Wangaratta Urban Waterways Flood Investigation

Study Report

August 2017

NORTH EAST CATCHMENT MANAGEMENT AUTHORITY

RURAL CITY OF WANGARATTA

State Government Victoria

Department of Environment, Land, Water & Planning

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PROJECT DETAILS

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Cover Photo: Ovens River, Wangaratta (taken during September 2010 flood, courtesy of NECMA)

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1. INTRODUCTION

1.1 Overview

Water Technology was commissioned by the North East Catchment Management Authority to undertake the Wangaratta Urban Waterways Flood Study. The objective of the study is to review and revise the current flood mapping and flood intelligence for Wangaratta's major waterways based on updated data and recent flood events. This mapping will be used to update flood intelligence for emergency response, and to provide flood data to inform planning within the present and future city area.

2. PROJECT BACKGROUND

The project aims to produce flood mapping and improve the flood intelligence for the major waterways in and around the City of Wangaratta. The key watercourses of interest are the Ovens and King Rivers, and Fifteen Mile, One Mile, Three Mile and Reedy Creeks. The study area is shown below in Figure 2-1.

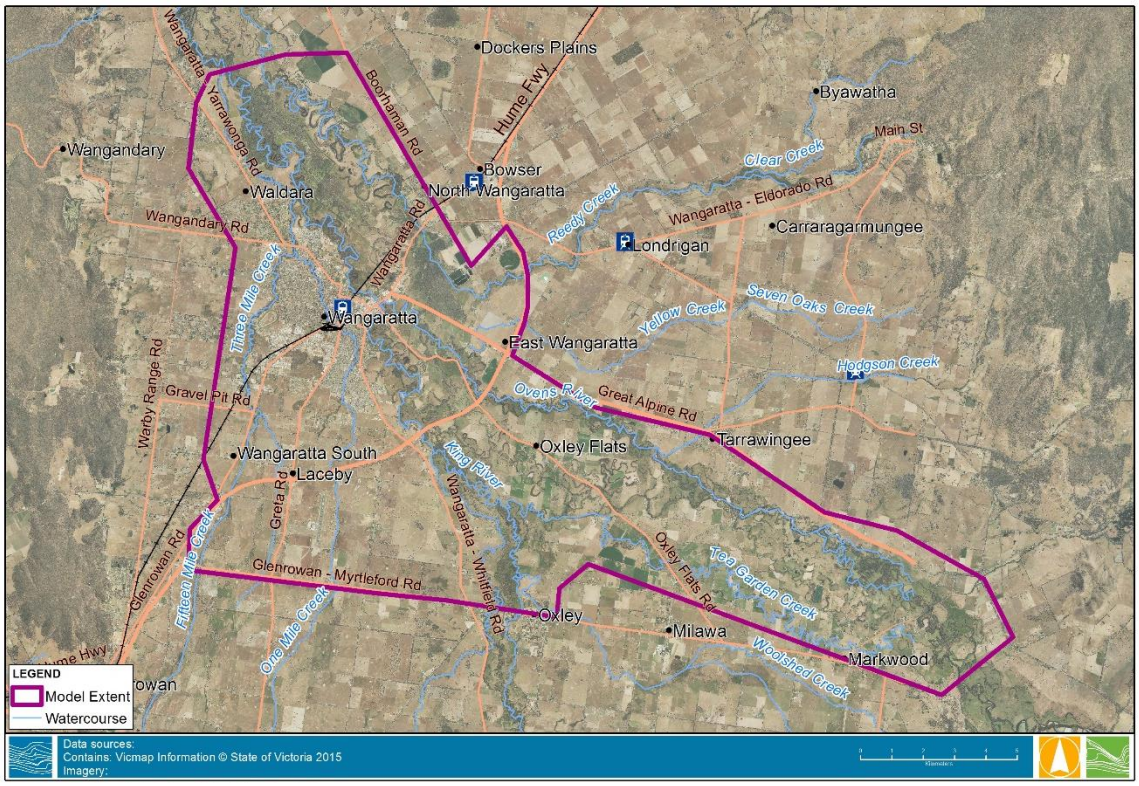

Figure 2-1 Study Area

There have been a number of significant past flood events in Wangaratta of which the October 1993 flood is the largest on record. The October 1993 flood led to significant inundation throughout the study area including above floor flooding at 117 houses[1] corresponding to a peak gauge reading of 12.98 m on the Wangaratta Gauge. The October 1993 flood is estimated to be approximately a 1% AEP event in the Ovens River based on updated flood frequency analysis completed in this study.

[1] HydroTechnology, *Documentation and Review of 1993 Victorian Flood – Ovens River Catchment Floods October 1993 Volume 3*, March 1995

Figure 2-2 Flooding during September 2010 in Apex Park, Wangaratta, over the iconic 'Yogi Bear'

Anecdotal evidence such as newspaper reports suggest that floods in 1870 and 1917 may have been larger than the October 1993 flood, however there is limited information available regarding these events. Significant floods also occurred in May 1974, July 1981, September 1998, September 2010 and October 2016 although they were considerably smaller in magnitude than 1993. The September 2010 event resulted in considerable riverbank erosion throughout the Ovens and King River systems. Properties inside Wilson Road levee in Wangaratta were evacuated due to stability concerns for the levee. This flood is estimated as a 5% AEP event in the Ovens River at Wangaratta based on updated flood frequency analysis recently completed by Water Technology in the Lower Ovens Connectivity Study (Water Technology 2014).

Sections of the study area are currently covered by a Land Subject to Inundation Overlay (LSIO) and a Floodway Overlay (FO). The Victorian Flood Database contains design flood extents for the 1% AEP design flood event only, along with historic flood extents for the 1955, 1974, 1981, 1993, 1998, and 2010 events. Peak historic flood levels across the study area are also contained within the Victorian Flood Database. The current 1% AEP design flood extent is based on flood aerial photography of 1993 and land mapping, and is shown in Figure 2-3.

Figure 2-3 Existing 1% AEP flood extent from Victorian Flood Database

3. PREVIOUS REPORTING

This report should be read in conjunction with the following previous reports:

- Preliminary Report, R01 (Water Technology, 2016a).
- Hydrology Report, R02 (Water technology, 2016b).
- Hydraulic Calibration Report, R03 (Water technology, 2017a).

The hydrology and hydraulics sections in this report present the key findings and not the analyses in their entirety. For the full hydrological and hydraulic analyses reporting, the specific milestone reports above should be consulted. This approach is recommended to improve the readability of the final report, with a focus on key findings from the investigation.

3.1 Data Review Report

The Data Review Report[2] documented previous flood related information for the study area, including a review of available topographic and structure (bridges and culverts) data. It also identified gaps in the available data and how those would be addressed within the study.

3.2 Hydrology Report

The Hydrology Report[3] documents the hydrological analyses undertaken as part of this study and includes:

- Flood Frequency Analysis at key streamflow gauges;
- Hydrologic modelling including development and calibration of a RORB rainfall-runoff model;
- Hydrological assessment of the Fifteen Mile Creek system through the development of a two-dimensional hydraulic model;
- Development of design event hydrographs by fitting the RORB model to Flood Frequency Analysis at key gauges; and
- Comparison of the hydrology of the 1% AEP design flood and the October 1993 flood event.

3.3 Hydraulic Calibration Report

The Hydraulic Calibration Report[4] documents the hydraulic analyses undertaken as part of the study which includes:

- Details of the model build including schematisation and model parameters;
- Summary of the hydraulic model calibration and verification process and results;
- Flood behaviour for the October 1993 and September 2010 calibration events;
- Overview of the design flood modelling process; and
- Comparison of the 1% AEP design flood and October 1993 flood hydraulic modelling results.

[2] Water Technology, *Wangaratta Urban Waterways Flood Study - Data Review Report*, February 2016
[3] Water Technology, *Wangaratta Urban Waterways Flood Study - Hydrology Report*, June 2016
[4] Water Technology, *Wangaratta Urban Waterways Flood Study - Hydraulic Calibration Report*, July 2017

4. HYDROLOGY AND HYDRAULICS SUMMARY

4.1 Overview

The hydrological analysis consisted of flood frequency analysis and the development of a hydrological (RORB) model of the entire Ovens River catchment. The RORB model was calibrated to two historic flood events – October 1993 and September 2010. Design flow estimates were determined by fitting the RORB flows to the flood frequency analysis at key gauge locations.

For the hydraulic analysis a two-dimensional (2D) multi-domain hydraulic model including one-dimensional (1D) elements was developed for the study area using TUFLOW Classic. Adopting a multi-domain modelling approach and including 1D elements allowed the hydraulic model to incorporate greater detail in areas of importance, whilst maintaining computational efficiency. This approach allows features within the broader floodplain and the township areas to be resolved in varying detail in the same model whilst maintaining appropriate run times.

4.1 Hydrology

4.1.1 Streamflow Gauging

There are a number of streamflow gauges of relevance to this study. The Ovens River at Wangaratta and Reedy Creek at Wangaratta North are two key gauges located in Wangaratta, while a number of important gauges are located upstream including the Ovens River at Rocky Point, King River at Docker Road Bridge and 15 Mile Creek at Greta South. All these gauges had reasonably long records with reasonable quality data and were suitable for flood frequency analysis and model calibration purposes. A detailed analysis of each gauge was undertaken and is presented in Section 3.2 of the Hydrology Report[5].

4.1.2 Flood Frequency Analysis

A flood frequency analysis was used to estimate the probability of different magnitude flood events at the five key gauges mentioned above. This allows the probability of previous historic events to be estimated and provides flood intelligence regarding the magnitude and frequency of future flood events.

The flood frequency analysis was based on an annual series of maximum flows at each gauge for the full record of data. Historic flood peaks were also included in some instances where recorded data was unavailable but anecdotal information indicated that a large flood event had occurred outside the gauge period. Further details are provided in Section 3.5 of the Hydrology Report[6].

The design peak flows arising from the flood frequency analysis at each gauge are shown in Table 4-1 through to Table 4-7. The analysis included a FFA of the combined flow at Wangaratta by combining the gauge records at the Ovens River at Wangaratta and Reedy Creek at Wangaratta gauges. The Reedy Creek gauge lies on the north side of the Ovens River floodplain and includes Ovens River floodplain flows in events of minor flood level and greater. A FFA on 4 day flood volumes was also undertaken to ensure design volumes were appropriate.

[5] Water Technology, *Wangaratta Urban Waterways Flood Study - Hydrology Report*, June 2016
[6] Water Technology, *Wangaratta Urban Waterways Flood Study - Hydrology Report*, June 2016

Table 4-1 FFA Peak Flow Estimates for Ovens River at Wangaratta gauge

AEP	Peak Flow Estimate (ML/d)	
	Log Pearson III (LP3)	5-95% Confidence Limits
50%	19,000	17,100- 21,200
20%	32,500	29,500- 35,900
10%	41,000	37,300- 45,300
5%	48,500	44,000- 54,100
2%	57,200	51,500- 65,600
1%	63,100	56,100- 74,000
0.5%	68,400	60,000- 82,200

Table 4-2 FFA Peak Flow Estimates for Reedy Creek at Wangaratta gauge

AEP	Peak Flow Estimate (ML/d)	
	Log Pearson III (LP3)	5-95% Confidence Limits
50%	14,600	11,600 – 18,300
20%	36,500	29,800 – 45,000
10%	55,900	45,400 – 69,100
5%	77,500	62,200 – 98,600
2%	108,800	84,900 – 147,500
1%	134,400	101,300 – 192,600
0.5%	161,200	117,200 – 246,500

Table 4-3 FFA Peak Flow Estimates for Combined Flows at Wangaratta gauge

AEP	Peak Flow Estimate (ML/d)	
	Log Pearson III (LP3)	5-95% Confidence Limits
50%	33,200	27,500 – 40,000
20%	70,100	59,300 – 83,300
10%	99,400	84,300 – 119,100
5%	130,100	108,900 – 159,600
2%	172,300	140,100 – 222,800
1%	205,300	162,400 – 278,500
0.5%	239,100	182,400 – 342,400

Table 4-4 FFA 5-day Peak Volume Estimates for Combined Flows at Wangaratta gauge

AEP	Volume (ML)	
	Log Pearson III (LP3)	5-95% Confidence Limits
50%	127,400	107,400 – 150,600
20%	239,800	208,400 – 275,000
10%	313,800	275,500 – 356,300
5%	380,300	335,000 – 436,500
2%	458,400	400,400 – 546,700
1%	510,800	439,600 – 634,400
0.5%	558,000	470,300 – 723,800

Table 4-5 FFA Peak Flow Estimates for Fifteen Mile Creek at Greta South gauge

AEP	Peak Flow Estimate (ML/d)	
	Log Pearson III (LP3)	5-95% Confidence Limits
50%	2,600	2,100 – 3,300
20%	6,200	4,700 – 8,200
10%	9,700	7,200 – 13,900
5%	14,200	9,900 – 22,300
2%	22,100	14,200 – 41,000
1%	29,700	17,700 – 63,800
0.5%	39,000	21,300 – 97,700

Table 4-6 FFA Peak Flow Estimates for King River at Docker Road Bridge gauge

AEP	Peak Flow Estimate (ML/d)	
	Log Pearson III (LP3)	5-95% Confidence Limits
50%	11,700	8,800 – 15,600
20%	30,600	23,500 – 40,200
10%	49,800	38,000 – 65,800
5%	73,800	55,300– 101,700
2%	113,700	81,000 – 172,800
1%	150,800	101,600 – 252,300
0.5%	194,600	122,400 – 361,400

Table 4-7 FFA Peak Flow Estimates for Ovens River at Rocky Point gauge

AEP	Peak Flow Estimate (ML/d)	
	Log Pearson III (LP3)	5-95% Confidence Limits
50%	23,000	18,900 – 28,100
20%	45,700	37,700- 55,500
10%	65,100	53,400- 79,700
5%	87,200	70,100 – 109,600
2%	120,800	93,800 – 163,500
1%	150,000	111,600 – 217,300
0.5%	182,700	130,100 – 285,300

4.1.3 Hydrologic Modelling

A hydrological model of the catchment was developed to produce design hydrographs to be used as boundary conditions in the Wangaratta Flood Study hydraulic model. The rainfall-runoff program, RORB (Version 6) was used for this study.

RORB is a non-linear rainfall runoff and streamflow routing model which is used for calculation of flow hydrographs in drainage and stream networks. The model requires catchments to be divided into subareas, connected by a series of conceptual reach storages. Design storm rainfall is input to the centroid of each subarea. Specified losses are then deducted, and the excess routed through the reach network. A detailed explanation of the hydrological model build is discussed in the Hydrology Report[8]. The RORB model layout is shown in Figure 4-1.

Five streamflow gauges (Ovens River at Wangaratta, Reedy Creek at Wangaratta North, Ovens River at Rocky Point, King River at Docker Road Bridge and 15 Mile Creek at Greta South) were used to calibrate the RORB model. Model parameter selection was based on calibration to all five gauges and comparison to accepted regional methods, and the design flows were validated against the flood frequency analysis.

Design flow hydrographs were developed using the calibrated routing parameters, and loss parameters adjusted to reconcile the flood peaks to the flood frequency analysis. The critical storm duration producing the highest flood level for design flood events was determined to be the 72 hour storm in the Ovens and King River systems and 12 hour storm for the 15 Mile Creek system. The hydrologic model was run for both durations for each design event and the results from the two durations were enveloped to provide a maximum output. The adopted peak design flows are provided in Table 4-8.

[8] Water Technology, *Wangaratta Urban Waterways Flood Study - Hydrology Report*, June 2016

Table 4-8 RORB Adopted Design peak flows

AEP	Design Peak Flow (m^3/s)			
	Ovens River at Rocky Point Gauge (ML/d)	King River at Dockers Road Gauge (ML/d)	Wangaratta Combined Flow (ML/d)	15 Mile at Greta South Gauge (ML/d)
20%	46915	27475	70848	6696
10%	65059	37843	100051	10282
5%	89338	46397	131242	14170
2%	120614	54259	171677	22205
1%	150854	57888	206669	29549
0.5%	200189	65059	238550	39139

* Adopted King River flows lower than FFA flows to ensure appropriate peak at Wangaratta

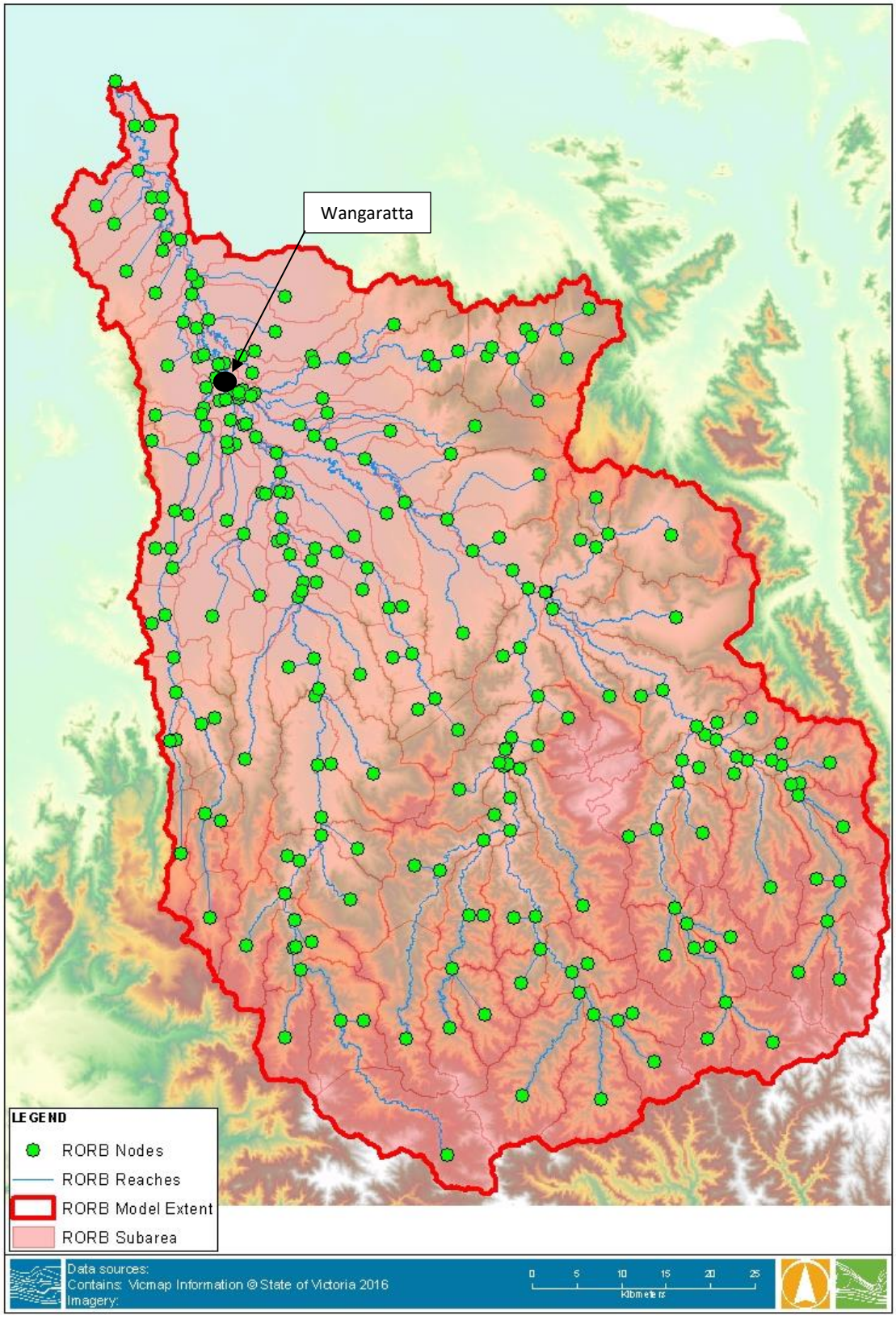

Figure 4-1 RORB Model Schematisation

4.2 Hydraulics

4.2.1 Overview

This section discusses the application of the hydraulic model to simulate flood behaviour (extents, depth, velocities) for a range of historic and design floods.

The hydrologic analysis provided flood inflow hydrographs for the hydraulic model. These inflow hydrographs were routed through the calibrated hydraulic model. This enabled the modelling of flood depths, extents and velocities over a range of design flood magnitudes. It also provided a tool to assist the understanding flood behaviour across the study area.

A detailed description of the hydraulic model setup, calibration, validation, sensitivity tests and design event simulations is provided in the Hydraulics Report[9]. This section summarises the general model development and key outcomes from the hydraulic modelling investigation.

4.2.2 Hydraulic Modelling

The hydraulic model framework was required to simulate the flow behaviour along the Ovens River, King River, Fifteen Mile Creek, Three Mile Creek, One Mile Creek and their tributaries in the vicinity of Wangaratta, whilst balancing model simulation times and topographic resolution. The final hydraulic modelling framework comprised of a linked one dimensional (1D) / two dimensional (2D) multi domain hydraulic model which is aimed at picking up broad scale floodplain features for large flood events, whilst also providing more refined results in areas of interest.

Three different domains and corresponding grid resolutions were utilised in the 2D modelling component; a five metre grid, a ten metre grid and a twenty metre grid. The finer grid resolution was used in the areas of significant interest which included the Wangaratta city area downstream of the Hume Freeway. Spatially varying the grid resolution allows the model run times to be optimised whilst maintaining element sizes needed to adequately describe flow features and map the study area. The model schematisation and multiple domains used are shown in Figure 4-2.

The modelling process involved the following stages:

- Model development and calibration;
- Validation and sensitivity tests; and
- Design flood simulations.

The calibration, validation and sensitivity assessments were completed during an iterative investigative process and all outcomes from these stages informed the final design flood simulations. All results from the hydraulic model have been processed at a 2.5 m x 2.5 m grid resolution.

[9] Water Technology, *Wangaratta Urban Waterways Flood Study - Hydraulics Report,* 2016

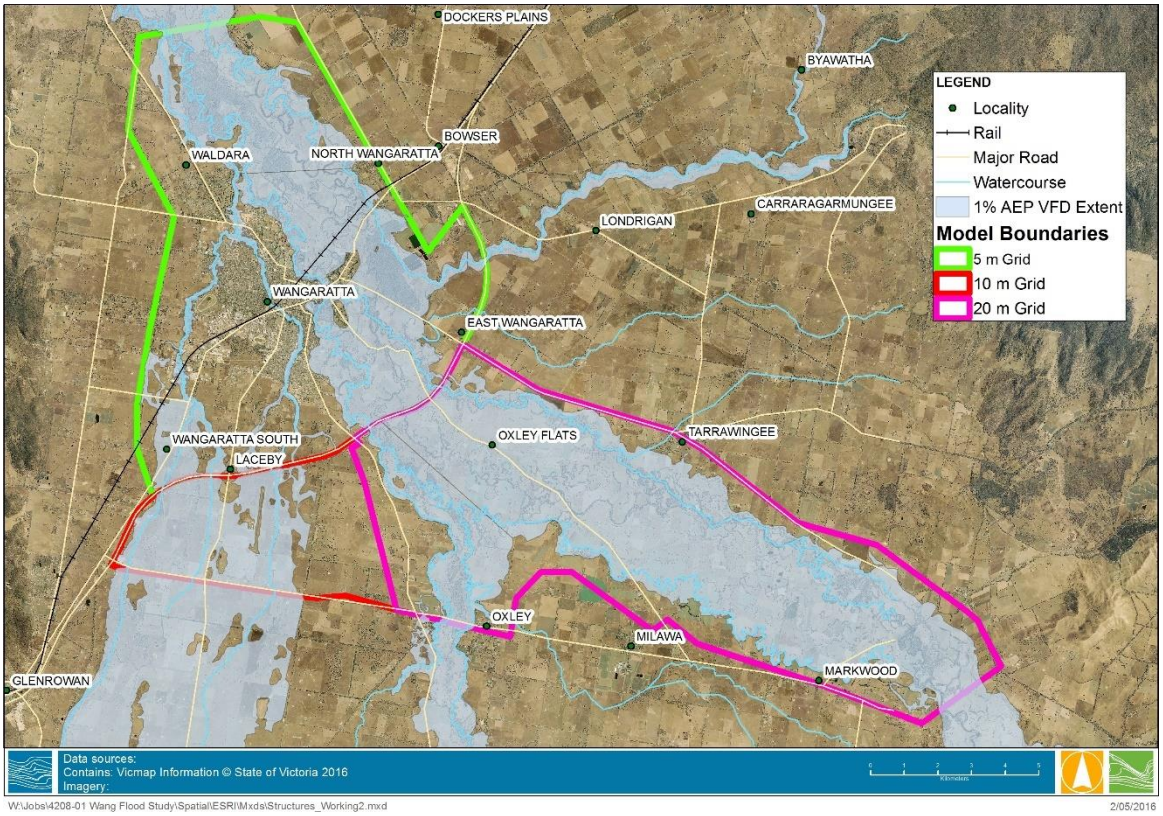

Figure 4-2 Hydraulic Model Schematisation

5. FLOOD BEHAVIOUR AND INTELLIGENCE OUTPUTS

5.1 Overview

The flood behaviour and intelligence outputs developed as part of the Wangaratta Urban Waterways Flood Study are described in this section. It should be noted that the model has adopted an Ovens dominant flow event with King contributing approximately 25% of total flow. All floods are different and it is possible that the Ovens impacts reported below may be larger than some actual events depending on the Ovens and King River contributions.

5.2 Gauge Height Relationships

For each design flood event the model results were interpreted to provide information on the relationship between the flood level at three key gauges (Ovens River at Wangaratta, Reedy Creek at Wangaratta North and 15 Mile Creek at Greta South) and the equivalent design flood magnitude (in % AEP and ARI (years)). Table 5-1, Table 5-2 and Table 5-3 show the results of the assessment. The Ovens River at Wangaratta gauge is best used to understand flood behaviour across the Ovens River floodplain, whilst the 15 Mile Creek at Greta South gauge is best used to understand flood behaviour through the 1 Mile, 3 Mile and 15 Mile Creek systems.

It should be noted that the Reedy Creek at Wangaratta North gauge lies on the Ovens River floodplain and subsequently, in large events (20% AEP and greater) when the full width of the floodplain is engaged, the Reedy Wangaratta North gauge incorporates flow in the Ovens River floodplain as well as Reedy Creek.

Table 5-1 Ovens River at Wangaratta Gauge Heights and Flows for Design Flood Events

Gauge Level [10]		Design Flood Event		Design Flood Flow* (Combined Flow Across Floodplain)	
Relative (m)	m AHD	AEP (%)	ARI (years)	ML/d	m^3/s
12.50	142.93	20	5	58,100	673
12.62	143.05	10	10	84,200	975
12.71	143.14	5	20	111,000	1280
12.82	143.25	2	50	144,000	1665
12.92	143.35	1	100	180,000	2084
13.03	143.46	0.5	200	201,900	2337

* Extracted from hydraulic model

[10] Ovens River at Wangaratta Gauge is located in Wangaratta immediately downstream of railway line. Gauge zero is 130.426 m AHD

Table 5-2 Reedy Creek at Wangaratta North Gauge Heights for Design Flood Events

Gauge Height[11]		Design Flood Event	
Relative (m)	m AHD	AEP (%)	ARI (years)
4.61	142.25	20	5
4.90	142.54	10	10
5.20	142.84	5	20
5.48	143.12	2	50
5.70	143.34	1	100
5.90	143.54	0.5	200

Table 5-3 15 Mile Creek at Greta South Gauge Heights for Design Flood Events

Gauge Height[12]		Design Flood Event		Design Flood Flows	
Relative (m)	m AHD	AEP (%)	ARI (years)	ML/d	m^3/s
3.80	191.09	20	5	6,200	72
4.83	192.12	10	10	9,700	112
6.04	193.33	5	20	14,200	164
8.10	195.39	2	50	22,100	256
N/A*	N/A*	1	100	29,700	344
N/A*	N/A*	0.5	200	39,000	451

* Beyond level of rating curve

[11] Reedy Creek at Wangaratta North gauge is located in North Wangaratta immediately downstream of Bowser Road on the Ovens River floodplain. Gauge zero is 137.636 m AHD. In large events both Wangaratta gauges carry Ovens River flows.

[12] The 15 Mile Creek at Greta South Gauge is located in Greta South immediately of Wangaratta-Kilfeera Road. Gauge zero is 187.29 m AHD

5.3 Summary of Flood Behaviour

Table 5-4 and Table 5-5 describe the key flood characteristics across the study area for each design flood. The table was developed to be read from top to bottom, with each subsequent larger magnitude event reporting on the incremental changes in consequences. For example, if the reader is wishing to understand the consequences of a 2% AEP event, then the flood characteristics should be read for the 20%, 10%, 5% and 2% AEP events in succession. It is also recommended that the reader refer to the corresponding PDF maps provided with the study. There is a separate map for each modelled design event which provides peak flood depths, extents and water surface elevations for each flood event.

A key aspect to note is that there are relatively low levels of above floor flooding until the 2% AEP design event at which point 28 properties are flooded above floor.

