ATTACHMENT TO AGENDA ITEM

Ordinary Meeting

18 September 2018

Agenda Item 10.6	**Draft Shepparton Mooroopna Flood Mapping and Flood Intelligence Project 2018 and Draft Greater Shepparton City Council Municipal Flood Emergency Plan 2018**

Final Report

Shepparton Mooroopna Flood Mapping and Flood Intelligence Study

Greater Shepparton City Council

16 August 2018

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Project Details

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EXECUTIVE SUMMARY

The Shepparton-Mooroopna Flood Mapping and Flood Intelligence Study provides a technical review and update to the previous flood study (SKM, 2002). This work is considered an improvement on the previous flood study for the following reasons:

- Technological advancements in topographic data capture (LiDAR) better representing the floodplain, including roads, levees, channel banks, new development, etc, improving the flood mapping.
- Flood modelling software has advanced significantly since the previous study, again improving the flood mapping outputs.
- An improved understanding of the timing of tributary flows and how breakouts from the Goulburn River, Broken River and Seven Creeks interact around the Goulburn Main Channel.
- The advancements in the modelling of this study is demonstrated through the excellent calibration achieved over the range of flood events modelled, (1974, 1993 and 2010). The calibration was informed by a large amount of observed historical flood data including aerial flood photography, surveyed flood levels, and recorded streamflow gauges.
- The hydrology and hydraulic model calibration were reviewed by an independent technical review panel appointed by the Department of Environment, Land, Water and Planning, providing confidence that the methods adopted were appropriate.

The study has produced an improved set of flood maps for a range of Goulburn River at Shepparton gauge height increments between 9.5 m and 12.5 m. The flood level at Shepparton is influenced by flood flows from the Goulburn River, Broken River and Seven Creeks, with flood mapping outputs produced for a Goulburn River dominant, Broken River / Seven Creeks dominant, and neutral flood scenarios. A gauge height level of 12.2 m at the Goulburn River at Shepparton gauge was determined to be equivalent to a 1% AEP flood event, and for design flood mapping purposes, all three tributary dominance scenarios were combined, taking the maximum of the three scenarios. When compared to the previous 1% AEP flood mapping, the new 1% AEP flood mapping shows a very similar extent across the floodplain, with the area of inundation reduced through Kialla West and Mooroopna due to the inclusion of more detailed representation of channel banks and roads which impact on the flood behaviour in those areas. The new 1% AEP flood mapping has therefore reduced the area of flood prone land in the Shepparton, Mooroopna and surrounding area.

The flood mapping has been formatted into Victoria Flood Database format and uploaded to Flood Zoom so the data is available for emergency services to use during a flood event. The flood mapping has been carefully examined to provide improved flood intelligence on areas inundated and flood impacts during the range of flood scenarios modelled. This information has been used to update the *Greater Shepparton City Council Flood Emergency Plan: A Sub-Plan of the Municipal Emergency Management Plan*. This Plan is used by emergency services personal and Council staff to guide emergency response actions. The Total Flood Warning System was reviewed, and several clear recommendations were made to further strengthen the system.

To ensure that the outcomes from this study directly benefited the communities of Shepparton, Mooroopna and surrounding areas, the flood mapping data was made available through an online flood mapping portal which can be accessed via www.floodreport.com.au. This portal allows individuals to visualise the flood mapping online for a range of flood events, and to click on any property within the study area and download a property specific flood report. The flood report provides flood information specific to that property along with a flood preparedness table which links the Goulburn River at Shepparton gauge height to a flood level and depth above or below floor level at that property. This allows residents to better understand their personal flood risk. The service replaces an outdated and no longer supported system that was previously hosted by Council.

The study has made several recommendations for Greater Shepparton City Council, Goulburn Broken CMA and Victoria State Emergency Services to consider. These recommendations are generally actions designed to make the most of the new flood mapping and flood intelligence generated by this study, and to further strengthen the existing Total Flood Warning System.

Water Technology would like to thank our project partners, HydroLogic and Michael Cawood and Associates for their role in delivering this study. Water Technology would like to specifically acknowledge the contributions of Guy Tierney of Goulburn Broken CMA and Greg McKenzie of Greater Shepparton City Council in the completion of this study, and their ongoing commitment to reducing flood risk in the Shepparton, Mooroopna and surrounding areas.

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1 INTRODUCTION

Water Technology was commissioned by the Greater Shepparton City Council to undertake the Shepparton Mooroopna Flood Mapping and Intelligence Project. This study was a review and technical update to the previous flood study (SKM, 2002). This study involved detailed hydrological and hydraulic modelling of the Goulburn River, Seven Creeks and the Broken River, flood mapping and collation of flood intelligence information. The main outcome of the study was to produce improved flood mapping information for use in sharing flood intelligence for the Shepparton Mooroopna area with multiple stakeholders and the community. The study has produced an online flood mapping portal to allow community members easy access to flood information, see www.floodreport.com.au.

As part of the initial scoping work, the data required for modelling and mapping was collated and reviewed. The hydrology approach adopted for this study utilised the extensive streamflow gauge network, using flood frequency analysis, past studies and past flood events to derive hydrographs for input into the hydraulic model. A hydraulic model was developed using TUFLOW software and was calibrated to the large flood event of October 1993 and the smaller September 2010 flood event, with validation to the May 1974 flood event.

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2 STUDY AREA

Shepparton and Mooroopna are situated on the Goulburn River at the confluence with the Broken River and Seven Creeks. The study area in the tender documentation extended upstream of Shepparton to Toolamba and downstream of Shepparton to Loch Garry on the Goulburn River, upstream of Shepparton to Kialla East on the Broken River and upstream of Shepparton to Kialla West on Seven Creeks.

To model the Goulburn River, Broken River and Seven Creeks system, coarse hydraulic models were extended upstream to suitable boundary locations, Murchison on the Goulburn River, Gowangardie on the Broken River and upstream of Kialla West on the Seven Creeks. These coarse models allowed flows to be developed at these gauging stations and routed downstream to the detailed hydraulic model area surrounding the urban area of Shepparton and Mooroopna, see Figure 2-1. The larger model area was separated into three separate hydraulic models. The upstream coarse models study the routing between the upstream gauges and Shepparton, and on the Broken River allow a better understanding of breakout flows leaving the river between Gowangardie and Shepparton. A higher resolution model of the flood mapping area extended from about 2.5 km upstream of East Goulburn Main Channel on the Broken River, 2 km upstream of the East Goulburn Main Channel on Honeysuckle/Irish Creeks, upstream of Union Road on Seven Creeks, and upstream of Bridge Road on the Goulburn River down to Loch Garry on the Goulburn River.

The hydrology of the system was considered across an even wider area, with many gauges outside the extended study area analysed.

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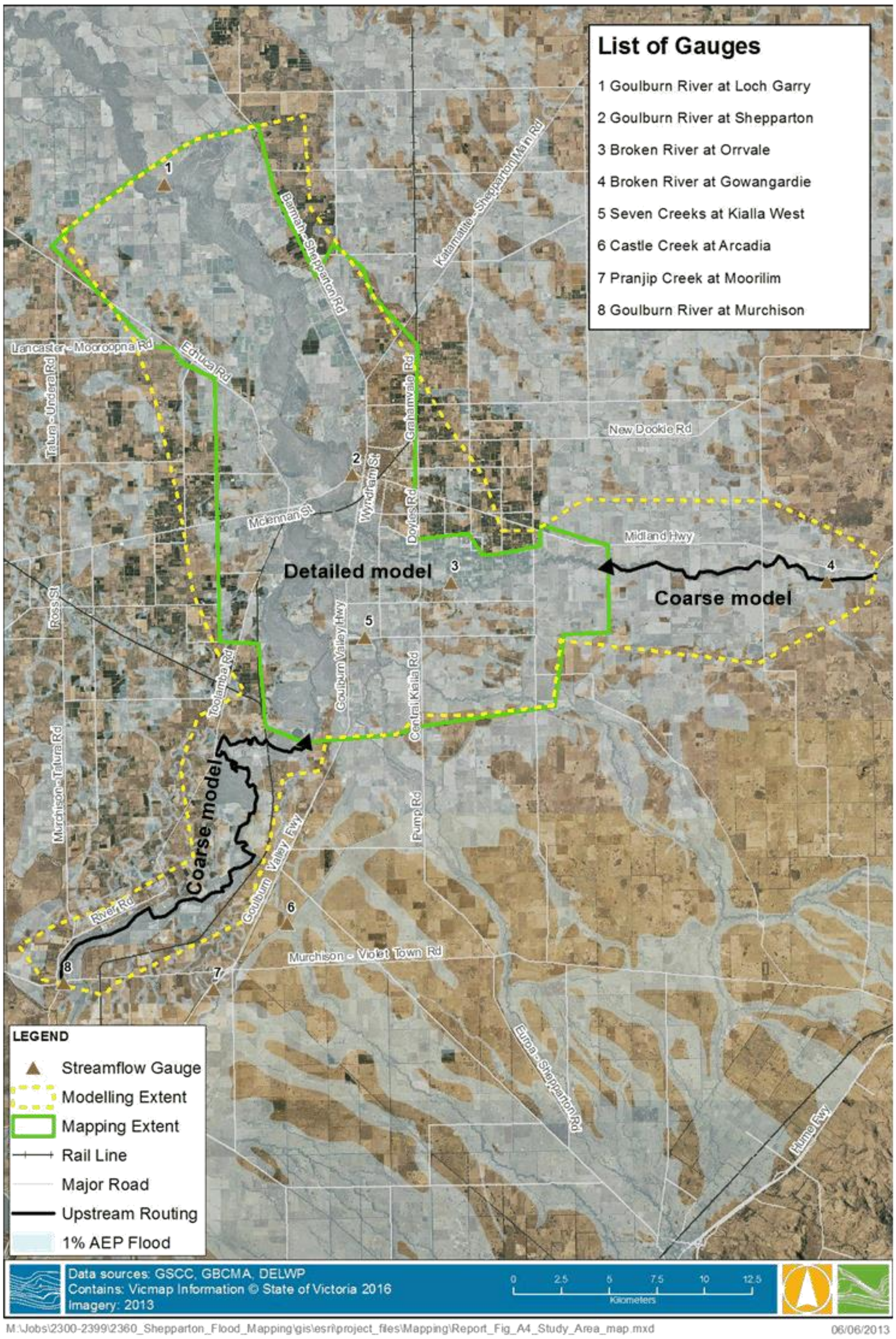

FIGURE 2-1 STUDY AREA EXTENT, REVISED MODEL AREA AND GAUGE LOCATIONS

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3 DATA REVIEW AND ASSESSMENT

3.1 Overview

A large amount of information was available within the study area and broader catchment to assist in this study. A significant amount of hydrological data was collated and analysed along with many different topographical datasets. Shepparton and Mooroopna have a long history of flooding so many historical accounts of flooding and observed data was collated. Information from Goulburn Broken Catchment Management Authority (GBCMA), Greater Shepparton City Council (GSCC), the Department of Environment Land Water and Planning (DELWP), hydrographers (Ventia), Goulburn Murray Water (GMW) and VicRoads was collated. The Shepparton Mooroopna Floodplain Management Study by Sinclair Knight & Merz (SKM, 2002) was a major study that considered the issues of flooding in the study area, and as such was reviewed in detail.

3.2 Hydrological Data

3.2.1 Streamflow Data

Streamflow data is required for the hydrological analysis. The details of the streamflow gauging stations used in this analysis are listed in Table 3-1. These streamflow gauging details include the period of continuous streamflow record for each gauge. The continuous period of record is the period of systematic recording of streamflow via a daily read staff gauge or a continuous recorder. For some streamflow gauges, records are available during flood events only. Streamflow data records have been sourced from the DELWP water data portal.

Rating tables for the various stream gauges within the catchment were provided by Goulburn Broken CMA, DELWP and Ventia. During the calibration stage of the project it was found that recent changes to rating tables applied back over the entire record of data at some gauge sites has significantly changed the peak flow record for some historic flood events. This has a significantly large impact on the results of any flood frequency analysis and resultant design flows for this study. As such this is discussed in detail in Section 4.2.

TABLE 3-1 STREAMFLOW GAUGE DETAILS

Station Name	Station No.	Area (km^2)	Period of record	Additional data since 2002 study
Broken River at Benalla	404203	1,461	1886 – 1961 (partial)* Oct 1977 to current	2002-now
Broken River at Casey's Weir (Goorambat)Headwater Gauge	404216	1,924	February 1888 to June 1916. July 1979 to current	2002 - now
Broken River at Casey's Weir (Goorambat) Tailwater Gauge	404200	1,924	July 1916 to June 1979	N/A
Broken River at Gowangardie	404224	2,396	January 1978 to July 1985 August 1991 to current	Not used in SKM study
Broken River at Orrvale	404222	2,508	June 1977 to current	2002 - now
Goulburn River at Goulburn Weir	405253	10,627	March 1967 to October 1985	N/A

Station Name	Station No.	Area (km²)	Period of record	Additional data since 2002 study
Goulburn River at Murchison	405200	10,772	June 1881 to March 1967 November 1984 to current	2002 - now
Goulburn River at Kialla West	405270	12,038	June 1977 to August 1985	N/A
Goulburn River at Shepparton	405204	16,125	June 1921 to current	2002 - now
Goulburn River at Loch Garry	405276	16,490	Feb-1978 to current	2002 - now
Seven Creeks at Euroa Township	405237	332	May 1963 to current	2002 - now
Seven Creeks at Kialla West	405269	1,505	June 1977 to current	2002 - now
Pranjip Creek at Moorilim	405226	787	December 1957 to current	Not used in SKM study
Castle Creek at Arcadia	405246	164	June 1970 to current	Not used in SKM study

** note that the rating curve for Benalla pre-1970 is no longer valid due to construction of the lake*

3.2.2 Peak Design Flow Estimates

The SKM (2002) study undertook a detailed flood frequency analysis for many gauges on the Goulburn and Broken Rivers. This analysis is provided below in Table 3-2. Note that for some sites the adopted design flows were from a combination of methods and unless otherwise indicated, estimates were from flood frequency analysis over the gauge period.

TABLE 3-2 SKM (2002) ADOPTED DESIGN PEAK FLOW ESTIMATES (ML/D)

	Goulburn River at Murchison	Broken River at Casey's Weir	Broken River at Benalla	Seven Creeks at Euroa	Goulburn River at Shepparton
Period for FFA	1956-1999, 1916 (1)	1889-1999	1955-1999, 1916, 1921	1956-1999, 1916, 1921	1921-1999, 1916
20%	51,900	23,300	30,900	11,800	73,400
10%	68,400	31,400	45,500	16,200	102,000
5%	87,000	40,500	61,600	20,200	137,000
2%	114,000	54,500	85,600(2)	25,800(3)	180,000
1%	134,000	66,900	106,000(2)	34,000(3)	219,000
0.5%	158,000	81,200	128,000	42,900(3)	261,000
0.2%	192,000	103,000	161,000	56,300(3)	336,000

(1) *1956-1999 chosen for FFA as it is period after construction of Big Eildon dam.*

(2) *Estimate adopted from calibrated rainfall-runoff modelling by Willing and Partners (1998) study instead of FFA.*

(3) *Estimate adopted from calibrated rainfall-runoff modelling by SKM (1997) study instead of FFA.*

The SKM (2002) study used several regression equations to transpose the peak design flows from the above-mentioned gauges to the boundaries of their study area. As volume is just as important as peak flow in large flat floodplains, the frequency analysis and transposition was repeated for five day volumes.

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3.2.3 Design Flow Hydrographs

To determine a design hydrograph, the SKM (2002) study scaled historic hydrographs to represent the design peak flow and 5 day volume. The 1974 hydrograph was adopted for the Goulburn River and the 1993 hydrographs for the Broken River and Seven Creeks.

The timing of the three major contributing catchments has a large impact on the resulting flood at Shepparton. The SKM (2002) study found that the peak flow of Seven Creeks at Kialla West generally occurs between 6-24 hours earlier than the Broken River at Orrvale, the study adopted the median 15 hour time offset for the peak flow for design purposes. The relative timing of the Goulburn and Broken River flood peaks was also investigated, however a lack of data hindered this assessment. A lag time of 33 hours was assumed between Goulburn Weir and Kialla West and 30 hours between Murchison and Kialla West. It was estimated that the peak flow in the Goulburn at Kialla West occurred approximately 15 hours after the peak flow on the Broken River at Orrvale for the 1974 event, with a 60 hour lag in the 1993 event. This longer lag in 1993 was attributed to the impact of Eildon attenuating the flood in the upper catchment, with the lower catchment having a smaller contribution to the Goulburn flows. For design purposes the 15 hour time lag from the 1974 event was adopted. Several design flood scenarios were developed using various combinations of Goulburn River, Broken River and Seven Creeks flows for a given design event at the Shepparton gauge. A similar approach in adopting appropriate timing for design events for the current investigation is discussed in more detail in Section 4.4.2 with timing tested in the hydraulic model to assess the sensitivity on flood levels shown in Section 6.1.

3.3 Topographic and Physical Survey

Several sources of topographic/survey data were obtained to prepare the hydraulic model. Most of the data was provided by GBCMA and GSCC. These include:

- Light detection and ranging (LiDAR) data
- Pipe Drainage Networks
- Survey Cross sections
- Photogrammetry
- Feature survey of Shepparton Mooroopna Causeway
- Feature survey of strategic levees downstream of Shepparton

3.3.1 LiDAR Data

LiDAR data for the region was made available by Goulburn Broken CMA and DELWP. A summary of available digital elevation model (DEM) data sets is summarised below in Table 3-3.

TABLE 3-3 AVAILABLE DIGITAL ELEVATION MODEL DATA SETS

DEM Data Set	Resolution	Year Flown	Vertical Accuracy
Fugro Spatial Systems (FSS)	1 m & 5 m DEM	2007	± 0.10 m
Index of Stream Condition (ISC)	1 m DEM	2011	± 0.15 m
Floodplain Set I	1 m DEM	2011	± 0.10 m
Think Spatial UAV	1m DEM	2013	± 0.15 m
VicMap Elevation	20 m DEM		
Geoscience Australia	1 Second DEM		

Figure 3-2 shows the extent of available DEMs used in the hydraulic modelling.

The 5 m/1 m Fugro Spatial Systems (FSS) data contained many gaps and 'holes' within the DEM. These were removed (using 12d terrain software) by creating a Triangulated Irregular Network (TIN) across the surrounding data points and exporting as a new DEM.

A comparison of the Floodplain (FP) and FSS datasets was undertaken in ARCGIS for a location where there was overlap. Both datasets had the same 1 m grid resolution. Very little elevation difference was observed where the two datasets overlapped, with the differences mostly present in channels and water bodies as well as variations in crop development. An example of the comparison in DEMs is shown in Figure 3-3. Areas of river channel, dense vegetation and crops showed elevated surface levels in the FP LiDAR compared to the FSS LiDAR, which indicated that the FSS LiDAR may be closer to the true ground level in these locations. Therefore, the FSS LiDAR was used in preference to the FP LiDAR where there was overlap.

The Index of Stream Condition (ISC) data follows the alignment of major waterways but doesn't extend far onto the floodplain. This data set was found to be the most consistent with the feature survey of the causeway, whereas the FSS LiDAR data set was found to be lower than the feature survey. This is demonstrated by the analysis of the feature survey along the Shepparton Mooroopna Causeway shown in Figure 3-1 and summarised in Table 3-4.

The ISC LiDAR is on average 0.2 cm lower than the feature survey and the FSS LiDAR is on average 7.8 cm lower. For this reason, the ISC LiDAR data set was chosen as the basis for the final model topography and the other data sets were adjusted to match. Several checks were carried out along the interface of the different datasets and following this analysis it was decided to raise the FSS and FP LiDAR datasets by 10 cm to ensure a smooth transition between the different data sets. The final composition of the LiDAR used in the topography is shown in Figure 3-4.

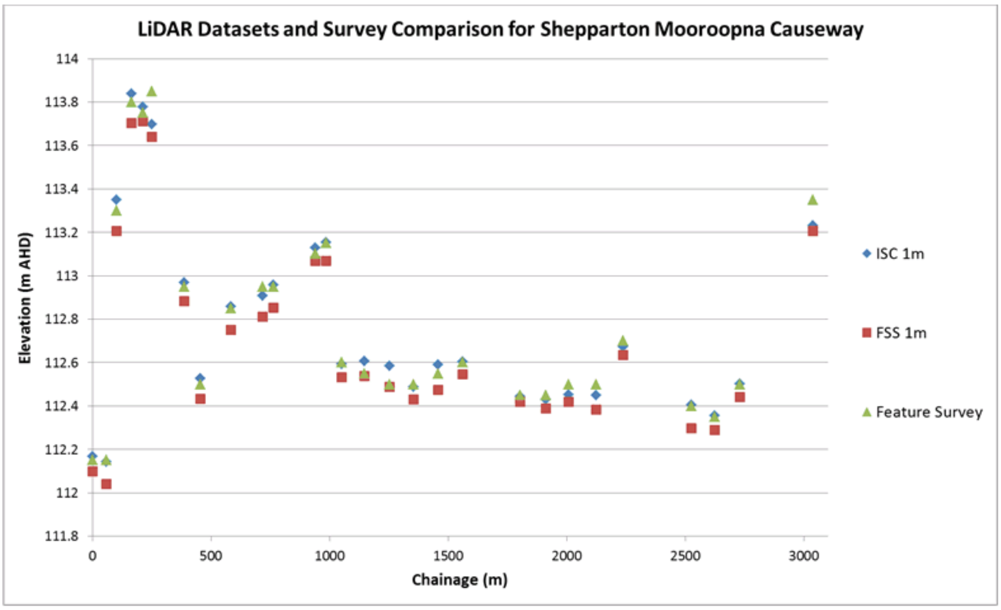

FIGURE 3-1 SURVEY AND LIDAR ELEVATION COMPARISON ALONG SHEPPARTON-MOOROOPNA CAUSEWAY

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TABLE 3-4 SURVEY AND LIDAR ELEVATION DIFFERENCES FOR SHEPPARTON MOOROOPNA CAUSEWAY

Chainage (m)	ISC 1 m Difference (cm)	FSS 1 m Difference (cm)	Chainage (m)	ISC 1 m Difference (cm)	FSS 1 m Difference (cm)
0	1.7	-5.2	1146	5.8	-1.1
59	-0.7	-11.0	1253	8.6	-1.1
101	4.9	-9.3	1354	-1.3	-7.0
166	3.8	-9.7	1457	3.9	-7.5
212	2.9	-3.7	1560	0.5	-5.4
252	-15.1	-21.1	1805	-0.6	-3.1
387	1.9	-6.6	1913	-2.1	-6.2
456	2.7	-6.8	2009	-4.8	-8.2
584	0.8	-10.0	2125	-5.0	-11.7
718	-4.3	-14.0	2238	-2.6	-6.5
764	0.7	-9.6	2526	0.5	-10.2
940	2.8	-3.1	2623	0.4	-6.0
987	0.3	-8.2	2731	0.1	-5.9
1051	-0.8	-6.9	3039	-11.8	-14.5
			Mean	-0.2	-7.8

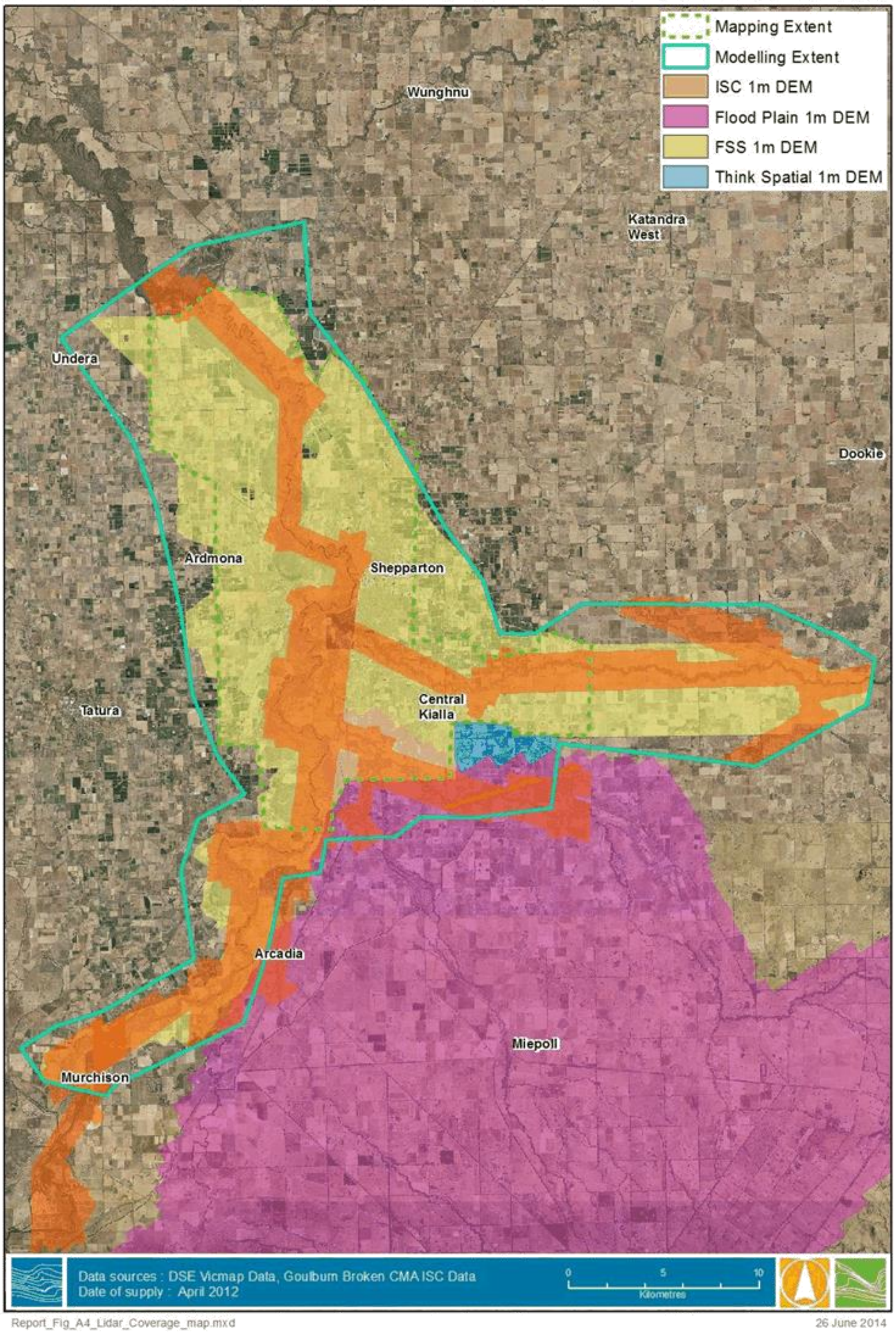

FIGURE 3-2 EXTENT OF AVAILABLE DEM'S

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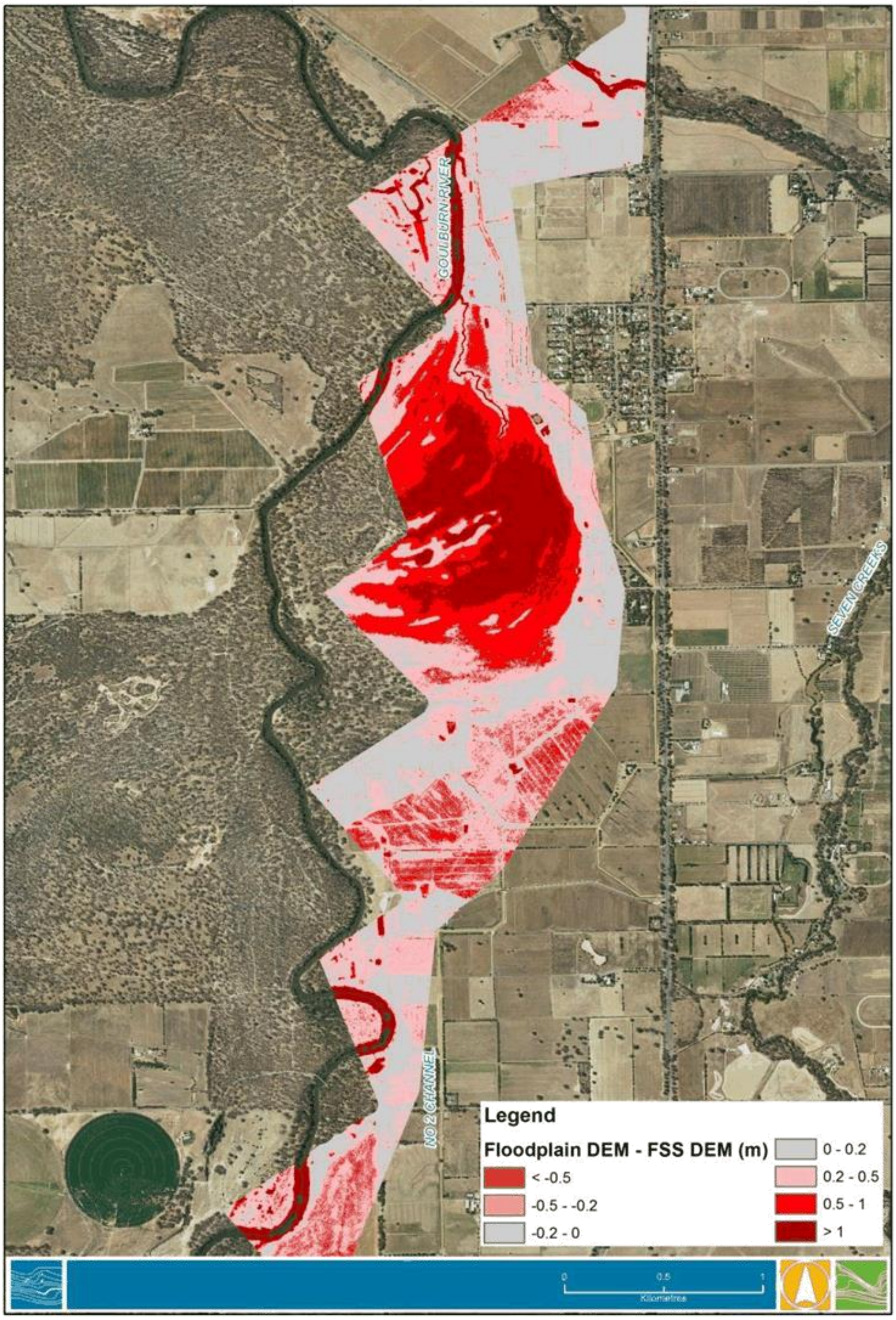

