m;
- For the 200 year ARI climate change scenarios, peak discharges at the reporting locations increase by between 15% and 22%. Peak flood levels increased up to 0.14m for most reporting locations while peak flood levels upstream of the Warrego Highway increased by up to 0.48m; and
- For the 500 year ARI climate change scenarios, peak discharges at the reporting locations increase by between 15% in and 22%. Peak flood levels increased by up to 0.16m for most reporting locations while peak flood levels upstream of the Warrego Highway increased by up to 0.54m.

Table 6.6 Sensitivity & Climate Change Analysis - Predicted Peak Flood Levels and Discharges at Reporting Locations

ARI (year)	Case Identifier	Reporting Location: 1 –O'Mara Rd. Flood Level (mAHD)	Discharge (m³/s)	2 –Troys Rd. Flood Level (mAHD)	Discharge (m³/s)	3 –Carrington Rd. Flood Level (mAHD)	Discharge (m³/s)	4 –Cumner Rd. Flood Level (mAHD)	Discharge (m³/s)	5 –Boundary St., cnr Gardner Ct. Flood Level (mAHD)	Discharge (m³/s)	6 –Boundary St., cnr Beacon Ct. Flood Level (mAHD)	Discharge (m³/s)	7 –Warrego Highway Flood Level (mAHD)	Discharge (m³/s)	8 –McDougall St. Flood Level (mAHD)	Discharge (m³/s)
								Sensitivity Cases									
100	DRC-V03-E-100Y-001H-Flow-Plus30pct	486.97	396	521.53	314	554.24	18.8	574.71	23.9	601.18	97.1	599.52	54.0	615.13	34.4	620.04	40.3
100	DRC-V03-E-100Y-001H-Flow-Minus30pct	486.64	205	521.14	175	553.92	9.2	574.50	12.9	600.94	53.8	599.41	34.6	613.93	22.7	619.87	21.6
100	DRC-V03-E-100Y-001H-Rough-Plus30pct	486.78	270	521.32	226	554.19	14.5	574.63[b]	18.5[b]	601.14[b]	76.4[b]	599.52	44.4	614.59[b]	29.1[b]	620.03[b]	31.0[b]
100	DRC-V03-E-100Y-001H-Rough-Minus30pct	486.80	323	521.35	248	554.16	14.5	574.61[b]	18.4[b]	601.03[b]	73.7[b]	599.45	45	614.56[b]	28.5[b]	619.94[b]	30.9[b]
100	DRC-V03-E-100Y-001H-Blockage-50pct	486.85	284	521.34	240	554.24	14.5	574.66	18.4	601.12	75.6	599.40	33.5	615.63	20.9	619.97	31.0
								Climate Change Cases									
100	DRC-V03-E-100Y-001H-CC2050	486.88	320	521.43	271	554.20	16.3	574.65	20.3	601.11	82.8	599.49	48.0	614.79	30.8	619.99	33.7
100	DRC-V03-E-100Y-001H-CC2070	486.91	357	521.46	284	554.21	17.2	574.67	21.3	601.13	86.5	599.50	49.6	614.90	31.8	620.01	35.1
100	DRC-V03-E-100Y-001H-CC2100	486.95	383	521.48	294	554.23	18.0	574.68	22.3	601.15	90.1	599.51	51.4	615.01	32.6	620.02	36.6
200[a]	DRC-V03-E-200Y-001H-CC2050	486.99	397	521.43	273	554.18	15.0	574.61	18.6	601.05	71.6	599.48	45.6	614.56	27.6	619.97	31.4
200[a]	DRC-V03-E-200Y-001H-CC2070	487.02	415	521.46	287	554.19	15.8	574.63	19.4	601.07	74.9	599.49	47.1	614.67	28.6	619.98	32.8
200[a]	DRC-V03-E-200Y-001H-CC2100	487.05	434	521.50	301	554.20	16.5	574.65	20.3	601.08	78.2	599.50	48.7	614.79	29.6	620.00	34.3
500	DRC-V03-E-500Y-001H-CC2050	487.10	473	521.57	333	554.23	18.1	574.68	22.1	601.12	85.3	599.52	52.3	615.02	32.0	620.02	37.4
500	DRC-V03-E-500Y-001H-CC2070	487.13	496	521.61	350	554.24	18.9	574.70	23.2	601.14	89.4	599.52	54.0	615.15	32.5	620.03	39.1
500	DRC-V03-E-500Y-001H-CC2100	487.15	516	521.64	363	554.25	19.9	574.71	24.2	601.16	93.4	599.53	56.1	615.30	33.6	620.04	40.8

a. Differences between ARR and GSDM temporal patterns result in lower flood level and peak flows in the upper catchment when comparing the 100 and 200 year ARI events.
b. These results show the influence of afflux at nearby hydraulic structures, leading to increased or decreased discharge as water level increases or decreases.
NOTE: These values are based on results output at 10minute intervals. For some locations or events, the actual peak values may have occurred between reporting intervals.

6.6 COMPARISON WITH PREVIOUS STUDY RESULTS

A single previous study, a storm water management study undertaken by the Toowoomba Regional Council in 2009, was found for comparison with the current study (TRC, 2009). Results of the 2009 study were compared with those of the current study.

The TRC (2009) study used XP-RAFTS and HEC-RAS for hydrological and hydraulic modelling. Peak discharge estimates in the 2009 study were validated against results from a DRAINS model, however very little information was provided on parameters adopted for the validation.

The TRC (2009) was prepared for an area of the Dry Creek catchment covering 2160ha, shown in Figure 6-3. This was slightly larger than the area considered by the current study (1732 ha).

Two locations were identified where XP-RAFTS nodes in the 2009 study corresponded with XP-RAFTS nodes in the current study. Table 6.7 shows a comparison of the estimated peak discharges for the 100 year ARI event at the two locations. The TRC study in 2009 did not report peak flood levels at these locations for existing catchment development conditions.

Table 6.7 Comparison of Peak Discharge at 2 Locations

TRC (2009)		Current Study	
Node[a]	Peak Discharge (m^3/s)	Node[b]	Peak Discharge (m^3/s)
X16	194	D14	230
X20	242	D19	293

a. Refer Figure 6-3
b. Refer Figure 3-1

The TRC 2009 study adopted initial and continuing losses for design events which were higher than those adopted by the current study. The 2009 study adopted initial losses of 1.5 and 30mm and continuing losses of 0 and 5 mm/hr for impervious and pervious areas respectively. Sensitivity analyses undertaken using the 2009 study loss rates with the current XP-RAFTS model produce peak discharge estimates very similar to those in the 2009 study. This indicates that the difference in adopted loss values was the primary reason for the differences in estimated peak discharges between the two studies.

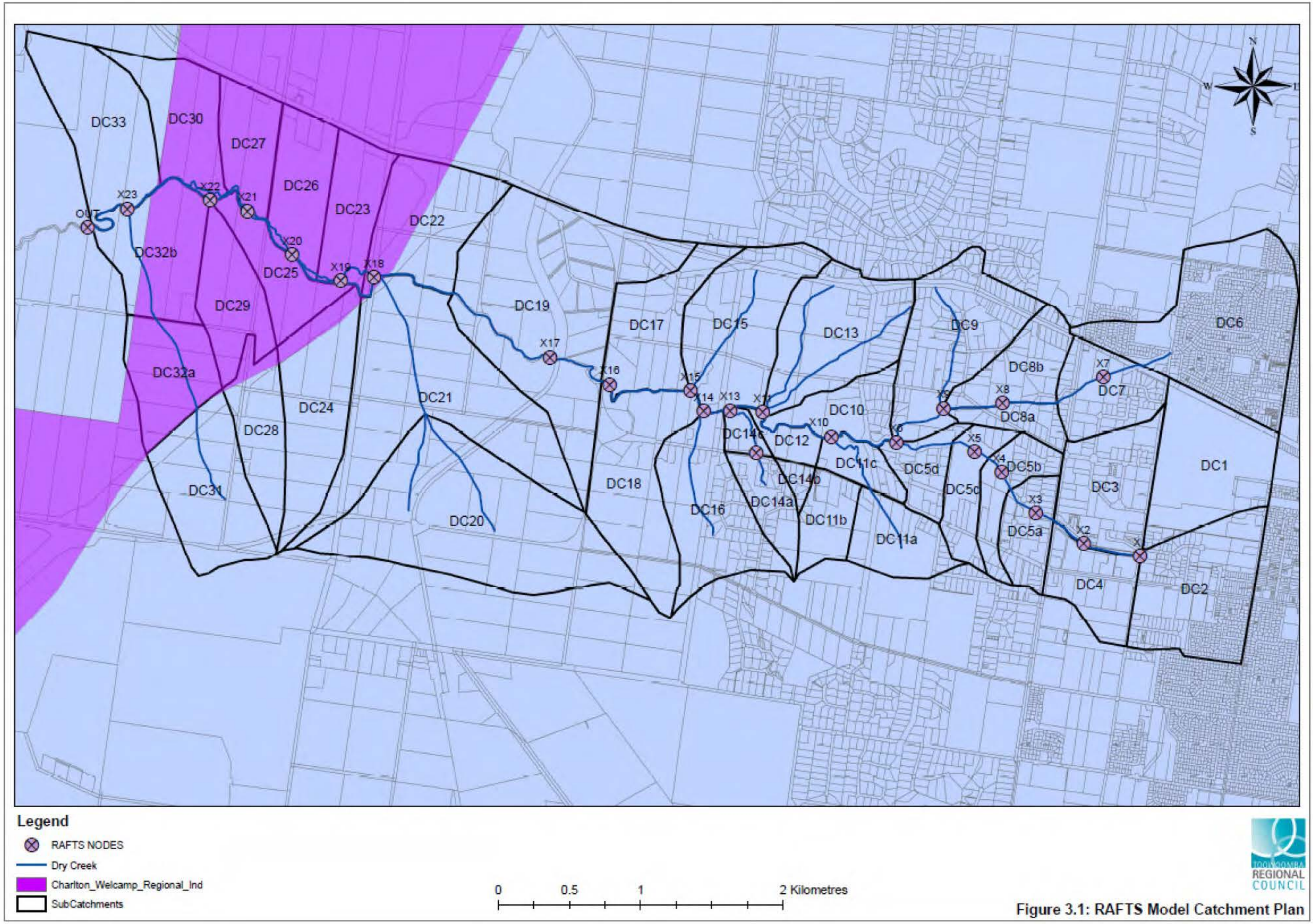

Figure 6-3 XP-RAFTS Sub-catchment Boundaries for TRC (2009)

7 SUMMARY AND CONCLUSIONS

The primary objective of this flood study is to define the nature and extent of flood behaviour in the Dry Creek catchment to enable TRC to develop a Flood Risk Management Study. This will allow TRC to amend the regional planning scheme to reflect flood requirements of the State Planning Policy and the recommendations of the Queensland Commission of Inquiry.

A hydrologic (XP-RAFTS) model and a coupled 1D/2D (MIKE FLOOD) hydraulic model have been successfully developed and validated for the Dry Creek study area. The models were validated for the January 2011 flood event using a joint calibration approach. The validation results were demonstrated graphically. A good fit between the modelled and observed assumed flood peak spot water level was achieved. The locations known to have been inundated during the January 2011 flood were also reproduced by the hydraulic model.

The hydraulic model results show that the Dry Creek catchment was not significantly affected by flooding during the January 2011 event. The flooding in the upstream part of the catchment was contained within the major overland flow paths and the Dry Creek channel. However, some rural areas in the downstream part of the catchment were inundated. Boundary Street, Wirth Road and O'Mara Road were cut off during the event.

Peak flood surface elevation and peak water depth maps are included in Appendix C of this report. Digital mapping and model data files were also delivered as part of the study.

This flood study has assessed historical event inundation in the defined creek system identified by the available LiDAR dataset, and field observations of the catchment. However it is noted that the model developed for this study does not include the stormwater pipe network system in the upper parts of the catchment between Toowoomba Airport and Torrington. There may be constraints within that system which would only be identified by detailed pipe network modelling, which is outside the scope of the current study.

The validated MIKE FLOOD model was used to estimate design peak flood surface elevations, peak water depths and velocities in the Dry Creek catchment for the 2, 5, 10, 20, 50, 100, 200 and 500 year ARI and PMF events. The sensitivity of predicted 100 year ARI model results was tested to assess the impacts of changes to adopted design discharges, hydraulic roughness and blockage of hydraulic structures. Additionally, the potential impact on flood behaviour was assessed for three climate change scenarios for the 100, 200 and 500 year ARI design events.

The study results show that:

- The 500 year ARI design discharges at the O'Mara Road and Troys Road reporting locations are up to 7 times larger than the 2 year ARI discharges and peak flood levels are up to 1.02m higher;
- The 500 year ARI design discharges at the Cumners Road, Boundary Street and McDougall Street reporting locations are up to 5 time larger than the 2 year ARI discharges, while the peak flood levels are up to 0.71m higher;
- Design flood levels at the Carrington Road and Warrego Highway reporting locations vary significantly with ARIs up to the 500 year ARI. The 500 year ARI design discharges at these locations are up to 5 times larger than the 2 year ARI discharges, while the peak flood levels are up to 2.8m higher;

- Most of the road crossings in the study area have low flood immunity. Four of the seven major road crossings modelled are overtopped in a 2 year ARI design event. The Warrego Highway crossing has flood immunity up to and including a 500 year ARI design event;
- Along the northern tributary of Dry Creek, fully-developed conditions have increased the degree of urbanisation. This has resulted in a more rapid runoff response. As a result, fully-developed conditions design discharges at locations 4, 6, 7 & 8 are 2% to 33% larger than the corresponding existing- development conditions design discharges. Peak flood levels at these locations are up to 0.16m higher than for the corresponding existing-development conditions;
- Along the upper reach of the southern tributary of Dry Creek, a small portion of the catchment south of Toowoomba Airport changes from commercial to residential land use. Along the remainder of the southern tributary, there is an increase in the degree of urbanisation. Fully-developed conditions design discharges at reporting location 5 are 2% to 28% larger than the corresponding existing-development conditions discharges, while peak flood levels are largely unchanged;
- Between the junction of the two Dry Creek tributaries and Troys Road the catchment becomes more urbanised. Fully-developed conditions design discharges at location 3 are 38% to 75% larger and peak flood levels are up to 1.13m higher than for the corresponding existing-development conditions; and
- As a result of the changes to runoff response times upstream and the resultant changes to the timing of discharge hydrographs, fully-developed conditions design discharges and peak flood levels at locations 1 & 2 are lower than for the corresponding existing-development conditions. Fully-developed conditions design discharges at locations 1 & 2 are up to 9% lower than the corresponding existing-conditions and peak flood levels are 0.02m to 0.11m lower.

Sensitivity analysis results for the 100 year ARI design event indicate the following:

- A 30% increase and decrease in design discharges results in peak flood levels increasing and decreasing by up to 0.17m and 0.25m respectively across the reporting locations. The exception being the upstream side of the Warrego Highway, where peak flood levels increase and decrease by 0.56m and 0.64m respectively;
- A 30% increase and decrease in roughness results in peak flood levels increasing and decreasing by up to 0.07m and 0.04m respectively; and
- A 50% blockage of structures results in the overtopping of the 'Carrington Road 1' and Warrego Highway crossings which were previously not overtopped. Design discharge at Boundary St, corner of Beacon Ct (reporting location 6) is reduced by 25% and peak flood level is reduced by 0.07m due to discharge attenuation caused upstream by the Warrego Highway crossing (reporting location 7) immediately upstream. Peak flood levels at the remaining reporting locations increased by up to 0.07m, while the peak discharge either decreased slightly or remained unchanged.

Climate change scenario results indicate the following:

- For all of the climate change scenarios, peak discharges increase at the reporting locations; and
- Peak flood levels for the 100 year, 200 year and 500 year ARI events increase by up to 0.44m, 0.48m and 0.54m respectively at the reporting locations.

Based on modelling results, the predicted design discharges and peak flood levels at some locations along the modelled lower reach of Dry Creek (e.g. at Troys Road) under full-developed conditions are lower than under existing conditions. When these results are used for future planning purposes, caution should be exercised before applying potentially reduced flood levels when considering proposed development within this catchment.

8 RECOMMENDATIONS

The following recommendations should be considered to improve the accuracy of the model performance.

1. Detailed calibration for at least two historical flood events should be performed to improve the model accuracy if more data becomes available. As the model has only been validated against one spot level and two locations of known flooding; the model results should be used with caution.
2. Should a flood event occur it is recommended that as a minimum peak flood levels and extents are collected to further aid the validity of the model.
3. Topographic survey of key structures and flow control thresholds within the catchment should be carried out to validate the assumptions made in developing the hydraulic model.

9 REFERENCES

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Toowoomba Regional Council, (2013)	SP 051 Flood Studies. Local Buy Contract BUS 226-0212. Engineering Consultancy Services. Work Package 8 – 2D Flood Studies for: Cotswold Hills (Gowrie Creek Catchment), Dry Creek (Charlton and Torrington), Westbrook and Westbrook Creek. Project Brief.
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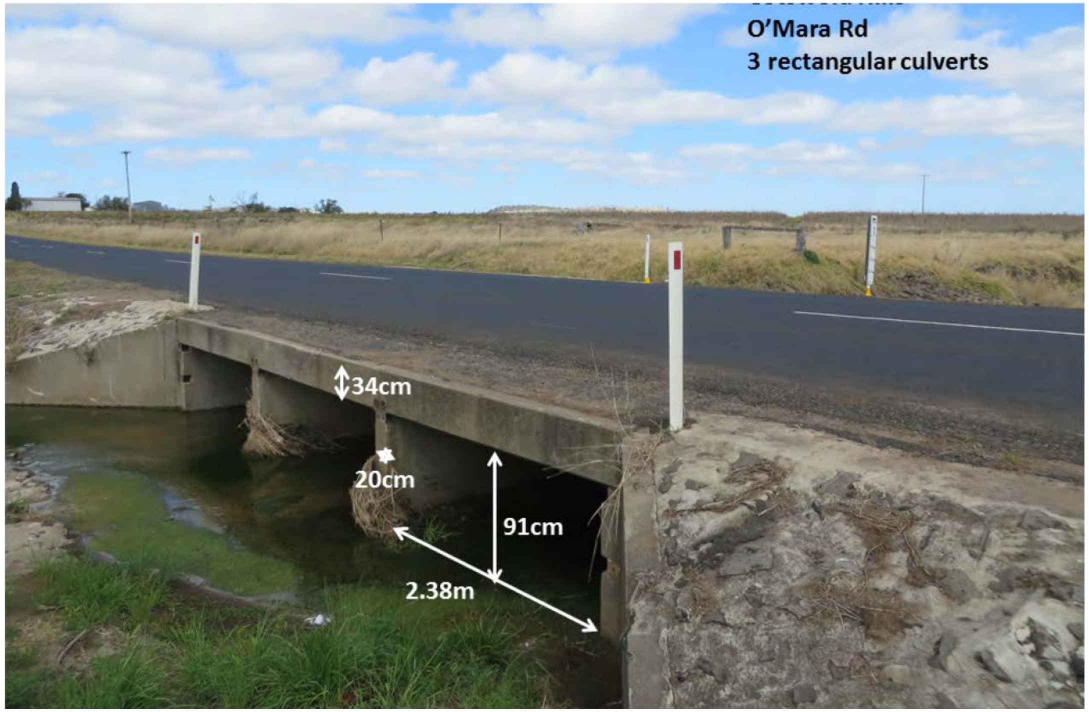
10 DISCLAIMER

Information used is the best information available at this time for the purposes of this study. Marks observed and other anecdotal information obtained after flood events have been obtained from a range of sources and have varying degrees of uncertainty.

While every care is taken by the Toowoomba Regional Council (TRC) to ensure the accuracy of the data used in the study and published in the report, Toowoomba Regional Council makes no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and disclaim all responsibility and all liability whether in contract, negligence or otherwise for all expenses, losses, damages (including indirect or consequential damage) and costs which may be incurred in any way and for any reason as a result of data being inaccurate or incomplete.

APPENDIX A

STRUCTURE ATTRIBUTES

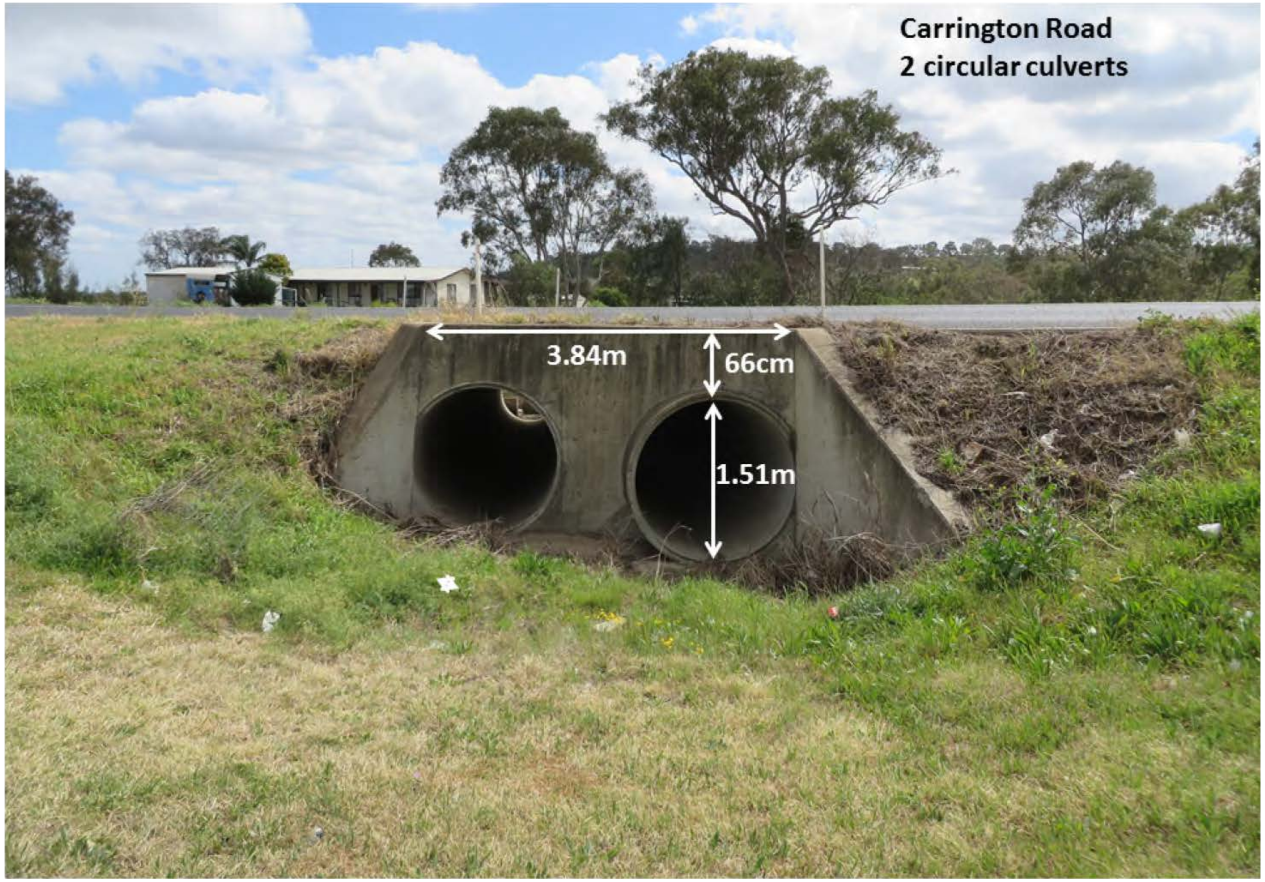


DRC-1
O’Mara Road (Dry Creek crossing)

Location:
-27.52763
151.847545

DRC-2
Troy Road (Dry Creek crossing)

Location:
-27.538123
151.871197



DRC-3
Carrington Road 1

Location:
-27.542207
151.877677

DRC-4
Carrington Road 2

Location:
-27.542756
151.882167

DRC-5
Graham Road

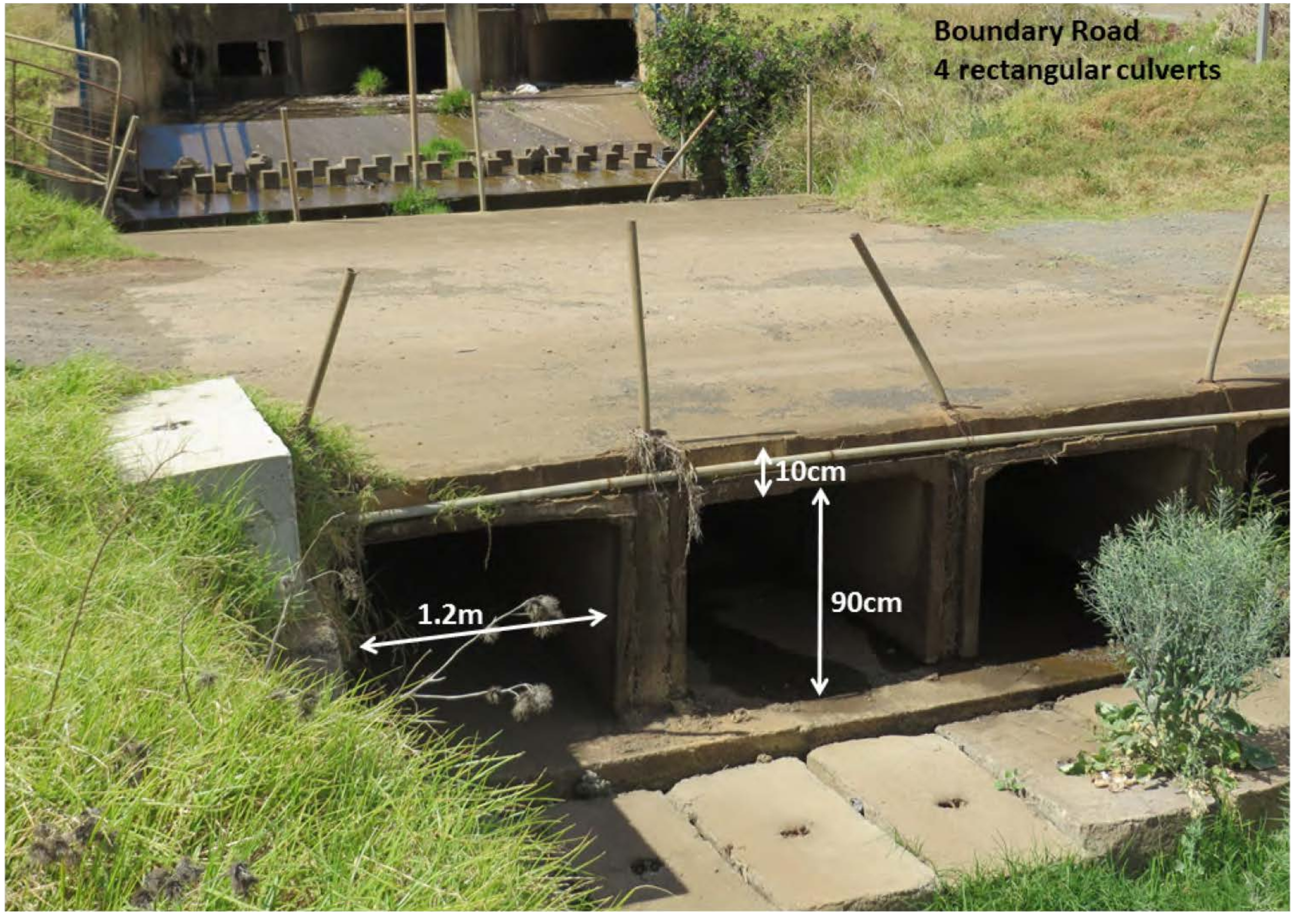
Location:
-27.536249
151.879458

DRC-6
Allen Court (Private Property)