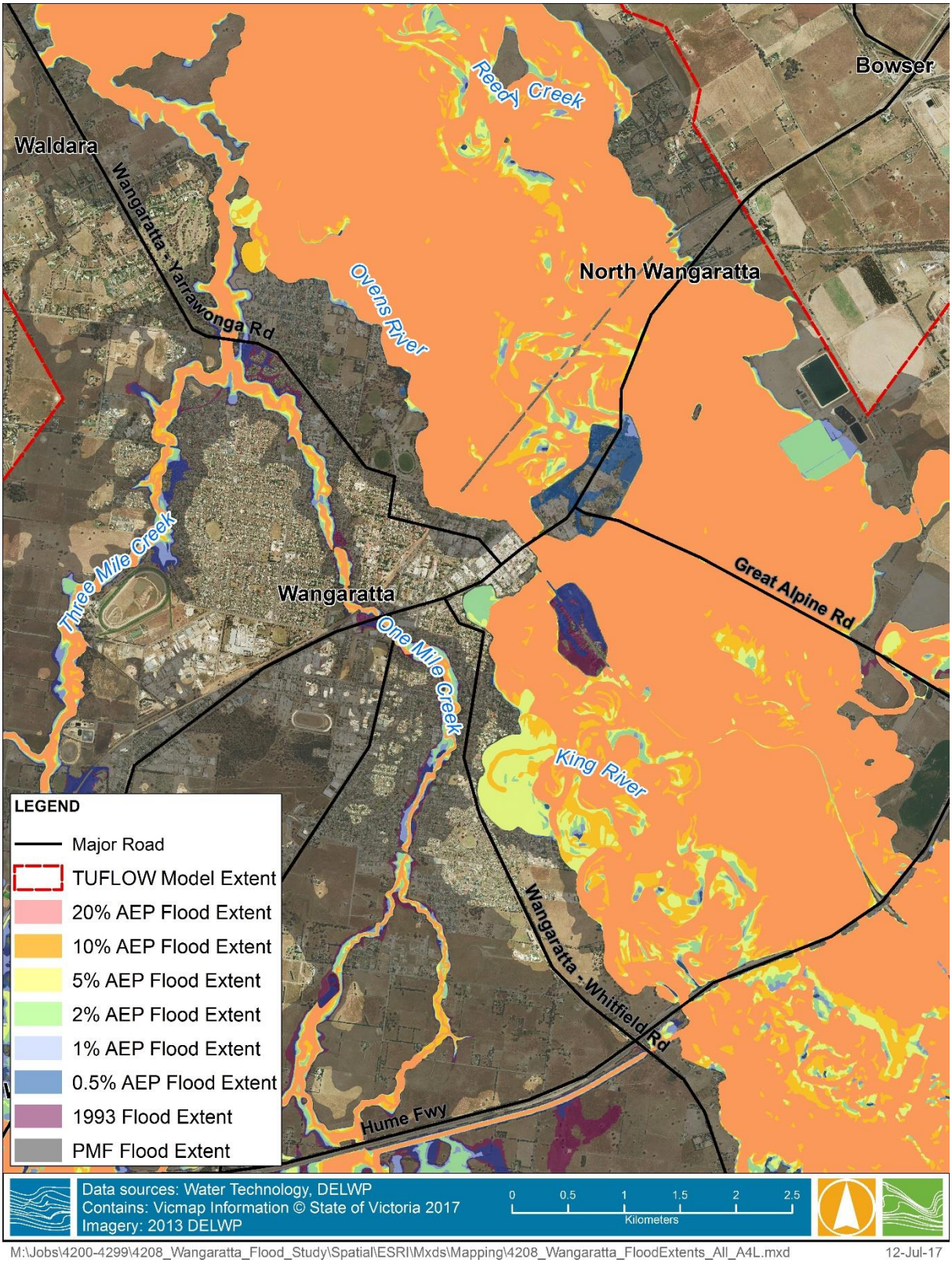

Figure 5-1 The full range of design flood extents overlaid in central Wangaratta

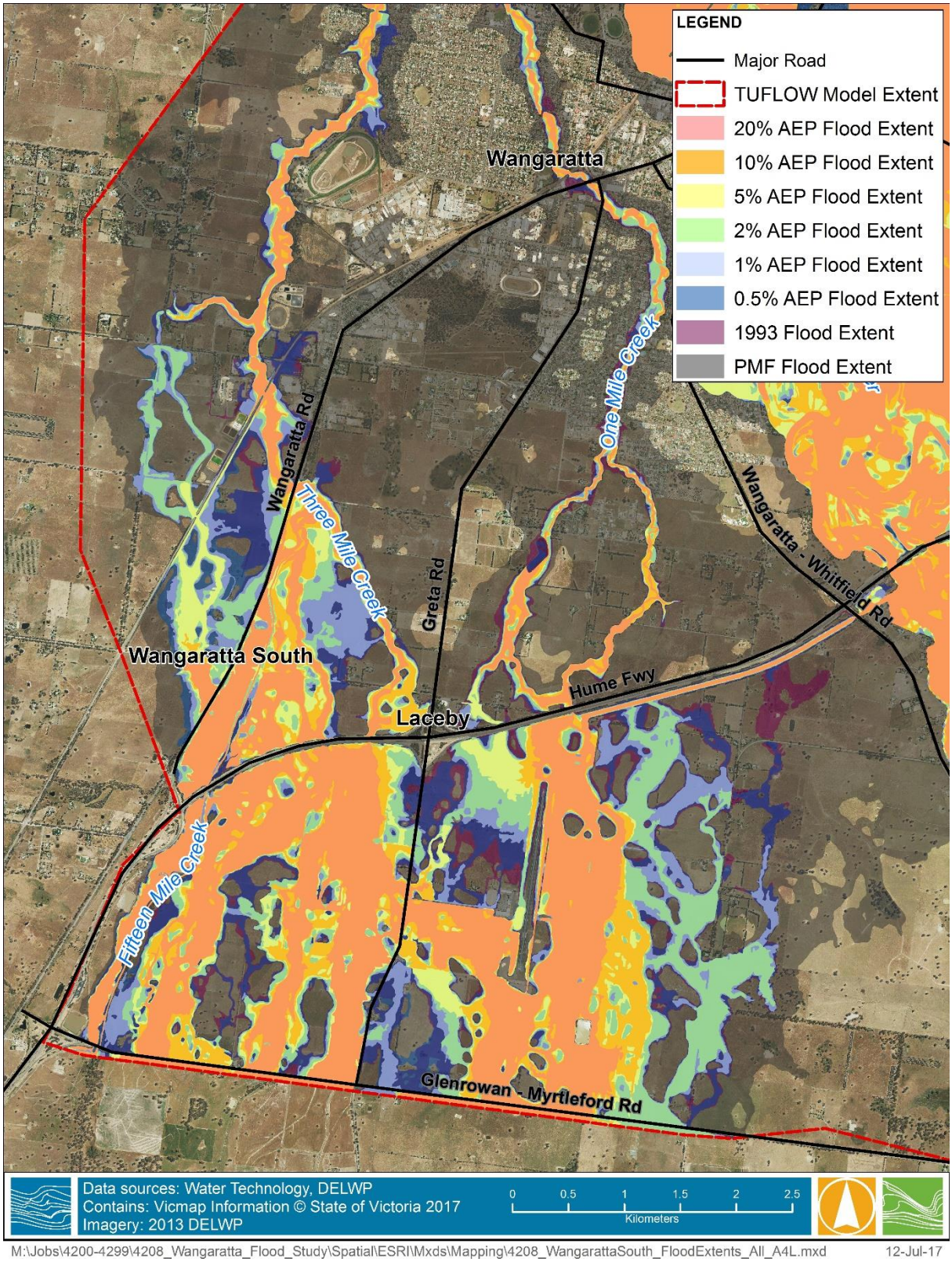

Figure 5-2 **The full range of design flood extents overlaid across the 15 Mile Floodplain to the south of Wangaratta**

Table 5-4 Summary of Flood Behaviour for Various Flood Events – Ovens and King River System

Event	Flood Characteristics – Ovens and King River Floodplains	Key roadways inundated
20% AEP **Ovens River at Wangaratta Gauge** • 12.5 m gauge level • 142.93 m AHD • 58,100 ML/d (combined flow)	• **Above floor flooding to 1 residential property at:** o **Dowling Lane, North Wangaratta** • **Key Locations of Interest inundated** o **Apex Park** o **Painters Island Caravan Park** • Large scale breakouts on the southern floodplain of the Ovens River downstream of Markwood-Everton Rd to Hume Freeway inundating agricultural land, wetlands, anabranches and flood channels. • Flood waters generally bound by Tea Garden Creek upstream of Allans Lane. • Tea Garden Creek begins to break out between Oxley Flats Road and Allans Lane. • Dwellings at 23 Ivones Lane, 613 Markwood-Tarrawingee Road, 669 Markwood-Tarrawingee Rd, 202 Milawa-Tarrawingee, 171 Oxley Flats Road, are impacted by floodwaters from the Ovens River (below floor level). • Localised breakouts on the northern floodplain of the Ovens River upstream of the Hume Freeway inundating agricultural land, wetlands and flood channels from Kays Road to approximately 4km upstream of the Hume Freeway. • The driveway at 336 River Road Tarrawingee, is impacted by floodwaters up to 900 mm deep. • Floodwaters from the Ovens River impacting on access to 44 Milawa-Tarrawingee Road, Milawa. • Flood waters impacting on dwelling and access to 191 and 219 Goodwins Lane, Milawa. • Large scale outbreaks onto agricultural land from the King River and Factory Creek around Oxley with flows primarily restricted between Factory Creek and Redferns Lane. • Floodwaters from the Ovens River and King River merge near the northern end of Redferns Lane. • Several residential properties on Oxley Flats Road and Williams Lane, Oxley Flats are impacted by flood waters with access to properties and dwellings impacted. • 650 and 606 Oxley Flats Road becomes cut off with flood water from the Ovens River covering the driveway up to 300 mm deep.	• Markwood-Everton Road • Markwood-Tarrawingee Road • Ivones Lane • Reids Lane • Milawa Tarrawingee Road • Goodwins Lane • River Road (Tarrawingee) • Oxley Flats Road and Wilson Road south of the Wilson Road levee • Oxley Plains Road • Williams Lane • Cockrofts Lane • Taylors Lane (flooding may occur due to an earlier peak in the King River) • Great Alpine Road, between the Rail Trail and Detour Road (closes at around minor flood level 11.9 m) • Bickerton Street, including the car parking areas • Pinkerton Crescent • The carpark at Baker Street • College Street, preventing access to the Northern

Event	Flood Characteristics – Ovens and King River Floodplains	Key roadways inundated
	• The area impacted by floodwaters from the Ovens River and King River is over 6km wide upstream of the Hume Freeway. • Downstream of the Hume Freeway there are widespread outbreaks from the Ovens River, King River Yellow Creek and Reedy Creek. • 171 Oxley Flats Road and 128 Wilson Road become cut off with flood waters up to 300 mm deep over the driveways. • Several properties on Taylors Lane, become inundated and cut off with flood water over Taylors Lane and several driveways. • The Wilson Road Levee protects properties from flood waters along Wilson Road. • Dwellings at 44 Fisher Lane, 194 Great Alpine Road and 23 Peruzzo Street are impacted by flood waters from the Ovens River (below floor). • The dwelling access to the dwelling at 19 Thomas Road is inundated by floodwaters up to 500 mm deep (below floor) and 113 Wilsons Road is impacted by floodwaters up to 350 mm deep (below floor level and protected by private levee) with floodwaters over 800 mm deep on sections of the driveway. • 194 Great Alpine Road becomes cut off with flood waters up to 700 mm deep over the driveway. • Flood waters from Reedy Creek impact on the perimeter of North East Water's wastewater ponds but do not over top the ponds • Floodwaters from the King River fill Kaluna Wetlands and Merriwa Park is protected by the levee. • Commercial and residential properties near Parfitt Road are protected by the levee. • Several buildings in Pinkerton Crescent, Nicholls Street, and Hoban Street are impacted by floodwaters (below floor level) • Apex Park is inundated with flood waters over 2 m deep in low lying areas. • Painters Island Caravan Park is inundated with flood water from the Ovens River with depths over 3.5 m in in the lagoon around the perimeter of the park and with most of the park inundated with up to 1.5m of floodwaters. • Sydney Beach carpark inundated with up to 1 m of flood water. • Several properties in Templeton Street are impacted by flood waters with some out buildings impacted.	Beaches carpark • Dowling Lane • Ambrosio Road • Stamps Lane • Tweed Street • Burrows Street

Event	Flood Characteristics – Ovens and King River Floodplains	Key roadways inundated
	• The Baker Street carpark is inundated with flood waters up to 600 mm deep. • The property including the dwelling at Dowling Lane is inundated by floodwaters (above floor level). • Wide spread breakouts from the Ovens River and Reedy Creek inundating agricultural land downstream of Bowser Road. • Flooding over Stamps Lane, near Bowser Road commences when the Wangaratta gauge is around 12.3m and the Reedy Creek gauge is around 4.2m • Several properties along Stamps Lane, Burrows Lane become cut off with flood waters covering the driveways over 300 mm deep. • Several properties in Ambrosio Road are impacted by floodwaters with dwellings (below floor level), out buildings and driveway access impacted with flood waters over 600 mm in some areas.	
10% AEP **Ovens River at Wangaratta Gauge** • 12.62 m gauge level • 143.05 m AHD • 84,200 ML/d (combined flow)	• **No additional properties flooded above floor** • **No additional key locations of interest inundated** • Flood waters upstream of the Hume Free generally increase by approximately 100-250 mm in depth with a slight increase in agricultural land inundated. • Increased extent of flooding around Markwood-Tarrawingee Road with additional driveways impacted by floodwaters <100 mm deep. • Dwelling at 665 Markwood-Tarrawingee Road becomes impacted by flood waters, below floor level. • Between the Hume Freeway and Parfitt Road flood waters from the Ovens and King Rivers generally increase in depth by 150-400 mm with a slight increase in inundated land, particularly around the King River. • The access to residential property at 28 Weir Street is impacted by flood water up to 800 mm over the driveway. • Dwelling at 194 Great Alpine Road is impacted by floodwaters <100 mm deep (below floor level). • Floodwaters associated with Reedy Creek upstream of Parfitt Road increase in depth by approximately 300 mm. • Flood waters associated with the Ovens River and Reedy Creek downstream of Parfitt Road generally increase in depth by approximately 300 mm.	• Minor inundation of Billabong Drive east of Kingfisher Drive • Willis street

Event	Flood Characteristics – Ovens and King River Floodplains	Key roadways inundated
	• Dwellings on Burrows Street begin to become impacted by floodwaters (below floor level).	
5% AEP **Ovens River at Wangaratta Gauge** • 12.71 m gauge level • 143.14 m AHD • 111,000 ML/d (combined flow)	• **Above floor flooding to an additional 5 residential properties (6 in total) at:** o **182 Markwood-Tarrawingee Road Markwood 3678** o **171 Oxley Flats Road Wangaratta 3677*** o **31-37 Weir Street Wangaratta 3677*** o **194 Great Alpine Road East Wangaratta** o **23 Peruzzo Street Wangaratta 3677#** • **No additional key locations of interest inundated** • Floodwaters depths from the Ovens and King River systems upstream of the Hume Freeway generally increase by approximately 200 mm. • Additional dwellings on Markwood-Tarrawingee Road become impacted by flood waters. • Flood extent slightly increases with Tea Garden Creek breaking out upstream of Allans Lane. • The dwelling at 22 Cockrofts Lane becomes impacted by flood waters < 10 mm deep (below floor). • Floodwater depths between the Hume Freeway and Parfitt Road associated with the Ovens River increase by approximately 250 mm. • Floodwater depths between the Hume Freeway and Parfitt Road associated with the King River increase by approximately 300 mm. • Floodwater depths between the Hume Freeway and Parfitt Road associated with the Reedy Creek increase by approximately 500 mm. • 41 Vernon Road becomes inundated with flood waters from the King River impacting the dwelling (below floor). • Floodwaters begin to impact low lying areas of Merriwa Park within the levee including Christopher Robin Kindergarten. • Floodwater depths that pass under Parfitt Road associated with the Ovens River and Reedy Creek increase by approximately 200 mm. • The dwelling at 22 Willis Street becomes impacted by floodwaters (below floor). • Dwellings on Dale Street become impacted by floodwaters (below floor). • The dwelling at 103 Burrows Street starts to become impacted by floodwaters (below	• Vernon Road preventing access to agricultural land • Markwood Everton Road • Allans Lane

Event	Flood Characteristics – Ovens and King River Floodplains	Key roadways inundated
	floor). • Properties on Grossman Drive are beginning to be impacted with a small number of out buildings also impacted.	
2% AEP **Ovens River at Wangaratta Gauge** • 12.82 m gauge level • 143.25 m AHD • 144,000 ML/d (combined flow)	• **Above floor flooding to an additional 8 residential properties (14 in total) at:** o **340 Markwood-Tarrawingee Road Markwood 3678** o **231 Ivones Lane Milawa 3678** o **49 Great Alpine Road Wangaratta 3677** o **61 Great Alpine Road Wangaratta 3677#** o **14 Taylors Lane Wangaratta 3677** o **49 Stamps Lane North Wangaratta 3678#** o **240 Stamps Lane North Wangaratta 3678#** o **150 Stamps Lane North Wangaratta 3678** • **Above floor flooding to 2 commercial/municipal properties at:** o **Wangaratta Lawn Tennis Club, Merriwa Park, Wangaratta** o **Christopher Robin Childcare, Merriwa Park, Wangaratta (assumes no temporary measures in place)** • **Key Locations of Interest inundated** o **Merriwa Park** • Floodwater depths on the Ovens and King River floodplains upstream of the Hume Freeway generally increase by approximately 100-200 mm with only minor increases to the flood extent. • Tea Garden Creek has breakouts along its extent impacting properties on Carboor-Everton Road including the dwelling at 92 Carboor-Everton Road (below floor). • A number of additional buildings impacted by shallow floodwaters (<100 mm) on Markwood-Everton Road, Markwood-Tarrawingee Road and Ivones Road including dwellings. • Dwelling at 44 Milawa-Tarrawingee Road is impacted by flood waters. • Dwellings at 606, 650, 707, 737 and 776 Oxley Flats Road begin to become impacted by shallow floodwaters (below floor). • Floodwater depths across the King River floodplain between the Hume Freeway and Parfitt Road increase by approximately 150-300 mm.	• Carboor-Everton Road, from the Markwood-Everton Road to the Snow Road. • Parfitt and Bowser Roads, north of the Parfitt Levee System

Event	Flood Characteristics – Ovens and King River Floodplains	Key roadways inundated
	• Floodwater depths between the Hume Freeway and Parfitt Road on the Reedy Creek floodplain increase by approximately 300-500 mm. • Dwellings at 139, 140 and 143 Taylors Lane become impacted by flood waters (below floor). • Some of North East Water's wastewater treatment ponds, off Detour Road, are breached by floodwaters. • The dwelling at 1 Bowser Road is impacted by floodwaters (below floor). • The levee around Merriwa Park is up to 700 mm below the floodwater resulting in the park including tennis club buildings and Christopher Robin Kindergarten being inundated with depths over 2 m in low lying areas. • Floodwater depths downstream of Parfitt Road associated with the Ovens River and Reedy Creek increase by approximately 150-250 mm. • The dwelling at 17-21 Pinkerton Crescent is impacted by floodwaters (below floor level).	
1% AEP **Ovens River at Wangaratta Gauge** • 12.92 m gauge level • 143.35 m AHD • 180,000 ML/d (combined flow)	• **Above floor flooding to an additional 15 residential properties (29 in total) at:** o **87 Milawa-Tarawingee Road Milawa 3678** o **5 Milawa-Tarrawingee Road Milawa 3678** o **707 Oxley Flats Road Oxley Flats 3678** o **137 Taylors Lane Wangaratta 3677** o **22 Taylors Lane Wangaratta 3677*** o **128 Wilson Road Wangaratta 3677** o **19 Thomas St Wangaratta 3677** o **49 Pinkerton Crescent Wangaratta 3677** o **1 Bowser Road Wangaratta 3677** o **57 Bowser Road North Wangaratta 3678*** o **53 Pinkerton Crescent Wangaratta 3677** o **1 Willis Street Wangaratta 3677** o **86 Stamps Lane North Wangaratta 3678** o **119 Stamps Lane North Wangaratta 3678** o **132 Stamps Lane North Wangaratta 3678*** • **No additional above floor flooding to commercial/municipal properties** • **No additional key locations of interest inundated** • Floodwaters depths from the Ovens and King River systems upstream of the Hume	

Event	Flood Characteristics – Ovens and King River Floodplains	Key roadways inundated
	Freeway generally increase by approximately 150 mm. • Residential properties including dwellings are impacted at Carboor-Everton Road (below floor). • Additional residential properties on Markwood-Tarrawingee Road and Markwood-Everton Road impacted by floodwaters including dwellings. • Additional dwellings on Oxley Flats Road are impacted by floodwaters. • Areas that are not protected by levees between Reedy Creek and the Ovens River, downstream of Fishers Lane are inundated by generally more than 1 m of water. • Flood levels on the Reedy Creek floodplain between the Great Alpine Road and railway line increase by around 400mm. • The Parfitt Road levee overtops along the north section of the levee where it crosses Parfitt Road. • Residential dwellings and commercial buildings within the levee on Wylie St and Parfitt Road north of Morgan Road become impacted by flood waters. • Several dwellings on Templeton Street are impacted by floodwaters (below floor).	
0.5% AEP **Ovens River at Wangaratta Gauge** • 13.03 m gauge level • 143.46 m AHD • 201,900 ML/d	• **Above Flooding impacted on an additional 10 residential properties (39 in total) at:** o **11 Carboor-Everton Road, Markwood** o **297 Markwood-Tarrawingee Road, Markwood 3678** o **113 Wilson Road, Wangaratta 3677** o **87 Taylors Lane, Wangaratta 3677** o **41 Vernon Road, Wangaratta 3677** o **4 Wylie Street, Wangaratta** o **3 Pinkerton Crescent, Wangaratta** o **110 Parfitt Road, Wangaratta** o **15 Dale Street, Wangaratta 3677** o **129 Stamps Lane, Wangaratta** • The flood extent in along the King River and Ovens River increases marginally with the largest increase of area inundated being around Markwood. • Wilson Road Levee is over topped at the northern end, impacting a number of properties and dwelling within the levee. • The majority of residential and commercial properties within the Parfitt Road levee are	• Wilson Road • Dunphy Street • Thomas Street • Boyd Street • Heach Street • Chandler Street • Parfitt Road • Wylie Street • Bickerton Street • Kett Street • Morgan Road • Regal Crescent • Potter Street

Event	Flood Characteristics – Ovens and King River Floodplains	Key roadways inundated
	impacted by flood waters. • The depth of inundation across the Ovens River and King River floodplains generally increases by 100-200mm.	
PMF **Ovens River at Wangaratta Gauge** • 16.88 m gauge level • 143.46 m AHD • 1,883,200 ML/d	• **Key locations of interest inundated include:** o The Wangaratta sporting precinct including the H.P. Barr Reserve, the Show Grounds and Norm Minns Oval o Galen College and Wangaratta High School. • Most of the Ovens River and King River floodplains are inundated with over 2 m of floodwater. • The flood extent extends beyond the model extent, eg, To the Snow Road at Markwood, and north of the Great Alpine Road downstream of Everton. • Both the Wilson Road and Parfitt Road levee are completely inundated with over 2m of water. • The Hume Freeway is inundated • A large number of properties in Billabong Drive, Shiraz Court, and Kingfisher Drive are inundated by over 2m of water. • Properties in Violet Court and Albert Court are inundated by up to 1.5 m. • A large number of houses and properties inundated in Hardisty St, Vernon Road, Vernon Terrace, Chomley Avenue, Gayer Avenue and Riverview Court. • Large scale flooding of residential and commercial properties in Ovens Street, Docker Street, Baker Street, Templeton Street, Mackay Street, Gray Street, Johnstons Lane and Edwards Street and north of Edward Street. • The majority of the area between the Ovens River and Detour Road is inundated by over 2m of water. • A number of properties in Grossman Estate are inundated by over 1 m of floodwater.	• Hume Freeway • Detour Road • Wilson Road • Parfitt Road • Rowan Street • Templeton Street • Edward Street • Park Lane

* A private levee has been constructed around the dwelling as such the dwelling might be protected.

It is believed that the dwelling has been raised since the floor levels were surveyed.

Table 5-5 Summary of Flood Behaviour for Various Flood Events – 15 Mile Creek System

Event	Flood Characteristics – 15 Mile Creek System	Key roadways inundated
20% AEP **15 Mile Creek at Greta South Gauge** • 3.80 m gauge level • 191.09 m AHD • 6,200 ML/d	• **No above floor flooding to residential or commercial/municipal properties** • **No key Locations of Interest inundated** • Generally shallow but widespread inundation (< 200 mm) across the 15 Mile Creek, Three Mile Creek and One Mile Creek floodplains upstream of the Hume Freeway. • Residential property at 501 Snow Road is cut off with water depths of <200 mm over the driveway. • Shallow inundation of undeveloped land around the airport but airport access, buildings and main runway not impacted • One Mile Creek bypass channel engaged. • Generally shallow inundation of agriculture land between the Hume Freeway and Arundels Lane from 15 Mile Creek breakouts and culverts under the freeway. • Shallow inundation of Arundels Lane (< 300mm) isolating properties at 112 and 113 Arundels Lane. • Within the urban areas of Wangaratta, flow in One Mile and Three Mile Creeks is generally confined within the channels with some minor breakouts into the waterway corridor impacting bike paths and walking tracks.	• Snow Road, between the Hume Freeway and Laceby-Targoora Road • Greta Road near corner of Brian Higgins Drive impacting access to the airport from both north and south • Arundels Lane • Tone Road, south of 3 Mile Creek • Clarkes Lane
10% AEP **15 Mile Creek at Greta South Gauge** • 4.83 m gauge level • 192.12 m AHD • 9,700 ML/d	• **No above floor flooding to residential or commercial/municipal properties** • **Key locations of interest inundated** o **Access to airport impacted** • Increased depths of inundation across the 15 Mile Creek, Three Mile Creek and One Mile Creek floodplains upstream of the Hume Freeway. Generally, depths of up to 300 mm with some deeper pockets up to 700 mm mainly where water is backing up behind the freeway. • Residential property at 501 Snow Road is cut off with water depths of >200 mm over the driveway. • Increased depths around the airport but runway and buildings not impacted. • Deeper inundation of agriculture land between the Hume Freeway and Arundels Lane from	• Gravel Pit Road • Glenrowan Road

Event	Flood Characteristics – 15 Mile Creek System	Key roadways inundated
	Fifteen Mile Creek breakouts and culverts under the freeway. • Deeper inundation across Arundels Lane (300-500 mm) leading to further isolation of properties at 112 and 113 Arundels Lane • Breakout from Fifteen Mile Creek flowing through culverts under Glenrowan Road 800 m north of Hume freeway resulting in shallow inundation of agricultural land and engagement of drainage line to the west of Glenrowan Road near Delloro Road. • Additional inundation of land downstream of the Hume Freeway from breaks from Fifteen Mile Creek • Low lying property at 1 Glenrowan Road, Wangaratta, (near the corner of Gravel Pit Road) is isolated from breakouts from 15 Mile Creek with depths of 200-300 mm across the driveway. • Flow in One Mile Creek still mainly confined to waterway corridor. Some impact to rear of properties along Graham Avenue and Perry Street, but homes not affected. Minor inundation at rear of several properties along Mannion Court and Martin Place. • Flow in Three Mile Creek also generally confined to waterway corridor. Some impact to rear of properties along Franklin Street but homes not affected. • Breakouts from Three Mile Creek leading to generally shallow inundation to the exterior of several properties on Laura Court and Scott Street.	
5% AEP **15 Mile Creek at Greta South Gauge** • 6.04 m gauge level • 193.33 m AHD • 14,200 ML/d	• **No above floor flooding to residential or commercial/municipal properties** • **No additional key locations of interest inundated** • Properties on Greta Rd near the airport are impacted with shallow water <100 mm • Increased depths around the airport but runway and buildings not impacted. • The break out from Fifteen Mile Creek extends under Delorro Road and the Railway line to Gravel Pit Road. The drainage line along the railway line carries flows back to Three Mile Creek. • Further breakouts under the Hume Freeway and Pyles Lane • Access to 117 Glenrowan Road starting to be impacted by shallow (<100 mm) flood water over the driveway. • Three Mile Creek downstream of Shanley Street remains largely within the waterway	

Event	Flood Characteristics – 15 Mile Creek System	Key roadways inundated
	corridor. • The One Mile Creek is largely confined to the creek corridor, with additional impacts on properties at 20 Turner Street, 13 and 14 Bronmar Street, 122-128, 118 and 116 Phillipson Street, 109 and 100 Edward Street (below floor).	
2% AEP **15 Mile Creek at Greta South Gauge** • 8.10 m gauge level • 195.39 m AHD • 22,100 ML/d	• **12 residential properties impacted by above floor flooding** • **15 Valdoris Avenue Wangaratta 3677** • **20 Graham Avenue Wangaratta 3677** • **10 Graham Avenue Wangaratta 3677** • **14 Graham Avenue Wangaratta 3677** • **16 Graham Avenue Wangaratta 3677** • **18 Graham Avenue Wangaratta 3677** • **35 Crisp Street Wangaratta 3677** • **37 Crisp Street Wangaratta 3677** • **13 Bronmar Street Wangaratta 3677** • **14 Bronmar Street Wangaratta 3677** • **2/85 Swan Street Wangaratta 3677** • **No commercial properties experience above floor flooding** • **No key locations of interest inundated** • Widespread inundation across the 15 Mile Creek floodplain between the Snow Road and Hume Freeway, generally depths of up to 500 mm with some deeper pockets up to 600 mm mainly where water is backing up behind the freeway. • Deeper inundation of agriculture land between the Hume Freeway and Arundels Lane from 15 Mile Creek breakouts and culverts under the freeway • Buildings at 112 and 113 Arundels Lane beginning to be impacted by flood water (below floor) and access to cut off by significant depths (> 500 mm) • Flows from the breakout from 15 Mile Creek flowing through culverts under Glenrowan Road 800 m north of Hume freeway and continuing north along a drainage channels through farming land to near the corner of Shanley St and Reith Rd before re-entering Three Mile Creek at the speedway. • Flood waters start to impact on the CFA training centre and the saleyard wastewater	• Valdoris Avenue • Graham Avenue • Crisp Street • Bronmar Street • Melba Street

