WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

# Expert Report

## Amendment C199 to the Greater Shepparton Planning Scheme

Greater Shepparton City Council

June 2017

## Project Details

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|---|---|
| **Project Name** | Amendment C199 to the Greater Shepparton Planning Scheme |
| **Report Prepared for** | Greater Shepparton City Council |
| **Instructed By** | Russell Kennedy Lawyers |
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# GLOSSARY

| Term | Description |
|---|---|
| **Annual Exceedance Probability (AEP)** | Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded; it would occur quite often and would be relatively small. A 1% AEP flood has a low probability of occurrence or being exceeded; it would be fairly rare but it would be of extreme magnitude. |
| **Australian Height Datum (AHD)** | A common national surface level datum approximately corresponding to mean sea level. Introduced in 1971 to eventually supersede all earlier datums. |
| **Average Recurrence Interval (ARI)** | Refers to the average time interval between a given flood magnitude occurring or being exceeded. A 10 year ARI flood is expected to be exceeded on average once every 10 years. A 100 year ARI flood is expected to be exceeded on average once every 100 years. The AEP is the ARI expressed as a percentage. |
| **Catchment** | The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream. |
| **Design flood** | A design flood is a probabilistic or statistical estimate, being generally based on some form of probability analysis of flood or rainfall data. An average recurrence interval or exceedance probability is attributed to the estimate. |
| **Discharge** | The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving. |
| **Flood** | Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from elevated sea levels and/or waves overtopping coastline defences. |
| **Flood damage** | The tangible and intangible costs of flooding. |
| **Flood frequency analysis** | A statistical analysis of observed flood magnitudes to determine the probability of a given flood magnitude. |
| **Flood mitigation** | A series of works to prevent or reduce the impact of flooding. This includes structural options such as levees and non-structural options such as planning schemes and flood warning systems. |
| **Floodplain** | Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land. |
| **Flood storages** | Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. |

| Term | Description |
|---|---|
| **Geographical information systems (GIS)** | A system of software and procedures designed to support the management, analysis and display of spatially referenced data. |
| **Hydraulics** | The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity. |
| **Hydrograph** | A graph that shows how the discharge changes with time at any particular location. |
| **Hydrology** | The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods. |
| **LiDAR** | Spot land surface heights collected via aerial light detection and ranging (LiDAR) survey. The spot heights are converted to a gridded digital elevation model dataset for use in modelling and mapping. |
| **Peak flow** | The maximum discharge occurring during a flood event. |
| **Probability** | A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Average Recurrence Interval. |
| **Probable Maximum Flood** | The flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in a particular drainage area. |
| **Risk** | Chance of something happening that will have an impact. It is measured in terms of consequence and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment. |
| **RORB** | A hydrological modelling tool used in this study to calculate the runoff generated from historic and design rainfall events. |
| **Runoff** | The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess. |
| **Stage** | Equivalent to 'water level'. Both are measured with reference to a specified datum. |
| **Stage hydrograph** | A graph that shows how the water level changes with time. It must be referenced to a particular location and datum. |
| **Topography** | A surface which defines the ground level of a chosen area. |
| **TUFLOW** | A hydraulic modelling tool used in this study to simulate the flow of flood water through the floodplain. The model uses numerical equations to describe the water movement. |

# CONTENTS

# LIST OF FIGURES



# LIST OF TABLES

# 1 REPORT AUTHOR

**Warwick Bishop**

Senior Principal Engineer, Director
Water Technology Pty Ltd
15 Business Park Drive
Notting Hill, VIC 3168

***Qualifications:***

- B.E. (Hons), University of Melbourne, 1993
- MEngSci, Monash University, 2000

***Affiliations:***

- Chartered Member, Institution of Engineers, Australia
- Chair, Engineers Australia, Victorian Water Engineering Branch Committee
- Member, International Association for Hydraulic Research
- Member, Australian Water Association
- Member, River Basin Management Society
- Member, Stormwater Victoria

**Experience**

I am a Director of Water Technology and have over 20 years' experience in hydrologic and hydraulic investigations, specialising in the development and application of rural and urban hydrodynamic models and their application to flooding, drainage, water quality, sediment transport and environmental values. I also have extensive experience in coastal and estuary modelling including wave, current, oil spill and coastal vulnerability investigations. I have worked extensively in the Murray Darling Basin, principally on environmental hydraulic investigations for the Living Murray Program. I was recently involved in the revision of Australian Rainfall and Runoff, with particular focus on the application of 2D hydraulic models to flooding in urban and rural areas. In 2011 I worked in the Flood Intelligence Unit of SES during the January floods and have provided advice to Catchment Management Authorities over the subsequent period. As Water Technology's Regional Manager of Victoria I have overseen hundreds of rural and urban flood investigations.

***Relevant Projects & Papers***

- Shepparton Mooroopna Floodplain Management Study, 2002. My role was a senior engineer and hydraulic modeller in charge of the hydraulic aspects of the study.
- Shepparton Flood Warning and Emergency Management Report (2007). I provided internal technical review and advice for this project.
- Shepparton Mooroopna Flood Mapping and Intelligence Study (current). I have provided internal project review and advice on this project.

# 2 STATEMENT OF EXPERTISE

With my qualifications and experience, I believe that I am well qualified to provide an expert opinion on the flooding issues related to Amendment C199 of the Greater Shepparton City Council.

# 3 REPORT CONTRIBUTORS

**Ben Tate**

Senior Principal Engineer

Water Technology Pty Ltd

***Qualifications:***

- Bachelor of Engineering with Honours (Environmental), University of Melbourne, 2002
- Bachelor of Science (Environmental Science), University of Melbourne, 2002

***Area of Expertise:***

Key areas of expertise relevant to this report are summarised below.

- Hydrologic and hydraulic investigations of urban and rural floodplains.
- Floodplain risk management, flood response and flood warning.
- Environmental floodplain and wetland management.
- One and two-dimensional hydrodynamic modelling.
- Application of GIS for flood mapping and terrain modelling.

***Scope of contribution:***

Ben provided input to the response to submissions and oversaw previous modelling for the *Shepparton Mooroopna Flood Mapping and Intelligence Study* and the *Investigation Area 1 – Flood Behaviour* project. Ben undertook report writing and figure preparation under my supervision.

**Lachlan Inglis**

Project Engineer

Water Technology Pty Ltd

***Qualifications:***

- Bachelor of Environmental Engineering with Honours, Monash University, 2011

***Area of Expertise:***

Key areas of expertise relevant to this report are summarised below.

- Hydrologic and hydraulic investigations of urban and rural floodplains.
- Application of GIS for flood mapping and terrain modelling.

***Scope of contribution:***

Lachlan completed previous modelling for the *Shepparton Mooroopna Flood Mapping and Intelligence Study* and the *Investigation Area 1 – Flood Behaviour* project. Lachlan undertook report writing and figure preparation under my supervision.

# 4 SCOPE OF REPORT

In relation to Amendment C199 of the Greater Shepparton Planning Scheme, I have been requested to provide an expert report on the matters listed below:

- History and nature of my involvement in this Amendment;
- The framework that applies to flood investigations in Victoria, including any requirements, guidelines and industry best practice;
- The work involved in the *Investigation Area 1 – Flood Behaviour* report, specifically the previous modelling for the *Shepparton Mooroopna Flood Mapping and Intelligence Study*, including the data used, technical approach, flood modelling, and outputs generated.

# 5 REPORT

## 5.1 Amendment C199 of the Greater Shepparton Planning Scheme

The proposed planning Amendment C199 states:

> Amend Schedule 4 to the Special Use Zone, Clause 21.04 Settlement, Clause 21.05 Environment and Clause 21.08 General Implementation to implement the findings of *the Goulburn Valley Harness and Greyhound Racing Precinct Feasibility Study and Master Plan*, July 2016, include it as a reference document at Clause 21.09 Reference Documents, and strengthen the policy guidance for Investigation Areas where an investigation area study has been completed.

The Master Plan has considered the nature of flooding in Investigation Area 1, of which the report *Investigation Area 1 – Flood Behaviour* (Water Technology, 2016), was the primary source of information, along with the existing flood controls currently in the Greater Shepparton Planning Scheme.

## 5.2 Study Area

The study area, known as Investigation Area 1, is located at Kialla on the southern fringes of the Shepparton urban area. The area extends over 301 hectares which includes the Goulburn Valley Harness and Greyhound Racing Precinct. The site includes around 40 hectares of the Kialla Paceway precinct which is zoned as Special Use Zone (SUZ4), the remaining area includes approximately 232 hectares of Farming Zone (FZ2), as well as two small areas totalling 29 hectares of Urban Floodway Zone (UFZ). The majority of the site has previously been identified as flood prone, with 209 hectares covered by a Land Subject to Inundation Overlay (LSIO), 45 hectares covered by Floodway Overlay (FO) and 29 Hectares within the UFZ as mentioned above. The current flood related zone and overlays are shown in Figure 5-1.

Seven Creeks flows across the south-west corner of Investigation Area 1, crossing Mitchell Road on the southern boundary and the Goulburn Valley Highway on the western boundary. A smaller anabranch of Seven Creeks runs through the north-west corner of the site. This anabranch has been significantly modified into a straighter drainage channel through the site. The anabranch travels north-west across the site from Archer Road to River Road, where it travels through a series of on farm crossings, under the Goulburn Valley Highway, and continues in a north westerly direction through a large wetland before returning to Seven Creeks. Flow into the anabranch breaks away from Seven Creeks around 2 km upstream of Investigation Area 1 and is controlled by a subway beneath a Goulburn-Murray Water (GMW) channel.

The site slopes to the north-west on a very flat gradient (approximately 1 in 1600). Surface elevations extracted from Light Detection and Ranging (LiDAR) topography show a maximum elevation of 115.50 m AHD in the south-east corner of the site, through to a minimum elevation of 114.0 m AHD at the north-west corner of the site, as shown in Figure 5-2. Several GMW channels traverse the site which form part of the 'backbone' and 'non-backbone' network of irrigation supply channels, including the No. 6 Main Channel which runs east-west through the middle of the site, immediately south of the Kialla Paceway.