Location:
-27.542076
151.89208

DRC-7
Boundary Road

Location:
-27.547068
151.903201



DRC-8
Adjacent to Boundary Road

Location:
-27.546918
151.902938

DRC-9
Adjacent to Boundary Road

Location:
-27.546328
151.901819

DRC-10
Cumner Road

Location:
-27.538899
151.895181

DRC-11
Cumner Road (near Joe Allen Park)

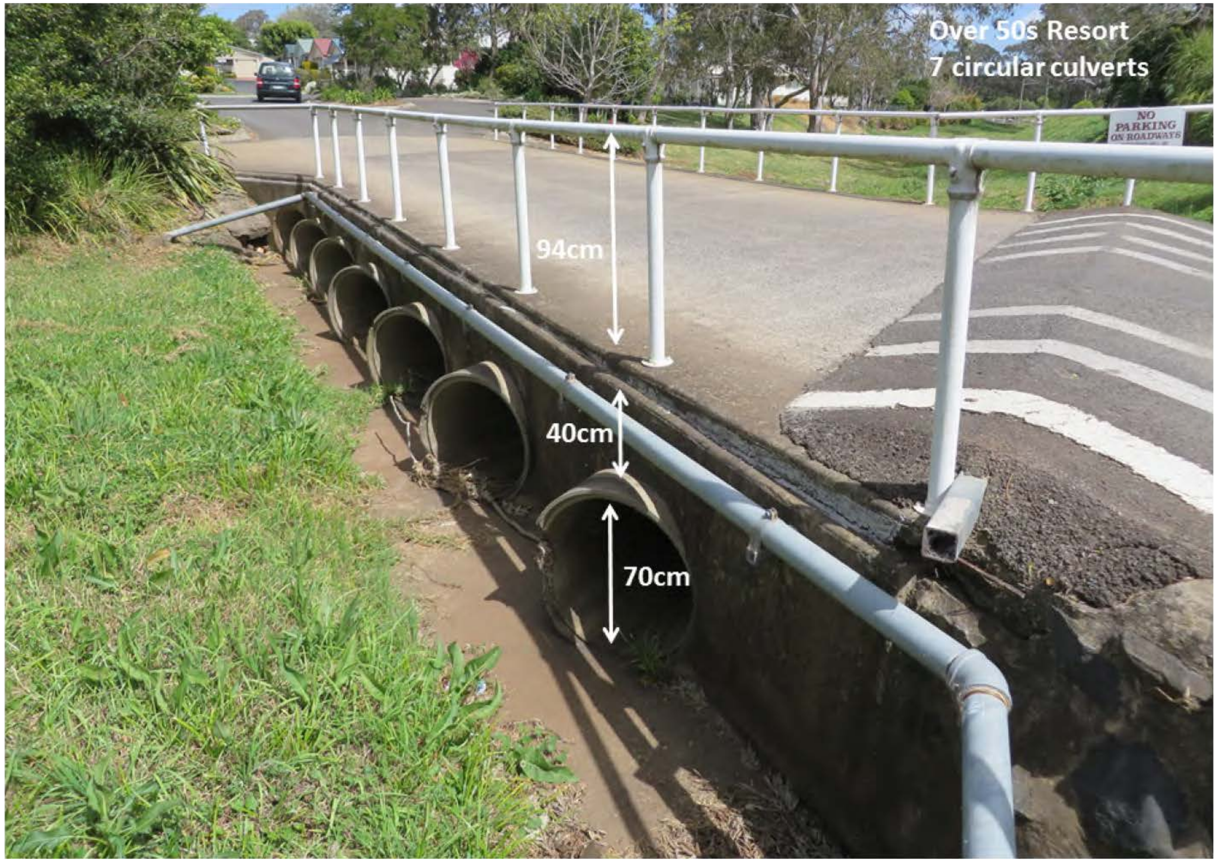
Location:
-27.539831
151.898062

DRC-12
Beacon Court (Private Property)

Location:
-27.539591
151.902353

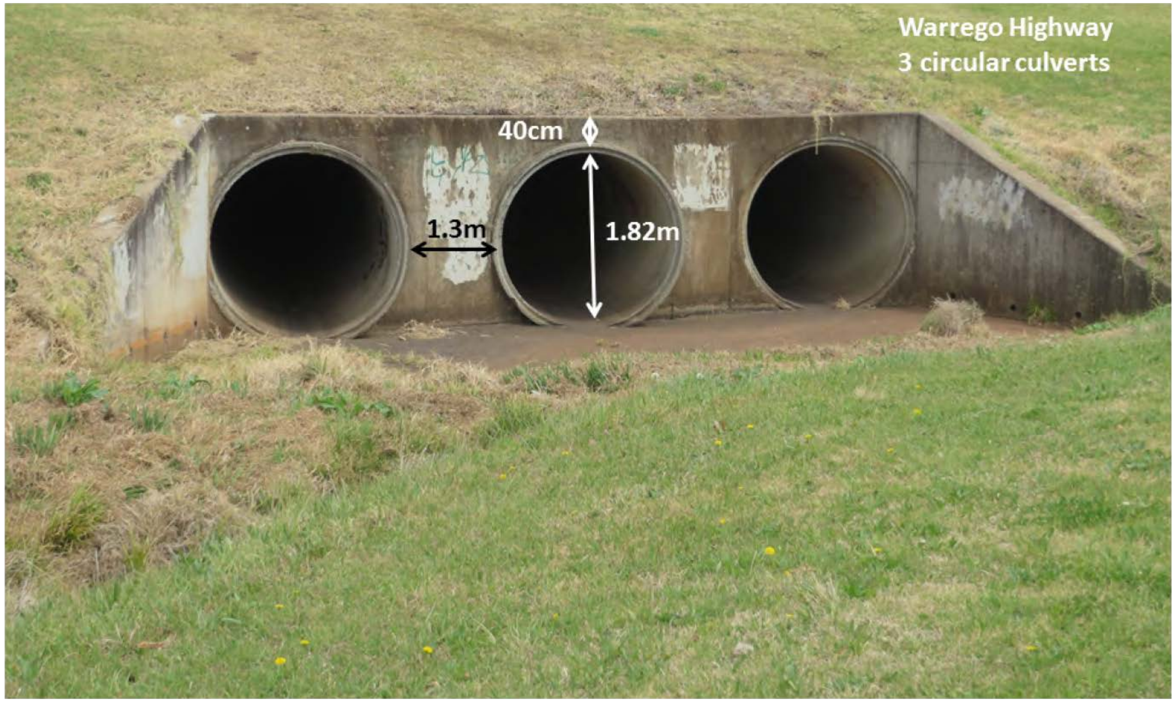
DRC-13
Boundary Road (near corner of Beacon Court)

Location:
-27.539106
151.904657



DRC-14
Crossing over Dry Creek in
Over 50's Resort

Location:
-27.538323
151.906194



DRC-15
Warrego Highway Crossing over Dry Creek (near Armstrong Street Park)

Location:
-27.537194
151.90886

DRC-16
Footbridge, Armstrong Street Park

Location:
-27.537051
151.910443

APPENDIX B

STRUCTURE HEAD LOSSES, DISCHARGES AND VELOCITIES FOR VALIDATION AND DESIGN EVENTS

Table B.1 Head Losses, Discharges and Velocities at Structures for the January 2011 Validation Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m^3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	486.73	485.70	486.47	484.40	485.31	0.26[b]	17.7	2.67	✓
DRC-2	521.20	520.30	520.79	516.45 US 515.40 DS	518.17 US 517.12 DS	0.41[b]	55.4	5.96	✓
DRC-3	543.18	543.90	542.07	541.80	543.31	1.11[b]	6.1	2.73	
DRC-4	553.11	554.00	550.36	550.00	551.05	2.75[b]	6.8	3.95	
DRC-5	544.45	544.30	544.32	542.30	543.82	0.13[b]	5.2	3.43	✓
DRC-6	558.02	560.40	557.95	555.55	559.60	0.07[a]	58.6	2.26	
DRC-7	600.94	600.30	600.79	598.61	599.84	0.15[b]	18.4	2.46	✓
DRC-8	600.07	598.30	599.88	597.45	598.35	0.19[a]	12.7	2.74	✓
DRC-9	595.67	594.35	595.60	593.50	594.40	0.07[a]	2.3	2.25	✓
DRC-10	574.51	574.20	574.44	572.30 US 572.00 DS	574.13 US 573.83 DS	0.07[b]	6.9	3.46	✓
DRC-11	577.35	577.20	577.29	575.17	576.72	0.06[a]	22.5	1.29	✓
DRC-12	591.62	590.70	591.45	589.00	590.48	0.17[b]	6.7	4.19	✓
DRC-13	599.42	599.00	599.21	598.30	598.68	0.21[b]	0.4	1.91	✓
DRC-14	604.18	603.50	603.91	602.40	603.10	0.27[a]	5.8	2.12	✓
DRC-15	613.90	615.40	612.66	611.60 US 611.45 DS	613.42 US 613.27 DS	1.24[a]	22.1	3.57	
DRC-16	615.23	615.24	614.88	614.10	615.00	0.35[b]	8.0	2.79	

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. These values are based on results output at 10minute intervals. For some locations in the upper catchment, the instantaneous peak values may not have been identified accurately.

Table B.2 Head Losses, Discharges and Velocities at Structures for the 2 Year ARI Design Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	486.13	485.70	485.85	484.40	485.31	0.28[b]	16.7	2.55	✓
DRC-2	520.47	520.30	520.34	516.45 US 515.40 DS	518.17 US 517.12 DS	0.13[b]	46.9	5.09	✓
DRC-3	542.64	543.90	541.90	541.80	543.31	0.74[b]	2.7	2.08	
DRC-4	551.40	554.00	550.25	550.00	551.05	1.15[b]	3.5	2.63	
DRC-5	543.56	544.30	542.23	542.30	543.82	1.33[b,5]	2.5	2.54	
DRC-6	557.03	560.40	556.93	555.55	559.60	0.10[a]	20.7	2.36	
DRC-7	600.56	600.30	600.53	598.61	599.84	0.03[b]	15.5	2.07	✓
DRC-8	599.44	598.30	599.35	597.45	598.35	0.09[a]	8.4	1.80	✓
DRC-9	594.91	594.35	594.83	593.50	594.40	0.08[a]	2.2	2.25	✓
DRC-10[4]	573.93	574.20	572.49	572.30 US 572.00 DS	574.13 US 573.83 DS	1.44[b,5]	4.3	2.87	
DRC-11[4]	576.59	577.20	576.57	575.17	576.72	0.02[a]	15.0	0.97	
DRC-12[4]	591.23	590.70	591.19	589.00	590.48	0.04[b]	5.6	3.70	✓
DRC-13[4]	599.23	599.00	599.01	598.30	598.68	0.22[b]	0.4	1.91	✓
DRC-14[4]	603.73	603.50	603.47	602.40	603.10	0.26[a]	5.2	1.93	✓
DRC-15[4]	612.81	615.40	612.34	611.60 US 611.45 DS	613.42 US 613.27 DS	0.47[a]	8.3	2.48	
DRC-16[4]	614.94	615.24	614.56	614.10	615.00	0.38[b]	5.0	2.38	

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. These values are based on results output at 10minute intervals. For some locations in the upper catchment, the instantaneous peak values may not have been identified accurately.
5. Large head losses likely due to orifice flow before the structure is drowned

Table B.3 Head Losses, Discharges and Velocities at Structures for the 5 Year ARI Design Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	486.33	485.70	486.04	484.40	485.31	0.29[b]	17.4	2.65	✓
DRC-2	520.74	520.30	520.49	516.45 US 515.40 DS	518.17 US 517.12 DS	0.25[b]	50.6	5.45	✓
DRC-3	542.91	543.90	541.98	541.80	543.31	0.93[b]	4.2	2.39	
DRC-4	552.28	554.00	550.32	550.00	551.05	1.96[b]	5.6	3.45	
DRC-5	543.95	544.30	542.30	542.30	543.82	1.65[b,5]	4.1	3.06	
DRC-6	557.58	560.40	557.52	555.55	559.60	0.06[a]	29.5	2.26	
DRC-7	600.66	600.30	600.60	598.61	599.84	0.06[b]	17.6	2.35	✓
DRC-8	599.72	598.30	599.59	597.45	598.35	0.13[a]	10.4	2.30	✓
DRC-9	595.24	594.35	595.16	593.50	594.40	0.08[a]	2.3	2.37	✓
DRC-10[4]	574.28	574.20	574.28	572.30 US 572.00 DS	574.13 US 573.83 DS	0.00[b]	6.1	3.27	✓
DRC-11[4]	576.84	577.20	576.81	575.17	576.72	0.03[a]	19.0	1.09	
DRC-12[4]	591.39	590.70	591.29	589.00	590.48	0.10[b]	6.1	3.89	✓
DRC-13[4]	599.29	599.00	599.09	598.30	598.68	0.20[b]	0.4	1.91	✓
DRC-14[4]	603.88	603.50	603.52	602.40	603.10	0.36[a]	6.3	2.32	✓
DRC-15[4]	613.24	615.40	612.70	611.60 US 611.45 DS	613.42 US 613.27 DS	0.54[a]	14.0	2.95	
DRC-16[4]	615.10	615.24	614.73	614.10	615.00	0.37[b]	6.3	2.59	

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. These values are based on results output at 10minute intervals. For some locations in the upper catchment, the instantaneous peak values may not have been identified accurately.
5. Large head losses likely due to orifice flow before the structure is drowned

Table B.4 Head Losses, Discharges and Velocities at Structures for the 10 Year ARI Design Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	486.54	485.70	486.26	484.40	485.31	0.28[b]	17.5	2.66	✓
DRC-2	521.00	520.30	520.66	516.45 US 515.40 DS	518.17 US 517.12 DS	0.34[b]	53.5	5.76	✓
DRC-3	543.20	543.90	542.08	541.80	543.31	1.12[b]	6.2	2.76	
DRC-4	553.47	554.00	550.38	550.00	551.05	3.09[b]	7.5	4.35	
DRC-5	544.44	544.30	544.32	542.30	543.82	0.12[b]	5.1	3.41	✓
DRC-6	557.85	560.40	557.78	555.55	559.60	0.07[a]	49.7	2.60	
DRC-7	600.93	600.30	600.79	598.61	599.84	0.14[b]	18.4	2.45	✓
DRC-8	600.06	598.30	599.88	597.45	598.35	0.18[a]	12.6	2.72	✓
DRC-9	595.67	594.35	595.60	593.50	594.40	0.07[a]	2.2	2.16	✓
DRC-10[4]	574.49	574.20	574.43	572.30 US 572.00 DS	574.13 US 573.83 DS	0.06[b]	6.8	3.43	✓
DRC-11[4]	577.23	577.20	577.18	575.17	576.72	0.05[a]	22.3	1.28	✓
DRC-12[4]	591.54	590.70	591.39	589.00	590.48	0.15[b]	6.6	4.11	✓
DRC-13[4]	599.39	599.00	599.18	598.30	598.68	0.21[b]	0.4	1.89	✓
DRC-14[4]	604.10	603.50	603.73	602.40	603.10	0.37[a]	6.5	2.39	✓
DRC-15[4]	613.79	615.40	612.74	611.60 US 611.45 DS	613.42 US 613.27 DS	1.05[a]	21.1	3.49	
DRC-16[4]	615.22	615.24	614.87	614.10	615.00	0.35[b]	7.9	2.78	

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. These values are based on results output at 10minute intervals. For some locations in the upper catchment, the instantaneous peak values may not have been identified accurately.

Table B.5 Head Losses, Discharges and Velocities at Structures for the 20 Year ARI Design Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	486.66	485.70	486.38	484.40	485.31	0.28[b]	17.6	2.67	✓
DRC-2	521.18	520.30	520.77	516.45 US 515.40 DS	518.17 US 517.12 DS	0.41[b]	55.1	5.93	✓
DRC-3	543.38	543.90	542.15	541.80	543.31	1.23[b]	7.9	3.02	
DRC-4	554.02	554.00	550.73	550.00	551.05	3.29[b]	8.3	4.77	✓
DRC-5	544.50	544.30	544.32	542.30	543.82	0.18[b]	5.3	3.48	✓
DRC-6	557.78	560.40	557.58	555.55	559.60	0.20[a]	60.9	2.85	
DRC-7	600.99	600.30	600.83	598.61	599.84	0.16[b]	18.7	2.50	✓
DRC-8	600.21	598.30	600.00	597.45	598.35	0.21[a]	13.3	2.97	✓
DRC-9	595.89	594.35	595.82	593.50	594.40	0.07[a]	2.4	2.17	✓
DRC-10[4]	574.54	574.20	574.46	572.30 US 572.00 DS	574.13 US 573.83 DS	0.08[b]	7.1	3.48	✓
DRC-11[4]	577.40	577.20	577.34	575.17	576.72	0.06[a]	22.5	1.29	✓
DRC-12[4]	591.66	590.70	591.48	589.00	590.48	0.18[b]	6.8	4.22	✓
DRC-13[4]	599.44	599.00	599.23	598.30	598.68	0.21[b]	0.4	1.90	✓
DRC-14[4]	604.16	603.50	603.78	602.40	603.10	0.38[a]	6.7	2.46	✓
DRC-15[4]	614.16	615.40	612.66	611.60 US 611.45 DS	613.42 US 613.27 DS	1.50[a]	24.6	3.77	
DRC-16[4]	615.26	615.24	614.93	614.10	615.00	0.33[b]	8.6	2.85	✓

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. These values are based on results output at 10minute intervals. For some locations in the upper catchment, the instantaneous peak values may not have been identified accurately.

Table B.6 Head Losses, Discharges and Velocities at Structures for the 50 Year ARI Design Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	486.78	485.70	486.52	484.40	485.31	0.26[b]	17.6	2.67	✓
DRC-2	521.28	520.30	520.85	516.45 US 515.40 DS	518.17 US 517.12 DS	0.43[b]	56.2	6.05	✓
DRC-3	543.62	543.90	542.23	541.80	543.31	1.39[b]	9.5	3.29	
DRC-4	554.13	554.00	550.86	550.00	551.05	3.27[b]	8.3	4.81	✓
DRC-5	544.54	544.30	544.33	542.30	543.82	0.21[b]	5.5	3.54	✓
DRC-6	558.00	560.40	557.92	555.55	559.60	0.08[a]	69.4	2.89	
DRC-7	601.03	600.30	600.86	598.61	599.84	0.17[b]	19.0	2.53	✓
DRC-8	600.29	598.30	600.07	597.45	598.35	0.22[a]	13.7	2.93	✓
DRC-9	596.02	594.35	595.95	593.50	594.40	0.07[a]	2.3	2.24	✓
DRC-10[4]	574.58	574.20	574.49	572.30 US 572.00 DS	574.13 US 573.83 DS	0.09[b]	7.3	3.54	✓
DRC-11[4]	577.48	577.20	577.42	575.17	576.72	0.06[a]	22.6	1.29	✓
DRC-12[4]	591.70	590.70	591.52	589.00	590.48	0.18[b]	6.9	4.27	✓
DRC-13[4]	599.45	599.00	599.24	598.30	598.68	0.21[b]	0.4	1.90	✓
DRC-14[4]	604.20	603.50	603.81	602.40	603.10	0.39[a]	6.8	2.51	✓
DRC-15[4]	614.37	615.40	612.58	611.60 US 611.45 DS	613.42 US 613.27 DS	1.79[a]	26.3	3.92	
DRC-16[4]	615.30	615.24	614.96	614.10	615.00	0.34[b]	8.9	2.88	✓

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. These values are based on results output at 10minute intervals. For some locations in the upper catchment, the instantaneous peak values may not have been identified accurately.

Table B.7 Head Losses, Discharges and Velocities at Structures for the 100 Year ARI Design Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	486.84	485.70	486.58	484.40	485.31	0.26[b]	17.7	2.67	✓
DRC-2	521.35	520.30	520.90	516.45 US 515.40 DS	518.17 US 517.12 DS	0.45[b]	56.9	6.12	✓
DRC-3	543.74	543.90	542.26	541.80	543.31	1.48[b]	10.3	3.44	
DRC-4	554.17	554.00	550.87	550.00	551.05	3.30[b]	8.4	4.84	✓
DRC-5	544.58	544.30	544.33	542.30	543.82	0.25[b]	5.6	3.59	✓
DRC-6	558.02	560.40	557.94	555.55	559.60	0.08[a]	69.6	2.76	
DRC-7	601.07	600.30	600.89	598.61	599.84	0.18[b]	19.1	2.54	✓
DRC-8	600.39	598.30	600.16	597.45	598.35	0.23[a]	14.0	2.98	✓
DRC-9	596.14	594.35	596.08	593.50	594.40	0.06[a]	2.3	2.26	✓
DRC-10[4]	574.61	574.20	574.51	572.30 US 572.00 DS	574.13 US 573.83 DS	0.10[b]	7.6	3.61	✓
DRC-11[4]	577.55	577.20	577.48	575.17	576.72	0.07[a]	22.9	1.31	✓
DRC-12[4]	591.74	590.70	591.55	589.00	590.48	0.19[b]	7.0	4.31	✓
DRC-13[4]	599.47	599.00	599.26	598.30	598.68	0.21[b]	0.4	1.91	✓
DRC-14[4]	604.23	603.50	603.82	602.40	603.10	0.41[a]	7.0	2.55	✓
DRC-15[4]	614.55	615.40	612.62	611.60 US 611.45 DS	613.42 US 613.27 DS	1.93[a]	27.8	4.05	
DRC-16[4]	615.33	615.24	615.00	614.10	615.00	0.33[b]	9.3	2.98	✓

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. These values are based on results output at 10minute intervals. For some locations in the upper catchment, the instantaneous peak values may not have been identified accurately.

Table B.8 Head Losses, Discharges and Velocities at Structures for the 200 Year ARI Design Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	486.93	485.70	486.68	484.40	485.31	0.25[b]	17.7	2.67	✓
DRC-2	521.36	520.30	520.90	516.45 US 515.40 DS	518.17 US 517.12 DS	0.46[b]	57.2	6.15	✓
DRC-3	543.77	543.90	542.46	541.80	543.31	1.31[b]	10.3	3.44	
DRC-4	554.16	554.00	550.86	550.00	551.05	3.30[b]	8.4	4.83	✓
DRC-5	544.62	544.30	544.34	542.30	543.82	0.28[b]	5.7	3.62	✓
DRC-6	557.99	560.40	557.91	555.55	559.60	0.08[a]	81.8	2.91	
DRC-7	601.01	600.30	600.84	598.61	599.84	0.17[b]	18.8	2.51	✓
DRC-8	600.23	598.30	600.02	597.45	598.35	0.21[a]	13.4	2.88	✓
DRC-9	595.88	594.35	595.82	593.50	594.40	0.06[a]	2.2	2.20	✓
DRC-10[4]	574.58	574.20	574.49	572.30 US 572.00 DS	574.13 US 573.83 DS	0.09[b]	7.2	3.52	✓
DRC-11[4]	577.45	577.20	577.39	575.17	576.72	0.06[a]	22.6	1.30	✓
DRC-12[4]	591.70	590.70	591.52	589.00	590.48	0.18[b]	6.9	4.27	✓
DRC-13[4]	599.46	599.00	599.26	598.30	598.68	0.20[b]	0.4	1.90	✓
DRC-14[4]	604.19	603.50	603.80	602.40	603.10	0.39[a]	6.8	2.50	✓
DRC-15[4]	614.32	615.40	612.57	611.60 US 611.45 DS	613.42 US 613.27 DS	1.75[a]	25.9	3.88	
DRC-16[4]	615.29	615.24	614.95	614.10	615.00	0.34[b]	8.5	2.85	✓

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. These values are based on results output at 10minute intervals. For some locations in the upper catchment, the instantaneous peak values may not have been identified accurately.

Table B.9 Head Losses, Discharges and Velocities at Structures for the 500 Year ARI Design Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	487.04	485.70	486.79	484.40	485.31	0.25[b]	17.8	2.69	✓
DRC-2	521.49	520.30	521.01	516.45 US 515.40 DS	518.17 US 517.12 DS	0.48[b]	58.3	6.27	✓
DRC-3	543.87	543.90	542.49	541.80	543.31	1.38[b]	10.5	3.47	
DRC-4	554.20	554.00	550.88	550.00	551.05	3.32[b]	8.4	4.87	✓
DRC-5	544.66	544.30	544.34	542.30	543.82	0.32[b]	5.8	3.67	✓
DRC-6	558.26	560.40	558.16	555.55	559.60	0.10[a]	94.9	2.83	
DRC-7	601.08	600.30	600.89	598.61	599.84	0.19[b]	19.0	2.53	✓
DRC-8	600.37	598.30	600.14	597.45	598.35	0.23[a]	13.9	2.96	✓
DRC-9	596.09	594.35	596.03	593.50	594.40	0.06[a]	2.2	2.16	✓
DRC-10[4]	574.64	574.20	574.53	572.30 US 572.00 DS	574.13 US 573.83 DS	0.11[b]	7.5	3.60	✓
DRC-11[4]	577.54	577.20	577.48	575.17	576.72	0.06[a]	22.6	1.29	✓
DRC-12[4]	591.76	590.70	591.57	589.00	590.48	0.19[b]	7.1	4.33	✓
DRC-13[4]	599.50	599.00	599.29	598.30	598.68	0.21[b]	0.4	1.86	✓
DRC-14[4]	604.25	603.50	603.84	602.40	603.10	0.41[a]	7.1	2.59	✓
DRC-15[4]	614.72	615.40	612.66	611.60 US 611.45 DS	613.42 US 613.27 DS	2.06[a]	29.1	4.16	
DRC-16[4]	615.34	615.24	615.02	614.10	615.00	0.32[b]	9.1	2.93	✓

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. These values are based on results output at 10minute intervals. For some locations in the upper catchment, the instantaneous peak values may not have been identified accurately.

Table B.10 Head Losses, Discharges and Velocities at Structures for the PMP Design Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	488.24	485.70	484.37	484.40	485.31	3.87[b]	34.3	4.83	✓
DRC-2	523.13	520.30	522.33	516.45 US 515.40 DS	518.17 US 517.12 DS	0.80[b]	71.4	7.68	✓
DRC-3	544.60	543.90	542.63	541.80	543.31	1.97[b]	14.0	4.17	✓
DRC-4	554.74	554.00	550.85	550.00	551.05	3.89[b]	9.2	5.30	✓
DRC-5	545.29	544.30	544.52	542.30	543.82	0.77[b]	7.6	4.39	✓
DRC-6	562.04	560.40	561.77	555.55	559.60	0.27[a]	392.8	4.89	✓
DRC-7	601.88	600.30	601.47	598.61	599.84	0.41[b]	21.8	2.91	✓
DRC-8	601.52	598.30	601.09	597.45	598.35	0.43[a]	19.2	3.89	✓
DRC-9	597.44	594.35	597.38	593.50	594.40	0.06[a]	2.3	2.18	✓
DRC-10[4]	575.31	574.20	575.05	572.30 US 572.00 DS	574.13 US 573.83 DS	0.26[b]	10.8	4.44	✓
DRC-11[4]	578.71	577.20	578.58	575.17	576.72	0.13[a]	28.3	1.62	✓
DRC-12[4]	592.90	590.70	592.77	589.00	590.48	0.13[b]	9.5	5.55	✓
DRC-13[4]	600.33	599.00	600.15	598.30	598.68	0.18[b]	0.4	1.82	✓
DRC-14[4]	605.40	603.50	604.84	602.40	603.10	0.56[a]	9.4	3.32	✓
DRC-15[4]	616.32	615.40	613.39	611.60 US 611.45 DS	613.42 US 613.27 DS	2.93[a]	39.7	5.13	✓
DRC-16[4]	616.43	615.24	616.24	614.10	615.00	0.19[b]	14.9	4.39	✓

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. These values are based on results output at 10minute intervals. For some locations in the upper catchment, the instantaneous peak values may not have been identified accurately.