Event	Flood Characteristics – 15 Mile Creek System	Key roadways inundated
	treatment ponds. • Flow in One Mile Creek still mainly confined to waterway corridor with some exceptions. • A number of properties along Graham Avenue are impacted by inundation with some dwellings and out building starting to be impacted by floodwaters. • Properties at 43 Cusack and 64 Swan Street becoming significantly impacted by inundation from One Mile Creek (below floor). The rear of several other properties along Swan Street, upstream of Rowan Street also impacted with some sheds/outbuildings affected. • 143, 152, 154, 151 and 156 Rowan Street starts to become inundated impacting buildings (below floor). • The land around the Lutheran Church at 7 Orwell Street becomes inundated by floodwaters. • Properties at the end of Olive Street, Bronmar Street and Turner Street start to become impacted externally from One Mile Creek. • Croquet pitch on Ryan Avenue becomes inundated by flood waters from the One Mile Creek. • Flooding of the south west corner of the high school extending and deepening with depths of up 1.5 m. • Properties from 145 Philipson Street to 159-163 Philipson Street starting to become impacted by flood waters. • Flood waters from One Mile Creek are starting to impact on the northern section of the Appin Park Primary School grounds with depths up 1 m in low lying areas. • One Mile Creek flow impacting the rear of several properties on Moran Court, Braithwaite St, Dalton Court, O'Callaghan Drive and Waratah Court, including out buildings. • Flood waters starting to impact outbuildings at properties on Mannion Court, and Martin Place • Flows starting to impact several properties in Hulme Drive. • Three Mile Creek starting to impact on Wangaratta Golf Course and properties at Maple Circuit and Macquarie Court. • 101 Williams Roads starts to become impacted by flood waters, but not impacting the dwelling. • Flow in Three Mile Creek generally confined to waterway corridor. Some impact to rear of	

Event	Flood Characteristics – 15 Mile Creek System	Key roadways inundated
	properties along Franklin Street but homes not affected. • Breakouts from Three Mile Creek leading to generally shallow inundation to the exterior of several properties on Laura Court and Scott Street and 46 Cruse Street.	
1% AEP **15 Mile Creek at Greta South Gauge** • Beyond level of rating curve • 29,700 ML/d	• **Above floor flooding to 10 additional residential properties at:** o **12 Graham Avenue Wangaratta 3677** o **22 Graham Avenue Wangaratta 3677** o **26 Graham Avenue Wangaratta 367** o **33 Crisp Street Wangaratta 3677** o **13 Walter Street Wangaratta 3677** o **15 Walter Street Wangaratta 3677** o **2/152 Rowan Street Wangaratta 3677** o **1/152 Rowan Street Wangaratta 3677** o **152a Rowan Street Wangaratta 3677** o **122-128 Phillipson Street Wangaratta 3677** • **No above floor flooding at commercial properties** • **No key locations of interest inundated** • Flood waters inundating the lower lying parts of the grounds of the Scout Hall on Vincent Road, but not the buildings. • Several more properties and dwellings along Graham Avenue impacted by flood water from One Mile Creek. • The dwellings at 31 – 37 Crisp Rd impacted by flood waters from the One Mile Creek (below floor). • Croquet hall and Church hall on Ryan Avenue becomes inundated by flood waters from the One Mile Creek. • The exterior of 43 Cusack Street becomes impacted by flood water. • Additional out buildings on the properties on Swan Street between Cusack Street and Rowan Street are impacted by flood waters from One Mile Creek. • 152-156 Rowan Street become inundated with out buildings and dwellings impacted (below floor). • Additional properties and dwellings impacted by water from the One Mile Creek at Bronmar Street, Olive Street and Turner Street.	• Vincent Road • Sunset Drive • Trotman Drive • Walter Street • Willow Drive • Edwards Street • Rattray Avenue • Panes Lane

Event	Flood Characteristics – 15 Mile Creek System	Key roadways inundated
	• Additional buildings, including dwellings impacted by flood water between 116 - 163 Philipson Street. • The dwellings at 14 and 16 Moran court becomes impacted by flood waters from the One Mile Creek (below floor). • The dwelling at 4 Mannion Court becomes impacted (below floor). • 105 and 107 Edwards Street start to become impacted by flood waters (below floor). • Buildings and dwelling at 117 Glenrowan Road become impacted by floodwater (below floor). • Low lying paddocks at the Tafe Campus at Tone Road start to become inundated. • Flood waters start to impact sheds at 79 Shanley Street. • Buildings and roadways at the Wangaratta Speedway become impacted by flood waters from the Three Mile Creek. • Flood waters from the Three Mile Creek begin to fill drainage lines and depressions. • The Three Mile Creek breaks out near Walter Street and impacts on dwellings at 13 and 15 Walter Street and 2 Sunset Drive (below floor). • Flood water start to impact a dwelling adjacent to 101 Williams Road (below floor). • Breakouts along Cruse St and impact properties at 1 and 2 Hayes Court.	
0.5% AEP **15 Mile Creek at Greta South Gauge** • Beyond level of rating curve • 39,000 ML/d	• **Above floor flooding to 18 additional residential properties at:** o **24 Graham Avenue Wangaratta 3677** o **27 Perry Street Wangaratta 3677** o **31 Perry Street Wangaratta 3677** o **2 Hayes Court Wangaratta 3677** o **64 Swan Street Wangaratta 3677[#]** o **1/85 Swan Street Wangaratta 3677** o **154 Rowan Street Wangaratta 3677** o **156 Rowan Street Wangaratta 3677** o **2 Sunset Drive Wangaratta 3677** o **4 Sunset Drive Wangaratta 3677** o **44 Franklin Street Wangaratta 3677** o **46 Franklin Street Wangaratta 3677** o **8 Sadler Street Wangaratta 3677**	• White Street • Franklin Street • Esmond Street

Event	Flood Characteristics – 15 Mile Creek System	Key roadways inundated
	○ **16 Olive Street Wangaratta 3677** ○ **11 Bronmar Street Wangaratta 3677** ○ **12 Bronmar Street Wangaratta 3677** ○ **22 Hulme Drive Wangaratta 3677** ○ **19 Martin Place Wangaratta 3677** • **1 commercial property is inundated** ○ **North East Water's sewage pumping station at 8 Graham Avenue, Wangaratta 3677** • Flood water depths between the Snow Road and the Hume Freeway generally increase by approximately 50-75mm and 150mm closer to the freeway. • Additional buildings, including dwellings, along the snow road and Greta Road are impacted by floodwaters (below floor). • Flood waters approach the northern end of the airport runway. • Additional agricultural land along Laceby-Targoora Road is inundated by floodwater. • Additional agricultural land along Glenrowan Road, to the south of gravel pit road, is inundated by floodwaters. • The One Mile Creek breaks out of the creek reserve along Rattray Avenue. • The One Mile Creek breaks out of the creek reserve between White Street and Vincent Road impacting a number of properties, including dwellings and Valdoris Avenue. • Additional dwellings impacted along Graham Avenue. • The croquet club and church on Ryan Avenue are inundated by floodwaters. • A breakout at Perry Street impacts dwellings at 27-33 Perry Street. • Dwellings on Cusack Street are impacted by floodwaters from One Mile Creek. • Additional impacts to dwellings on the Swan Street and Rowan Street. • Additional impacts to dwellings and residential properties along Phillipson Street, Hulme Drive, Moran Court, Dalton Court, Ocallaghan Drive, Warratah Court, Mannion Court and Edward Street. • Significant impact to the saleyards wastewater treatment ponds. • Additional impact on buildings at 79 Shanley Street. • Floodwaters approaching and impacting on stables at the Turf Club. • Dwellings impacted at 1 and 2 Hayes Court. • Buildings impacted by floodwaters at 1 Scott Street.	

Event	Flood Characteristics – 15 Mile Creek System	Key roadways inundated
	• The breakout at the corner of Walter Street and Sunset Drive impact on additional properties including the dwelling at 2-6 Sunset Drive. • Breakout across park adjacent to police station • The dwelling at 22 Willow Drive is impacted by floodwaters. • Dwelling at 42-48 and 59-61 Franklin Street are impacted by floodwaters. • Dwellings from 42-46 Trotman Drive are impacted by flood waters.	
PMF **15 Mile Creek at Greta South Gauge** • Beyond level of rating curve • 205,460 ML/d	• There are large scale breakouts across the entire modelled area. Flood waters from the Fifteen Mile Creek System connects with floodwaters from the Ovens River and King River between Pyles Lane and Clarkes Lane, near Vincent Road and north of Edwards Street. • The majority of the area bound by the Snow Road, the Hume Freeway and Laceby-Targoora Road is inundated with flood waters up to 2m deep. Flood waters are over 2m deep where it has backed up behind the Hume Freeway. • The main run way at the airport is inundated by over 1 m of floodwater at the northern end. • Wide spread inundation of agricultural properties downstream of the Freeway. • Wide spread inundation of commercial and residential properties to the south of Tone Road. • Wide spread inundation of commercial and residential properties along both sides of One Mile Creek and Three Mile Creek throughout Wangaratta.	• Wangaratta-Whitfield Road • Hume Freeway • Greta Road • Tone Road • Murdoch Road • Swan Street • Philipson Street • Williams Road • Wangandary Road • Wangaratta-Yarrawonga Road

5.4 Levee Freeboard Assessment

An assessment of the Parfitt Road and Wilsons Road levee has been undertaken to understand the level of protection they currently provide. The assessment assumed no temporary measures such as sandbagging is in place. The results of the levee assessment are presented graphically in Appendix B and a summary of the key findings is provided below. The assessment has been conducted by comparing the surveyed levee crest levels (Urban Levee Survey, Jacobs, 2014) to the 1% AEP peak water levels.

The assessment is based on the assumption that a minimum design freeboard of 300 mm is preferred. Whilst 300 mm is the typical freeboard adopted for structural mitigation works across Victoria it may not be sufficient in all circumstances. Other factors such as fetch and localised hydraulics can result in localised increases in water levels and a larger freeboard will be appropriate in some locations.

The key findings form the levee assessment are provided below:

Parfitt Road Levee Key Findings:

- Sufficient 1% AEP freeboard is available along the western portion of the levee from Pinkerton Crescent to Bowser Road (Chainage 50 m to 1250 m) with there generally being a minimum of 500-600 mm freeboard through this section.
- A shallow overtop (less than 30 mm) occurs at the northern boundary of the levee system across Bowser Road (Chainage 1300 m). Sandbagging is required in this location and this has occurred in recent major flood events.
- Along the eastern section of the levee (Chainage 1300 to 3100 m) approximately 50% of the reach does not have the minimum 300 mm freeboard. There is a particularly low section from Chainage 1650 to 2150 m where the freeboard is as low as 140 mm.
- There is reduced freeboard in the south-western corner of the levee system along Pinkerton Crescent (Chainage 3350 to 0 m) with the lowest freeboard of 50-60 mm occurring at Chainage 0, near the entrance road to Painters Island Caravan Park.

Overall the assessment has identified that the Parfitt Road Levee system currently does not provide adequate 1% AEP protection with potential shallow overtopping of Parfitt Rd at the northern end of the levee and where the levee is formed by Pinkerton Crescent. As permanently raising the levee would impact on road levels, these areas would require sandbagging during floods to provide 300mm freeboard. Most of the levee between Wylie Street and the Frank Garth reserve also has less than 300mm freeboard and should be raised.

Wilson Road Levee Key Findings

- Sufficient 1% AEP freeboard is available along the eastern section of the levee from Wilson Road (northern end) to Wilson Road (southern end), aside from a low point at Chainage 50 where survey indicates the freeboard reduces to 130 mm. It is likely the survey is incorrect at this location as an pronounced dip has not been observed on-site. For the remainder of this section freeboard is generally in the range of 350 to 450 mm.
- Along the south-eastern section of the levee (Chainage 900 to 1700 m) there is generally adequate freeboard of 300-400 mm aside from a 100 metre section (Chainage 1050 to 1150 m) where freeboard drops to 240 – 270 mm.
- Along the south-western section (Chainage 1700 to 2050 m) the freeboard is generally adequate however there is a 100 metre section (Chainage 1750 to 1850 m) where the freeboard drops to 250-280 mm.

Overall the assessment has identified that the Wilson Road Levee system currently does not provide adequate 1% AEP protection with two main sections of the levee having less than the preferred 300

mm freeboard. A low point is also noted in the north-west section of the levee where freeboard drops to 130 mm.

5.5 Model Result Outputs

The model result data including grids and extents were provided in the specified Victorian Flood Database (VFD) format for each flood event. The following result components were generated:

- Flood level, flood depth, flood velocity, flood hazard and model topography grids
- Flood elevation contours
- Flood extents
- Hydrographs at key locations
- Long-section of river water levels

5.5.1 Data Sets

The following datasets were provided. All GIS files will be provided in ESRI VFD format and ASCII format. A summary of the datasets is provided below and an example of the mapped 1% AEP outputs is provided in Appendix A.

Grids

Gridded datasets of model results were provided for the following:

- Design events (20%, 10%, 5%, 2%, 1%, 0.5% and PMF events) – maximum depth, hazard, velocity and water surface elevation.
- Calibration events (October 1993 and September 2010 events) – maximum depth, hazard, velocity and water surface elevation.
- Model topography

Vector Data

ERSI shapefiles in VFD format were provided for the following:

- Peak flood extents
- Peak flood elevation contours
- Levee Layer
- Mapping limits

The hydraulic analysis provides a regular grid of flood elevations across the hydraulic model study area. The flood extent was defined by converting the flood elevation grid to an extent polygon. The extent is smoothed to remove the sharp edges of the grid cells for cartographic / presentation purposes.

5.5.2 Maps

The flood response inundation maps were produced for the following design flood events:

- Maximum depth for all modelled design events (20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% AEP events and PMF).

Each map includes:

- Flood extent;
- Flood level contour at 1 m intervals;
- Depth of inundation;
- Identification of essential services;
- Major Road/street names;
- Cadastral base; and
- Gauge height indication at the key gauges on the Ovens River and 15 Mile Creek – Ovens River at Wangaratta and 15 Mile Creek at Greta South.

For each design event, a map was provided of the entire study area, as well as two zoomed maps.

A mapping limits layer was provided in the vector data. This layer shows the model extent and is important because it identifies where modelling from this study finished. This allows the users of the outputs to understand that flooding does not stop at the flood mapping limit. The mapping limits simply represent the limit of mapping created in this investigation.

The above maps are provided as standalone PDF maps. Mapping for the 1% AEP design event is provided in Appendix A.

6. FLOOD DAMAGES ASSESSMENT

6.1 Overview

A flood damages assessment was undertaken for the study area under existing conditions. The flood damage assessment determined the monetary flood damages across the range of design floods (20%, 10%, 5%, 2%, 1% and 0.5% AEP flood events). Floor level survey was obtained for 160 properties in the study area and combined with existing floor level datasets provided by the North East CMA. The combined floor level dataset was one of the principal inputs for the damages assessment.

Water Technology has developed an industry best practice damage assessment methodology that has been utilised for a number of studies in Victoria, combining aspects of the Rapid Appraisal Method, ANUFLOOD and other relevant flood damage literature. A review by economists Aither on behalf of DELWP has led to the conclusion that ANUFLOOD stage damage curves underestimate flood damages, particularly for shallow above floor depths and for below floor flooding. The stage-damage curves developed by the New South Wales Office of Water have been recommended by Aither and were used for this study. The model results for all mapped flood events were processed to calculate the number and location of properties affected. This included properties with buildings inundated above floor, properties with buildings inundated below floor and properties where the building was not impacted but the grounds of the property were inundated. In addition to the flood affected properties, lengths of flood affected roads for each event were also calculated. Damage to agricultural parcels was also included in the assessment.

6.2 Existing conditions

The 1% AEP flood damage estimate for existing conditions was calculated to be just over $6 million. A total of 307 properties are predicted to be flood affected in a 1% AEP flood event, with 55 of those properties flooded above floor level. The Average Annual Damages (AAD) was determined as part of the flood damage assessment. The AAD is a measure of the average flood damage per year. The AAD for existing conditions for the study area is estimated to be **$512,662**.

The AAD is effectively a measure of the amount of money that must be put aside each year to compensate for the physical impacts of flooding over time. This figure is comparable to a number of other towns in northern Victoria located on major rivers which are impacted by regular flooding. It is of note that the number of properties inundated above floor is reduced due to the protection of levee systems. The external damages make up a significant proportion of the total damage costs which is a result of the large number of rural properties impacted by flooding. External damages are also high as a result of the study area being so large and covering the Ovens River floodplain for 20 km upstream of Wangaratta.

Table 6-1 Flood damage assessment for existing conditions

Parameter	Annual Exceedance Probability					
	20%	10%	5%	2%	1%	0.50%
Residential Buildings Flooded Above Floor	1	2	7	28	53	81
Commercial Buildings Flooded Above Floor	0	0	0	2	2	3
Properties Flooded Below Floor	125	166	188	234	252	308
Total Properties Flooded	**126**	**168**	**195**	**264**	**307**	**392**
Direct Potential External Damage Cost	$861,765	$1,176,667	$1,403,276	$1,770,143	$1,749,068	$2,286,038
Direct Potential Residential Damage Cost	$64,373	$138,177	$449,038	$1,738,582	$3,414,331	$5,355,059
Direct Potential Commercial Damage Cost	$0	$0	$0	$117,618	$130,360	$144,240
Total Direct Potential Damage Cost	**$926,138**	**$1,314,844**	**$1,852,314**	**$3,626,343**	**$5,293,759**	**$7,785,337**
Total Actual Damage Cost *(0.8*Potential)*	**$740,910**	**$1,051,875**	**$1,481,851**	**$2,901,074**	**$4,235,007**	**$6,228,270**
Infrastructure Damage Cost	**$889,196**	**$1,108,946**	**$1,269,490**	**$1,658,685**	**$1,946,432**	**$2,365,882**
Total Cost	**$1,630,106**	**$2,160,821**	**$2,751,342**	**$4,559,759**	**$6,181,440**	**$8,594,152**
Average Annual Damage	**$512,662**					

* Figures do not include rural parcels where dwellings are not impacted by above or below flood flooding. These have been costed as rural damages but property numbers are not reported in this table.
** The NSW Office of Water stage damage curves incorporate indirect costs into direct potential costs so they are not listed separately.

7. AERODROME PRECINT DEVELOPMENT MODELLING

7.1 Overview

Modelling of proposed development at the Wangaratta Aerodrome was completed within the scope of the flood investigation. The aerodrome precinct is understood to be an area being considered for future commercial and industrial development and as such an assessment of the development from a flood risk perspective was required.

Three proposed development zones were modelled within the 15 Mile Creek system to determine any negative upstream or downstream impacts caused by the proposed development footprint. The three development zones assessed are referred to as;

- Aerodrome Zone A
- Aerodrome Zone B
- Aerodrome Zone C

Modelling of Aerodrome Zone A included the annexing of this area from the floodplain as included within the planned zones. This was represented by filling the development area above the 1% AEP flood level with freeboard.

The layout of the three zones are shown in Figure 7-1 from mapping provided with the tender brief.

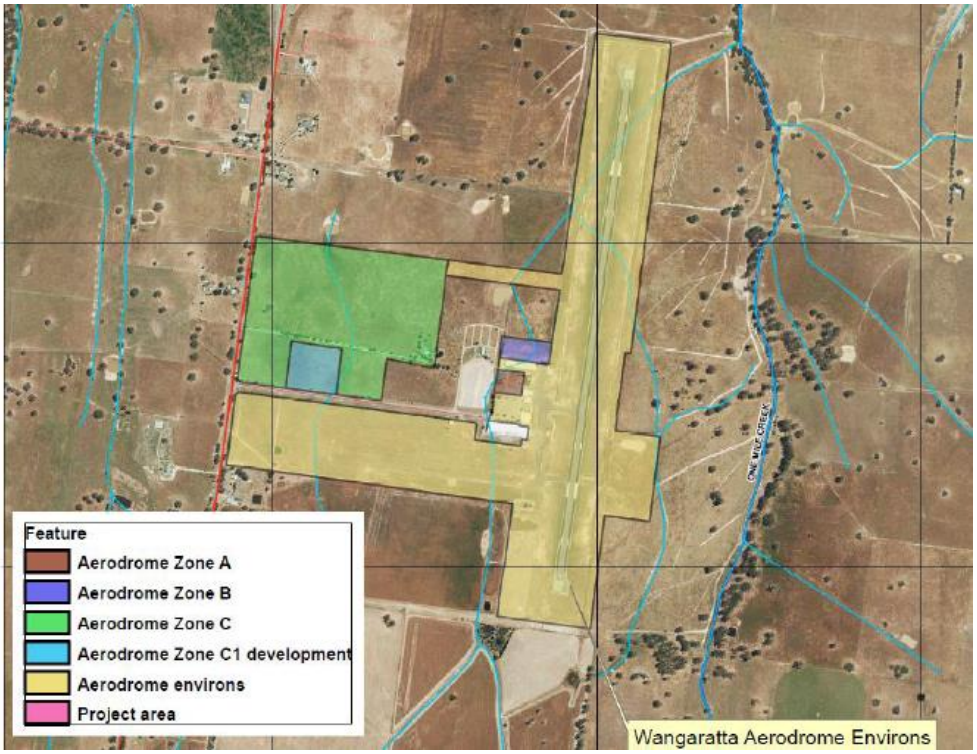

Figure 7-1 Wangaratta Aerodrome Environs – Development Zones

7.2 Aerodrome Modelling Results

Aerodrome Zone A Results

Modelling of the Aerodrome Zone A scenario involved complete blockage of the Zone A footprint representing the site being filled above the 1% AEP design flood level. Only the 1% AEP design flood event was considered for this analysis.

As shown in Figure 7-2, there is very little change to the 1% AEP design flood extent in the Zone A development scenario. A small increase in the extent can be observed, resulting in one area, shown in blue, becoming wet. This a result of very minor increases in peak flood levels to the south of the development zone, of less than 10 mm. There are no significant upstream or downstream impacts predicted with this development scenario.

The modelling has determined that Zone A would have minimal impact from a flood risk perspective and there would be no need for mitigation measures to be included with this level of development.

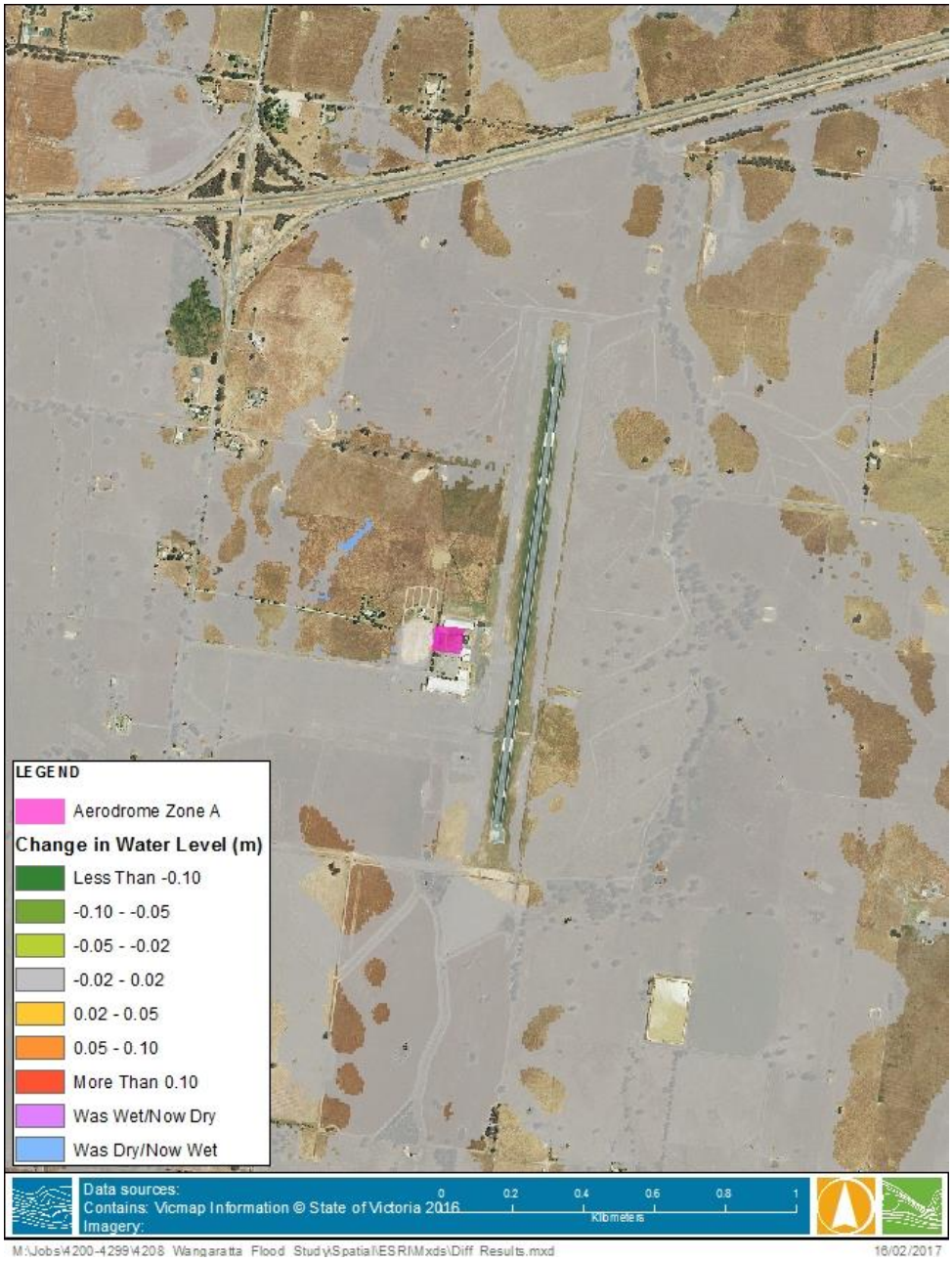

Figure 7-2 Change in water level due to development at Zone A

Aerodrome Zone B Results

Modelling of the Aerodrome Zone B scenario involved complete blockage of the Zone B footprint representing the site being filled above the 1% AEP design flood level. Only the 1% AEP design flood event was considered for this analysis.

The results are shown in Figure 7-3 and it can be seen that there is no change to the 1% AEP flood extent or water level due to the development. The location of the Zone B development does not cause any upstream or downstream flood impacts.

The modelling has determined that Zone B would have minimal impact from a flood risk perspective and there would be no need for mitigation measures to be included with this development area.

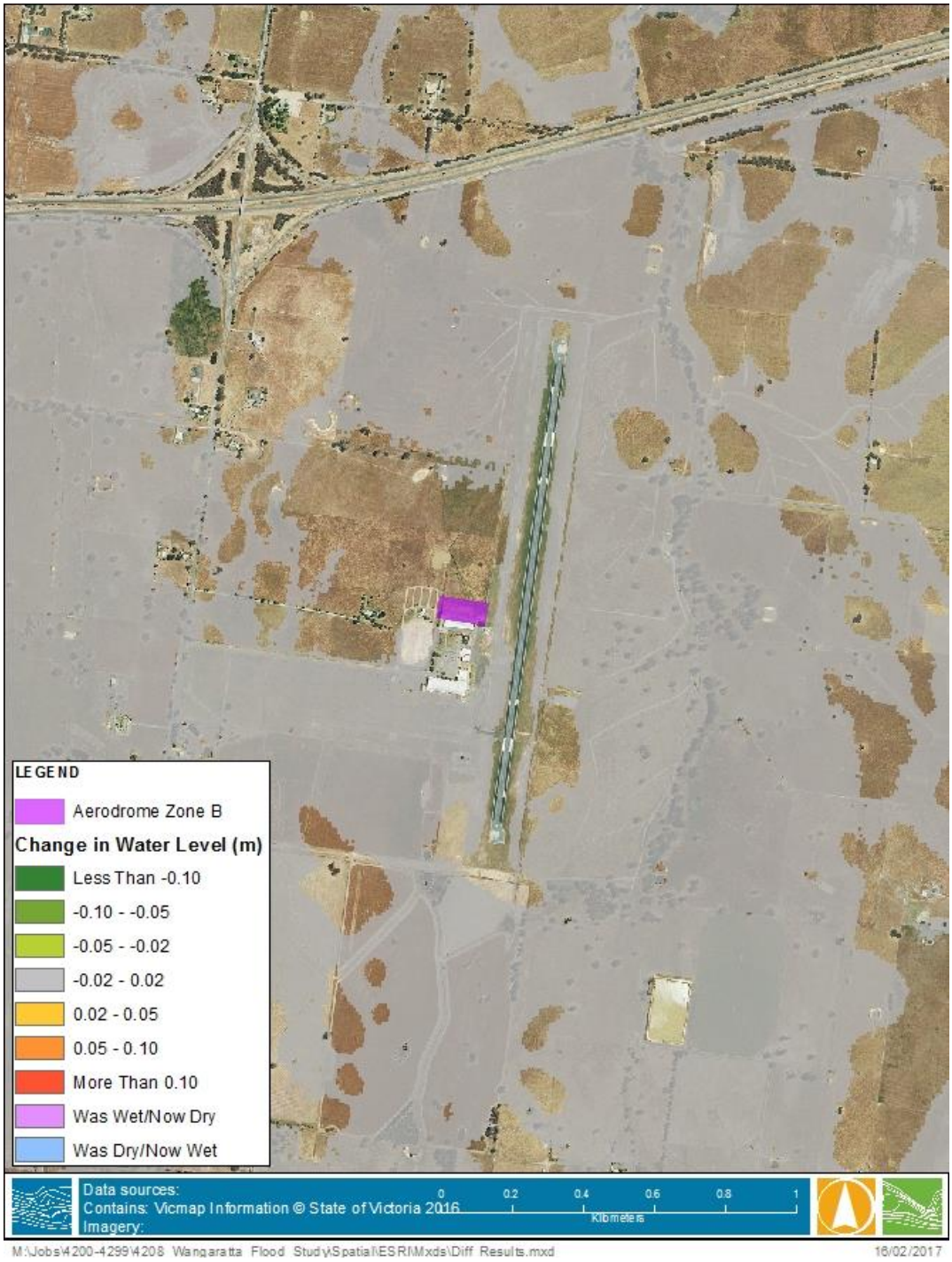

Figure 7-3 Change in water level due to development at Zone B

Aerodrome Zone C

Modelling of the Aerodrome Zone C scenario involved complete blockage of the Zone C footprint representing the site being filled above the 1% AEP design flood level. Only the 1% AEP design flood event was considered for this analysis.