FIGURE 3-3 VERTICAL COMPARISON OF FLOODPLAIN DEM AND FSS DEM

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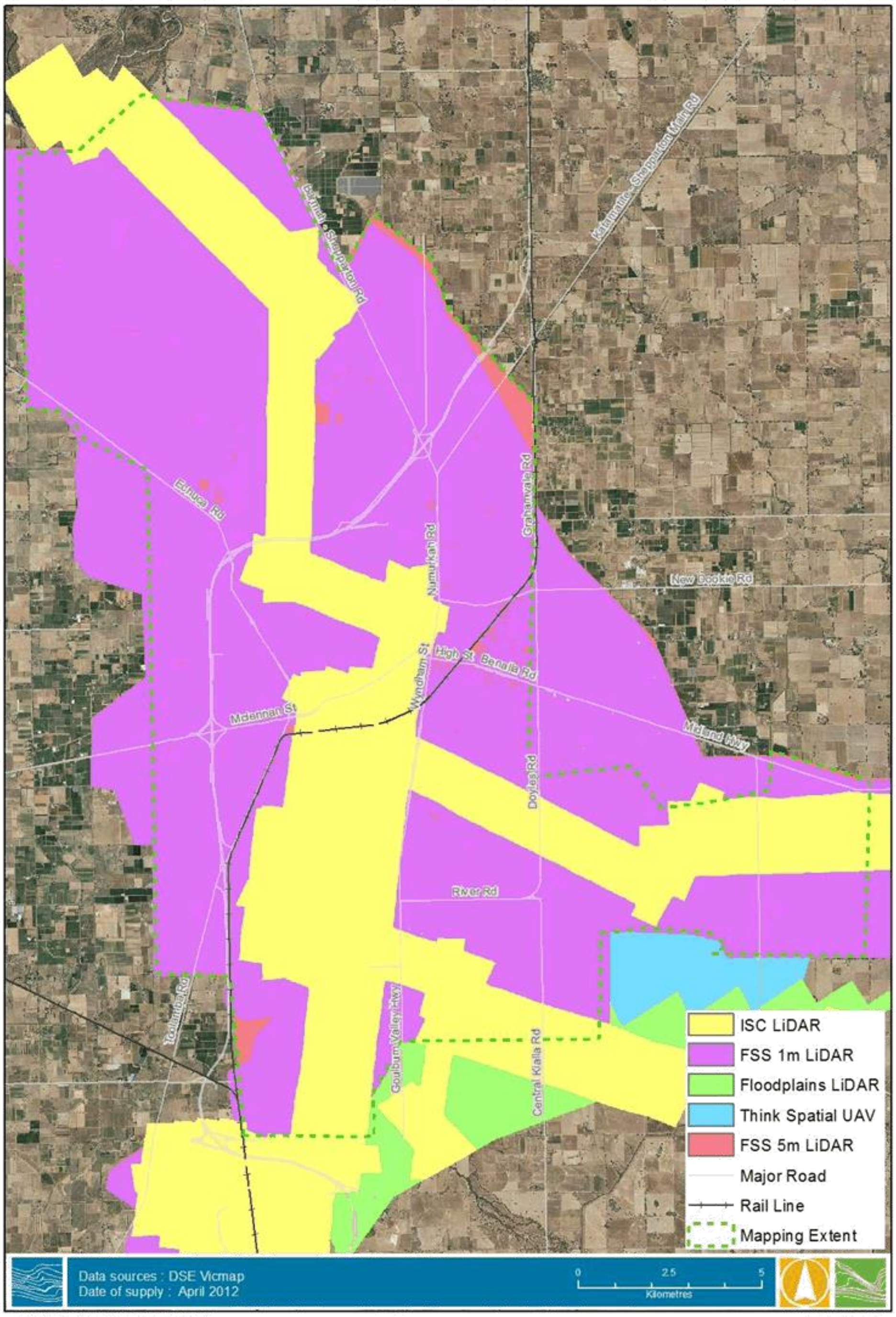

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FIGURE 3-4 DEMS USED IN HYDRAULIC MODEL TOPOGRAPHY

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3.3.2 Stormwater Drainage

Details of the underground drainage network are important for the establishment of the hydraulic model and identification of flood related drainage issues. It should be noted however that this study was not intended to consider the entire stormwater system. The study focussed on larger riverine flood events and included pipes greater than 600 mm in diameter, as identified within the GSCC GIS database. Other smaller pipes were included in areas where it was thought that they may be important in conveying floodwaters from the river to low lying areas that would be otherwise disconnected. Council was consulted on the pipes and pits that were to be included in the hydraulic modelling and approved the selection.

Greater Shepparton City Council supplied their drainage network layout for Shepparton and Mooroopna. The network was received in an ESRI shapefile format of the pipes and pits.

The shapefiles indicated conduit/pit locations and conduit sizes for constructed pipes. The shapefile drainage network consisted of 8,091 conduits of which 8,078 had recorded diameters and 3,055 had recorded inverts. The drainage network is shown in Figure 3-6.

In addition to the underground pipe network, several major culverts, siphons and bridges were incorporated into the hydraulic model, Figure 3-7. Existing survey of the Shepparton-Mooroopna Causeway was available from earlier studies, with several hardcopy plans also made available from VicRoads, VicTrack and GMW.

3.3.3 Feature Survey

Two sets of feature survey were made available for this study, the survey of the Shepparton Mooroopna Causeway and the survey of the strategic levees downstream of Shepparton on the Goulburn River. The survey of the causeway was used to verify the LiDAR data as mentioned in Section 3.3.1. The survey of the levees was stamped onto the hydraulic model topography as thin break lines in the TUFLOW model topography. The location of the feature survey is shown in Figure 3-8.

Although the feature survey defined crest elevation for the causeway, the waterway openings were not defined. The Goulburn Broken CMA took photos and sketched up dimensions of all the waterway openings so that they could be well defined within the hydraulic model. The sketch provided for Daintons Bridge over the Goulburn River is shown in Figure 3-5. This is the main bridge crossing the Goulburn River, which was modelled as a 1D structure within the 1D Goulburn River Channel network. The remaining waterway openings were modelled as 2D structures, applying form losses, blockage from piers and the bridge deck and rails.

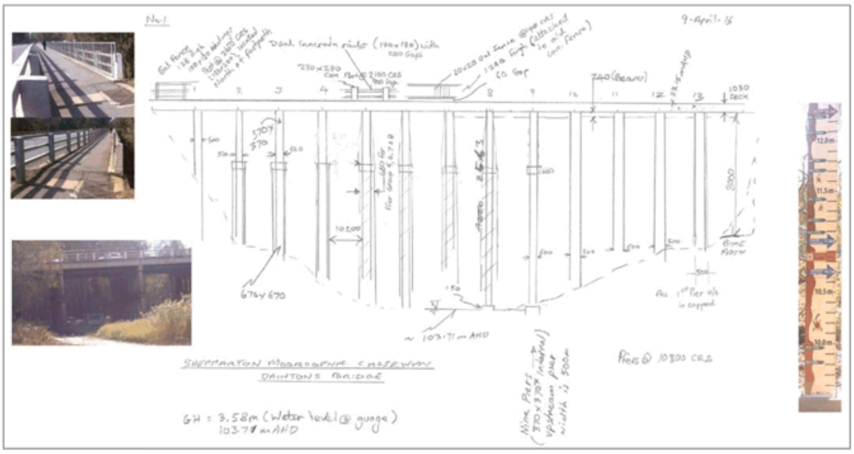

FIGURE 3-5 DAINTONS BRIDGE SKETCH PROVIDED BY GOULBURN BROKEN CMA

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3.3.4 Irrigation Channels

The Goulburn Broken CMA provided ESRI shapefiles of the irrigation network. The data showed the location of channels and is shown in Figure 3-8. The irrigation channel banks form hydraulic barriers across the floodplain and were stamped onto the topography as thin break lines in the TUFLOW hydraulic model. The irrigation channel banks were digitised using the irrigation channel network shapefiles, refined using the 1 m LiDAR datasets.

Very limited information other than the alignment of these irrigation and drain features was available other than that extracted from LiDAR information. Some feature survey was available for small sections of channel bank and was included.

3.3.5 Aerial Photos and Observed Flood Extents

Aerial photos of the 1974 and 1993 flood events were received from Goulburn Broken CMA as well as digitised flood extents generated from the photos. Aerial photos for the 2010 flood event were sourced from NearMap and flood extents were digitised from this photography. The flood extents and photos were used to validate the hydraulic model for the calibration events. It should be noted that these images do not necessarily represent the peak of the flood event, with the 1993 image taken 2 days after the flood peak.

A recent aerial photo from 14th December 2013 was used for mapping purposes as a background image. This image was supplied by the Goulburn Broken CMA.

3.3.6 Observed Flood Levels and Floor Levels

The Goulburn Broken CMA provided flood levels from the Victorian Flood Database (VFD) which contain levels for a range of events including the 1974, 1993 and 2010 events. These levels were used to calibrate the hydraulic model. Figure 3-9 shows the available observed levels for the three calibration events.

3.3.7 Waterway survey

State Rivers and Water Supply Commission (SRWC) survey was used to define the channel invert within the waterway. This survey was undertaken for the 1982 Shepparton Mooroopna Flood Study undertaken by Sinclair Knight and Partners (SKP).

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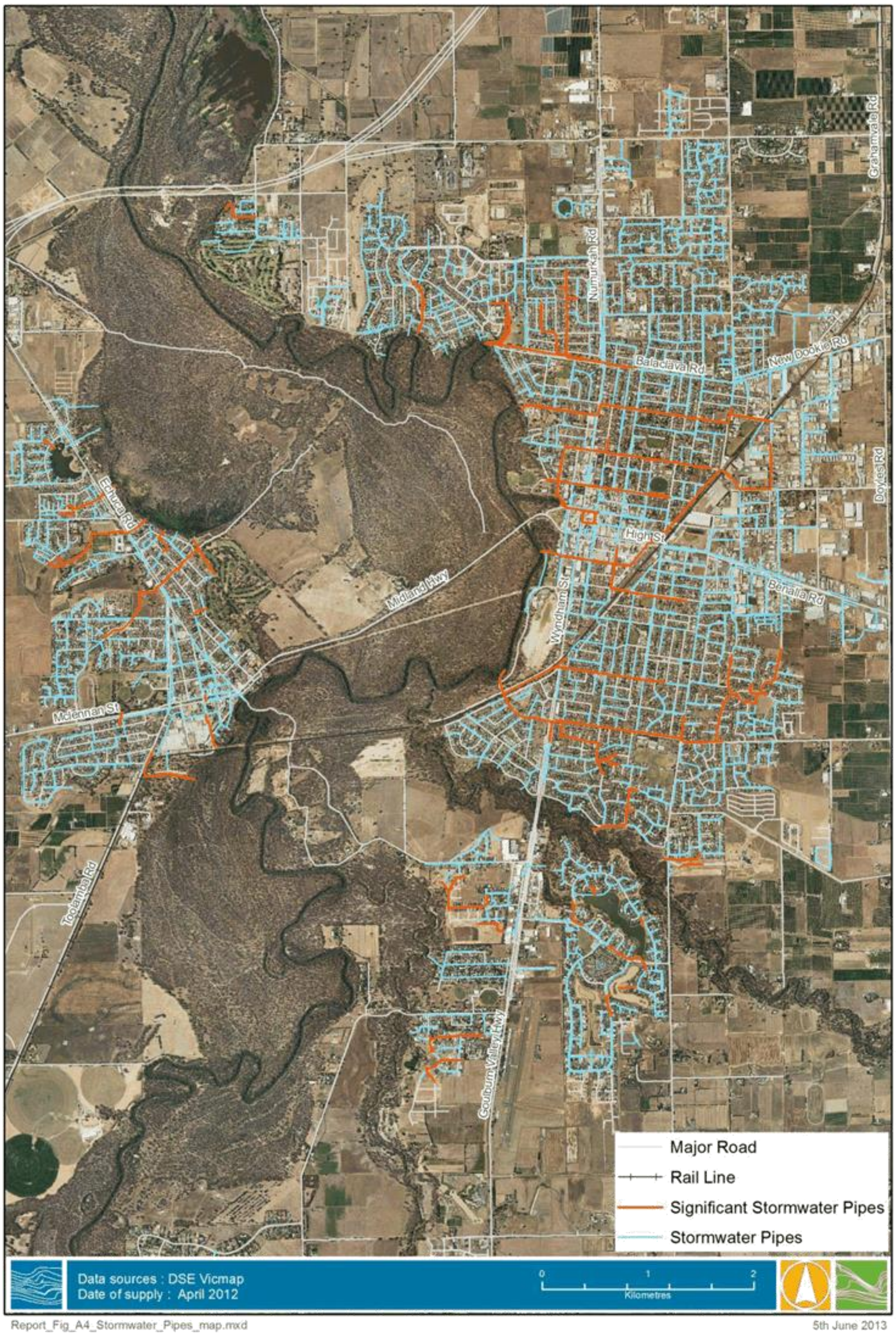

FIGURE 3-6 SHEPPARTON-MOOROOPNA STORMWATER PIPE SYSTEM

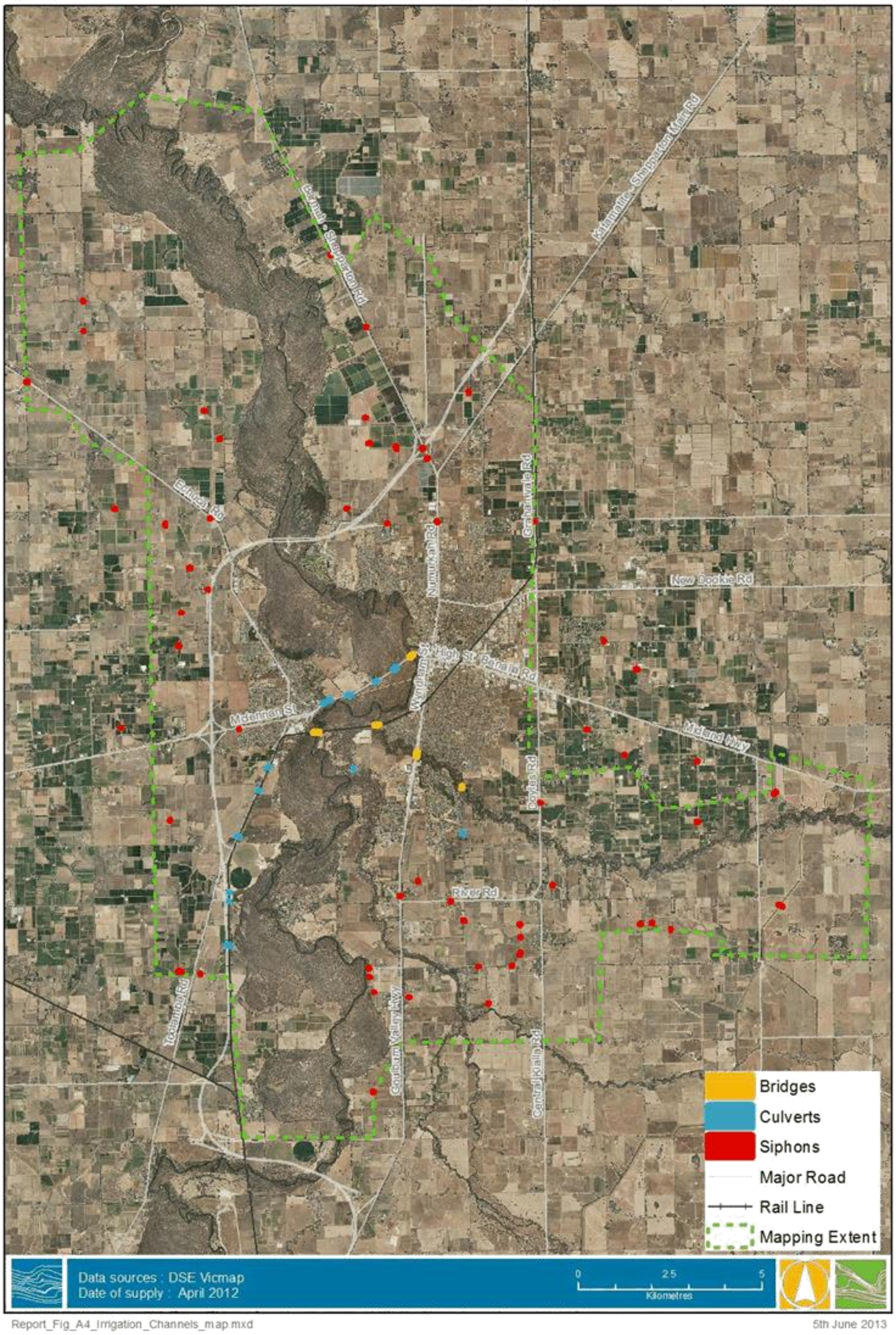

FIGURE 3-7 SHEPPARTON-MOOROOPNA CULVERTS, SIPHONS AND BRIDGES

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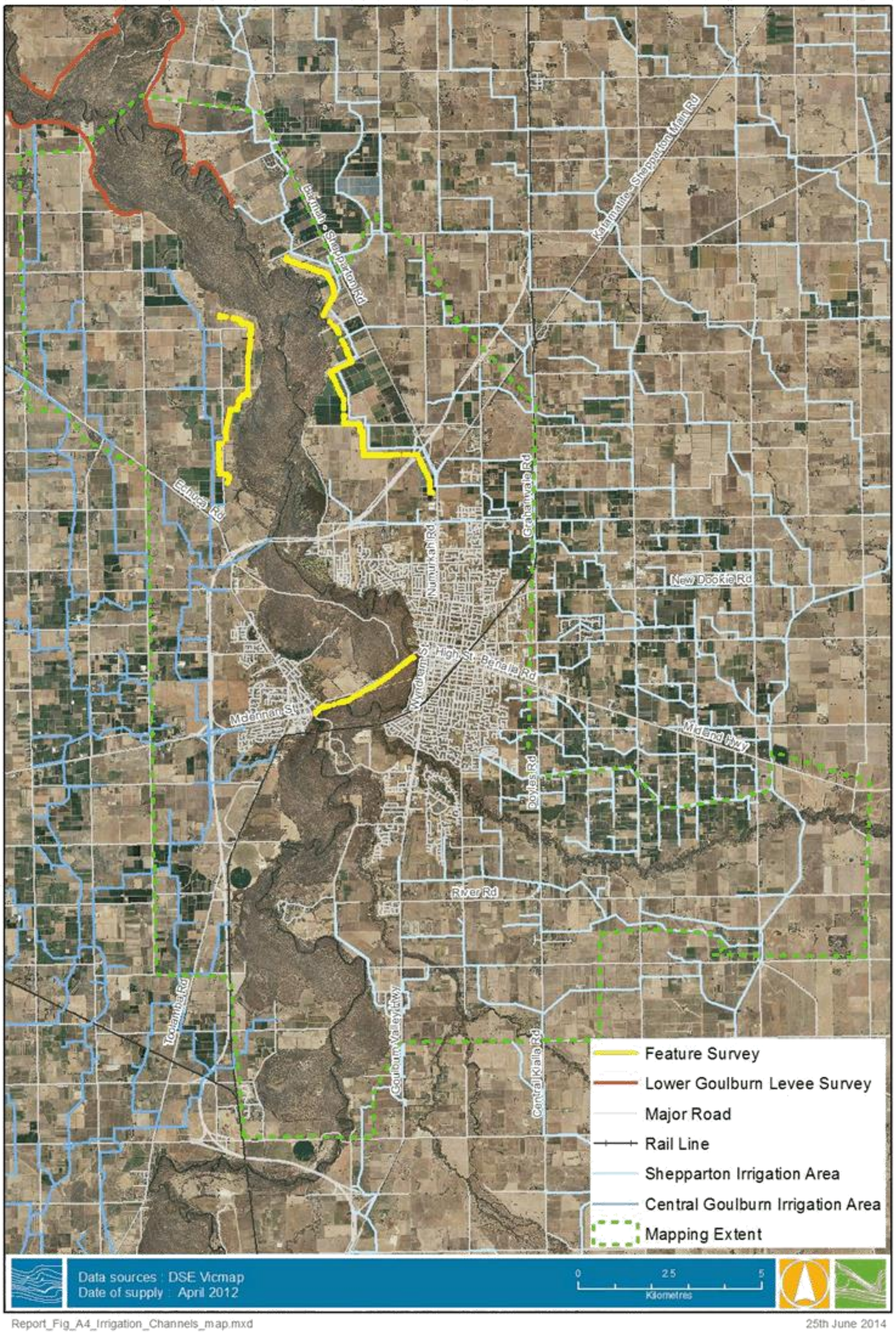

FIGURE 3-8 SHEPPARTON-MOOROOPNA IRRIGATION CHANNELS AND FEATURE SURVEY

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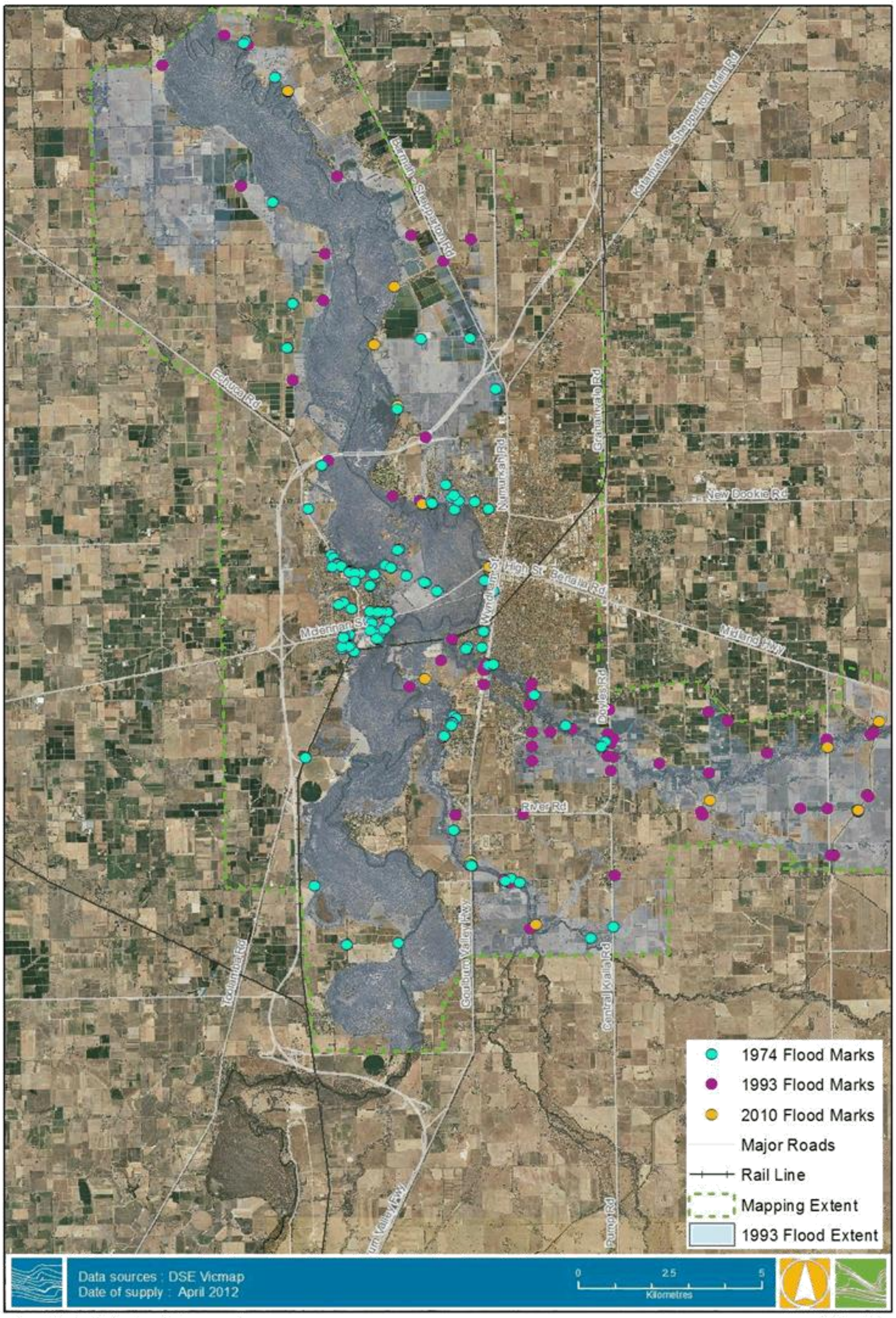

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FIGURE 3-9 SHEPPARTON-MOOROOPNA OBSERVED FLOOD LEVELS

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4 HYDROLOGY

4.1 Overview

Shepparton and Mooroopna are located on the floodplain of the Goulburn River, Broken River and Seven Creeks. The total catchment area of the Goulburn River at Shepparton is approximately 16,000 km^2 (2,525 km^2 in the Broken River catchment, 1,510 km^2 in the Seven Creeks/Honeysuckle Creek catchment, 800 km^2 in the Pranjip Creek catchment and 280 km^2 on the Castle Creek catchment). Given the size of the combined catchment of the Goulburn River upstream of Shepparton and the significance of Lake Eildon in the upper catchment, it was considered impractical to develop a single hydrological model of the area. Any model of the whole area would require numerous assumptions about design considerations and may not make the best use of available streamflow information. Furthermore, breakout flows are likely to occur in the Broken River and Seven Creeks catchments because of the extremely flat floodplain, making calibration of a hydrological model impractical. This was demonstrated in earlier hydrological studies of the Seven Creeks catchment. Given the uncertainties regarding an appropriate spatial and temporal distribution of design rainfall over such a large and varying catchment, not to mention drawdown considerations of Lake Eildon, it is considered more practical and a more efficient approach to update the methodology adopted in the SKM (2002) study, which used Flood Frequency Analysis of the long period of gauge records.

The hydrology approach adopted by SKM (2002) was robust but was improved and updated to take advantage of:

- Additional data from rainfall and streamflow events between 2002 and present day;
- New techniques and research undertaken as part of the revision of Australian Rainfall and Runoff; and,
- Inclusion of outputs from studies completed since 2002.