Table B.11 Head Losses, Discharges and Velocities at Structures for the 2 Year ARI Ultimate-Development Conditions Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	486.02	485.70	485.03	484.40	485.31	0.99[b]	18.9	3.02	✓
DRC-2	520.42	520.30	520.33	516.45 US 515.40 DS	518.17 US 517.12 DS	0.09[b]	46.4	5.05	✓
DRC-3	543.02	543.90	542.18	541.80	543.31	0.84[b]	5.5	2.63	
DRC-4	551.99	554.00	550.29	550.00	551.05	1.70[b]	5.2	3.30	
DRC-5	544.19	544.30	541.62	542.30	543.82	2.57[b,4]	4.9	3.35	
DRC-6	557.25	560.40	557.20	555.55	559.60	0.05[a]	15.4	1.86	
DRC-7	600.56	600.30	600.53	598.61	599.84	0.03[b]	15.6	2.08	✓
DRC-8	599.44	598.30	599.35	597.45	598.35	0.09[a]	8.6	1.85	✓
DRC-9	594.89	594.35	594.80	593.50	594.40	0.09[a]	2.3	2.23	✓
DRC-10	573.98	574.20	572.20	572.30 US 572.00 DS	574.13 US 573.83 DS	1.78[b,4]	4.6	2.92	
DRC-11	576.60	577.20	576.58	575.17	576.72	0.02[a]	15.3	1.14	
DRC-12	591.26	590.70	591.21	589.00	590.48	0.05[b]	5.7	3.73	✓
DRC-13	599.23	599.00	599.02	598.30	598.68	0.21[b]	0.4	1.92	✓
DRC-14	603.76	603.50	603.51	602.40	603.10	0.25[a]	5.2	1.94	✓
DRC-15	612.87	615.40	612.40	611.60 US 611.45 DS	613.42 US 613.27 DS	0.47[a]	9.2	2.55	
DRC-16	614.93	615.24	614.56	614.10	615.00	0.37[b]	5.2	2.41	

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. Large head losses likely due to orifice flow before the structure is drowned

Table B.12 Head Losses, Discharges and Velocities at Structures for the 5 Year ARI Ultimate-Development Conditions Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	486.24	485.70	485.07	484.40	485.31	1.17[b]	22.0	3.35	✓
DRC-2	520.71	520.30	520.47	516.45 US 515.40 DS	518.17 US 517.12 DS	0.24[b]	50.1	5.39	✓
DRC-3	543.52	543.90	542.35	541.80	543.31	1.17[b]	8.5	3.12	
DRC-4	553.41	554.00	550.37	550.00	551.05	3.04[b]	7.5	4.31	
DRC-5	544.53	544.30	544.33	542.30	543.82	0.20[b]	5.4	3.52	✓
DRC-6	557.32	560.40	557.23	555.55	559.60	0.09[a]	30.1	2.85	
DRC-7	600.68	600.30	600.61	598.61	599.84	0.07[b]	17.7	2.36	✓
DRC-8	599.68	598.30	599.57	597.45	598.35	0.11[a]	13.5	3.18	✓
DRC-9	595.18	594.35	595.11	593.50	594.40	0.07[a]	2.3	2.23	✓
DRC-10	574.27	574.20	574.28	572.30 US 572.00 DS	574.13 US 573.83 DS	0.00[b]	6.4	3.35	✓
DRC-11	576.85	577.20	576.82	575.17	576.72	0.03[a]	19.1	1.09	
DRC-12	591.40	590.70	591.29	589.00	590.48	0.11[b]	6.1	3.91	✓
DRC-13	599.29	599.00	599.09	598.30	598.68	0.20[b]	0.4	1.92	✓
DRC-14	603.93	603.50	603.57	602.40	603.10	0.36[a]	6.3	2.34	✓
DRC-15	613.31	615.40	612.75	611.60 US 611.45 DS	613.42 US 613.27 DS	0.56[a]	14.9	3.03	
DRC-16	615.14	615.24	614.77	614.10	615.00	0.37[b]	6.7	2.64	

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge

Table B.13 Head Losses, Discharges and Velocities at Structures for the 10 Year ARI Ultimate-Development Conditions Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	486.47	485.70	485.06	484.40	485.31	1.41[b]	23.5	3.55	✓
DRC-2	520.96	520.30	520.64	516.45 US 515.40 DS	518.17 US 517.12 DS	0.32[b]	53.7	5.78	✓
DRC-3	543.70	543.90	542.51	541.80	543.31	1.19[b]	10.3	3.45	
DRC-4	554.10	554.00	550.85	550.00	551.05	3.25[b]	8.3	4.81	✓
DRC-5	544.57	544.30	544.33	542.30	543.82	0.24[b]	5.8	3.65	✓
DRC-6	557.66	560.40	557.53	555.55	559.60	0.13[a]	50.2	2.81	
DRC-7	600.92	600.30	600.78	598.61	599.84	0.14[b]	18.5	2.46	✓
DRC-8	600.02	598.30	599.84	597.45	598.35	0.18[a]	12.4	2.69	✓
DRC-9	595.61	594.35	595.54	593.50	594.40	0.07[a]	2.2	2.23	✓
DRC-10	574.50	574.20	574.43	572.30 US 572.00 DS	574.13 US 573.83 DS	0.07[b]	6.9	3.46	✓
DRC-11	577.23	577.20	577.18	575.17	576.72	0.05[a]	22.3	1.28	✓
DRC-12	591.56	590.70	591.40	589.00	590.48	0.16[b]	6.6	4.12	✓
DRC-13	599.39	599.00	599.18	598.30	598.68	0.21[b]	0.4	1.92	✓
DRC-14	604.11	603.50	603.75	602.40	603.10	0.36[a]	6.5	2.41	✓
DRC-15	613.87	615.40	612.69	611.60 US 611.45 DS	613.42 US 613.27 DS	1.18[a]	21.9	3.55	
DRC-16	615.22	615.24	614.88	614.10	615.00	0.34[b]	8.2	2.81	

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge

Table B.14 Head Losses, Discharges and Velocities at Structures for the 20 Year ARI Ultimate-Development Conditions Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	486.64	485.70	484.37	484.40	485.31	2.27[b]	24.5	3.68	✓
DRC-2	521.16	520.30	520.76	516.45 US 515.40 DS	518.17 US 517.12 DS	0.40[b]	54.9	5.91	✓
DRC-3	543.76	543.90	542.52	541.80	543.31	1.24[b]	10.7	3.51	
DRC-4	554.13	554.00	550.85	550.00	551.05	3.28[b]	8.4	4.86	✓
DRC-5	544.60	544.30	544.33	542.30	543.82	0.27[b]	5.9	3.70	✓
DRC-6	558.06	560.40	557.99	555.55	559.60	0.07[a]	61.7	2.39	
DRC-7	600.99	600.30	600.83	598.61	599.84	0.16[b]	18.7	2.49	✓
DRC-8	600.20	598.30	599.99	597.45	598.35	0.21[a]	13.2	2.85	✓
DRC-9	595.84	594.35	595.78	593.50	594.40	0.06[a]	2.3	2.36	✓
DRC-10	574.54	574.20	574.46	572.30 US 572.00 DS	574.13 US 573.83 DS	0.08[b]	7.2	3.52	✓
DRC-11	577.42	577.20	577.36	575.17	576.72	0.06[a]	23.1	1.32	✓
DRC-12	591.66	590.70	591.48	589.00	590.48	0.18[b]	6.9	4.25	✓
DRC-13	599.43	599.00	599.23	598.30	598.68	0.20[b]	0.4	1.91	✓
DRC-14	604.17	603.50	603.79	602.40	603.10	0.38[a]	6.7	2.48	✓
DRC-15	614.21	615.40	612.75	611.60 US 611.45 DS	613.42 US 613.27 DS	1.46[a]	25.0	3.81	
DRC-16	615.26	615.24	614.92	614.10	615.00	0.34[b]	8.8	2.87	✓

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge

Table B.15 Head Losses, Discharges and Velocities at Structures for the 50 Year ARI Ultimate-Development Conditions Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	486.73	485.70	485.03	484.40	485.31	1.70[b]	25.1	3.76	✓
DRC-2	521.24	520.30	520.82	516.45 US 515.40 DS	518.17 US 517.12 DS	0.42[b]	55.8	6.00	✓
DRC-3	543.85	543.90	542.55	541.80	543.31	1.30[b]	11.0	3.56	
DRC-4	554.15	554.00	550.86	550.00	551.05	3.29[b]	8.5	4.88	✓
DRC-5	544.63	544.30	544.34	542.30	543.82	0.29[b]	6.0	3.73	✓
DRC-6	557.98	560.40	557.90	555.55	559.60	0.08[a]	77.2	2.82	
DRC-7	601.03	600.30	600.85	598.61	599.84	0.18[b]	19.0	2.53	✓
DRC-8	600.31	598.30	600.08	597.45	598.35	0.23[a]	13.7	2.93	✓
DRC-9	595.99	594.35	595.93	593.50	594.40	0.06[a]	2.3	2.31	✓
DRC-10	574.58	574.20	574.49	572.30 US 572.00 DS	574.13 US 573.83 DS	0.09[b]	7.5	3.58	✓
DRC-11	577.50	577.20	577.44	575.17	576.72	0.06[a]	22.8	1.30	✓
DRC-12	591.70	590.70	591.51	589.00	590.48	0.19[b]	7.0	4.30	✓
DRC-13	599.45	599.00	599.23	598.30	598.68	0.22[b]	0.4	1.91	✓
DRC-14	604.20	603.50	603.81	602.40	603.10	0.39[a]	6.9	2.52	✓
DRC-15	614.43	615.40	612.75	611.60 US 611.45 DS	613.42 US 613.27 DS	1.68[a]	26.8	3.96	
DRC-16	615.30	615.24	614.96	614.10	615.00	0.34[b]	9.1	2.93	✓

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge

Table B.16 Head Losses, Discharges and Velocities at Structures for the 100 Year ARI Ultimate-Development Conditions Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	486.78	485.70	485.06	484.40	485.31	1.72[b]	25.5	3.80	✓
DRC-2	521.31	520.30	520.88	516.45 US 515.40 DS	518.17 US 517.12 DS	0.43[b]	56.6	6.09	✓
DRC-3	543.86	543.90	542.56	541.80	543.31	1.30[b]	11.2	3.61	
DRC-4	554.17	554.00	550.87	550.00	551.05	3.30[b]	8.5	4.91	✓
DRC-5	544.66	544.30	544.34	542.30	543.82	0.32[b]	6.1	3.77	✓
DRC-6	558.12	560.40	558.04	555.55	559.60	0.08[a]	76.3	2.87	
DRC-7	601.07	600.30	600.88	598.61	599.84	0.19[b]	19.0	2.54	✓
DRC-8	600.40	598.30	600.17	597.45	598.35	0.23[a]	14.0	2.97	✓
DRC-9	596.13	594.35	596.07	593.50	594.40	0.06[a]	2.3	2.34	✓
DRC-10	574.61	574.20	574.51	572.30 US 572.00 DS	574.13 US 573.83 DS	0.10[b]	7.7	3.64	✓
DRC-11	577.57	577.20	577.51	575.17	576.72	0.06[a]	22.8	1.32	✓
DRC-12	591.74	590.70	591.55	589.00	590.48	0.19[b]	7.1	4.35	✓
DRC-13	599.47	599.00	599.25	598.30	598.68	0.22[b]	0.4	1.91	✓
DRC-14	604.23	603.50	603.83	602.40	603.10	0.40[a]	7.0	2.57	✓
DRC-15	614.62	615.40	612.64	611.60 US 611.45 DS	613.42 US 613.27 DS	1.98[a]	28.3	4.10	
DRC-16	615.33	615.24	615.00	614.10	615.00	0.33[b]	9.5	3.04	✓

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge

Table B.17 Head Losses, Discharges and Velocities at Structures for the Flow Plus 30% Sensitivity Case Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	486.97	485.70	486.72	484.40	485.31	0.25[b]	17.7	2.67	✓
DRC-2	521.53	520.30	521.01	516.45 US 515.40 DS	518.17 US 517.12 DS	0.52[b]	58.7	6.32	✓
DRC-3	543.85	543.90	542.48	541.80	543.31	1.37[b]	10.6	3.49	
DRC-4	554.24	554.00	550.86	550.00	551.05	3.38[b]	8.5	4.90	✓
DRC-5	544.64	544.30	544.34	542.30	543.82	0.30[b]	5.8	3.67	✓
DRC-6	558.48	560.40	558.36	555.55	559.60	0.12[a]	86.9	2.80	
DRC-7	601.18	600.30	600.96	598.61	599.84	0.22[b]	19.3	2.57	✓
DRC-8	600.62	598.30	600.38	597.45	598.35	0.24[a]	14.4	3.05	✓
DRC-9	596.41	594.35	596.35	593.50	594.40	0.06[a]	2.2	2.35	✓
DRC-10[4]	574.71	574.20	574.58	572.30 US 572.00 DS	574.13 US 573.83 DS	0.13[b]	8.1	3.72	✓
DRC-11[4]	577.68	577.20	577.61	575.17	576.72	0.07[a]	22.9	1.31	✓
DRC-12[4]	591.84	590.70	591.64	589.00	590.48	0.20[b]	7.2	4.39	✓
DRC-13[4]	599.52	599.00	599.31	598.30	598.68	0.21[b]	0.4	1.91	✓
DRC-14[4]	604.32	603.50	603.89	602.40	603.10	0.43[a]	7.2	2.65	✓
DRC-15[4]	615.20	615.40	612.75	611.60 US 611.45 DS	613.42 US 613.27 DS	2.45[a]	32.6	4.50	
DRC-16[4]	615.43	615.24	615.18	614.10	615.00	0.25[b]	10.1	3.21	✓

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. These values are based on results output at 10minute intervals. For some locations in the upper catchment, the instantaneous peak values may not have been identified accurately.

Table B.18 Head Losses, Discharges and Velocities at Structures for the Flow Minus 30% Sensitivity Case Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	486.64	485.70	486.36	484.40	485.31	0.28[b]	17.6	2.67	✓
DRC-2	521.14	520.30	520.74	516.45 US 515.40 DS	518.17 US 517.12 DS	0.40[b]	54.7	5.88	✓
DRC-3	543.33	543.90	542.13	541.80	543.31	1.20[b]	7.9	3.03	
DRC-4	553.92	554.00	550.40	550.00	551.05	3.52[b]	8.2	4.75	
DRC-5	544.49	544.30	544.32	542.30	543.82	0.17[b]	5.3	3.48	✓
DRC-6	557.75	560.40	557.59	555.55	559.60	0.16[a]	58.4	2.82	
DRC-7	600.94	600.30	600.79	598.61	599.84	0.15[b]	18.5	2.46	✓
DRC-8	600.09	598.30	599.90	597.45	598.35	0.19[a]	12.7	2.74	✓
DRC-9	595.72	594.35	595.65	593.50	594.40	0.07[a]	2.2	2.18	✓
DRC-10[4]	574.50	574.20	574.43	572.30 US 572.00 DS	574.13 US 573.83 DS	0.07[b]	7.0	3.47	✓
DRC-11[4]	577.34	577.20	577.28	575.17	576.72	0.06[a]	22.4	1.29	✓
DRC-12[4]	591.61	590.70	591.44	589.00	590.48	0.17[b]	6.7	4.17	✓
DRC-13[4]	599.41	599.00	599.20	598.30	598.68	0.21[b]	0.4	1.92	✓
DRC-14[4]	604.12	603.50	603.75	602.40	603.10	0.37[a]	6.6	2.42	✓
DRC-15[4]	613.96	615.40	612.71	611.60 US 611.45 DS	613.42 US 613.27 DS	1.25[a]	22.7	3.62	
DRC-16[4]	615.22	615.24	614.87	614.10	615.00	0.35[b]	8.3	2.82	

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. These values are based on results output at 10minute intervals. For some locations in the upper catchment, the instantaneous peak values may not have been identified accurately.

Table B.19 Head Losses, Discharges and Velocities at Structures for the Roughness Plus 30% Sensitivity Case Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	486.78	485.70	486.55	484.40	485.31	0.23[b]	16.7	2.53	✓
DRC-2	521.32	520.30	520.87	516.45 US 515.40 DS	518.17 US 517.12 DS	0.45[b]	56.5	6.07	✓
DRC-3	543.73	543.90	542.28	541.80	543.31	1.45[b]	10.2	3.42	
DRC-4	554.19	554.00	550.87	550.00	551.05	3.32[b]	8.4	4.86	✓
DRC-5	544.59	544.30	544.34	542.30	543.82	0.25[b]	5.6	3.60	✓
DRC-6	558.12	560.40	558.04	555.55	559.60	0.08[a]	76.9	2.58	
DRC-7	601.14	600.30	600.94	598.61	599.84	0.20[b]	19.0	2.53	✓
DRC-8	600.18	598.30	599.93	597.45	598.35	0.25[a]	14.2	3.04	✓
DRC-9	596.18	594.35	596.12	593.50	594.40	0.06[a]	2.2	2.20	✓
DRC-10[4]	574.63	574.20	574.53	572.30 US 572.00 DS	574.13 US 573.83 DS	0.10[b]	7.6	3.62	✓
DRC-11[4]	577.63	577.20	577.57	575.17	576.72	0.06[a]	22.6	1.30	✓
DRC-12[4]	591.78	590.70	591.58	589.00	590.48	0.20[b]	7.1	4.33	✓
DRC-13[4]	599.52	599.00	599.36	598.30	598.68	0.16[b]	0.4	1.84	✓
DRC-14[4]	604.27	603.50	603.89	602.40	603.10	0.38[a]	6.8	2.49	✓
DRC-15[4]	614.57	615.40	612.65	611.60 US 611.45 DS	613.42 US 613.27 DS	1.92[a]	28.0	4.06	
DRC-16[4]	615.39	615.24	615.08	614.10	615.00	0.31[b]	9.6	3.07	✓

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. These values are based on results output at 10minute intervals. For some locations in the upper catchment, the instantaneous peak values may not have been identified accurately.

Table B.20 Head Losses, Discharges and Velocities at Structures for the Roughness Minus 30% Sensitivity Case Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	486.80	485.70	484.37	484.40	485.31	2.43[b]	26.2	3.90	✓
DRC-2	521.35	520.30	520.88	516.45 US 515.40 DS	518.17 US 517.12 DS	0.47[b]	57.1	6.14	✓
DRC-3	543.74	543.90	542.26	541.80	543.31	1.48[b]	10.3	3.44	
DRC-4	554.16	554.00	550.85	550.00	551.05	3.31[b]	8.4	4.84	✓
DRC-5	544.57	544.30	544.33	542.30	543.82	0.24[b]	5.6	3.58	✓
DRC-6	558.04	560.40	557.96	555.55	559.60	0.08[a]	86.6	2.84	
DRC-7	601.03	600.30	600.86	598.61	599.84	0.17[b]	19.5	2.61	✓
DRC-8	600.36	598.30	600.09	597.45	598.35	0.27[a]	14.7	3.12	✓
DRC-9	596.07	594.35	596.01	593.50	594.40	0.06[a]	2.3	2.20	✓
DRC-10[4]	574.61	574.20	574.50	572.30 US 572.00 DS	574.13 US 573.83 DS	0.11[b]	7.6	3.60	✓
DRC-11[4]	577.52	577.20	577.45	575.17	576.72	0.07[a]	23.1	1.32	✓
DRC-12[4]	591.73	590.70	591.54	589.00	590.48	0.19[b]	7.0	4.30	✓
DRC-13[4]	599.45	599.00	599.21	598.30	598.68	0.24[b]	0.4	1.94	✓
DRC-14[4]	604.20	603.50	603.80	602.40	603.10	0.40[a]	7.0	2.57	✓
DRC-15[4]	614.53	615.40	612.71	611.60 US 611.45 DS	613.42 US 613.27 DS	1.82[a]	27.6	4.03	
DRC-16[4]	615.28	615.24	614.95	614.10	615.00	0.33[b]	9.0	2.91	✓

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. These values are based on results output at 10minute intervals. For some locations in the upper catchment, the instantaneous peak values may not have been identified accurately.

Table B.21 Head Losses, Discharges and Velocities at Structures for the 50% Blockage Sensitivity Case Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	486.85	485.70	486.52	484.40	485.31	0.33[b]	8.7	2.64	✓
DRC-2	521.34	520.30	520.90	516.45 US 515.40 DS	518.17 US 517.12 DS	0.44[b]	30.1	6.44	✓
DRC-3	544.03	543.90	542.23	541.80	543.31	1.80[b]	6.1	3.60	✓
DRC-4	554.24	554.00	550.56	550.00	551.05	3.68[b]	3.9	4.58	✓
DRC-5	544.61	544.30	544.35	542.30	543.82	0.26[b]	3.2	3.71	✓
DRC-6	558.75	560.40	558.30	555.55	559.60	0.45[a]	82.9	3.99	
DRC-7	601.12	600.30	600.92	598.61	599.84	0.20[b]	11.1	2.98	✓
DRC-8	600.39	598.30	600.14	597.45	598.35	0.25[a]	5.7	2.49	✓
DRC-9	596.14	594.35	596.08	593.50	594.40	0.06[a]	1.3	2.25	✓
DRC-10[4]	574.66	574.20	574.54	572.30 US 572.00 DS	574.13 US 573.83 DS	0.12[b]	5.0	4.02	✓
DRC-11[4]	577.57	577.20	577.32	575.17	576.72	0.25[a]	18.1	2.07	✓
DRC-12[4]	591.69	590.70	591.49	589.00	590.48	0.20[b]	3.7	4.36	✓
DRC-13[4]	599.40	599.00	599.19	598.30	598.68	0.21[b]	0.2	1.58	✓
DRC-14[4]	604.43	603.50	603.52	602.40	603.10	0.91[a]	3.9	2.94	✓
DRC-15[4]	615.59	615.40	612.72	611.60 US 611.45 DS	613.42 US 613.27 DS	2.87[a]	17.2	4.40	✓
DRC-16[4]	615.66	615.24	615.62	614.10	615.00	0.04[b]	5.0	3.08	✓

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. These values are based on results output at 10minute intervals. For some locations in the upper catchment, the instantaneous peak values may not have been identified accurately.

Table B.22 Head Losses, Discharges and Velocities at Structures for the 2050, 100 Year ARI Climate Change Scenario Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	486.88	485.70	486.63	484.40	485.31	0.25[b]	17.7	2.67	✓
DRC-2	521.43	520.30	520.96	516.45 US 515.40 DS	518.17 US 517.12 DS	0.47[b]	57.6	6.20	✓
DRC-3	543.80	543.90	542.47	541.80	543.31	1.33[b]	10.2	3.43	
DRC-4	554.20	554.00	550.88	550.00	551.05	3.32[b]	8.4	4.87	✓
DRC-5	544.61	544.30	544.33	542.30	543.82	0.28[b]	5.7	3.63	✓
DRC-6	558.20	560.40	558.12	555.55	559.60	0.08[a]	80.8	3.01	
DRC-7	601.11	600.30	600.91	598.61	599.84	0.20[b]	19.2	2.55	✓
DRC-8	600.47	598.30	600.24	597.45	598.35	0.23[a]	14.1	3.01	✓
DRC-9	596.25	594.35	596.19	593.50	594.40	0.06[a]	2.3	2.29	✓
DRC-10[4]	574.65	574.20	574.54	572.30 US 572.00 DS	574.13 US 573.83 DS	0.11[b]	7.8	3.66	✓
DRC-11[4]	577.60	577.20	577.53	575.17	576.72	0.07[a]	22.8	1.30	✓
DRC-12[4]	591.78	590.70	591.58	589.00	590.48	0.20[b]	7.1	4.34	✓
DRC-13[4]	599.49	599.00	599.28	598.30	598.68	0.21[b]	0.4	1.88	✓
DRC-14[4]	604.26	603.50	603.85	602.40	603.10	0.41[a]	7.1	2.61	✓
DRC-15[4]	614.79	615.40	612.67	611.60 US 611.45 DS	613.42 US 613.27 DS	2.12[a]	29.6	4.21	
DRC-16[4]	615.36	615.24	615.05	614.10	615.00	0.31[b]	9.6	3.09	✓

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. These values are based on results output at 10minute intervals. For some locations in the upper catchment, the instantaneous peak values may not have been identified accurately.

Table B.23 Head Losses, Discharges and Velocities at Structures for the 2070, 100 Year ARI Climate Change Scenario Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	486.91	485.70	486.66	484.40	485.31	0.25[b]	17.7	2.68	✓
DRC-2	521.46	520.30	520.98	516.45 US 515.40 DS	518.17 US 517.12 DS	0.48[b]	58.0	6.24	✓
DRC-3	543.84	543.90	542.48	541.80	543.31	1.36[b]	10.4	3.46	
DRC-4	554.21	554.00	550.88	550.00	551.05	3.33[b]	8.4	4.88	✓
DRC-5	544.63	544.30	544.34	542.30	543.82	0.29[b]	5.8	3.65	✓
DRC-6	558.44	560.40	558.35	555.55	559.60	0.09[a]	99.0	2.88	
DRC-7	601.13	600.30	600.93	598.61	599.84	0.20[b]	19.2	2.56	✓
DRC-8	600.51	598.30	600.28	597.45	598.35	0.23[a]	14.3	3.03	✓
DRC-9	596.30	594.35	596.24	593.50	594.40	0.06[a]	2.3	2.30	✓
DRC-10[4]	574.67	574.20	574.55	572.30 US 572.00 DS	574.13 US 573.83 DS	0.12[b]	7.9	3.68	✓
DRC-11[4]	577.62	577.20	577.55	575.17	576.72	0.07[a]	22.7	1.30	✓
DRC-12[4]	591.79	590.70	591.60	589.00	590.48	0.19[b]	7.1	4.36	✓
DRC-13[4]	599.50	599.00	599.28	598.30	598.68	0.22[b]	0.4	1.88	✓
DRC-14[4]	604.28	603.50	603.87	602.40	603.10	0.41[a]	7.1	2.61	✓
DRC-15[4]	614.90	615.40	612.70	611.60 US 611.45 DS	613.42 US 613.27 DS	2.20[a]	30.5	4.29	
DRC-16[4]	615.37	615.24	615.08	614.10	615.00	0.29[b]	9.8	3.13	✓

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. These values are based on results output at 10minute intervals. For some locations in the upper catchment, the instantaneous peak values may not have been identified accurately.

Table B.24 Head Losses, Discharges and Velocities at Structures for the 2100, 100 Year ARI Climate Change Scenario Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	486.95	485.70	486.71	484.40	485.31	0.24[b]	17.7	2.68	✓
DRC-2	521.48	520.30	520.99	516.45 US 515.40 DS	518.17 US 517.12 DS	0.49[b]	58.3	6.28	✓
DRC-3	543.87	543.90	542.50	541.80	543.31	1.37[b]	10.5	3.48	
DRC-4	554.23	554.00	550.86	550.00	551.05	3.37[b]	8.5	4.89	✓
DRC-5	544.64	544.30	544.34	542.30	543.82	0.30[b]	5.8	3.66	✓
DRC-6	558.35	560.40	558.25	555.55	559.60	0.10[a]	88.6	2.85	
DRC-7	601.15	600.30	600.94	598.61	599.84	0.21[b]	19.3	2.57	✓
DRC-8	600.55	598.30	600.32	597.45	598.35	0.23[a]	14.3	3.04	✓
DRC-9	596.34	594.35	596.28	593.50	594.40	0.06[a]	2.2	2.31	✓
DRC-10[4]	574.68	574.20	574.56	572.30 US 572.00 DS	574.13 US 573.83 DS	0.12[b]	8.0	3.71	✓
DRC-11[4]	577.64	577.20	577.57	575.17	576.72	0.07[a]	22.7	1.30	✓
DRC-12[4]	591.81	590.70	591.61	589.00	590.48	0.20[b]	7.2	4.38	✓
DRC-13[4]	599.51	599.00	599.29	598.30	598.68	0.22[b]	0.4	1.89	✓
DRC-14[4]	604.29	603.50	603.88	602.40	603.10	0.41[a]	7.2	2.62	✓
DRC-15[4]	615.01	615.40	612.72	611.60 US 611.45 DS	613.42 US 613.27 DS	2.29[a]	31.3	4.37	
DRC-16[4]	615.39	615.24	615.12	614.10	615.00	0.27[b]	10.0	3.17	✓

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. These values are based on results output at 10minute intervals. For some locations in the upper catchment, the instantaneous peak values may not have been identified accurately.