The results are shown in Figure 7-4 and, similar to the Zone A and Zone B analyses, there is very little change to the predicted 1% AEP design flood extent. A slight decrease occurs to the north of the development as the building area blocks a minor flow path. A small pocket to the east of the development (between the development area and the existing airport precinct) experiences an increase in water levels of up to 130 mm and an increase in the flood extent. These changes do not impact the roadways or any existing buildings at the site and are isolated to undeveloped, grassed land. There are no further upstream or downstream impacts associated with this scenario.

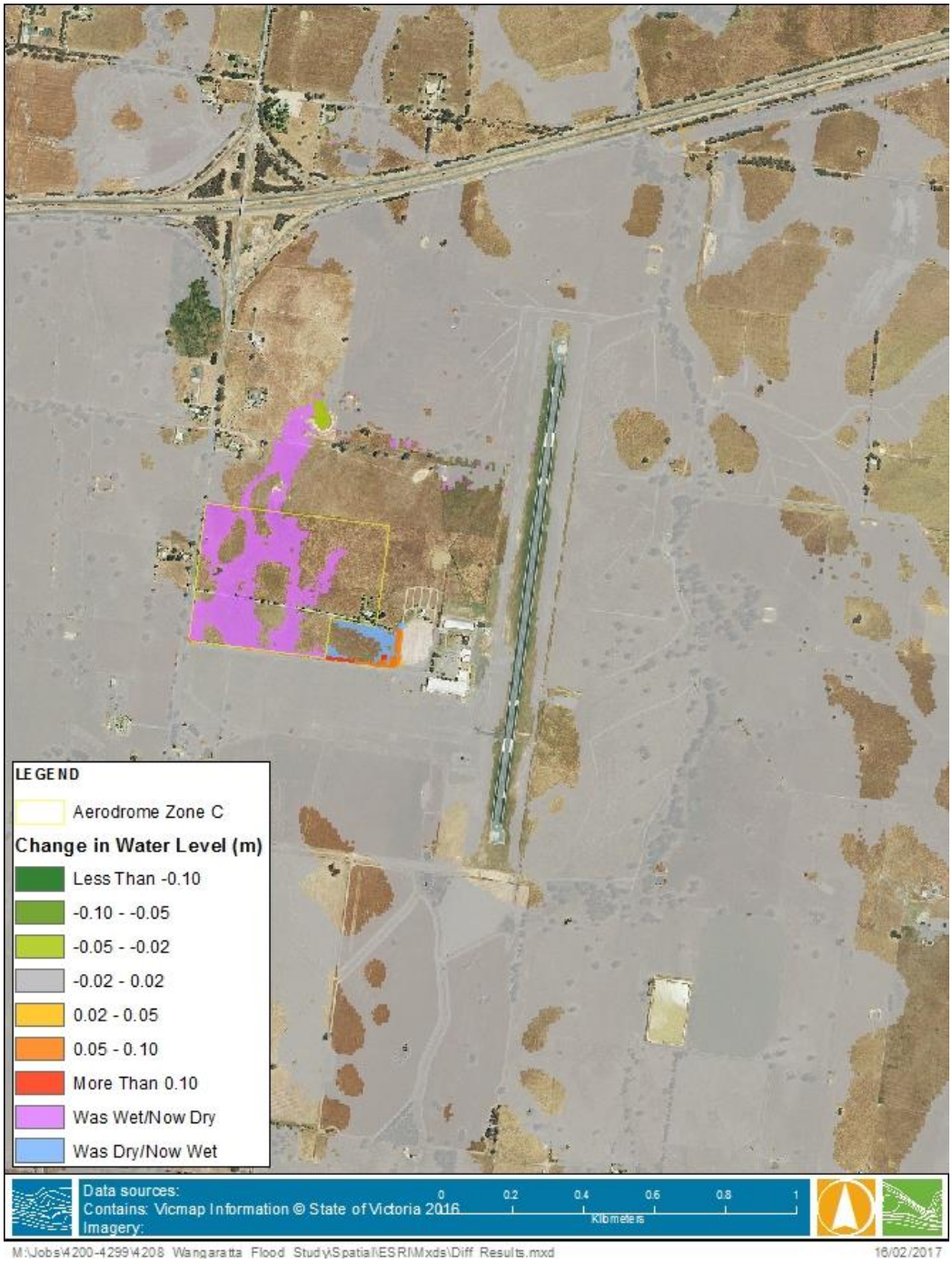

Figure 7-4 Change in water level due to development at Zone C

The modelling has determined that full development of Zone C would have minimal impact, from a flood risk perspective, and there would be no need for mitigation measures to be included with this development area. Some minor works could be included to mitigate the small pocket of increased water levels immediately to the east of the Zone C footprint. This would likely involve an open drain along the eastern boundary of the development to direct water to the north.

Aerodrome Development Zones - Modelling Summary

The result of the three modelled development scenarios show that full development of all three of the proposed development zones would be expected to have minimal impact on flood levels in and around the Aerodrome. There are very minor localised increases due to a small displacement of water and blockage of a minor flow path. No significant adverse impacts occur upstream or downstream of the proposed development zones.

8. SCENARIO MODELLING

8.1 Overview

The major focus of the investigation was improved flood intelligence for Wangaratta however a number of scenarios were also modelled which aimed to understand the potential improvements in flood risk that could be achieved around the Wangaratta. The scenarios examined both existing and proposed conditions or mitigation features.

Options investigated through hydraulic modelling are listed below:

- Scenario A: Impact of in-channel vegetation reduction
- Scenario B: Fishers Levee breach
- Scenario C: Fishers Levee removal/degradation
- Scenario D: Painters Island Mitigation Options
- Scenario E: Increase Roughness of One Mile Creek Floodways

8.2 Scenario Description and Results

Scenario A – Impact of In-channel vegetation and snag reduction

This scenario examined whether the removal or thinning of in-channel vegetation can reduce flood risk through Wangaratta and the surrounding floodplains.

Scenario A represents the impacts of in-stream vegetation removal/reduction through One and Fifteen Mile Creeks and the Ovens River downstream of the Hume Freeway during a 1% AEP design flood. To represent these modified conditions, the Manning's 'n' within the stream/river channel was reduced by 25%. This is a significant reduction in hydraulic roughness and sits at the upper end of changes that would be expected of vegetation reduction that could realistically be achieved through on ground works and maintenance.

The results show that the reduction of in-channel vegetation along the key waterways has resulted in a decrease in water levels in a number of pockets through the Ovens River and Fifteen Mile creek floodplain downstream of the Hume Freeway, as shown in Figure 8-1**.** The reduction in flood level is generally minor and less than 50 mm.

A similar decrease in water levels occurs along Fifteen Mile Creek, One Mile Creek and Three Mile Creek with some pockets of larger reductions in levels. There is a significant decrease in levels occurring along Fifteen Mile Creek in the vicinity of the railway line, upstream of Shanley Street. Levels have reduced by up to 150 mm through this area. There is also a significant reduction along One Mile Creek between Cribbes Road and Clarke Lane. Changes in peak flood levels along these three watercourses are shown in Figure 8-3**.** The reduction in levels has not made a significant change to overall flood risk with the differences generally minor, and there being little 1% AEP above floor flooding where the larger reductions in levels are noted.

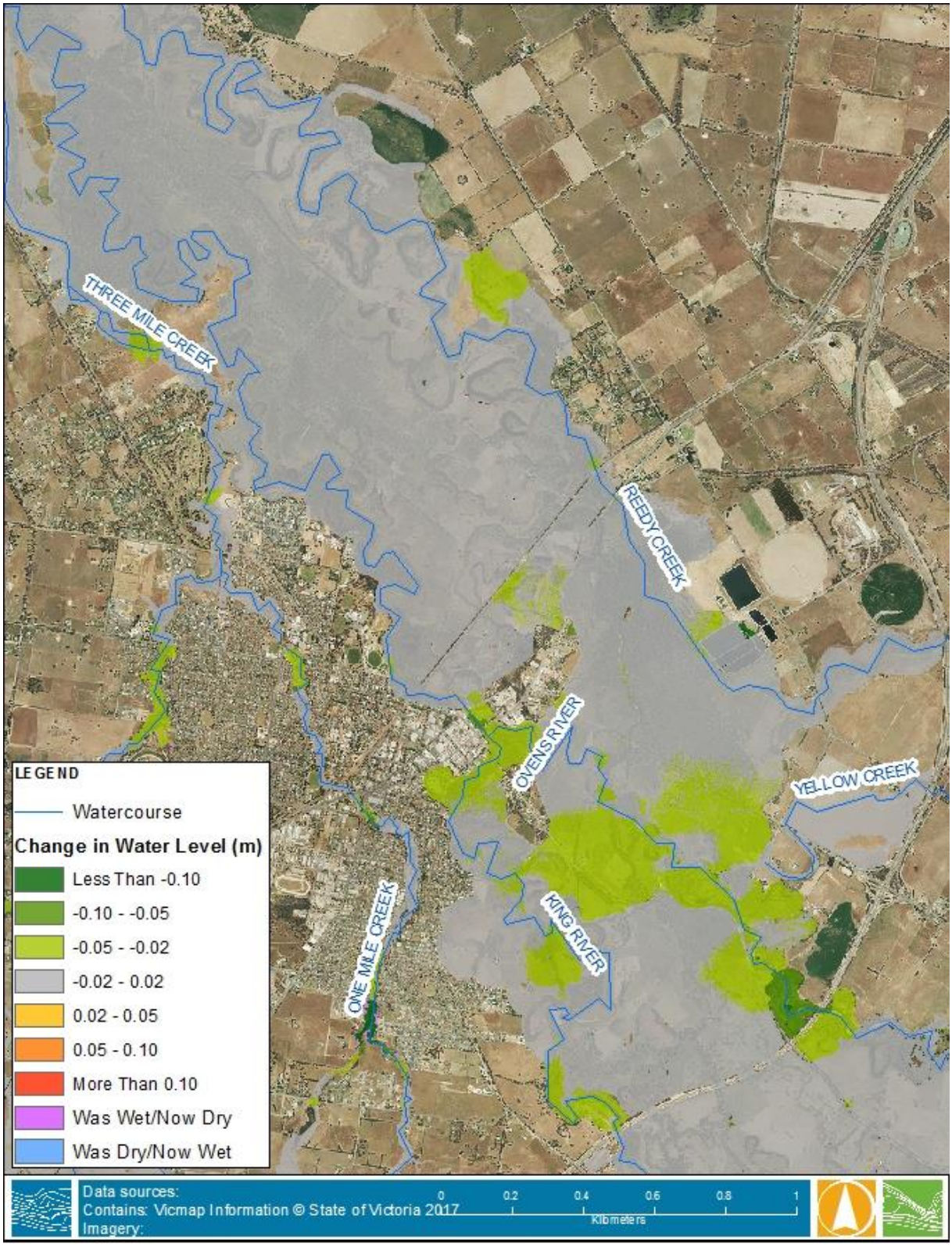

Figure 8-1 Change in 1% AEP water levels downstream of the Hume Freeway due to instream vegetation/debris reduction

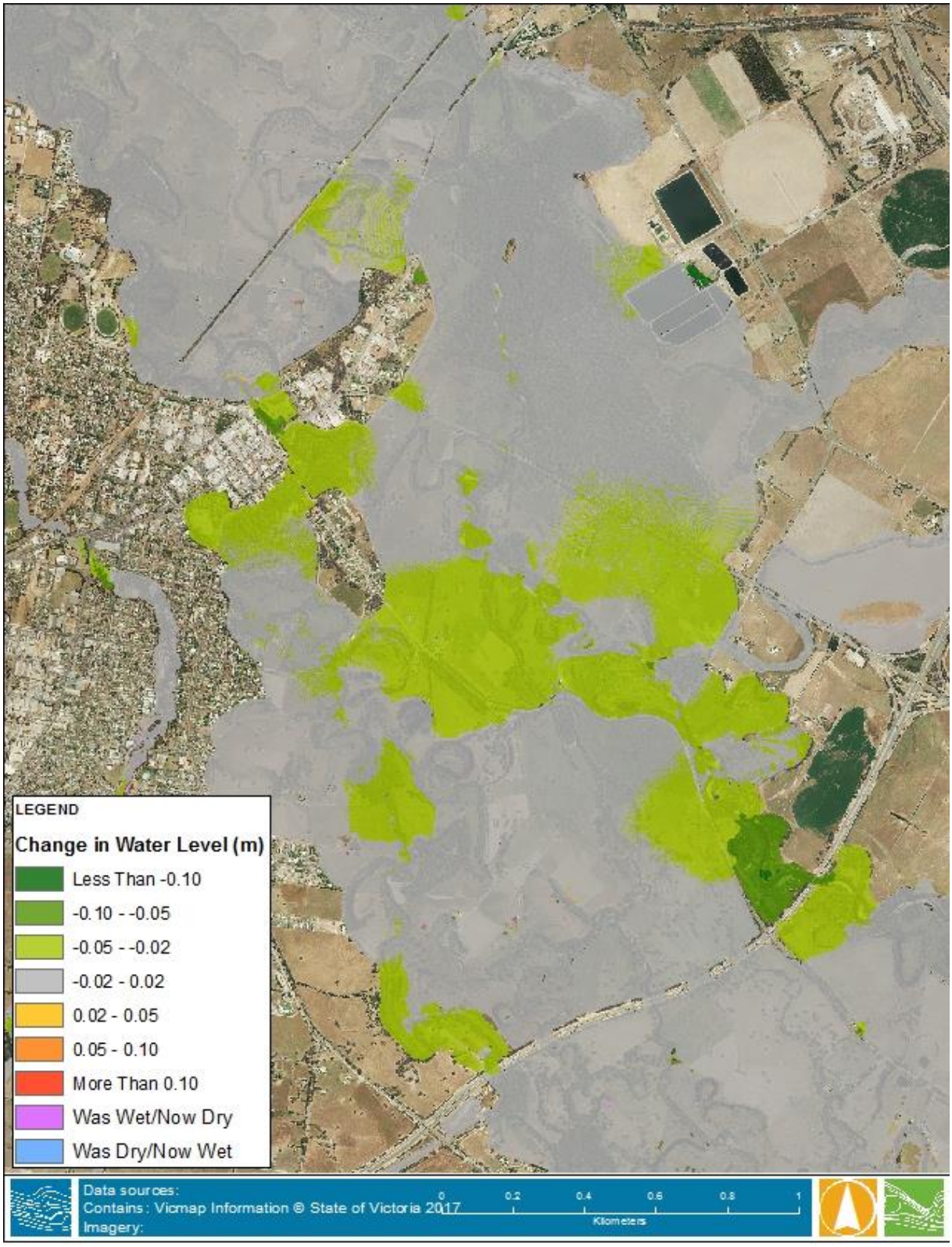

Figure 8-2 **Changes in 1% AEP water levels along the Ovens River, King River and Reedy Creek due to in-stream vegetation/debris**

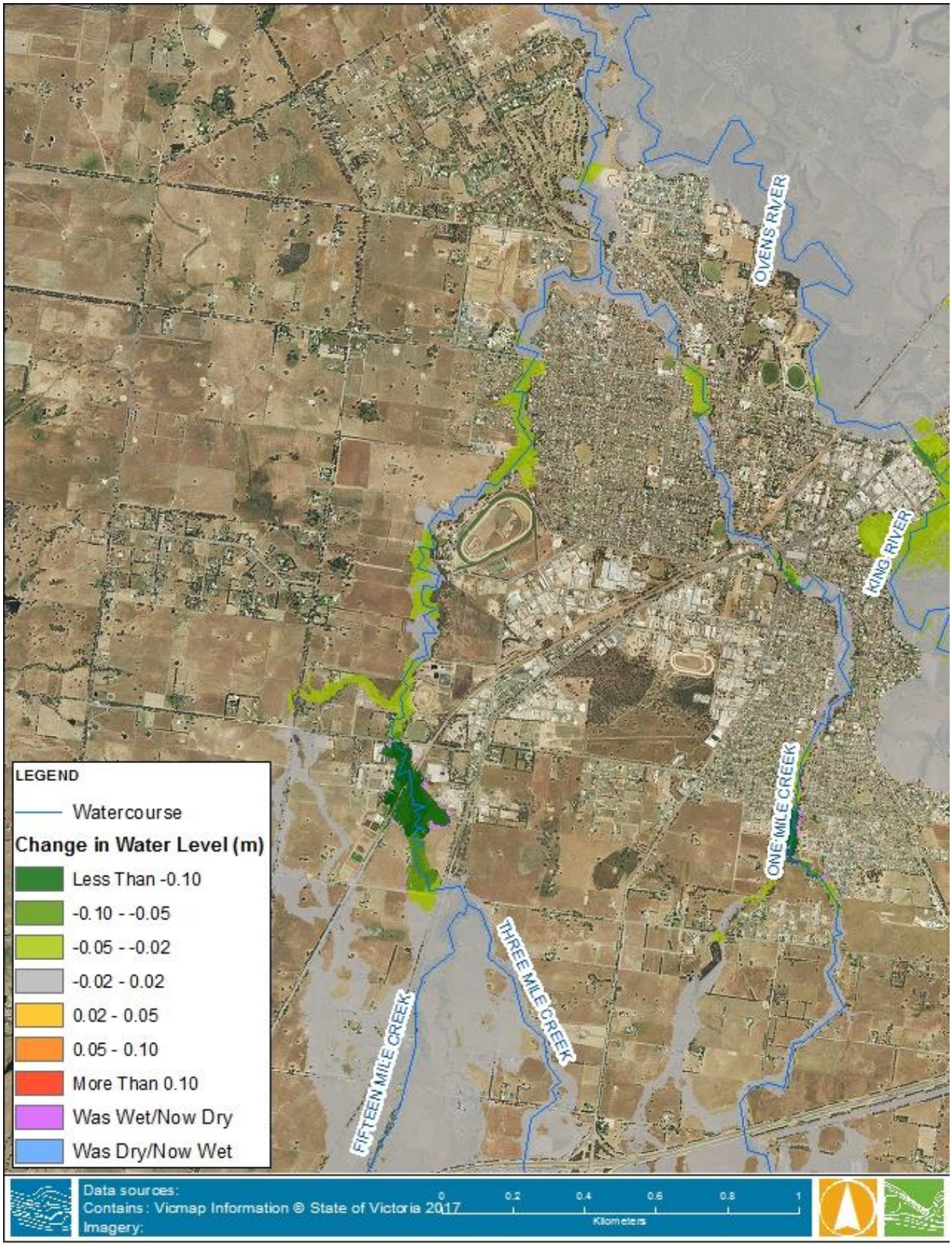

Figure 8-3 **Change in 1% AEP water levels along 15 Mile, 3 Mile and 1 Mile Creeks due to in-stream vegetation/debris reduction**

Scenario A Summary

The results of Scenario A show that a substantial reduction of in-stream roughness, representing removal or thinning of vegetation and debris, would have a minor impact on peak 1% AEP flood levels with some localised pockets of larger reductions. The results indicate that the removal or thinning of vegetation and debris would have a minimal impact on flood risk and flood damages through Wangaratta and surrounds. Vegetation removal of this scale and ongoing management would incur substantial cost and unlikely to be cost-effective.

Scenario B – Fishers Levee Breach

Fishers levee, located to the east of Wangaratta on the Ovens river floodplain and shown in Figure 8-4 is understood to have been originally constructed to provide protection to agricultural land behind the levee. In its current condition, the levee does not prevent flooding during a 20% AEP flood event, with flood water outflanking the levee in that event and also overtopping the levee in some low sections. The potential benefit of maintaining the levee was assessed through two modelling scenarios:

- A 25 metre breach in the levee (Scenario B); and
- A complete removal of the levee which represents the levee not being maintained and degrading over the long-term (Scenario C).

Modelling of the levee with a breach was undertaken to determine potential impacts if the levee is not maintained and failed during a 1% AEP event. The modelled breach, shown in Figure 8-4, is 25 m wide and is located on the east end of the levee in an existing low point. The breach was modelled under 1% AEP flood event conditions.

During a 1% AEP flood event, water levels increased downstream of the breach, with increased levels extending for approximately 600 metres to the north. A slight increase in water level of approximately 50 mm was observed in the north-east corner of one of the North East Water's wastewater ponds. This is an important finding and the future impacts of such a breach or general levee degradation over time should be considered by North East Water due to the potential impacts on their infrastructure.

The modelling results show that the breach resulted in a significant decrease in water levels between the Ovens River and Oxley Flats Road, extending for 1 km upstream and approximately 1.5 km downstream, as shown in Figure 8-5. The reductions in water level are generally in the range of 20 to 100 mm with the larger reduction occurring upstream of the breach. All observed changes to water levels were localised to this area with no significant impacts occurring downstream within central Wangaratta or further downstream along Reedy Creek.

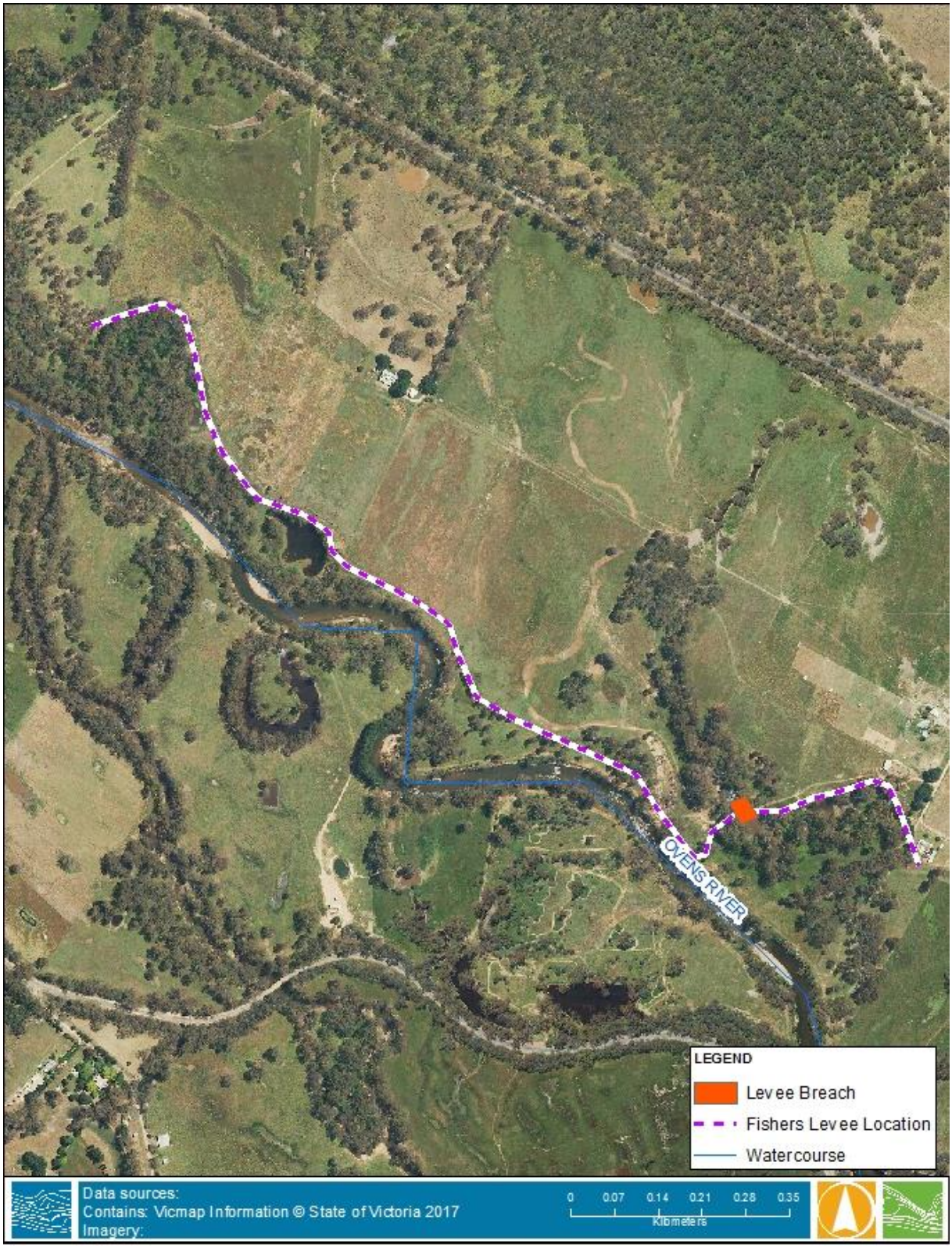

Figure 8-4 Fishers Levee alignment and modelled breach location

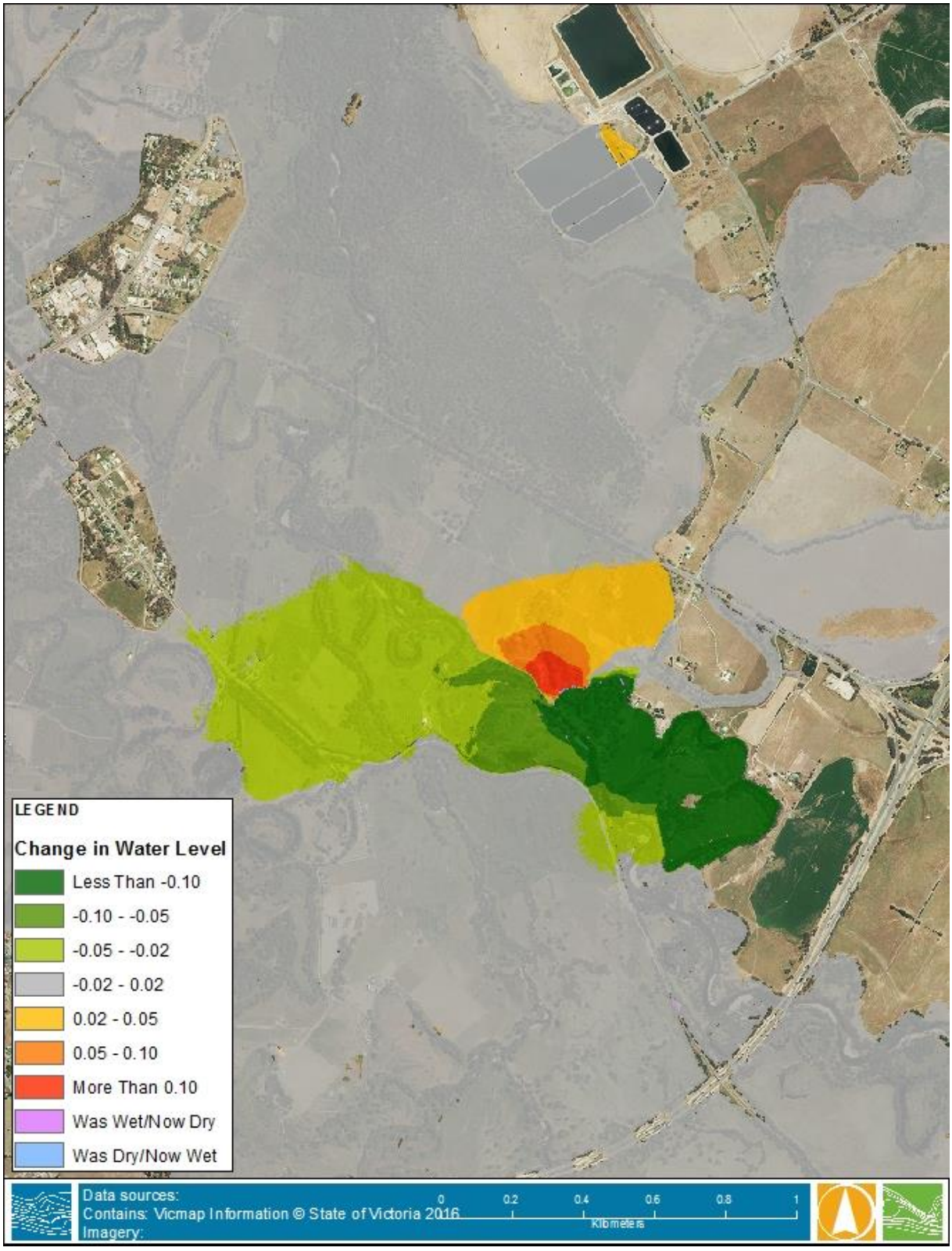

Figure 8-5 Change in 1% AEP water levels due to Fishers Levee breach

Scenario B Summary

The results of Scenario B show that the modelled 25 m breach in Fisher's Levee has had a significant impact on flood levels in the vicinity of the levee. There are localised increases to the north extending for approximately 600 metres and also impacting one of the North East Water treatment ponds. Additionally, the breach led to decreased water levels along the Ovens River between the Hume Freeway and the Wilson Road Levee along a 2.5 km reach.