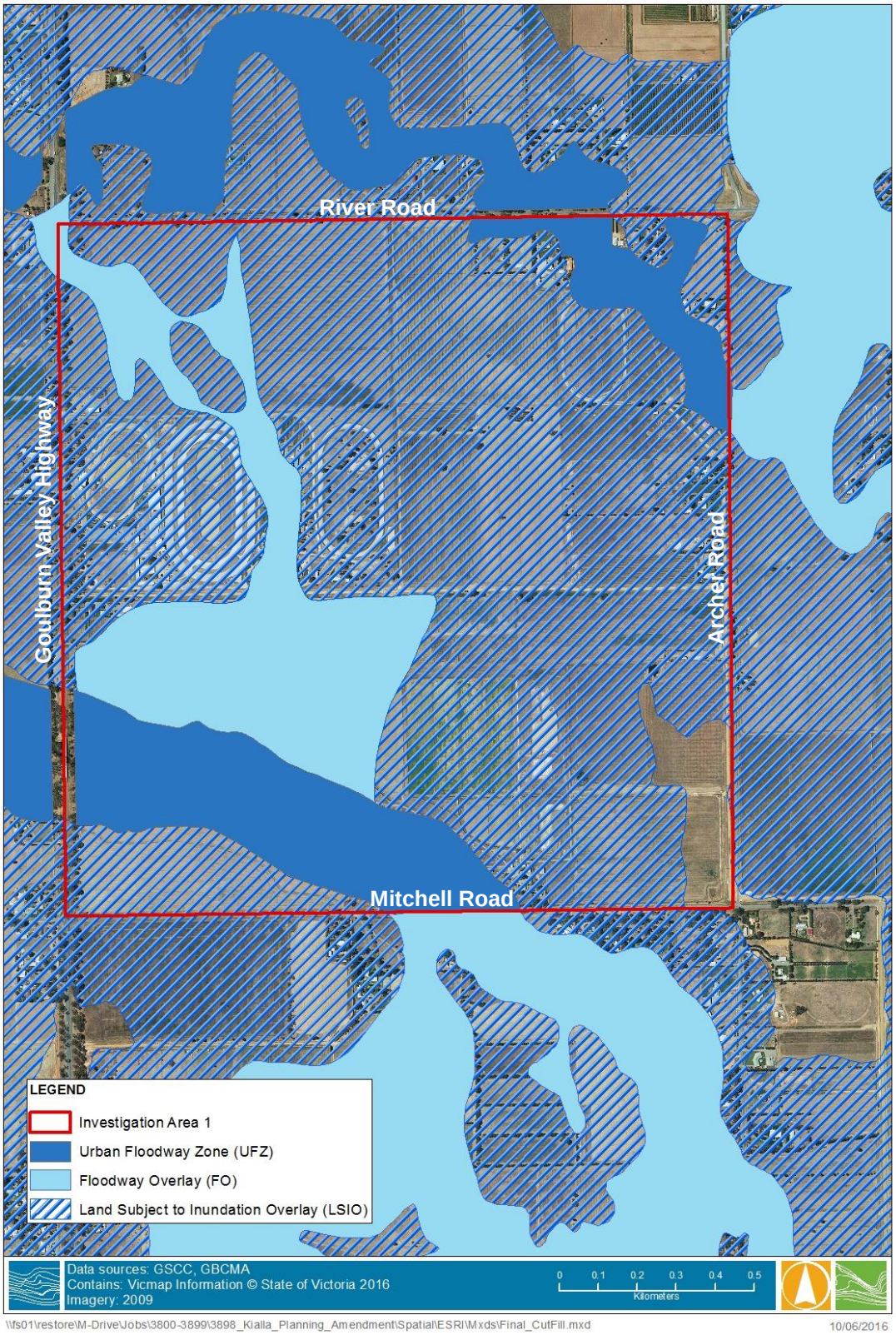


**FIGURE 5-1 EXISTING FLOOD CONTROLS IN THE GREATER SHEPPARTON PLANNING SCHEME**

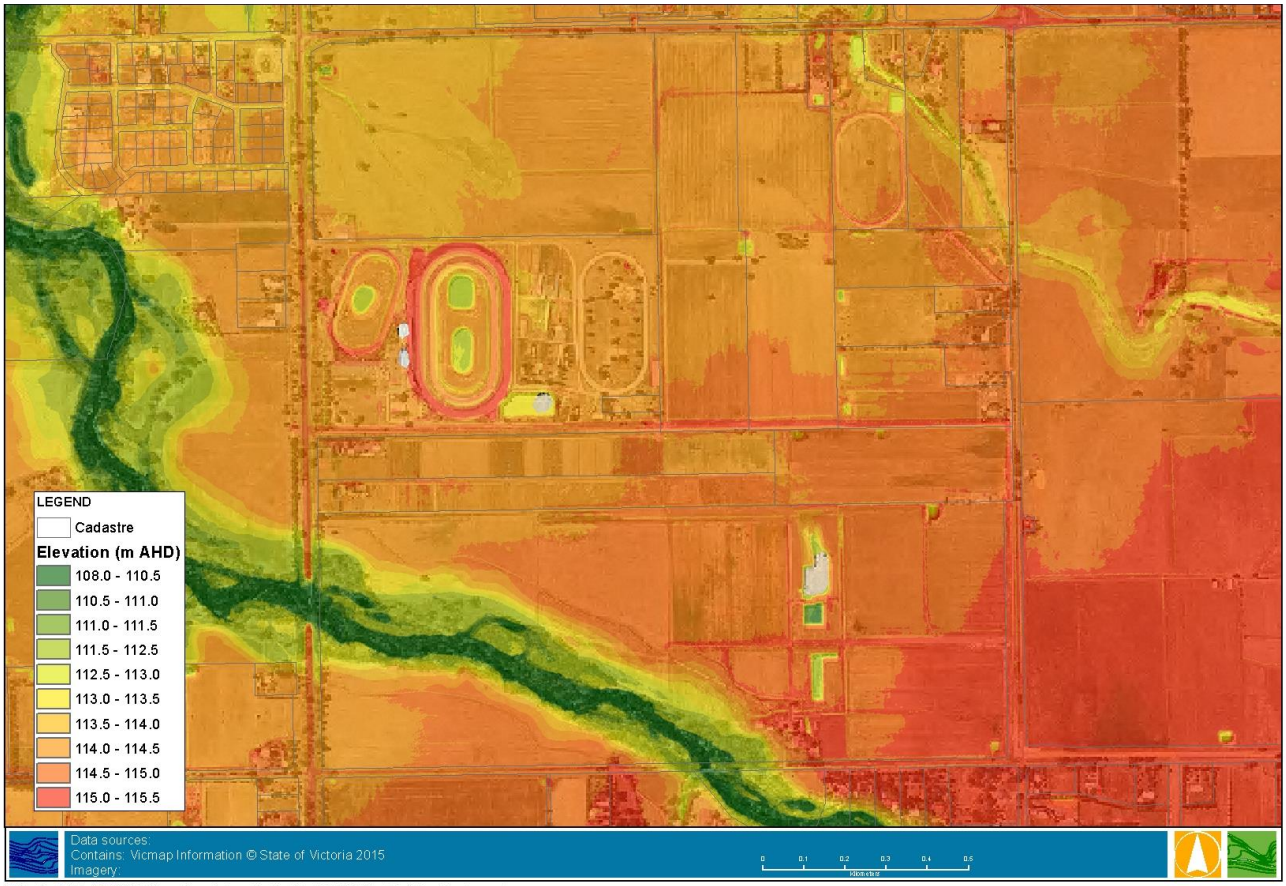


**FIGURE 5-2 SITE TOPOGRAPHY**

## 5.3 Flood Investigation Framework

The *Victorian Floodplain Management Strategy* (DELWP, 2016) in *Section 11 Evaluating Flood Risk*, lists the components typically expected of a Flood Study in Victoria. It is noted that this is a comprehensive list of what a Flood Study should entail, and often the scope of a Flood Study as determined by a local Council, Catchment Management Authority, DELWP, or other entity, may be different to that described in the *Victorian Floodplain Management Strategy (VFMS)*. The definition of a Flood Study within the VFMS, whilst not explicitly stated, is generally understood to refer to a comprehensive township or locality-based study that aims to address all aspects of flood risk and outline options for structural and non-structural flood mitigation measures. These studies are typically funded jointly by local, state and federal governments.

Not all flood studies have the same requirements or goals and hence the scope can vary between studies. For example some studies are commissioned by land-owners to address specific flood risk at the property scale.

Figure 5-3 outlines a standard approach to Flood Study undertaken in Victoria. Depending on the scope of the study, all, or only some of the components may be undertaken.

Typically, a municipal Flood Study is overseen by a project steering committee, comprising of a range of representatives. They often include representatives from the State Government, the relevant Catchment Management Authority, the relevant Council(s), Victoria State Emergency Service (VICSES), and sometimes one or more community representatives. Other agencies that may be involved include the Bureau of Meteorology, VicRoads, VicTrack and the relevant urban or rural water authority.

The project steering committee typically meets over the course of the study; at project inception, on completion of the hydrology and/or hydraulics components, during or following the mitigation options (if included), and on completion of the investigation. The project steering committee also receives copies of the draft project reports for review prior to finalisation of each component of the study.

In some Flood Studies, the complexity of the floodplain and associated flood behaviour means a joint calibration approach between the hydrology and hydraulics components may be required. This is the case with the current *Shepparton Mooroopna Flood Mapping and Intelligence Study*.

Independent technical experts appointed by DELWP also review the technical components of the study which often include:

- Data review and proposed methodology,
- Hydrology,
- Hydraulics.

There may be one or more technical reviewers for each technical component and they provide detailed feedback to the agency coordinating the study. Review comments are categorised according to their importance to the outcomes of the study and whether further analysis or resolution of the issue identified is required prior to approval of the technical work. This is provided to the consultant who must address all comments and issues. This may require a further round of technical review. The project will not progress until all critical issues are resolved. For the *Shepparton Mooroopna Flood Mapping and Intelligence Study* the technical review panel have now reviewed the *Data Collation, Hydrology and Hydraulic Calibration* report and Water Technology have addressed all comments to the satisfaction of Greater Shepparton City Council and Goulburn Broken CMA.

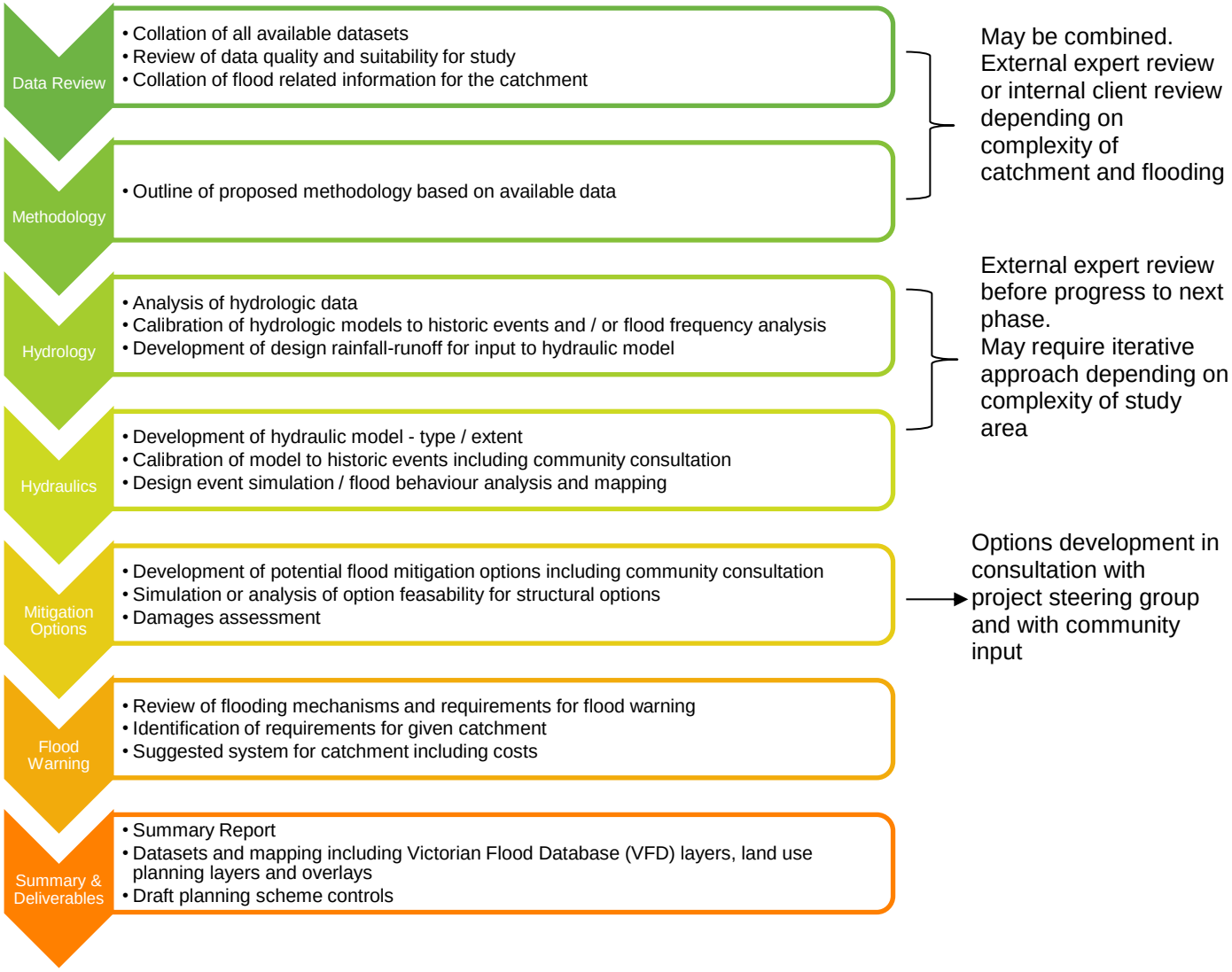


**Figure 5-3 Flood Study Framework in Victoria**

Industry best practice with regard to specific technical components of flood study investigations is outlined in Australian Rainfall and Runoff (2016). These guidelines are published by Geoscience Australia and contain a series of books and chapters providing technical guidance on the approaches related to hydrologic and hydraulic investigations.

The latest revision process for Australian Rainfall and Runoff was underway during the *Shepparton Mooroopna Flood Mapping and Intelligence Study* and where applicable the latest approaches or updates have been incorporated into the relevant analysis. The independent technical experts who reviewed the project also provided feedback on the applicability of any relevant revised approaches.

## 5.4 Existing Reports

### 5.4.1 Shepparton Mooroopna Floodplain Management Study (2002)

The Shepparton Mooroopna Floodplain Management Study was undertaken in 2002 by Sinclair Knight Merz in conjunction with Lawson and Treloar Pty Ltd. This study used numerical floodplain modelling to calibrate the flood events of 1974 and 1993 to within +/- 500 mm of observed flood levels. The model topography utilised photogrammetry flown in September 1999 and a model grid resolution of 12.5 m for the 'inner area' and 25 m in the 'outer area' was applied. Investigation Area 1 is within the 'outer area'.

The modelling undertaken in this study formed the basis for the current planning scheme flood-related zone and overlays. The existing 1% AEP flood levels for Investigation Area 1 range from 115.4 m AHD in the south-east to 114.2 m AHD in the north-west. This study involved extensive community consultation including the distribution of resident surveys/questionnaires to 18,000 properties. A total of 941 responses were received which included approximately 300 references to flood marks. Where possible, these flood marks were surveyed and used in the hydraulic model calibration.

### 5.4.2 Flood Warning and Emergency Management Report (2007)

Water Technology completed a Flood Warning and Emergency Management Report for Greater Shepparton City Council in 2007. This involved implementing a number of recommendations from the SKM (2002) study regarding flood preparedness, flood warning, flood response and the development of improved information management systems. This project developed property-specific flood charts for over 6,000 properties within the flood risk area, a flood monitoring plan and community flood alerting system.

### 5.4.3 Shepparton Mooroopna Flood Mapping and Intelligence Study (ongoing)

This study was initiated following significant flood events throughout Victoria from 2010 through to 2012, with major flooding at Shepparton in September 2010. Prior to these events the Shepparton Mooroopna area experienced significant flooding in 1870, 1916, 1939, 1956, 1974 and 1993. Advancements in hydrology approaches and hydraulic modelling, improved survey data and flood mapping procedures since the SKM (2002) study, and the recent September 2010 event highlighted the need for a revised flood investigation at a higher resolution for Shepparton and Mooroopna.

A key outcome of this study is to produce outputs that can be used in the future to update existing planning controls across the wider Shepparton and Mooroopna area, including the Investigation Area 1 site. The project will also produce updated flood mapping and flood intelligence linked to gauge heights to allow community members and flood management agencies to better prepare for and respond to future floods. Hydraulic modelling for the *Shepparton Mooroopna Flood Mapping and Intelligence Study* used high resolution LiDAR survey, sampled on a 10 x 10 m grid resolution. An extensive calibration process was undertaken in conjunction with the Goulburn Broken CMA for three historical floods including comparison of modelled results to streamflow gauge records along with surveyed flood height marks from the 1993 and 2010 floods and further validated for the 1974 flood. Calibration of the surveyed flood marks aimed to replicate these levels within +/- 200 mm.

The use of aerial imagery for validation was adopted with some caution as the timing of the photography does not coincide with the peak of the flood event. Additionally, local rainfall before, during or after the flood can cause inundation or ponding of water in areas which may not be influenced by flooding from the main river system, as is the case in Shepparton East. The calibration process undertaken for this investigation is discussed in Section 5.5.2. At the time the *Investigation Area 1 – Flood Behaviour* project was undertaken, the calibration of the model to historical events had been completed along with 1% AEP design modelling. Since

the submission of the *Investigation Area 1 – Flood Behaviour* report, the *Data Review, Hydrology and Hydraulic Calibration* report has been submitted and reviewed by the DELWP technical review panel. The development of design flood conditions for the *Shepparton Mooroopna Flood Mapping and Intelligence Study* are detailed in Section 5.5.3. The flood mapping outputs from this study are likely to be adopted into the Greater Shepparton Planning Scheme subject to a future Planning Scheme Amendment.

### 5.4.4 Investigation Area 1 – Flood Behaviour (2016)

Water Technology was engaged in 2015 by Greater Shepparton City Council to undertake modelling of flood behaviour for the area known as Investigation Area 1 (*Greater Shepparton Housing Strategy*, 2011). The model of flood behaviour included a comparison of existing flood behaviour with the proposed design conditions based on a Master Plan developed by Urban Enterprise Pty Ltd as part of the *Goulburn Valley Harness and Greyhound Racing Precinct Feasability Study and Master Plan (2016)*.

The model of flood behaviour developed for Investigation Area 1 utilised the modelling being undertaken for the ongoing *Shepparton Mooroopna Flood Mapping and Intelligence Study* to maintain consistency. This involved utilising the same hydrology design conditions along with the same hydraulic model parameters on a localised model extent. Checks were completed to ensure existing conditions flood levels matched the broader flood study results. Details of the hydrology and hydraulic parameters are discussed in Section 5.6.

Ben Tate and Lachlan Inglis prepared the report and briefed Greater Shepparton City Councillors on the work undertaken for the *Investigation Area 1 – Flood Behaviour*. This included discussing the results of the existing conditions modelling, the initial masterplan conditions and three further iterations to the Master Plan design that aimed to meet the criteria put forth by Goulburn Broken CMA and the Greater Shepparton City Council planning team. The criteria was to ensure that the proposed Master Plan did not adversely impact properties outside of the Investigation Area 1 by changing the course of flow, raising flood levels or increasing flood risk.

Following the submission of the *Investigation Area 1 – Flood Behaviour* report, Lachlan Inglis from Water Technology met and discussed the results of the study with a number of land holders from within Investigation Area 1 at the Greater Shepparton City Council offices.

## 5.5 Study Process

The following section details the methodology undertaken to develop the hydrology and hydraulic models for the *Shepparton Mooroopna Flood Mapping and Intelligence Study* and how the flood model was then adapted for the *Investigation Area 1 – Flood Behaviour* project.