Table B.25 Head Losses, Discharges and Velocities at Structures for the 2050, 200 Year ARI Climate Change Scenario Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	486.99	485.70	486.75	484.40	485.31	0.24[b]	17.8	2.68	✓
DRC-2	521.43	520.30	520.95	516.45 US 515.40 DS	518.17 US 517.12 DS	0.48[b]	57.9	6.22	✓
DRC-3	543.83	543.90	542.48	541.80	543.31	1.35[b]	10.3	3.44	
DRC-4	554.18	554.00	550.86	550.00	551.05	3.32[b]	8.4	4.85	✓
DRC-5	544.64	544.30	544.34	542.30	543.82	0.30[b]	5.8	3.65	✓
DRC-6	558.14	560.40	558.03	555.55	559.60	0.11[a]	73.2	2.59	
DRC-7	601.05	600.30	600.87	598.61	599.84	0.18[b]	19.0	2.53	✓
DRC-8	600.31	598.30	600.09	597.45	598.35	0.22[a]	13.7	2.93	✓
DRC-9	596.01	594.35	595.94	593.50	594.40	0.07[a]	2.2	2.34	✓
DRC-10[4]	574.61	574.20	574.51	572.30 US 572.00 DS	574.13 US 573.83 DS	0.10[b]	7.4	3.57	✓
DRC-11[4]	577.50	577.20	577.44	575.17	576.72	0.06[a]	22.6	1.30	✓
DRC-12[4]	591.73	590.70	591.55	589.00	590.48	0.18[b]	7.0	4.30	✓
DRC-13[4]	599.48	599.00	599.26	598.30	598.68	0.22[b]	0.4	1.92	✓
DRC-14[4]	604.22	603.50	603.82	602.40	603.10	0.40[a]	6.9	2.54	✓
DRC-15[4]	614.52	615.40	612.61	611.60 US 611.45 DS	613.42 US 613.27 DS	1.91[a]	27.5	4.02	
DRC-16[4]	615.32	615.24	614.99	614.10	615.00	0.33[b]	8.8	2.87	✓

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. These values are based on results output at 10minute intervals. For some locations in the upper catchment, the instantaneous peak values may not have been identified accurately.

Table B.26 Head Losses, Discharges and Velocities at Structures for the 2070, 200 Year ARI Climate Change Scenario Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	487.02	485.70	486.78	484.40	485.31	0.24[b]	17.9	2.70	✓
DRC-2	521.46	520.30	520.97	516.45 US 515.40 DS	518.17 US 517.12 DS	0.49[b]	58.1	6.26	✓
DRC-3	543.85	543.90	542.48	541.80	543.31	1.37[b]	10.4	3.46	
DRC-4	554.19	554.00	550.86	550.00	551.05	3.33[b]	8.4	4.86	✓
DRC-5	544.65	544.30	544.34	542.30	543.82	0.31[b]	5.8	3.66	✓
DRC-6	558.19	560.40	558.10	555.55	559.60	0.09[a]	78.7	2.55	
DRC-7	601.07	600.30	600.88	598.61	599.84	0.19[b]	19.0	2.53	✓
DRC-8	600.35	598.30	600.12	597.45	598.35	0.23[a]	13.8	2.95	✓
DRC-9	596.06	594.35	595.99	593.50	594.40	0.07[a]	2.2	2.35	✓
DRC-10[4]	574.63	574.20	574.52	572.30 US 572.00 DS	574.13 US 573.83 DS	0.11[b]	7.5	3.59	✓
DRC-11[4]	577.53	577.20	577.46	575.17	576.72	0.07[a]	22.6	1.29	✓
DRC-12[4]	591.75	590.70	591.56	589.00	590.48	0.19[b]	7.0	4.32	✓
DRC-13[4]	599.49	599.00	599.28	598.30	598.68	0.21[b]	0.4	1.85	✓
DRC-14[4]	604.24	603.50	603.83	602.40	603.10	0.41[a]	7.0	2.57	✓
DRC-15[4]	614.63	615.40	612.64	611.60 US 611.45 DS	613.42 US 613.27 DS	1.99[a]	28.4	4.10	
DRC-16[4]	615.33	615.24	615.01	614.10	615.00	0.32[b]	9.0	2.90	✓

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. These values are based on results output at 10minute intervals. For some locations in the upper catchment, the instantaneous peak values may not have been identified accurately.

Table B.27 Head Losses, Discharges and Velocities at Structures for the 2100, 200 Year ARI Climate Change Scenario Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	487.05	485.70	486.80	484.40	485.31	0.25[b]	17.9	2.69	✓
DRC-2	521.50	520.30	521.00	516.45 US 515.40 DS	518.17 US 517.12 DS	0.50[b]	58.4	6.29	✓
DRC-3	543.87	543.90	542.49	541.80	543.31	1.38[b]	10.6	3.48	
DRC-4	554.20	554.00	550.87	550.00	551.05	3.33[b]	8.4	4.87	✓
DRC-5	544.67	544.30	544.34	542.30	543.82	0.33[b]	5.8	3.68	✓
DRC-6	558.27	560.40	558.18	555.55	559.60	0.09[a]	88.0	2.55	
DRC-7	601.08	600.30	600.89	598.61	599.84	0.19[b]	19.0	2.53	✓
DRC-8	600.38	598.30	600.15	597.45	598.35	0.23[a]	13.9	2.97	✓
DRC-9	596.10	594.35	596.04	593.50	594.40	0.06[a]	2.2	2.16	✓
DRC-10[4]	574.65	574.20	574.53	572.30 US 572.00 DS	574.13 US 573.83 DS	0.12[b]	7.6	3.61	✓
DRC-11[4]	577.55	577.20	577.49	575.17	576.72	0.06[a]	22.5	1.29	✓
DRC-12[4]	591.77	590.70	591.58	589.00	590.48	0.19[b]	7.1	4.33	✓
DRC-13[4]	599.50	599.00	599.29	598.30	598.68	0.21[b]	0.4	1.86	✓
DRC-14[4]	604.26	603.50	603.84	602.40	603.10	0.42[a]	7.1	2.60	✓
DRC-15[4]	614.75	615.40	612.66	611.60 US 611.45 DS	613.42 US 613.27 DS	2.09[a]	29.4	4.18	
DRC-16[4]	615.35	615.24	615.02	614.10	615.00	0.33[b]	9.1	2.94	✓

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. These values are based on results output at 10minute intervals. For some locations in the upper catchment, the instantaneous peak values may not have been identified accurately.

Table B.28 Head Losses, Discharges and Velocities at Structures for the 2050, 500 Year ARI Climate Change Scenario Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	487.10	485.70	486.86	484.40	485.31	0.24[b]	17.9	2.69	✓
DRC-2	521.57	520.30	521.04	516.45 US 515.40 DS	518.17 US 517.12 DS	0.53[b]	59.0	6.35	✓
DRC-3	543.92	543.90	542.50	541.80	543.31	1.42[b]	10.8	3.52	✓
DRC-4	554.23	554.00	550.88	550.00	551.05	3.35[b]	8.5	4.89	✓
DRC-5	544.69	544.30	544.35	542.30	543.82	0.34[b]	5.9	3.70	✓
DRC-6	558.26	560.40	558.18	555.55	559.60	0.08[a]	84.5	2.78	
DRC-7	601.12	600.30	600.92	598.61	599.84	0.20[b]	19.1	2.54	✓
DRC-8	600.45	598.30	600.22	597.45	598.35	0.23[a]	14.1	2.99	✓
DRC-9	596.21	594.35	596.15	593.50	594.40	0.06[a]	2.2	2.18	✓
DRC-10[4]	574.68	574.20	574.56	572.30 US 572.00 DS	574.13 US 573.83 DS	0.12[b]	7.7	3.65	✓
DRC-11[4]	577.59	577.20	577.53	575.17	576.72	0.06[a]	22.6	1.29	✓
DRC-12[4]	591.80	590.70	591.61	589.00	590.48	0.19[b]	7.1	4.36	✓
DRC-13[4]	599.52	599.00	599.30	598.30	598.68	0.22[b]	0.4	1.87	✓
DRC-14[4]	604.29	603.50	603.87	602.40	603.10	0.42[a]	7.1	2.62	✓
DRC-15[4]	614.99	615.40	612.75	611.60 US 611.45 DS	613.42 US 613.27 DS	2.24[a]	31.1	4.35	
DRC-16[4]	615.38	615.24	615.10	614.10	615.00	0.28[b]	9.4	3.01	✓

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. These values are based on results output at 10minute intervals. For some locations in the upper catchment, the instantaneous peak values may not have been identified accurately.

Table B.29 Head Losses, Discharges and Velocities at Structures for the 2070, 500 Year ARI Climate Change Scenario Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	487.13	485.70	486.89	484.40	485.31	0.24[b]	17.9	2.70	✓
DRC-2	521.61	520.30	521.08	516.45 US 515.40 DS	518.17 US 517.12 DS	0.53[b]	59.4	6.39	✓
DRC-3	543.94	543.90	542.51	541.80	543.31	1.43[b]	10.9	3.55	✓
DRC-4	554.24	554.00	550.86	550.00	551.05	3.38[b]	8.5	4.90	✓
DRC-5	544.71	544.30	544.35	542.30	543.82	0.36[b]	6.0	3.72	✓
DRC-6	558.33	560.40	558.24	555.55	559.60	0.09[a]	100.8	2.76	
DRC-7	601.14	600.30	600.93	598.61	599.84	0.21[b]	19.1	2.55	✓
DRC-8	600.49	598.30	600.25	597.45	598.35	0.24[a]	14.2	3.01	✓
DRC-9	596.26	594.35	596.20	593.50	594.40	0.06[a]	2.3	2.18	✓
DRC-10[4]	574.70	574.20	574.57	572.30 US 572.00 DS	574.13 US 573.83 DS	0.13[b]	7.8	3.66	✓
DRC-11[4]	577.61	577.20	577.55	575.17	576.72	0.06[a]	22.6	1.30	✓
DRC-12[4]	591.82	590.70	591.62	589.00	590.48	0.20[b]	7.2	4.37	✓
DRC-13[4]	599.52	599.00	599.31	598.30	598.68	0.21[b]	0.4	1.89	✓
DRC-14[4]	604.31	603.50	603.88	602.40	603.10	0.43[a]	7.2	2.64	✓
DRC-15[4]	615.13	615.40	612.74	611.60 US 611.45 DS	613.42 US 613.27 DS	2.39[a]	32.1	4.45	
DRC-16[4]	615.38	615.24	615.16	614.10	615.00	0.22[b]	9.6	3.07	✓

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. These values are based on results output at 10minute intervals. For some locations in the upper catchment, the instantaneous peak values may not have been identified accurately.

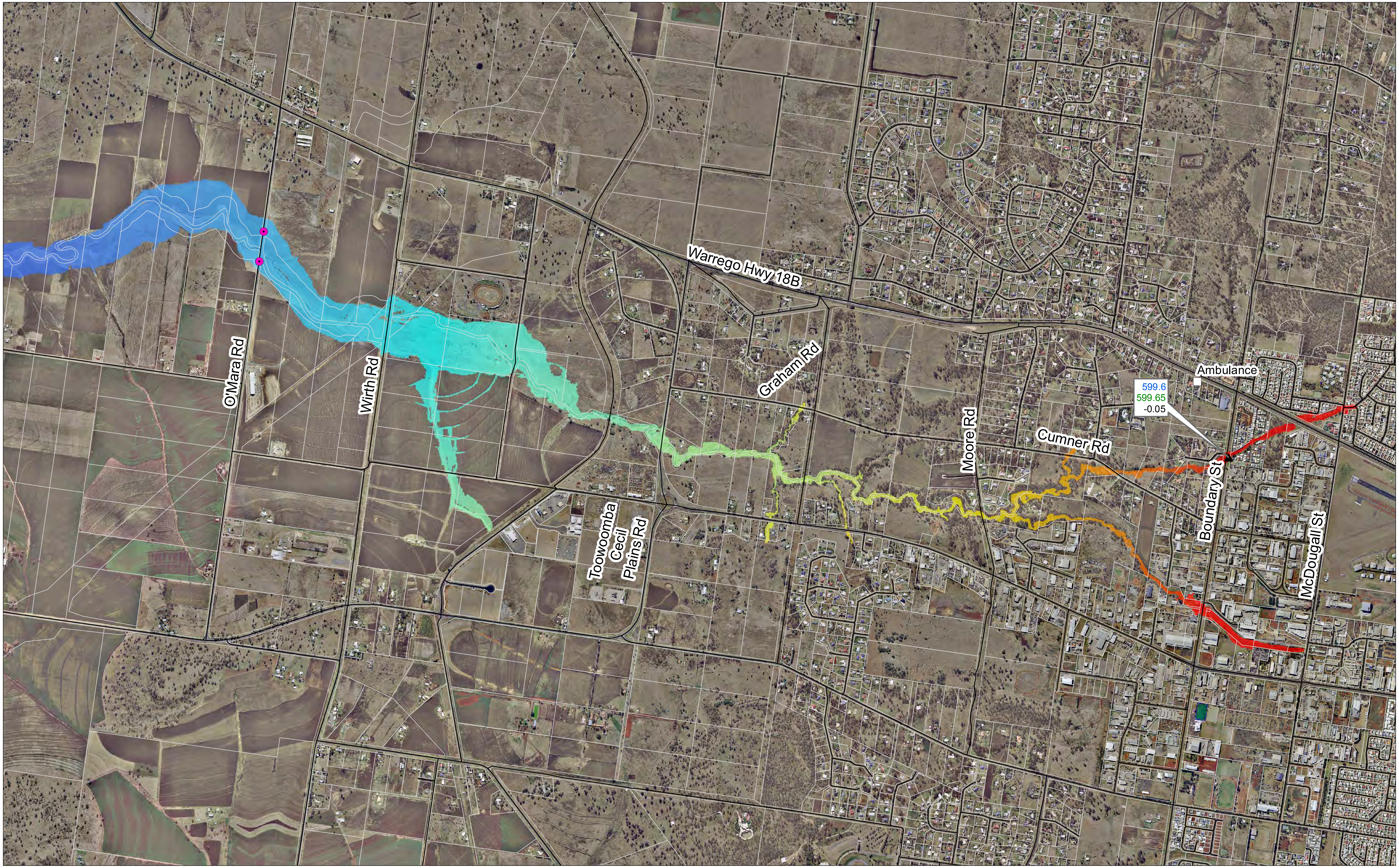
Table B.30 Head Losses, Discharges and Velocities at Structures for the 2100, 500 Year ARI Climate Change Scenario Event

Structure	Upstream Water Level (mAHD)	Road Level (mAHD)	Downstream Water Level (mAHD)	Structure Invert (mAHD)	Structure Obvert (mAHD)	Head Loss[1] (m)	Peak Discharge[2] (m3/s)	Peak Velocity[3] (m/s)	Road Overtopped
DRC-1	487.15	485.70	486.91	484.40	485.31	0.24[b]	18.0	2.71	✓
DRC-2	521.64	520.30	521.10	516.45 US 515.40 DS	518.17 US 517.12 DS	0.54[b]	59.6	6.42	✓
DRC-3	543.96	543.90	542.51	541.80	543.31	1.45[b]	11.0	3.56	✓
DRC-4	554.25	554.00	550.86	550.00	551.05	3.39[b]	8.5	4.91	✓
DRC-5	544.72	544.30	544.35	542.30	543.82	0.37[b]	6.0	3.73	✓
DRC-6	558.38	560.40	558.30	555.55	559.60	0.08[a]	115.9	2.93	
DRC-7	601.16	600.30	600.95	598.61	599.84	0.21[b]	19.2	2.56	✓
DRC-8	600.52	598.30	600.29	597.45	598.35	0.23[a]	14.2	3.02	✓
DRC-9	596.31	594.35	596.25	593.50	594.40	0.06[a]	2.3	2.19	✓
DRC-10[4]	574.71	574.20	574.58	572.30 US 572.00 DS	574.13 US 573.83 DS	0.13[b]	7.9	3.68	✓
DRC-11[4]	577.63	577.20	577.57	575.17	576.72	0.06[a]	22.7	1.30	✓
DRC-12[4]	591.84	590.70	591.64	589.00	590.48	0.20[b]	7.2	4.39	✓
DRC-13[4]	599.53	599.00	599.32	598.30	598.68	0.21[b]	0.4	1.91	✓
DRC-14[4]	604.32	603.50	603.90	602.40	603.10	0.42[a]	7.3	2.66	✓
DRC-15[4]	615.26	615.40	612.77	611.60 US 611.45 DS	613.42 US 613.27 DS	2.49[a]	33.1	4.55	
DRC-16[4]	615.41	615.24	615.27	614.10	615.00	0.14[b]	9.7	3.11	✓

1. The head loss is calculated as the difference between the upstream and downstream peak water levels in [a]MIKE 11 or [b]MIKE 21, see Section 5 for explanation
2. Peak discharge is reported through the culvert or bridge
3. Peak velocity is reported through the culvert or bridge
4. These values are based on results output at 10minute intervals. For some locations in the upper catchment, the instantaneous peak values may not have been identified accurately.

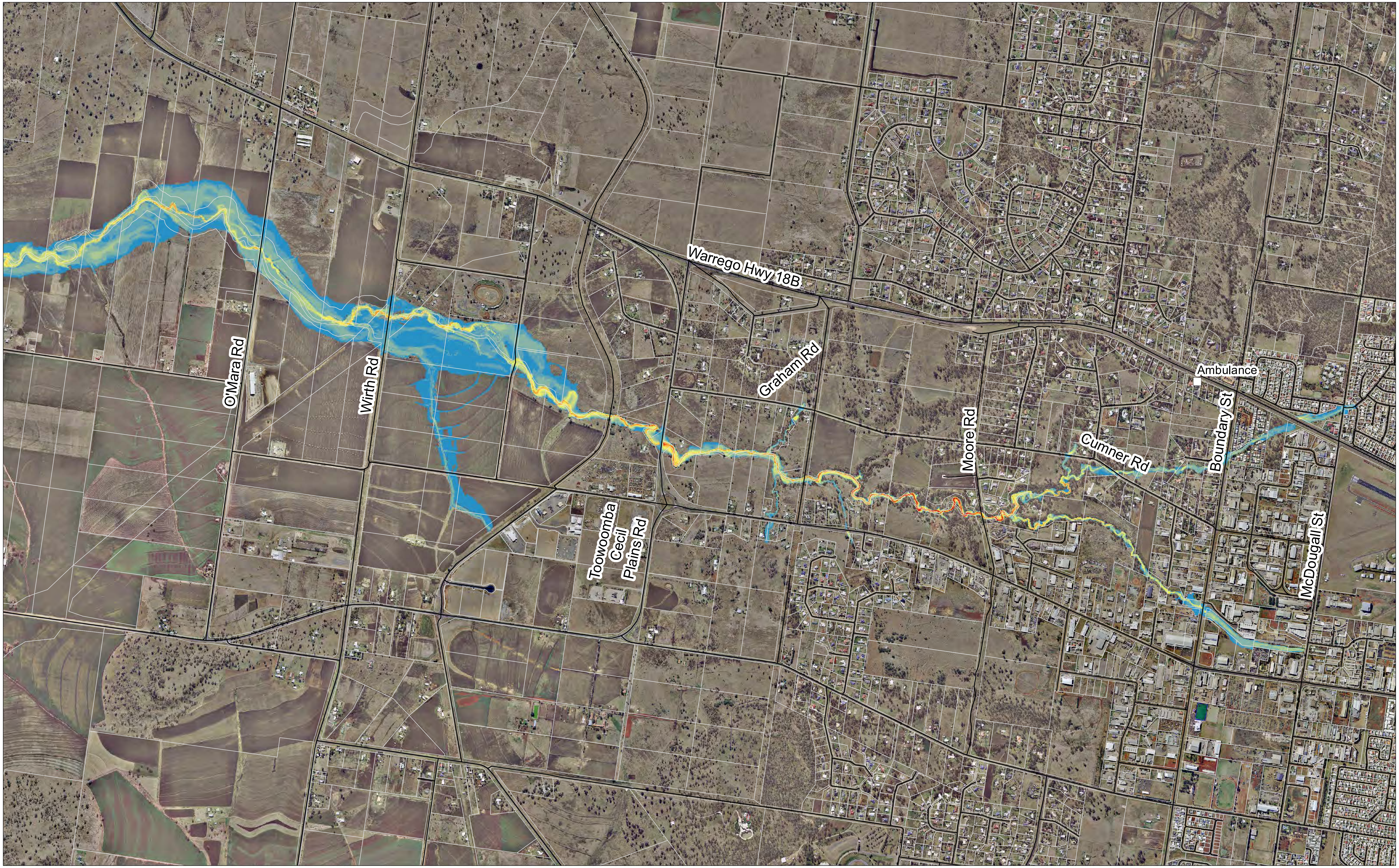
APPENDIX C

MODEL VALIDATION MAPPING



Disclaimer: The flood information contained in the maps is based on debris lines and marks that were visible and accessible at the time of recording after the January 2011 flood event and may not be accurate or complete and reliance should not be placed on it. Toowoomba Regional Council makes no representations or warranties about the accuracy, reliability, completeness or suitability for any particular purpose and disclaim all responsibility and all liability whether in contract, negligence or otherwise for all expenses, losses, damages (including indirect or consequential damage) and costs which may be incurred in any way and for any reason as a result of the flood information contained in the maps being inaccurate or incomplete.

SP051 Flood Studies
Work Package 8 Dry Creek
January 2011
Water Surface Elevation



TOOWOOMBA REGIONAL COUNCIL

1:20,000 (at A3)

0 200 400 800
Meters

N

GDA 1994 MGA Zone 56

Legend

Peak Water Depth (m)

0 - 0.25, 0.25 - 0.5, 0.5 - 1, 1 - 1.5, 1.5 - 2, 2 - 2.5, 2.5 - 3, 3 - 3.5, 3.5 - 4, 4 - 4.5, 4.5 - 5, >5

Road Centrelines

Cadastre

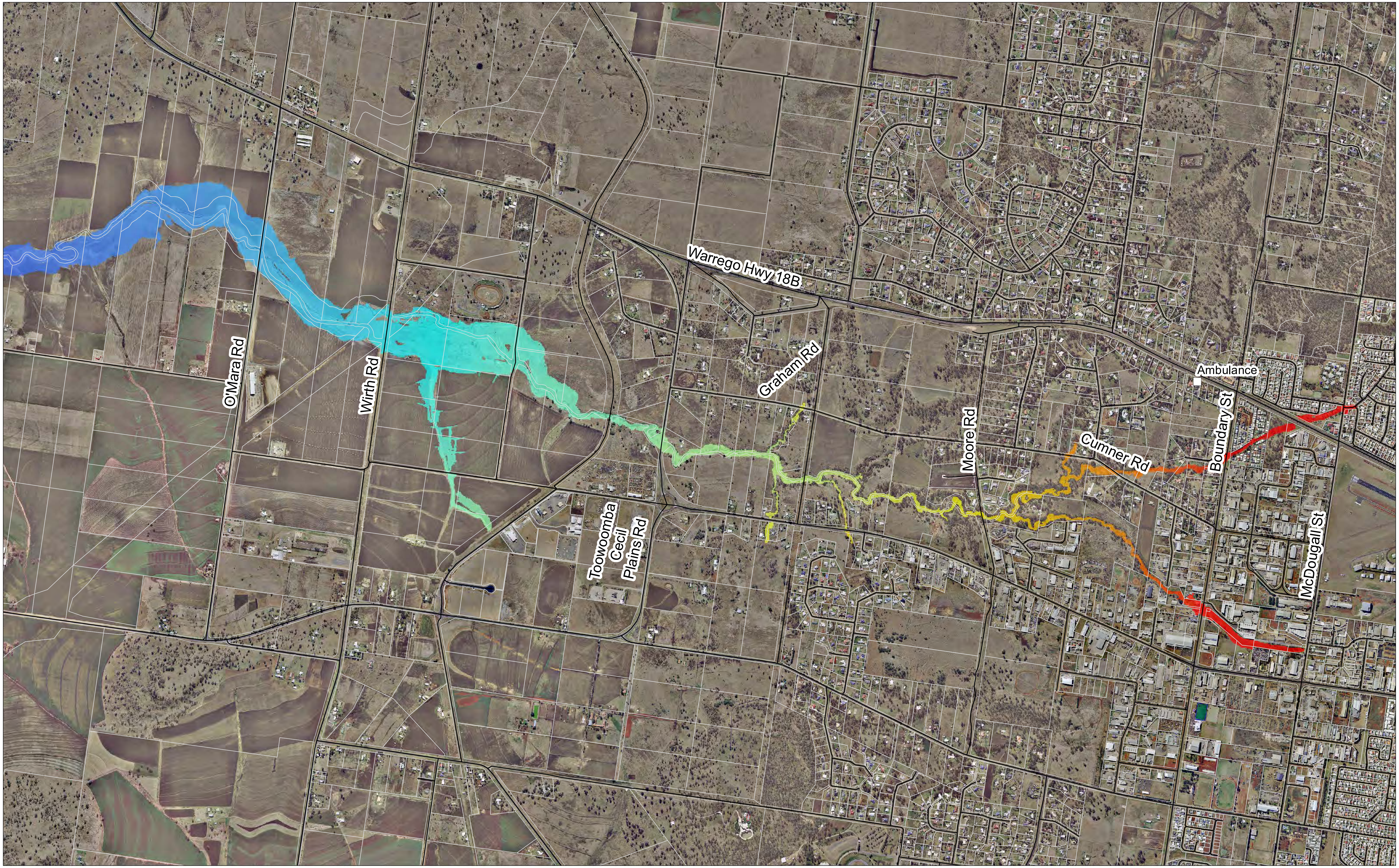
Emergency Services

Disclaimer: The flood information contained in the maps is based on debris lines and marks that were visible and accessible at the time of recording after the January 2011 flood event and may not be accurate or complete and reliance should not be placed on it. Toowoomba Regional Council makes no representations or warranties about the accuracy, reliability, completeness or suitability for any particular purpose and disclaim all responsibility and all liability whether in contract, negligence or otherwise for all expenses, losses, damages (including indirect or consequential damage) and costs which may be incurred in any way and for any reason as a result of the flood information contained in the maps being inaccurate or incomplete.