More specifically the hydrology approach outlined in the study was similar to SKM (2002) with the following updates and enhancements:

- The historical flow series used in flood frequency analysis was updated to include events up to 2012, including the large event in September 2010;
- Flood frequency analysis used updated procedures as outlined in the revised edition of Australian Rainfall and Runoff for fitting design distributions.
- Streamflow gauge ratings were reviewed, with the most appropriate streamflow data utilised;
- Additional routing was carried out within hydraulic models from established gauge locations to the township model boundary to aid in adopting time lags between upstream gauges and model inflow boundaries;
- Specific modelling of major breakouts from the Broken River to the Broken Creek catchment was completed for a range of events; and,
- Recent flood events and available hydrodynamic modelling of the Goulburn was utilised to inform timing of coincident flows for design purposes.

The following sections summarise the hydrological analysis that was undertaken as part of this project, building on the review of previous work undertaken in the SKM (2002) study.

Based on the availability of flood data (aerial imagery, survey and anecdotal evidence), the October 1993, September 2010 and May 1974 events have been used to calibrate the hydraulic model. There is an emphasis on these events in the following discussion around hydrology.

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4.2 Rating Curve Review

4.2.1 Overview

Streamflow data was collated for all relevant gauges in the catchment from the Water Information Management System (http://data.water.vic.gov.au/monitoring.htm), and directly from DELWP. The data was compared, and it was found that the two datasets had significant discrepancies in the instantaneous peak flows and average daily computed flow. Upon further analysis, a similar trend was observed across most gauges assessed. It was identified that this discrepancy was due to recent rating curve revisions, some of which had been applied back over the entire gauge period. To illustrate this, the 1916 peak flow was revised for the Goulburn River at Murchison gauge from 195,000 ML/d to 311,000 ML/d, close to a 60% increase in the peak flow. If this flow increase was adopted it would mean that the revised 1% AEP flow would be larger than the previous 0.2% AEP flow, dramatically changing design flood levels and influencing planning decisions. As the Goulburn River at Murchison gauge was used to produce the upstream model inflows on the Goulburn River, it was decided to undertake a thorough review of the rating curve using a detailed hydraulic model of Murchison.

4.2.2 Recent Changes to the Rating Curves

DELWP supplied rating curves along with instantaneous and daily mean streamflow records for all relevant gauges requested. Figure 4-1 below compares rating curves at different time periods (1974, 1993, 2010 and current) for all relevant gauges.

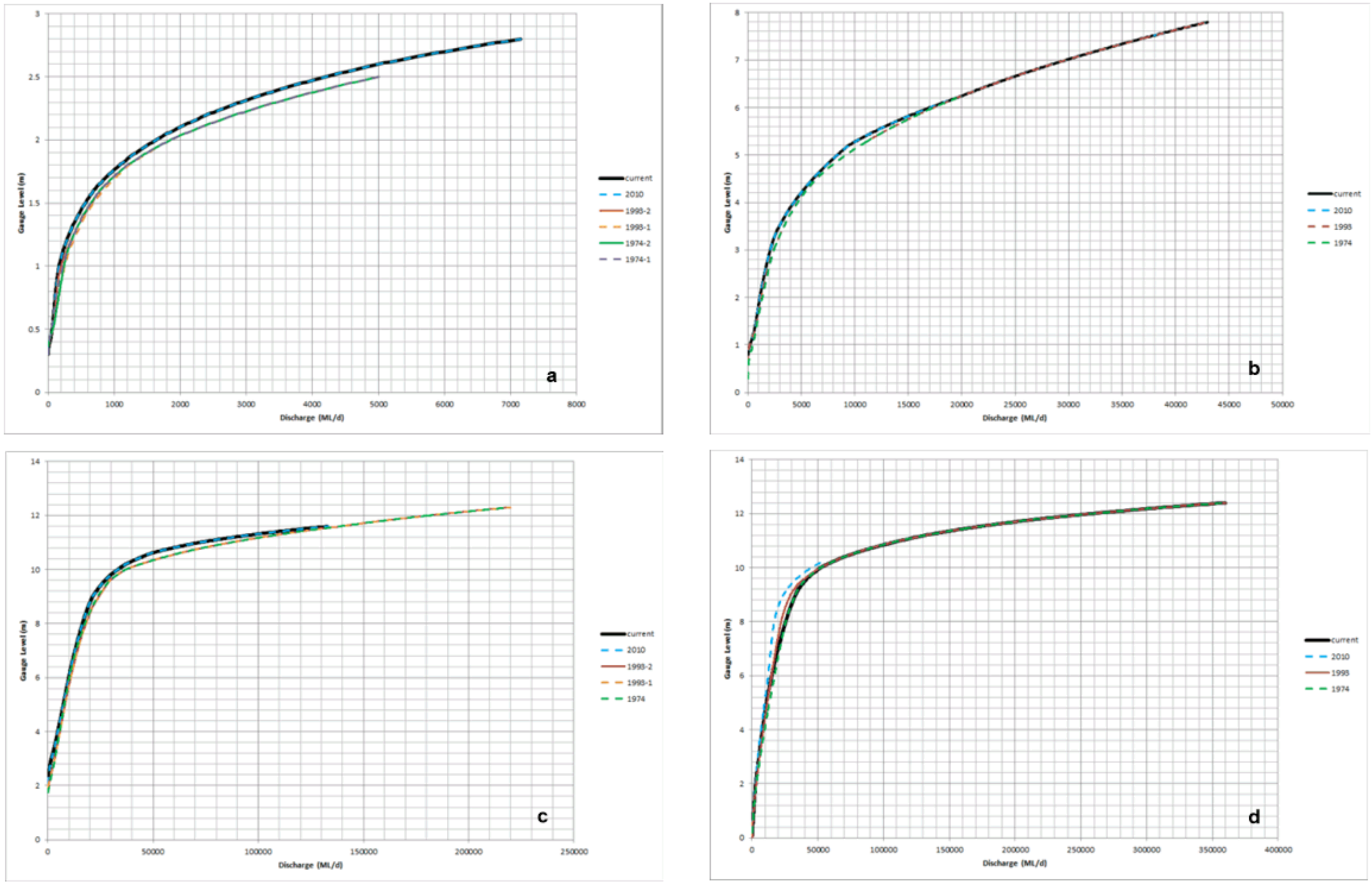
All the rating curves have experienced significant change over the past 40 years. Of interest was the Goulburn River at Murchison rating curve. Although the rating curve has not experienced much change in the high flow section of the rating curve since 1974, when comparing previously accepted estimates of the largest historic flood events to flows estimated using the recent rating curves, major discrepancies were identified.

4.2.3 Goulburn River at Murchison

The rating curve review and update of the Goulburn River at Murchison gauge is fully detailed in the Murchison Flood Mapping Study Report (Water Technology, 2014) and is summarised below.

The Murchison gauge has operated since 1887 and has a significant number of gaugings (610) that have made up the current rating curve (rating table number 73.00). The current rating curve is considered reliable up to a relative gauge height of 11.6 m or 184,000 ML/d. The highest gauging used to construct the rating curve was taken in 1974 at a relative gauge height of 10.915 m and approximately 100,000 ML/d, so even within the 'reliable' section of the curve there has been some extrapolation. The rating curve has been extrapolated out to a gauge height of 12.4 m or 360,000 ML/d.

The need to complete a full rating curve review became apparent when comparing the previously accepted flow estimates of the largest of the historic flood events with flows estimated using the extrapolated section of the current rating curve. The previously accepted flow estimate for the 1916 flood was 195,000 ML/d at Murchison. Using the current rating curve, the 1916 flow is estimated at 311,000 ML/d. This increase in the flow of the 1916 event and other large events would have a significant impact on flood frequency analysis and design flood flows if adopted. This revised flow for 1916 did not correspond with other regional flow estimates on the Goulburn River, i.e. it was significantly larger than upstream and downstream gauge readings, warranting further investigation.


a
Gauge Level (m)
Discharge (ML/d)
current
2010
1993-2
1993-1
1974-2
1974-1
b
current
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2010
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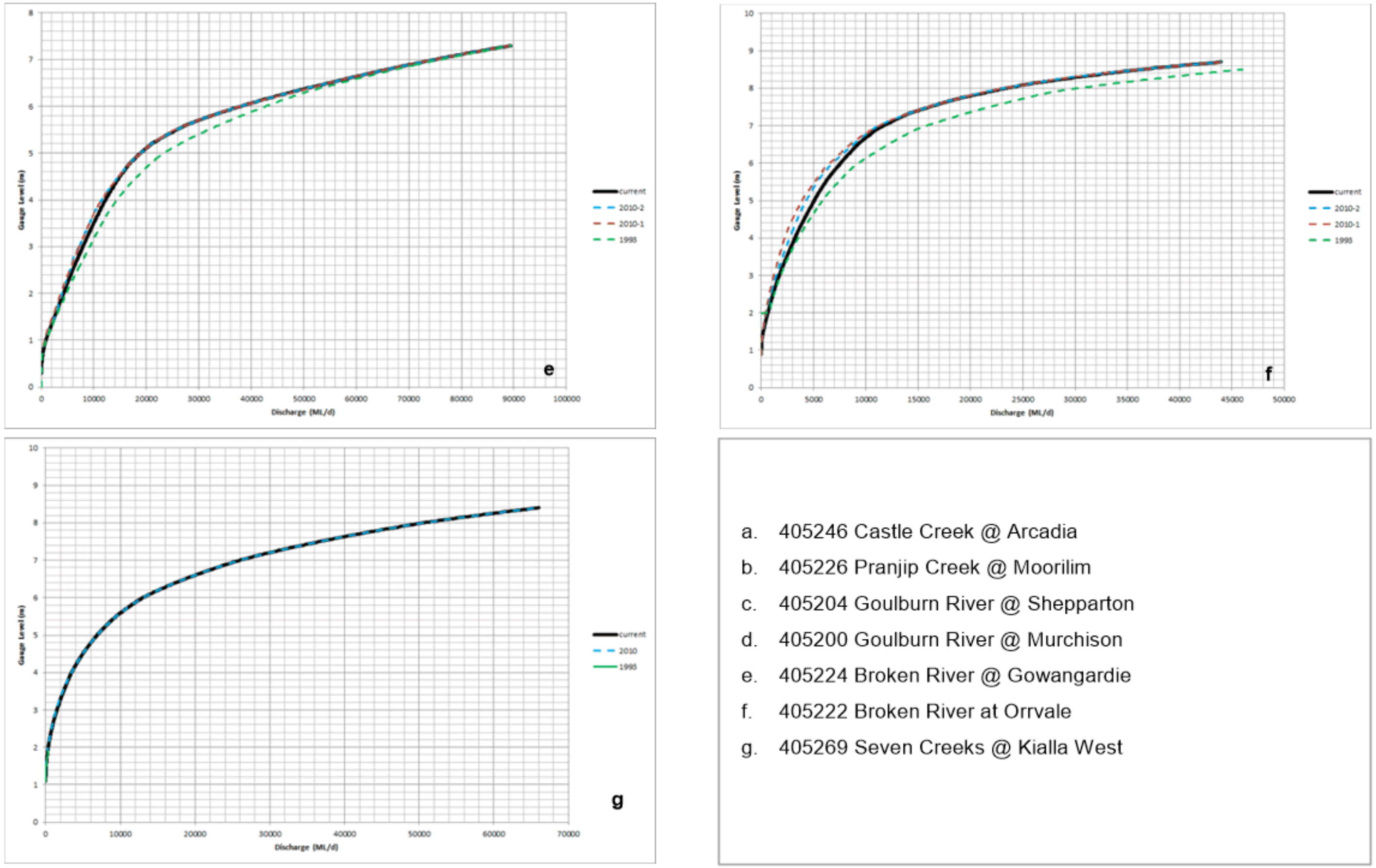

FIGURE 4-1 RECENT RATING CURVE REVISIONS

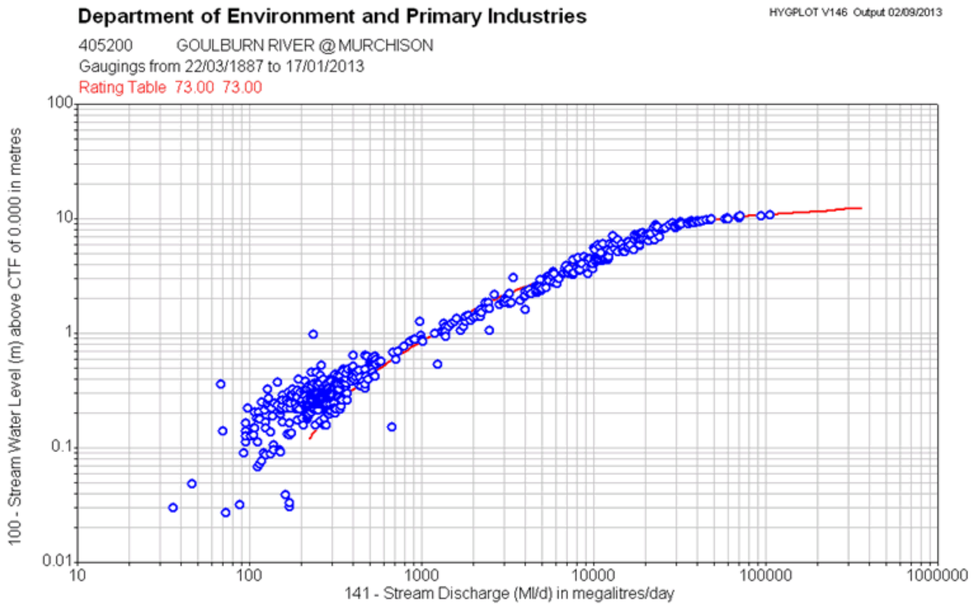

FIGURE 4-2 MURCHISON CURRENT RATING CURVE AND GAUGINGS (SOURCE: DELWP)

4.2.3.1 Murchison Hydraulic Modelling

A 1D-2D TUFLOW model with a grid resolution of 5 m was developed for the Murchison area, extending 4 km upstream and over 11 km downstream of the gauge site. The model was calibrated at the gauge site using the water levels and flows available for the 1974, 1993 and 2010 events. Another three steady state flows were run through the model to provide further verification points along the rating curve at the gauge site. The downstream boundary was set as a constant water level, 1.68 m below the level expected at the Murchison gauge site, based on analysis of the water surface profile captured by the ISC LiDAR. Although this is a simplistic assumption, it was tested through sensitivity and was shown to not unduly impact on model results due to its distance downstream.

The water levels predicted by the model at the gauge site for each flow are shown in Table 4-1 and Figure 4-3. The level for the 20,000 ML/d flow was 0.16 m lower than the current rating curve, however it was well within the envelope formed by the historic gaugings. It is understood that there exists a very large hysteresis loop in the rating curve at the site, with flows measured on the rising limb of a flood being very different to the flows measured on the falling limb of the flood. The levels were within 0.1 m of the current rating curve for flows from 50,000 to 100,000 ML/d. Given that gaugings only extend up to 100,000 ML/d this is a good calibration result, with the rating curve well-matched within this flow range. Above this flow, the modelled levels started to diverge from the rating curve significantly, and the modelled level for a flow of 184,000 ML/d was 0.62 m higher than the rating curve. This indicates that the extrapolation of the current rating curve above this flow is most likely to overestimate flows for a given level.

This result is supported by a comparison of upstream and downstream gauges and previously adopted lower flow rates for the larger historic events.

TABLE 4-1 MURCHISON CALIBRATION RESULTS

Flow	Level (current rating curve)		Year	Tailwater level	Modelled Level		Deviation from Rating Curve	Deviation from historic levels
(ML/d)	(m)*	(m AHD)		(m AHD)	(m)	(m AHD)	(m)	(m)
20,000	7.04	115.72		114.04	6.88	115.56	-0.16	-
50,200	9.93	118.61**	2010	116.93	9.87	118.55	-0.06	-0.27 (2010)
63,500	10.27	118.95	1993	117.27	10.22	118.90	-0.05	-0.05 (1993)
100,000	10.84	119.52		117.84	10.93	119.61	+0.09	-
142,000	11.29	119.97	1974	118.29	11.64	120.32	+0.35	+0.35
184,000	11.60	120.28		118.60	12.22	120.90	+0.62	-

** Gauge zero 108.679 m AHD*

*** A level of 118.82 was measured in 2010 with a flow of 50,200 ML/d for this event; the current rating curve differs slightly.*

Two sensitivity analyses were performed by reducing the tailwater level by 1 m and increasing roughness by 25%. Figure 4-3 shows the results of the sensitivity analysis. This showed that the model is moderately sensitive to the adopted roughness values with water levels raised by between 0.18 and 0.35 m at the gauge location. It showed that the model is sensitive to the tailwater condition at low flows but less sensitive at high flows. Even with variation in the possible modelled rating curve, the current rating curve over predicts flow at high stages.

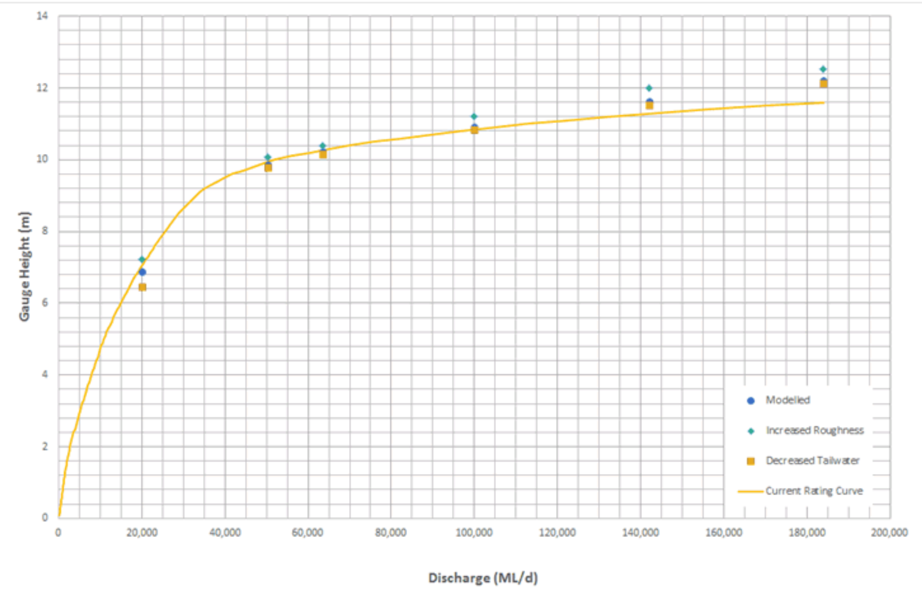

FIGURE 4-3 MURCHISON CALIBRATION AND SENSITIVITY RESULTS

Given the good calibration to the high reliability section of the rating curve between 20,000 and 100,000 ML/d, and the relative insensitivity to tailwater conditions and roughness, the calibration was adequate for simulation of flood levels at the Murchison gauge. It was concluded that the current rating curve significantly overestimates the flow for a given stage at high flows. A revised rating curve was developed using the existing rating curve up to a relative gauge level of 10.5 m or 76,000 ML/d, with the rest of the curve interpolated between the modelled points from 10.5 m to 12.22 m.

The revised rating curve resulted in the 1916 flood level of 12.22 m having a peak flow of 178,000 ML/d which is much closer to the previously accepted estimate of 195,000 ML/d as compared to the current rating curves estimate of 311,000 ML/d. This flow estimate for 1916 is in line with estimates for other upstream and downstream gauges, so provides further confidence that the revised rating curve is an improvement on the current rating curve for the Goulburn River at Murchison.

At the time of writing this report, Ventia was in the process of updating the rating curve in the extrapolated region using the modelled rating curve as suggested. This will be back dated to 2010 and will be used as part of the official rating curve at this site into the future. Ventia have created a new quality code to indicate the flow is based on a modelled extrapolated rating curve.

It should be noted that the recorded peak flow for 1975 at this gauge was found to be inconsistent with upstream and downstream gauges. The method adopted for estimating the actual 1975 peak flow is discussed below, in Section 4.3.4.

4.3 Design Flow Estimates

Flood frequency analysis was previously undertaken for the Shepparton Mooroopna Floodplain Management Study (SKM, 2002), which included flow data up till 1999. The flood frequency analysis was updated for this study utilising additional data from 2000 to 2012. There were also some issues identified with the flow gauging data which resulted in changes to the peak flow magnitudes included in the annual series.

4.3.1 Method

The following streamflow gauges were subject to a flood frequency analysis and revised estimates of design flood peaks were calculated:

- Broken River @ Benalla (404203)
- Broken River @ Orrvale (404222)
- Goulburn River @ Goulburn Weir (405253)
- Goulburn River @ Murchison (405200)
- Goulburn River @ Shepparton (405204)
- Seven Creeks @ Kialla West (405269)
- Pranjip Creek @ Moorilim (405226)
- Castle Creek @ Arcadia (405246)

Design peak flow estimates were derived directly from flood frequency analysis for most of the gauges. Estimates for the Broken River @ Benalla were adopted directly from SKM (2002), as there was no new flow data available. Estimates for Seven Creeks at Kialla West were derived from a regression with upstream gauges, due to a lack of long-term gauge data at Kialla West. This was possible because there was a good gauge record at Euroa and a strong relationship between peak flows at the two gauges. For gauges at the hydraulic model boundaries, flood frequency analysis on volume was also carried out to enable design volumes to be estimated along with the design peak flows.

4.3.2 Data Review

A summary of the available gauge data for relevant gauges on the Goulburn River, Broken River and Seven Creeks is provided in Table 4-2 below. There were some discrepancies between the period of data available, and the recorded flow magnitudes, in the SKM (2002) report and the currently available dataset, this is described further below. A summary of the data used by SKM (2002) is provided in Table 4-3 below.

TABLE 4-2 AVAILABLE GAUGE DATA

Gauge Number	Gauge Name	DELWP Water Monitoring Portal	RWC Blue Book (RWC, 1990)	Historic Peaks
404203	Broken River @ Benalla	1978-1981, 1983-1984, 1993, 1995-1996, 1998	1956, 1958, 1964 (Inst Flow) 1955-1964 (MDF)	
404200	Broken River @ Goorambat (Casey Weir T. Gauge)	1916-1973 (MDF) 1973-1979		
404216	Broken River @ Goorambat (Casey Weir H. Gauge)	1888-1916 (MDF) 1972-2013	1888-1916 (MDF) 1979-1986	
404222	Broken River @ Orrvale	1977-2013		1993
404224	Broken River @ Gowangardie	1991-2013		1993
405253	Goulburn River @ Goulburn Weir	1974-1980 1967-1980 (MDF)	1967-1984 (MDF)	1916, 1934, 1956
405200	Goulburn River @ Murchison	1881-2013		1916
405204	Goulburn River @ Shepparton	1974-2013 1921-2013 (MDF)	1921-1984	1916
405237	Seven Creeks @ Euroa	1973-2013 1963-1973 (MDF)		
405269	Seven Creeks @ Kialla West	2003-2013		1974#, 1993#
405226	Pranjip Creek @ Moorilim	1974-2013	1958-1986	
405246	Castle Creek @ Arcadia	1974-2013	1970-1986	

#*Based on SKM Hydraulic Modelling (SKM, 2002)*

TABLE 4-3 DATA USED BY SKM (2002) FOR FLOOD FREQUENCY ANALYSIS

Gauge Number	Gauge Name	Annual Series	Historic Peaks	1% AEP Flow (ML/d)
404203	Broken River @ Benalla	1955-1999	1916, 1921	103,000
404200	Broken River @ Casey's Weir	1889-1999		66,900
404222	Broken River @ Orrvale*	1955-1999	1916, 1921	43,500
405253	Goulburn River @ Goulburn Weir			N/A
405200	Goulburn River @ Murchison	1956-1999	1916	134,000
405204	Goulburn River @ Shepparton	1921-1999	1916	219,000
405269	Seven Creeks @ Kialla West**	1963-1995	1916	69,900

** Regression with Broken River @ Benalla using 1977-1993 data*

*** Regression with Seven Creeks @ Euroa using 1977-1996 data*

4.3.2.1 Broken River @ Benalla (404203)

Some discrepancies between DELWP and RWC data, and the flows reported in SKM (2002) were found.

- DELWP has only recorded 20 years of instantaneous flow data between 1978 and 1998, of which almost 10 years is classified as missing data.
- 10 years of mean daily flow data are recorded in the RWC Blue Book from 1955 to 1964 (RWC, 1990). No information was available on historic floods.
- The SKM analysis used a full annual series of peak flows from 1955 to 1998 plus historic peaks in 1916 and 1921.
- The peak flow for 1993 provided by DELWP was confirmed to be the same as the flow reported in SKM (2002).
- Most of the flow data used by SKM (2002) could not be located.

4.3.2.2 Goulburn River @ Murchison (405200)

Some discrepancies between DELWP and RWC data, and the flows reported in SKM (2002) were found.

- There are no records in the Blue Book from 1967 to 1984.
- The Victorian Water Resources Data Warehouse station level and instantaneous flow data set is missing from January 1970 to June 1977 and January 1981 to November 1984.
- The DELWP Instantaneous flow dataset is complete from 1881 to 2013.
- The 1916 flow in the DELWP dataset was 311,000 ML/d, compared to 195,000 ML/d (average daily flow) in the Blue Book.
- The 1974 flow in the DELWP dataset was 142,000 ML/d, compared with 111,000 in SKM (2002).
- The 1975 flow in the DELWP dataset was 411,000 ML/d, significantly larger than 1975 flows at upstream and downstream gauges, and larger than the 1916 largest event on record.

A revised rating curve was developed for the high flow region of this gauge through 1D/2D hydraulic modelling for the Murchison Flood Mapping (Water Technology, 2014), see Section 4.2. With the revised rating curve applied to the DELWP dataset, the 1916 flow is estimated at 178,180 ML/d and the 1974 flow is estimated at 117,860 ML/d, which are more consistent with the data in SKM (2002). The flood frequency analysis for this gauge was undertaken with both the raw DELWP dataset and the revised rating curve dataset for comparison. Additional information from the Granite Creeks regional flood mapping study was used to provide an input for Pranjip and Castle Creek, tributaries of the Goulburn River between Murchison and the Seven Creeks outfall.

4.3.3 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. This is discussed further in Section 5.4.1

4.3.3.1 Broken River @ Benalla (404203)

Given that there is no additional recent flow data available, and less historic data is now available compared to what was used in SKM (2002), the SKM peak flow estimates were adopted (Table 4-4). The approximate AEP for a selection of recorded floods are provided in Table 4-5.

TABLE 4-4 DESIGN PEAK FLOWS FOR BROKEN RIVER @ BENALLA (404203)

AEP	ARI (1 in X years)	Peak Flow (ML/d) Adopted from SKM (2002)
20%	5	30,900
10%	10	45,500
5%	20	61,600
2%	50	83,400
1%	100	103,000
0.5%	200	128,000
0.2%	500	161,000

TABLE 4-5 HIGHEST RECORDED FLOWS AND CORRESPONDING AEP FOR BROKEN RIVER @ BENALLA (404203)

Year	Peak Flow (ML/d)	Approx. AEP
1993	112,000	1-0.5%
1981	41,400	20-10%
1956	37,700	20-10%
1996	33,400	20-10%

4.3.3.2 Broken River @ Casey Weir (404200/404216)

The Casey Weir gauge was reviewed, and an initial flood frequency analysis was performed. It was found that the design flows were significantly different to that obtained in the previous SKM (2002) study and were significantly different to the downstream Orrvale gauge. On inspection of the rating curve it was found that the maximum gauged level at 1.9 m or 17,000 ML/d was sufficiently low, that 44 years within the annual series exceeded the maximum gauging. The reliability of the rating curve was questionable, and further analysis was not completed as it added no value to the project.

4.3.3.3 Broken River @ Gowangardie (404224)

The Gowangardie gauge has a very short period of record, not enough to allow a flood frequency analysis to be performed with any degree of certainty. No further analysis was completed for this gauge.

4.3.3.4 Broken River @ Orrvale (404222)

Peak flows from 1978-2012 (35 years) were used for the annual series.

Log Pearson III and GEV distributions were fitted. 11 low flows less than 4,000 ML/d were omitted from the fitting of the distribution, as they appeared to follow a different distribution to the higher flows. The GEV distribution was judged to have the best fit (Figure 4-4). The resulting peak flow estimates are provided in Table 4-6. 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 4-7).