### 5.5.1 Methodology Outline

Based on the results of the data review an outline of the proposed technical methodology was developed and detailed in Water Technology (2017). As noted in the report, the detailed methodology developed for the hydrologic and hydraulic modelling was subsequently modified and updated as the project progressed. The final approach adopted for the *Shepparton Mooroopna Flood Mapping and Intelligence Study* is detailed in the *Data Review, Hydrology and Hydraulic Calibration* report (Water Technology, 2017).

### 5.5.2 Hydrologic and Hydraulic Calibration

Water Technology (2017) details the combined hydrologic and hydraulic modelling aspects of the investigation. These components have been included in a combined report due to the technical approach adopted.

Due to the large and complex nature of the Goulburn River, Broken River and Seven Creeks catchments, and the previous difficulties with hydrologic calibration reported by SKM (2002), a traditional rainfall-runoff hydrologic modelling approach (RORB) was not suitable to generate inflows for the hydraulic model. This is

largely due to the number of hydraulic controls (irrigation channels, drains and roadways), significant storages such as Lake Eildon, and cross-catchment flows in the Seven Creeks catchment. A hydrology approach very similar to SKM (2002) was adopted, primarily relying on streamflow data. Where good quality, long-term gauge record is available at a site, a Flood Frequency Analysis (FFA) is the best hydrology approach to adopt for a flood mapping study. To generate flows for the calibration events, the methodology included:

- Use of upstream flow gauge records on the Goulburn River (Murchison) and Broken River (Casey's Weir and Gowangardie); and
- Additional routing within hydraulic models from the abovementioned established gauge locations to the township model boundary to aid in defining time lags between upstream gauges and model inflow boundaries;
- Development of a relationship with upstream flow gauges on the Seven Creeks system to help infill flow data gaps at the Seven Creeks at Kialla West gauge;
- Updated Flood Frequency Analysis (FFA) on all available gauges within the study area; and
- A rating curve review at the Goulburn River at Murchison streamflow gauge. The review was initially undertaken as part of the *Murchison Flood Mapping Study* (Water Technology, 2014).

It was recognised that the development and calibration of a hydrological model for the Shepparton-Mooroopna area is a complex. This is due to the culmination of three waterway systems (Goulburn River, Broken River and Seven Creeks) at one location. Figure 5-4 shows the current streamflow gauge locations and the flood mapping study area.

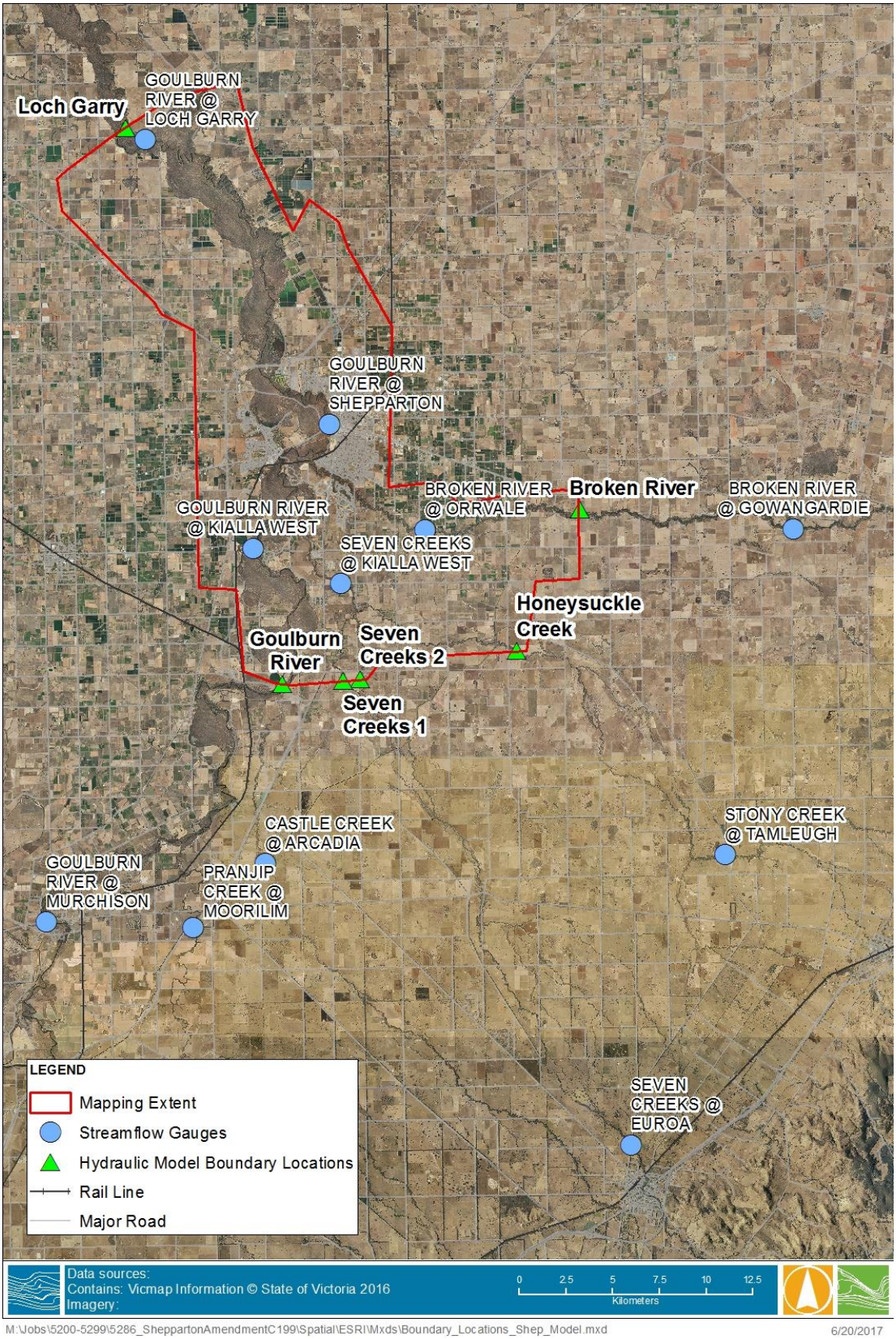


**FIGURE 5-4 STREAMFLOW GAUGE AND HYDRAULIC MODEL INFLOW LOCATIONS**

A detailed combined 1D-2D hydraulic model of the township and surrounding floodplain was developed for the determination of flood levels and extents over a range of historical and design floodss. The calibrated hydraulic model simulates flood flow behaviour of the Goulburn River, Broken River and Seven Creeks as well as the overbank flow throughout the floodplain. The hydraulic modelling approach consisted of the following components:

- One dimensional (1D) hydraulic model of key hydraulic structures, pipes and river channels.
- Two dimensional (2D) hydraulic model of the Shepparton, Mooroopna, Kialla areas at a 10 m grid resolution.
- Two dimensional (2D) hydraulic model of remaining waterways and the broader floodplain downstream of the Shepparton Golf Course at a 20 m grid resolution.
- Links between the 1D and 2D hydraulic models to integrate the 1D hydraulic components with the broader floodplain flow.

The hydraulic modelling software TUFLOW was used for this study. TUFLOW is an industry standard tool for flood modelling.

It was also necessary to balance model resolution with the computational time requirements to ensure the modelling simulations were maintained at a manageable time frame. Different grid resolutions were tested during the initial model development to optimise the choice of the two grid sizes. The grid resolutions used on the *Shepparton Mooroopna Flood Mapping and Intelligence Study* are typical of large 2D flood models for rural and urban areas in Victoria. Features such as roadways, irrigation channels and embankments which have the potential to influence flood behaviour are specifically incorporated into the model grid during the model development. The accuracy of levels associated with these features is then checked during the model calibration process.

Both the hydrologic and hydraulic model underwent a rigorous calibration process that was carried out in consultation with the Goulburn Broken CMA. The calibration process consisted of systematic comparison of observed and modelled flow and flood levels. A robust calibration requires the comparison of modelled and observed flood behaviour across a range of flow magnitudes. The historical flood events used to calibrate/validate the models were chosen based on available observed flood information and the need to provide a range in event magnitudes to ensure the model performs across a spectrum of flood severity.

The calibration process was undertaken in two stages; firstly a hydraulic calibration to observed flood levels and extents for the 1993 and 2010 flood events; secondly, a validation to the 1974 flood.

- The hydraulic calibration process incorporated detailed comparisons between observed and modelled flood levels and flood extents. The model parameters were adjusted to minimise the differences between the modelled and observed data. The September 2010 and October 1993 events were selected for calibration given their relatively large magnitude and reasonable abundance of observed flood information.
- Validation to the 1974 Goulburn River dominant flood was also included. This event had less available flood information and a higher degree of uncertainty in the floodplain topography and infrastructure present at the time of the flood.

Figure 5-5 to Figure 5-7 show the calibration to surveyed flood marks for the 1993 and 2010 calibration events and the 1974 validation event. The results show the model generally replicated the surveyed flood levels in the proximity of Investigation Area 1 well. The 1993 event modelled flood calibration points had 51 of the 66 (77%) within a 200 mm tolerance. The 2010 flood event matched 12 of the 15 (80%) of the surveyed flood levels within 200 mm. The 1974 validation results show the modelled flood height to be around 400 mm higher at the Goulburn Highway and along Seven Creeks. Given the uncertainty in our representation of the floodplain topography at that time, including the location and height of floodplain features like levees, roads and channel banks, this event was used as a validation event. 60% of the modelled validation points were within a 200 mm tolerance, which is considered an acceptable outcome.

The hydrology and hydraulic model calibration was independently reviewed by the DELWP technical review panel. The review feedback considered the model calibration to historical flood events to be acceptable.