SP051 Flood Studies
Work Package 8 Dry Creek
January 2011
Peak Water Depth

APPENDIX D

DESIGN EVENT MAPPING



1:20,000 (at A3)

0 200 400 800
Meters

N

GDA 1994 MGA Zone 56

TOOWOOMBA REGIONAL COUNCIL

Legend

Surface Elevation [mAHD]

600

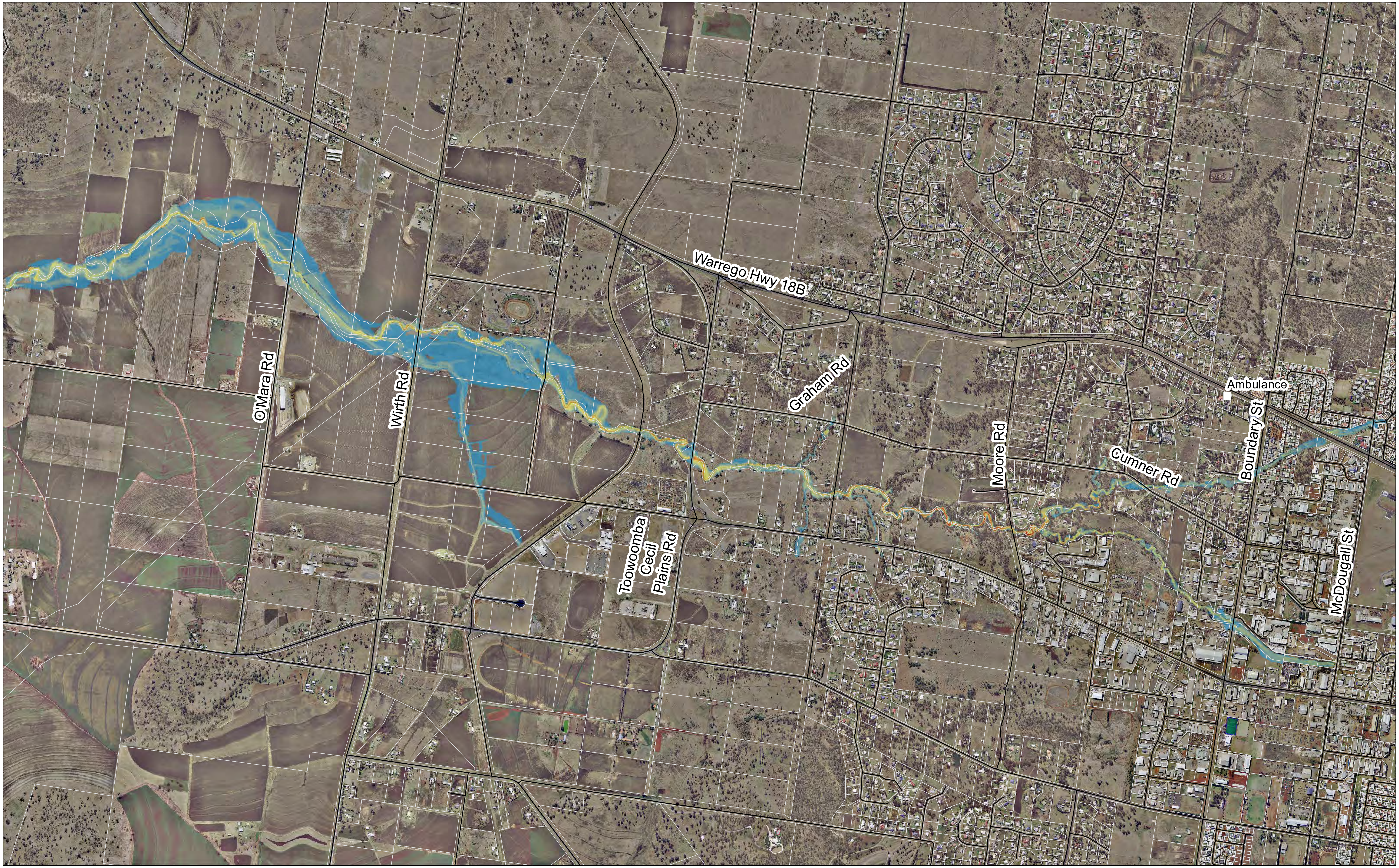
450

Road Centrelines

Cadastre

Emergency Services

SP051 Flood Studies
Work Package 8 Dry Creek
10 Year ARI Event
Water Surface Elevation



SP051 Flood Studies
Work Package 8 Dry Creek
10 Year ARI Event
Peak Flood Depths

TOOWOOMBA REGIONAL COUNCIL

1:20,000 (at A3)

0 200 400 800
Meters

GDA 1994 MGA Zone 56

N

Legend

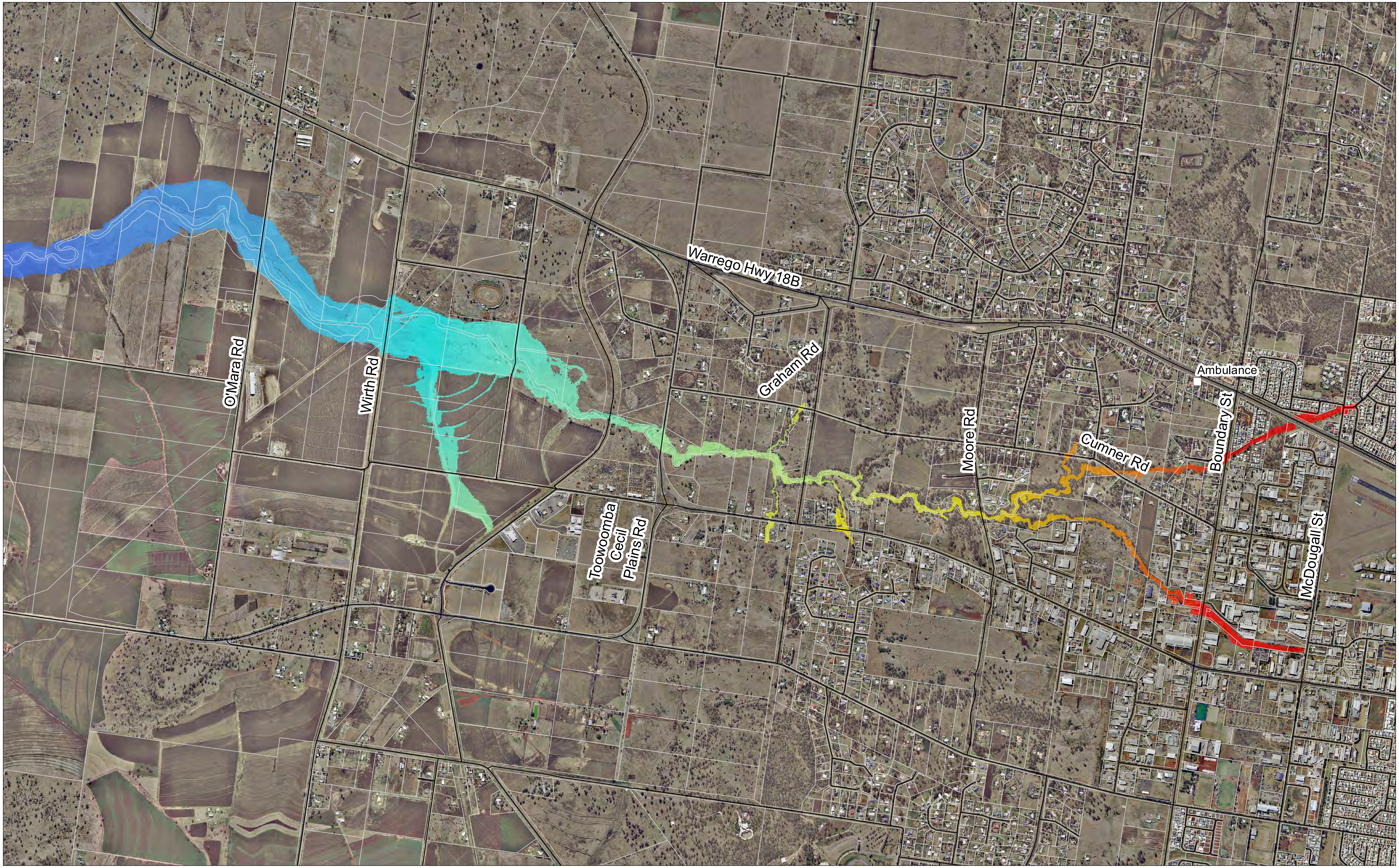
Peak Water Depth (m)

0 - 0.25, 0.25 - 0.5, 0.5 - 1, 1 - 1.5, 1.5 - 2, 2 - 2.5, 2.5 - 3, 3 - 3.5, 3.5 - 4, 4 - 4.5, 4.5 - 5, >5

Road Centrelines

Cadastre

Emergency Services



TOOWOOMBA REGIONAL COUNCIL

1:20,000 (at A3)

0 200 400 800
Meters

GDA 1994 MGA Zone 56

N

Legend

Surface Elevation [mAHD]

600

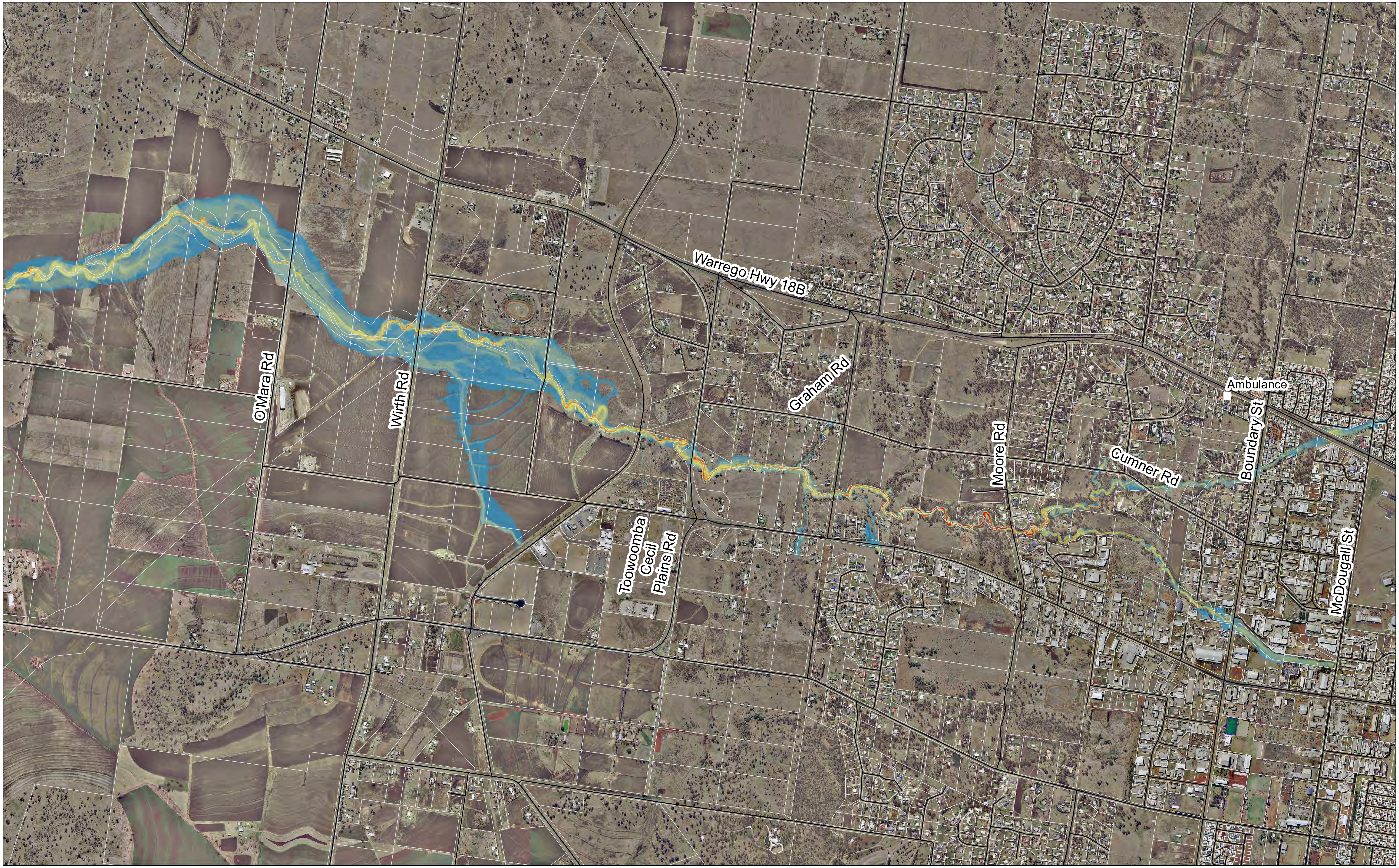
450

Road Centrelines

Cadastre

Emergency Services

SP051 Flood Studies
Work Package 8 Dry Creek
50 Year ARI Event
Water Surface Elevation



1:20,000 (at A3)

0 200 400 800
Meters

GDA 1994 MGA Zone 56

N

TOOWOOMBA REGIONAL COUNCIL

Legend

Peak Water Depth (m)

0 - 0.25, 0.25 - 0.5, 0.5 - 1, 1 - 1.5, 1.5 - 2, 2 - 2.5, 2.5 - 3, 3 - 3.5, 3.5 - 4, 4 - 4.5, 4.5 - 5, >5

Road Centrelines

Cadastre

Emergency Services

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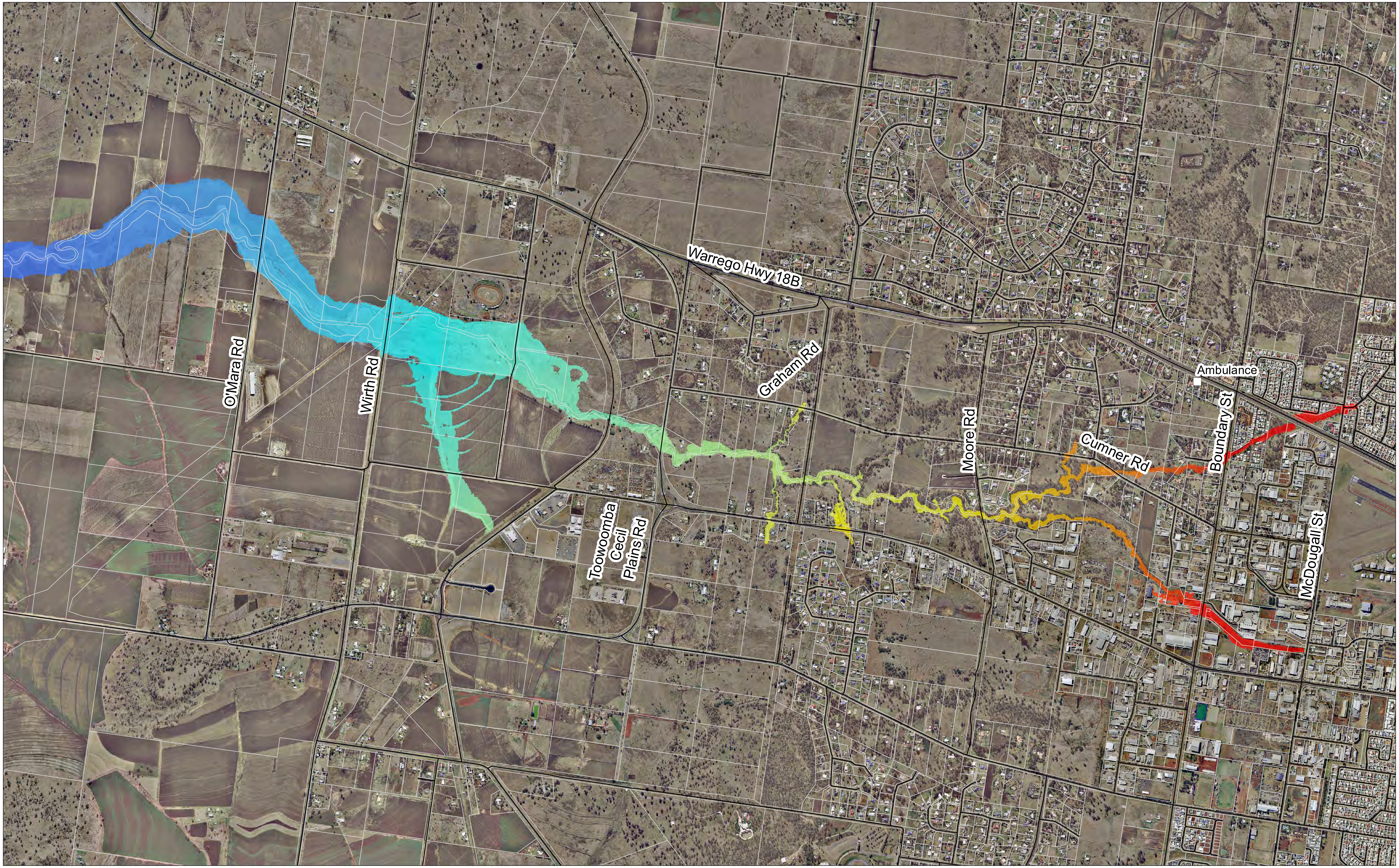
SP051 Flood Studies
Work Package 8 Dry Creek
50 Year ARI Event
Peak Flood Depths



1:20,000 (at A3)

0 200 400 800
Meters
GDA 1994 MGA Zone 56

N

Legend

Surface Elevation [mAHD]

600

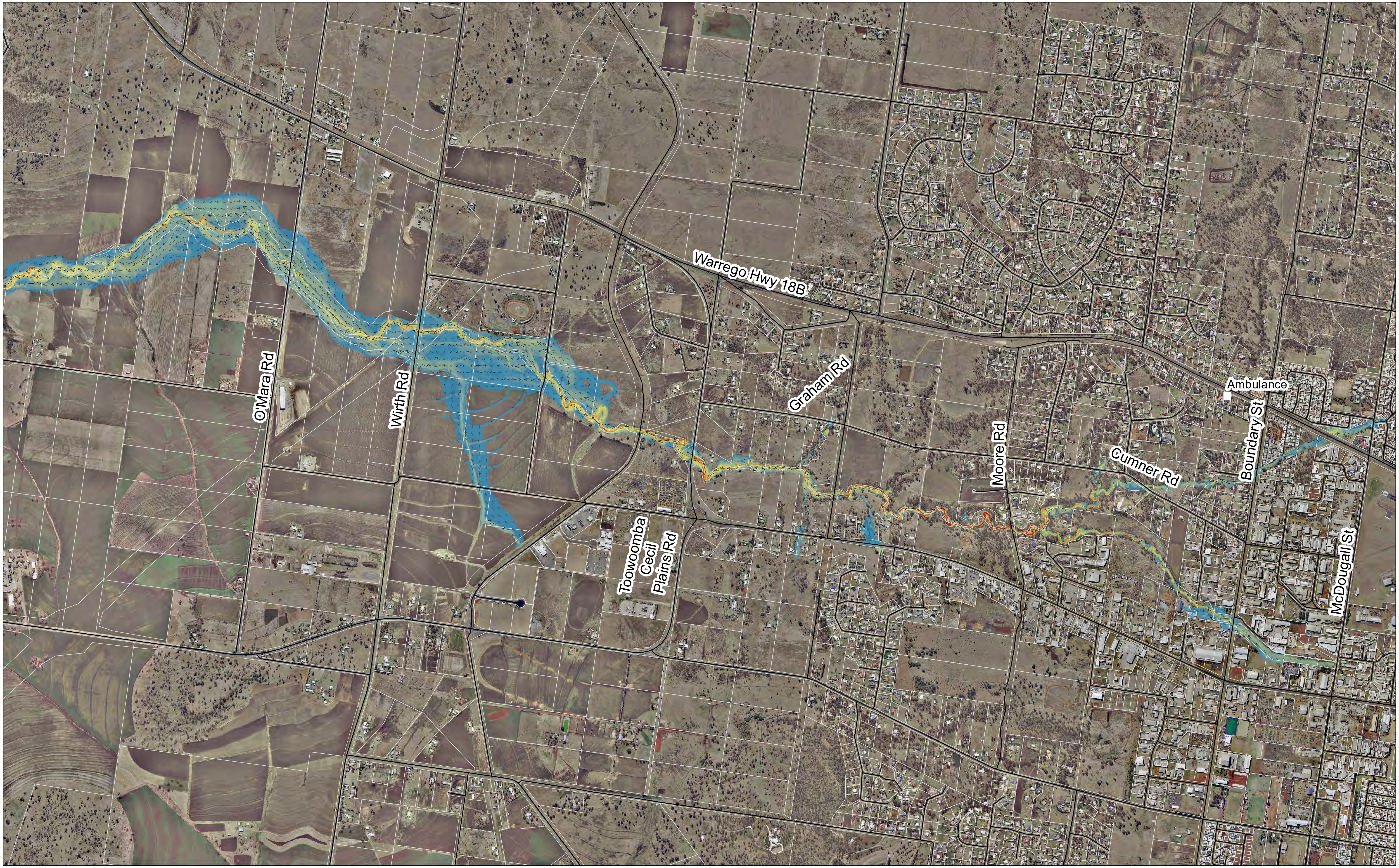
450

Road Centrelines

Cadastre

Emergency Services

SP051 Flood Studies
Work Package 8 Dry Creek
100 Year ARI Event
Water Surface Elevation



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0 200 400 800
Meters

GDA 1994 MGA Zone 56

N

TOOWOOMBA REGIONAL COUNCIL

Legend

Peak Water Depth (m)

0 - 0.25, 0.25 - 0.5, 0.5 - 1, 1 - 1.5, 1.5 - 2, 2 - 2.5, 2.5 - 3, 3 - 3.5, 3.5 - 4, 4 - 4.5, 4.5 - 5, >5

Road Centrelines

Cadastre

Emergency Services

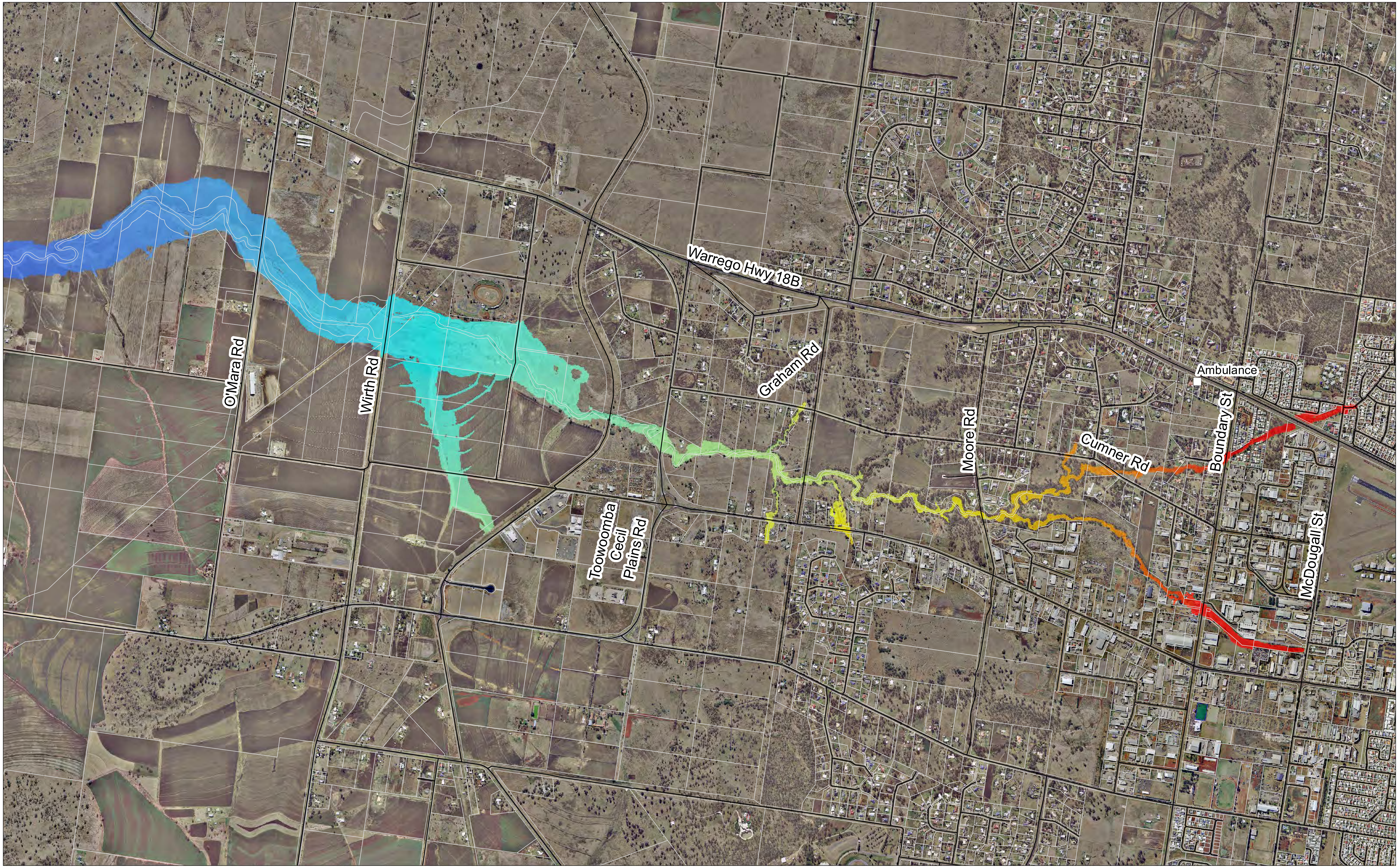
Velocity (m/s)

0 - 1

1 - 2

>2

SP051 Flood Studies
Work Package 8 Dry Creek
100 Year ARI Event
Peak Flood Depths and Velocities



TOOWOOMBA REGIONAL COUNCIL

1:20,000 (at A3)

0 200 400 800
Meters

GDA 1994 MGA Zone 56

N

Legend

Surface Elevation [mAHD]

600

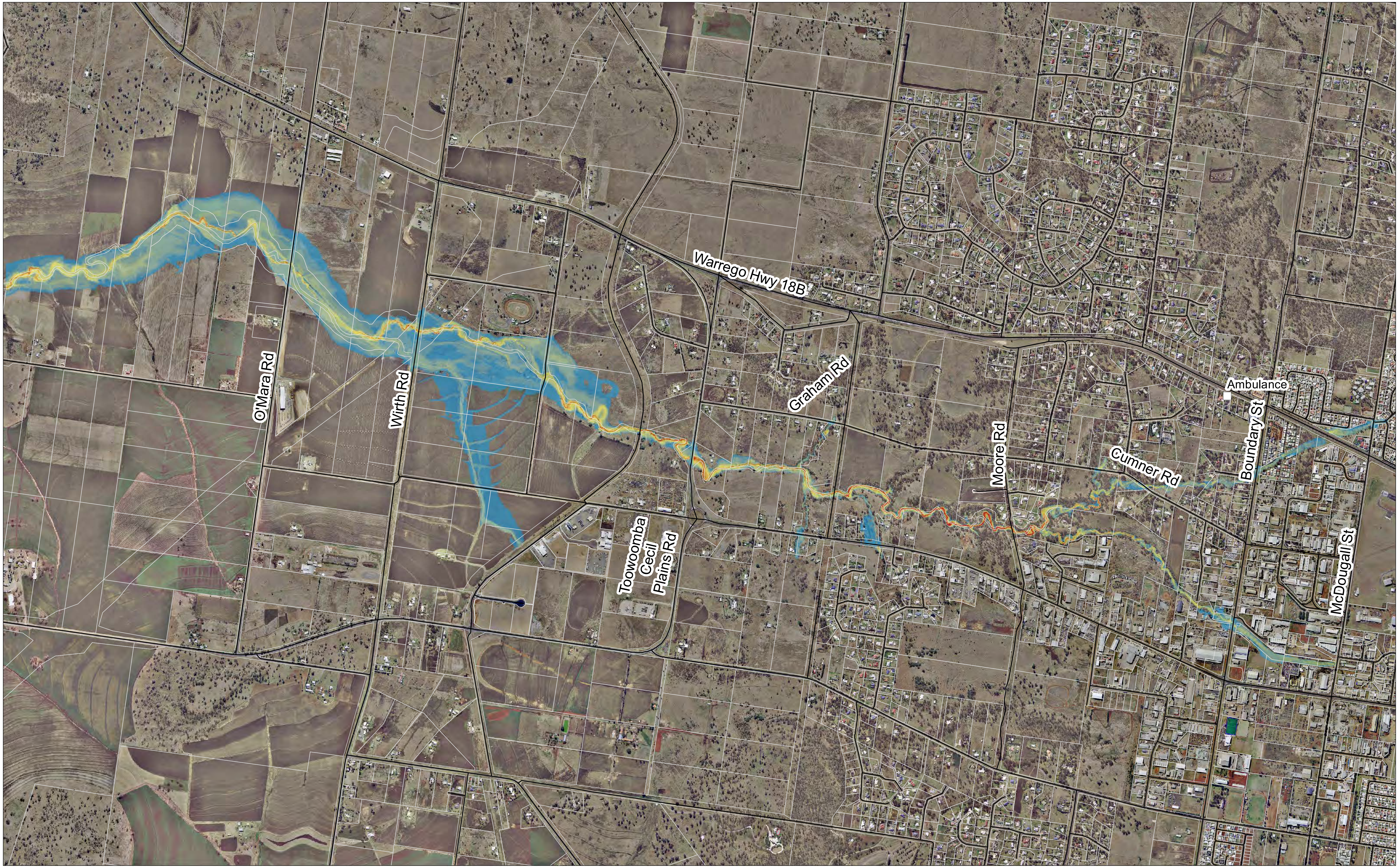
450

Road Centrelines

Cadastre

Emergency Services

SP051 Flood Studies
Work Package 8 Dry Creek
200 Year ARI Event
Water Surface Elevation