Scenario C – Fishers Levee Removal

Scenario C examined the impact of complete removal of Fishers levee on the surrounding floodplain. This scenario represents the potential long-term degradation of the levee if it wasn't maintained. Modelling was undertaken for the 1% AEP flood event only with the topography at the Fishers levee location smoothed to match the surrounding natural surface levels.

The modelling results show localised increases to water levels across the agricultural land to the north of the levee, extending for approximately 2.5 km to the north to the North East Water treatment ponds. At the treatment ponds, water levels are approximately 80 mm higher than existing conditions in the north-east pond. This is a significant finding which North East water should consider in future planning.

A significant decrease in the flood extent and water levels occurs to the south of the levee alignment, as shown in Figure 8-6. These decreases extend along the Ovens River and the King River to their confluence in Wangaratta, a distance of approximately 1.5 km.

In general, the impacts from the removal of Fishers Levee remain fairly localised, affecting the riparian corridor and agricultural areas but not further downstream in central Wangaratta. One house at 194 Great Alpine Road is impacted by the increased water levels with increases of 60 mm however the property is not flooded above floor, and is noted to remain flood-free even in the 0.5% AEP event under existing conditions.

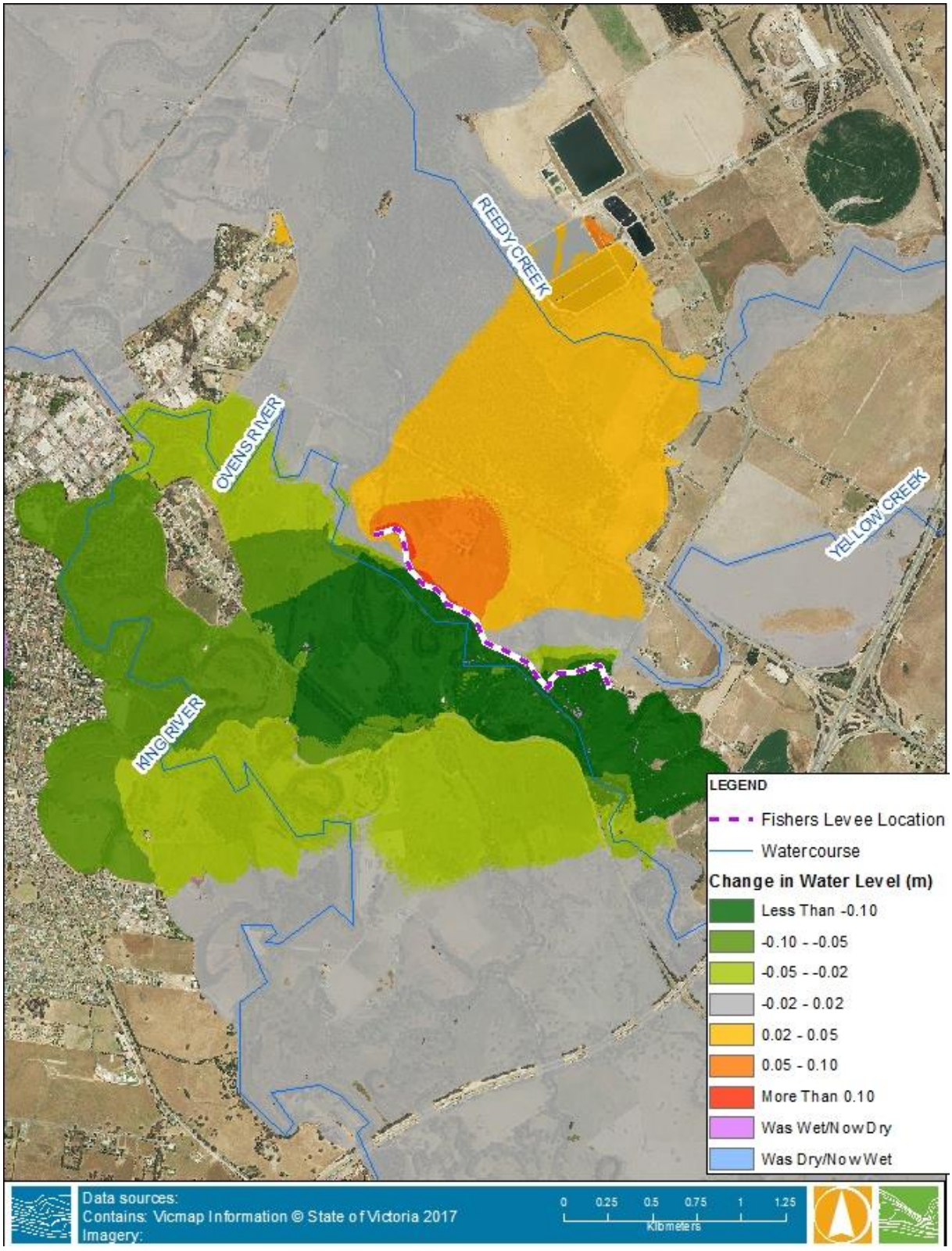

Figure 8-6 Change in 1% AEP water levels due to Fishers Levee Removal

Scenario C Summary

The results of Scenario C show that removal of Fishers levee increases water levels north of the levee for a distance of 1.5 km, and impacts one of the North East Water treatment ponds. Decreased water levels occur along the river side of the existing levee alignment extending for 1.5 km both upstream and downstream of the levee. Overall it is predicted that, if the levee was to degrade or fail over time through a lack of maintenance, the adverse impacts are fairly localised and don't cause a significant increase in flood risk to Wangaratta.

Scenario D – Painters Island Mitigation Modelling

Scenario D consisted of testing a number of levee arrangements to provide benefit to the Painters Island Caravan Park. The caravan park currently experiences disruptive flooding at minor flood level, which is 0.6 metres lower than the 20% AEP flood at the Ovens at Wangaratta gauge. Several levee arrangement options were modelled to determine what could be achieved for the caravan park whilst limiting impacts to the nearby existing levee system and properties where possible.

Scenario D, Option 1 – Moderate Flood Protection

A levee was designed to provide protection up to the 20% AEP flood event (just above moderate flood level), and so would also provide protection from a minor flood event. The levee height was designed to the 20% AEP flood level based on existing conditions modelling results, with an additional 100 mm included to cater for local increases in water level as a result of the levee being in place. The modelled levee represents an increase in current surface levels of approximately 1 m along Bickerton Street between Pinkerton Crescent and the Ovens River, and an increase of 200-300 mm along the existing levee which runs between the caravan park and the Ovens River.

The Option 1 levee alignment was simulated for both the 20% AEP and 1% AEP events so the impacts of the levee could be understood across the range of flood events. The modelled levee alignment can be seen in Figure 8-7 with the mitigated 20% AEP depths also shown.

The results show that the modelled levee is just overtopped during the 20% AEP event as the presence of the levee causes increased water levels in Apex Park due to the reduction in flood storage and constriction created by the levee. Whilst portions of the caravan park still flood to shallow depths, the levee achieves the purpose of protecting the permanent structures and caravans from a 20% AEP event and up to around Moderate flood level. Note however that the extent of flooding within the levee will depend on the duration of overtopping and hence may be greater than modelled. Upstream impacts in the 20% AEP event are significant with increased water levels of up to 160 mm extending upstream for approximately 2.4 km, with the impacts diminishing further upstream. Water levels increase by up to 60 mm along the Ovens River side of the Parfitt Road and Wilson Road Levee upstream of Parfitt Road bridge. The change in water levels during a 20% AEP event due to the Option 1 levee design are shown in Figure 2-1.

During a 1% AEP event water overtops the levee system and water levels are increased through the caravan park as a result of the raising of Pinkerton Crescent at the rear of the caravan park, which traps water within the caravan park area. The raising of Pinkerton Crescent would not be required if this option was further considered as a review of the results has shown that the levee upgrade along the southern and western boundaries of the park is sufficient to meet the objective of the scheme.

Levels within Apex Park and along the Parfitt Road levee in that area increase with this option, with increases of up to 200 mm predicted through that area. Several residences on the northern side of Pinkerton Crescent are flooded due to the increased flood levels. There is also a significant increase

in water levels along the Ovens river extending for 700 m upstream, including along the Parfitt Road and Wilson Road levees further reducing the available freeboard discussed in Section 5.4. Water levels decrease over the floodplain to the north of the levee, upstream of the railway line. The change in water levels during a 1% AEP event due to the Option 1 levee design are shown in Figure 8-8.

Overall the results show that Moderate flood protection can be achieved for the caravan park, however there are significant adverse impacts in both the 20% and 1% AEP flood events. The increase in upstream water levels reduces the available freeboard of the existing levee system, which is already inadequate in some areas. If such works were to be further considered, they would need to be combined with levee upgrades of the Parfitt and Wilson Road levees to ensure appropriate freeboard was maintained.

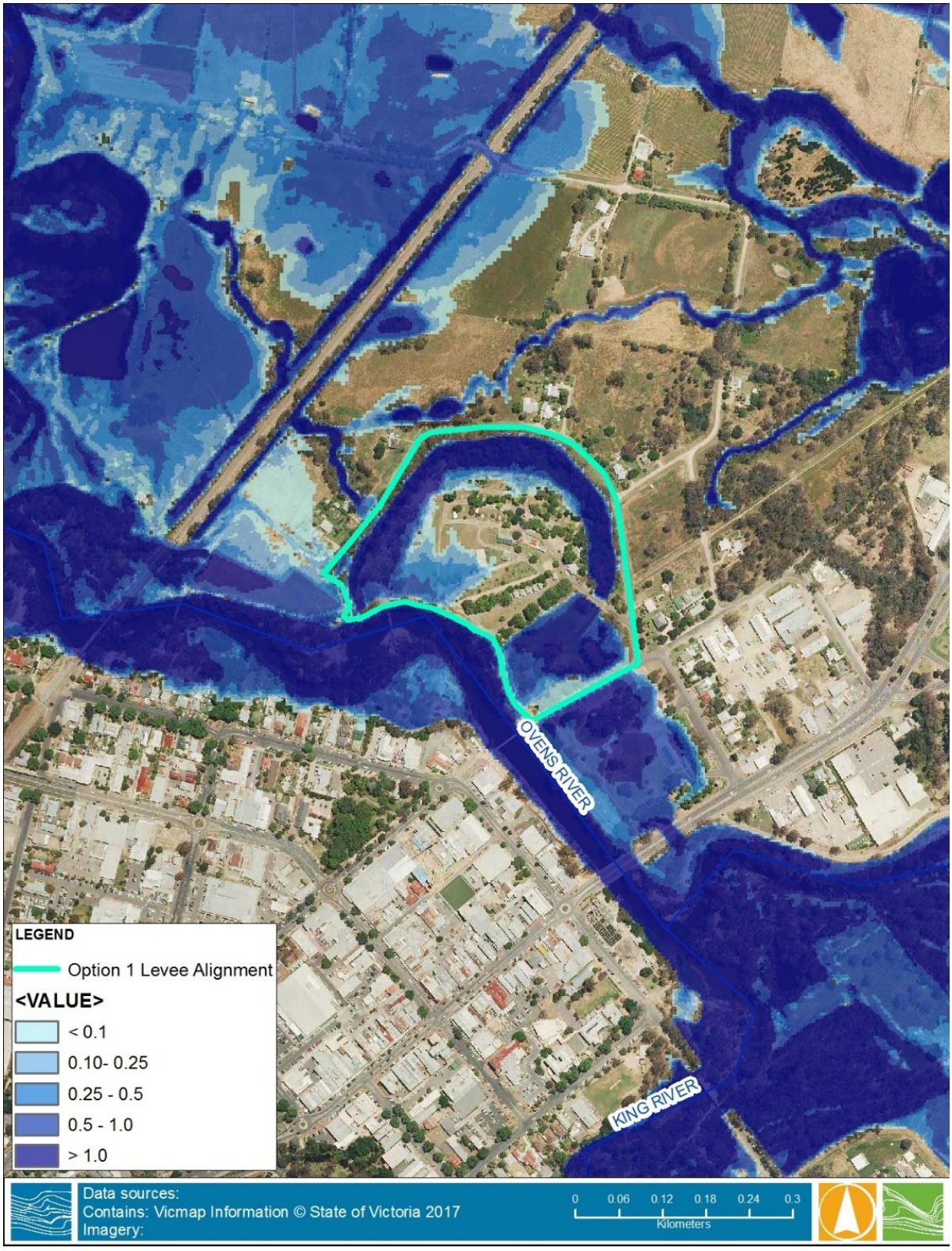

Figure 8-7 Scenario D Option 1 levee alignment with mitigated 20% AEP depths

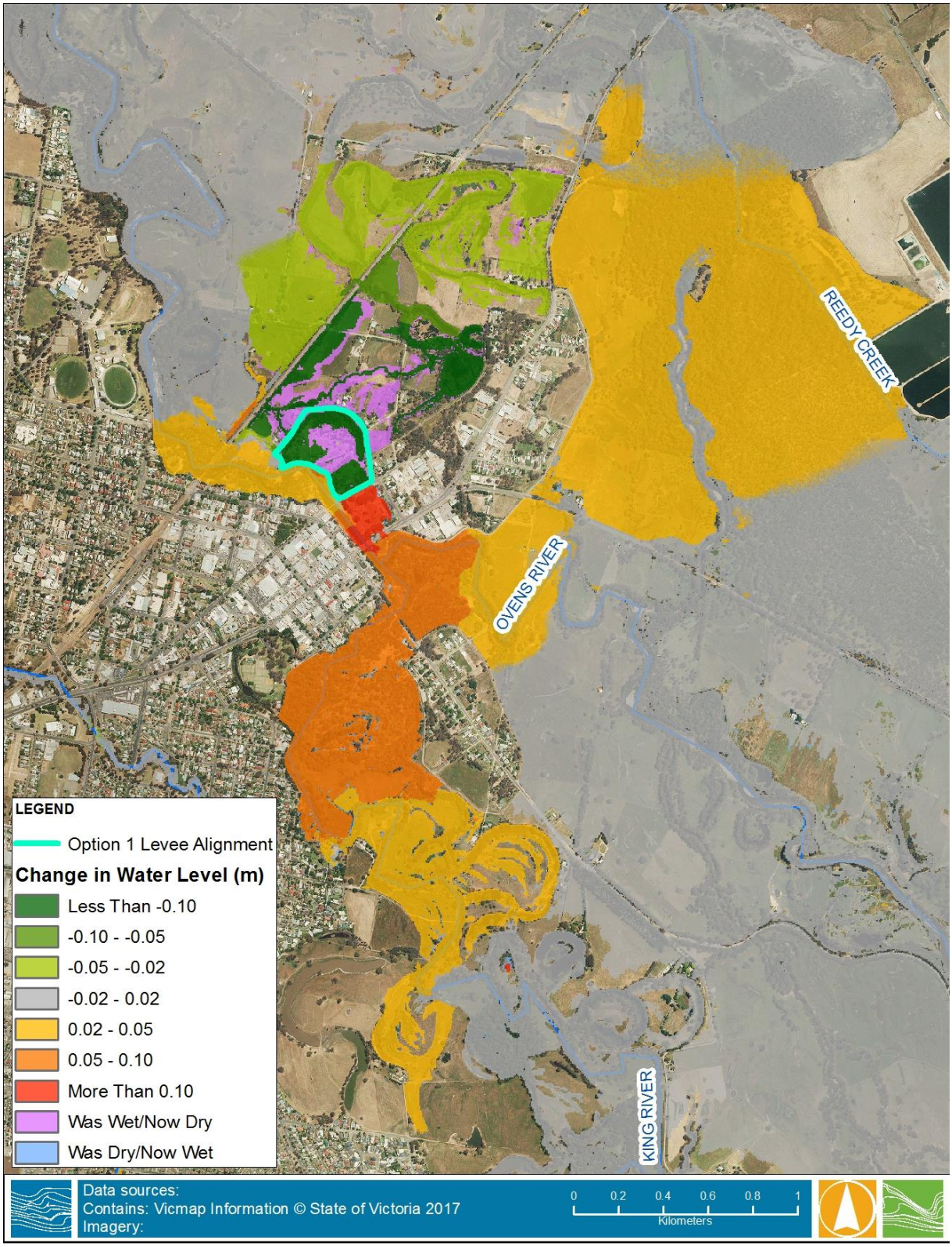

Figure 8-8 Change in 20% AEP water Level due to Option 1 Levee

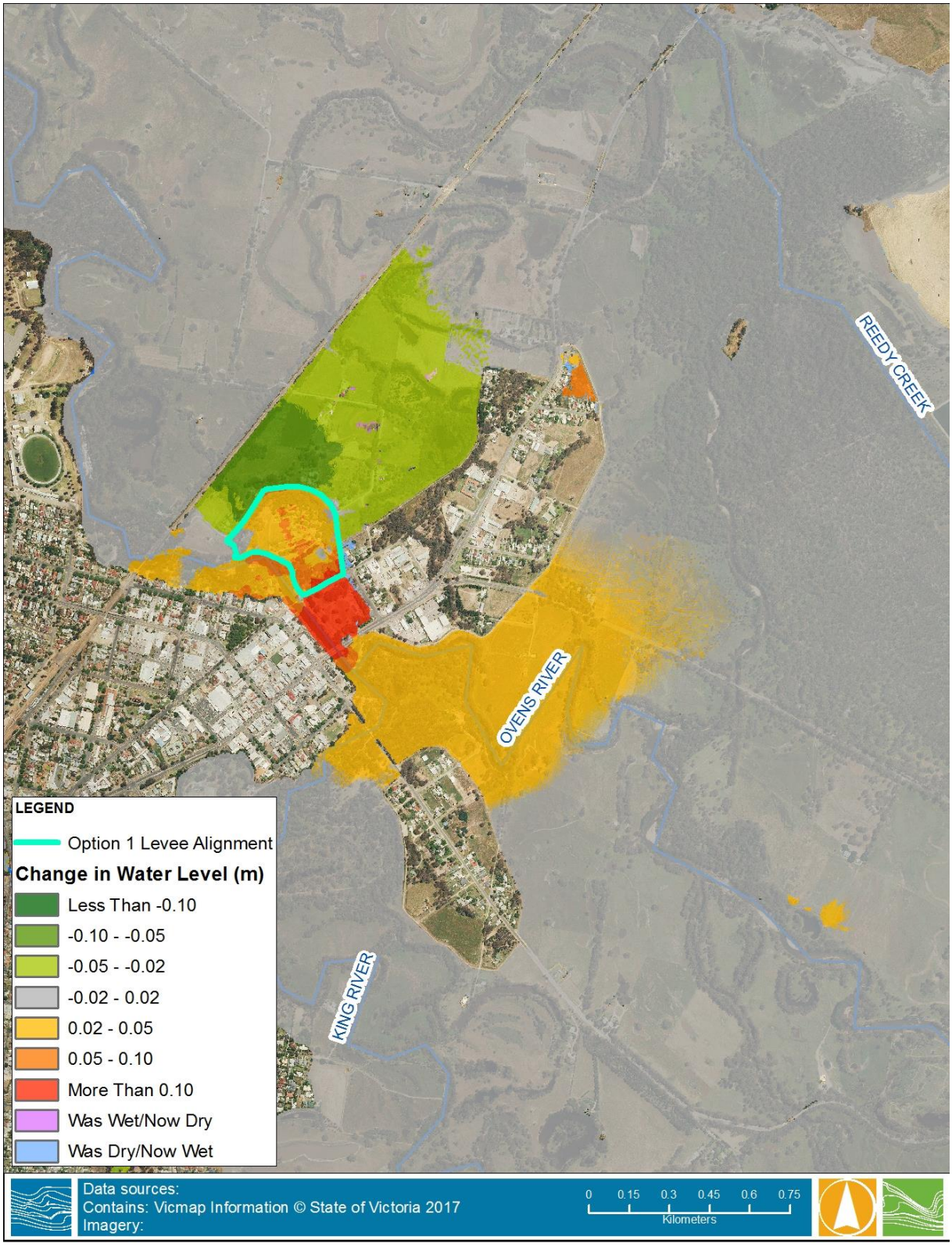

Figure 8-9 Difference in 1% AEP water levels due to Option 1 levee

Scenario D, Option 2 – Alternative Moderate Flood Protection

An alternative levee alignment was considered which aimed to provide protection up to and including the 20% AEP event with the Option 1 levee extended to the railway line. As with Option 1 the levee was designed to the existing 20% AEP flood levels with an additional 100 mm height. The alignment for Option 2 can be seen in Figure 8-10.

The levee scenario was modelled for both the 20% and 1% AEP floods and compared to the depths modelled under existing conditions to determine the impacts caused by the levee. As with Option 1, during a 20% AEP flood event the levee protects the majority of caravans and permanent structures in the Painters Island Caravan Park. Changes in water level during a 20% AEP flood event due to the Option 2 Levee design are shown in Figure 8-11.

In the 20% AEP event the levee causes increased water levels upstream and downstream of Painters Island. There are significant increases in flood levels in Apex Park of approximately 180-200 mm due to the displaced water and hydraulic constriction. Significant impacts extend for 2.4 km upstream to the Wilson Road Levee with the Parfitt Road Levee also impacted. Adverse impacts extend 800 m downstream along the Ovens River impacting residences on Templeton Street and Gray Street.

During a 1% AEP event there are increases of 200 mm through Apex Park and the floodway that passes under Parfitt Road. As expected the levee design does not protect the caravan park in a 1% AEP flood event and the levee is overtopped. Flood levels decrease within Painters Island Caravan Park by less than 100 mm however flood depths of over 1 m remain around the permanent buildings. The impacts in the 1% are not as great as the 20% AEP event because the levee becomes drowned out and the flood flow is able to continue across the caravan park and over Pinkerton Crescent. Changes in water levels during a 1% AEP flood event due to the Option 2 levee design are shown in Figure 8-12.

Overall this option was found to provide protection to the permanent structures in the caravan park in the 20% AEP event but is associated with adverse impacts in both the 20% and 1% AEP events which would need to be considered if this option is considered further. The option would need to be combined with Parfitt Road levee upgrades to ensure the required freeboard was maintained for that structure.