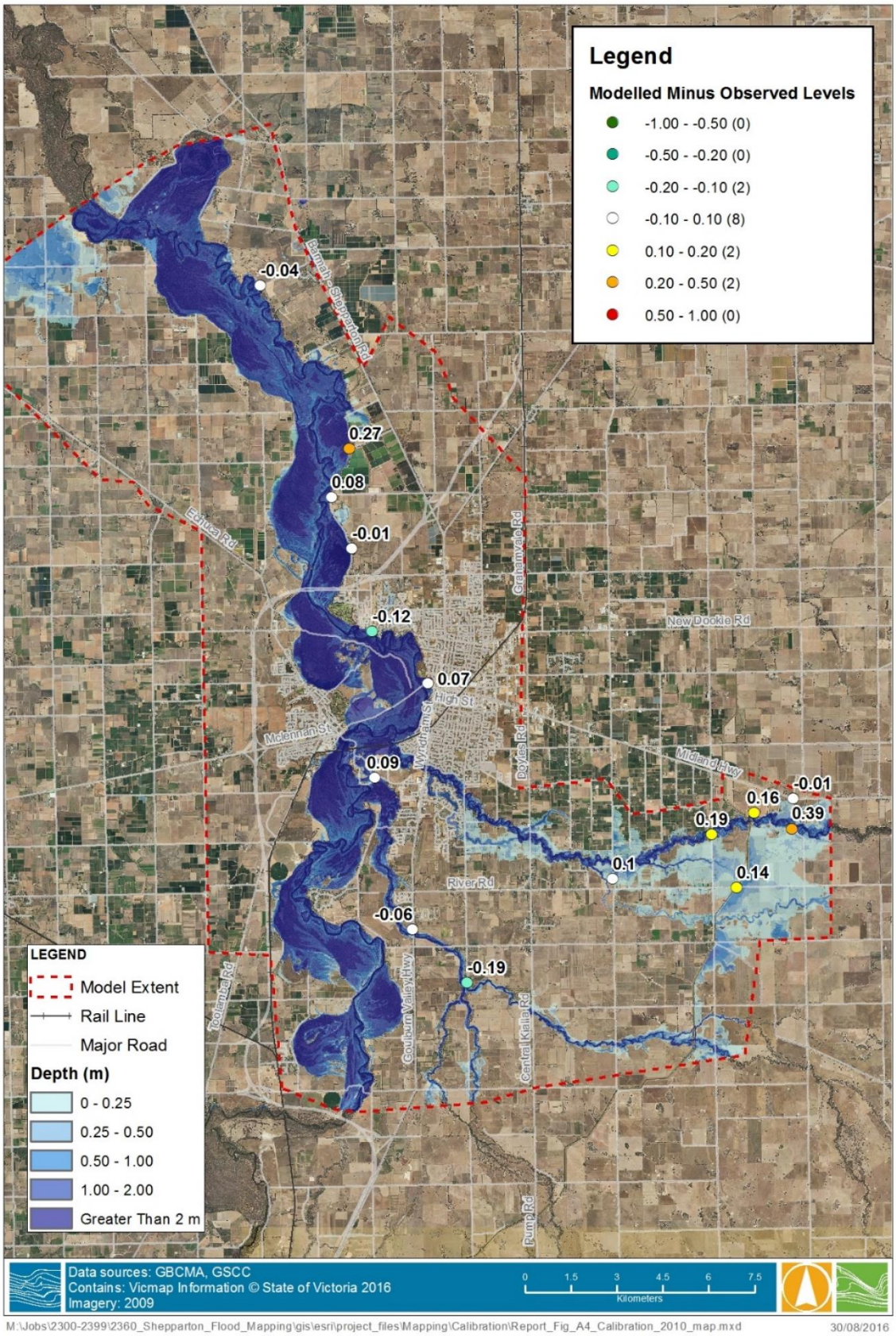


**FIGURE 5-5 SEPTEMBER 2010 MODLLED MINUS OBSERVED WATER LEVELS - CALIBRATION PLOT**

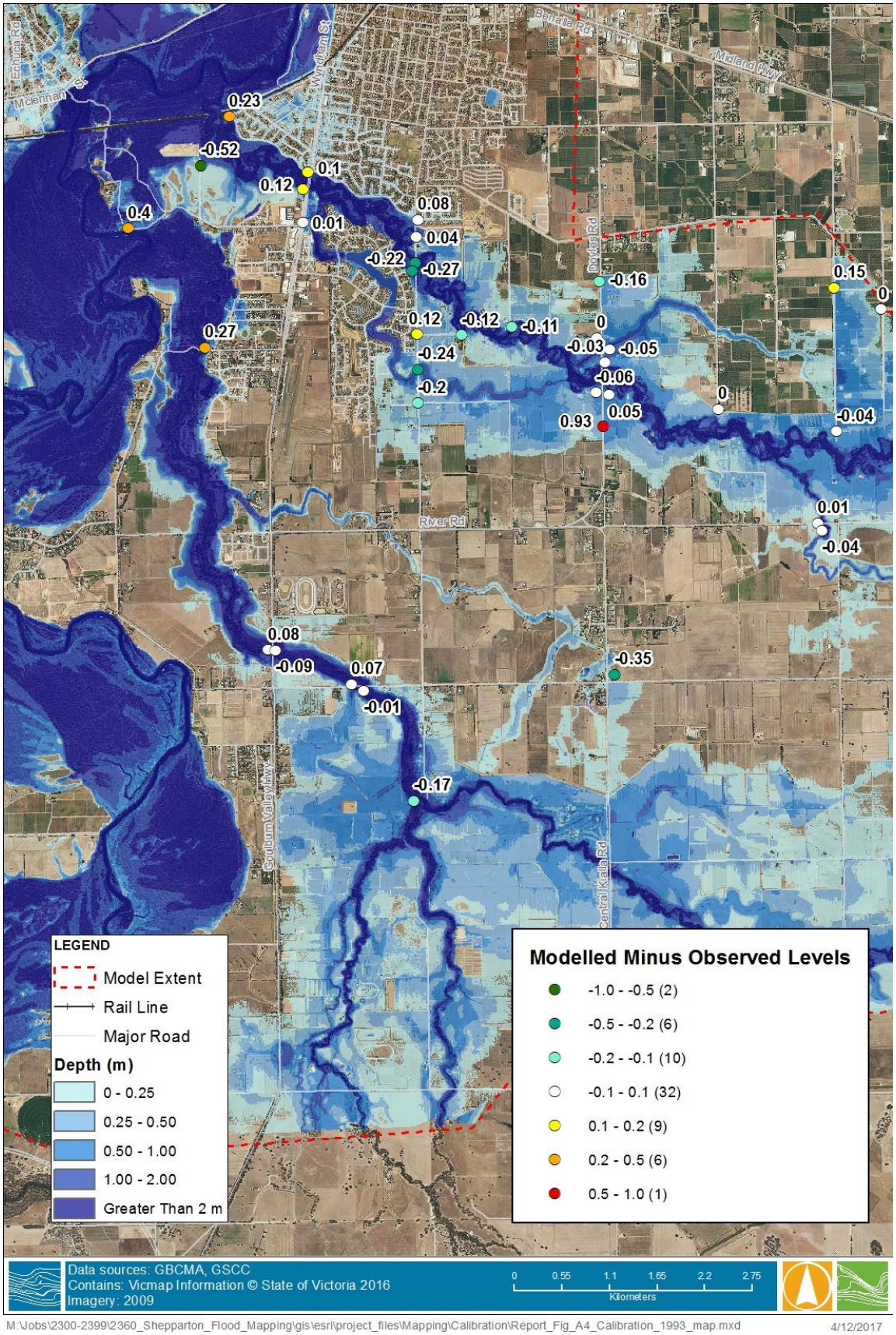


**FIGURE 5-6 OCTOBER 1993 MODLLED MINUS OBSERVED WATER LEVELS - CALIBRATION PLOT**

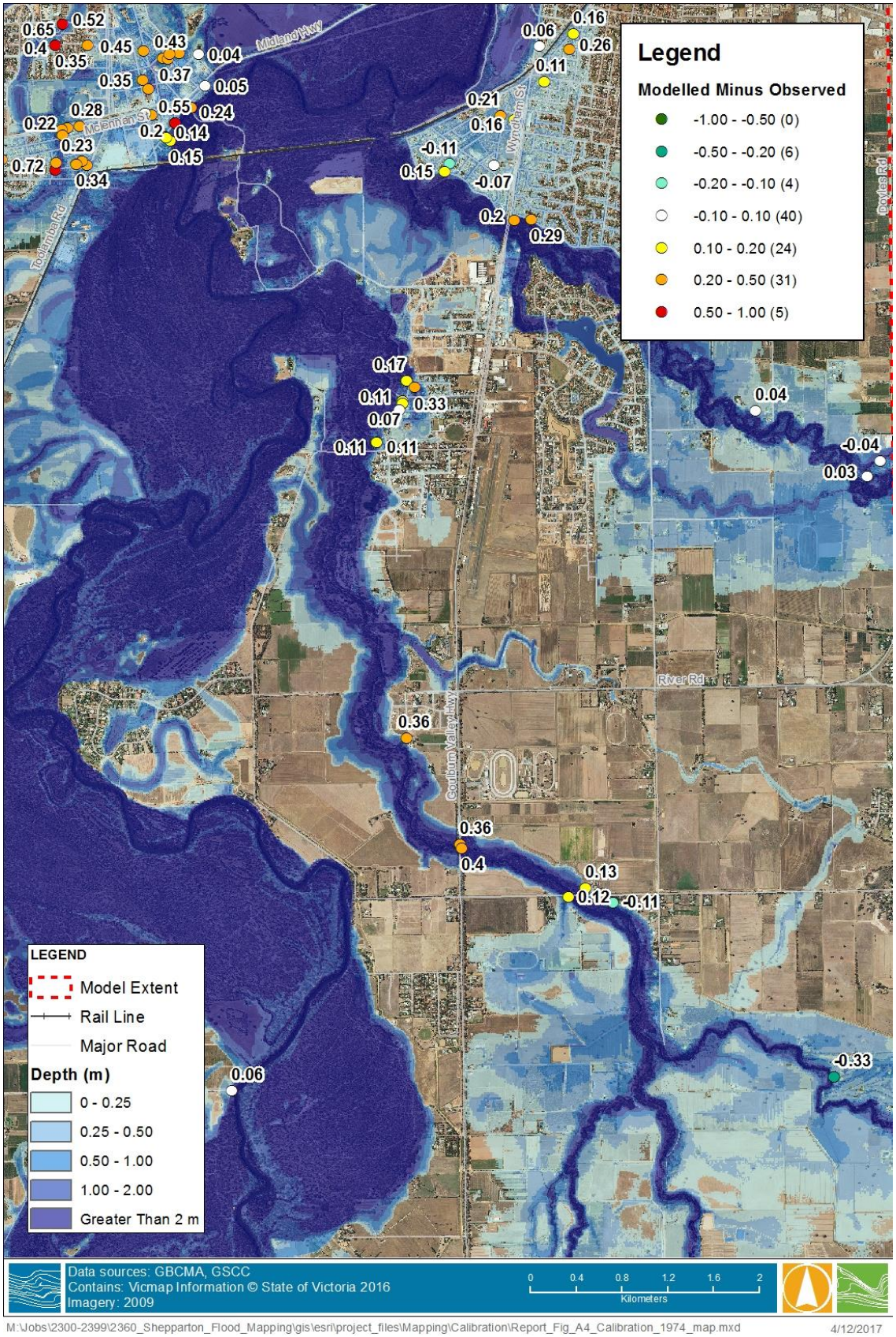


**FIGURE 5-7 MAY 1974 MODLLED MINUS OBSERVED WATER LEVELS - VALIDATION PLOT**

### 5.5.3 Hydrologic and Hydraulic Design Modelling

The following section describes the methods used to develop the inflow boundaries for the *Shepparton Mooroopna Flood Mapping and Intelligence Study* hydraulic model.

#### SEVEN CREEKS FLOWS

The Seven Creeks system has a large catchment area with Seven Creeks and Honeysuckle Creek combining 1.8 km upstream of the Seven Creeks @ Kialla West gauge. The inflow boundaries to the detailed Shepparton-Mooroopna hydraulic model are further upstream on both these tributaries. The Honeysuckle Creek inflow boundary is located upstream of the Shepparton-Euroa Road, and the Seven Creeks inflow boundaries are split on the two anabranches of the creek upstream of Union Road.

To develop historic and design flows for Seven Creeks and Honeysuckle Creek, the Seven Creeks at Kialla West gauge was used as a combined flow, which was then split evenly between the two tributaries. The even split was based on the catchment areas which are roughly the same. This split was later verified through hydraulic model calibration.

In order to develop the combined flow estimate at Kialla West, a regression analysis was used with upstream gauges in both catchments to extend the estimated streamflow record for the Seven Creeks at Kialla West streamflow gauge. Without this regression analysis, the period of record was too short to complete a reliable flood frequency analysis. This system has significant cross-catchment flows making hydrological catchment modelling difficult, necessitating the flood frequency approach.

A flood frequency analysis on the extended gauge record was then undertaken. The resulting peak flow estimates are provided in Table 5-1. Approximate AEPs for the three flood events that were calibrated are provided in Table 5-2.

Whilst the resultant design flows in this analysis are slightly higher than those estimated in the SKM (2002), they are considered to provide reasonable peak design flood estimates. The flow values calculated from the flood frequency analysis were split and placed several kilometres upstream of the Seven Creeks @ Kialla West (405269) streamflow gauge on the Seven Creeks and Honeysuckle Creek System as described above. It is likely that some attenuation may occur between the inflow locations and the streamflow gauge.

**TABLE 5-1 DESIGN PEAK FLOWS FOR SEVEN CREEKS @ KIALLA WEST (405269)**

| AEP | ARI (1 in X years) | SKM (2002) Method Peak Flow (ML/d) | Updated Method Peak Flow (ML/d) |
|---|---|---|---|
| 20% | 5 | 17,000 | 21,400 |
| 10% | 10 | 27,100 | 33,400 |
| 5% | 20 | 38,700 | 46,300 |
| 2% | 50 | 56,600 | 64,100 |
| 1% | 100 | 72,300 | 77,700 |
| 0.5% | 200 | 89,600 | 91,200 |
| 0.2% | 500 | 115,000 | 108,703 |

**TABLE 5-2 HIGHEST RECORDED FLOWS AND CORRESPONDING AEP FOR SEVEN CREEKS @ KIALLA WEST (405269)**

| Year | Peak Flow (ML/d) | Approx. AEP |
|---|---|---|
| 1993 | 62,000* | 2% |
| 1974 | 50,000** | 5-2% |
| 2010 | 20,500 | 20% |

*Estimated based on Shepparton-Mooroopna Flood Study (SKM, 2002)
**Estimated based on Regression Equation with Seven Creeks at Euroa streamflow gauge

### BROKEN RIVER FLOWS

The Broken River inflow boundary to the detailed Shepparton-Mooroopna hydraulic model was located approximately 1.5 km upstream of the East Goulburn Main Channel. To determine design hydrology for this location, a coarse Broken River model was developed from Gowangardie to downstream of the East Goulburn Main Channel. This model determined the magnitude of flow splits leaving the Broken River, and was used to determine the ratio of flows between the downstream Broken River at Orrvale gauge and the inflow boundary to the detailed Shepparton-Mooroopna flood model. A flood frequency analysis on the Orrvale gauge was completed and flows at the inflow boundary upstream of the East Goulburn Main Channel were scaled up using the ratio determined from the coarse Broken River modelling. The inflow boundary was scaled up as it was demonstrated that breakouts occur away from the river and the East Goulburn Main Channel redirects some of the flow, reducing the flow passing the Orrvale gauge.

The resulting peak flow estimates are provided in Table 5-3. The resulting 1% AEP flow was broadly consistent with (but slightly higher than) the SKM (2002) estimate, which was derived from a regression relationship with Broken River at Benalla.

Under this distribution, the 1993 flood has an AEP of between 2% and 1%, and the 1981, 2010 and 1996 floods have an AEP between 10% and 5% (Table 5-4).

**TABLE 5-3 DESIGN PEAK FLOWS FOR BROKEN RIVER @ ORRVALE (404222)**

| AEP | ARI (1 in X years) | GEV Peak Flow (ML/d) 11 low flows censored |
|---|---|---|
| 20% | 5 | 17,900 |
| 10% | 10 | 24,800 |
| 5% | 20 | 31,600 |
| 2% | 50 | 40,800 |
| 1% | 100 | 48,000 |
| 0.5% | 200 | 55,400 |
| 0.2% | 500 | 65,600 |

**TABLE 5-4 HIGHEST RECORDED FLOWS AND CORRESPONDING AEP FOR BROKEN RIVER @ ORRVALE (404222)**

| Year | Peak Flow (ML/d) | Approx. AEP |
|---|---|---|
| 1993 | 42,900 | 2-1% |
| 1981 | 28,300 | 10-5% |

| Year | Peak Flow (ML/d) | Approx. AEP |
|---|---|---|
| 2010 | 27,300 | 10-5% |
| 1996 | 27,100 | 10-5% |

Using the relationship developed between the Gowangardie streamflow gauge to downstream of the East Goulburn Main Channel. Design flows for the additional hydraulic model inflow location south of the Broken River (to account for out of bank flows leaving the Broken River) were developed. This hydraulic model inflow location is shown in Figure 5-4. The design estimates for the Broken River inflow and the inflow to the South of the Broken River are listed in Table 5-5. The combination of these flows is generally higher than the design flows listed in Table 5-4 due to attenuation and cross catchment flows.

**TABLE 5-5 DESIGN PEAK FLOWS FOR BROKEN RIVER INFLOW BOUNDARIES**

| AEP | ARI (1 in X years) | Broken River Boundary Peak Flow (ML/d) | Boundary Location South of the Broken River Peak Flow (ML/d) |
|---|---|---|---|
| 20% | 5 | 17,900 | 0 |
| 10% | 10 | 24,800 | 4,800 |
| 5% | 20 | 31,600 | 11,100 |
| 2% | 50 | 40,800 | 13,000 |
| 1% | 100 | 48,000 | 15,400 |
| 0.5% | 200 | 55,400 | 17,300 |
| 0.2% | 500 | 65,600 | 19,000 |

### GOULBURN RIVER FLOWS

Historic hydrographs from Murchison were routed through a coarse Goulburn River model to the detailed Shepparton-Mooroopna flood model inflow boundary (shown in Figure 5-4) to provide an estimate of model routing time. These routing times were also applied to the design hydrographs from Murchison to the model inflow boundary. The tributary inflows from Castle Creek and Pranjip Creek were also assessed, but after an analysis of both gauges it was found the gauge rating curves for both sites were highly uncertain for flood flows. Given their contributions are relatively small, a simplified approach of adding a small flow contribution from the two gauges to the design event was adopted. This involved increasing the Murchison flows by 10,000 ML/d for the 1% AEP design event.

An extensive rating curve review for the Murchison streamflow gauge was undertaken in a previous investigation (Water Technology, 2014). This involved developing a revised rating curve. The annual maximum flow series was constructed utilising the revised rating curve for levels in the extrapolated region of the rating curve. The annual series was then used to develop a revised Flood Frequency Analysis (FFA). The FFA undertaken on the full record period produced peak flow estimates that were lower than or equal to the post-Big Eildon Dam (Construction of the Big Eildon Dam in 1916) record FFA for 2% AEP flows and above. The two time periods were then combined, adopting the post-dam period for events up to the 1% AEP and the full period for the rare 0.5% and 0.2% AEP events.

The *Shepparton Mooroopna Flood Mapping and Intelligence Study* has demonstrated that the revised rating curve is a better representation of the stage-flow relationship for larger events than the previous rating curve, fitting with the regional hydrology upstream and downstream, and the understanding of historic flood flows in the Goulburn River. The official rating curve for this gauge has been updated to reflect these changes. Table 5-6 was adopted for design flows at Murchison for the purposes of this study.

TABLE 5-6 DESIGN PEAK FLOWS FOR GOULBURN RIVER @ MURCHISON (405200), REVISED RATING CURVE DATA

| AEP | ARI (1 in X years) | GEV Peak Flow (ML/d) Post-Big Eildon Record 1956-2012 plus 1916 | GEV Peak Flow (ML/d) Entire Record 1881-2012 | Adopted Peak Flow (ML/d) |
|---|---|---|---|---|
| 20% | 5 | 49,100 | 59,700 | 49,100 |
| 10% | 10 | 69,000 | 78,600 | 69,000 |
| 5% | 20 | 90,900 | 97,700 | 90,900 |
| 2% | 50 | 123,900 | 123,900 | 123,900 |
| 1% | 100 | 152,600 | 144,700 | 152,600 |
| 0.5% | 200 | 185,200 | 166,500 | 166,500 |
| 0.2% | 500 | 235,200 | 196,900 | 196,900 |

TABLE 5-7 HIGHEST RECORDED FLOWS AND CORRESPONDING AEP FOR GOULBURN RIVER @ MURCHISON (405200), REVISED RATING CURVE DATA

| Year | Peak Flow (ML/d) | Approx. AEP |
|---|---|---|
| 1916 | 178,200 | 0.5-0.2% |
| 1956 | 123,200 | 2% |
| 1974 | 117,900 | 5-2% |
| 1993 | 80,000 | 10-5% |

### COMPARISON WITH SKM (2002)

Comparisons between the current 1% AEP peak flow estimates at streamflow gauges throughout the catchment with the SKM (2002) estimates are provided in Table 5-8. Most of the estimates are broadly consistent. The estimates for Goulburn River @ Murchison diverge due to the updated rating curve at Murchison.