SP051 Flood Studies
Work Package 8 Dry Creek
200 Year ARI Event
Peak Flood Depths

TOOWOOMBA REGIONAL COUNCIL

1:20,000 (at A3)

0 200 400 800
Meters

GDA 1994 MGA Zone 56

N

Legend

Peak Water Depth (m)

0 - 0.25, 0.25 - 0.5, 0.5 - 1, 1 - 1.5, 1.5 - 2, 2 - 2.5, 2.5 - 3, 3 - 3.5, 3.5 - 4, 4 - 4.5, 4.5 - 5, >5

Road Centrelines

Cadastre

Emergency Services

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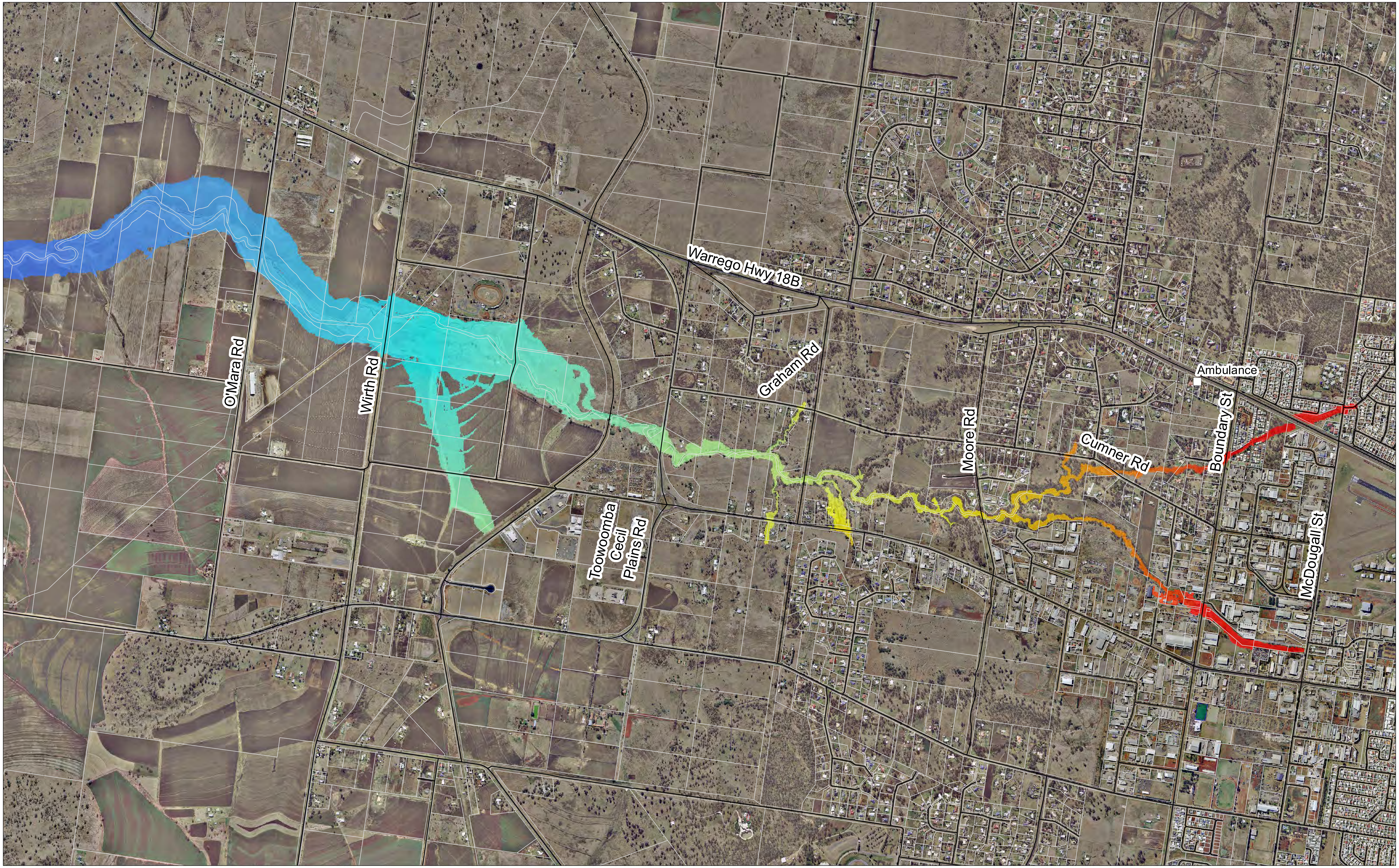

TOOWOOMBA REGIONAL COUNCIL

1:20,000 (at A3)

0 200 400 800

Meters

GDA 1994 MGA Zone 56

N

Legend

Surface Elevation [mAHD]

600

450

Road Centrelines

Cadastre

Emergency Services

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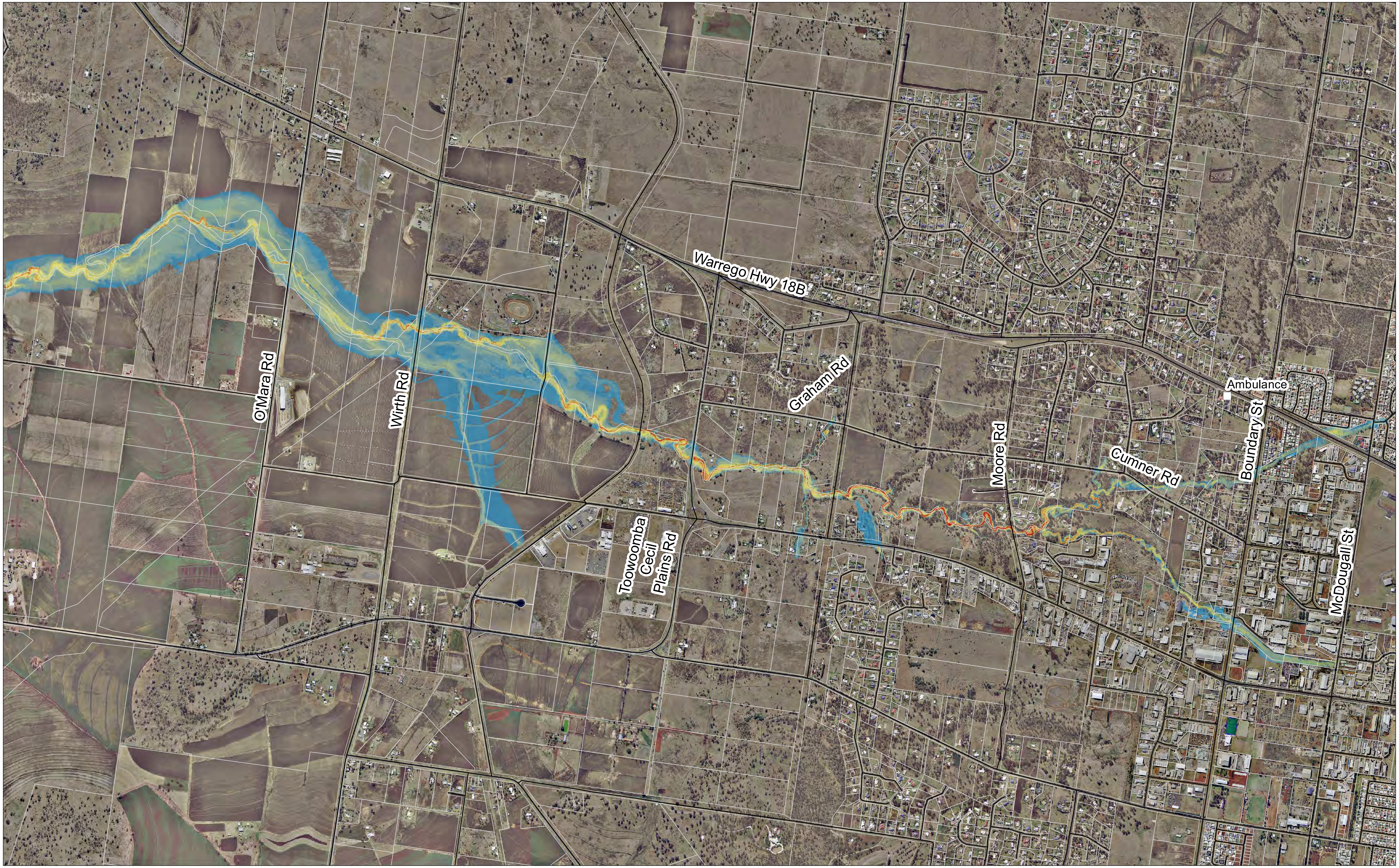
SP051 Flood Studies
Work Package 8 Dry Creek
500 Year ARI Event
Water Surface Elevation



TOOWOOMBA REGIONAL COUNCIL

1:20,000 (at A3)

0 200 400 800
Meters

GDA 1994 MGA Zone 56

N

Legend

Peak Water Depth (m)

0 - 0.25, 0.25 - 0.5, 0.5 - 1, 1 - 1.5, 1.5 - 2, 2 - 2.5, 2.5 - 3, 3 - 3.5, 3.5 - 4, 4 - 4.5, 4.5 - 5, >5

Road Centrelines

Cadastre

Emergency Services

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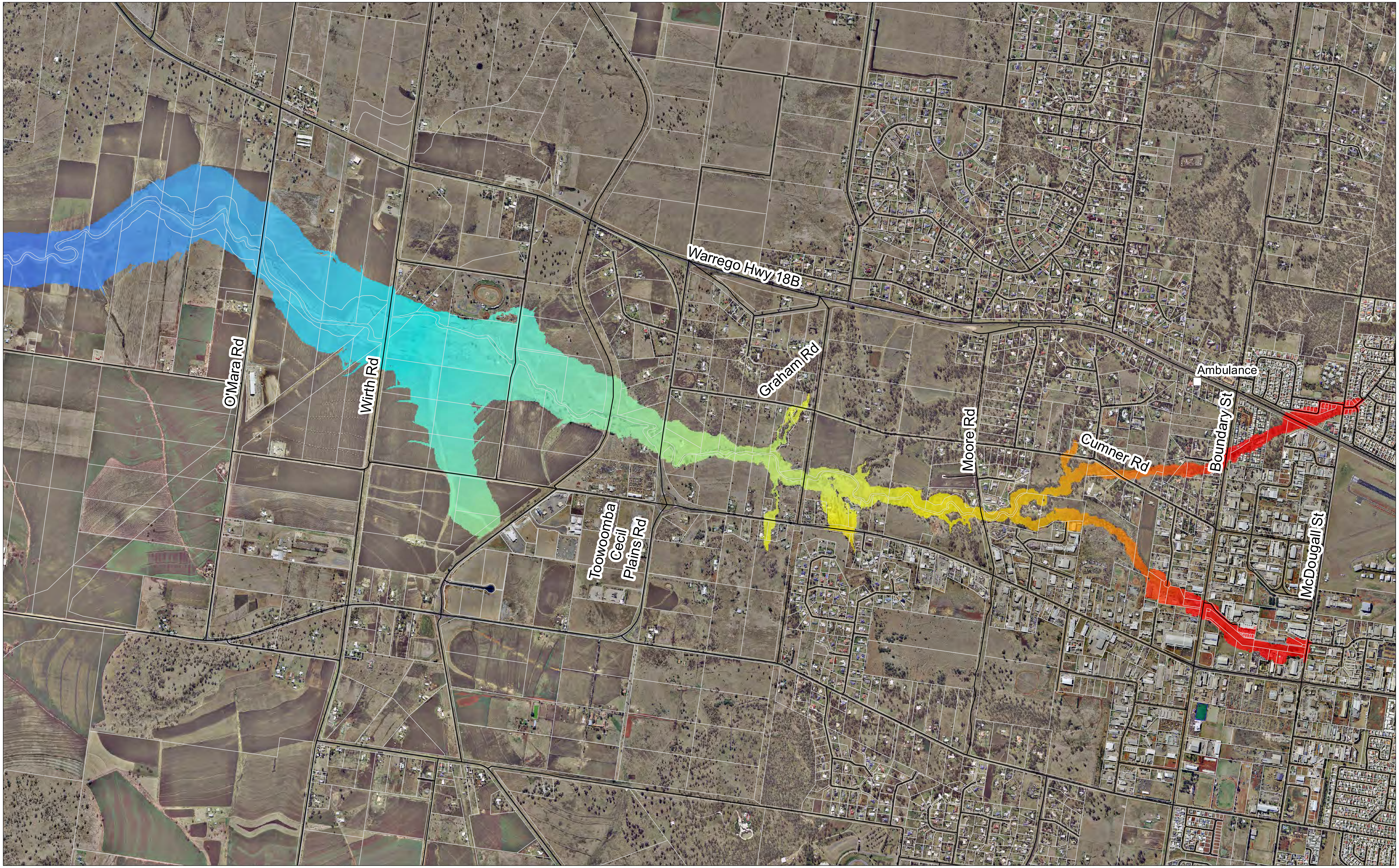
SP051 Flood Studies
Work Package 8 Dry Creek
500 Year ARI Event
Peak Flood Depths



TOOWOOMBA REGIONAL COUNCIL

1:20,000 (at A3)

0 200 400 800
Meters

N

GDA 1994 MGA Zone 56

Legend

Surface Elevation [mAHD]

600

450

Road Centrelines

Cadastre

Emergency Services

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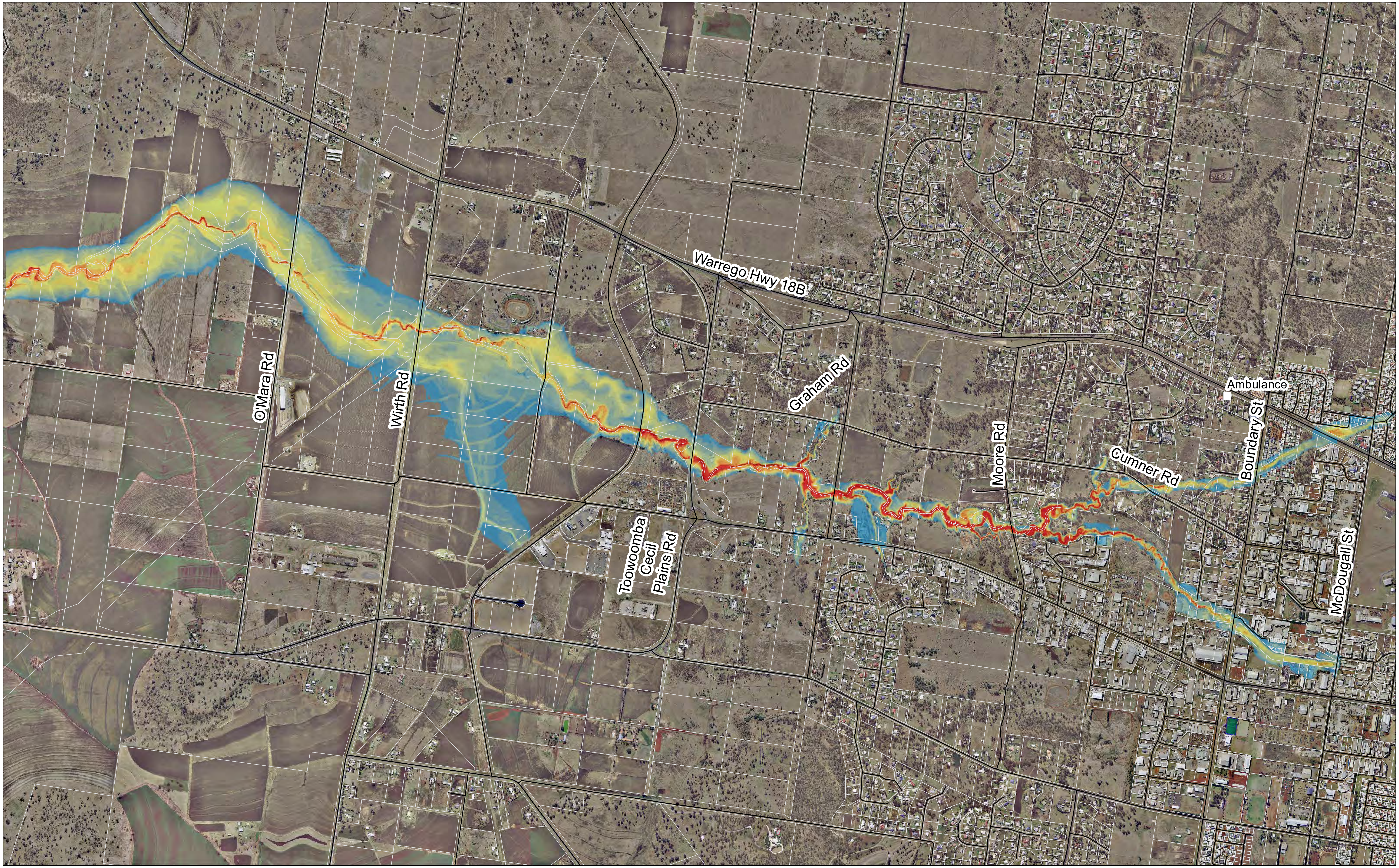
SP051 Flood Studies
Work Package 8 Dry Creek
Probable Maximum Flood Event
Water Surface Elevation



TOOWOOMBA REGIONAL COUNCIL

1:20,000 (at A3)

0 200 400 800
Meters

GDA 1994 MGA Zone 56

N

Legend

Peak Water Depth (m)

0 - 0.25, 0.25 - 0.5, 0.5 - 1, 1 - 1.5, 1.5 - 2, 2 - 2.5, 2.5 - 3, 3 - 3.5, 3.5 - 4, 4 - 4.5, 4.5 - 5, >5

Road Centrelines

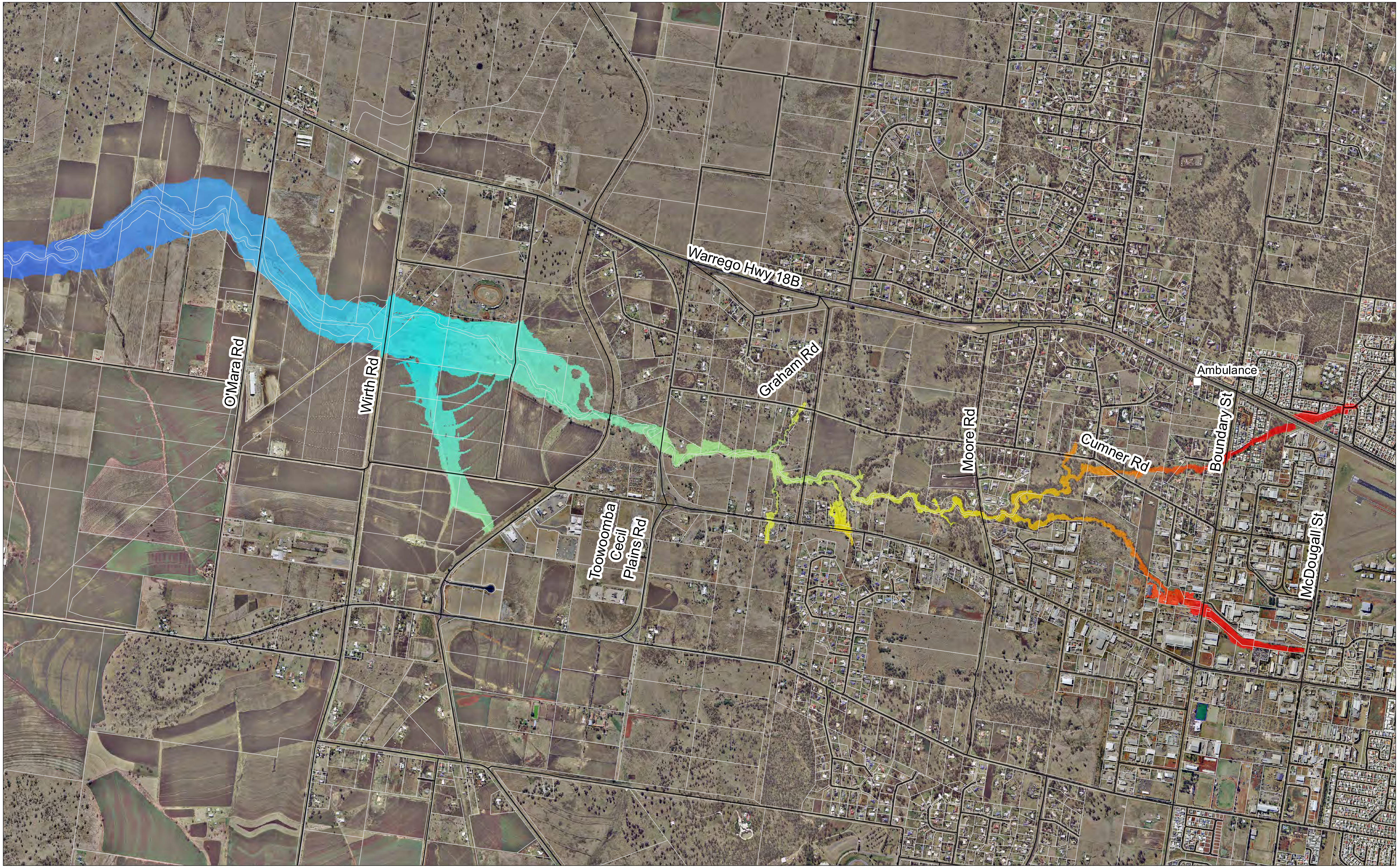
Cadastre

Emergency Services

SP051 Flood Studies
Work Package 8 Dry Creek
Probable Maximum Flood Event
Peak Flood Depths

APPENDIX E

CLIMATE CHANGE FLOOD MAPPING



TOOWOOMBA REGIONAL COUNCIL

1:20,000 (at A3)

0 200 400 800
Meters

N

GDA 1994 MGA Zone 56

Legend

Surface Elevation [mAHD]

600

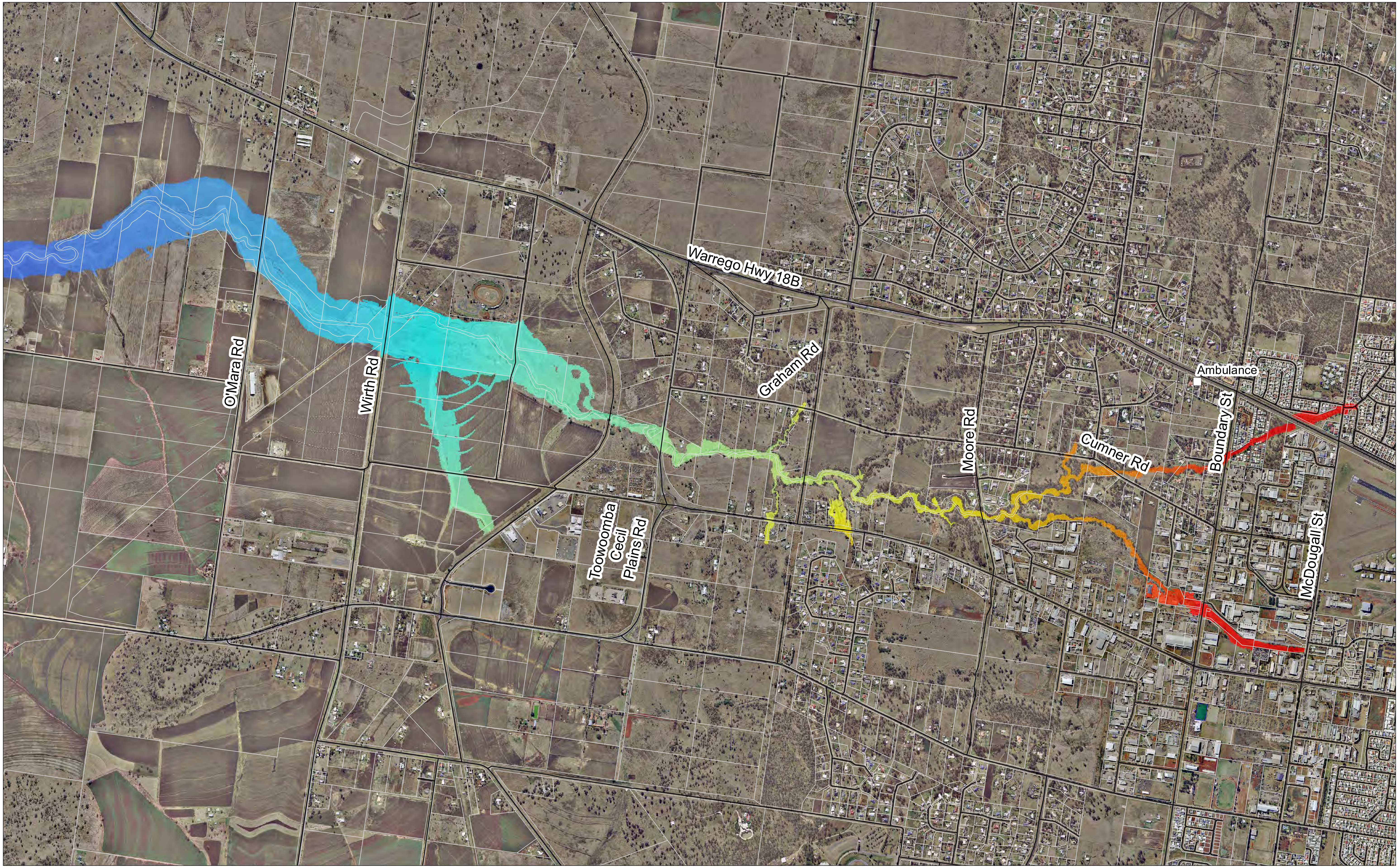
450

Road Centrelines

Cadastre

Emergency Services

SP051 Flood Studies
Work Package 8 Dry Creek
100 Year ARI Event Climate Change 2050
Water Surface Elevation



TOOWOOMBA REGIONAL COUNCIL

1:20,000 (at A3)

0 200 400 800
Meters

GDA 1994 MGA Zone 56

N

Legend

Surface Elevation [mAHD]