TABLE 4-6 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

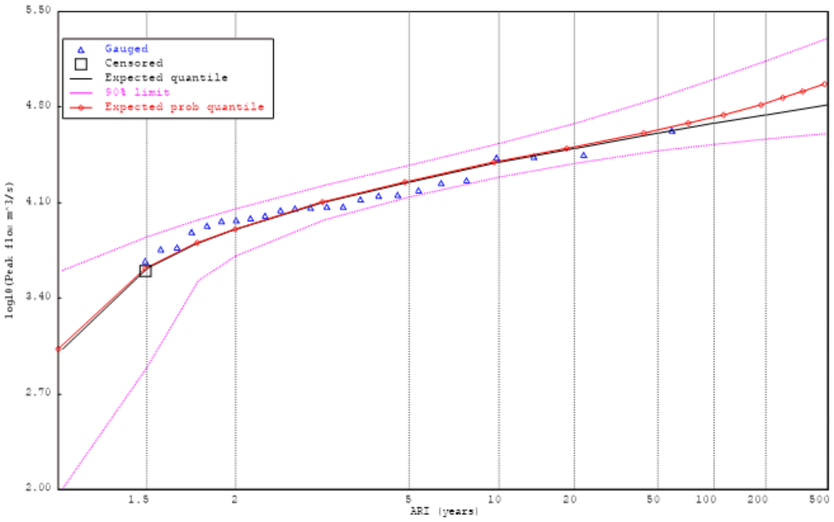

FIGURE 4-4 GEV DISTRIBUTION FITTED TO ANNUAL SERIES FOR BROKEN RIVER @ ORRVALE (404222)

TABLE 4-7 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%
2010	27,300	10-5%
1996	27,100	10-5%

4.3.4 Goulburn River Flows

The Goulburn River at Murchison gauge was the focus for defining the historic and design flows for the Goulburn River. The detailed Shepparton-Mooroopna flood model boundary on the Goulburn River was in Toolamba between the railway bridge crossing and Bridge Road at the location of the Castle Creek confluence. Historic hydrographs from Murchison were routed through the coarse Goulburn River model to the detailed Shepparton-Mooroopna flood model inflow boundary 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 curve for both sites had a high degree of uncertainty associated with 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 is discussed further in Section 5.4.1

4.3.4.1 Goulburn River @ Goulburn Weir (405253)

Instantaneous flow data was available for 1968-1969 and 1975-1979. Mean daily flow was available from 1967-1984. A regression analysis was undertaken on the coincident instantaneous flows and mean daily flows, and the relationship INSTANTANEOUS=1.0862*AVERAGE DAILY was derived (r^2 = 0.99). This was applied to the mean daily flow data to fill in the missing years in the instantaneous flow annual maximum series. The resulting annual series had 18 years of data from 1967-1984. This limited flow record may result in high uncertainty of peak flow estimates, particularly for large events.

The 1974 flood was the highest recorded flow at Goulburn Weir. The 1975 peak at Goulburn Weir was a much lower event (72,000 ML/d), compared to the recorded flow at Murchison in the DELWP Water Information Monitoring System database (411,000 ML/d). This indicates a possible error in one or both measurements as the flow between Goulburn Weir and Murchison is not likely to be very different. The peak at Goulburn Weir is coded as "Unedited data". This provides further weight to the earlier discussion regarding the overestimation of flows using the current rating curve at Murchison. The revised 1975 peak flow at Murchison correcting for the revised rating curve was 223,000 ML/d, which is still significantly higher than the Goulburn Weir recorded flow, it is likely that the Goulburn Weir flow may be underestimated for this event.

The 1974 flow was exceeded at Murchison three times in the period 1881-1966, and never in the period 1985-2012. The three floods in 1916, 1934 and 1956 were included as peaks over the threshold of 121,000 ML/d (the 1974 flow at Goulburn Weir), as there is good evidence of a strong correlation between flows at Murchison and Goulburn Weir.

Log Pearson III and GEV distributions were fitted. The GEV distribution was judged to have the best fit (Figure 4-5). The resulting peak flow estimates are provided in Table 4-8. Approximate AEPs for recorded floods are provided in Table 4-9.

TABLE 4-8 DESIGN PEAK FLOWS FOR GOULBURN RIVER @ GOULBURN WEIR (405253)

AEP	ARI (1 in X years)	GEV Peak Flow (ML/d) 3 peaks over threshold and 111 peaks under threshold of 121,000 ML/d
20%	5	59,500
10%	10	80,000
5%	20	101,600
2%	50	132,600
1%	100	158,400
0.5%	200	186,500
0.2%	500	227,700

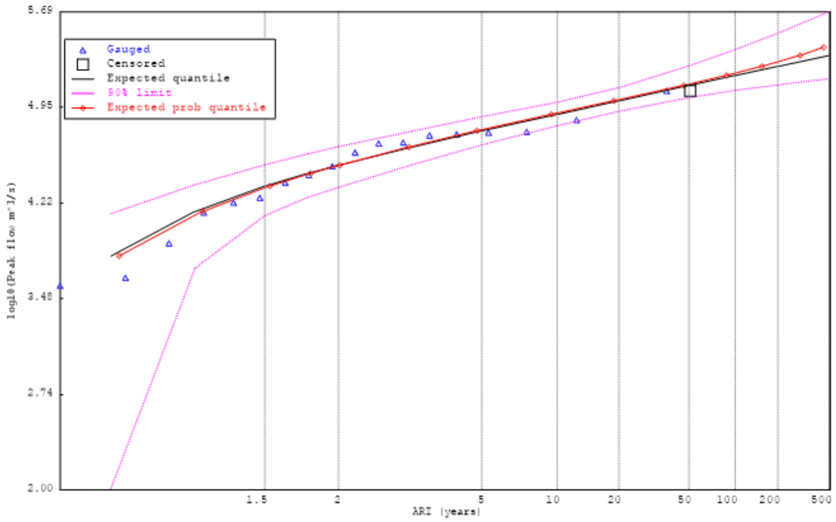

FIGURE 4-5 GEV DISTRIBUTION FITTED TO ANNUAL SERIES FOR GOULBURN RIVER @ GOULBURN WEIR (405253)

TABLE 4-9 HIGHEST RECORDED FLOWS AND CORRESPONDING AEP FOR GOULBURN RIVER @ GOULBURN WEIR (405253)

Year	Peak Flow (ML/d)	Approx. AEP
1974	120,600	5-2%
1981	59,000	20%

4.3.4.2 Goulburn River @ Murchison (405200)

SKM (2002) adopted data from 1956-1999 plus 1916 peak. There is evidence in the record that moderate flood flows were smaller after 1956 (after construction of Big Eildon dam) than before. The 1916 event was included for the following reason (SKM 2002, p. 22):

> *The rainfall spatial pattern for the 1916 event (SKP 1982) indicates significant rainfall fell downstream of Eildon. The 1916 event occurred in September, a time of year where the storage level in Lake Eildon is usually high. Given the size, the spatial rainfall pattern and time of year the event occurred, it is considered reasonable to assume the presence of Big Eildon, if constructed, may have had little impact on the peak flow at Murchison for the 1916 event. As a result, the peak flow for the 1916 event is included in the frequency analysis without modification.*

As discussed previously in Section 4.2.3, a review of the Murchison rating curve was conducted, and it was found that the rating curve required revision for high levels in the extrapolated area of the curve. Flood frequency analysis was performed on the Murchison gauge data using both the raw data from the DELWP Water Information Monitoring System and with the gauge record adjusted using the recommended revised rating curve. The flood frequency analysis for both sets of analysis are provided below, but it is recommended that the revised rating curve flows be adopted for this study.

4.3.4.2.1 EXISTING RATING CURVE PEAK FLOW ANALYSIS

The annual series was constructed using the same period of record used by SKM (2002), post-Big Eildon Dam from 1956, plus 1916, and extended through to 2012. The analysis was also run on the entire record from 1881 to 2012 for comparison.

The 1984 maximum was missing from the gauge record and the 1975 peak flow was inconsistent with upstream and downstream gauges. The 1984 peak was excluded from the annual series. The 1975 peak was estimated from the upstream gauge at Goulburn Weir (405253). Monthly maximum flows at Murchison have a strong correlation with Goulburn Weir, following the relationship MURCHISON=0.8585*GOULBURN WEIR ($R^2 = 0.98$). A 1975 peak flow of 62,200 ML/d was adopted using this relationship.

The GEV distribution was adopted following initial trials of GEV and Log Pearson III. Low flows below 6,000 ML/d were considered "non-flood" years and excluded from the distribution fitting. There were 8 of these non-flood years over the 1956-2012 period and a further two over the pre-1956 period.

The adopted distribution is shown in Figure 4-6 and Figure 4-7, with the resulting peak flow estimates provided in Table 4-10.

Approximate AEPs for recorded floods are given in Table 4-11. Upon review of the results it was noted that the full record period produced peak flow estimates that were higher for events between 20% and 5% AEP, and lower for the larger events as compared to the post-Big Eildon record FFA. This may be explained by the lower range of peak annual flows being slightly higher pre-1956 due to the reduced storage of Eildon and the lack of any large floods above 100,000 ML/d in the 35 year period between 1881 to 1915. The two time periods have been combined, adopting the post-dam period for events up to the 1% AEP, and for the rare 0.5% and 0.2% AEP events, the full period of record was adopted. The rationale behind this decision is that in the rare events the impact of the dam would be minimal, and the full record can be used in the annual series.

TABLE 4-10 DESIGN PEAK FLOWS FOR GOULBURN RIVER @ MURCHISON (405200), EXISTING RATING CURVE

AEP	ARI (1 in X years)	GEV Peak Flow (ML/d) Post-Big Eildon Record 1956-2012 plus 1916 8 low flows censored, 74 flows below 1916 threshold censored	GEV Peak Flow (ML/d) Entire Record 1881-2012 10 low flows censored	Adopted Peak Flow (ML/d)
20%	5	49,900	59,800	49,900
10%	10	74,700	82,800	74,700
5%	20	105,500	108,500	105,500
2%	50	158,400	147,800	158,400
1%	100	210,800	182,700	210,800
0.5%	200	277,100	222,900	222,900
0.2%	500	392,800	285,400	285,400

TABLE 4-11 HIGHEST RECORDED FLOWS AND CORRESPONDING AEP FOR GOULBURN RIVER @ MURCHISON (405200), EXISTING RATING CURVE

Year	Peak Flow (ML/d)	Approx. AEP
1916	311,000	<0.2%
1956	154,000	5-2%
1974	142,000	5-2%
1993	80,200	10-5%

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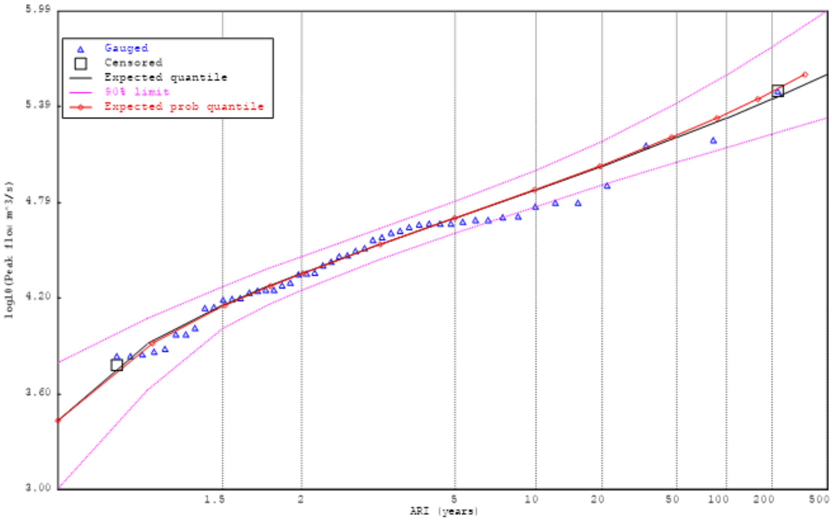

FIGURE 4-6 GEV DISTRIBUTION FITTED TO ANNUAL SERIES FOR GOULBURN RIVER @ MURCHISON (405200), DELWP RATING CURVE, POST-BIG EILDON RECORD PLUS 1916

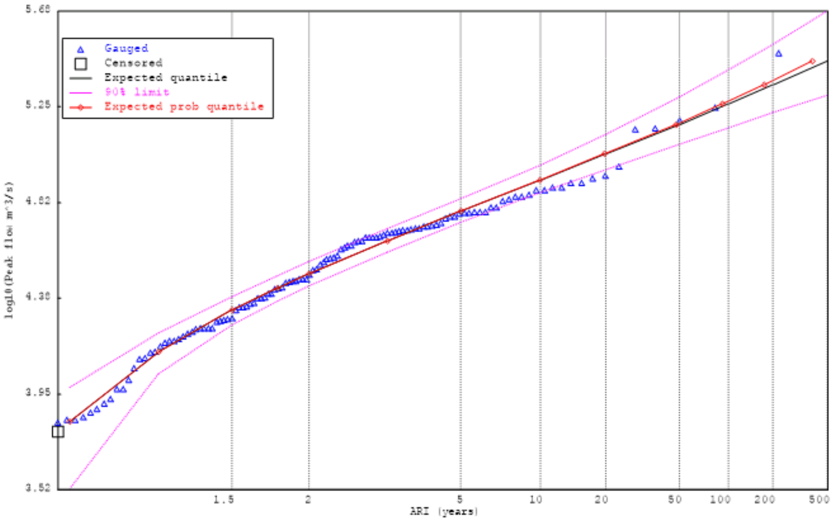

FIGURE 4-7 GEV DISTRIBUTION FITTED TO ANNUAL SERIES FOR GOULBURN RIVER @ MURCHISON (405200), DELWP RATING CURVE, ENTIRE RECORD

4.3.4.2.2 REVISED RATING CURVE PEAK FLOW ANALYSIS

The annual maximum flow series was constructed utilising the revised rating curve discussed in Section 4.2.3 for levels in the extrapolated region of the rating curve. The time periods, peaks over threshold and low flow censoring treatment was the same as the FFA for the existing rating curve analysis described above.

The adopted distribution is shown in Figure 4-8 and Figure 4-9, with the resulting peak flow estimates provided in Table 4-12. Approximate AEPs for recorded floods are provided in Table 4-13.

Similarly, to the existing rating curve FFA, the full record period produced peak flow estimates that were lower than or equal to the post-Big Eildon record FFA for 2% AEP flows and above. The two time periods were again combined, adopting the post-dam period for events up to the 1% AEP and the full period for the rarer 0.5% and 0.2% AEP events.

As seen in Table 4-10 and Table 4-12, using the revised rating curve to construct the annual series significantly reduces the design flows at Murchison for events greater in magnitude than a 10% AEP. It has been demonstrated that the revised rating curve is a better representation of the stage-flow relationship for larger events than the current rating curve, fitting with the regional hydrology upstream and downstream, and the understanding of historic flood flows in the Goulburn River. At the time of finalising this report it is understood that Ventia will be updating the rating curve for this location using the modelled rating curve in the extrapolated region of the curve. Table 4-12 was adopted for design flows at Murchison for the purposes of this study.

TABLE 4-12 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 8 low flows censored, 74 flows below 1916 threshold censored	GEV Peak Flow (ML/d) Entire Record 1881-2012 10 low flows censored	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 4-13 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%

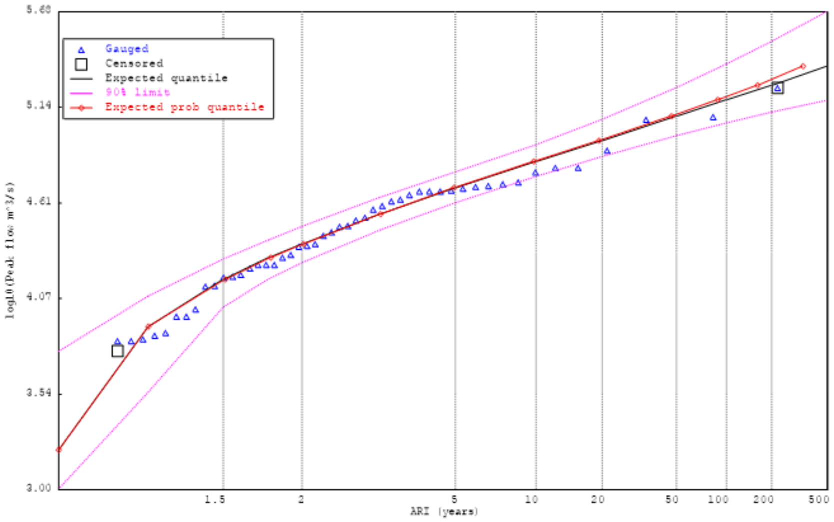

FIGURE 4-8 GEV DISTRIBUTION FITTED TO ANNUAL SERIES FOR GOULBURN RIVER @ MURCHISON (405200), REVISED RATING CURVE DATA, POST-BIG EILDON RECORD PLUS 1916

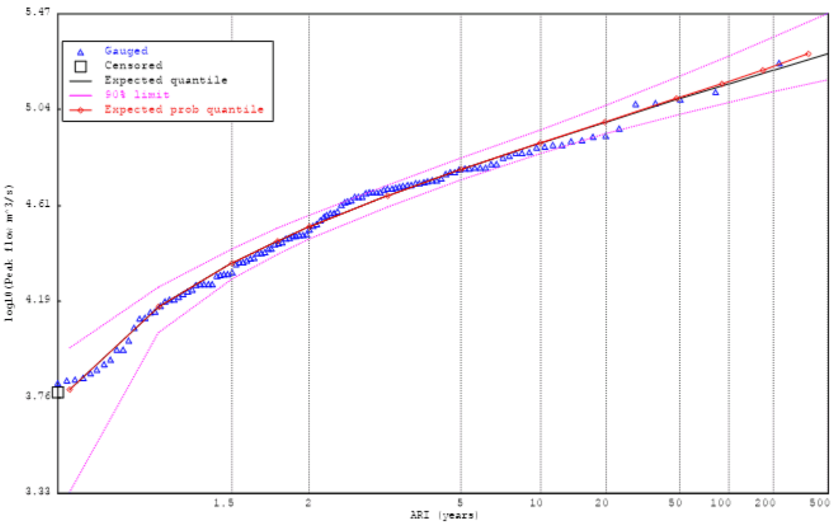

FIGURE 4-9 GEV DISTRIBUTION FITTED TO ANNUAL SERIES FOR GOULBURN RIVER @ MURCHISON (405200), REVISED RATING CURVE DATA, ENTIRE RECORD

4.3.4.2.3 VOLUME ANALYSIS

A flood frequency analysis on 5 day volume was undertaken using the revised rating curve. The Log Pearson III distribution was found to provide a much better fit than the GEV distribution, the Log Pearson III distribution was adopted. Similar to the flood frequency on peak flow, the 1975 and 1984 events were excluded from the analysis due to missing data. Unlike the flood frequency analysis on peak flow, the analysis was performed on the entire period of record. Inconsistencies in the volumes arrived if the entire record analysis was combined with the post Big Eildon analysis. The analysis on the entire record had much tighter confidence intervals and is thought to provide reasonable results (Figure 4-10). The resulting five day volume estimates are provided in Table 4-14.

TABLE 4-14 GOULBURN RIVER @ MURCHISON 5 DAY VOLUME

AEP	ARI (1 in X years)	LPIII 5 day volume (ML)
20%	5	244,500
10%	10	312,100
5%	20	375,000
2%	50	452,600
1%	100	507,500
0.5%	200	559,600
0.2%	500	624,400

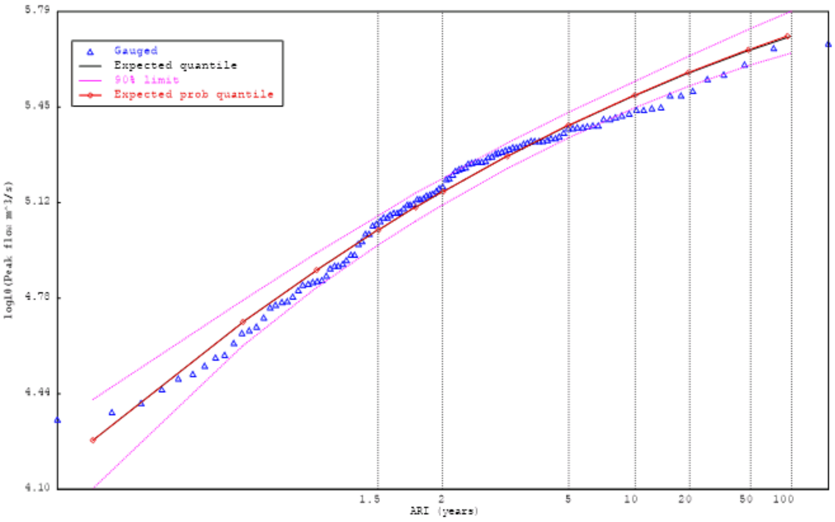

FIGURE 4-10 LPIII DISTRIBUTION FITTED TO ANNUAL SERIES OF 5 DAY VOLUMES FOR GOULBURN RIVER @ MURCHISON 405200 (SOURCE: DELWP)

4.3.4.3 Goulburn River @ Shepparton (405204)

Instantaneous flow data was available for 1941-1968 and 1974-2012. Mean daily flow was available from 1921-2012. A regression analysis was undertaken on the coincident instantaneous flows and mean daily flows, and the relationship INSTANTANEOUS=1.071*AVERAGE DAILY was derived (r^2 = 0.99). This was applied to the mean daily flow data to fill in the missing years in the instantaneous flow annual maximum series. The resulting annual series had 92 years of data from 1921-2012.

The 1974 peak flow was revised down in the latest DELWP data to 191,000 ML/d (from 214,000 ML/d in the SKM study in 2002) and the 1993 peak flow to 150,000 ML/d in the latest DELWP data (from 160,500 ML/d in the SKM study in 2002). It is presumed this revision in flow is due to changes in the rating curves applied back to the historic record.

An estimate of the 1916 peak of 233,300 ML/d from SKM (2002) was used as a historic peak. This is lower than the previous estimate of the 1916 flood of 267,000 ML/d in the Shepparton Flood Study by Sinclair Knight and Partners (SKP 1982). Again, it is presumed that this reduction in the historic peak flow is due to a change in the upper end of the rating curve applied back to the historic flow series.

Log Pearson III and GEV distributions were fitted. 15 low flows less than 10,000 ML/d were omitted from the fitting of the distribution, as they appeared to follow a different distribution to the higher flows. The GEV distribution was judged to have the best fit (Figure 4-11). The resulting peak flow estimates are provided in Table 4-15. Approximate AEPs for recorded floods are provided in Table 4-16.

TABLE 4-15 DESIGN PEAK FLOWS FOR GOULBURN RIVER @ SHEPPARTON (405204)

AEP	ARI (1 in X years)	GEV Peak Flow (ML/d) 15 low flows censored, 39 flows below 1916 threshold censored
20%	5	70,000
10%	10	97,800
5%	20	128,200
2%	50	173,800
1%	100	213,200
0.5%	200	257,800
0.2%	500	325,700

TABLE 4-16 HIGHEST RECORDED FLOWS AND CORRESPONDING AEP FOR GOULBURN RIVER @ SHEPPARTON (405204)

Year	Peak Flow (ML/d)	Approx. AEP
1916	233,300	1-0.5%
1974	191,000	2-1%
1939	161,000	5-2%
1993	150,000	5-2%
1956	121,000	10-5%

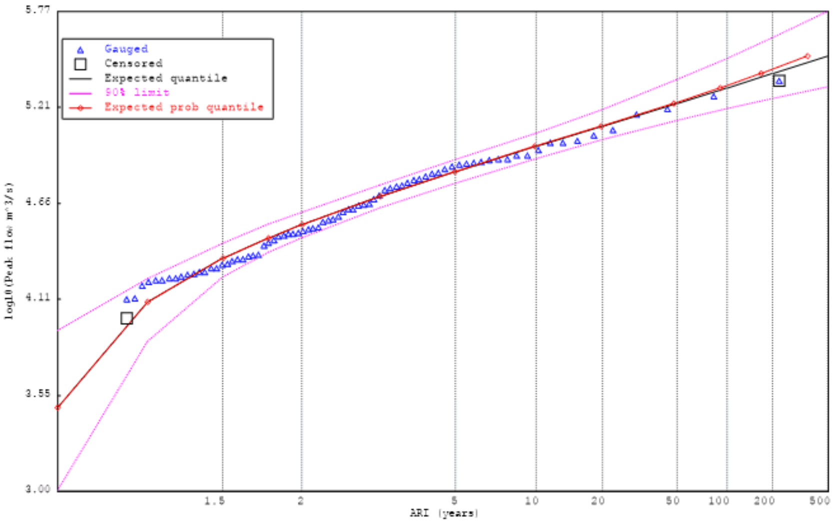

FIGURE 4-11 GEV DISTRIBUTION FITTED TO ANNUAL SERIES FOR GOULBURN RIVER @ SHEPPARTON (405204)

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4.3.4.4 Pranjip Creek @ Moorilim (405226)

4.3.4.4.1 PEAK FLOW ANALYSIS

Instantaneous flow data was available for 1974-2013. Monthly maximum instantaneous flow was available in the RWC Blue Book for 1965-1986 and monthly maximum mean daily flow was available for 1958-1986 (RWC, 1990). A regression analysis was undertaken on the coincident maximum annual instantaneous flows and mean daily flows, and the relationship INSTANTANEOUS = 1.125*AVERAGE DAILY was derived. This was applied to the mean daily flow data to fill in the missing years in the instantaneous flow annual maximum series. The resulting annual series had 56 years of data from 1958-2013.

Log Pearson III and GEV distributions were fitted. Nine low flow outliers were detected using the multiple Grubbs Beck test and were censored. The LPIII distribution was judged to have the best fit (Figure 4-12). The resulting peak flow estimates are provided in Table 4-17. The AEP of the highest recorded flood events is provided in Table 4-18.

TABLE 4-17 DESIGN PEAK FLOWS FOR PRANJIP CREEK @ MOORILIM (405226)

AEP	ARI	LPIII Peak Flow (ML/d)
20%	5	6,200
10%	10	6,400
5%	20	12,800
2%	50	17,200
1%	100	20,400
0.5%	200	23,500
0.2%	500	27,400

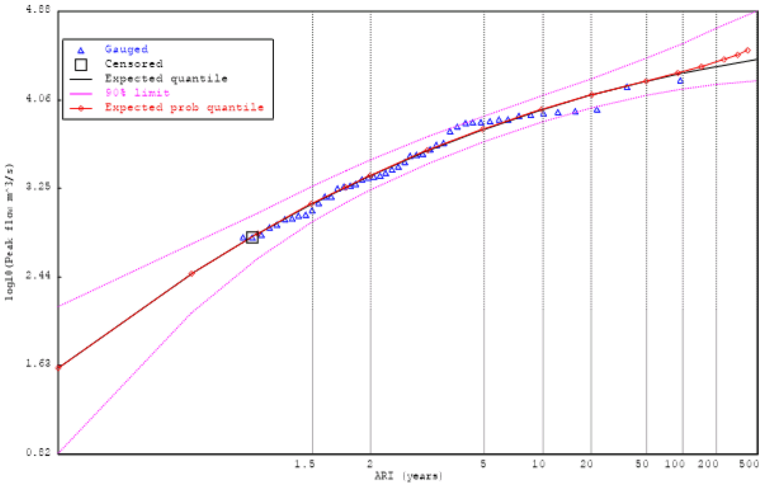

FIGURE 4-12 LOG PEARSON III DISTRIBUTION FITTED TO ANNUAL SERIES FOR PRANJIP CREEK @ MOORILIM (405226)

TABLE 4-18 HIGHEST RECORDED FLOWS AND CORRESPONDING AEP FOR PRANJIP CREEK @ MOORILIM (405226)

Year	Peak Flow (ML/d)	Approx. AEP
1974	17,444	2%
1993	15,209	5-2%
1973	9,410	10-5%

The Pranjip Creek @ Moorilim gauge rating curve is coded as extrapolated for flows above 7,400 ML/d, this equates to an event slightly larger than a 10% AEP event. The gauge is located at a siphon on the East Goulburn Main Channel, where the channel runs under Pranjip Creek. Immediately downstream the creek is crossed by the Goulburn Valley Highway. It is likely that at high flows, these structures have an impact on the hydraulics of the floodplain, and that without high flow gauging there is likely to be significant uncertainty in the recorded flows and thus the flood frequency analysis on peak flow. The Granite Creeks Regional Flood Mapping Study (Water Technology, ongoing at time of writing this report), has shown that the East Goulburn Main Channel does impact on flood flows, at Pranjip Creek.

4.3.4.4.2 VOLUME ANALYSIS

A flood frequency analysis of three day volumes was undertaken for the period from 1958-2013, using mean daily flows for 1958-1973 and instantaneous flows for 1974-2013.