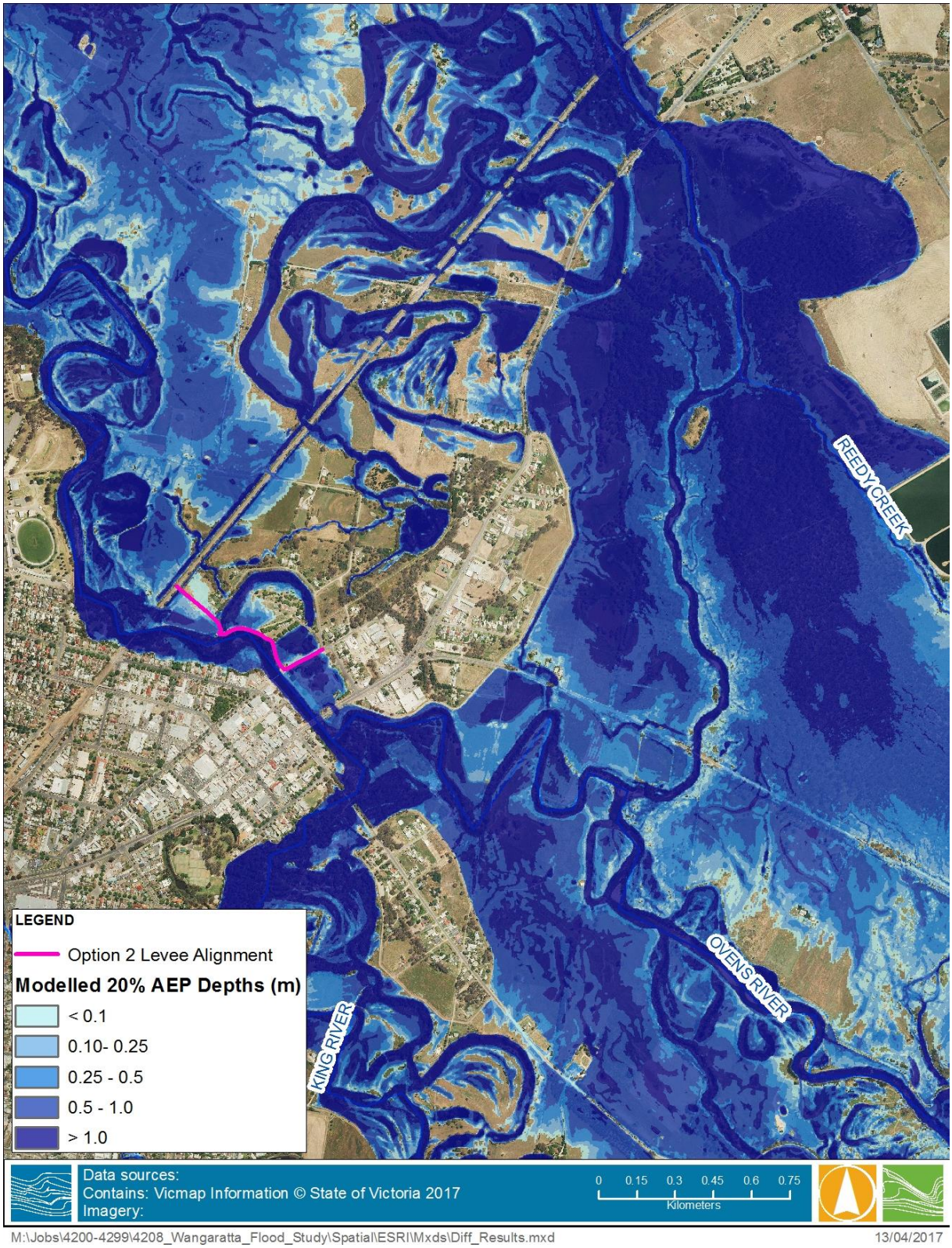

Figure 8-10 Option 2 levee alignment and 20% AEP mitigated flood depths

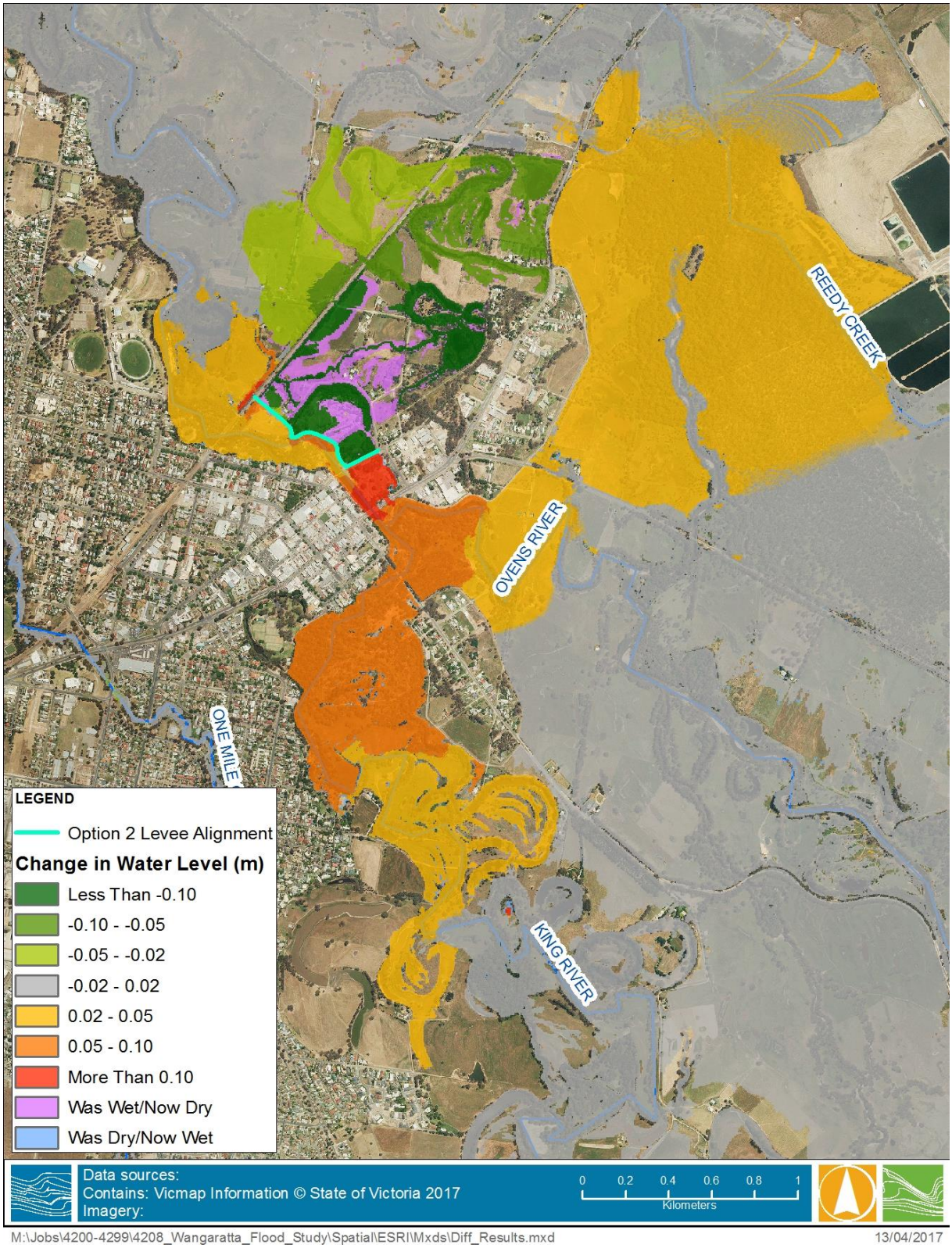

Figure 8-11 Change in 20% AEP water level with Option 2 Levee

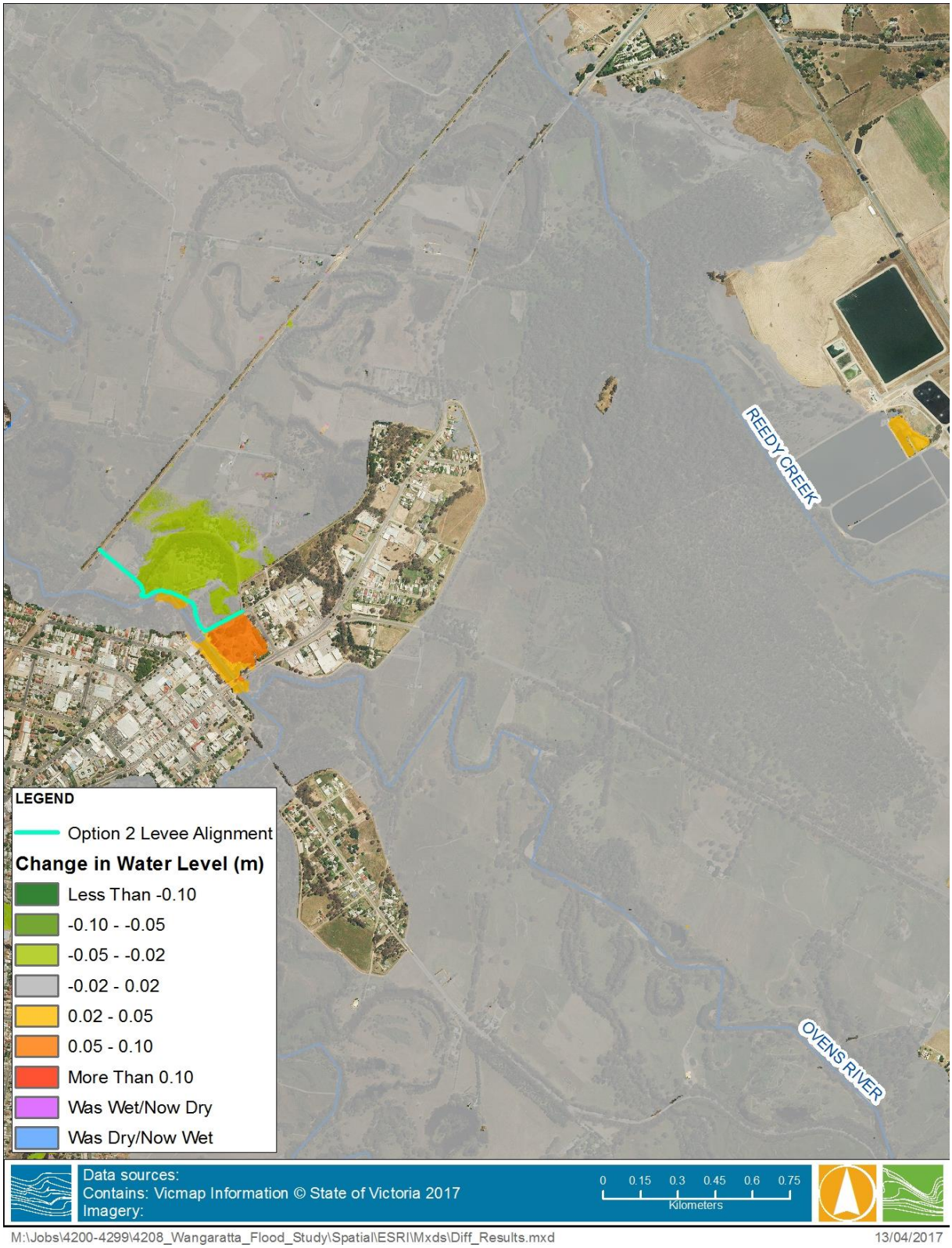

Figure 8-12 Change in 1% AEP water level with Option 2 Levee

Option 3 – 1% AEP Protection

Another option was tested which aimed to provide 1% AEP protection to the caravan park. A ring levee was constructed around Painters Island Caravan Park to a level that exceeds the 1% AEP flood extent, providing full protection to the buildings and permanent structures on site. The levee was located on the inner side of the channel that surrounds Painters Island, shown with the 1% AEP flood event depths in Figure 8-13. The alignment was chosen so as to limit the constriction created by the levee, thus minimising upstream impacts.

Option 3 was modelled for the 1% AEP flood event only and water levels were compared to those modelled under existing conditions. The change in water level due to the levee structures is shown in Figure 8-13.

Water levels increase significantly upstream of the levee through Apex Park, extending upstream to the Wilson Road Levee, and northwards along the Parfitt Road Levee. Water levels are increased by up to 170 mm through these areas. There are also increases on the southern bank of the Ovens River, extending downstream to Baker Street. Several houses along Templeton Street are impacted by these increases.

The increased levels result in the Parfitt Road Levee overtopping at Pinkerton Crescent with flood water flowing around the back of houses on the north side of Ashmore Street, then crossing Parfitt Road and running down Potter Street and the Great Alpine Road. Several residences on the corner of Bickerton Street and Pinkerton Crescent/Clements Street are also impacted, with increases in flood depths on these properties exceeding 0.2 m in some locations.

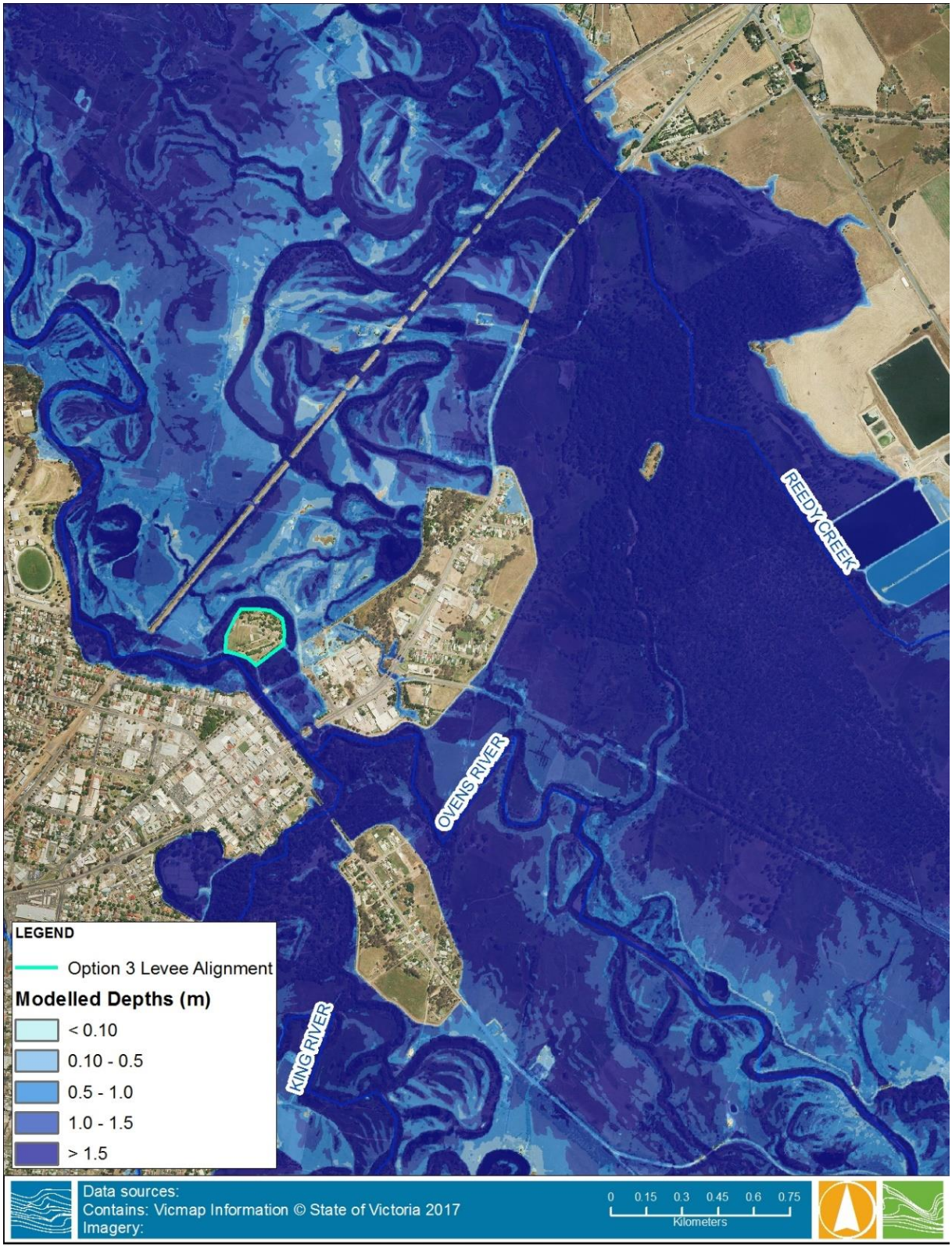

Figure 8-13 Option 3 levee alignment and modelled flood depths during a 1% AEP event

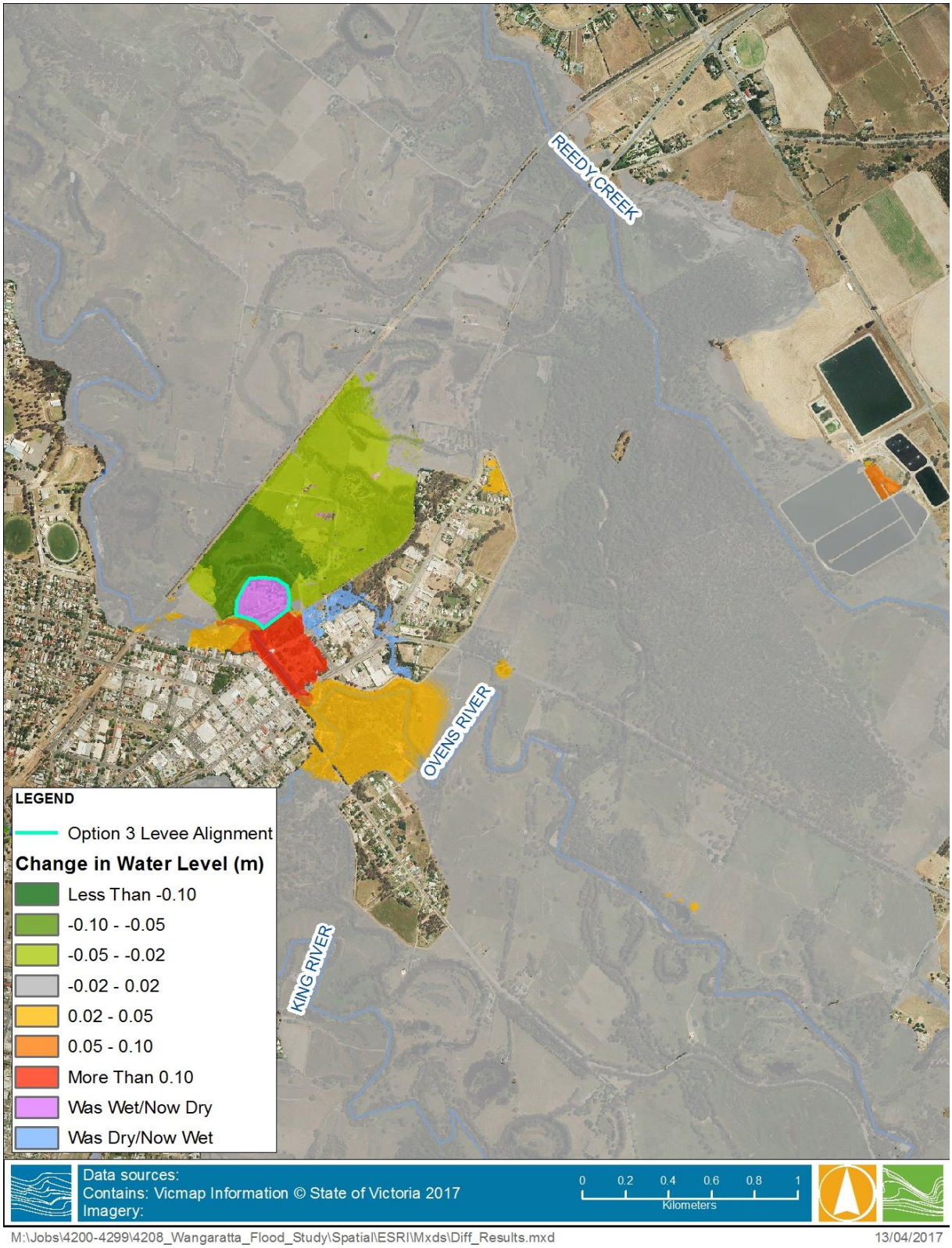

Figure 8-14 Change in 1% AEP water levels for Option 3

Scenario D Summary

A range of scenarios were tested which aimed to provide minor and major flood protection to the Painters Island Caravan Park. All scenarios result in significant adverse impacts upstream of Painters Islands. The results show that minor flood protection could be achieved but would need to be associated with levee upgrades upstream to ensure adequate freeboard is maintained. Flood protection in the 1% AEP event can be achieved however it is associated with very significant adverse impacts upstream and it is highly unlikely the option would be feasible

Scenario E

A number of floodways were constructed along One Mile Creek in the mid 1980s to improve flood risk by providing additional flow conveyance. The Rural City of Wangaratta maintains the One Mile Creek floodways with the maintenance including regular mowing of the floodway grassed areas.

An investigation into the impacts of ceasing the mowing program, resulting in increased vegetation along the floodways, was completed through a 1% AEP modelled scenario. The maintained floodways were identified through the One Mile Creek mitigation work plans developed in 1984 (SRWSC) and cross-checked against site visit data and through discussions with NECMA. The identified floodways are shown in Figure 8-15 below.

To model the increase in vegetation, Manning's "n" roughness values were increased by 20% in the identified floodways. This increase in roughness represents a change from short, mowed grass to longer, unmaintained grass and shrubs. The model was run for the 1% AEP event to understand the impacts of the changes in a large flood event.

The results showed pockets of minor to moderate increased water levels (20-50 mm) generally in the vicinity of key hydraulic controls such as culverts under Tone Road, Phillipson Street and the railway line. Additionally, some small localised increases occurred near the mowed floodways between White Street and Vincent Road.

The results indicate that the works have a greater impact in areas close to a constriction in the waterway. The differences in water level are modest and do not occur in the vicinity of above floor flooding. Subsequently it is considered that ceasing to mow these floodways or mowing them less frequently is unlikely to have a significant impact on flood risk and flood damages through Wangaratta.

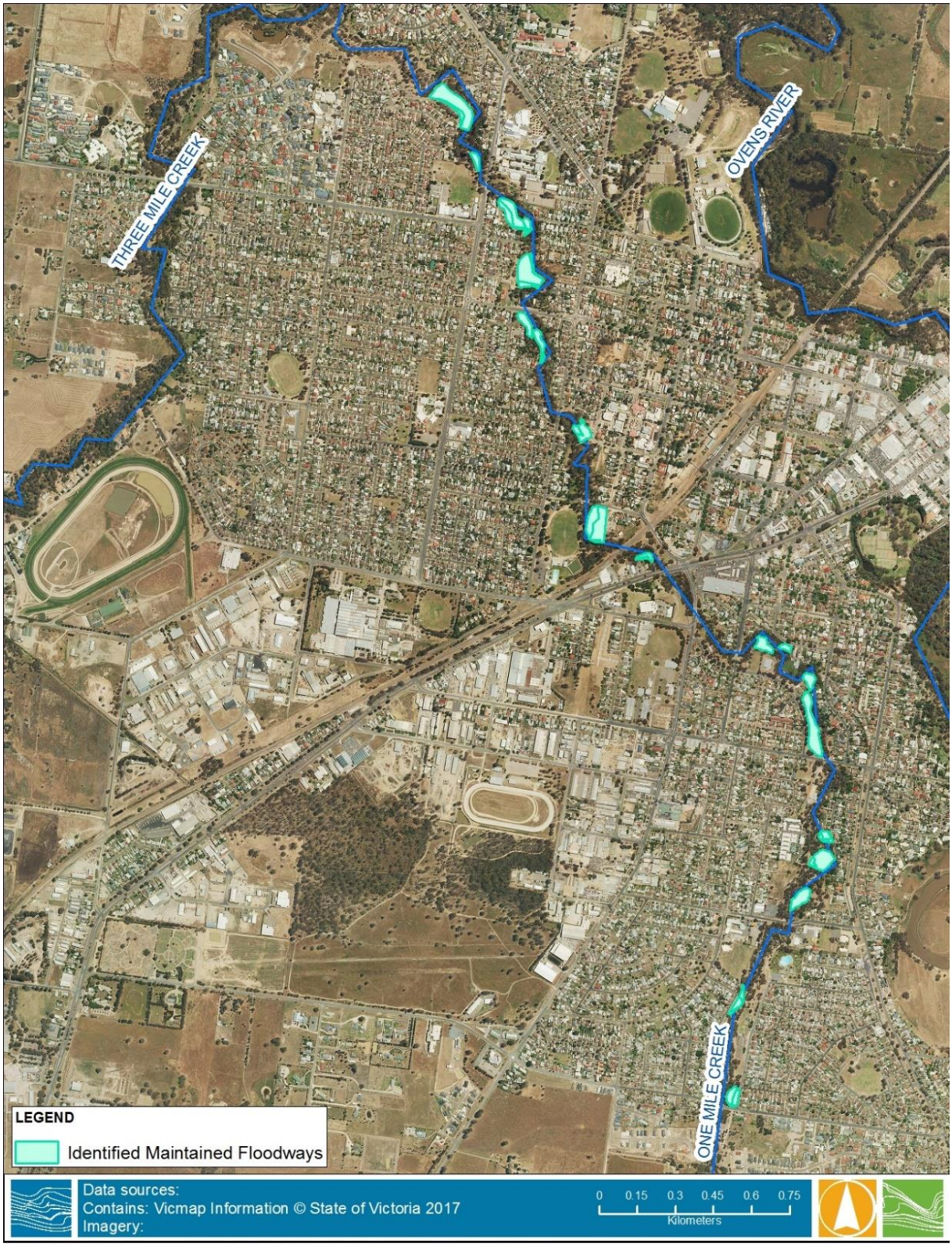

Figure 8-15 Floodways identified as being maintained along One Mile Creek in Wangaratta

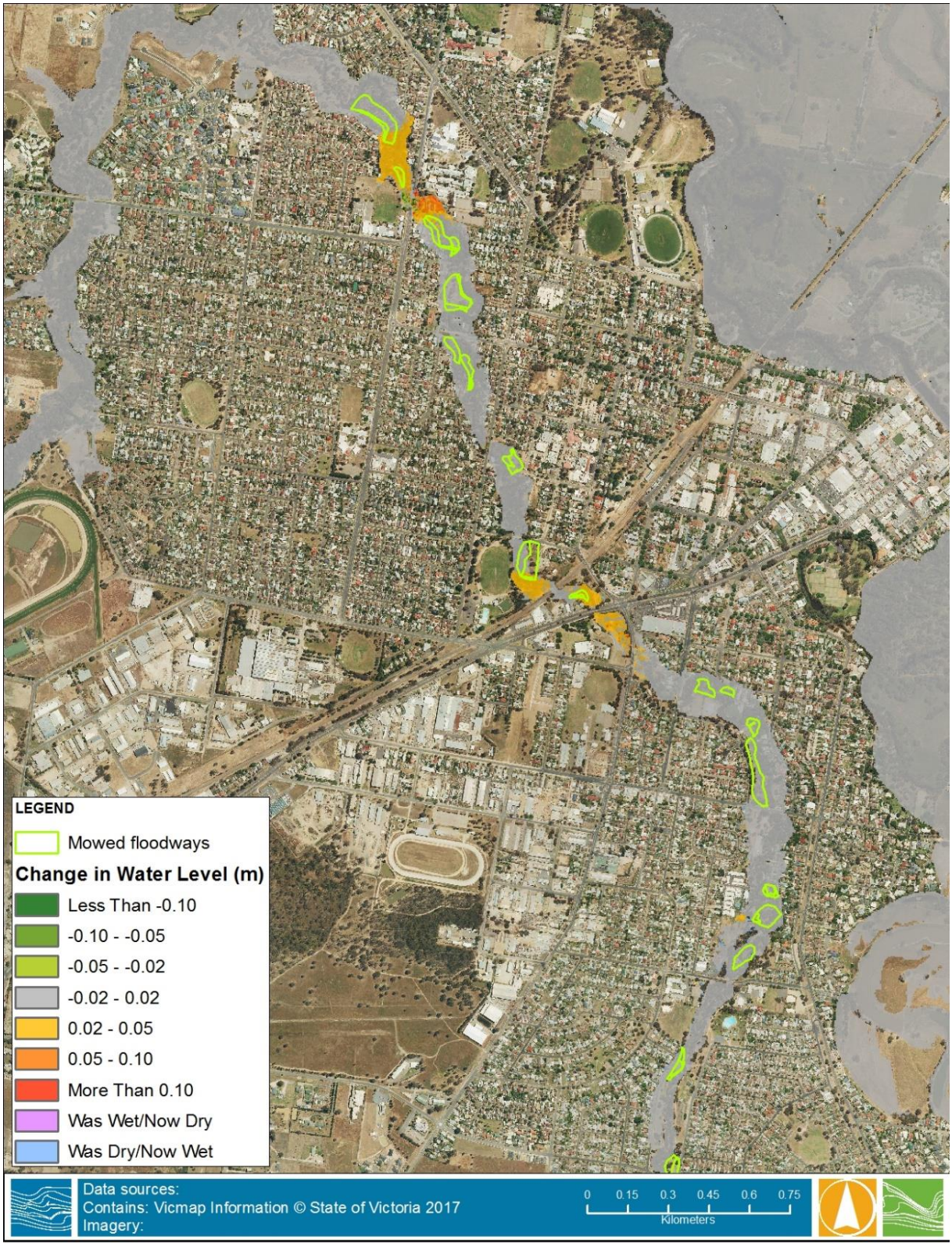

Figure 8-16 Change in 1% AEP water levels due to floodway increased roughness

Scenario E Summary

The result of modelling increased roughness through the One Mile Creek floodways show generally minor increases in flood levels in the 1% AEP event, with larger differences occurring in some pockets around hydraulic constrictions. The impacts are generally minor and indicate that maintaining the floodways is unlikely to have a significant impact on flood risk or flood damages along One Mile Creek.

9. CONCLUSIONS

9.1 Overview

The Wangaratta Flood Investigation provides an improved understanding of flood behaviour through the study area. This will ensure future flood-related planning decisions are soundly based and key agencies and residents have a much better understanding of flood risk through the city. The investigation has provided a comprehensive analysis and review of existing and future potential flood risk in the township and surrounding areas. The study involved:

- Collection and review of a range of data relevant to the definition of flooding within the study area.
- A rigorous hydrologic analysis to develop robust design flood estimates for the study area including in both the Fifteen Mile Creek, Ovens and King River catchments.
- Development of a detailed hydraulic model that is capable of predicting flood impacts in the complex floodplains of the King and Ovens rivers as well as the Fifteen Mile Creek, One Mile Creek and Three Mile Creek. The hydrological assessment also examined the interaction of Reedy Creek and several small tributaries on the Ovens floodplain.
- Quantification of flood risk in terms of flood damages.
- Examination of a range of existing and potential flood mitigation options at various locations within the study area.
- Assessment of the flood impacts associated with development of the Aerodrome Precinct.
- Review of flood warning and emergency management for the catchment including recommendations for improvement of the current total flood warning system (presented in a separate flood warning report).

9.2 Key Outcomes

The key findings and outcomes of the Wangaratta Flood Investigation are:

Study Area Hydrology & Hydraulic Characteristics **-** The study area covers the whole of the Wangaratta township and outlying areas. This includes a number of smaller tributaries which traverse the township as well as the King River, Ovens River, and the Fifteen Mile Creek systems. Extensive hydrological and hydraulic analysis was completed for the complex floodplains surrounding Wangaratta. It was found that the Fifteen Mile Creek and One Mile Creek system have a shorter critical storm duration of 12 hours whilst the King and Ovens River have longer critical durations of 72 hours.

Flood Damages – The 1% AEP flood damage estimate for existing conditions was calculated to be just over $6 million. A total of 307 properties are predicted to be flooded affected in a 1% AEP flood event, with 55 residential and two commercial properties flooded above floor level. The Average Annual Damages (AAD) was determined as part of the flood damage assessment and estimated to be **$512,662.**

Levee Assessment - An assessment of the Parfitt Road and Wilsons Road levee systems has been undertaken to understand the level of protection they currently provide. The analysis identified that the levees do not provide adequate protection in the 1% AEP event with the Parfitt Road levee overtopping in one location and both levees providing less than the required 300 mm of freeboard in numerous locations.

Future Development - The results of the investigation can be used to guide future development of Wangaratta and outlying areas. In addition, modelling of potential development scenarios around the Wangaratta Aerodrome precinct has assessed the potential flood impacts associated with such

development. The impacts were found to be minor and the modelling results can be used to guide development of this area.

Scenario Modelling **-** A number of scenarios were modelled which predominately examined existing and proposed mitigation measures. A range of findings were made regarding several locations and mitigation features including the Painters Island Caravan Park area, impacts of in-channel vegetation and debris on flood risk and the role of existing levee systems including the Parfitt Road, Wilson Road and Fishers Levee.

Flood warning – A comprehensive assessment of the current flood warning system has been made and a number of recommendations made. These are detailed in a separate flood warning report.

9.3 Recommendations

Following the investigations undertaken for this study it is recommended that:

- The NECMA and the Rural City of Wangaratta adopt the determined design flood levels for future planning purposes.
- In conjunction with VICSES, the Rural City of Wangaratta and NECMA continue to engage the community in the treatment of flood risks through regular flood awareness programs such as the VICSES FloodSafe program, starting with an update of the local flood guide.
- In consultation with VICSES, the Rural City of Wangaratta and NECMA explore further the recommendations for enhanced flood response through co-operation with VICSES and Victoria Police, utilising the flood inundation maps and flood intelligence findings detailed in the flood intelligence report.
- The Rural City of Wangaratta and NECMA further consider the findings regarding existing and proposed mitigation options around Wangaratta as well as the findings regarding development of the Aerodrome Precinct.

10. REFERENCES

Hill P, Mein R, Siriwardena L, *How Much Rainfall Becomes Runoff? Loss Modelling For Flood Estimation,* Industry Report, Cooperative Research Centre for Catchment Hydrology, 1998

Hill P, Graszkiewicz Z, Taylor M, and Nathan R, 23 October 2014, Australian Rainfall and Runoff Revision Project 6: Loss models for catchment simulation: Phase 4 Analysis of Rural Catchments, ARR Report Number P6/S3/016B, ISBN 978-085825-9775

Pilgrim, DH, (ed)., Australian Rainfall & Runoff – A Guide to Flood Estimation, Institution of Engineers, Australia, Barton, ACT, 1987.

Siriwardena, L., Weinmann, P. (1996) *Derivation of Areal Reduction Factors for Design Rainfalls in Victoria,* Report No. 96/4, CRC for Catchment Hydrology.