600

450

Road Centrelines

Cadastre

Emergency Services

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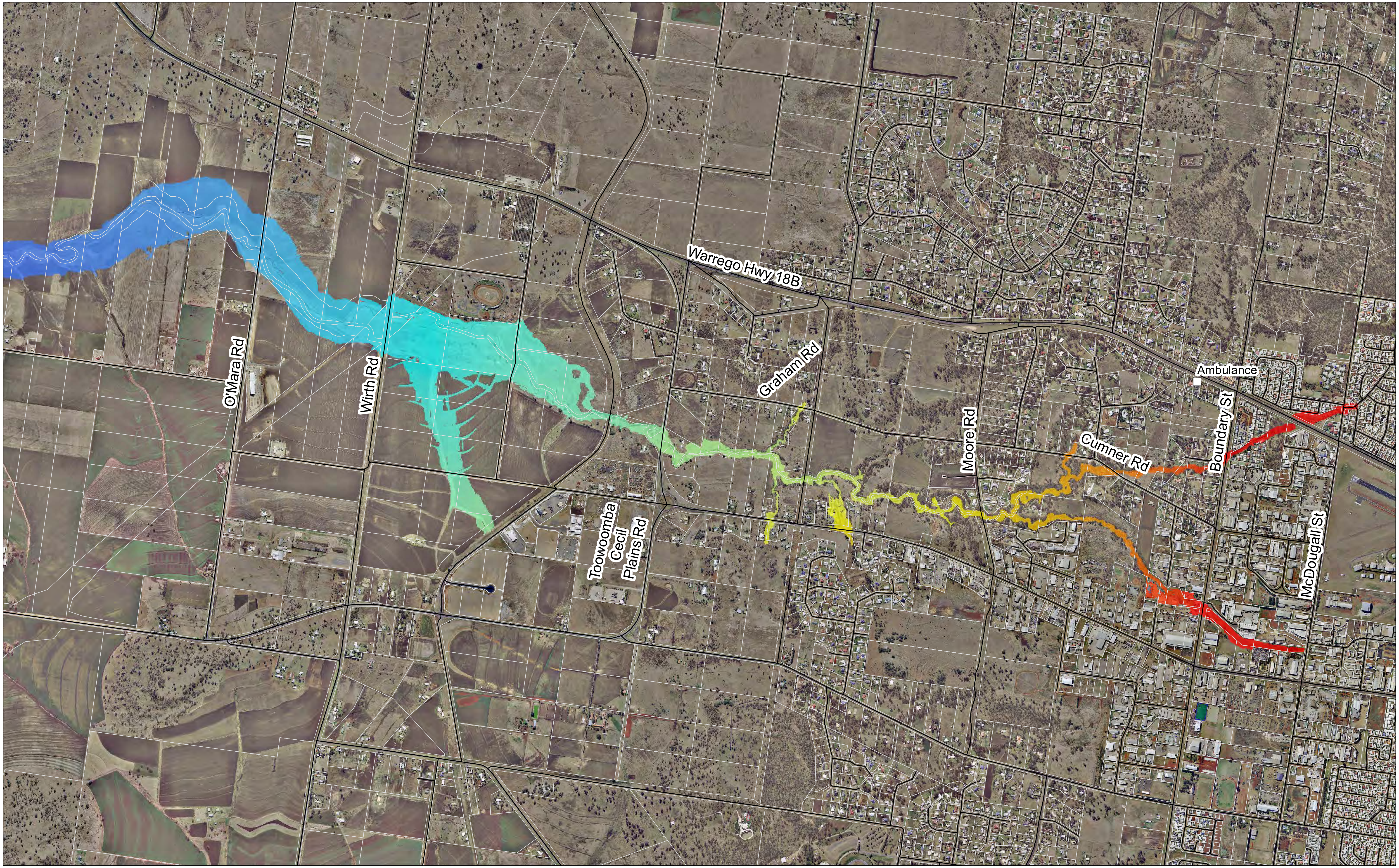
SP051 Flood Studies
Work Package 8 Dry Creek
100 Year ARI Event Climate Change 2070
Water Surface Elevation



1:20,000 (at A3)

0 200 400 800
Meters

GDA 1994 MGA Zone 56

N

TOOWOOMBA REGIONAL COUNCIL

Legend

Surface Elevation [mAHD]

600

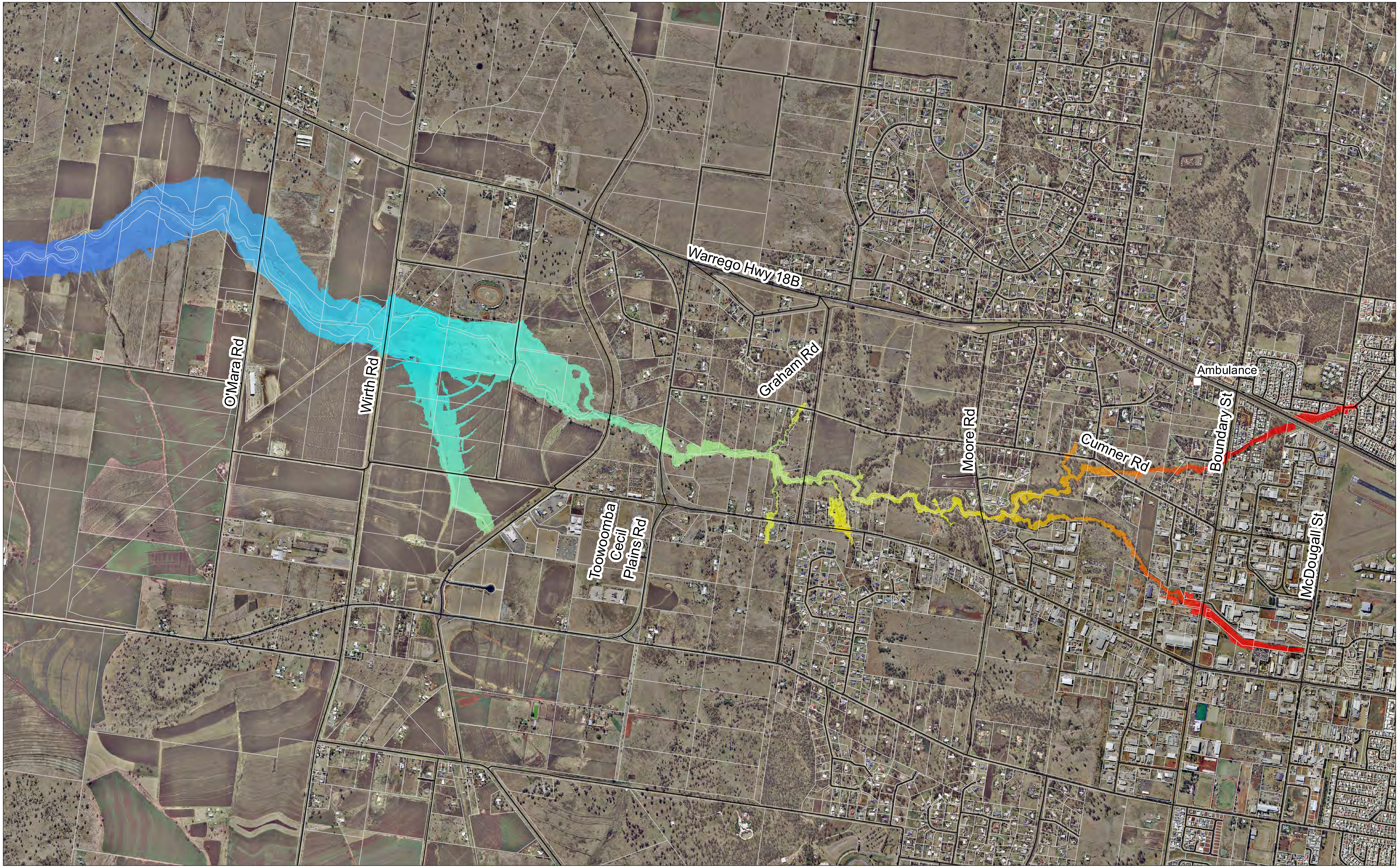
450

Road Centrelines

Cadastre

Emergency Services

SP051 Flood Studies
Work Package 8 Dry Creek
100 Year ARI Event Climate Change 2100
Water Surface Elevation



1:20,000 (at A3)

0 200 400 800
Meters

GDA 1994 MGA Zone 56

N

TOOWOOMBA REGIONAL COUNCIL

Legend

Surface Elevation [mAHD]

600

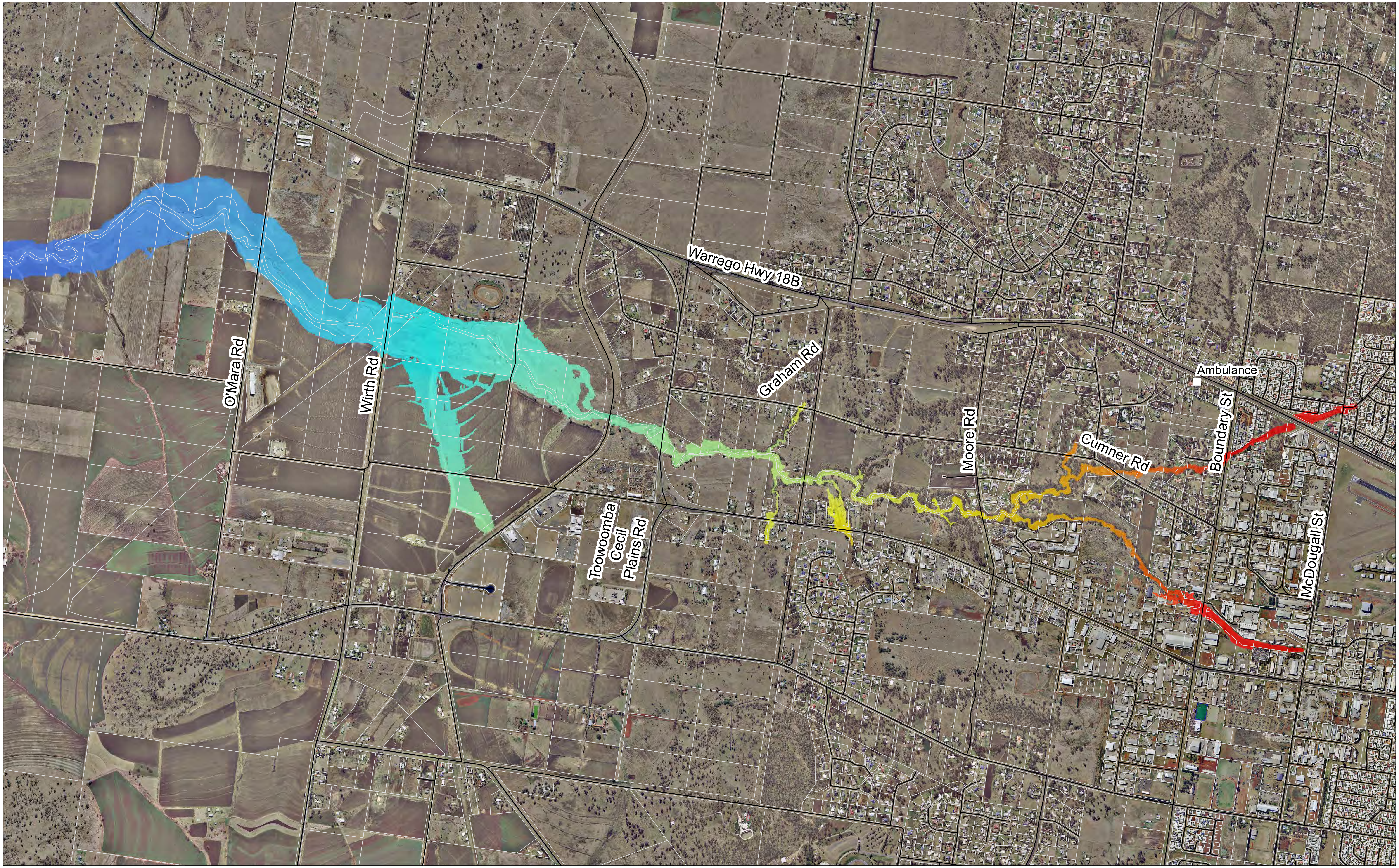
450

Road Centrelines

Cadastre

Emergency Services

SP051 Flood Studies
Work Package 8 Dry Creek
200 Year ARI Event Climate Change 2050
Water Surface Elevation



TOOWOOMBA REGIONAL COUNCIL

1:20,000 (at A3)

0 200 400 800
Meters

GDA 1994 MGA Zone 56

N

Legend

Surface Elevation [mAHD]

600

450

Road Centrelines

Cadastre

Emergency Services

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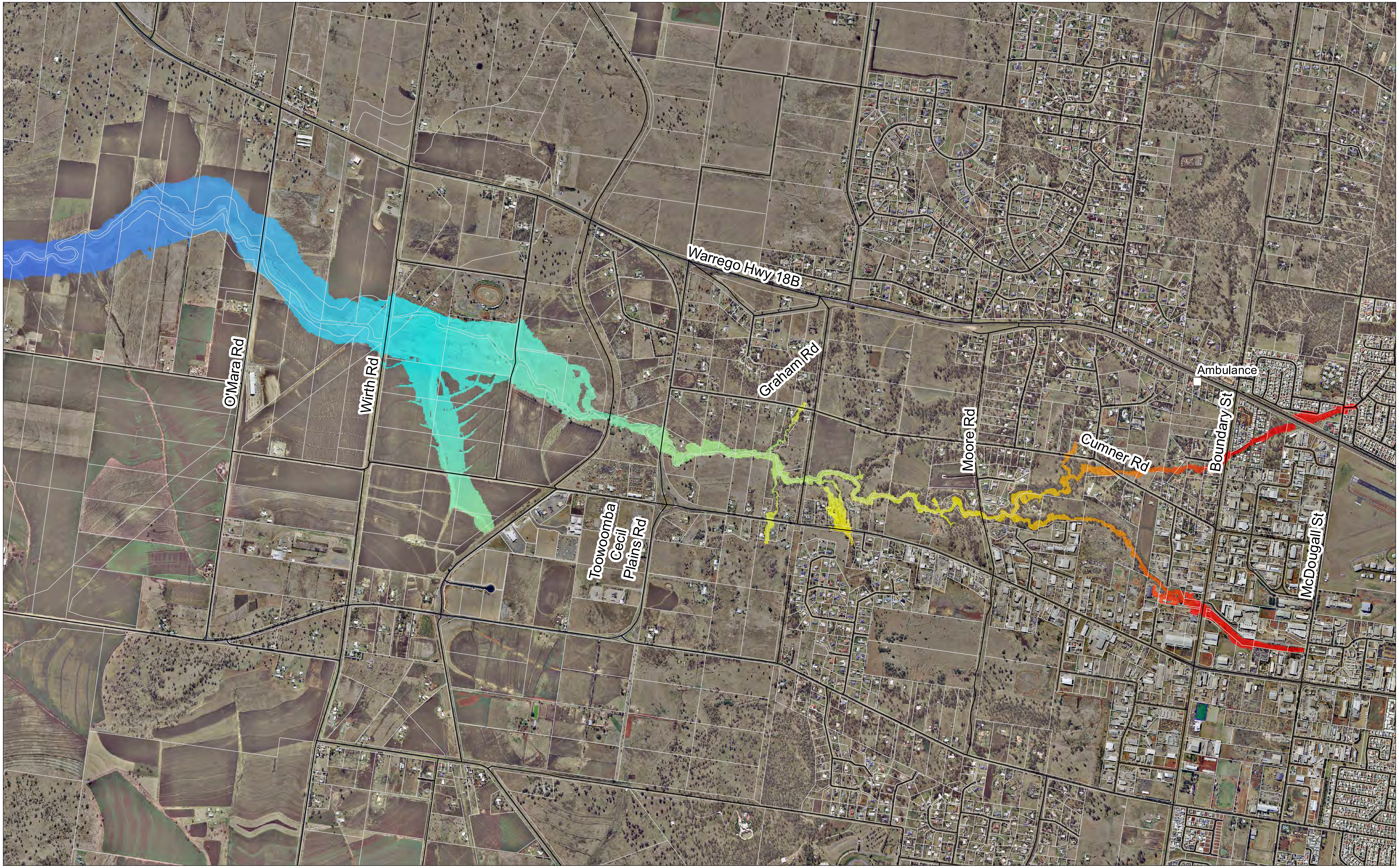
SP051 Flood Studies
Work Package 8 Dry Creek
200 Year ARI Event Climate Change 2070
Water Surface Elevation



TOOWOOMBA REGIONAL COUNCIL

1:20,000 (at A3)

0 200 400 800
Meters

N

GDA 1994 MGA Zone 56

Legend

Surface Elevation [mAHD]

600

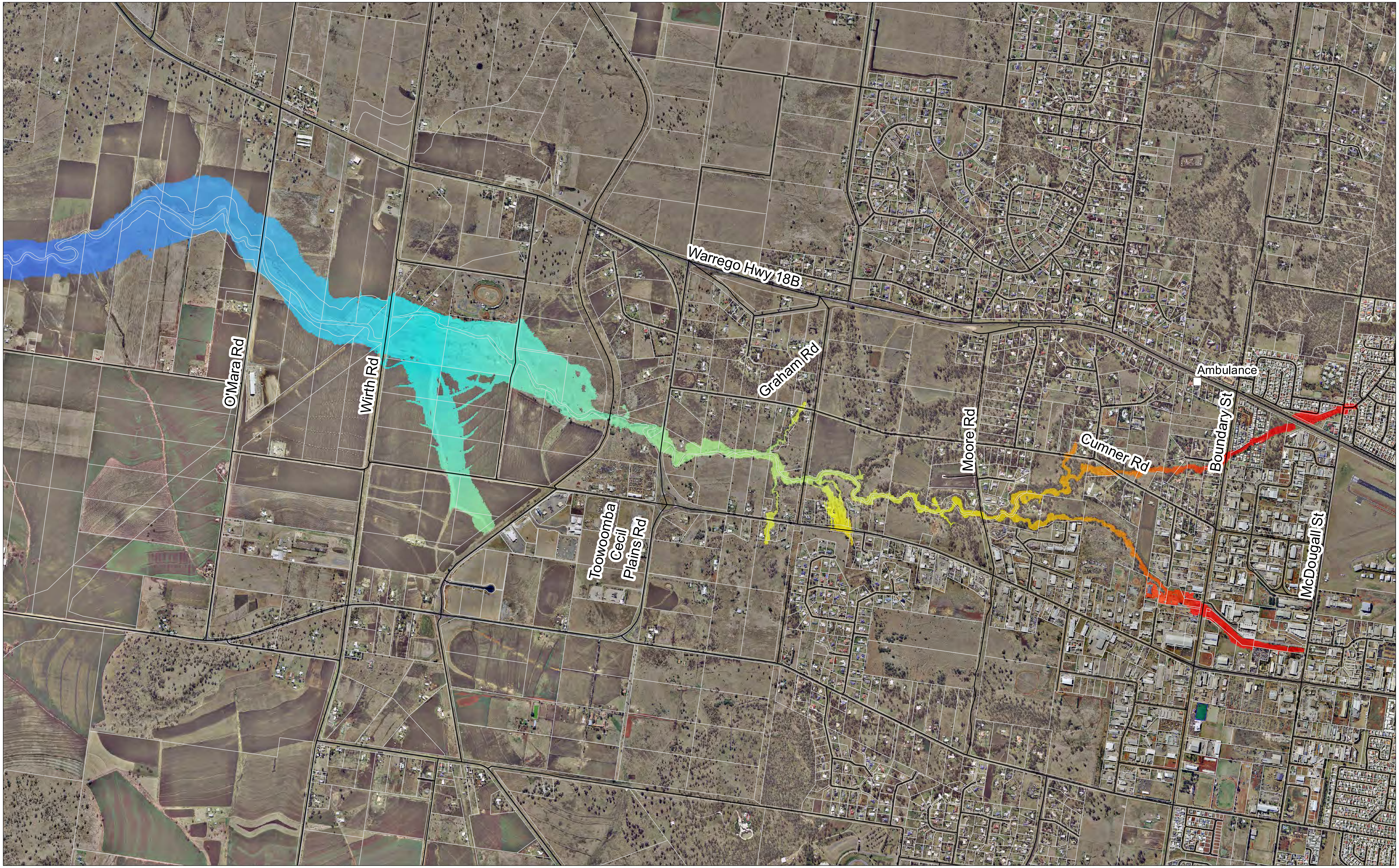
450

Road Centrelines

Cadastre

Emergency Services

SP051 Flood Studies
Work Package 8 Dry Creek
200 Year ARI Event Climate Change 2100
Water Surface Elevation



TOOWOOMBA REGIONAL COUNCIL

1:20,000 (at A3)

0 200 400 800
Meters

GDA 1994 MGA Zone 56

N

Legend

Surface Elevation [mAHD]

600

450

Road Centrelines

Cadastre

Emergency Services

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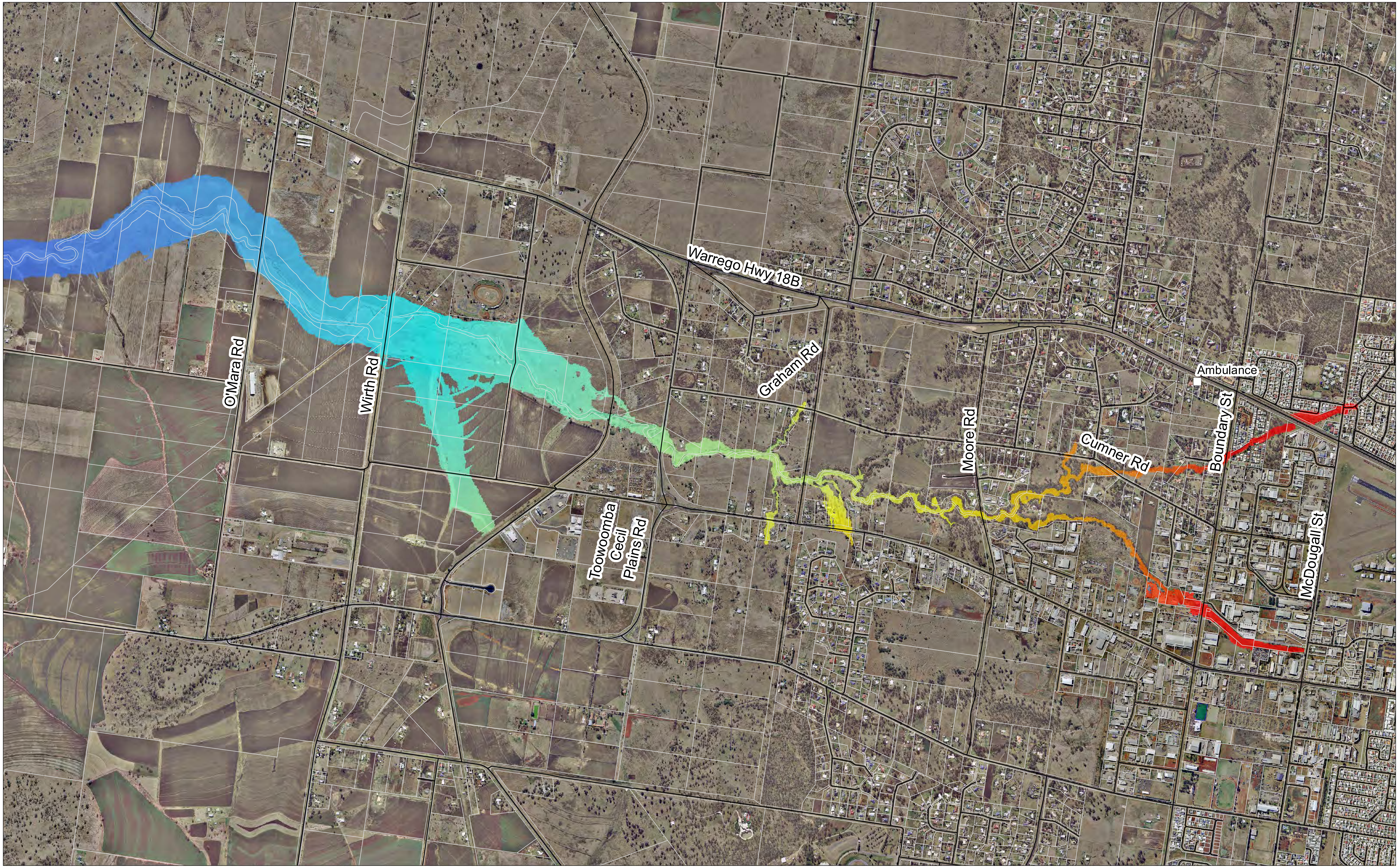
SP051 Flood Studies
Work Package 8 Dry Creek
500 Year ARI Event Climate Change 2050
Water Surface Elevation



1:20,000 (at A3)

0 200 400 800
Meters

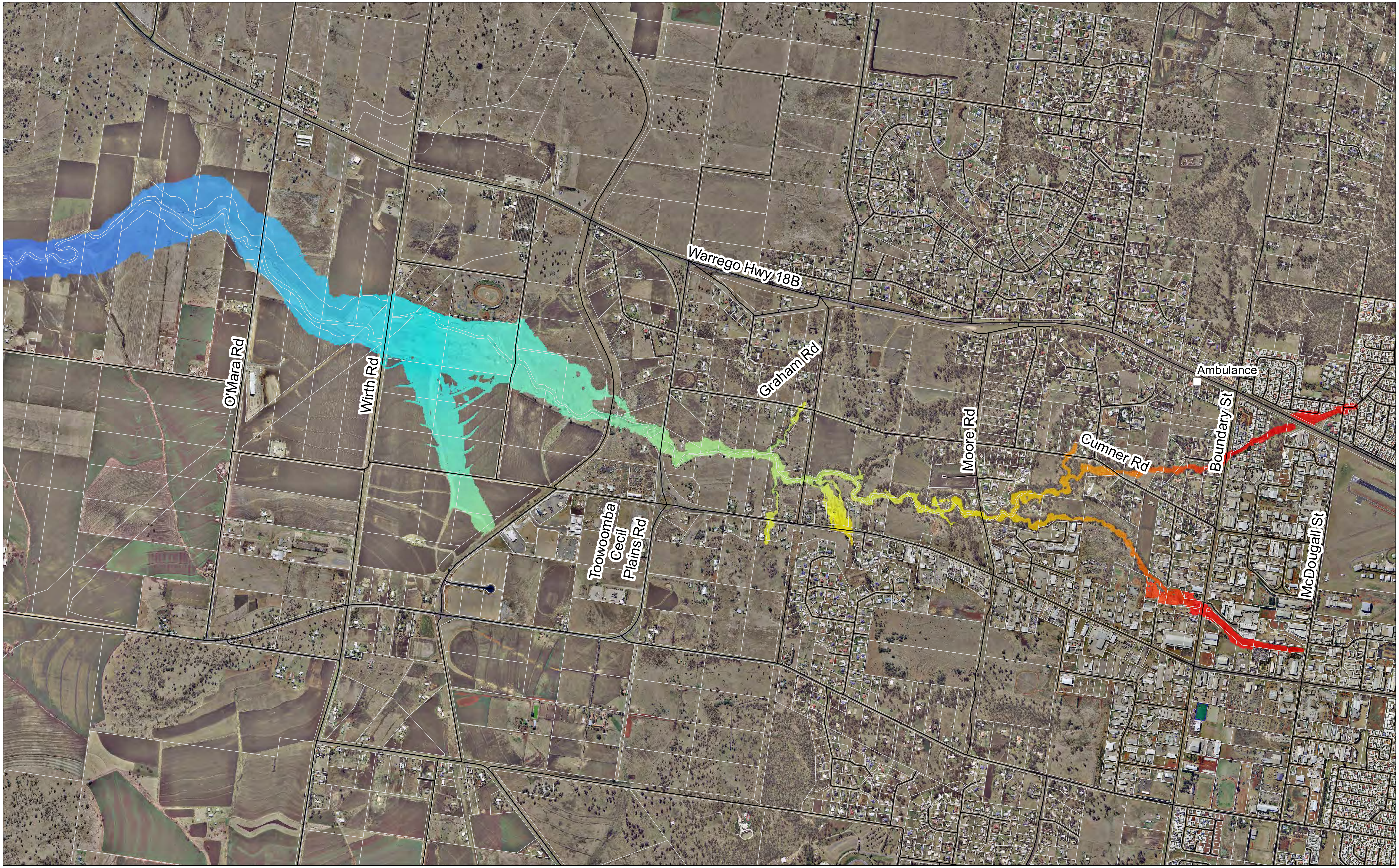
GDA 1994 MGA Zone 56

Legend

Surface Elevation [mAHD]
600
450

Road Centrelines
Cadastre
Emergency Services

SP051 Flood Studies
Work Package 8 Dry Creek
500 Year ARI Event Climate Change 2070
Water Surface Elevation



TOOWOOMBA REGIONAL COUNCIL

1:20,000 (at A3)

0 200 400 800
Meters

GDA 1994 MGA Zone 56

N

Legend

Surface Elevation [mAHD]