TABLE 5-8 COMPARISON OF UPDATED DESIGN 1% AEP PEAK FLOWS WITH SKM (2002) ESTIMATES

| Gauge | 1% AEP Flow (Updated FFA) | 1% AEP Flow (SKM 2002) |
|---|---|---|
| Broken River @ Casey's Weir | ^ | 66,900 |
| Broken River @ Orrvale | 48,000 | 43,500 |
| Goulburn River @ Murchison | 152,600* | 134,000 |
| Goulburn River @ Shepparton | 213,200 | 219,000 |
| Seven Creeks @ Kialla West | 77,700 | 69,900 |

* *Updated FFA estimate using revised rating curve from hydraulic modelling*
^ *1% AEP Flow at Casey's Weir not reliable due to poor rating curve*

## 5.6 Adoption of Flood Model for Investigation Area 1 - Flood Behaviour

Water Technology was engaged in 2015 by Greater Shepparton City Council to undertake a model of flood behaviour for the area known as Investigation Area 1 (*Greater Shepparton Housing Strategy*, 2011). The model of flood behaviour included a comparison of existing flood behaviour with the proposed design conditions based on a Master Plan developed by Urban Enterprise Pty Ltd as part of the *Goulburn Valley Harness and Greyhound Racing Precinct Feasability Study and Master Plan*.

The existing *Shepparton Mooroopna Flood Mapping and Intelligence Study* TUFLOW hydraulic model was reduced in extent to include only the Seven Creeks system (Figure 5-8), in order to reduce model run times. The inflow boundaries for Seven Creeks were kept in the same location while the Honeysuckle Creek inflow was extracted along the East Goulburn Main Channel which was the boundary location of the new model. The downstream model boundary was located approximately 4 km downstream of the site. A downstream water level vs time boundary was extracted from the *Shepparton Mooroopna Flood Mapping and Intelligence Study* hydraulic model results. A 10 m grid resolution was maintained for the Investigation Area 1 model of flood behaviour, this was considered appropriate to resolve the physical features of the study area and to ensure consistency with the *Shepparton Mooroopna Flood Mapping and Intelligence Study*.

The 1% AEP model was simulated for the *Investigation Area 1 – Flood Behaviour* model and compared to the water surface levels from the *Shepparton Mooroopna Flood Mapping and Intelligence Study* (Figure 5-9). The results showed the peak flood levels matched well. The difference plot shows that levels in the southern part of the local model are 3-5 cm higher than the *Shepparton Mooroopna Flood Mapping and Intelligence Study*. This is likely due to minor changes in the boundaries and altering of the 2D model origins when resizing the grid. The hydraulic model was considered fit for purpose for use in the *Investigation Area 1 – Model of Flood Behaviour* Study.

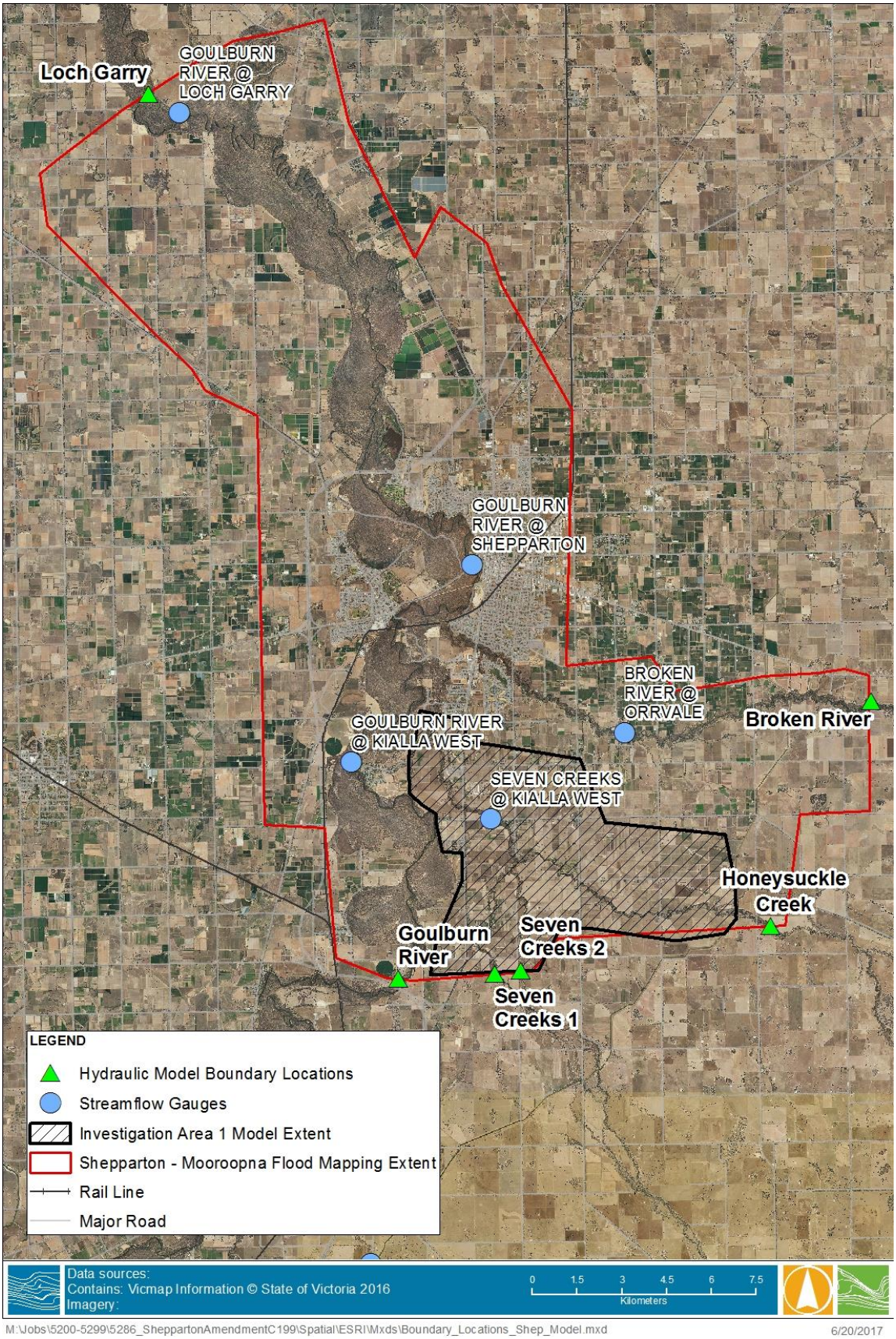


**FIGURE 5-8 INVESTIGATION AREA 1 FLOOD MODEL EXTENT**

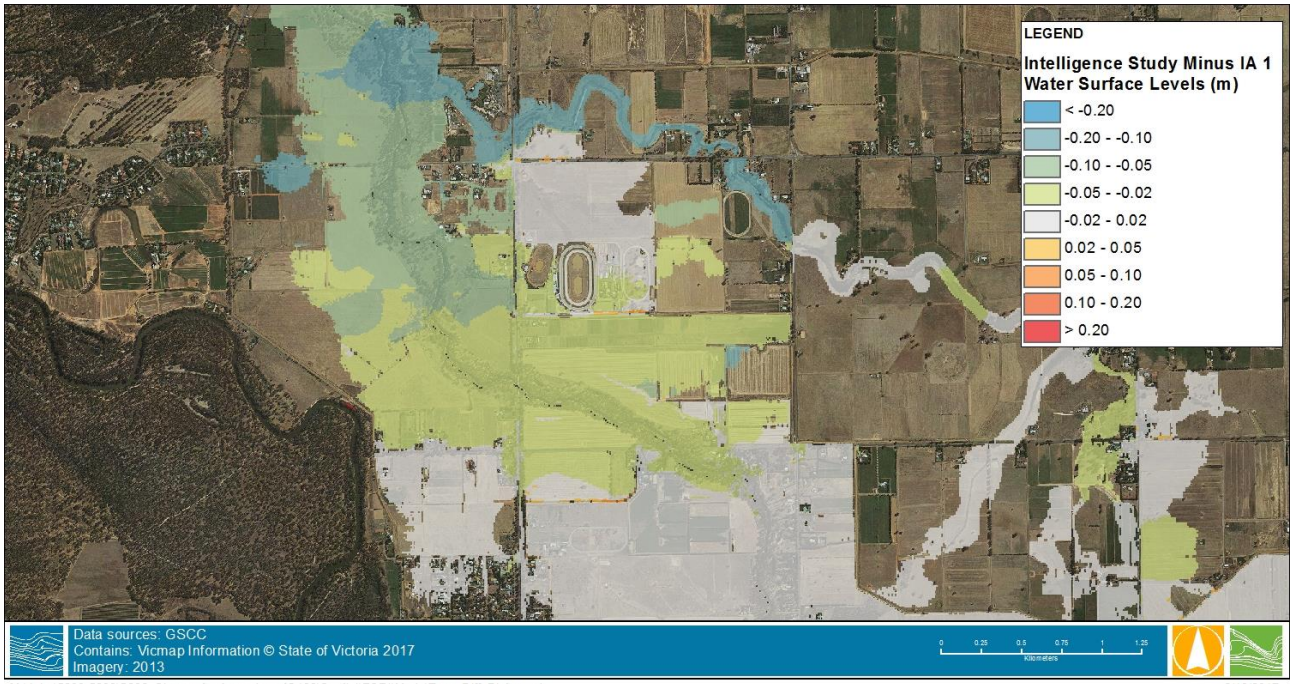


**FIGURE 5-9 COMPARISON OF EXISTING CONDITIONS 1% AEP FLOOD LEVELS BETWEEN SHEPPARTON MOOROOPNA MAPPING AND INTELLIGENCE STUDY AND INVESTIGATION AREA 1 - FLOOD BEHAVIOUR MODELS**

## 5.7 Investigation Area 1 Masterplan

The initial masterplan provided to Water Technology by Greater Shepparton City Council was produced by Urban Enterprise and is shown in Figure 5-10. Based on consultation with the Goulburn Broken CMA and Greater Shepparton City Council, changes to the topography identified in the initial masterplan were undertaken to reflect the initial zoning in the Master Plan. A summary of the changes based on zonings are listed below:

- Low Density Residential Zone (LDRZ) – Raised parcel above 1% AEP Flood Level
- Rural Residential Living – Building envelope (approx. 2500m$^2$) raised above 1% AEP Flood Level
- Rural Equine Living - Building envelope (approx. 2500m$^2$) raised above 1% AEP Flood Level
- Caravan Park - Raised parcel above 1% AEP Flood Level
- Integrated Holiday and Leisure Park - Raised parcel above 1% AEP Flood Level
- Recreation Equine Use- Not raised, can be used for Cut area
- Internal Roadways – 1% AEP Flood Depth not to exceed 0.30 metres
- Petrol Station/Truck Stop - Raised parcel above 1% AEP Flood Level
- Existing Paceway Area (Special Use Zone 4) – Level maintained

Furthermore, the No. 6 Main Channel located within the investigation area was to be maintained at existing surface levels to ensure no detrimental flooding impacts on downstream properties.

These changes to the topography were implemented based on the masterplan layout. The 1% AEP flood event was then simulated and a comparison with existing conditions flood levels was undertaken. The comparison of flood levels with existing conditions found that the changes to the topography resulted in increased water levels off site, Figure 5-11.