Log Pearson III and GEV distributions were fitted. 22 low outliers were detected using the multiple Grubbs Beck test and were censored. The GEV distribution was judged to have the best fit (Figure 4-13). The resulting three day volume estimates are provided in Table 4-19.

TABLE 4-19 DESIGN 3 DAY VOLUMES FOR PRANJIP CREEK @ MOORILIM (405226)

AEP	ARI (1 in X years)	GEV 3 Day Volume (ML)
20%	5	14,700
10%	10	20,100
5%	20	25,200
2%	50	31,600
1%	100	36,200
0.5%	200	40,600
0.2%	500	46,200

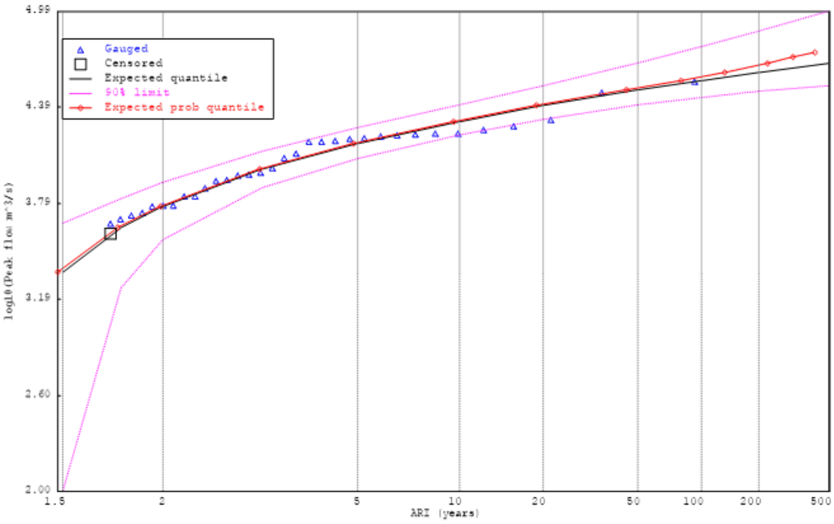

FIGURE 4-13 GEV DISTRIBUTION FITTED TO ANNUAL SERIES OF 3 DAY VOLUMES FOR PRANJIP CREEK @ MOORILIM (405226)

4.3.4.5 Castle Creek @ Arcadia (405246)

4.3.4.5.1 PEAK FLOW ANALYSIS

Instantaneous flow data was available for 1974-2013. Monthly maximum instantaneous flow was available in the RWC Blue Book for 1970-1986 (RWC, 1990). The resulting annual series had 42 years of data from 1970-2013, with two years of data missing in 1989 and 1990. These two years were excluded completely from the series (i.e. the series length was shortened by two years).

Log Pearson III and GEV distributions were fitted. 21 low outliers were detected using the multiple Grubbs Beck test. This was not thought to be reasonable as it left a very small sample size in the annual series. The number of flows censored was reduced to 12 after inspection of the annual series. The GEV distribution was judged to have the best fit (Figure 4-14). The resulting peak flow estimates are provided in Table 4-20.

TABLE 4-20 DESIGN PEAK FLOWS FOR CASTLE CREEK @ ARCADIA (405246)

AEP	ARI (1 in X years)	GEV Peak Flow (ML/d)
20%	5	2,400
10%	10	3,200
5%	20	4,000
2%	50	5,000
1%	100	5,700
0.5%	200	6,400
0.2%	500	7,300

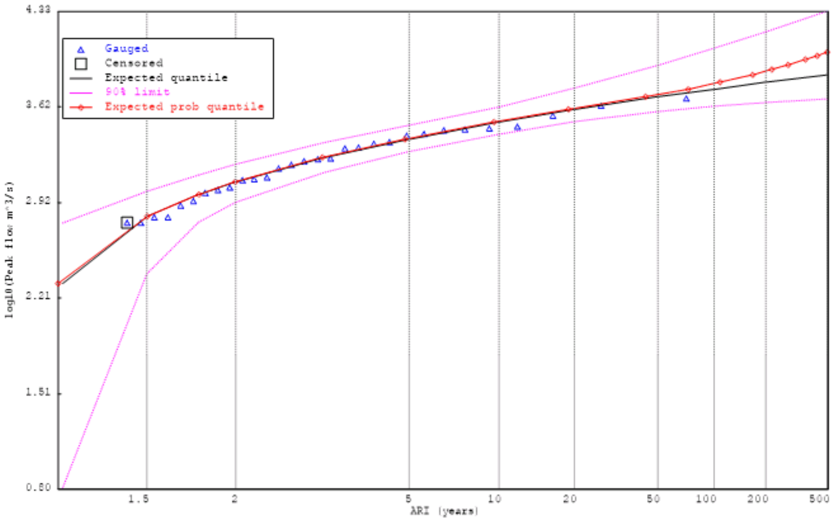

FIGURE 4-14 GEV DISTRIBUTION FITTED TO ANNUAL SERIES FOR CASTLE CREEK @ ARCADIA (405246)

TABLE 4-21 HIGHEST RECORDED FLOWS AND CORRESPONDING AEP FOR CASTLE CREEK @ ARCADIA (405246)

Year	Peak Flow (ML/d)	Approx. AEP
1993	4,835	2%
1974	4,264	5%
2012	3,606	10-5%
2010*	3,034	10%

** note that the peak flow recorded in 2010 occurred in December. This report uses the September 2010 flood event as a calibration event.*

The Castle Creek @ Arcadia gauge rating curve is coded as extrapolated for flows above 2,410 ML/d, this equates to a 20% AEP event. The gauge is located at a siphon on the East Goulburn Main Channel, where the channel runs under Castle Creek. It is likely that at high flows, the channel has an impact on the hydraulics of the floodplain, and that without high flow gauging there is likely to be significant uncertainty in the recorded flows and thus the flood frequency analysis on peak flow. The Granite Creeks Regional Flood Mapping Study (Water Technology, ongoing at time of writing this report), has shown that the East Goulburn Main Channel does impact on flood flows, at Castle Creek and Pranjip Creek.

4.3.4.5.2 VOLUME ANALYSIS

A flood frequency analysis of three day volumes was undertaken for the period from 1970-2013, using mean daily flows for 1970-1973 and instantaneous flows for 1974-2013. The resulting annual series had two years of missing data in 1989 and 1990; these years were excluded completely from the series.

Log Pearson III and GEV distributions were fitted. 19 low outliers were detected using the multiple Grubbs Beck test. This was not thought to be reasonable due to the small sample size remaining, and the number of flows censored was reduced to 11, after inspection of the annual series. The Log Pearson III distribution was judged to have the best fit (Figure 4-15). The resulting three-day volume estimates are provided in Table 4-22.

TABLE 4-22 DESIGN 3 DAY VOLUMES FOR CASTLE CREEK @ ARCADIA (405246)

AEP	ARI (1 in X years)	LPIII 3 Day Volume (ML)
20%	5	4,100
10%	10	5,700
5%	20	7,200
2%	50	8,900
1%	100	10,000
0.5%	200	11,000
0.2%	500	12,100

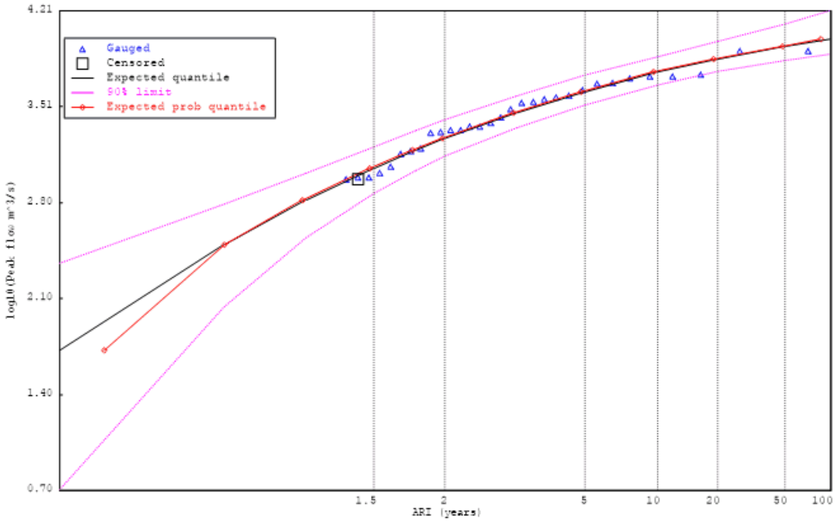

FIGURE 4-15 LPIII DISTRIBUTION FITTED TO ANNUAL SERIES OF 3 DAY VOLUMES FOR CASTLE CREEK @ ARCADIA (405246)

4.3.5 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 were roughly the same. This split was later verified through hydraulic model calibration.

To develop the combined flow 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 flood frequency analysis. This catchment has significant cross-catchment flows making hydrological catchment modelling difficult, necessitating the flood frequency approach.

4.3.5.1 Seven Creeks @ Kialla West (405269)

The quality of the DELWP data is questionable up to 2003, as peak flows appear to be missing. There is only 10 years of data available between 2003-2012, this does not constitute sufficient record for undertaking a flood frequency analysis. Regressions with two upstream gauges (Seven Creeks @ Euroa and Stony Creek @ Tamleugh) were developed to infill the years between 1977-2003 to extend the Seven Creeks @ Kialla West annual series. The gauge Stony Creek @ Tamleugh is named incorrectly, it is on Honeysuckle Creek downstream of the confluence with Stony Creek. This was raised with the Regional Water Monitoring Partnership during the Granite Creeks Regional Flood Mapping Study, and it is recommended that the name be changed to avoid confusion in the future.

The regression was undertaken between monthly maximum flows at each gauge from 1977-2013. As the data from the three gauges had significant periods of missing data there was a very limited period where all three gauges overlapped. This meant that a multiple regression relationship could not be established, instead a linear relationship was established between Seven Creeks @ Kialla West and each of the two upstream gauges. The maximum of the two regression equations was then used to infill the annual series for the Seven Creeks @ Kialla West gauge. The following relationships were produced: KIALLA WEST=2.20*EUROA (r^2 = 0.83) and KIALLA WEST = 2.613 * TAMLEUGH (r^2 = 0.88).

A flood frequency analysis on the extended gauge record was then undertaken and fitted using Log Pearson III and GEV distributions. The Log Pearson III distribution was judged to have the best fit and is shown in Figure 4-16. The resulting peak flow estimates are provided in Table 4-23. Approximate AEPs for the three flood events that are to be calibrated are provided in Table 4-24.

The resultant design flows in this analysis are slightly higher than those estimated in the SKM (2002) study. They are still relatively similar and are thought to provide reasonable design estimates. The flow values calculated from the flood frequency analysis are to be placed several kilometres upstream of the Seven Creeks @ Kialla West (405269) streamflow gauge on the Seven Creeks and Honeysuckle System. It is likely that some attenuation may occur between the inflow locations and the streamflow gauge.

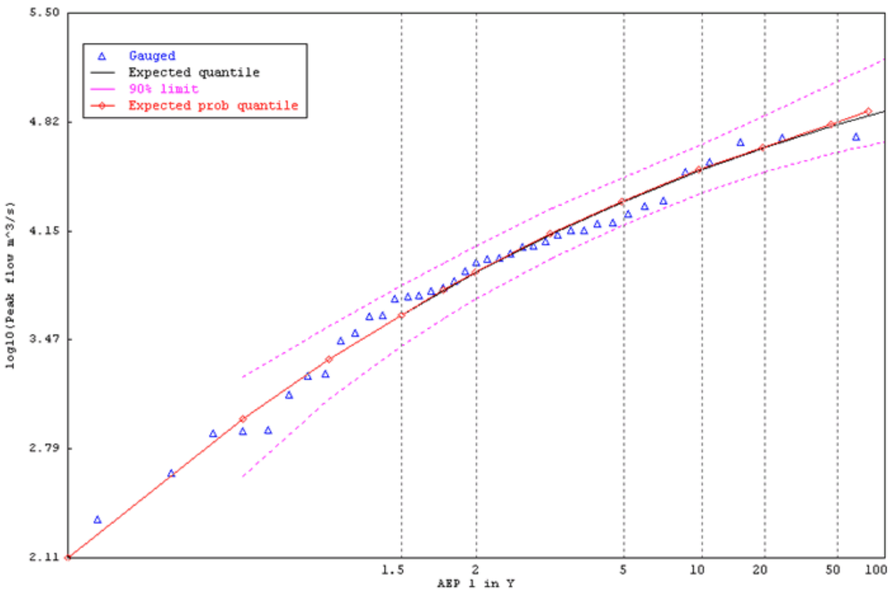

FIGURE 4-16 LOG PEARSON III DISTRIBUTION FITTED TO ANNUAL SERIES FOR SEVEN CREEKS @ KIALLA WEST (405269)

TABLE 4-23 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 4-24 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*

4.3.6 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 4-25. Most of the estimates were broadly consistent. The estimates for Goulburn River @ Murchison diverge, but using the updated rating curve at Murchison, the results are more consistent with the SKM (2002) estimate.

TABLE 4-25 COMPARISON OF UPDATED DESIGN 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 @ Goulburn Weir	158,400	-
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% Flow at Casey's Weir not reliable due to poor rating curve*

4.4 Design Flow Hydrographs

To determine a design hydrograph the SKM (2002) study scaled historic hydrographs to represent the design peak flow and 5 day volume. The 1974 hydrograph was adopted for the Goulburn River and the 1993 hydrographs for the Broken River and Seven Creeks. The design hydrographs were scaled and lagged from the upstream gauges to the model boundary.

The major difference between the hydraulic model inflow hydrographs of this study and that of the SKM (2002) study is that in this study coarse hydraulic models were developed to route flows from the upstream gauges to the model boundaries of the detailed Shepparton-Mooroopna flood model. This allowed a more accurate lag time to be applied to the historic and design hydrographs developed at gauges and transferred to the model boundaries. It also allowed for an improved understanding of breakout flows and the impact of structures such as the East Goulburn Main Channel. Another difference was when considering the volume on the Goulburn River, a 5 day volume was considered but on the Broken River and on the smaller tributaries, a 3 day volume was considered as the large historic hydrographs all showed a duration closer to 3 days than 5 days.

4.4.1 Previous Approach

The timing of the three major contributing catchments has a large impact on the resulting flood at Shepparton. The SKM (2002) study found that the peak flow of Seven Creeks at Kialla West generally occurs between 6-24 hours earlier than the Broken River at Orrvale, the study adopted the median 15 hour time offset for the peak flow for design purposes. The relative timing of the Goulburn and Broken Rivers was also investigated; however, a lack of data did hinder this assessment. A lag time of 33 hours was assumed between Goulburn Weir and Kialla West, and 30 hours between Murchison and Kialla West. It was estimated that the peak flow in the Goulburn at Kialla West occurred approximately 15 hours after the peak flow on the Broken River at Orrvale for the 1974 event, with a 60 hour lag in the 1993 event. This longer lag in 1993 was attributed to the impact of Eildon attenuating the flood in the upper catchment, with the lower catchment having a smaller contribution to the Goulburn flows. For design purposes the 15 hour time lag from the 1974 event was adopted. Several design flood scenarios were developed using various combinations of Goulburn River, Broken River and Seven Creeks flows for a given AEP event at the Shepparton gauge.

4.4.2 Current Approach

Coarse hydraulic models were developed for the Goulburn River from Murchison to downstream of Toolamba, and on the Broken River from upstream of Gowangardie streamflow gauge to downstream of the East Goulburn Main Channel. The detailed Shepparton-Mooroopna model had hydraulic model boundaries located at Toolamba on the Goulburn River at the confluence with Castle Creek, upstream of the East Goulburn Main Channel on the Broken River, a Broken River breakout flow boundary 2.5 km south of the Broken River, upstream of Shepparton-Euroa Road on Honeysuckle Creek, and upstream of Union Road on the two Seven Creeks anabranches.

Using results from the coarse hydraulic modelling for a range of flows, the hydrographs developed for Seven Creeks at Kialla West, Broken River at Orrvale and Goulburn River at Murchison were scaled and lagged to allow for the floodplain characteristics between the gauge locations and the inflow boundary locations. For design purposes, typical relative hydrograph timing was applied to represent a likely design event scenario. It must be noted that every flood is different, and the subtleties in tributary timing may result in differences in the resulting flood levels at Shepparton. This has been tested through this study during sensitivity analysis and is discussed further in Section 6.1

It is accepted that various combinations of hydrograph peak flows, volume, shape and timing with tributaries will lead to significant differences in flood level throughout the study area. The hydrology documented above has estimated various design peak flows and volumes for all modelled tributaries.

The combination of these inputs will be discussed further below in Section 6, with the timing of hydrographs summarised below.

Similar to the earlier SKM (2002) study, for design events the 1974 hydrograph shape was scaled for the Goulburn River, and the 1993 hydrographs scaled for Broken River and Seven Creeks.

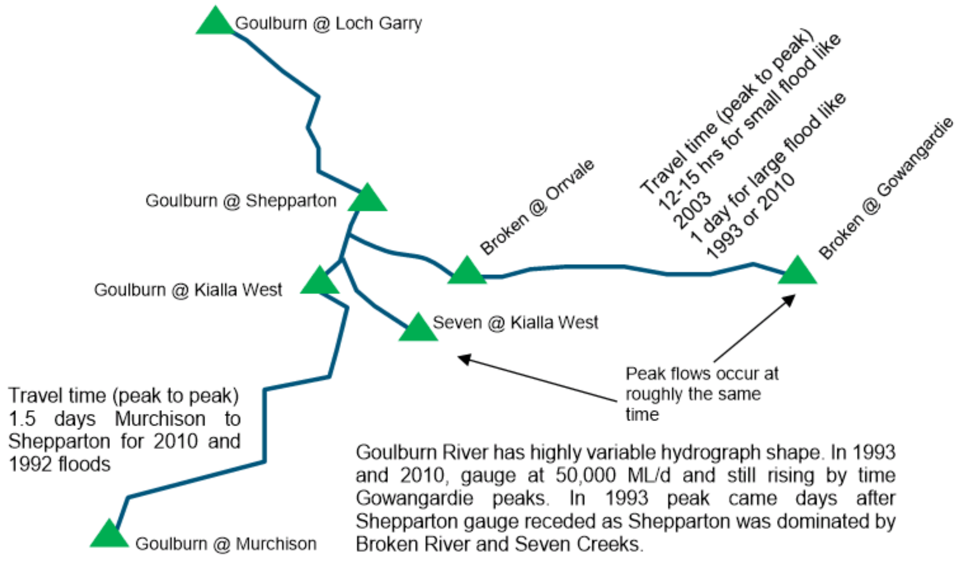

FIGURE 4-17 ANALYSIS OF HISTORIC FLOODS FOR TRIBUTARY TIMING

The final design modelling adopted tributary timing as follows.

- Seven Creeks model inflow peaks first.
- Broken River model inflow peaks 26 hours after Seven Creeks model inflow.
- Goulburn River model inflow peaks 10 hours after Broken River model inflow.
- Broken River breakout model inflow peaks 24 hours after the Broken River model inflow.

The above timings are based on an analysis of historic events routed through the coarse upper floodplain models from Murchison on the Goulburn River and Gowangardie on the Broken River. The timings of the peaks are different to that of the previous SKM study because of the new information from the coarse floodplain models and the change in inflow boundary locations. Consensus was reached on this approach with Greater Shepparton City Council and Goulburn Broken CMA.

Many design hydrograph combinations were modelled in the hydraulic model. The aim was to provide increments at thirteen different water level heights at the Goulburn River at Shepparton gauge. The approximate water level heights are 9.5 (minor flood level), 10.1, 10.5, 10.7 (moderate flood level), 10.9, 11.0 (major flood level), 11.1, 11.3, 11.5, 11.7, 11.9, 12.1, 12.2, 12.3 and 12.5 m. These incremental water level heights at the Goulburn River at Shepparton gauge were produced using three different scenarios, assuming either the Goulburn River was dominant, the Broken River/Seven Creeks was dominant, and a neutral scenario with no dominance. For each modelled scenario, maximum depth, velocity, water surface and flood hazard mapping were produced. An additional Probable Maximum Flood (PMF) scenario was also modelled. Section 6 includes further information regarding the design scenarios modelled.

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4.4.3 Summary of Adopted Design Inflows at Hydraulic Model Boundaries

The design flows determined at the gauge locations were scaled slightly to appropriately account for the attenuation experienced across the floodplain. For Instance, the design flows developed for the Broken River at Orrvale gauge were scaled up for the upstream inflow boundary location to account for the attenuation experienced because of the East Goulburn Main Channel. A summary of the adopted design inflows is provided in Table 4-26. The Seven Creeks inflow in Table 4-26 includes both the Seven Creeks and Honeysuckle Creek inflows.

TABLE 4-26 ADOPTED DESIGN EVENT INFLOW SUMMARY

Design Event	Goulburn River (ML/d)	Broken River (ML/d)	Seven Creeks (ML/d)
20 % AEP	49,100	17,900	22,500
10 % AEP	69,000	29,600	35,100
5 % AEP	90,900	42,700	48,600
2 % AEP	123,900	53,800	67,300
1 % AEP	162,600	63,430	82,100
0.5 % AEP	176,500	72,680	95,760

5 HYDRAULIC MODELLING

5.1 Approach

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 flood events primarily to inform flood intelligence for the study area. 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 remaining waterways and the broader floodplain; and
- Links between the 1D and 2D hydraulic models to integrate the 1D hydraulic components with the broader floodplain flow.

The hydraulic modelling software TUFLOW developed by BMT-WBM was used for this study. TUFLOW is a state-of-the-art tool for floodplain modelling that combines the dynamic coupling of the 1D ESTRY river model and 2D TUFLOW model systems. Through coupling of these two systems it is possible to accurately represent river, pipe and floodplain processes.

The model was initially calibrated to the October 1993 and September 2010 flood events, and verified to the May 1974 flood event, with the model calibrated to reproduce the observed flood heights and extents.

5.2 Information Used

The key information used to develop and run the hydraulic model is discussed below.

5.2.1 LiDAR data

LiDAR data for the region was made available from three different data sets, referred to as floodplain (FP), Fugro Spatial Systems (FSS) and Index of Stream Condition (ISC). A comparison of these datasets was undertaken as described in Section 3.3.1. The 1m ISC DEM was approximately 100 mm above the FSS and FP DEMs. The available LiDAR grids are shown in Figure 3-2.

After careful analysis it was decided to use the ISC DEM as the base data set as it correlated the best with the feature survey and compliment the ISC with the FSS and FP DEMS respectively. The FSS data was raised 100 mm to ensure there was no banding where the two datasets met.

5.2.2 Field Survey

Key survey data collated for the study included:

- Culvert crossings and bridge structure survey;
- Floor level survey of affected properties;
- Feature survey of the Shepparton Mooroopna causeway;
- Photos and sketches of the Shepparton Mooroopna causeway waterways;
- Feature survey of strategic levees downstream of Shepparton;
- Survey of key local drainage assets;
- Flood marks for the May 1974, October 1993 and September 2010 events; and
- SR&WSC Waterway cross sections used as part of SKP 1982

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5.2.3 Hydrological Data

As part of the current study a detailed hydrologic analysis of the study area was undertaken and is detailed in Section 4.

The hydrology data was used as the input boundaries to the hydraulic model for the Goulburn River at Murchison, the Broken River at Gowangardie, Castle Creek at Arcadia, Pranjip Creek at Moorilim, and Seven Creeks at Kialla West. The hydrology of these boundaries was derived for a range of design events and the available gauge data was used directly for the May 1974, October 1993 and September 2010 calibration events. The rating curve for the Goulburn River at Loch Garry was used as the downstream model boundary, and the Goulburn River at Shepparton and the Broken River at Orrvale were used for calibration. Details of these gauges and the relevant available calibration data is shown in Table 5-1 and the locations of the gauges are shown in Figure 5-1.

TABLE 5-1 AVAILABLE GAUGE DATA AND PEAK FLOW DATA FOR CALIBRATION EVENTS

Site Number	Site Name	Catchment Area (Km^2)	Peak Flow 2010 (ML/d)	Peak Flow 1993 (ML/d)	Peak Flow 1974 (ML/d)
405246	CASTLE CREEK @ ARCADIA	164	2,870*	4,840	4,260
405226	PRANJIP CREEK @ MOORILIM	787	7,310	15,200	17,400
405269	SEVEN CREEKS @ KIALLA WEST	1,505	20,500	N/A	N/A
404224	BROKEN RIVER @ GOWANGARDIE	2,396	51,100	59,600	N/A
404222	BROKEN RIVER @ ORRVALE	2,508	27,300	42,900	N/A
405200	GOULBURN RIVER @ MURCHISON	10,772	50,200	63,500	117,900
405204	GOULBURN RIVER @ SHEPPARTON	16,125	78,600	150,000	191,000
405276	GOULBURN RIVER @ LOCH GARRY	16,490	57,100	97,400	N/A

** note that a higher flow was recorded in December 2010, however this investigation utilises the September 2010 event for calibration*

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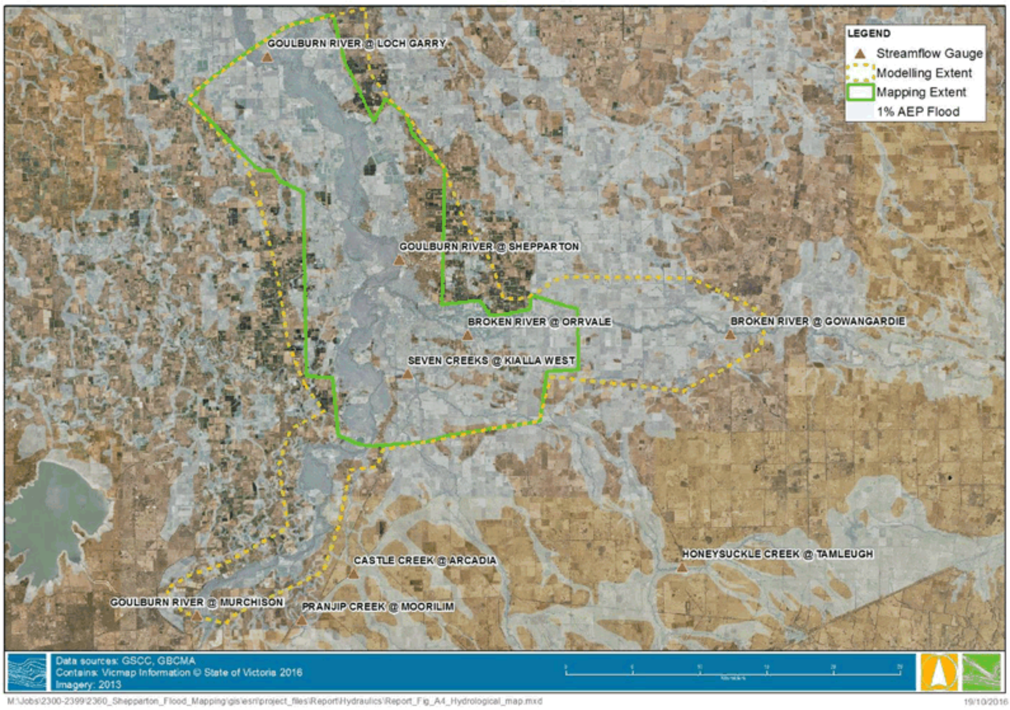

FIGURE 5-1 LOCATION OF AVAILABLE STREAM GAUGES AND MAPPING EXTENT

5.3 Hydraulic Model Development

5.3.1 Overview

Due to the complex nature of the floodplain within the study area, several hydraulic modelling options were tested. Through this process, several grid sizes and model extents were trialled. A single model extending from Murchison to Loch Garry on the Goulburn River and Gowangardie to Shepparton on the Broken River was initially trialled, but due to long run times this was split into three separate models. The approach then adopted two coarse resolution models on the upstream extents of the rivers, routing flows to the detailed Shepparton model area. The detailed Shepparton model initially represented the Goulburn River in 2D but was converted to a 1D-2D model to improve run times. The 2D grid resolution was tested also to optimise the balance between run time and resolution. This section describes the final hydraulic model development.

5.3.2 Topography

The model covers a large area surrounding Shepparton, extending approximately 30 km up the Goulburn River to Murchison, approximately 26 km up the Broken River to Gowangardie Weir, and approximately 18 km downstream of Shepparton to Loch Garry. Shepparton is located at the confluence of the Goulburn and Broken Rivers, with heights ranging across the area from 116 m AHD near Murchison to around 105 m AHD within Loch Garry. Across the floodplain there are several small ephemeral watercourses, structures, irrigation channels, levees, railways and roadways which all influence flood behaviour, as well as the pipe drainage network within Shepparton itself.