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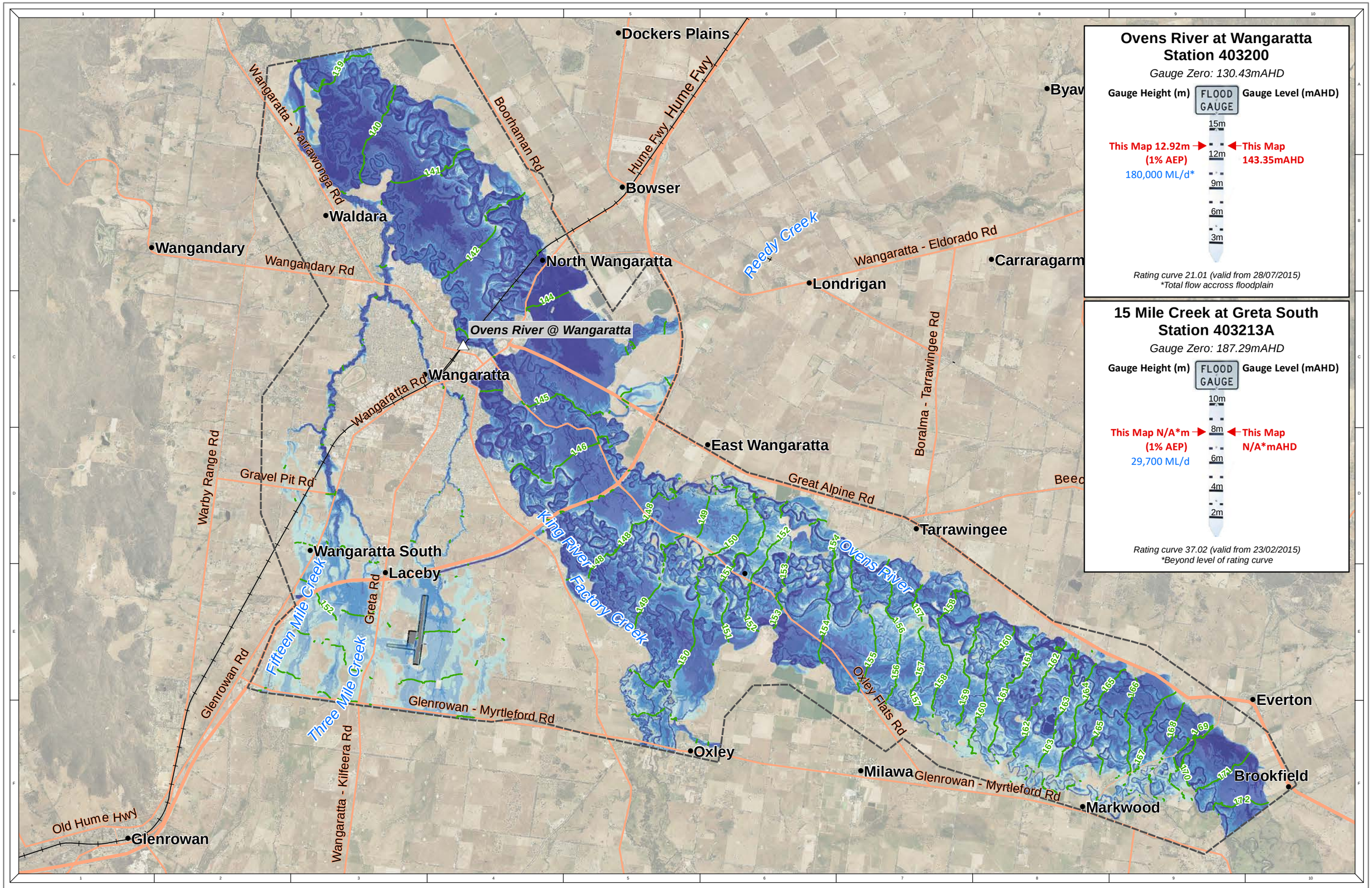
APPENDIX A
1% AEP DESIGN MAPS



Ovens River at Wangaratta Station 403200

Gauge Zero: 130.43mAHD

Gauge Height (m) | FLOOD GAUGE | Gauge Level (mAHD)

15m
12m
9m
6m
3m

This Map 12.92m (1% AEP) 180,000 ML/d*

This Map 143.35mAHD

Rating curve 21.01 (valid from 28/07/2015)
**Total flow accross floodplain*

15 Mile Creek at Greta South Station 403213A

Gauge Zero: 187.29mAHD

Gauge Height (m) | FLOOD GAUGE | Gauge Level (mAHD)

10m
8m
6m
4m
2m

This Map N/A*m (1% AEP) 29,700 ML/d

This Map N/A*mAHD

Rating curve 37.02 (valid from 23/02/2015)
**Beyond level of rating curve*

NOTE
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N W E S

Stream Gauge
Water Level (mAHD)
Railway
Highway
Major Road
Minor Road
Airport
Hydraulic Model Extent

0 1 2 3 4 5 Kilometers

Flood Depth (m)
< 0.25
0.25 - 0.5
0.5 - 1
1 - 2
> 2

1:90,000 at A3

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

NORTH EAST CATCHMENT MANAGEMENT AUTHORITY

RURAL CITY OF WANGARATTA

Victoria Department of Environment, Land, Water & Planning

1% AEP Flood Depth

Wangaratta Urban Waterways Flood Investigation

REFERENCE: M:\JOBS\4200-4299\4208_WANGARATTA_FLOOD_STUDY\SPATIAL\ESRIMXDS\MAPPING\REVISED\A3\4208_STUDYAREA_DEPTHMAP-REVISED_100Y_A3L.MXD

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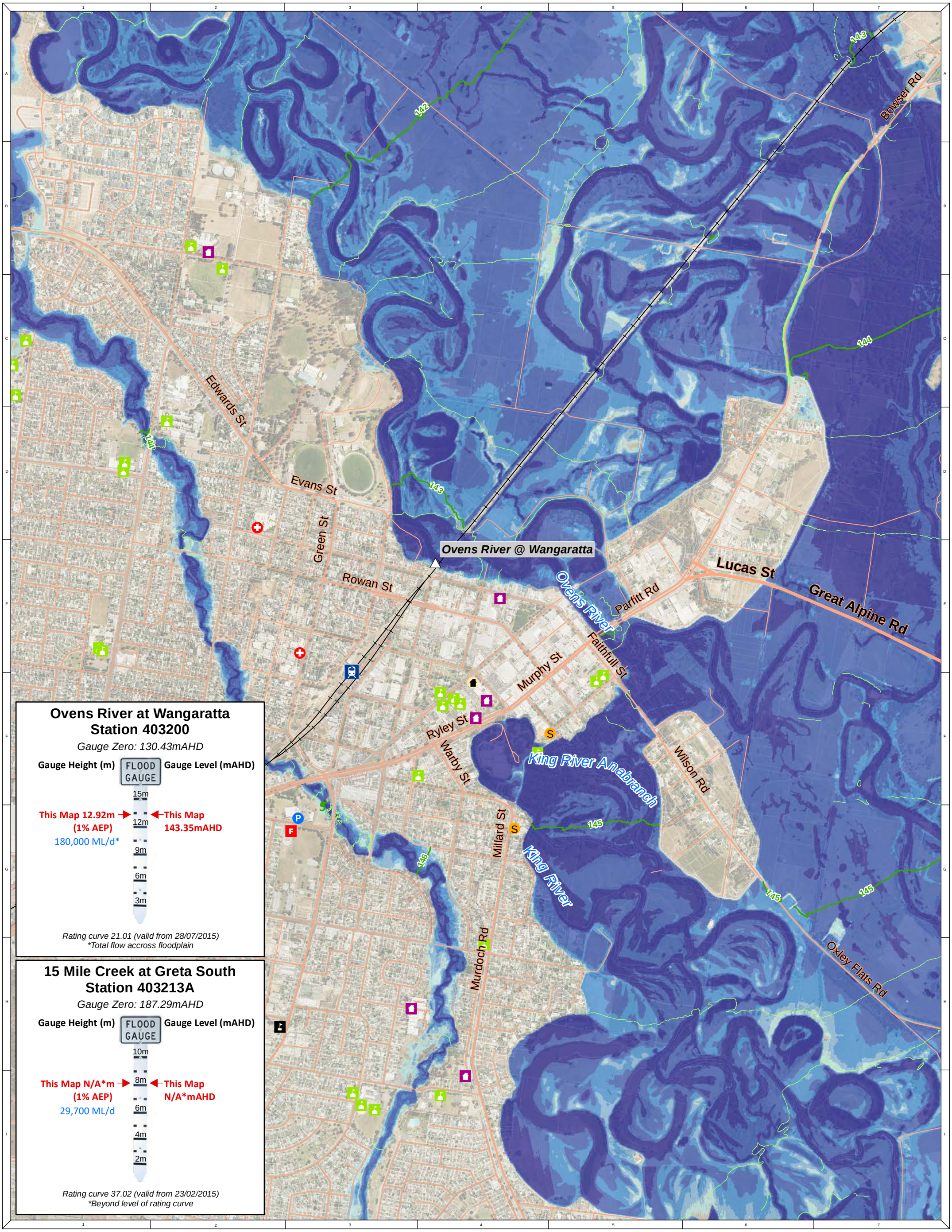

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Aged Care
Community Centre
Depot
Fire Station
Hospital / Ambulance
Police Station
School / Child Care
SES
Stream Gauge
Highway
Major Road
Minor Road
Railway
Water Level (mAHD)

Flood Depth (m)
< 0.25
0.25 - 0.5
0.5 - 1
1 - 2
> 2

0 90 180 270 360 450 Meters

1:15,000 at A3

RURAL CITY OF WANGARATTA
WATER TECHNOLOGY
NORTH EAST CATCHMENT MANAGEMENT AUTHORITY
State Government Victoria
Department of Environment, Land, Water & Planning

1% AEP Flood Depth

Wangaratta Urban Waterways
Flood Investigation

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SHEET: 5 of 8
DRAWING NUMBER: 100Y

Ovens River at Wangaratta
Station 403200

Gauge Zero: 130.43mAHD

Gauge Height (m) | FLOOD GAUGE | Gauge Level (mAHD)

15m
12m
9m
6m
3m

This Map 12.92m (1% AEP) 180,000 ML/d*

This Map 143.35mAHD

Rating curve 21.01 (valid from 28/07/2015)
**Total flow accross floodplain*

15 Mile Creek at Greta South
Station 403213A

Gauge Zero: 187.29mAHD

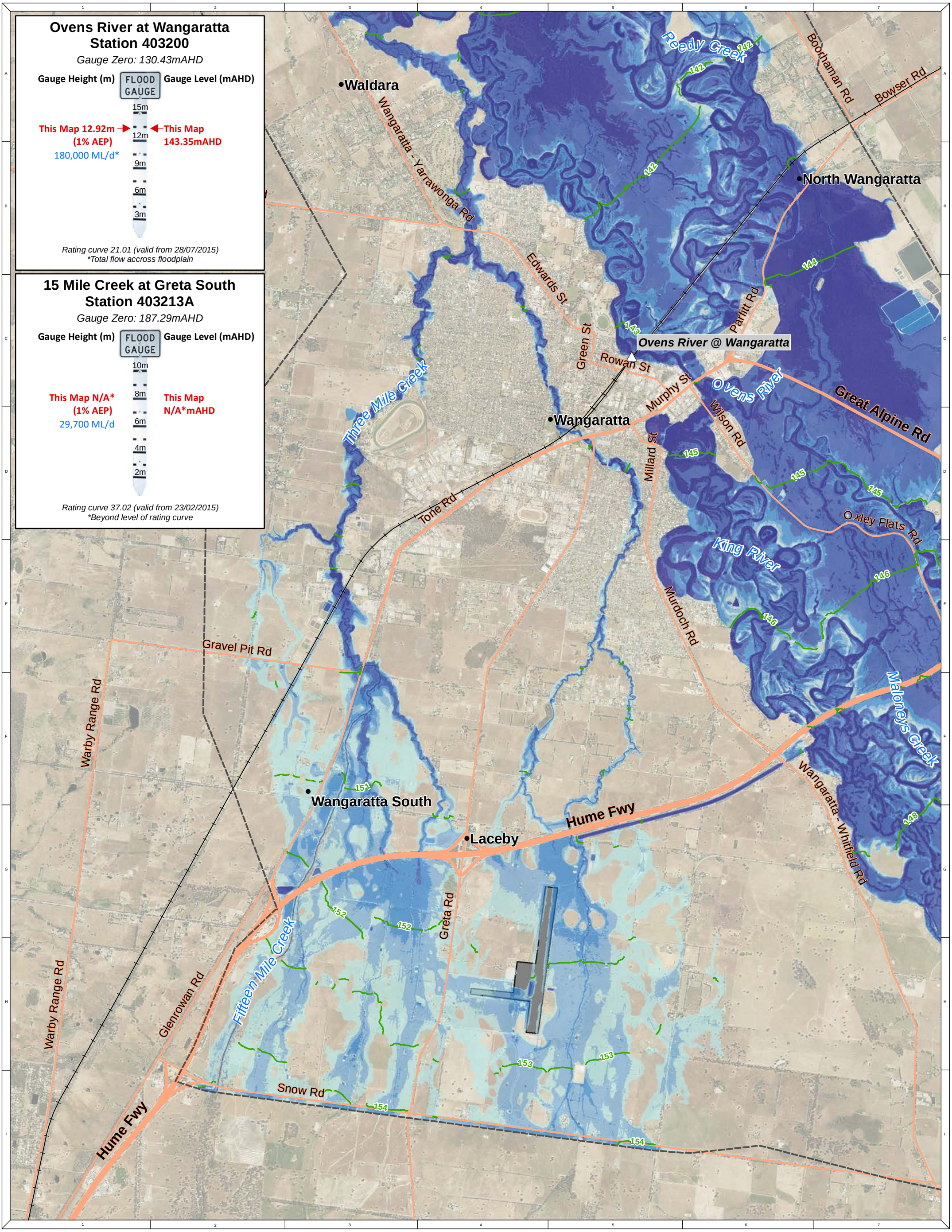
Gauge Height (m) | FLOOD GAUGE | Gauge Level (mAHD)

10m
8m
6m
4m
2m

This Map N/A* (1% AEP) 29,700 ML/d

This Map N/A*mAHD

Rating curve 37.02 (valid from 23/02/2015)
**Beyond level of rating curve*



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Stream Gauge
Water Level (mAHD)
Railway
Highway
Major Road
Hydraulic Model Extent
Airport

Flood Depth (m)
< 0.25
0.25 - 0.5
0.5 - 1
1 - 2
> 2

0 0.5 1 2 Kilometers

1:40,000 at A3

RURAL CITY OF WANGARATTA
WATER TECHNOLOGY
NORTH EAST CATCHMENT MANAGEMENT AUTHORITY
State Government Victoria Department of Environment, Land, Water & Planning

1% AEP Flood Depth

Wangaratta Urban Waterways
Flood Investigation

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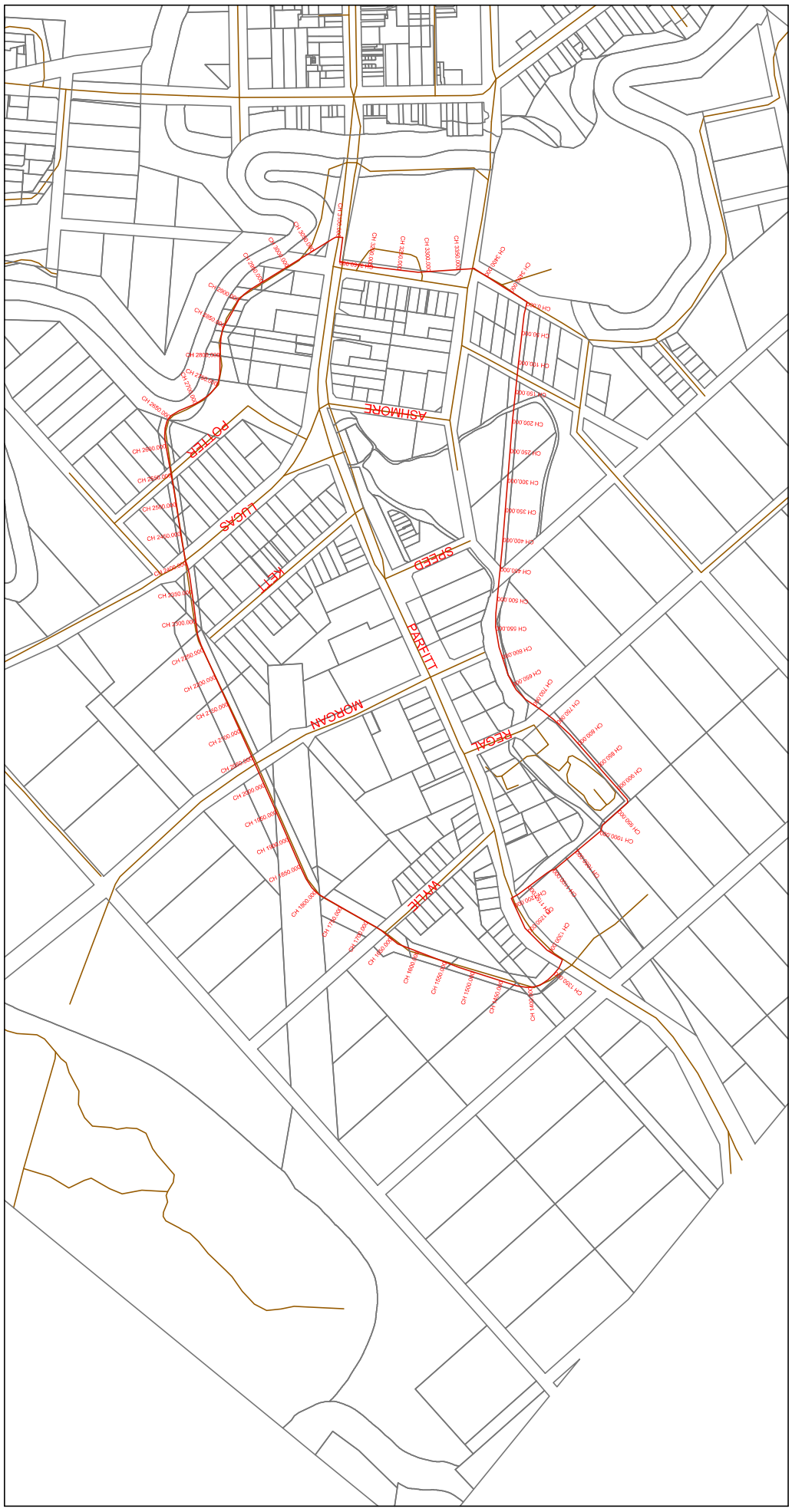
APPENDIX B
LEVEE FREEBOARD ANALYSIS

LEVEE CREST LEVELS AND FREEBOARD

DATUM 141.000

CHAINAGES	EXISTING SURFACE	MAX WSE	LEVEE ELEVATION	FREE BOARD
0	143.64	143.638	143.69	0.05
50	144.19	143.596	144.33	0.74
100	144.15	143.587	144.3	0.71
150	144.01	143.373	144.29	0.92
200	144.07	143.364	144.29	0.92
250	144.06	143.352	144.42	1.07
300	144.1	143.337	144.56	1.23
350	143.96	143.326	144.39	1.06
400	143.92	143.317	144.13	0.82
450	143.99	143.311	144.02	0.7
500	143.89	143.31	143.97	0.65
550	143.72	143.313	143.8	0.49
600	143.8	143.312	143.95	0.64
650	143.76	143.308	143.87	0.56
700	143.64	143.305	143.73	0.42
750	142.74	143.29	143.82	0.54
800	142.89	143.213	143.82	0.61
850	142.84	143.227	143.82	0.6
900	142.93	143.265	143.82	0.56
950	142.7	143.218	143.92	0.7
1000	143.02	143.285	143.77	0.49
1050	143.11	143.222	143.82	0.6
1100	143.39	143.286	143.88	0.59
1150	143.78	143.266	143.76	0.5
1200	143.62	143.155	143.79	0.63
1250	143.92	142.925	144.05	1.13
1300	143.77	143.804	143.88	0.07
1350	144.21	143.93	144.34	0.41
1400	144.45	143.975	144.47	0.5
1450	144.31	143.829	144.48	0.65
1500	144.26	143.923	144.44	0.52
1550	144.36	144.017	144.41	0.39
1600	144.08	144.110	144.4	0.29
1650	144.28	144.204	144.43	0.23
1700	144.27	144.204	144.44	0.24
1750	144.27	144.22	144.42	0.2
1800	144.35	144.231	144.39	0.16
1850	144.44	144.316	144.46	0.14
1900	144.53	144.328	144.49	0.16
1950	144.44	144.371	144.52	0.15
2000	144.5	144.352	144.58	0.23
2050	144.58	144.385	144.64	0.25
2100	144.45	144.399	144.65	0.25
2150	144.55	144.414	144.65	0.24
2200	144.63	144.426	144.68	0.25
2250	144.65	144.42	144.67	0.25
2300	144.69	144.344	144.71	0.36
2350	144.74	144.412	144.82	0.41
2400	144.85	144.451	144.82	0.37
2450	144.83	144.482	144.78	0.29
2500	144.92	144.479	144.86	0.38
2550	144.91	144.476	144.88	0.41
2600	144.8	144.525	144.84	0.31
2650	144.92	144.53	144.87	0.34
2700	144.79	144.546	144.72	0.17
2750	144.83	144.537	144.74	0.21
2800	144.83	144.543	144.87	0.32
2850	144.84	144.524	144.8	0.28
2900	144.86	144.505	144.9	0.39
2950	144.71	144.496	144.76	0.26
3000	144.72	144.468	144.88	0.41
3050	144.9	144.466	144.93	0.46
3100	144.87	144.379	144.91	0.53
3150	144.59	144.091	144.6	0.51
3200	144.27	143.804	144.3	0.5
3250	144.11	143.775	144.2	0.42
3300	143.99	143.776	144.15	0.37
3350	144.07	143.779	144.06	0.28
3400	143.89	143.745	143.94	0.19
3450	143.8	143.714	143.78	0.06
3485.437	143.64	143.638	143.69	0.05



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Approved: JLS
Date: 26/04/17

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Drawn: BE
Designed: JLS
Modelled: JLS
Project: J4208-01

Client: NORTH EAST CMA

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VIC 3166
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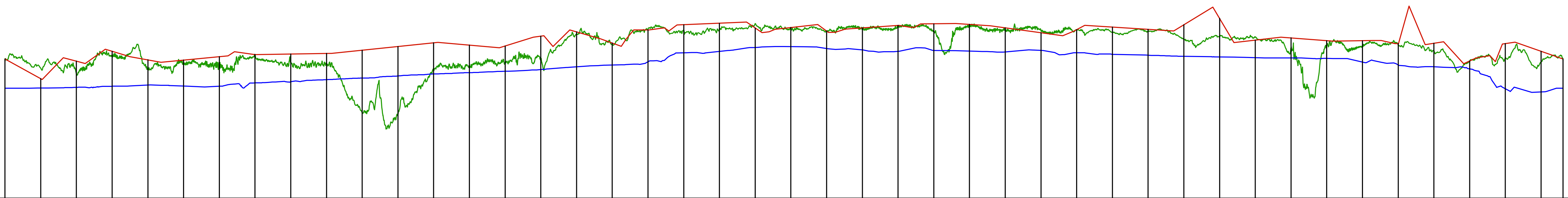
Tel: +61 3 8526 0800
Fax: +61 3 9558 9365
Email: admin@watech.com.au
Web: http://www.watertech.com.au

Title: WANGARATTA FLOOD INVESTIGATION
PARFITT ROAD LEVEE ANALYSIS

Dwg. No. 1
Job No. J4208-01
Page Size A1



DATUM 143.000

CHAINAGES	EXISTING SURFACE	MAX WSE	LEVEE ELEVATION	FREE BOARD
0	144.92	144.536	144.94	0.41
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100	144.73	144.548	144.91	0.37
150	144.99	144.562	145.05	0.49
200	144.81	144.58	144.93	0.35
250	144.86	144.567	144.93	0.36
300	144.83	144.565	144.98	0.41
350	145	144.611	145.01	0.4
400	144.89	144.626	145.01	0.39
450	144.88	144.656	145.02	0.37
500	144.19	144.678	145.07	0.39
550	144.17	144.707	145.12	0.41
600	144.8	144.736	145.17	0.44
650	144.85	144.754	145.14	0.38
700	144.89	144.774	145.13	0.35
750	144.94	144.797	145.26	0.47
800	145.29	144.836	145.32	0.49
850	145.15	144.86	145.17	0.31
900	145.36	144.906	145.35	0.45
950	145.34	145.032	145.42	0.39
1000	145.35	145.049	145.44	0.39
1050	145.44	145.106	145.38	0.27
1100	145.36	145.117	145.38	0.27
1150	145.33	145.091	145.34	0.24
1200	145.36	145.071	145.38	0.31
1250	145.39	145.051	145.41	0.36
1300	145.33	145.062	145.44	0.37
1350	145.42	145.055	145.43	0.37
1400	145.36	145.044	145.38	0.34
1450	145.35	145.065	145.31	0.25
1500	145.35	145.032	145.35	0.32
1550	145.32	145.009	145.39	0.38
1600	145.33	144.997	145.36	0.36
1650	145.22	144.981	145.42	0.44
1700	145.26	144.974	145.51	0.54
1750	145.25	144.963	145.21	0.25
1800	145.1	144.959	145.24	0.28
1850	145.13	144.953	145.2	0.25
1900	145.12	144.903	145.2	0.3
1950	145.14	144.861	145.16	0.3
2000	145.06	144.836	145.16	0.33
2050	144.92	144.806	144.92	0.11
2100	144.96	144.529	145.16	0.63
2150	144.9	144.484	145.05	0.57
2180.734	144.92	144.536	144.94	0.41

LEVEE CREST LEVELS AND FREEBOARD

Issue	Description	Approved	Date	Issue	Description	Checked	Approved	Date
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Scale HORZ 1:3500 VERT 1:35

Chainage Ch 0 to Ch 2180.734

Drawn BE
Designed JLS
Modelled JLS
Project: J4208-01

Client NORTH EAST CMA

NORTH EAST CATCHMENT MANAGEMENT AUTHORITY

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Web: http://www.watertech.com.au

WATER TECHNOLOGY WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

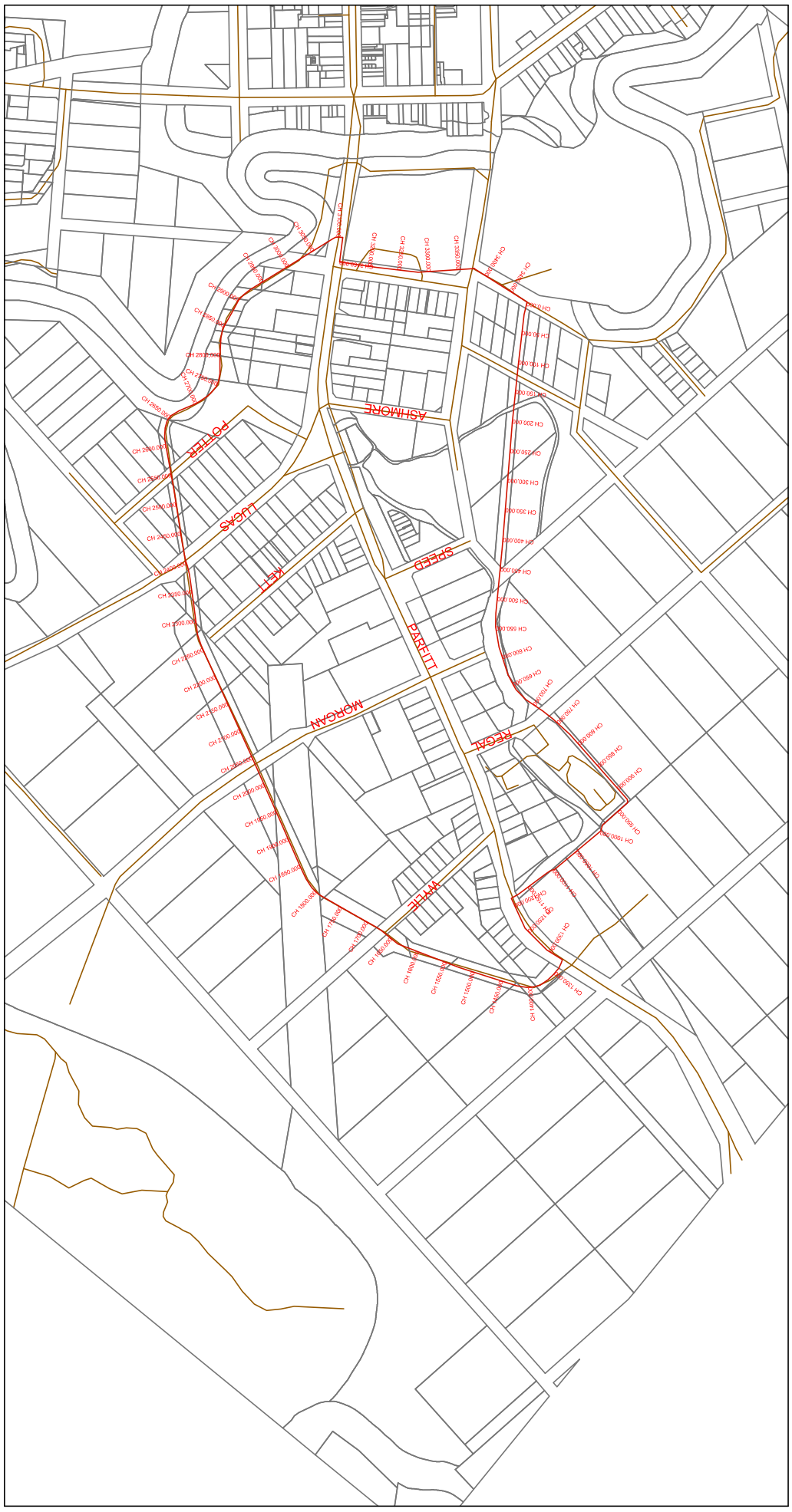
Title WANGARATTA FLOOD INVESTIGATION WILSON ROAD LEVEE ANALYSIS