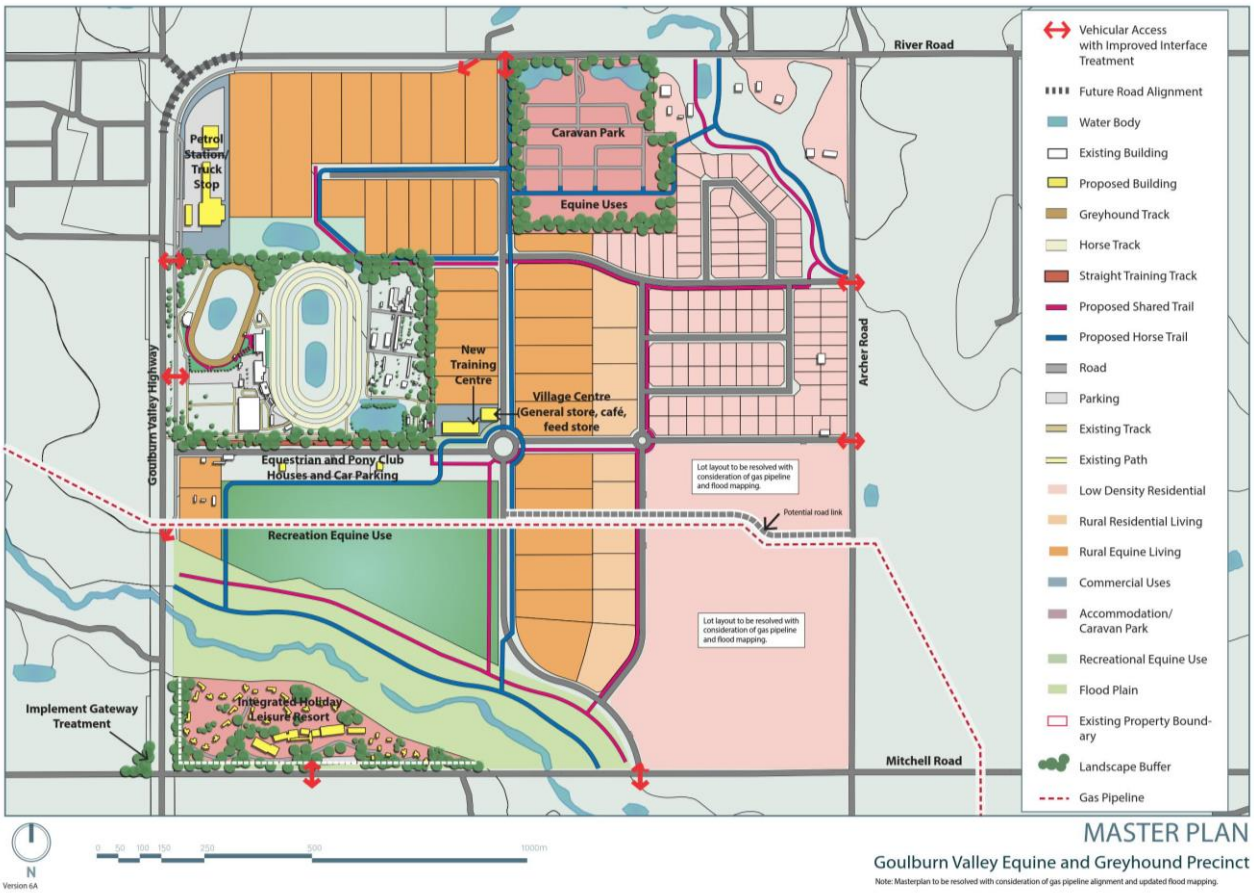


**FIGURE 5-10 INITIAL MASTERPLAN PROVIDED TO WATER TECHNOLOGY**

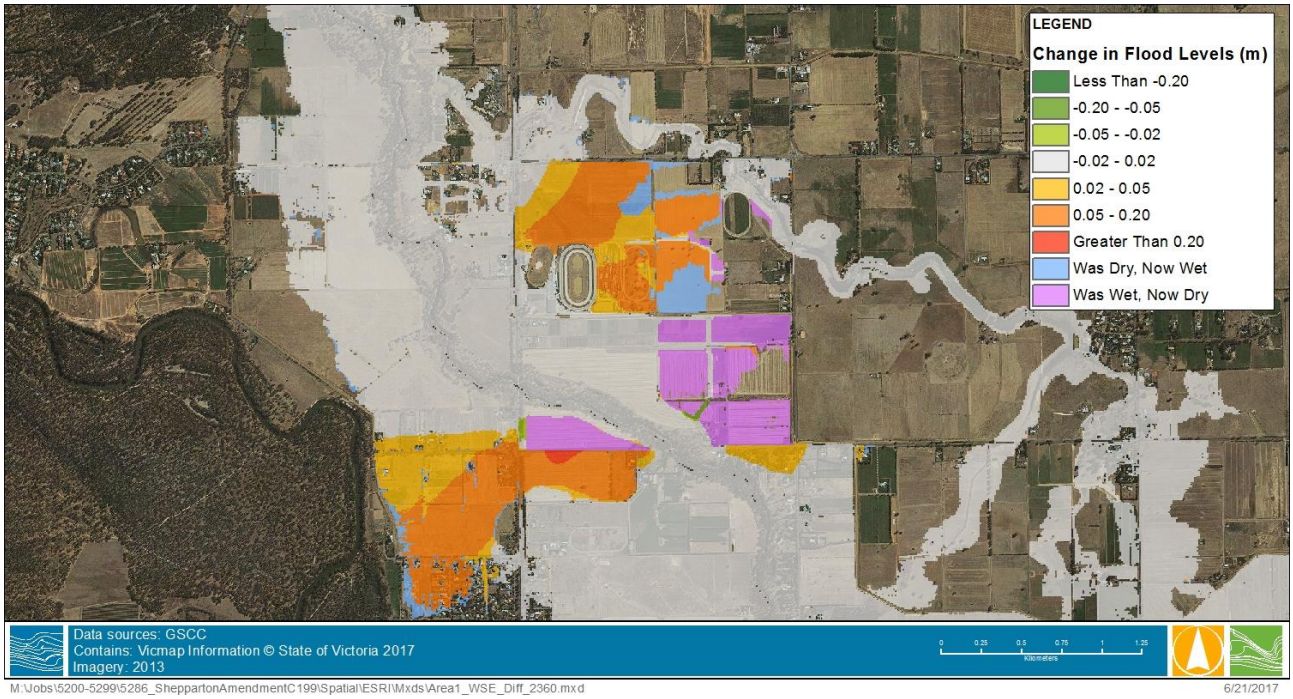


**FIGURE 5-11 1% AEP WATER LEVEL DIFFERENCE PLOT FOR INITIAL MASTERPLAN**

## 5.8 Investigation Area 1 Final Masterplan Layout

Three design iterations were undertaken to incorporate different land uses, with the aim of reducing any off-site flood impacts. The final masterplan layout is shown in Figure 5-12. Details of the two intermediate design iterations can be found in the *Investigation Area 1 – Flood Behaviour* report (Water Technology, 2016).

Changes to the final design iteration compared with the initial masterplan included the removal of the Petrol Station/Truck Stop in the north west of the site (due to large fill depths required), the removal of some rural living zone properties in the north of the site due to existing flood depths, the removal of the Integrated Holiday Leisure Resort in the south west of the site (raising this area above the flood level resulted in increased flood levels to neighbouring properties). The flood level comparison for the 1% AEP flood event between the final masterplan layout and the existing conditions is shown in Figure 5-13. This shows no afflux (outside of a +/- 0.02 m threshold) to neighbouring properties.

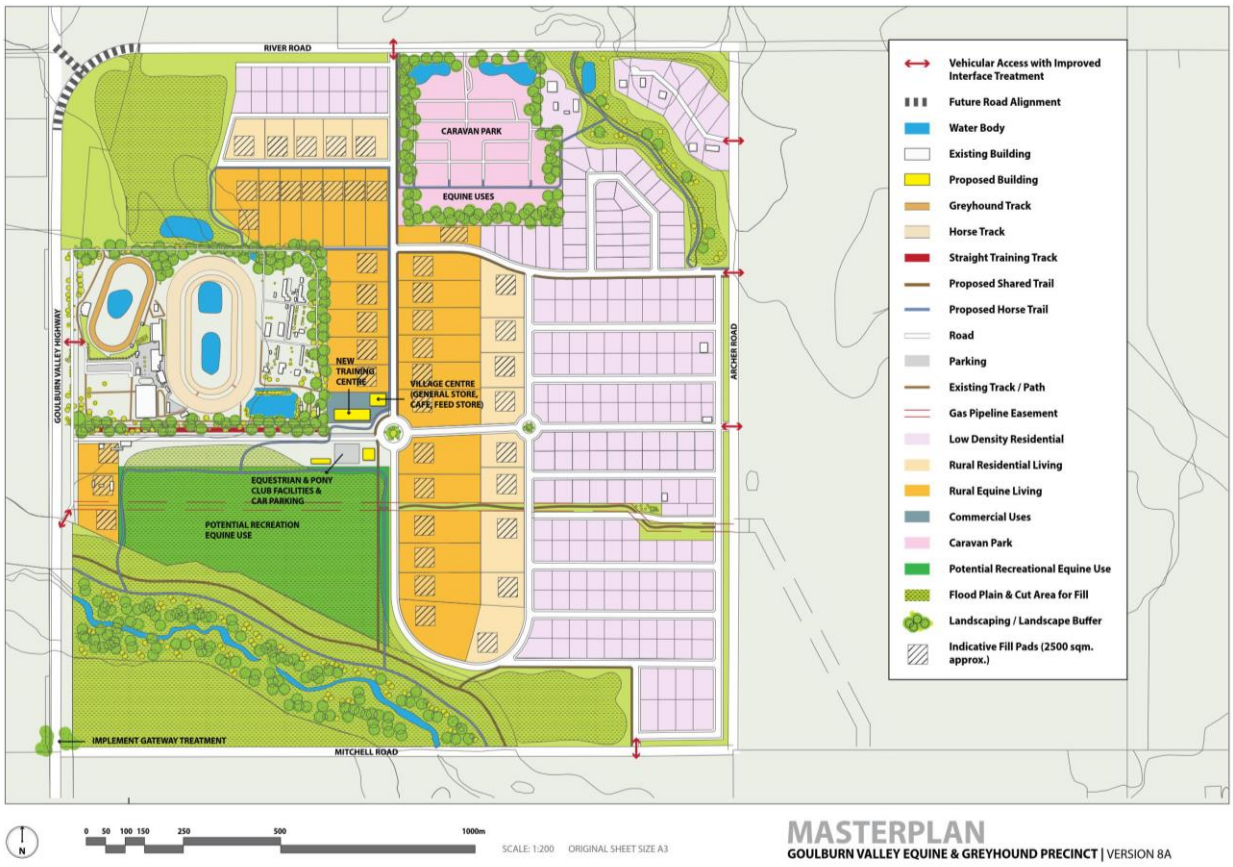


**FIGURE 5-12 FINAL MASTERPLAN LAYOUT**

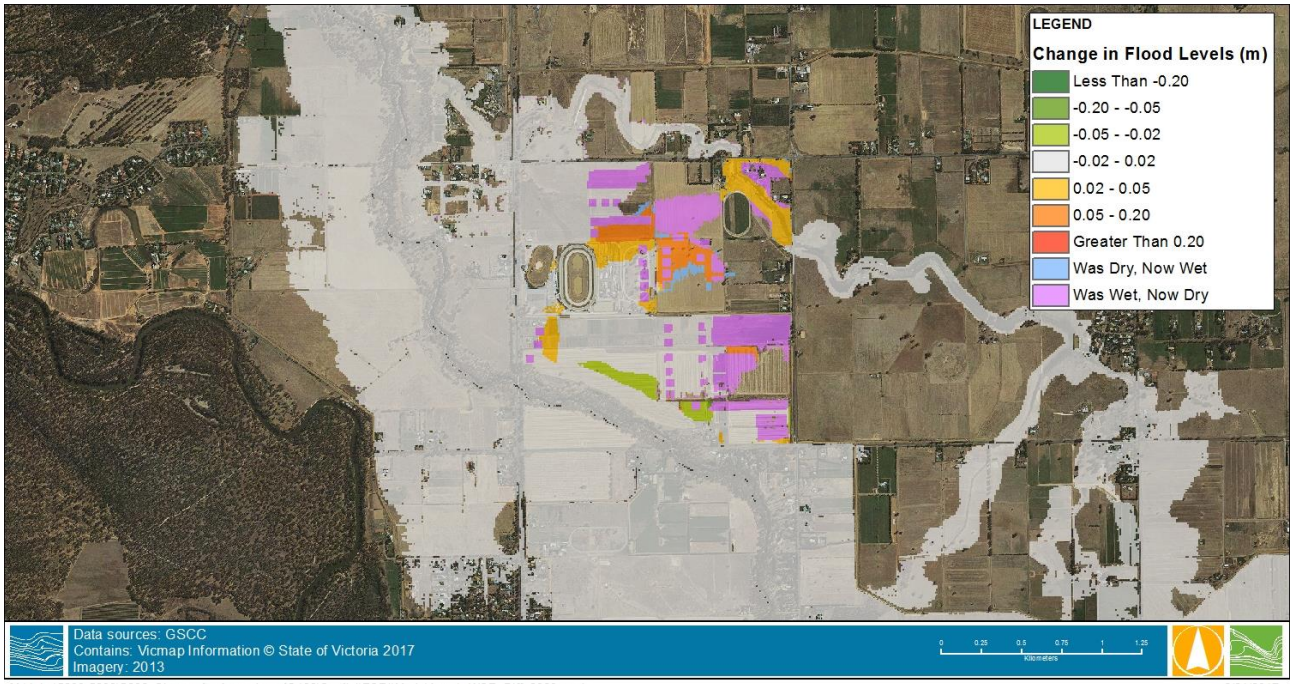


**FIGURE 5-13 FINAL MASTERPLAN LAYOUT – WATER LEVEL DIFFERENCE PLOT**

# 6 SUBMISSIONS

Council has received 24 submissions relating to Amendment C199. Many of these relate to policy and planning issues and the potential impact on property values. Several concerns within the submissions relate to a perception that Amendment C199 seeks to change the current flood controls over Investigation Area 1, which is not the case. Amendment C199 will make no changes to the existing LSIO and FO overlays or the UFZ zone within the Greater Shepparton Planning Scheme. Many submissions by local landholders suggest that Amendment C199 is inconsistent with past studies, policies, strategies and documents, however the submissions provide few, if any, specific references to these perceived inconsistencies. In response to these submissions every effort has been made to address matters related to flooding where the intent of the submission has been reasonably inferred. This section provides my response to the 24 submissions received for Amendment C199 to the Shepparton Planning Scheme, as they refer to flooding. Copies of the submissions were provided by Russell Kennedy Lawyers and are summarised below in Table 6-1.

**TABLE 6-1 SUBMISSIONS RECEIVED TO AMENDMENT C199 TO THE SHEPPARTON PLANNING SCHEME**

| Submission Number | Name of Submitter | Date of Submission |
|---|---|---|
| 1 | Goulburn-Murray Water | 26 April 2017 |
| 2 | Goulburn Broken CMA | 19 April 2017 |
| 3 | DELWP | 10 May 2017 |
| 4 | EPA | 12 May 2017 |
| 5 | Submitter 5 | 15 May 2017 |
| 6 | Goulburn Valley Water | 15 May 2017 |
| 7 | Submitter 7 | 10 May 2017 |
| 8 | Submitter 8 | 18 May 2017 |
| 9 | Submitter 9 | 18 May 2017 |
| 10 | Submitter 10 | 17 May 2017 |
| 11 | Submitter 11 | 18 May 2017 |
| 12 | Submitter 12 | 19 May 2017 |
| 13 | Submitter 13 | 19 May 2017 |
| 14 | Submitter 14 | 18 May 2017 |
| 15 | Submitter 15 | 19 May 2017 |
| 16 | Submitter 16 | 19 May 2017 |
| 17 | APA VTS Australia (Operations) Pty Ltd | 19 May 2017 |
| 18 | Submitter 18 | 18 May 2017 |
| 19 | Submitter 18 | 18 May 2017 |
| 20 | DEDJTR | 19 May 2017 |
| 21 | Submitter 21 | 19 May 2017 |
| 22 | APT O&M Services Pty Ltd | 19 May 2017 |
| 23 | Shepparton Harness Racing Club Inc. | 28 May 2017 |
| 24 | CFA | 2 June 2017 |

### Submission 1 - Goulburn-Murray Water

Goulburn-Murray Water (GMW) have no objection to Planning Scheme Amendment C199. GMW make note of the current Floodway Overlay (FO) and the Urban Floodway Zone (UFZ). There is also a Land Subject to Inundation Overlay (LSIO) in areas not covered by the FO and UFZ. These flood related overlays and zones may be subject to future amendment on completion of the Shepparton-Mooroopna Flood Mapping and Intelligence Study (Water Technology, ongoing).

GMW comment that development proposals must not impact detrimentally on GMW infrastructure, of which Supply Channel 6 is of particular interest. On page 34 of the *Investigation Area 1 – flood behaviour report* (Water Technology, 2016), Water Technology has also stated the importance of this channel in any future development. It is a critical hydraulic control on the floodplain and should be maintained in its current form and not altered without investigations into the potential flood impacts of any works.

### Submission 2 - Goulburn Broken Catchment Management Authority

Goulburn Broken Catchment Management Authority (GBCMA) have no objection to Planning Scheme Amendment C199. GBCMA note the current FO and LSIO in the planning scheme, and also note that a 1% Annual Exceedance Probability (AEP) flood level has been declared for this area under provisions of the *Water Act* (1989). GBCMA state that the declared 1% AEP flood level for this area is 114.6 m AHD. GBCMA also provide a link to their website where declared flood levels can be accessed.

The declared flood level for the 1% AEP event of 114.6 m AHD is shown in Figure 6-1 running along the upstream side of Mitchell Road (black contour). The revised 1% AEP flood contours generated from the *Investigation Area 1* modelling are also shown (blue contours). The more recent 1% AEP contours are different because of the higher resolution of the revised modelling and improved topography. It can be seen that the revised contours follow topographic features like channel banks more closely than the currently declared levels.