To best represent the region, while allowing for reasonable run times, the model topography was split into three separate hydraulic models. To extend the model to the Murchison and Gowangardie gauges upstream of Shepparton, two smaller models were constructed using a 20 m grid resolution to route the flows from the gauges to the flood mapping extent along the Goulburn and Broken Rivers respectively. In both models the river channel was represented by a 1D channel and allowed to surcharge onto the 2D floodplain.

The larger Shepparton model covers the flood mapping extent with both the Goulburn and Broken Rivers and Seven Creeks again represented in 1D. The grid resolution for this model was split into two sections so that the Shepparton Township and surrounds could be modelled at the higher 10 m resolution and the routing downstream to Loch Garry is modelled at the lower 20 m grid resolution. The change in grid resolution occurs approximately 250 m north of Wanganui Road. The schematisation of the hydraulic model is shown in Figure 5-2 below.

Cross sectional survey was used to 'stamp' in the geometry of the main waterway channels on the LiDAR, so that the conveyance was accurately represented.

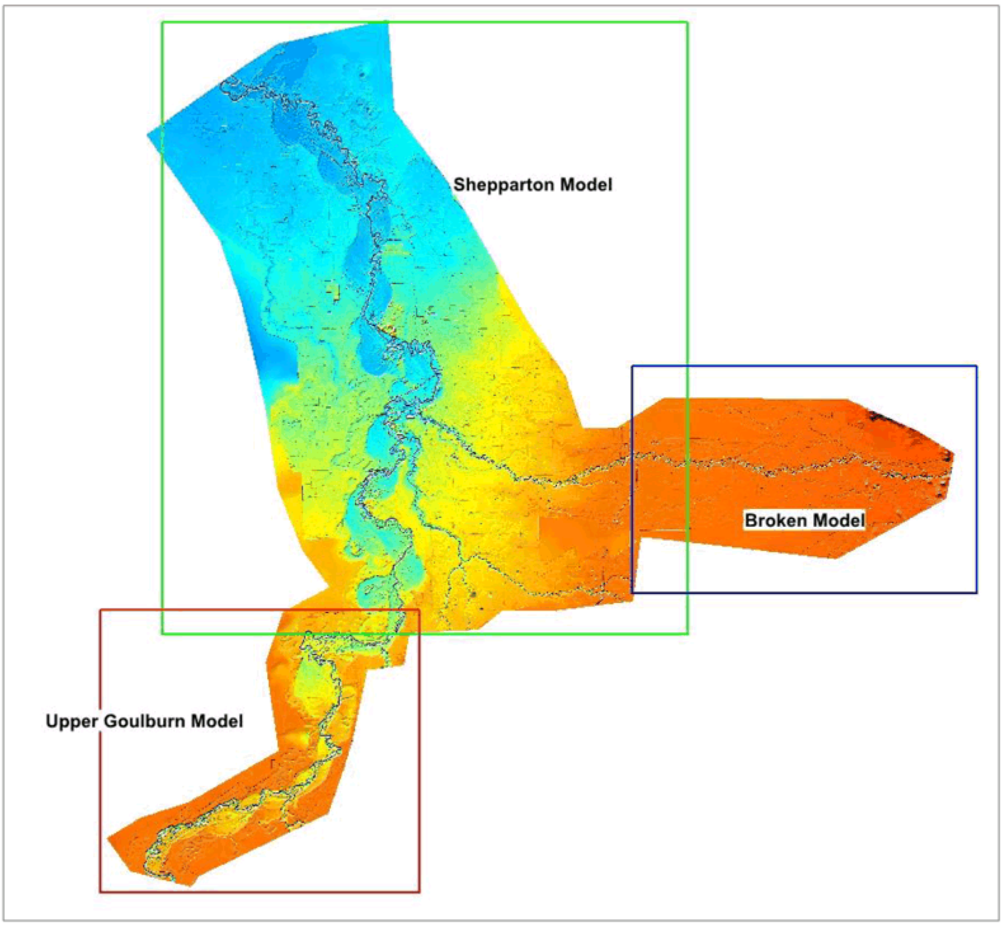

FIGURE 5-2 SHEPPARTON HYDRAULIC MODEL SCHEMATISATION

5.3.3 Key Structures

Information about the key hydraulic structures within the floodplain including dimensions and inverts were required for input into the hydraulic model. The main structures within the study area were:

- East Goulburn Main Channel and the associated syphons;
- The railway bridge over the Goulburn and Broken Rivers;

- The causeway between Shepparton and Mooroopna across the Goulburn River floodplain;
- The levees adjacent to the Goulburn River;
- The Shepparton and Mooroopna drainage pipe network;
- The channels associated with the irrigation network;
- The Goulburn Valley Highway bridge over the Broken River; and
- Numerous drainage structures at various locations in the floodplain, such as culverts associated with the railway, roads and the irrigation channels.

Cross section details, dimensions and/or obverts of several hydraulic structures were not known and required estimation. LiDAR data was used to estimate invert levels and cross sections, and various imagery was used to estimate structure dimensions. It is expected that this method of estimating the structure inverts and dimensions will be accurate to +/-150 mm and as such will not have a significant impact on the model accuracy.

The main opening in the causeway (Daintons Bridge) is modelled as a (BW) Bridge Weir Structure in the 1D domain. The remaining openings in the Midland Highway have been modelled using an increased roughness.

Several other bridges within the model extent were modelled as openings as identified in the LiDAR.

5.3.4 Hydraulic Roughness

The variation in hydraulic roughness within the study area was schematised as two separate roughness layers, one representing all the roads and the other representing the other various hydraulic roughness values (e.g. floodplain, channels, vegetation etc.). Areas with different roughness types were identified using aerial photographs and VicMap data layers. The values adopted for the two-dimensional hydraulic model are summarised in Table 5-2 and shown in Figure 5-3 below. These values were based on standard industry roughness values and were modified during the calibration process. The values adopted are reasonable estimates of hydraulic roughness given the floodplain condition.

TABLE 5-2 HYDRAULIC ROUGHNESS PARAMETERS

Land Type	Roughness (Manning's "n")
Roads	0.015
Crops	0.05
Medium Density Vegetation	0.07
High Density Vegetation	0.10
Stagnant Water Bodies	0.03
Residential	0.06
Industrial	0.06
Cleared Land/Open Space	0.04
Goulburn River Channel	0.065
Seven Creeks Channel	0.06
Broken River	0.10
Pipes/Culverts	0.012

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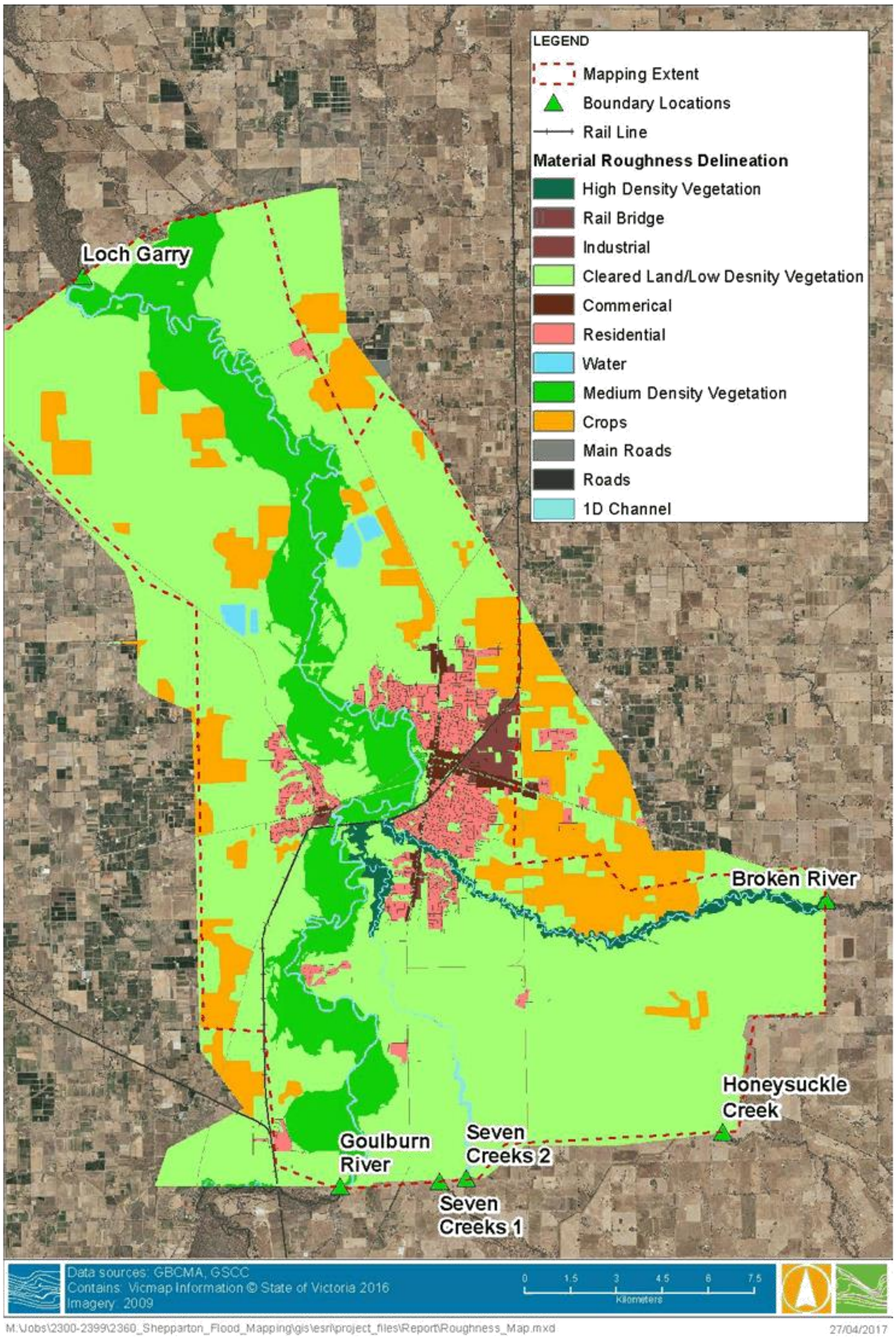

FIGURE 5-3 2D MATERIAL ROUGHNESS MAP

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5.3.5 Boundary Conditions

5.3.5.1 Broken Model

The Broken model was developed with a single inflow boundary for the Broken River at Gowangardie Weir, located 26 km upstream of the confluence with the Goulburn River. This location was specifically chosen so that recorded flows from the gauge at Gowangardie could be input directly into the model for historical events, and flood frequency analysis at the gauge can be used for the design events.

The downstream boundaries were placed just downstream of the East Goulburn Main Channel, defined using the automatically generated Q-H relationships. Hydrographs for the Shepparton model were extracted for the Broken River and a breakout flow to the south upstream of the East Goulburn Main Channel. This structure acts as a major hydraulic control on the floodplain and greatly influences flow paths during overbank flow events. This barrier makes an ideal location to separate the hydraulic models.

Flow from the Broken River can also overtop the Midland Highway just to the north of the river and enter the Pine Lodge Creek system. Another Q-H boundary has been placed on Pine Lodge Creek to the north to take this flow out of the model, and a flow extraction line (TUFLOW PO line) has been placed there to quantify this breakout.

5.3.5.2 Upper Goulburn Model

Like the Broken model, the Upper Goulburn model has an inflow point on the Goulburn River at Murchison. There are also two tributaries that enter downstream of Murchison, being Pranjip Creek at Moorilim and Castle Creek at Arcadia. All three of these flows are taken directly from the gauged data for the historical events and from the flood frequency analysis for the design events.

The downstream Q-H boundary of the Upper Goulburn model has been placed just upstream of the flood mapping extent, downstream of Bridge Road near Toolamba. The flow extraction line for the Shepparton model has been placed just upstream of Bridge Road.

5.3.5.3 Shepparton Model

The Shepparton model has numerous inflow boundaries not only from the Upper Goulburn and Broken models, but for Seven Creeks as well. The Shepparton model overlaps the Upper Goulburn and Broken models and uses the flows extracted from those models as the upstream boundaries for the Goulburn River, the Broken River and the breakout south of the Broken River upstream of the East Goulburn Main Channel.

As the gauge for Seven Creeks at Kialla West is within the flood mapping extent, the inflow boundary was split into three boundaries upstream of the confluence of Seven Creeks and Honeysuckle Creek The catchment areas for Honeysuckle Creek and Seven Creeks at this point are approximately the same, so the inflows have been split evenly between Honeysuckle Creek and Seven Creeks, with the Seven Creeks inflow split evenly again between the two branches. The inflows at these boundaries had to be scaled up slightly to ensure that the flow at the gauge was accurately reproduced (to account for floodplain storage between the boundary inflows and the streamflow gauge). A similar approach was adopted for the Broken River inflows, with the main Broken River inflow placed upstream of the East Goulburn Main Channel and a secondary Broken River inflow placed south of the Broken River. With both inflows upstream of the Broken River at Orrvale streamflow gauge, flows were scaled up to simulate the design flow estimates from the flood frequency analysis at the streamflow gauge.

The downstream extent of the model incorporates Loch Garry and the gauge on the Goulburn River approximately 18 km downstream of Shepparton. The rating curve from the gauge has been used for the Q-H relationship on the Goulburn River downstream boundary. There is also an automatically generated Q-H boundary on the floodplain adjacent to the Goulburn River outside of the levee to the south west, and another Q-H boundary on the floodplain north of the Loch Garry levee. An automatically generated Q-H boundary has also been used for the structure within Loch Garry to estimate the operation of the weir during flood events. All model boundary locations are shown in Figure 5-4.

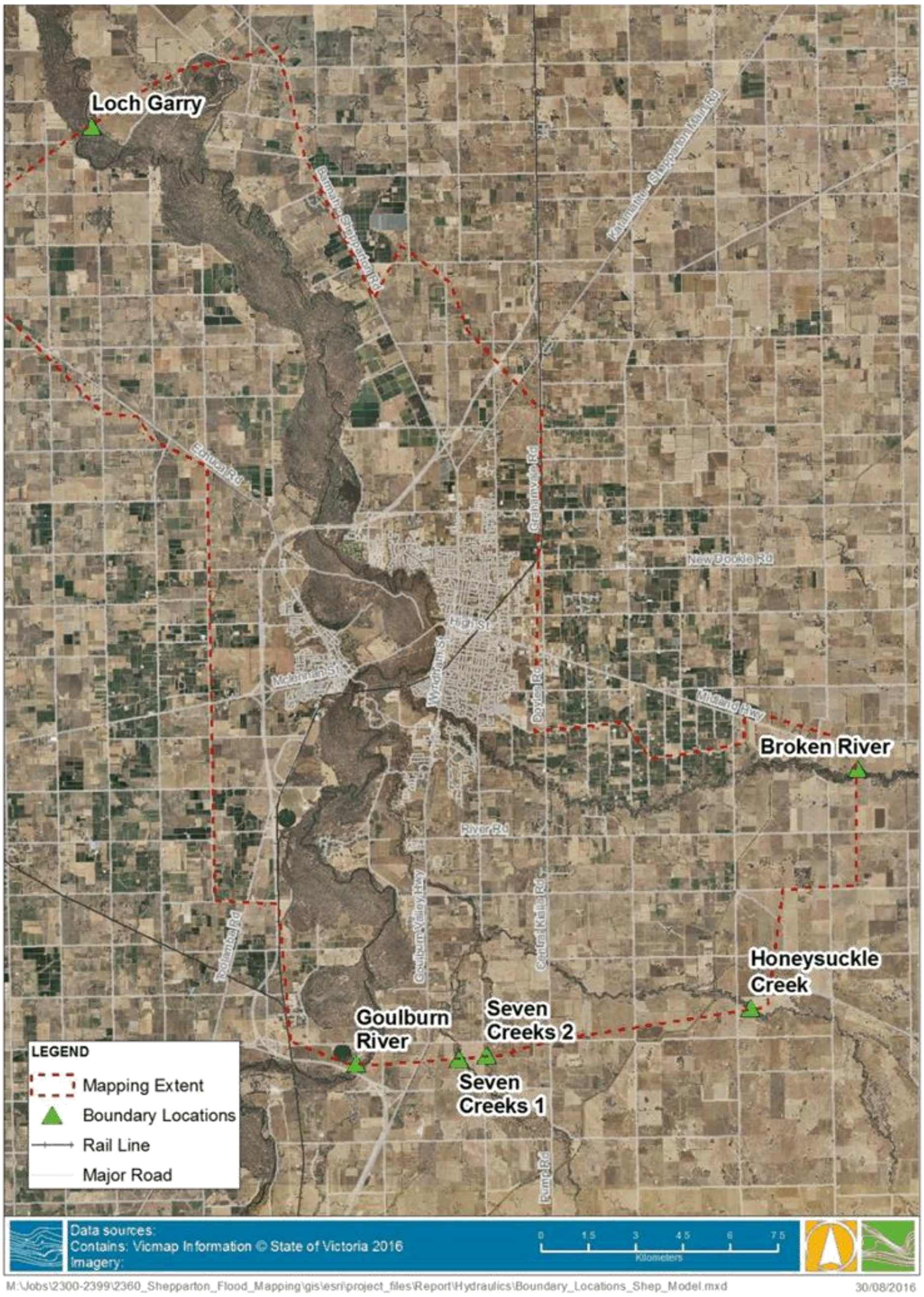

FIGURE 5-4 SHEPPARTON MOOROOPNA HYDRAULIC MODEL BOUNDARY LOCATIONS

5.3.6 1D Pipe Network

There are areas of Shepparton and Mooroopna that are inundated due to the backflow of pipes and council has requested that these be included in the hydraulic model. The entire stormwater network was provided by Council and after discussions with Council and the Goulburn Broken CMA it was decided to include those pipes greater than 600 mm in diameter. Figure 5-5 shows the selected pipes from the stormwater water pipe system for Shepparton and Mooroopna that have been included in the TUFLOW hydraulic model.

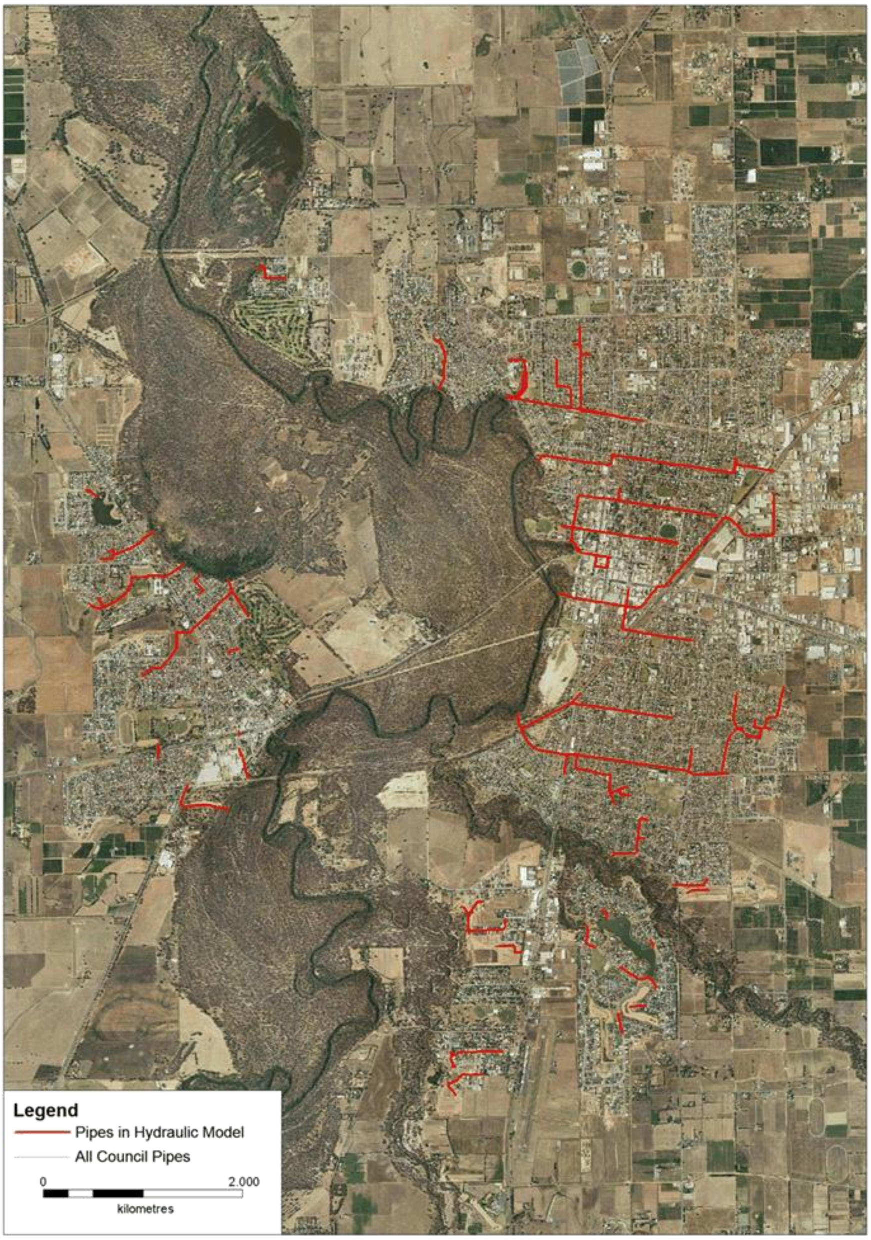

FIGURE 5-5 SELECTED SHEPPARTON AND MOOROOPNA STORMWATER PIPES

5.4 Hydraulic Model Calibration

5.4.1 Overview

The following Section discusses the fine-tuning of the hydraulic model parameters through calibration against observed flood data. The model was calibrated to the large flood event of October 1993 and smaller September 2010 flood event in tandem, with validation to the May 1974 flood event. Surveyed flood marks (provided by the Goulburn Broken CMA), gauged river heights and aerial photographs of the floods were the basis for comparison to the modelled results.

Several sensitivity runs were undertaken with minor changes to the model parameters to get a better match to gauged river levels, surveyed flood levels and flood extents, namely:

- Adjusting the Broken River channel cross section near the East Goulburn Main Channel to allow more flow to pass through the gap in the high channel banks. The East Goulburn Main Channel creates a major hydraulic barrier, so time was spent ensuring the afflux across the structure was modelled correctly.
- Adding the culverts under the railway line near Toolamba Road.
- Increased the Goulburn River and Seven Creeks roughness from 0.045 to 0.06 and the Broken River roughness from 0.06 to 0.10 (reasonable given the dense vegetation and woody debris along the channel). This helped raise flood levels to better match the observed flood levels for the 1993 and 2010 calibration events.
- Incorporating crest levels from the Goulburn River levee survey downstream of Shepparton from the Goulburn River Levee Audit project completed on behalf of the Goulburn Broken CMA. This provided a more accurate representation of the levee, which was otherwise not adequately defined in 2D at the model resolution.
- Layered flow constrictions and form losses were applied along the Shepparton-Mooroopna Causeway waterway opening after receiving the detailed gauging record from the 1974 flood event and structure details from the Goulburn Broken CMA. This additional information helped refine the flow through the causeway structures.

The final roughness parameters determined from the calibration process are shown in Table 5-2.

It should be noted that while flood mark survey is available for the calibration events there is inherent inaccuracies in the collection of those levels. The levels are primarily based on flood debris marks which may be significantly higher or lower than the true peak due to several reasons such as debris piling up on the upstream side of an obstruction or debris collecting on the recession of a flood, and obstructions causing a bow wave effect (with higher levels on the upstream face and lower on the downstream face).

A certain degree of engineering judgement is required in the collection of this data and inaccuracies in the data at some locations are likely.

5.4.2 September 2010 Calibration

15 flood marks within the flood mapping extent from the September 2010 flood event were collected by the Goulburn Broken CMA. These flood marks were complimented with aerial photography of the flood extent and river gauge data to check the modelled flood extent.

The 15 survey flood marks located within the study area were compared to the modelled flood levels:

- 12 points were within +/- 200 mm;
- 2 points had modelled water levels with a difference greater than 200 mm;
- On average the model levels were 49 mm higher than the observed flood marks.

The overall trend showed that the modelled flood levels were slightly higher than the surveyed flood levels. All modelled flood levels were well within the error threshold for the hydraulic model calibration for the September 2010 flood event.

Figure 5-6 below shows a plot of the water level for the gauge on the Goulburn River at Shepparton comparing the model results to the gauged data. The graphs show that the rising limb of the modelled hydrograph arrives slightly earlier than the gauged data; nevertheless, the peak elevation is well represented in the model. A calibration plot for the September 2010 flood event is shown in Figure 5-9. The aerial imagery obtained after the flood peak from Nearmap (Figure 5-10) shows the flood extent matches well around the Kialla West area along the Broken River.

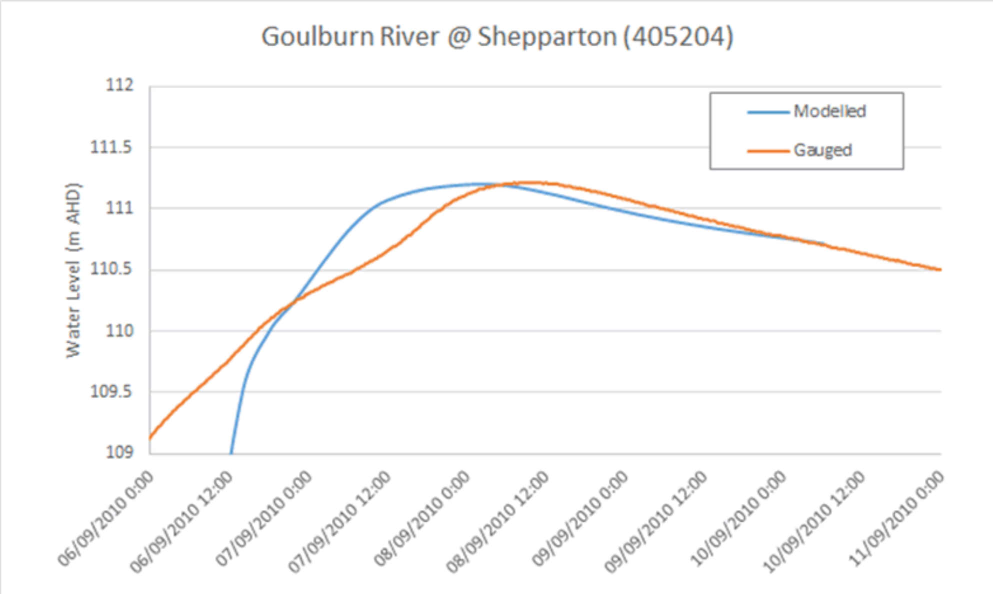

FIGURE 5-6 COMPARISON BETWEEN MODELLED AND GAUGED WATER LEVELS FOR THE GOULBURN RIVER AT SHEPPARTON DURING THE SEPTEMBER 2010 EVENT

Figure 5-7 below shows a plot of the water level for the gauge on the Broken River at Orrvale comparing the model results to the gauged data. The graphs show that the rising limb of the modelled hydrograph compares well with the gauged data, the peak elevation is well represented in the model, and only the falling limb does not compare well, receding quicker than the gauged data. Figure 5-8 shows the comparison of the modelled and gauged water levels at the Seven Creeks at Kialla streamflow gauge. This shows the modelled peak flood level being slightly lower (110 mm) compared to the gauged flood level. The rising limb is not shown in this plot as the final calibration run utilised a hot start initial condition at 6:00am on the 6th September 2010.