Dwg. No. 1
Job No. J4208-01
Page Size A1

LEVEE CREST LEVELS AND FREEBOARD

DATUM 141.000

CHAINAGES	EXISTING SURFACE	MAX WSE	LEVEE ELEVATION	FREE BOARD
0	143.64	143.638	143.69	0.05
50	144.19	143.596	144.33	0.74
100	144.15	143.587	144.3	0.71
150	144.01	143.373	144.29	0.92
200	144.07	143.364	144.29	0.92
250	144.06	143.352	144.42	1.07
300	144.1	143.337	144.56	1.23
350	143.96	143.326	144.39	1.06
400	143.92	143.317	144.13	0.82
450	143.99	143.311	144.02	0.7
500	143.89	143.31	143.97	0.65
550	143.72	143.313	143.8	0.49
600	143.8	143.312	143.95	0.64
650	143.76	143.308	143.87	0.56
700	143.64	143.305	143.73	0.42
750	142.74	143.29	143.82	0.54
800	142.89	143.213	143.82	0.61
850	142.84	143.227	143.82	0.6
900	142.93	143.265	143.82	0.56
950	142.7	143.218	143.92	0.7
1000	143.02	143.285	143.77	0.49
1050	143.11	143.222	143.82	0.6
1100	143.39	143.286	143.88	0.59
1150	143.78	143.266	143.76	0.5
1200	143.62	143.155	143.79	0.63
1250	143.92	142.925	144.05	1.13
1300	143.77	143.804	143.88	0.07
1350	144.21	143.93	144.34	0.41
1400	144.45	143.975	144.47	0.5
1450	144.31	143.829	144.48	0.65
1500	144.26	143.923	144.44	0.52
1550	144.36	144.017	144.41	0.39
1600	144.08	144.110	144.4	0.29
1650	144.28	144.204	144.43	0.23
1700	144.27	144.204	144.44	0.24
1750	144.27	144.22	144.42	0.2
1800	144.35	144.231	144.39	0.16
1850	144.44	144.316	144.46	0.14
1900	144.53	144.328	144.49	0.16
1950	144.44	144.371	144.52	0.15
2000	144.5	144.352	144.58	0.23
2050	144.58	144.385	144.64	0.25
2100	144.45	144.399	144.65	0.25
2150	144.55	144.414	144.65	0.24
2200	144.63	144.426	144.68	0.25
2250	144.65	144.42	144.67	0.25
2300	144.69	144.344	144.71	0.36
2350	144.74	144.412	144.82	0.41
2400	144.85	144.451	144.82	0.37
2450	144.83	144.482	144.78	0.29
2500	144.92	144.479	144.86	0.38
2550	144.91	144.476	144.88	0.41
2600	144.8	144.525	144.84	0.31
2650	144.92	144.53	144.87	0.34
2700	144.79	144.546	144.72	0.17
2750	144.83	144.537	144.74	0.21
2800	144.83	144.543	144.87	0.32
2850	144.84	144.524	144.8	0.28
2900	144.86	144.505	144.9	0.39
2950	144.71	144.496	144.76	0.26
3000	144.72	144.468	144.88	0.41
3050	144.9	144.466	144.93	0.46
3100	144.87	144.379	144.91	0.53
3150	144.59	144.091	144.6	0.51
3200	144.27	143.804	144.3	0.5
3250	144.11	143.775	144.2	0.42
3300	143.99	143.776	144.15	0.37
3350	144.07	143.779	144.06	0.28
3400	143.89	143.745	143.94	0.19
3450	143.8	143.714	143.78	0.06
3485.437	143.64	143.638	143.69	0.05



Issue: 01
Description: DRAFT 01
Approved: JLS
Date: 26/04/17

Scale: HORZ 1:5000 VERT 1:50
Chainage: Ch 0 to Ch 3485.437

Drawn: BE
Designed: JLS
Modelled: JLS
Project: J4208-01

Client: NORTH EAST CMA

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15 Business Park Drive
Notting Hill
VIC 3166
ACN 056 019 713
Tel: +61 3 8526 0800
Fax: +61 3 9558 9365
Email: admin@watech.com.au
Web: http://www.watertech.com.au

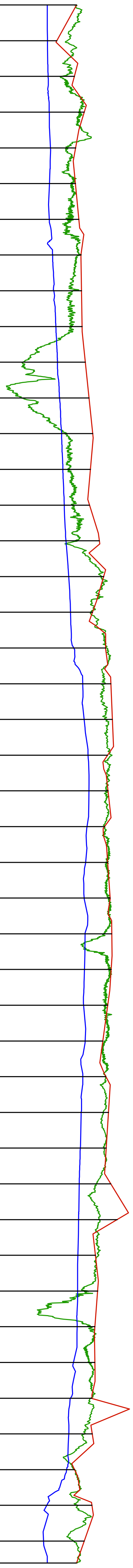
Title: WANGARATTA FLOOD INVESTIGATION
PARFITT ROAD LEVEE ANALYSIS

Dwg. No. 1
Job No. J4208-01
Page Size A1

LEVEE CREST LEVELS AND FREEBOARD

DATUM 143.000

CHAINAGES	EXISTING SURFACE	MAX WSE	LEVEE ELEVATION	FREE BOARD
0	144.92	144.536	144.94	0.41
50	144.82	144.539	144.67	0.13
100	144.73	144.548	144.91	0.37
150	144.99	144.562	145.05	0.49
200	144.81	144.58	144.93	0.35
250	144.86	144.567	144.93	0.36
300	144.83	144.565	144.98	0.41
350	145	144.611	145.01	0.4
400	144.89	144.626	145.01	0.39
450	144.88	144.656	145.02	0.37
500	144.19	144.678	145.07	0.39
550	144.17	144.707	145.12	0.41
600	144.8	144.736	145.17	0.44
650	144.85	144.754	145.14	0.38
700	144.89	144.774	145.13	0.35
750	144.94	144.797	145.26	0.47
800	145.29	144.836	145.32	0.49
850	145.15	144.86	145.17	0.31
900	145.36	144.906	145.35	0.45
950	145.34	145.032	145.42	0.39
1000	145.35	145.049	145.44	0.39
1050	145.44	145.106	145.38	0.27
1100	145.36	145.117	145.38	0.27
1150	145.33	145.091	145.34	0.24
1200	145.36	145.071	145.38	0.31
1250	145.39	145.051	145.41	0.36
1300	145.33	145.062	145.44	0.37
1350	145.42	145.055	145.43	0.37
1400	145.36	145.044	145.38	0.34
1450	145.35	145.065	145.31	0.25
1500	145.35	145.032	145.35	0.32
1550	145.32	145.009	145.39	0.38
1600	145.33	144.997	145.36	0.36
1650	145.22	144.981	145.42	0.44
1700	145.26	144.974	145.51	0.54
1750	145.25	144.963	145.21	0.25
1800	145.1	144.959	145.24	0.28
1850	145.13	144.953	145.2	0.25
1900	145.12	144.903	145.2	0.3
1950	145.14	144.861	145.16	0.3
2000	145.06	144.836	145.16	0.33
2050	144.92	144.806	144.92	0.11
2100	144.96	144.529	145.16	0.63
2150	144.9	144.484	145.05	0.57
2180.734	144.92	144.536	144.94	0.41



Issue	Description	Approved	Date
01	DRAFT 01	JLS	28/04/17

Scale: HORZ 1:3500 VERT 1:35

Chainage: Ch 0 to Ch 2180.734

Drawn: BE
Designed: JLS
Modelled: JLS
Project: J4208-01

Client: NORTH EAST CMA

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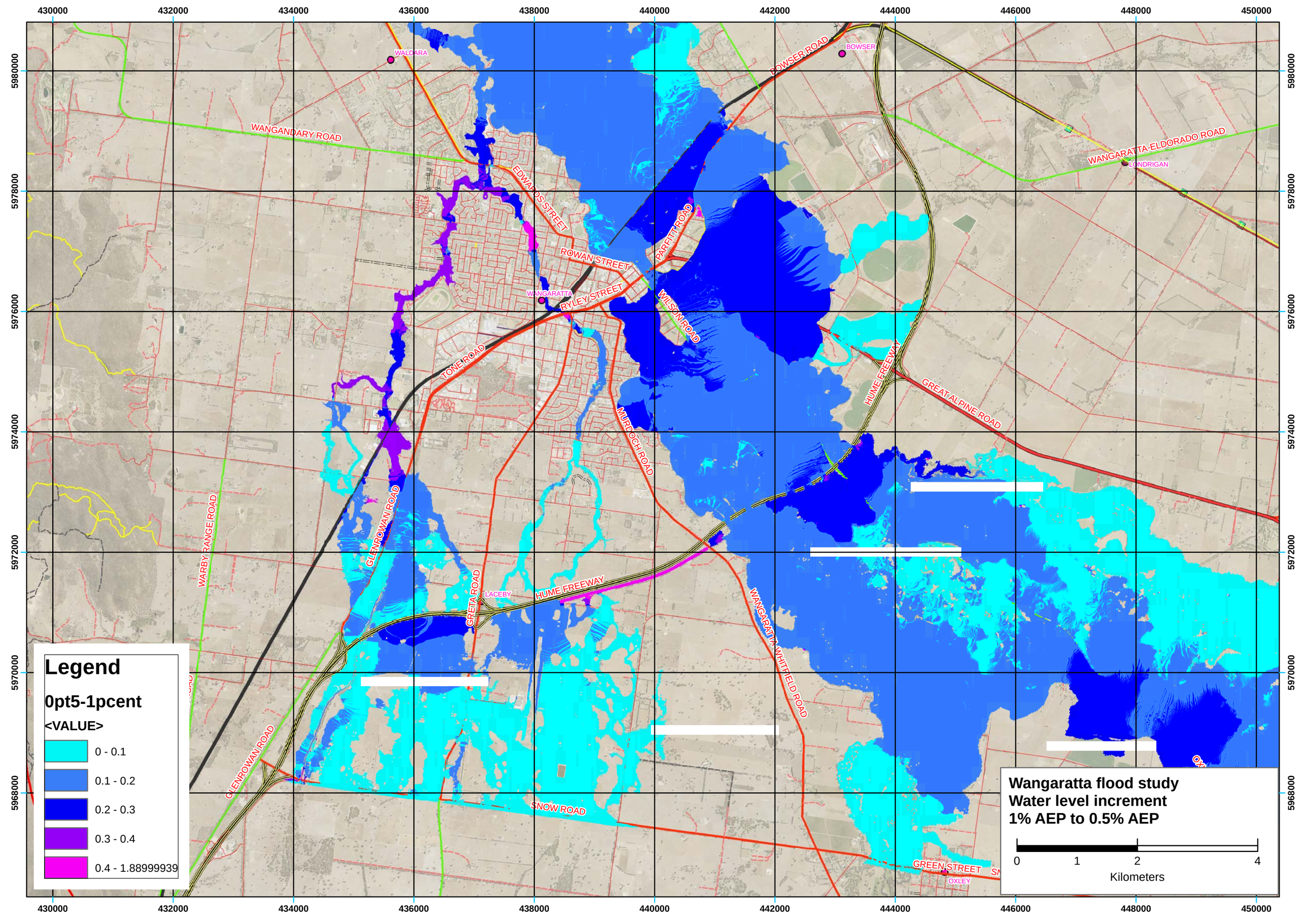
ACN 056 019 713
Tel: +61 3 8526 0800
Fax: +61 3 9558 9365
Email: admin@watech.com.au
Web: http://www.watertech.com.au

Title: WANGARATTA FLOOD INVESTIGATION
WILSON ROAD LEVEE ANALYSIS

Dwg. No. 1
Job No. J4208-01
Page Size A1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WALDARA
BOWSER
LONDRIGAN
WANGARATTA
LACEBY
OXLEY
WANGANDARY ROAD
EDWARDS STREET
ROWAN STREET
RYLEY STREET
PARFITT ROAD
WILSON ROAD
TONE ROAD
MURDOCH ROAD
BOWSER ROAD
WANGARATTA-ELDORADO ROAD
HUME FREEWAY
GREAT ALPINE ROAD
WARBY RANGE ROAD
GLENROWAN ROAD
GRETA ROAD
WANGARATTA-WHITFIELD ROAD
SNOW ROAD
GREEN STREET
Legend
0pt5-1pcent
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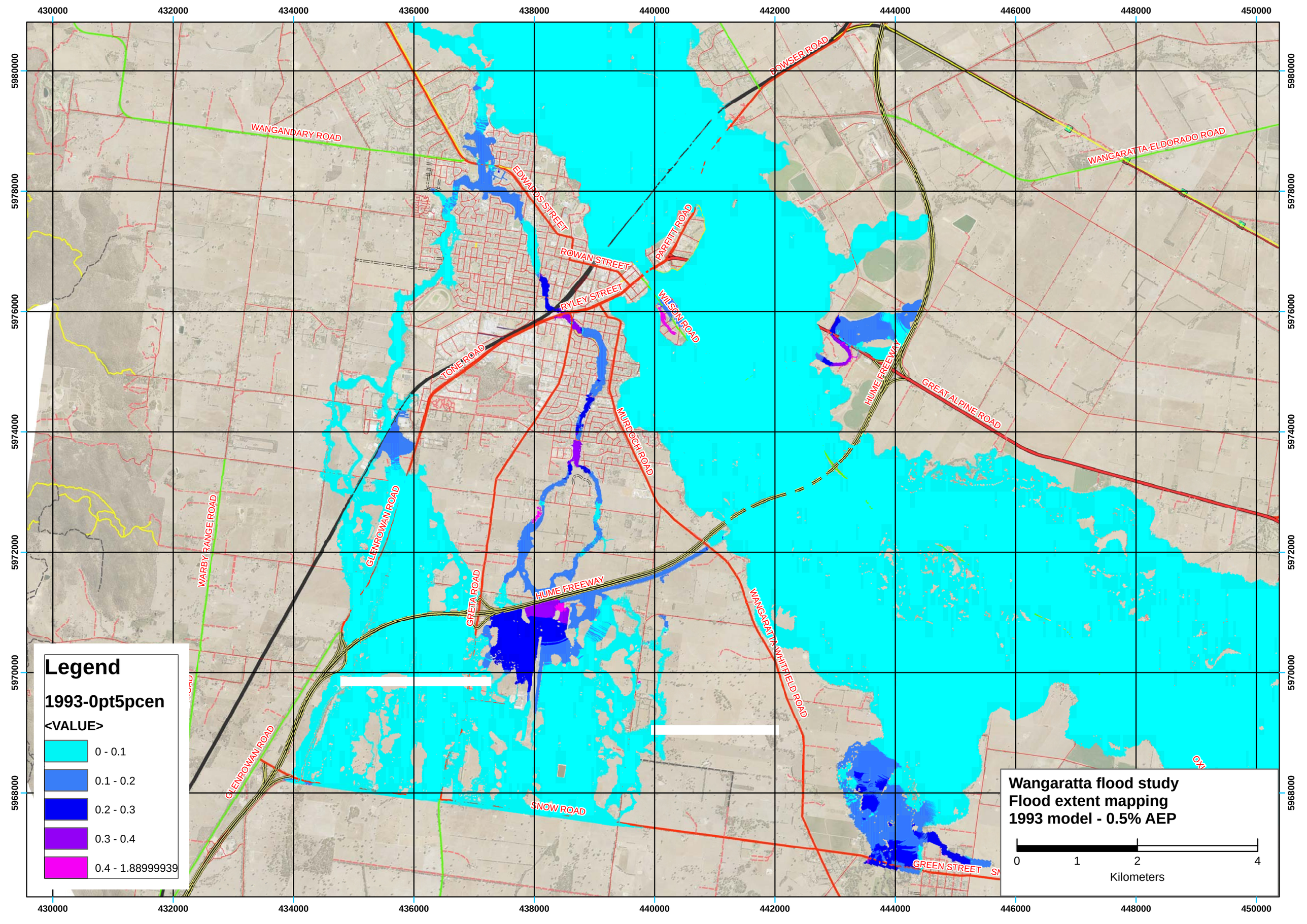
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 1.88999939
Wangaratta flood study
Water level increment
1% AEP to 0.5% AEP
0
1
2
4
Kilometers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EDWARDS STREET
ROWAN STREET
RYLEY STREET
TONE ROAD
PARFITT ROAD
WILSON ROAD
MURDOCH ROAD
BOWSER ROAD
WANGARATTA-ELDORADO ROAD
HUME FREEWAY
GREAT ALPINE ROAD
WARBY RANGE ROAD
GLENROWAN ROAD
GREITA ROAD
HUME FREEWAY
WANGARATTA-WHITFIELD ROAD
SNOW ROAD
GREEN STREET
Legend
1993-0pt5pcen
<VALUE>
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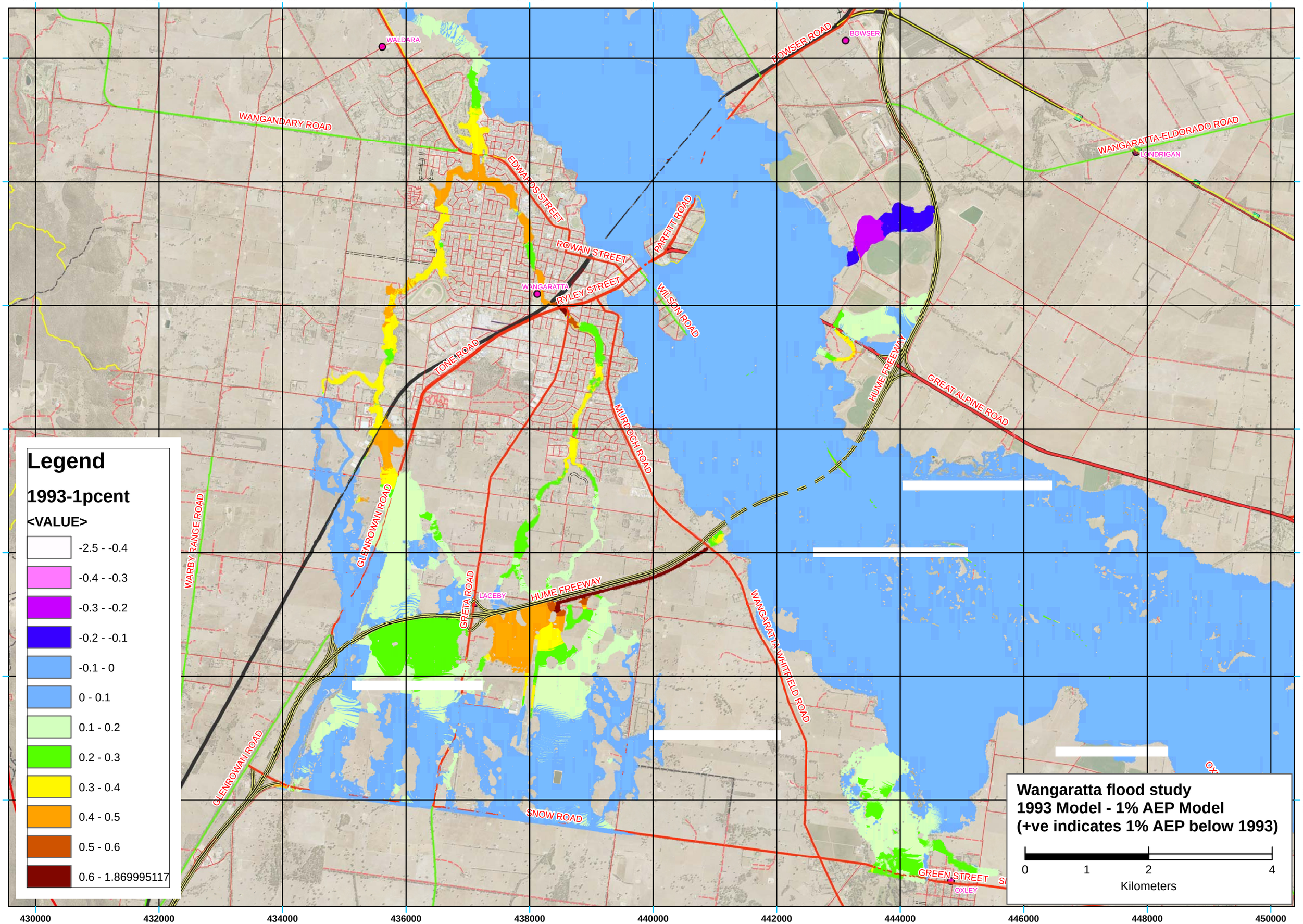
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 1.88999939
Wangaratta flood study
Flood extent mapping
1993 model - 0.5% AEP
0
1
2
4
Kilometers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BOWSER ROAD
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WANGARATTA-ELDORADO ROAD
LONDRIGAN
EDWARDS STREET
ROWAN STREET
PARFITT ROAD
WANGARATTA
RYLEY STREET
WILSON ROAD
TONE ROAD
MURDOCH ROAD
HUME FREEWAY
GREAT ALPINE ROAD
WARBY RANGE ROAD
GLENROWAN ROAD
GREITA ROAD
LACEBY
HUME FREEWAY
WANGARATTA-WHITFIELD ROAD
GLENROWAN ROAD
SNOW ROAD
GREEN STREET
OXLEY
Legend
1993-1pcent
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-0.3 - -0.2
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-0.1 - 0
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
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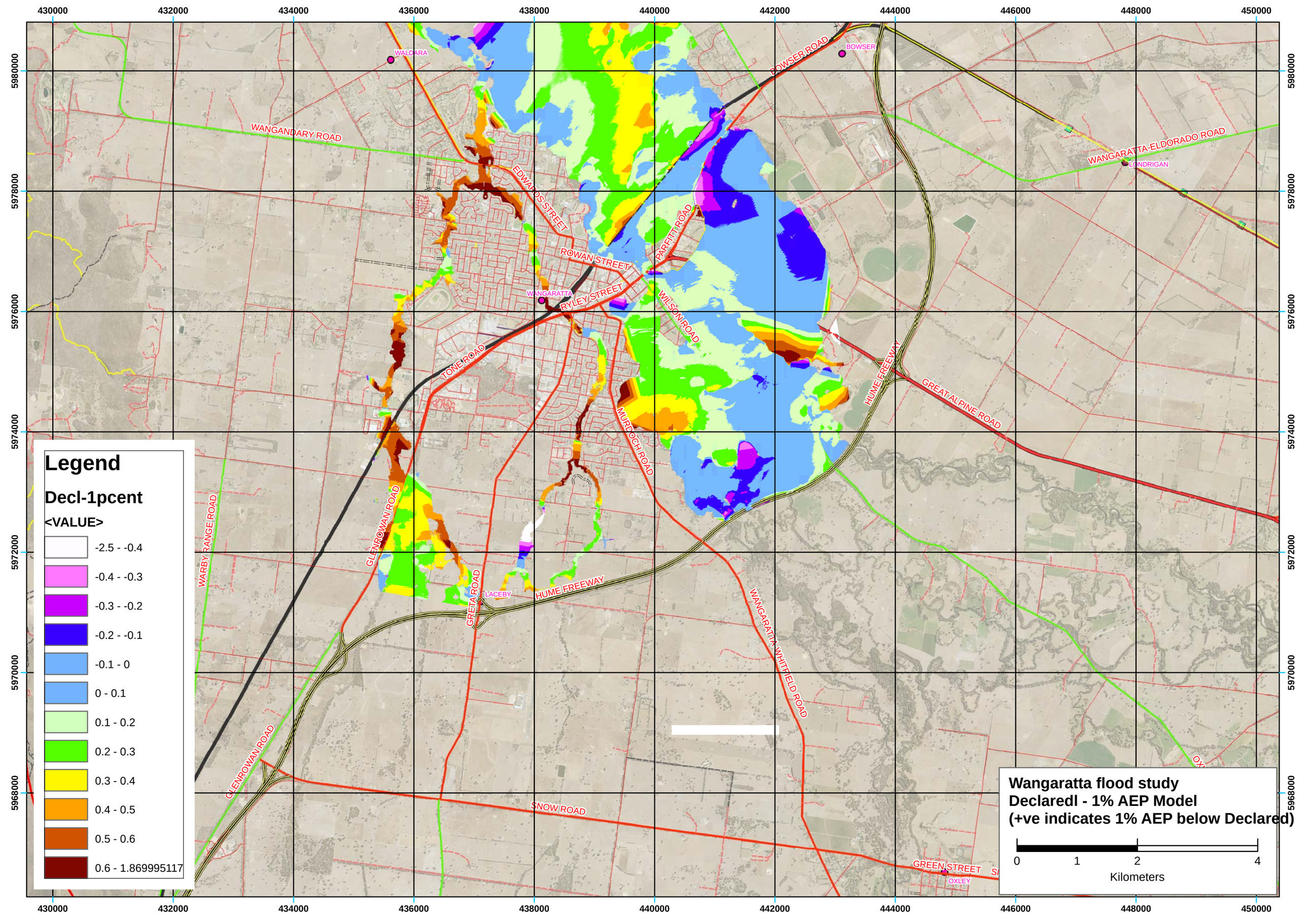
Wangaratta flood study
1993 Model - 1% AEP Model
(+ve indicates 1% AEP below 1993)
0
1
2
4
Kilometers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5968000
WALDARA
BOWSER
LONDRIGAN
WANGARATTA
LACEBY
OXLEY
WANGANDARY ROAD
EDWARDS STREET
ROWAN STREET
RYLEY STREET
PARFITT ROAD
WILSON ROAD
TONE ROAD
MURDOCH ROAD
BOWSER ROAD
WANGARATTA-ELDORADO ROAD
HUME FREEWAY
GREAT ALPINE ROAD
GLENROWAN ROAD
WARBY RANGE ROAD
CRETA ROAD
WANGARATTA-WHITFIELD ROAD
SNOW ROAD
GREEN STREET
Legend
Decl-1pcent
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-0.4 - -0.3
-0.3 - -0.2
-0.2 - -0.1
-0.1 - 0
0 - 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
0.5 - 0.6
0.6 - 1.869995117
Wangaratta flood study
Declaredl - 1% AEP Model
(+ve indicates 1% AEP below Declared)
0
1
2
4
Kilometers

434000 436000 438000 440000 442000 444000

5978000 5976000 5974000 5972000

WANGANDARY ROAD
EDWARDS STREET
GREEN STREET
ROWAN STREET
RYLEY STREET
TONE ROAD
WANGARATTA
PARFITT ROAD
WILSON ROAD
BOWSER ROAD
WANGARATTA-ELDORADO ROAD
GREAT ALPINE ROAD
HUME FREEWAY
OXLEY FLATS ROAD
MURDOCH ROAD
WANGARATTA-WHITFIELD ROAD
GLENROWAN ROAD
GRETA ROAD
LACEBY
HUME FREEWAY

Legend

1993-1pcent

<VALUE>

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- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - 0
- 0 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 1.869995117

Wangaratta flood study
1993 model - 1% AEP Model
(+ve indicates 1% AEP below 1993)

0 0.5 1 2
Kilometers

434000 436000 438000 440000 442000 444000

5978000 5976000 5974000 5972000

WANGANDARY ROAD
EDWARDS STREET
GREEN STREET
ROWAN STREET
RYLEY STREET
TONE ROAD
WANGARATTA
PARFITT ROAD
BOWSER ROAD
WILSON ROAD
WANGARATTA-ELDORADO ROAD
GREAT ALPINE ROAD
HUME FREEWAY
OXLEY FLATS ROAD
MURDOCH ROAD
WANGARATTA-WHITFIELD ROAD
GRETA ROAD
GLENROWAN ROAD
LACEBY

Legend

Decl-1pcent

<VALUE>

- -2.5 - -0.4
- -0.4 - -0.3
- -0.3 - -0.2
- -0.2 - -0.1
- -0.1 - 0
- 0 - 0.1
- 0.1 - 0.2
- 0.2 - 0.3
- 0.3 - 0.4
- 0.4 - 0.5
- 0.5 - 0.6
- 0.6 - 1.869995117

Wangaratta flood study
Declared - 1% AEP Model
(+ve indicates 1% AEP below Declared)

0 0.5 1 2
Kilometers

434000
436000
438000
440000
442000
444000

5978000
5976000
5974000
5972000

WANGARATTA
LACEBY

Legend

Change

- Add
- Remove
- Retain

Wangaratta flood study
Overlay change at 0.5% AEP

0 0.5 1 2
Kilometers

434000
436000
438000
440000
442000
444000

5978000
5976000
5974000
5972000

WANGARATTA
LACEBY

Legend

Change

Add
Remo
Ret

Wangaratta flood study
Overlay change at 1% AEP

0 0.5 1 2
Kilometers

430000 432000 434000 436000 438000 440000 442000 444000 446000 448000 450000

5980000 5978000 5976000 5974000 5972000 5970000 5968000

Legend

- Wang17RvExtentARI5
- Wang17RvExtentARI10
- Wang17RvExtentARI20
- Wang17RvExtentARI50
- Wang17RvExtentARI100
- Wang17RvExtentARI200

Wangaratta flood study
Flood extent mapping

0 1 2 4
Kilometers

436000
438000
440000
5978000
5976000

142
142.600006
142.8
142.2
143.3
142.6
142.8
143.4
143.2
143
143.4
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143.6
143.8
144.2
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145.4
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144.6
144.8
145
WANGARATTA

Legend

Wang17RvContourARI100

Q100_Wang Declared

Wangaratta flood study
Declared and modelled
1% AEP contours

0 0.25 0.5 1
Kilometers

436000

438000

440000

5978000

5978000

5976000

5976000

WANGARATTA

Legend

Change

Add

Remo

Ret

Wangaratta flood study
Overlay change at 1% AEP

0 0.25 0.5 1

Kilometers

436000

438000

440000