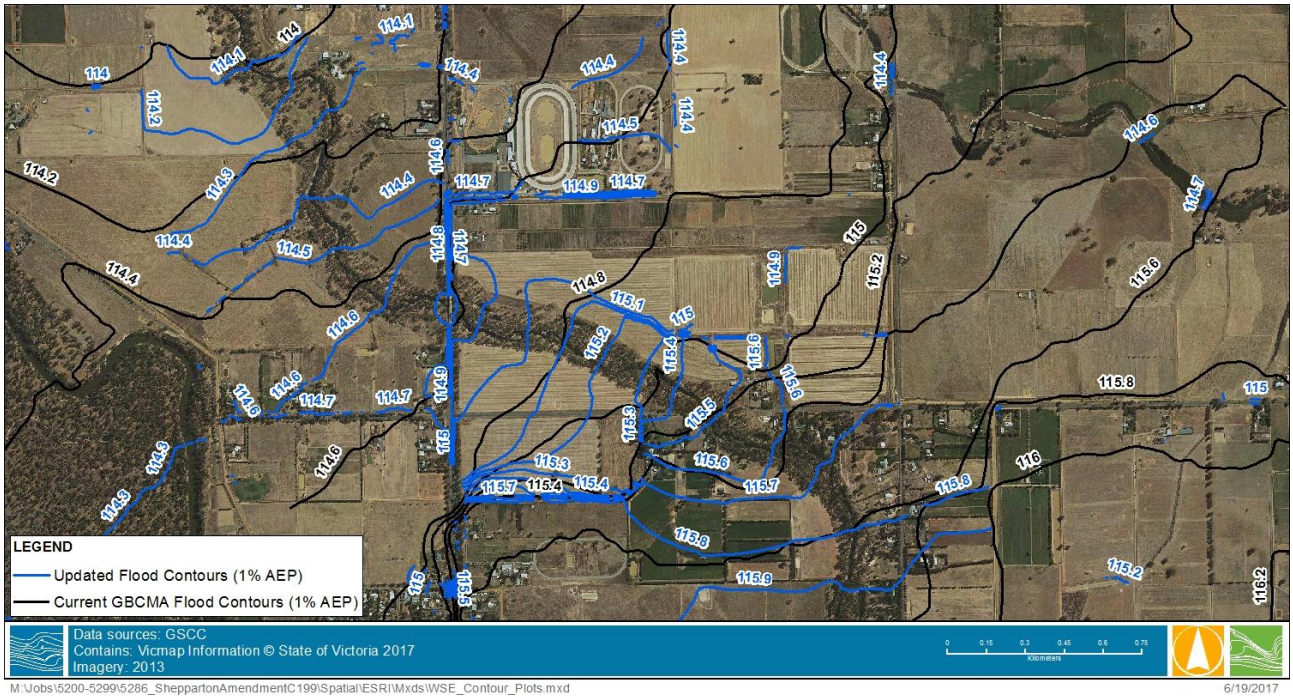


**FIGURE 6-1 COMPARISON OF INVESTIGATION AREA 1 AND CURRENT GBCMA 1% AEP FLOOD CONTOURS**

The revised levels are also based on slightly different hydrology, with the *Investigation Area 1* modelling using the revised hydrology completed in the *Shepparton-Mooroopna Flood Mapping and Intelligence Study* (Water Technology, ongoing). This study has been peer reviewed by an independent expert panel appointed by the Department of Environment, Land, Water and Planning (DELWP). The study has used current best practice, which has advanced since the declared levels were set. It utilises a longer period of gauge record for the development of design flow estimates, and should be used in preference to the older *Shepparton Mooroopna Floodplain Management Study* (SKM 2002) hydrology which was used as the basis of the declared levels.

In general, the elevation of the contours are similar, within 0.2 to 0.3 m, with the revised modelling higher due to improved survey and representation of the critical irrigation channel embankments surrounding the area. Importantly, the 2002 study did not accurately represent the channel banks of the No. 6 Main Channel to the south-east of Investigation Area 1 accurately, resulting in more flow heading north from Honeysuckle Creek east of Archer Road in the vicinity of the Kialla Country Club.

### Submission 3 – Department of Environment, Land, Water and Planning

Department of Environment, Land, Water and Planning (DELWP) have no objection to Planning Scheme Amendment C199. There were no specific flood related issues mentioned in their submission.

### Submission 4 – Environment Protection Authority

Environment Protection Authority (EPA) have no objection to Planning Scheme Amendment C199. There were no specific flood related issues mentioned in their submission.

### Submission 5

Submitter 5 objects to Planning Scheme Amendment C199, stating that it is *"inconsistent with other studies Strategies Policies and documentation"*. With respect to floodplain management, Amendment C199 is consistent with previous and current flood studies that have identified the site as flood prone and at significant risk from flooding. It is also consistent with the Greater Shepparton Planning Scheme and the State Planning Policy Framework which have provisions regarding the protection of life, property and infrastructure from flood hazard. Amendment C199 seeks to minimise any adverse flood impacts in accordance with appropriate floodplain management practice. This has been achieved in cooperation with Council and the Goulburn Broken CMA, which is the responsible floodplain authority. The application of floodplain management principles used in the development of the Amendment is consistent with the Victorian Floodplain Management Strategy.

### Submission 6 - Goulburn Valley Water

Goulburn Valley Water have no objection to Planning Scheme Amendment C199. Goulburn Valley Water note that the proposed development is outside of the water/sewer district boundary and would require significant augmentation works to facilitate these developments, this would require further assessments. There were no specific flood related issues mentioned in their submission.

### Submission 7

Submitter 7 objects to Planning Scheme Amendment C199. A number of concerns have been outlined in the submission, with my response to flood related concerns within my area of expertise below.

Concern 2 – Concern is raised that:

- The strategic assessment fails to address flooding.
- A formal flood study has not been adopted by the Planning Minister.

- Harness Racing stables have been established in a Flood Overlay and that this overlay should not be removed

In Section 7, the Goulburn Valley Harness & Greyhound Racing Precinct Feasibility Study & Master Plan addresses flooding as an issue and references the Water Technology (2016) report. The supporting documentation to the Amendment directly addresses flooding issues and concerns.

The formal adoption of a Flood Study by the Planning Minister is not a requirement for the use of a flood study to inform planning controls of planning decisions. Planning and floodplain authorities use the best available flood information at the time when making decisions. This generally takes into account the nature of the information, including its currency and reliability. The *Investigation Area 1* flood mapping uses current best practice approaches and is therefore considered reasonable and appropriate for Council to use the results of the recent flood modelling undertaken by Water Technology to inform the Amendment.

Regarding the establishment of the harness racing stables within the Floodway Overlay. There are numerous legacy flooding issues throughout Victoria. Planning decisions can only be made based on the best information available at the time, and we should always be looking to develop safely and sustainably for the future. Amendment C199 does not seek to remove the current flood related overlays or introduce new flood related overlays as implied within the submission.

Concern 3 – Concern is raised that:

- Goulburn-Murray Water's No. 6 Main Channel provides a physical barrier across the floodplain, which impacts on several members properties.
- The channel banks are being relied upon to protect the stable area. The stables should not have been built within the Flood Overlay.
- Under the Water Act any barrier to the natural flow of flood water should be removed or compensation paid.
- GMW agrees that this bank does not form a protective levee and could be removed if the channel is ever piped.

The Goulburn-Murray Water No 6 Main Channel is a significant local feature on the floodplain and does influence the distribution and depth of flood water within the study area. Flooding behaviour across the Shepparton area is significantly influenced by supply channels, roads and other features in the floodplain. In general, these features were constructed prior to the implementation of contemporary floodplain management practices and planning controls. Present floodplain management must deal with legacy structures across the floodplain. When considering development, floodplain management practice will seek to maintain the status quo, or reduce flood impacts where that can be achieved without adverse consequences on others.

The current location of the stables within a flood prone area is a legacy matter.

The submission suggests that under the *Water Act* (1989) any physical barrier to the natural flow of flood water should be removed, or compensation paid to affected landowners. The *Water Act* (1989) is not my area of expertise and I won't comment further on the details of the submission statement. It is however my understanding that GMW do not intend to replace or decommission the No 6 Channel in the foreseeable future. The GMW submission (Submission 1), makes no objections to Amendment C199, makes no mention of decommissioning the No. 6 Channel, and states that any development proposals must not impact detrimentally on GMW infrastructure. Regardless of current plans for the No. 6 Channel, if the channel was to be decommissioned, it would need to be demonstrated that no detrimental impact would result for surrounding areas.

The final paragraph of the submission requests that *"no further action be taken in Kialla Investigation Area 1 until flood issues are formally resolved"*. It is my opinion that there is a detailed understanding of the flood risk

within Investigation Area 1 and I do not believe that delaying the Amendment would result in improved advice to Council with respect to flood risk management.

### Submission 8

Submitter 8 objects to Planning Scheme Amendment C199. The submission suggests that Amendment C199 is inconsistent with the Shepparton Floodplain Management Plan.

I believe Amendment C199 is consistent with the *Shepparton Mooroopna Floodplain Management Study* (2002) which formed the basis of the current flood planning controls. Whilst there are some differences between the 2002 and the present flood modelling, these do not alter the overall flood risk assessment of the area and are not inconsistent. The changes are primarily due to advances in data and hydrological and hydraulic flood modelling since the *Shepparton-Mooroopna Floodplain Management Study* (SKM, 2002) was completed. I was involved in the hydraulic modelling for the *Shepparton-Mooroopna Floodplain Management Study* (SKM, 2002) and can confidently confirm the available topography data, modelling software and approaches have improved over time. The current modelling is able to pick up a higher level of detail, and this has resulted in an improved understanding of flood risk across this area. I believe that if the previous (2002) hydraulic model had been used to assess the master plan, a similar flood risk outcome would have resulted. Particularly with respect to the off-site impacts on flooding due to development in the south-west corner of Investigation Area 1.

### Submission 9

Submitter 9 states that Amendment C199 is inconsistent with the previous master plan, strategy documentation, policies and procedures. As discussed in Section 5.7 and 5.8, the Master Plan has changed from the initial version to provide for development opportunities without creating adverse impacts for adjacent landholders outside the study area. As discussed in my response to Submission 2 and Submission 8, the flood modelling that Amendment C199 has relied on is superior to that which was produced for the Shepparton-Mooroopna Floodplain Management Study (2002), which I was involved in. This is due to advances in LiDAR survey techniques, a longer period of gauge record, updates to hydrological estimation approaches and significant improvements in hydraulic modelling software. The application of floodplain management principles within the Amendment is consistent with state and local policies and procedures.

### Submission 10

Submitter 10 objects to Planning Scheme Amendment C199. There were no specific flood related issues mentioned in their submission other than questions relating to permits for previous development within the Harness Racing Club which are not considered relevant.

### Submission 11

Submission 11 is similar to Submission 9, please see my response above.

### Submission 12

Submitter 12 objects to Planning Scheme Amendment C199. The submission entails an initial letter and a 16 page supplementary submission.

In refence to the letter, it is suggested that:

- The analysis in the Water Technology report is inaccurate and has serious and material shortcomings. Specifically, the model does not match what has occurred in past flooding events.
- The likely effect of adopting the Proposed Amendment would be to designate most of the submitters land as subject to flooding and unable to be developed, impacting its value.

The Water Technology modelling is based on the current Shepparton Mooroopna Flood Mapping and Intelligence Study. This model has been calibrated against historic floods including October 1993, and has been subjected to a rigorous peer review process. The model reflects the flood behaviour that was observed in 1993 and has been verified against observed water levels.

Amendment C199 does not implement any flood controls into the planning scheme in terms of zones or overlays. The land is already designated as flood prone and the Amendment will not change this. Land valuations are generally not a consideration in the implementation of appropriate floodplain risk management planning controls.

The following responses refer to the supplementary submission's numbering, and addresses any flood related issues I have identified.

**8.3 –** The submission suggests that the *Investigation Area 1 - Flood Behaviour* report (Water Technology, 2016) was not prepared in accordance with the *Victorian Floodplain Management Strategy* (VFMS, DELWP, 2016), nor the *Planning Practice Note "Applying the Flood Provisions in Planning Schemes: A guide for councils"*.

The *Investigation Area 1 – Flood Behaviour* report was based on hydrological and hydraulic modelling completed in the more comprehensive *Shepparton-Mooroopna Flood Mapping and Intelligence Study - Data Review, Hydrology and Hydraulic Model Calibration* report (Water Technology, 2017). This wider study is consistent as a subset of the requirements described in the *Victorian Floodplain Management Strategy,* as not all flood investigations incorporate the full scope outlined in Part 1, Section 11 of the VFMS. It is common practice for flood investigations to have varying levels of consultation and reporting, adopting different modelling approaches depending on the intended purpose. It is also noted that the scope of the *Shepparton-Mooroopna Flood Mapping and Intelligence Study* was set well before the release of the *Victorian Floodplain Management Strategy*. The hydrology and hydraulic modelling approaches are in line with current best practice techniques used in the Victorian floodplain management industry and have been reviewed by an independent technical review panel appointed by DELWP. *Planning Practice Note 12 - Applying the Flood Provisions in Planning Schemes – a guide for councils* (DELWP, 2015) explains that flood information is available from various sources, including "detailed flood studies" and "flood mapping projects", this is referring to flood investigations of different levels of detail for different purposes. It also describes a process whereby the flood related planning layers should be based on best available information and adjusted when improved information becomes available. The suggestion that the *Investigation Area 1 – Flood Behaviour* report has not been prepared in accordance with the Victorian Floodplain Management Strategy or Planning Practice Note 12 is not correct.

**8.6 –** The submission makes the statement that expert evidence to be filed on behalf of Basic Property Holdings Pty Ltd finds that the *Investigation Area 1 – Flood Behaviour* report (Water Technology, 2016) is fundamentally flawed.

The submission does not provide any further specifics regarding any supposed flaws. As previously stated, the basis of the flood modelling (*Shepparton-Mooroopna Flood Mapping and Intelligence Study)* has been completed using industry best practice and has been reviewed by the GHCMA and DELWP independent technical review panel.

**8.7 and 8.8 –** The submission again suggests that the *Investigation Area 1 – Flood Behaviour* report (Water Technology, 2016) is not in accordance with the *Victorian Floodplain Management Strategy* (DELWP, 2016). This is discussed above in my response to 8.3 of the submission.