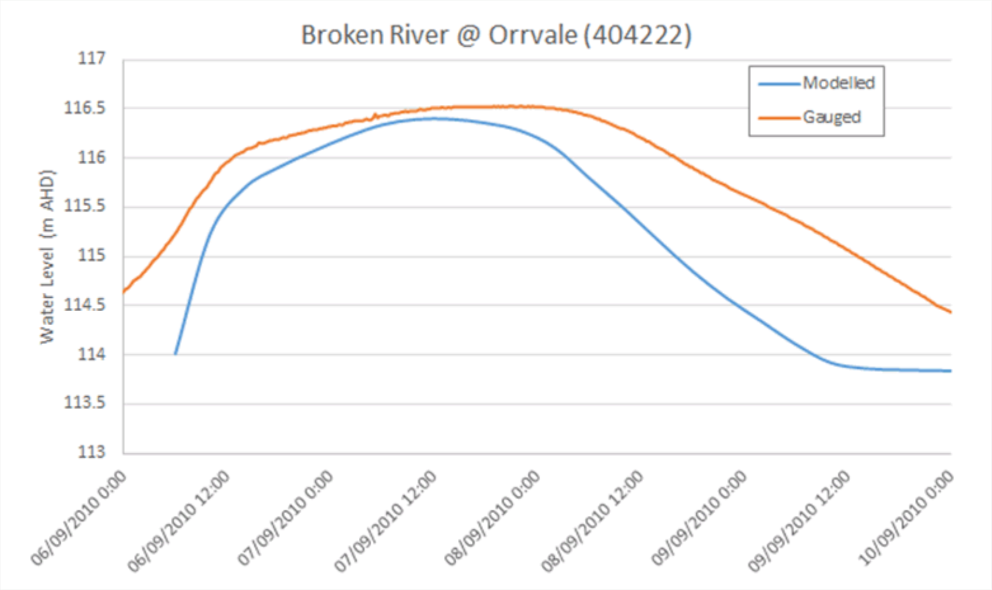

FIGURE 5-7 COMPARISON BETWEEN MODELLED AND GAUGED WATER LEVELS FOR THE BROKEN RIVER AT ORRVALE DURING THE SEPTEMBER 2010 EVENT

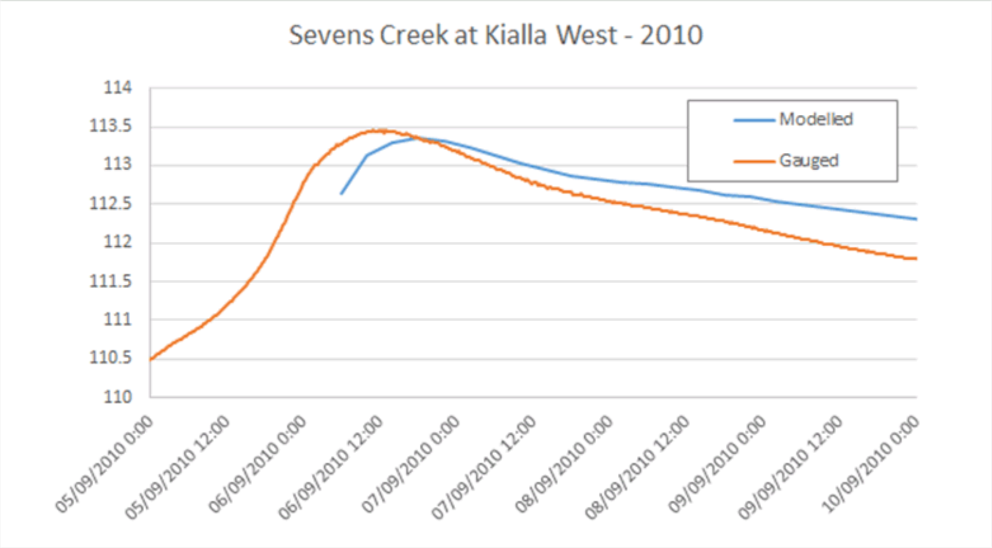

FIGURE 5-8 COMPARISON BETWEEN MODELLED AND GAUGED WATER LEVELS FOR THE SEVEN CREEKS AT KIALLA WEST DURING THE SEPTEMBER 2010 EVENT

The modelled flood extent matched very well with observations, gauged river heights and aerial photographs, and was deemed an acceptable calibration result. Figure 5-11 shows the water surface profiles along the three main waterways. These are plotted with the chainage distance of the waterway along the x – axis and the running distances (provided by the GBCMA) have also been included at key features along the waterways.

5.4.2.1 Flood Behaviour

Heavy rainfall occurred in the north east of Victoria on Saturday 4th and Sunday 5th September 2010, particularly in the alpine areas including the upper Goulburn and Broken catchments. On Monday 6th September, the Seven Creeks at Kialla West peaked just above the major flood level of 6.6 m, and shortly after the Broken River at Orrvale peaked overnight at 8.19 m, again above the major flood level of 7.9 m. On Wednesday 8th September, the Goulburn River at Shepparton also peaked just above the major flood level of 11 m. Minor tributaries into the Goulburn, Castle Creek and Pranjip Creek, also flooded.

The September 2010 event was mostly contained within the lower floodplain area on the Goulburn River, however low-lying areas near the Broken River were inundated. The SES advised that 13 houses and 31 structures were damaged by the floods. Approximately 30 local roads were closed due to flooding, however all major roads surrounding Shepparton remained open for the duration of the event. Figure 5-9 below shows the modelled peak flood extent which was consistent with the observed flood extent. This shows that low lying areas between Archer Road and the East Goulburn Main Channel along the Broken River were inundated during the event, whilst areas outside of the Goulburn River lower floodplain were not affected.

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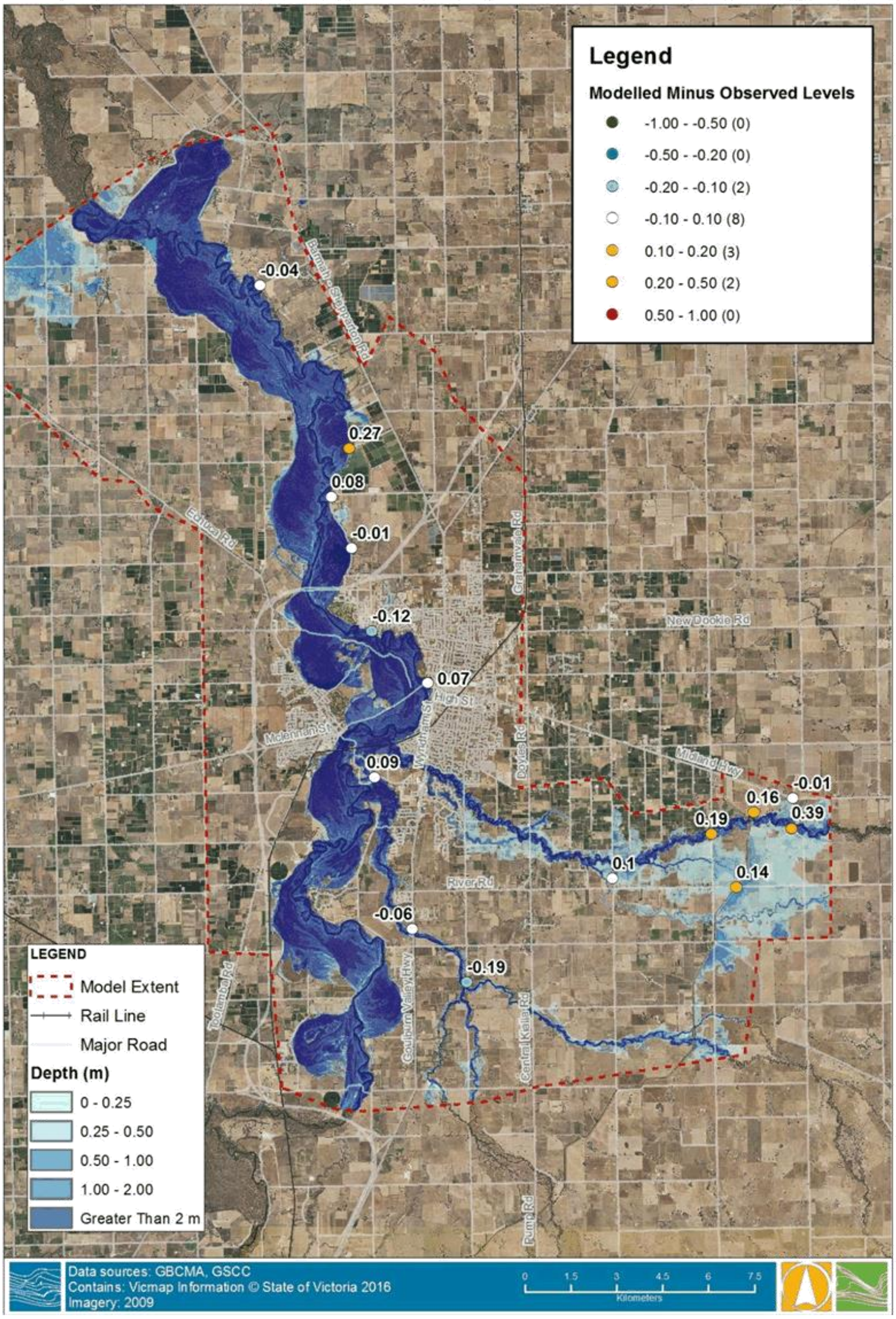

FIGURE 5-9 HYDRAULIC MODEL CALIBRATION PLOT – SEPTEMBER 2010

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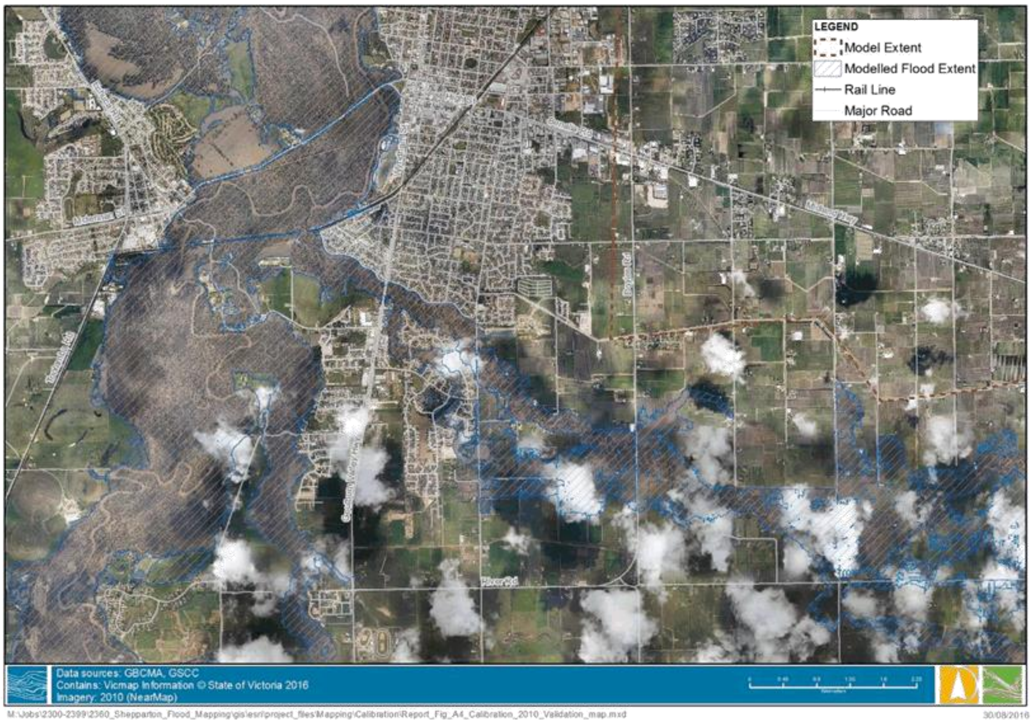

FIGURE 5-10 SEPTEMBER 2010 MODELLED FLOOD EXTENT AERIAL IMAGERY VALIDATION (SOURCE: NEARMAP)

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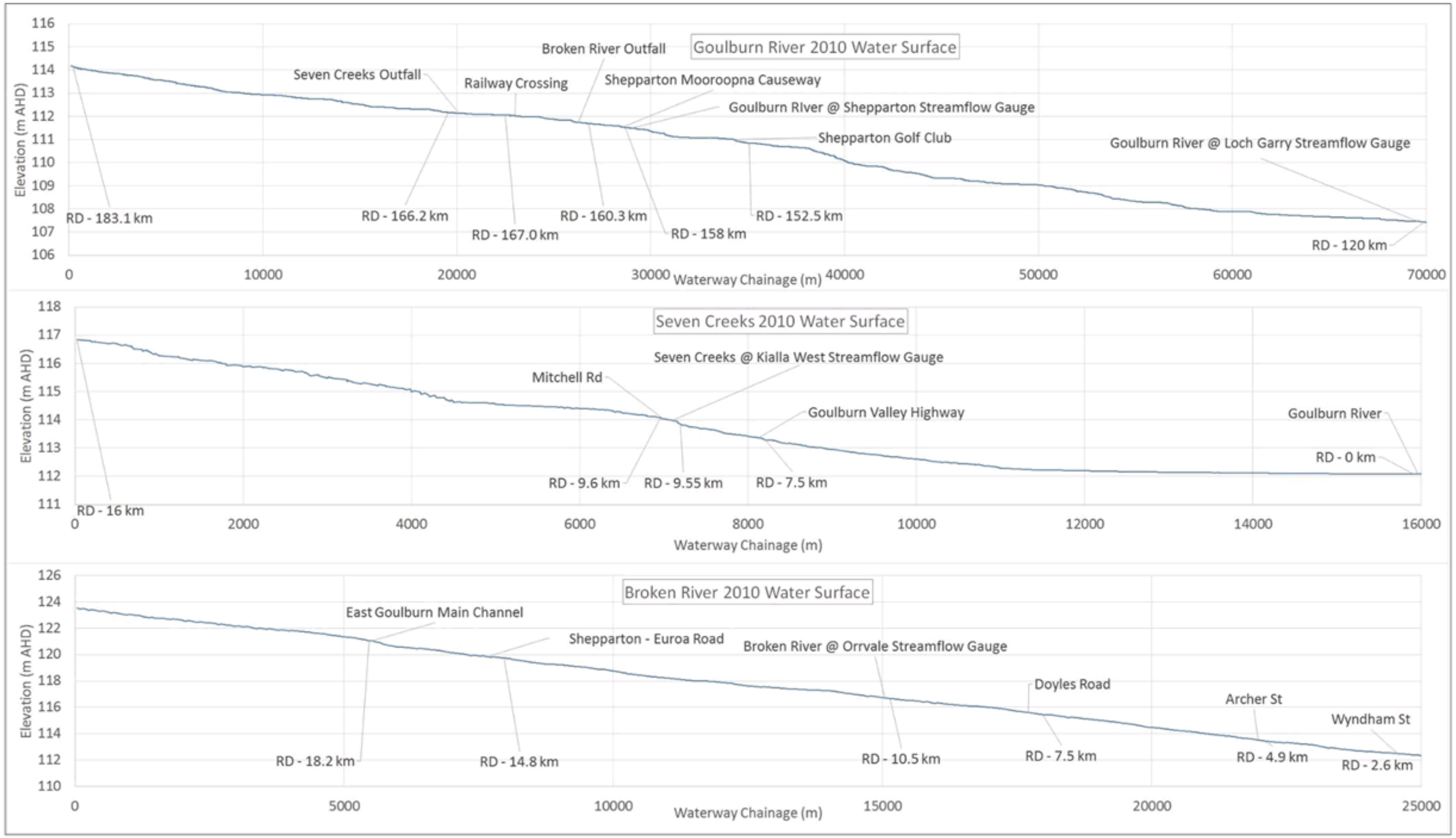

FIGURE 5-11 SEPTEMBER 2010 – WATER SURFACE PROFILES

5.4.3 October 1993 Calibration

Many survey flood marks were collected for the October 1993 flood event. In total, there were 66 survey points to which the model results were calibrated, giving confidence in the reliability of the reproduced flood behaviour. Calibration plots of the October 1993 flood event are shown in Figure 5-14. Of the 66 survey flood marks located within the study area:

- 32 (48%) points were within +/- 100 mm;
- 19 (29%) points were within +/- 100 - 200 mm;
- 8 (12%) points were within +/- 200 - 300 mm;
- 4 (6%) points were below 300mm and were mainly near the Broken River just upstream of the confluence with the Goulburn River;
- 3 (5%) points were above 300mm; and
- On average the 66 observed flood levels that sit within the modelled flood extent showed no overall difference above or below the surveyed flood marks, with a standard deviation of 219 mm.

The overall trend showed that the modelled flood levels had no bias higher or lower than the surveyed flood levels and were predominately well within the satisfactory error interval expected for flood modelling scenarios.

Figure 5-12 below shows a plot of the water level for the gauge on the Goulburn River at Shepparton comparing the model results to the gauged data. The graphs show that the rising and falling limbs of the modelled hydrograph are well represented within the model, and the peak elevation is approximately 110 mm higher than the gauged data.

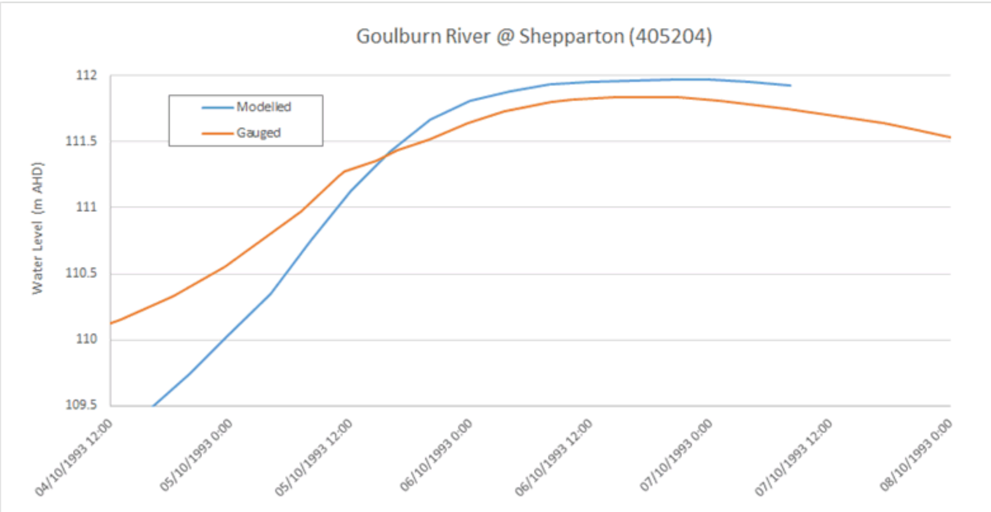

FIGURE 5-12 COMPARISON BETWEEN MODELLED AND GAUGED WATER LEVELS FOR THE GOULBURN RIVER AT SHEPPARTON DURING THE OCTOBER 1993 EVENT

Figure 5-13 below shows a plot of the water level for the gauge on the Broken River at Orrvale comparing the model results to the gauged data. The graphs show that the rising limb of the modelled hydrograph arrives slightly later than the gauged data, and the peak elevation is well represented in the model, despite overestimating the peak by 150 mm.

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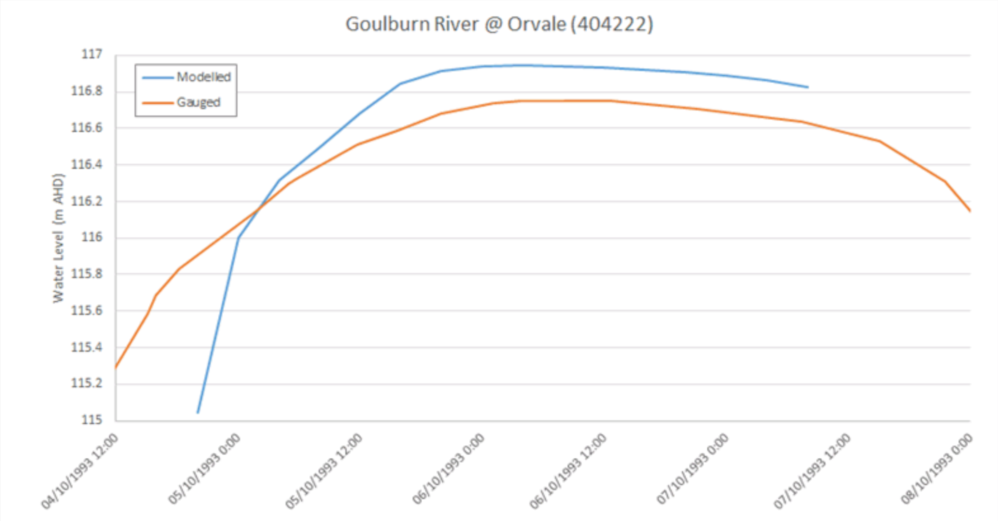

FIGURE 5-13 COMPARISON BETWEEN MODELLED AND GAUGED WATER LEVELS FOR THE BROKEN RIVER AT ORRVALE DURING THE OCTOBER 1993 EVENT

There is limited streamflow data for Seven Creeks at Kialla West for the 1993 flood event.

The modelled flood extent matched very well with observations, gauged river heights and aerial photographs, and was deemed an acceptable calibration result. Figure 5-15 shows the water surface profiles along the three main waterways. These are plotted with the chainage distance of the waterway along the x – axis and the running distances (provided by the GBCMA) have also been included at key features along the waterways.

5.4.3.1 Flood Behaviour

In the lead up to the October 1993 flood, the Goulburn River had sustained high water levels for the majority of September. The Broken River and Seven Creeks during this time were relatively low until they both received a big inflow that started around 3rd October and lasted until early on the 9th October. The Goulburn River peaked again at the same time and stayed high until around the 16th October when it finally receded. Even though the peak in the Goulburn River wasn't as high upstream of Shepparton as it was in September, the combination of the three systems caused a peak water level of approximately 11.7 m at the gauge in Shepparton on Wednesday 6th October.

Upstream of Shepparton on the Goulburn River most of the flow was contained within the lower floodplain. The flows in the Goulburn River, Broken River and Seven Creeks were all larger than 2010, particularly in Seven Creeks where significant overbank flood flow occurred in surrounding low lying areas. Parts of the town of Shepparton were inundated during the event and significant areas downstream of Shepparton were also inundated, particularly around the water treatment plant. The 1993 flood event is referred to as a 'Broken River and Seven Creeks dominant event'. This refers to the two systems mentioned being the dominant flooding mechanism and the flows recorded on these systems being of higher magnitude compared to the Goulburn River during the flood event.

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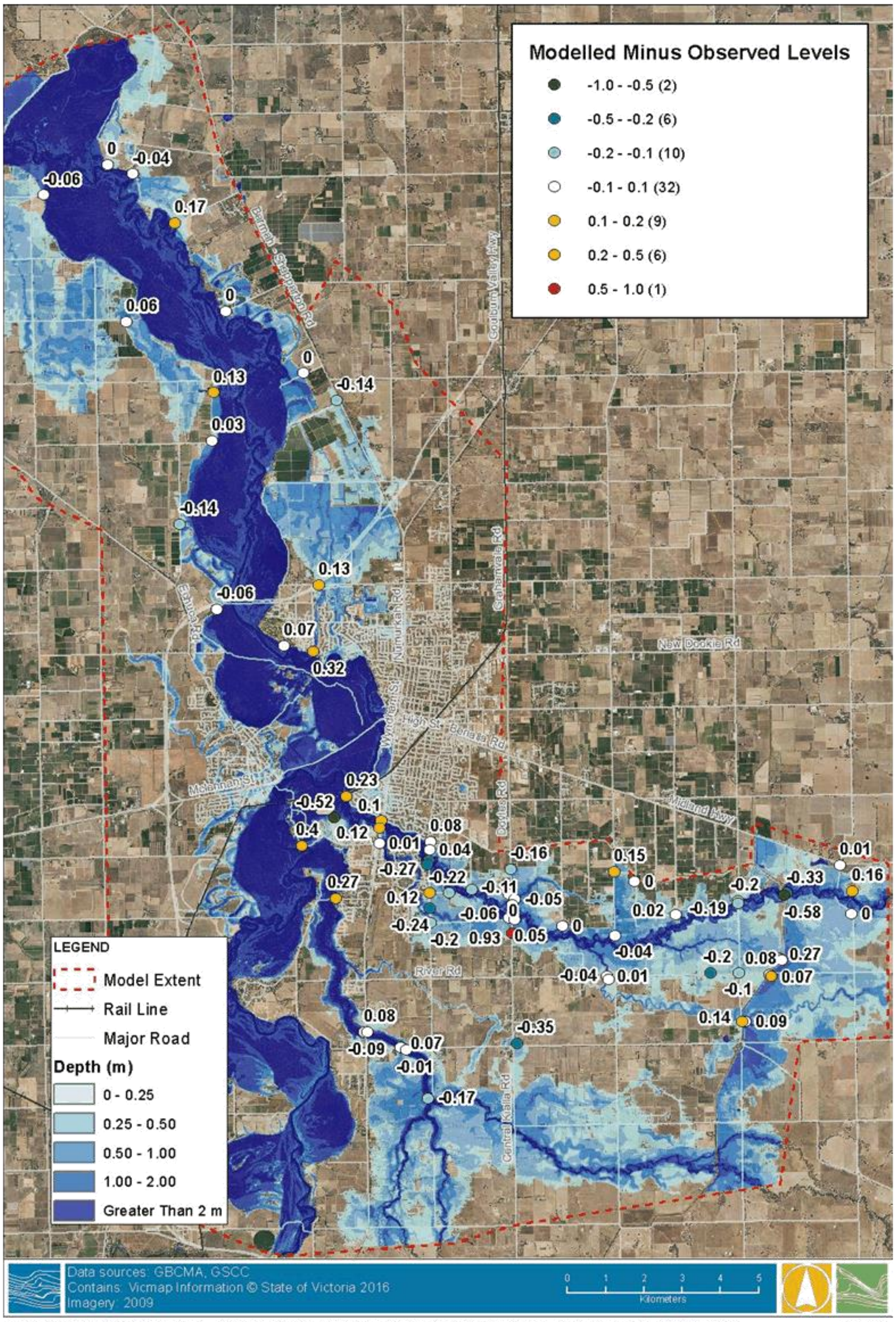

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FIGURE 5-14 HYDRAULIC MODEL CALIBRATION PLOT – OCTOBER 1993 EVENT

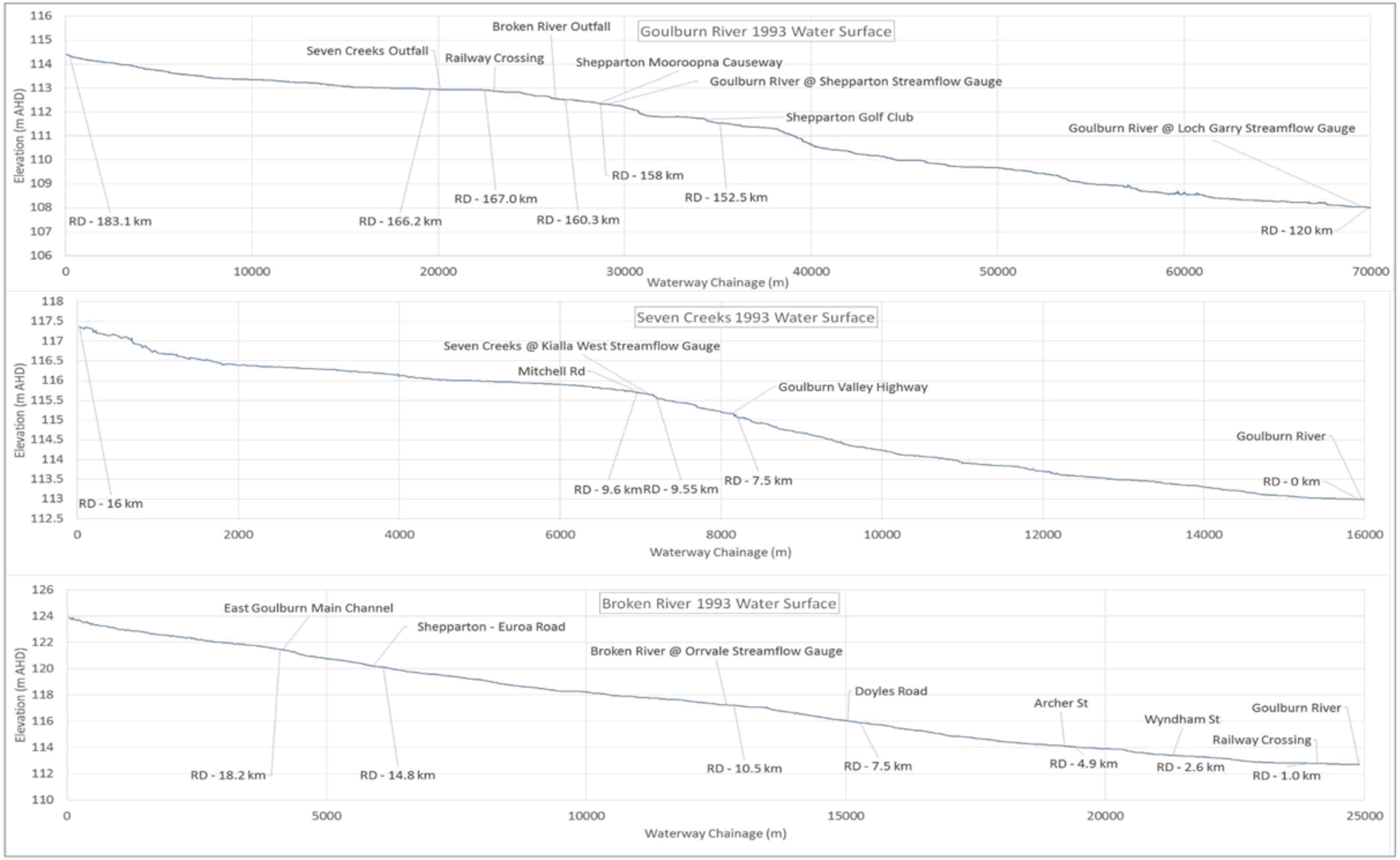

FIGURE 5-15 OCTOBER 1993 - WATER SURFACE PROFILES

5.4.4 May 1974 Validation

Many survey flood marks were collected for the May 1974 flood event. In total there were 377 survey points available in the VFD, 114 of these points were classified with a reliability of 'Good' or 'High'. Only the surveyed points with these levels of reliability were used to validate the hydraulic model, giving confidence in the reliability of the reproduced flood behaviour. Validation plots of the May 1974 flood event are shown in Figure 5-17 and Figure 5-18. Of the 114 survey flood marks located within the study area:

- 40 (35%) points were within +/- 100 mm;
- 28 (25%) points were within +/- 100 - 200 mm;
- Approximately 60% of the modelled validation points were within 200 mm;
- 19 (17%) points were within +/- 200 300 mm;
- 3 (3%) points were below 300mm;
- 20 (18%) points were above 300mm.
- 4 (4%) points were not in the modelled flood extent; and
- On average the modelled water levels were 124 mm above the surveyed flood marks, with a standard deviation of 201 mm.