600

450

Road Centrelines

Cadastre

Emergency Services

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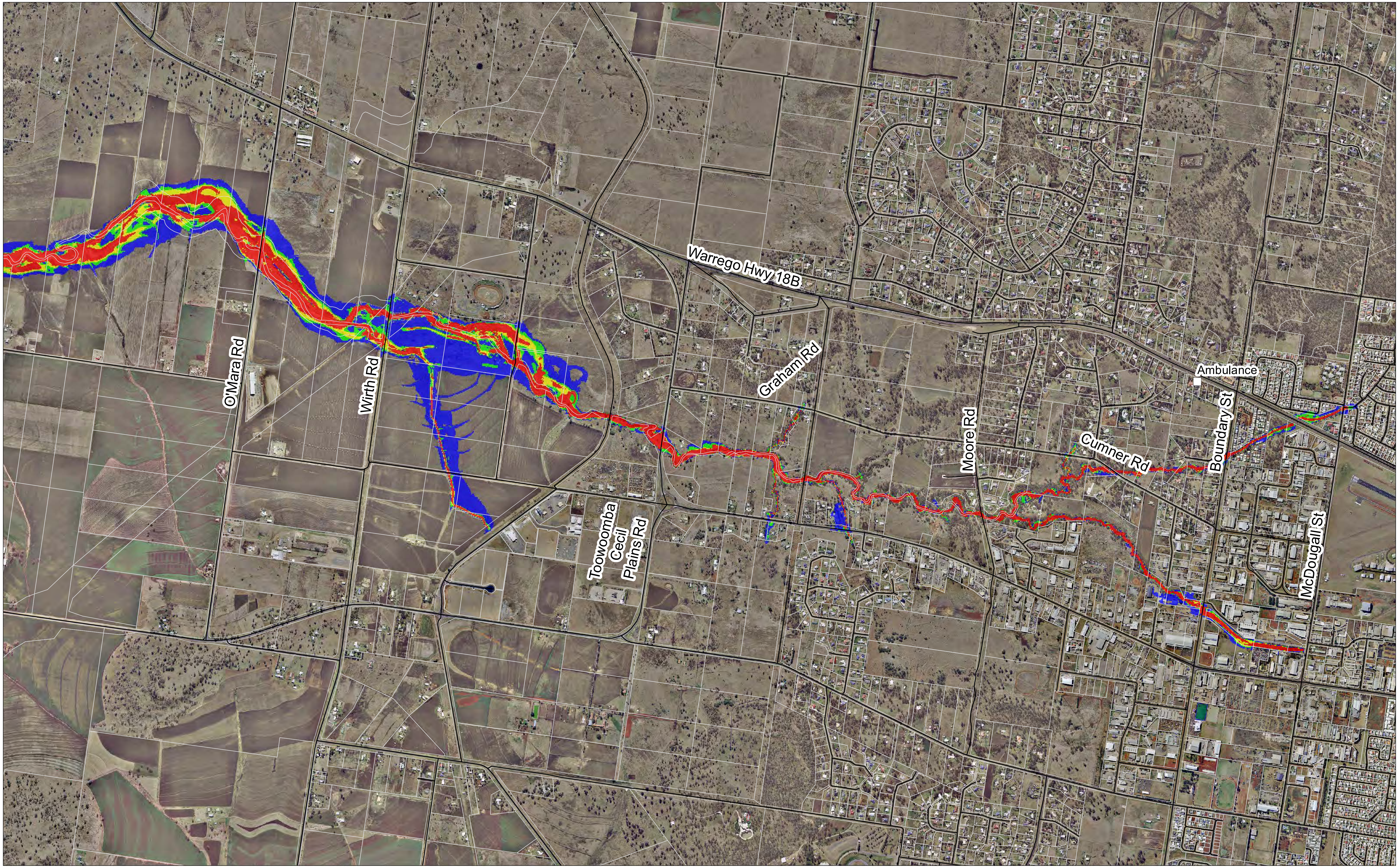
SP051 Flood Studies
Work Package 8 Dry Creek
500 Year ARI Event Climate Change 2100
Water Surface Elevation

APPENDIX F

HYDRAULIC AND HAZARD CATEGORY MAPPING



TOOWOOMBA REGIONAL COUNCIL

1:20,000 (at A3)

0 200 400 800
Meters

N

GDA 1994 MGA Zone 56

Legend

- Low
- Significant
- High
- Extreme
- Road Centrelines
- Cadastre
- Emergency Services

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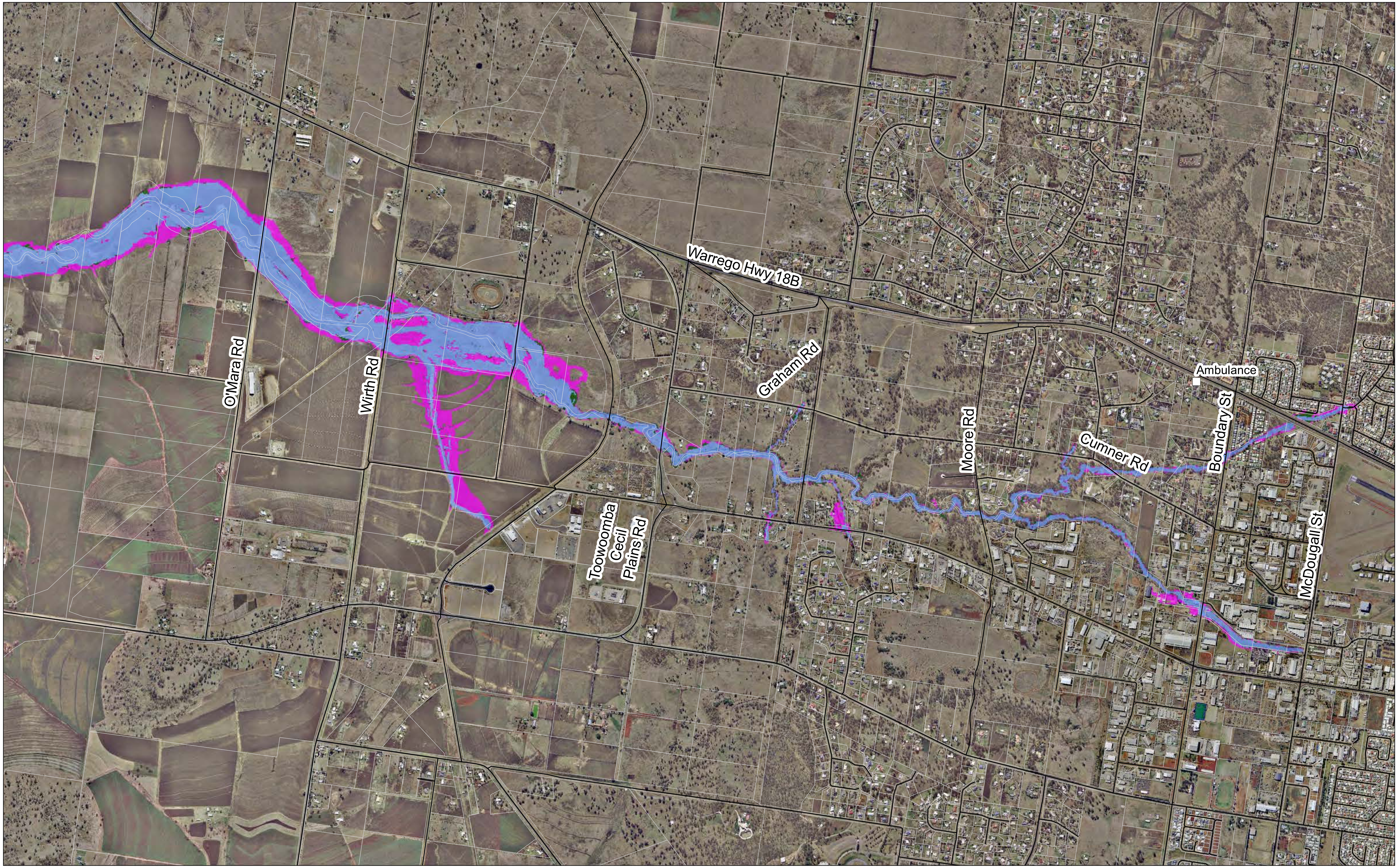
SP051 Flood Studies
Work Package 8 Dry Creek
100 Year ARI Event
Hazard Category



TOOWOOMBA REGIONAL COUNCIL

1:20,000 (at A3)

0 200 400 800
Meters

GDA 1994 MGA Zone 56

N

Legend

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway
- Road Centrelines
- Cadastre
- Emergency Services

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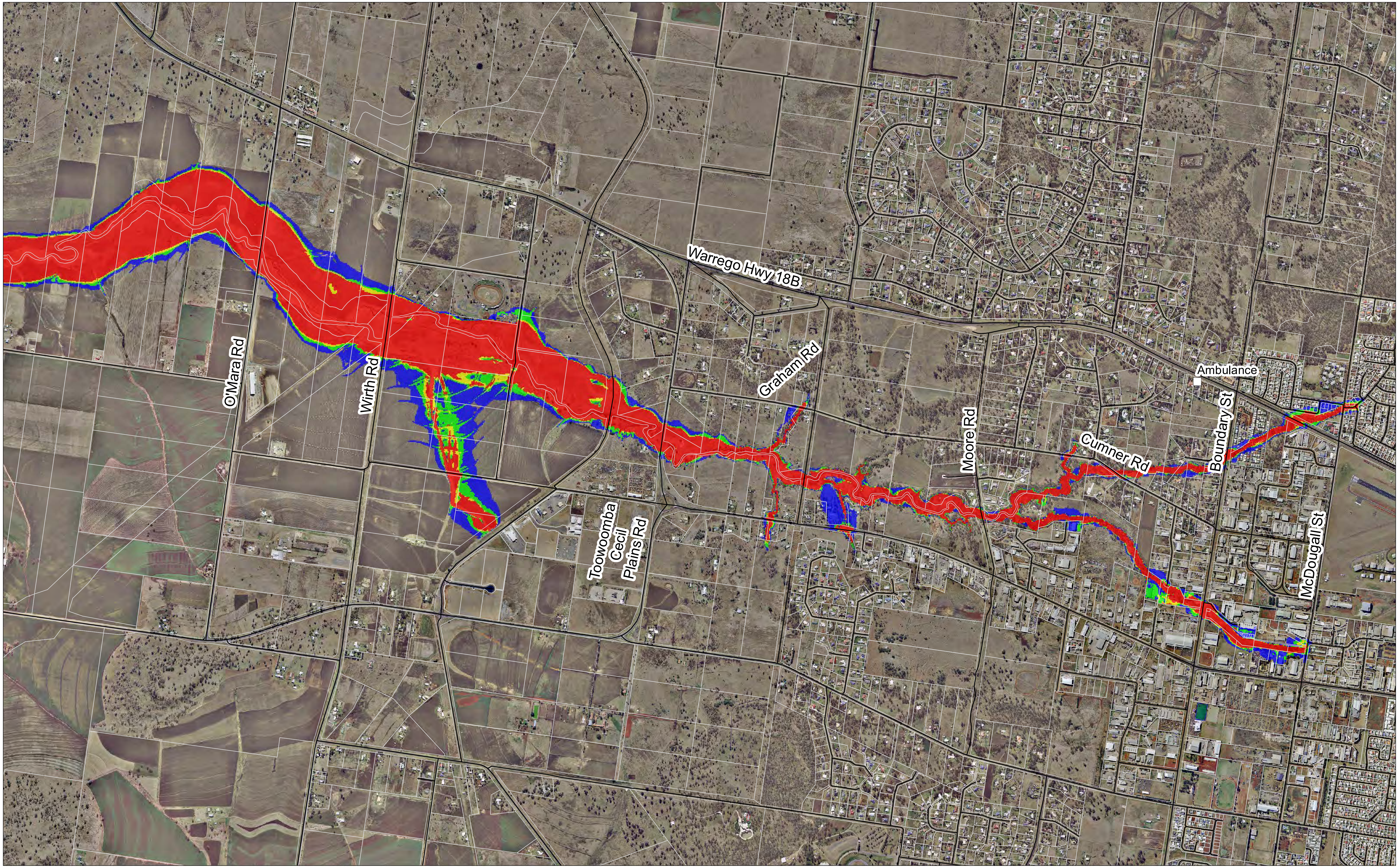
SP051 Flood Studies
Work Package 8 Dry Creek
100 Year ARI Event
Hydraulic Category



TOOWOOMBA REGIONAL COUNCIL

1:20,000 (at A3)

0 200 400 800
Meters

GDA 1994 MGA Zone 56

N

Legend

- Low
- Significant
- High
- Extreme
- Road Centrelines
- Cadastre
- Emergency Services

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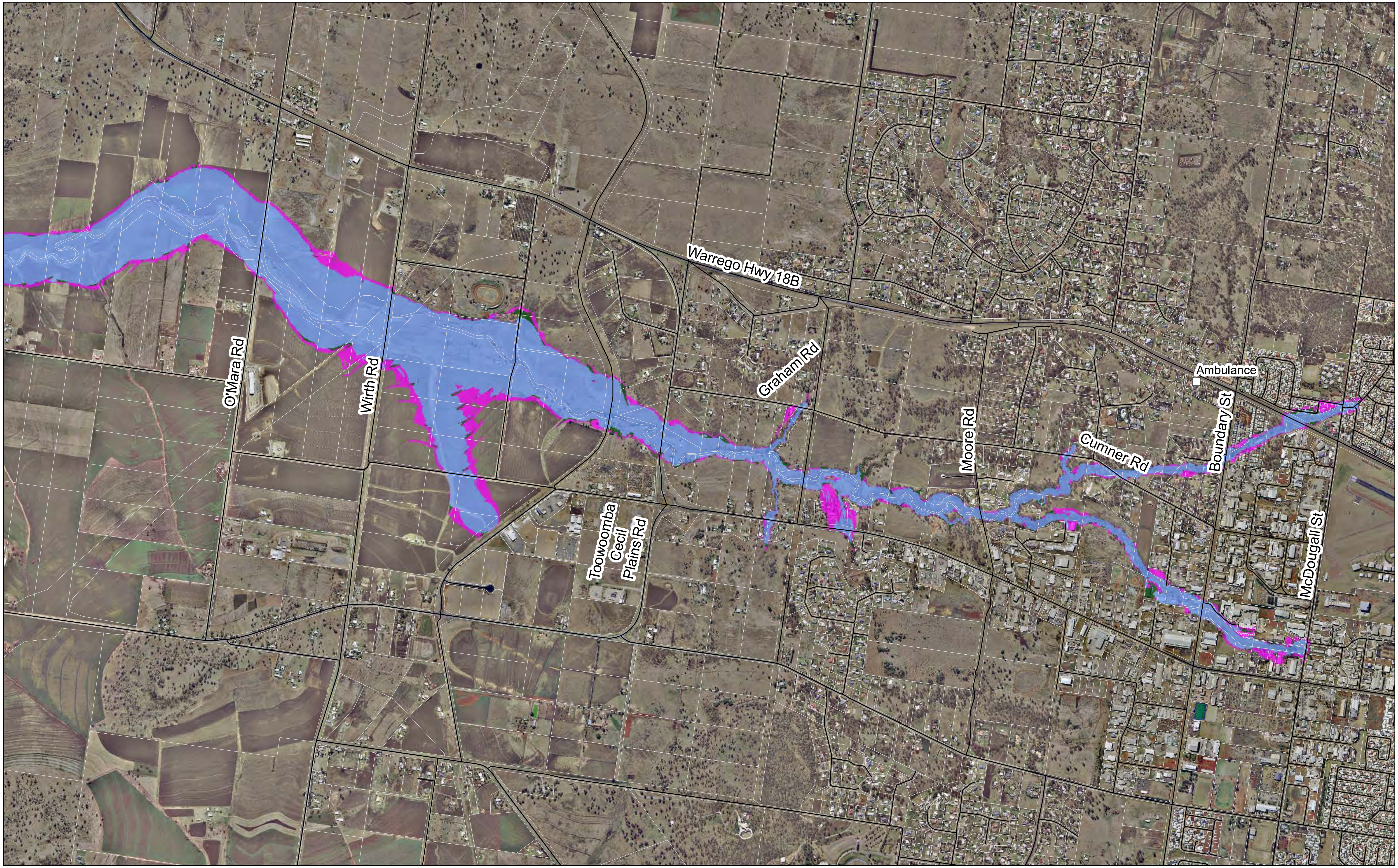
SP051 Flood Studies
Work Package 8 Dry Creek
Probable Maximum Flood Event
Hazard Category



TOOWOOMBA REGIONAL COUNCIL

1:20,000 (at A3)

0 200 400 800
Meters

GDA 1994 MGA Zone 56

N

Legend

Hydraulic Category
- Flood Fringe
- Flood Storage
- Floodway

- Road Centrelines
- Cadastre
- Emergency Services

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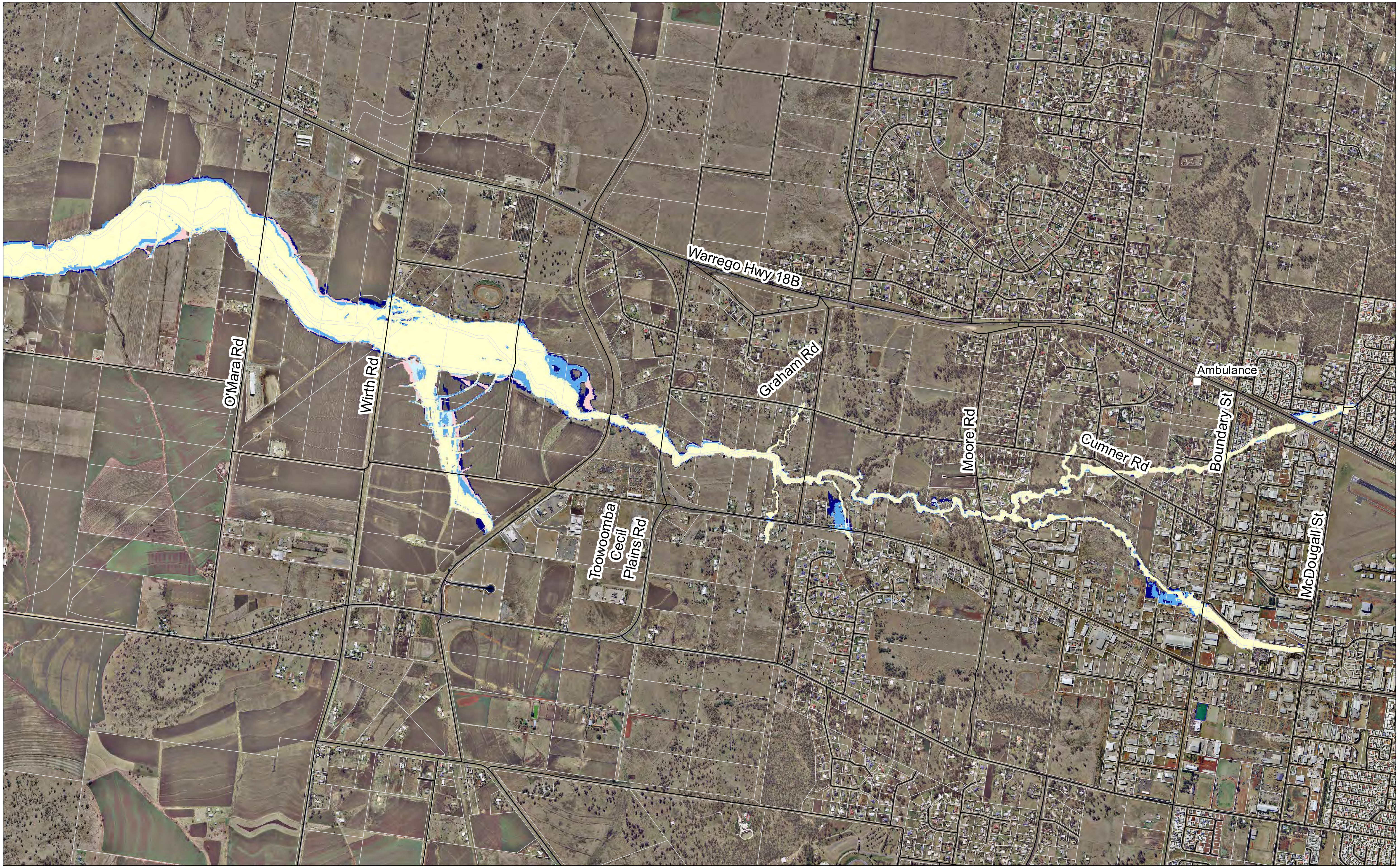
SP051 Flood Studies
Work Package 8 Dry Creek
Probable Maximum Flood Event
Hydraulic Category

APPENDIX G

SENSITIVITY ANALYSIS MAPPING



1:20,000 (at A3)

0 200 400 800
Meters

N

GDA 1994 MGA Zone 56

TOOWOOMBA REGIONAL COUNCIL

Legend

Inundation Extent

- 30% Reduction in Flow
- 30% Reduction in Roughness
- Baseline
- 30% Increase in Roughness
- 30% Increase in Flow
- Emergency Services
- Road Centrelines
- Cadastre

SP051 Flood Studies
Work Package 8 Dry Creek
Sensitivity to Flow and Roughness

SP051 Flood Studies
Work Package 8 Dry Creek
Sensitivity to Blockage of Structures

TOOWOOMBA REGIONAL COUNCIL

1:20,000 (at A3)

0 200 400 800
Meters

GDA 1994 MGA Zone 56

N

Legend

- Baseline
- 50% Blockage of Structures
- Emergency Services
- Road Centrelines
- Cadastre

TOOWOOMBA
REGION

131 872 | info@tr.qld.gov.au | www.tr.qld.gov.au
PO Box 3021 Toowoomba QLD 4350 | Toowoomba Regional Council

yoursay.toowoombaRC.qld.gov.au/flood-resilience

TOOWOOMBA REGION
Rich traditions. Bold ambitions.

Dry Creek Catchment Studies Information Sheet

WHY UNDERTAKE FLOOD STUDIES?

Following extensive flooding across the Toowoomba region, we commissioned a number of flood studies to better understand how flooding can impact our communities. These studies are now complete and available on our website.

The flood studies found that flood behaviour can be complex and vary between locations, depending on landscape, infrastructure and rainfall pattern.

SOME BASIC FLOOD TERMS

1. **Overland flow** – short duration flooding of backyards, drainage paths, streets and rural properties caused by stormwater as it makes its way into the creek/river system;

2. **Creek flooding** – short to medium duration flooding caused by creeks rising and breaking their banks, which can then flood nearby homes, businesses and rural properties;

3. **River flooding** – longer duration flooding caused by significant rises in a river which can break its banks in the same way as smaller creeks.

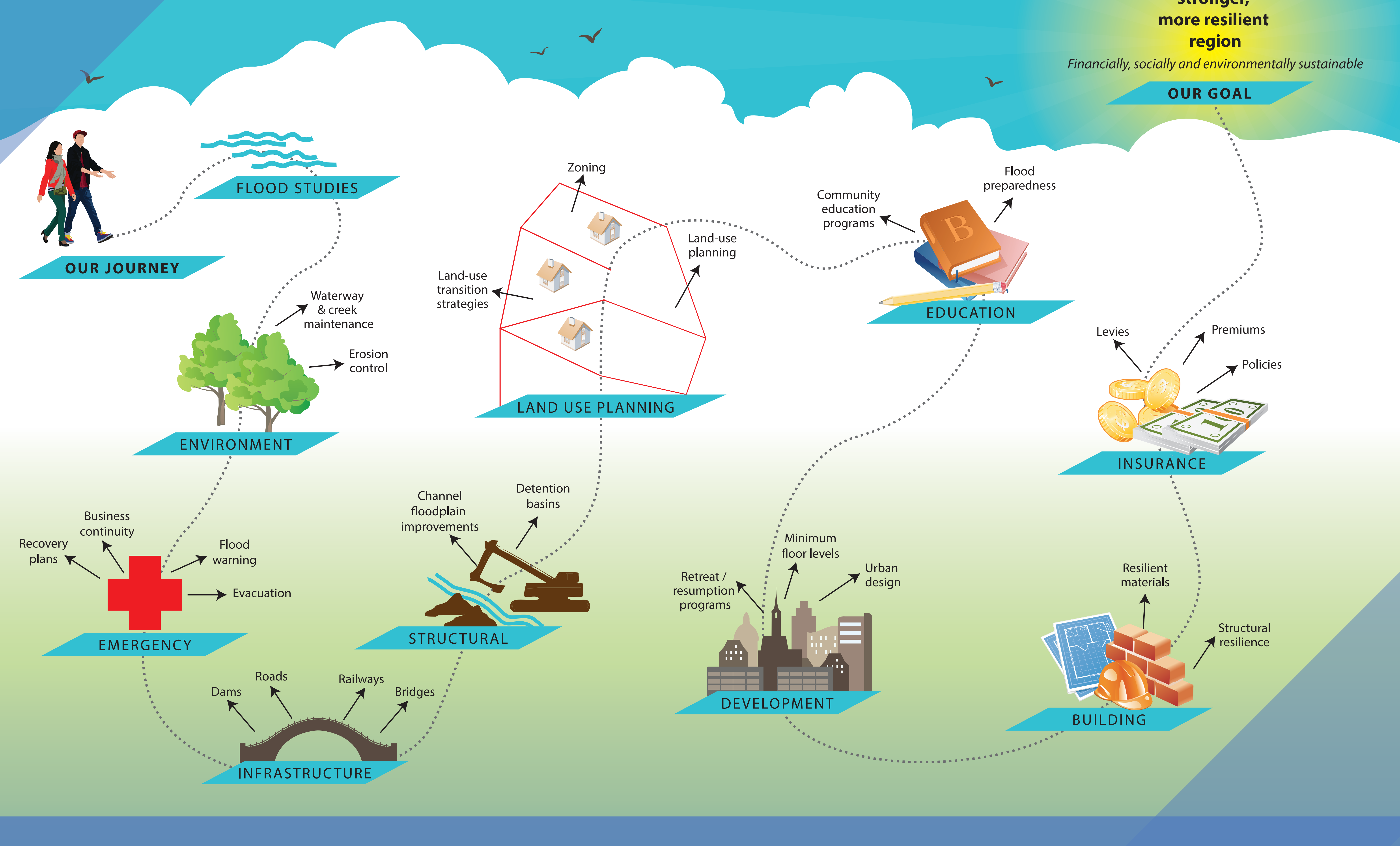
Most of the studies undertaken or commissioned by Council relate to the first two types of flooding – overland flow and creek flooding. It's important to note that these types of flooding can occur separately or together.

KEY MESSAGES

1. Council has a legislative requirement to undertake flood management and the whole community needs to be involved.
2. Flood studies are a foundation and an essential step towards our goal of a safer, stronger, more resilient region.
3. Flood studies have been undertaken by specialist engineers and incorporate the latest data, modelling techniques and community input.
4. Community consultation enables two-way information sharing about the project to increase community awareness, enhance decision making and help achieve our goal of a safer, stronger, more resilient region.

Flood + us - our journey

Steps on the path to achieving our goal



Dry Creek Catchment Studies Information Sheet

WHAT'S DRY CREEK CATCHMENT'S FLOOD STORY?

A flood study and flood maps are now available for the Dry Creek catchment area, which includes the communities of Charlton and Torrington. The primary flood risk in the catchment is from overland flow and local drainage issues.

Dry Creek was not greatly affected by flooding during the January 2011 flood event. The flooding in the upstream part of the catchment was contained within the major overland flow paths and the Dry Creek channel. However, some rural areas in the downstream part of the catchment were flooded. Boundary Street, Wirth Road and O'Mara Road were cut off during the event. The study suggests that the January 2011 event compared to a more frequent 10% Annual Exceedance Probability flood event – meaning there is a 10% chance in a year to see a flood of this size or larger occurring.

The comprehensive modelling undertaken through the study showed that most of the road crossings have low flood immunity, apart from the Warrego Highway crossing, which has flood immunity up to and including the more rare flood event of 0.2% Annual Exceedance Probability.

The study provides a range of flood scenarios from the more frequent floods through to the large, rare and extreme events. Given the nature and structure of the flow paths in the area, any significant flood hazard is generally confined to the channel.

Annual Exceedance Probability (AEP) means the chance of a flood of a given size or larger size occurring in any one year, usually expressed as a percentage.

COMMUNITY INVOLVEMENT

Improving the way we prepare for and respond to flooding as a community is very important to us. Many residents in our region contributed information to build and validate our flood knowledge during the region-wide consultation sessions and other flood studies engagement opportunities.

Community involvement with this project continues to help our region become safer, stronger and more resilient. We encourage you to access the flood study information online and stay up to date with the project by visiting the web address below.

GET INFORMED

You can access our region's current flood studies and maps by heading to
http://yoursay.toowoombarc.qld.gov.au/flood-resilience
For more information, please contact the project team by phone, email or post.

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