Under Section 11.1 of the VFMS, the following list of requirements is provided as guidance for flood studies and is referred to in the submission. I have addressed each of these points individually:

- *Model the hydrologic inputs – including rainfall and runoff – that lead to floods of different sizes and calibrate these models against historic floods* – This aspect has been considered in the Water Technology study.
- *Model the hydraulic behaviour of floods – including flood heights, extents and velocities as they vary with time – and calibrate these models against historical floods* - This aspect has been considered in the Water Technology study.
- *Understand the varying hydraulic nature of the floodplain being studied* - This aspect has been considered in the Water Technology study.
- *Understand the varying flood hazards within the floodplain* - This aspect has been considered in the Water Technology study.
- *Assess the scale of potential flood damages for the existing community* - This aspect has not been considered in the Water Technology study. It was not part of the scope and is not necessary in order to progress non-structural planning measures or determine hydraulic impacts.
- *Assess the potential for flood damage on areas of the floodplain that may be considered for future development* - This aspect has been considered in the Water Technology study.
- *Analyse risk treatment options* - This aspect has been partly considered in the Water Technology study in terms of planning controls for future development but not with respect to structural mitigation measures. This was not part of the scope and is not necessary for the implementation of planning measures.
- *Consult with local communities to take advantage of local knowledge* – This aspect has been considered in the Water Technology study, however not to the extent that would be undertaken for a full floodplain management plan.
- *Consult with local Aboriginal communities to ensure cultural values are considered in assessing and mapping flood risks* - This aspect has not been considered in the Water Technology study. It was not part of the scope of the investigations. Whilst it is a desirable activity and would add value to future studies and flood management plans, it is not expected to impact the flood-related inputs to the present Amendment.
- *Assess the consequences of floods of different sizes* - This aspect has been considered in the Water Technology study. For planning purposes, the 1% AEP design flood is the relevant event to consider. The flood behaviour of historic events has also been considered, although the development scenarios were only simulated for the 1% design flood. This is standard practice in flood investigations for floodplain development.
- *Capture the local community's experience and knowledge of floods* - This aspect has been considered in the Water Technology study.

**8.9 –** The submission again suggests that the *Investigation Area 1 – Flood Behaviour* report (Water Technology, 2016) is not in accordance with the *Victorian Floodplain Management Strategy* (DELWP, 2016) and the *Planning Practice Note 12 - Applying the Flood Provisions in Planning Schemes – a guide for councils* (DELWP, 2015). This is discussed above in my response to 8.3 of the submission. Further the submission suggests that the Amendment C199 is *"intended to modify the Planning Scheme flood controls in Investigation Area 1"*. Amendment C199 is not seeking to change the planning scheme flood controls.

The UFZ and flood overlays will not change because of this amendment. Further the area outside the SUZ and UFZ will remain as farm zone. Hence the land-use and planning controls over the area outside the SUZ remain unchanged. My understanding of the planning scheme is that any application for development would be subject to exactly the same process as is the case now. The flood overlays would trigger referral to the CMA and standard criteria for development within floodplains would need to be met. Obviously the adoption of the master plan will set expectations for the future land-use, however that use is based on flooding

constraints that already exist with limits on appropriate development, taking into account flood risks and potential impacts, guided by the GHCMA. This has been demonstrated through the assessment of previous development applications in the area.

**8.10 and 8.11 –** The submission suggests that the Investigation Area 1 – Flood Behaviour report (Water Technology, 2016) "failed to take advantage of local knowledge of the flooding of the 2 properties south of the Harness Racing Club, well after the peak recorded on the flood gauge on the 5th October 1993". The 405269 Seven Creeks at Kialla West gauge which is located at Mitchell Road, peaked around midday on the 5th October 1993. The Statutory Declarations of Lorenzini, Fishera and Gagliardi all attest that flooding from the irrigation channel occurred on 4th October 1993 early in the morning, which appears contrary to the submission, which states that flooding from the channel occurred well after the creek peaked on the 5th October 1993. The Statutory Declarations all say that water was observed to be coming from the irrigation channel on the morning of the 4th October 1993. It is quite common in flood events to have flood waters flowing into irrigation channels and spilling out in other locations. None of the Statutory Declarations refer to flood conditions closer to the peak of the flood on the creek on the following day around midday on the 5th October 1993.

An analysis of the available water level gauge data, which is limited during the 1993 event to a small period between midnight on the 4th October to 1pm on the 6th October 1993, shows that leading up to the peak the gauge was rising at approximately 0.5 m every 6 hours. Extrapolating this back to the time at which the Statutory Declarations describe flooding from irrigation water, the water level in Seven Creeks may have been over 2 m lower than that observed at the peak of the flood, and would have been largely confined to the low levels of the floodplain (roughly equivalent to the section that is currently vegetated with mature trees). Figure 6-2 shows the extrapolated gauge water level record. Aerial imagery of the flood was captured on the 6th October 1993 between midday and 5pm, Figure 6-3. At the time of this imagery capture the water level on the creek at the gauge was approximately 0.7 to 0.8 m lower than the peak. To demonstrate how the model of the 1993 flooding is consistent with the observations from the gauge record and the aerial flood imagery, Figure Figure 6-4 presents the peak 1993 flood extent and the flood extent obtained by subtracting 0.7 m from the peak levels (equivalent to the drop in water level observed at the streamflow gauge from the peak of flooding to the time the imagery was captured).

Figure 6-4 shows that the likely extent of flooding from the peak of the modelling less the observed 0.7 m drop in water levels, reproduces the flooding observed along Seven Creeks in the aerial flood imagery taken on the 6th October 1993 very closely. The modelling by Water Technology for the 1993 event was calibrated to 66 surveyed flood heights throughout the Shepparton-Mooroopna area, 4 of which are within or immediately adjacent to Investigation Area 1, as shown in Figure 5-6. The calibration to the 1993 event is of high quality, with 32 points within 100 mm of surveyed flood heights, 19 within 200 mm, 8 within 300 mm, and 7 points outside 300 mm of the surveyed flood levels. The overall model calibration for 1993 shows no bias higher or lower than surveyed flood levels. The modelling used to support the Planning Scheme Amendment C199 is for a 1% AEP event, which is a larger magnitude flood than the 1993 historic event. Observations from the 1993 flood do not have direct relevance to the flood behaviour of the larger magnitude 1% AEP flood event.

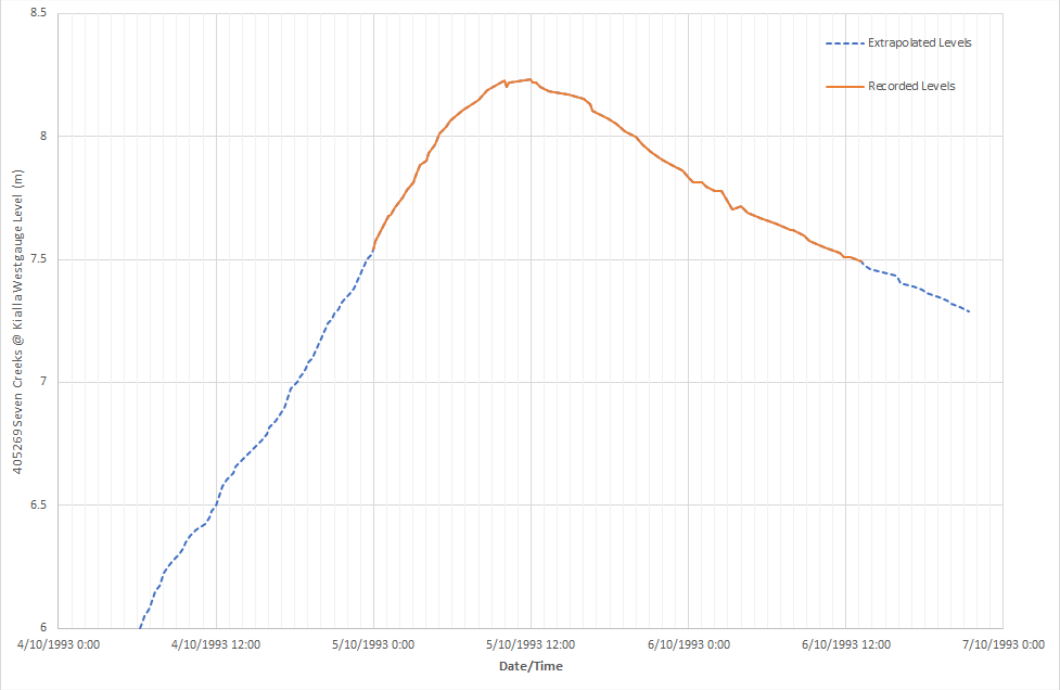


**FIGURE 6-2 405269 SEVEN CREEKS AT KIALLA WEST WATER LEVEL GAUGE**


**FIGURE 6-3 AERIAL FLOOD IMAGERY CAPTURED ON 6TH OCTOBER 1993 BETWEEN MIDDAY AND 5PM**

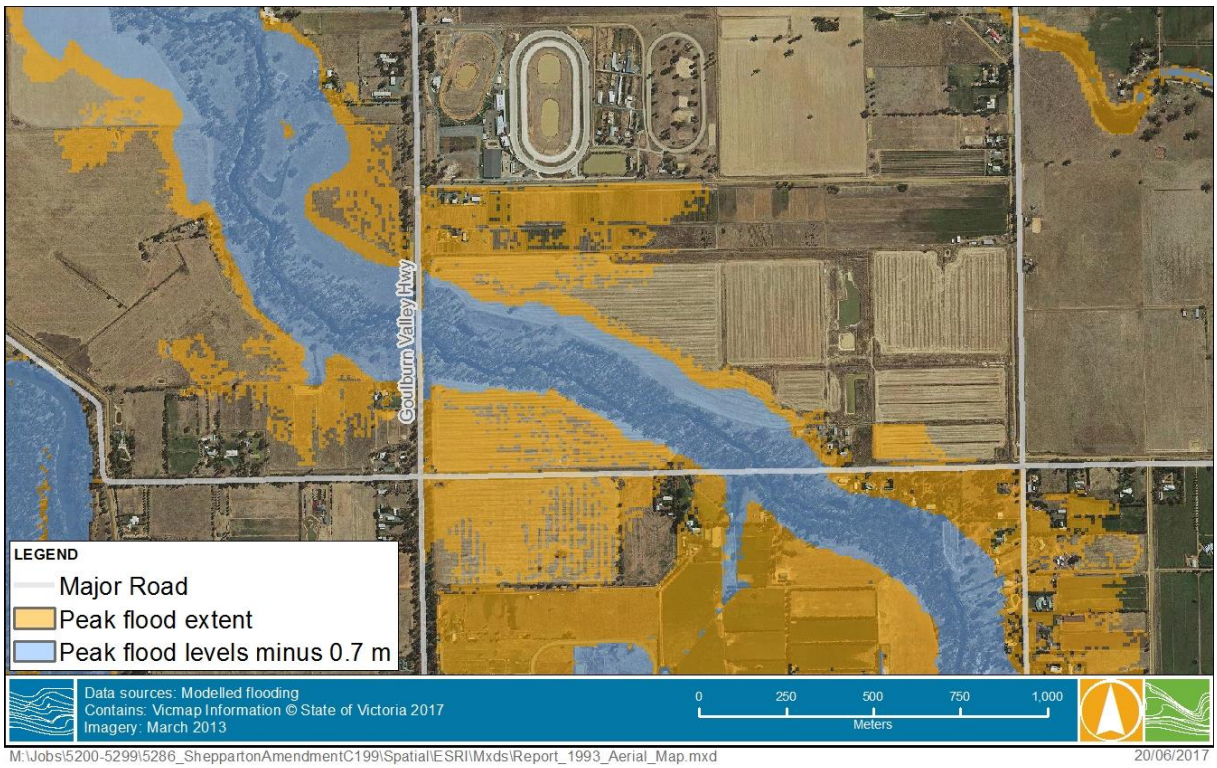


**FIGURE 6-4 FLOOD MAPPING OF THE MODELLED PEAK OF OCTOBER 1993 FLOOD, AND EXTENT ONCE THE WATER LEVELS HAD DROPPED BY 0.7 M WHEN THE AERIAL FLOOD IMAGERY WAS CAPTURED**

**8.12 –** The submission has attempted to question the integrity of the Water Technology flood modelling work that has been used as a basis for the Amendment C199. The work has been conducted using industry best practice, it has been independently reviewed by technical experts in flooding, and provides flood information superior to that developed during the previous Shepparton-Mooroopna Floodplain Management Study (SKM, 2002).

**10.1** – With respect to flooding, the Amendment does not constrain development beyond what already exists in the planning scheme. The flood risks are already there and the current flood planning controls require that any proposed development has to meet the requirements of the Planning Scheme and VPP.

**10.3 –** The submission alleges the flood modelling from the *Investigation Area 1 – Flood Behaviour* report (Water Technology, 2016) is *"inaccurate"* and *"incorrect"*. I refer to previous comments above in relation to the Water Technology modelling.

### Submission 13

Submitter 13 objects to Planning Scheme Amendment C199. The submission states the Amendment C199 has *"inconsistencies with other studies, documents, strategies and policies"*. This is a similar to previously discussed Submissions 5, 8, 9 and 11.

### Submission 14

Submitter 14 objects to Planning Scheme Amendment C199. The submission states the Amendment C199 is *"inconsistent with other studies, strategies, policies and documents"*. This is a similar submission to previously discussed Submissions 5, 8, 9, 11 and 13.

### Submission 15

Submitter 15 objects to Planning Scheme Amendment C199. The submission states the Amendment C199 is *"inconsistent with other studies, strategies, policies and documents"*. This is a similar submission to previously discussed Submissions 5, 8, 9, 11, 13 and 14.

### Submission 16

Submitter 16 objects to Planning Scheme Amendment C199. The submission states the Amendment C199 is *"inconsistent with other studies, strategies, policies and documents"*. This is a similar submission to previously discussed Submissions 5, 8, 9, 11, 13, 14 and 15.

### Submission 17 - APA VTS Australia (Operations) Pty Ltd

APA VTS Australia (Operations) Pty Ltd object to Planning Scheme Amendment C199. There were no specific flood related issues mentioned in their submission.

### Submission 18

Submitter 18 objects to Planning Scheme Amendment C199. The submission states the Amendment C199 has *"many inconsistencies, with findings, studies, strategies, etc".* This is a similar submission to previously discussed Submissions 5, 8, 9, 11, 13, 14, 15 and 16.

### Submission 19

Submitter 19 objects to Planning Scheme Amendment C199. The submission states the Amendment C199 *"seems to contradict many studies that have been taken over the years. It's very inconsistent".* This is a similar submission to previously discussed Submissions 5, 8, 9, 11, 13, 14, 15, 16 and 18.

### Submission 20 – Department of Economic Development, Jobs, Transport and Resources

There are no flood related issues raised in the Department of Economic Development, Jobs, Transport and Resources (DEDJTR) submission.

### Submission 21

Submitter 21 objects to Planning Scheme Amendment C199. The submission is similar to Submission 8. Refer to Submission 8 for my response.

### Submission 22 - APT O&M Services Pty Ltd

APT O&M Services Pty Ltd have no objection to the Planning Scheme Amendment C199. There are no flood related issues raised in the submission.

### Submission 23 - Shepparton Harness Racing Club Inc.

Shepparton Harness Racing Club Inc has no objection to the Planning Scheme Amendment C199. There are no flood related issues raised in the submission.

### Submission 24 – Country Fire Authority

Country Fire Authority (CFA) has no objection to the Planning Scheme Amendment C199. There are no flood related issues raised in the submission.

# 7 DECLARATION

I have made all the inquires that I believe are desirable and appropriate and no matters of significance which I regard as relevant have to my knowledge been withheld from the Panel.

Warwick A Bishop

B.E. (Hons), MEngSci

22 June 2017

# 8 REFERENCES

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Water Technology (2016). Investigation Area 1 - Model of Flood Behaviour Report, prepared for the Greater Shepparton City Council

Water Technology (2017). Shepparton Mooroopna Flood Mapping and Intelligence Study - Data Review, Hydrology and Hydraulic Calibration Report prepared for the Greater Shepparton City Council

# APPENDIX A – ATTACHED DOCUMENTS

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