The overall trend showed that the modelled flood levels were slightly higher than the surveyed flood levels but the majority within the satisfactory error interval expected for flood modelling scenarios. Most of the modelled flood levels which were higher than observed levels were centred around the Mooroopna area. A comparison of aerial imagery from 1974 and present day shows extensive development to the north of the Midland Highway in Mooroopna. It would be expected that development through this area would have likely required earthworks to infill the floodplain which may have resulted in an increase in flood levels.

Figure 5-16 below shows a plot of the water level for the gauge on the Goulburn River at Shepparton comparing the model results to the gauged data. The graphs show that the rising limb of the modelled hydrograph arrives slightly later than the gauged data, the peak elevation is approximately 100 mm lower than the gauged data, and the falling limb receding slightly later than the gauged data as well.

Figure 5-19 shows the water surface profiles along the three main waterways. These are plotted with the chainage distance of the waterway along the x – axis and the running distances (provided by the GBCMA) have also been included at key features along the waterways.

Figure 5-20 provides a summary of the longitudinal section for the peak flood level for each waterway during the three historical events modelled. This helps to provide context for the magnitude of the events on each of the waterways.

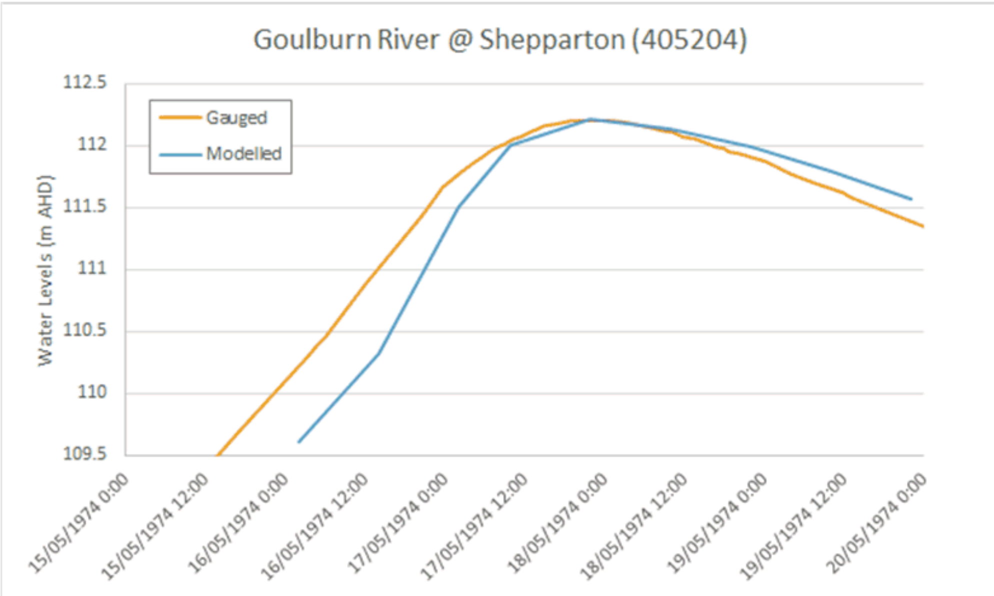

FIGURE 5-16 COMPARISON BETWEEN MODELLED AND GAUGED WATER LEVELS FOR THE GOULBURN RIVER AT SHEPPARTON DURING THE MAY 1974 EVENT

No streamflow data for the Broken River at Orrvale or the Seven Creeks at Kialla West gauge exists for the 1974 flood event. Both gauges were installed in 1977.

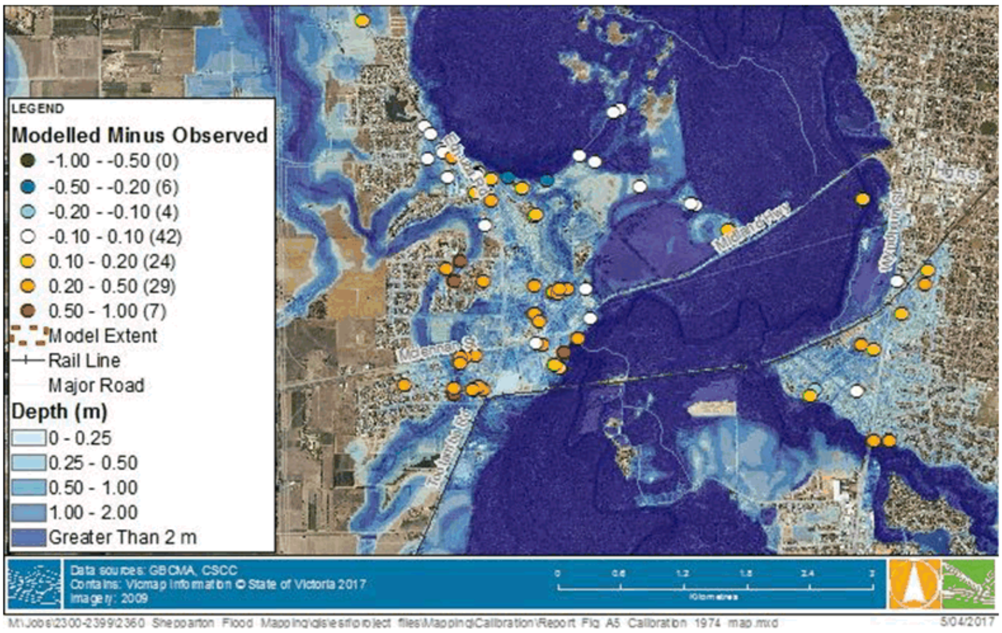

FIGURE 5-17 HYDRAULIC MODEL VALIDATION PLOT – MAY 1974 EVENT (TOWNSHIP)

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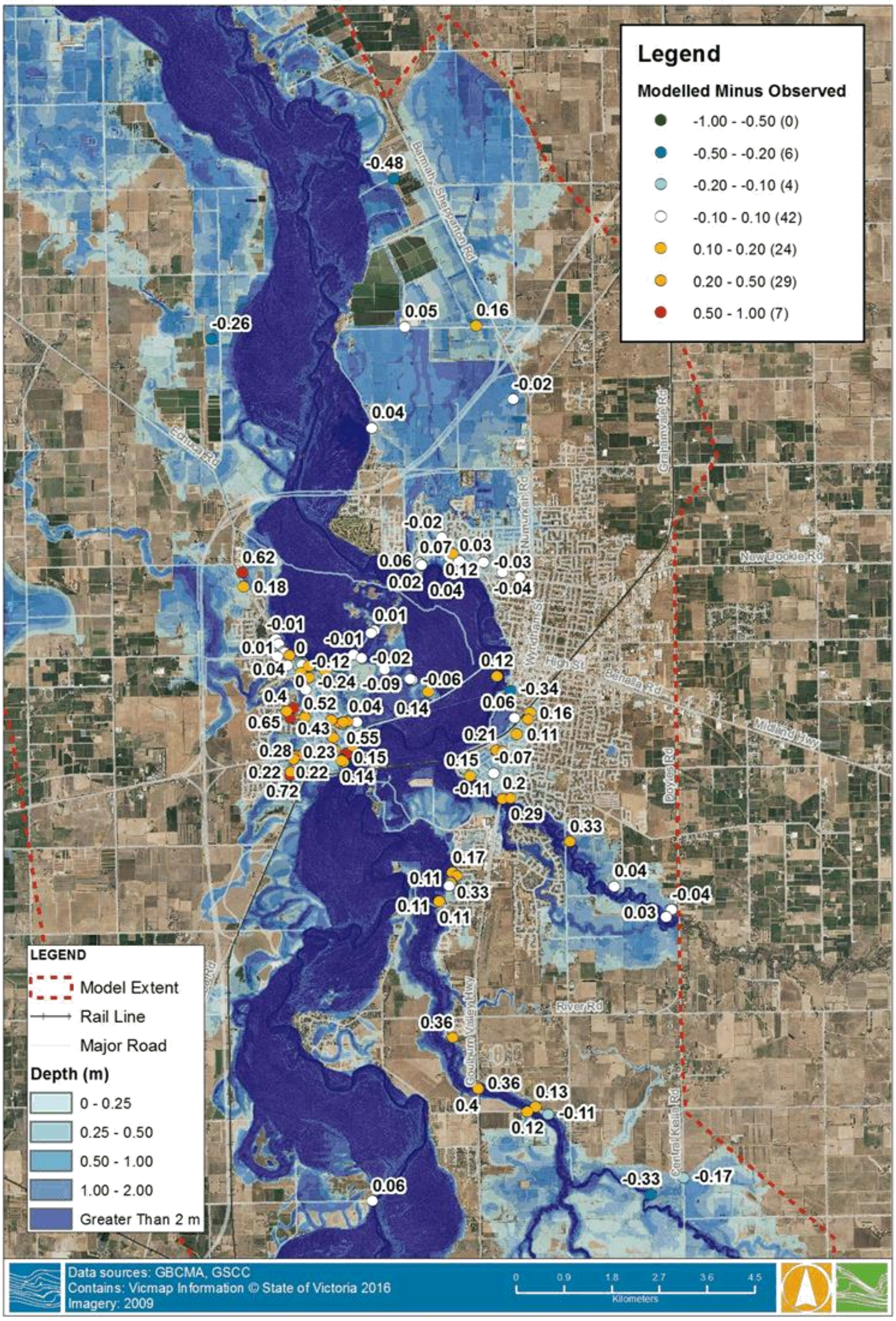

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FIGURE 5-18 HYDRAULIC MODEL VALIDATION PLOT – MAY 1974 EVENT

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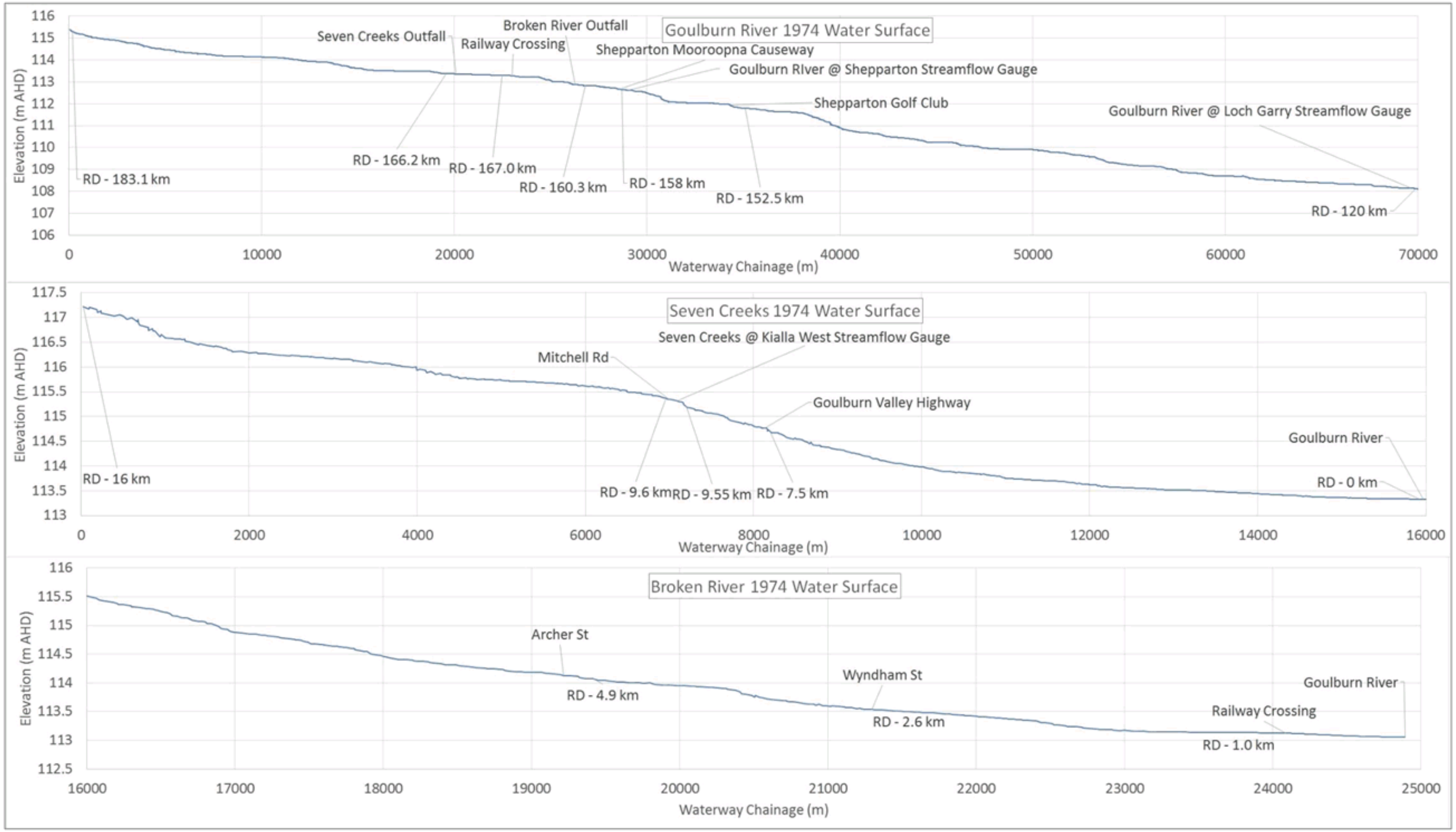

FIGURE 5-19 MAY 1974 - WATER SURFACE PROFILES

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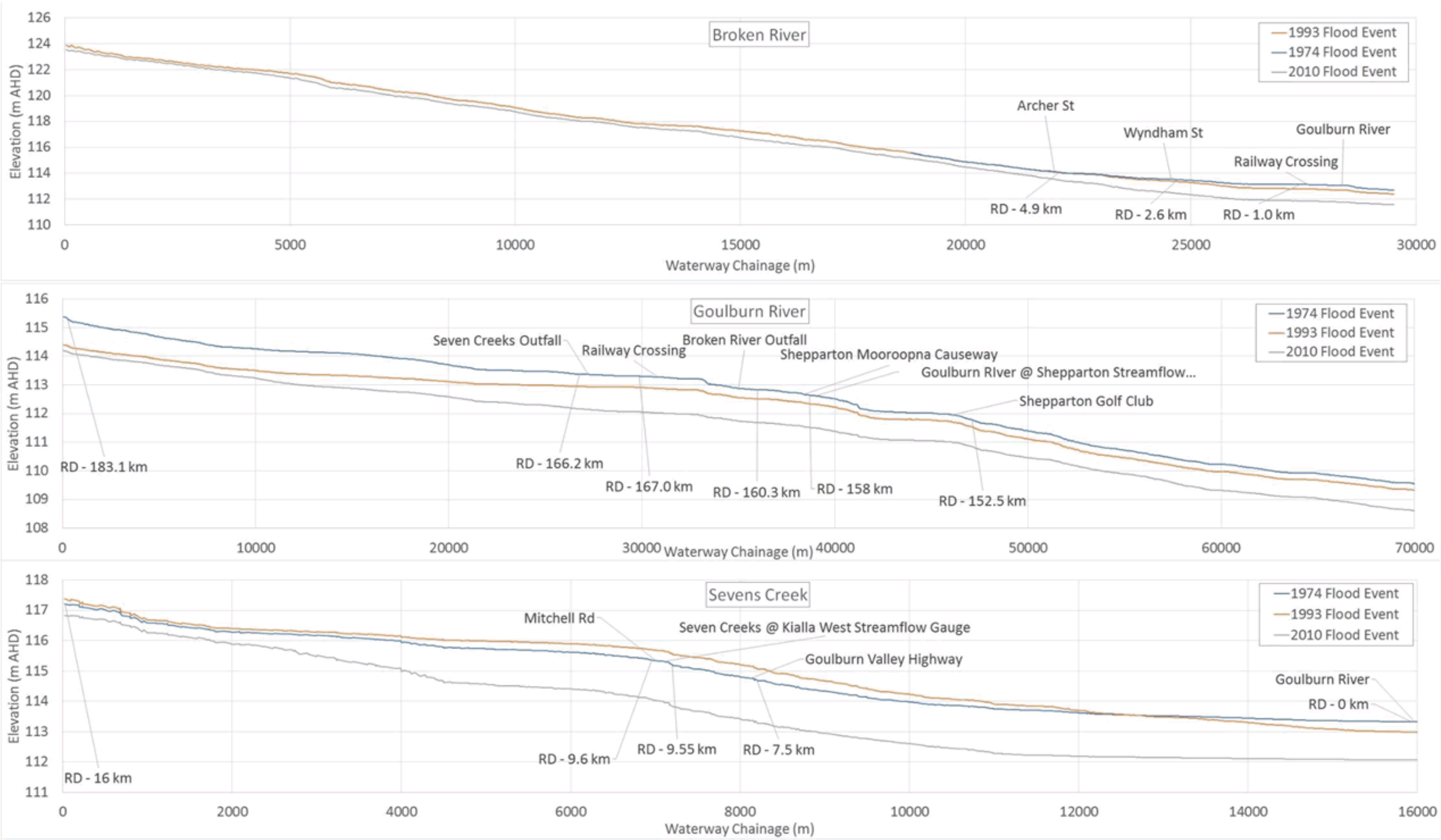

FIGURE 5-20 CALIBRATION EVENT SUMMARY - WATER SURFACE PROFILES

5.4.5 Hydraulic Model Calibration Summary

The hydraulic model calibration and validation results demonstrated the ability of the model to represent the flood behaviour for Shepparton and surrounding areas for the May 1974, October 1993 and September 2010 flood events. The modelling demonstrates that the events were quite different in nature with May 1974 being a Goulburn River dominated event whilst October 1993 and September 2010 were Broken River and Seven Creeks dominant events.

The October 1993 event and May 1974 event inundated approximately 30 and 600 residential and commercial buildings above floor respectively because of large breakouts from the Goulburn River, Broken River and Seven Creeks (SES, 2013). The September 2010 event resulted in damage to 13 houses and 31 structures. It is noted that increased development along the Broken River near Shepparton means that a flood of the magnitude of October 1993 would result in many more properties being affected if it were to occur again.

The model results for the May 1974, October 1993 and September 2010 floods replicated the observed flood behaviour through Shepparton and surrounding areas quite accurately; this was confirmed by a comparison to observed flood marks, aerial images as well as gauged data. A summary of the peak flood levels at the Shepparton gauge is shown in Table 5-3.

TABLE 5-3 COMPARISON OF PEAK FLOOD LEVELS AT SHEPPARTON GAUGE

Flood Level	1974	1993	2010
Observed	112.21 m AHD	111.84 m AHD	111.21 m AHD
Modelled	112.19 m AHD	111.95 m AHD	111.19 m AHD
Comparison	-0.02 m	+0.11 m	-0.02 m

Throughout the course of the lengthy calibration process, the sharing of information with Greater Shepparton City Council and the Goulburn Broken CMA has allowed for independent checking of results. This careful interrogation has led to a successful calibration which is considered fit for purpose for design event modelling.

6 DESIGN FLOOD MODELLING

The design hydrographs were generated for 15 flood events ranging from a gauge height of 9.5 m up to 12.5 m at the Shepparton gauge, Table 6-1.

Each of these gauge increments was replicated across three scenarios;

- A Goulburn dominant event – where the Goulburn River was the dominant flooding mechanism at the Shepparton gauge, like the 1974 flood event.
- A Broken/Seven dominant event – where the Broken River and Seven Creeks are the dominant flooding mechanism within Shepparton, like the 1993 flood event.
- A neutral flood event – where the flood magnitude of all events is approximately the same.

The peak flow and approximate AEP of the 45 combinations as well as the PMF design flows are shown in Table 6-2. Several iterations of design model scenarios were run to achieve the target flood levels at Shepparton, with tributary flows slightly changed. Sensitivity modelling as outlined in Section 6.1 was also conducted.

TABLE 6-1 GOULBURN RIVER AT SHEPPARTON DESIGN LEVELS TO BE MODELLED

Event	Goulburn River @ Shepparton Gauge Height (m AHD)	Goulburn River @ Shepparton Gauge Level (m)
Minor Flood	109.627	9.5
20-10%	110.227	10.1
Moderate Flood	110.827	10.7
10%	111.027	10.9
Major Flood 2010	111.127	11.0
10-5%	111.227	11.1
5%	111.427	11.3
5-2%	111.627	11.5
1993	111.827	11.7
2%	112.027	11.9
1974	112.227	12.1
1%	112.327	12.2
0.5%	112.427	12.3
0.2%	112.627	12.5
PMF		

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TABLE 6-2 FLOOD MAPPING TRIBUTARY FLOW COMBINATION MATRIX

Event	Goulburn River at Shepparton Gauge (m)	Goulburn Dominant			Broken/Seven Dominant			Neutral		
		Goulburn River Flow	Broken River Flow	Seven Creeks Flow	Goulburn River Flow	Broken River Flow	Seven Creeks Flow	Goulburn River Flow	Broken River Flow	Seven Creeks Flow
Minor Flood	9.5	19,100 ML/d	6,000 ML/d	4,300 ML/d	13,000 ML/d	8,700 ML/d	6,000 ML/d	15,000 ML/d	7,800 ML/d	5,200 ML/d
		1EY	2EY	1EY	1EY	50% AEP	1EY	1EY	50% AEP	1EY
	10.1	34,900 ML/d	12,500 ML/d	11,000 ML/d	24,300 ML/d	21,600 ML/d	11,200 ML/d	32,000 ML/d	13,800 ML/d	11,300 ML/d
		50% AEP	50% AEP	50% AEP	1EY	20% AEP	50% AEP	50% AEP	50% AEP	50% AEP
	10.5	43,200 ML/d	13,000 ML/d	11,000 ML/d	34,900 ML/d	18,000 ML/d	18,800 ML/d	39,700 ML/d	15,600 ML/d	18,300 ML/d
		50-20% AEP	50% AEP	50% AEP	50% AEP	20% AEP	50-20% AEP	50-20% AEP	20% AEP	50-20% AEP
Moderate Flood	10.7	52,300 ML/d	18,100 ML/d	11,300 ML/d	34,900 ML/d	32,700 ML/d	29,400 ML/d	45,800 ML/d	17,300 ML/d	22,500 ML/d
		20% AEP	20% AEP	50% AEP	50% AEP	5% AEP	20-10% AEP	20% AEP	20% AEP	20% AEP
	10.9	56,200 ML/d	28,100 ML/d	11,300 ML/d	36,700 ML/d	34,700 ML/d	35,400 ML/d	54,400 ML/d	20,700 ML/d	28,500 ML/d
		20-10% AEP	10-5% AEP	50% AEP	50% AEP	5% AEP	10% AEP	20% AEP	10% AEP	20-10% AEP
Major Flood (2010)	11	62,600 ML/d	10%	13,800 ML/d	40,300 ML/d	37,400 ML/d	38,900 ML/d	69,100 ML/d	24,200 ML/d	32,000 ML/d
		20-10% AEP	20% AEP	50% AEP	50% AEP	5-2% AEP	10-5% AEP	10% AEP	10% AEP	10% AEP
	11.1	69,100 ML/d	24,200 ML/d	32,000 ML/d	43,200 ML/d	42,300 ML/d	42,300 ML/d	62,000 ML/d	25,900 ML/d	32,800 ML/d
		10% AEP	10% AEP	10% AEP	50-20% AEP	2% AEP	5% AEP	10% AEP	10% AEP	10% AEP
	11.3	82,000 ML/d	27,600 ML/d	18,100 ML/d	51,800 ML/d	46,700 ML/d	49,200 ML/d	73,400 ML/d	30,200 ML/d	33,700 ML/d
		10-5% AEP	10-5% AEP	20% AEP	20% AEP	2-1% AEP	5% AEP	10% AEP	5% AEP	10% AEP
	11.5	92,900 ML/d	30,200 ML/d	22,500 ML/d	60,500 ML/d	50,100 ML/d	56,200 ML/d	86,400 ML/d	34,600 ML/d	36,800 ML/d%
		5% AEP	5% AEP	20% AEP	20-10% AEP	1% AEP	5-2% AEP	10-5% AEP	5% AEP	10% AEP
1993	11.7	108,800 ML/d	34,600 ML/d	26,400 ML/d	77,800 ML/d	53,600 ML/d	62,200 ML/d	96,800 ML/d	37,800 ML/d	40,600 ML/d
		5-2% AEP	5% AEP	20-10% AEP	10% AEP	1% AEP	2% AEP	5% AEP	5-2% AEP	10-5% AEP
		138,200 ML/d	43,200 ML/d	34,600 ML/d	111,400 ML/d	57,500 ML/d	68,600 ML/d	121,00 ML/d	44,000 ML/d	49,700 ML/d

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Event	Goulburn River at Shepparton Gauge (m)	Goulburn Dominant			Broken/Seven Dominant			Neutral		
		Goulburn River Flow	Broken River Flow	Seven Creeks Flow	Goulburn River Flow	Broken River Flow	Seven Creeks Flow	Goulburn River Flow	Broken River Flow	Seven Creeks Flow
	11.9	2-1% AEP	2% AEP	10% AEP	5-2% AEP	1% AEP	2-1% AEP	2% AEP	2-1% AEP	5% AEP
1974	12.1	151,200 ML/d	47,500 ML/d	35,900 ML/d	116,600 ML/d	58,800 ML/d	69,100 ML/d	137,400 ML/d	60,500 ML/d	58,800 ML/d
		1% AEP	5-2% AEP	10% AEP	5-2% AEP	1% AEP	2-1% AEP	2-1% AEP	0.5-0.2% AEP	5-2% AEP
	12.2	162,500 ML/d	53,100 ML/d	36,700 ML/d	125,300 ML/d	71,300 ML/d	79,500 ML/d	164,200 ML/d	71,700 ML/d	79,500 ML/d
		1% AEP	1% AEP	10-5% AEP	2% AEP	0.2% AEP	1% AEP	0.50% AEP	0.20% AEP	1% AEP
	12.3	216,000 ML/d	69,100 ML/d	69,100 ML/d	155,500 ML/d	86,400 ML/d	88,100 ML/d	186,600 ML/d	75,600 ML/d	82,100 ML/d
		0.50% AEP	0.2% AEP	2% AEP	1% AEP	0.2-0.1% AEP	0.50% AEP	0.5-0.2% AEP	0.2% AEP	1-0.5% AEP
	12.5	259,200 ML/d	82,100 ML/d	82,100 ML/d	190,100 ML/d	151,200 ML/d	151,200 ML/d	216,000 ML/d	121,000 ML/d	121,000 ML/d
		0.2-0.1% AEP	0.2-0.1% AEP	1% AEP	0.2% AEP	0.10% AEP	0.2-0.1% AEP	0.2-0.1% AEP	0.2-0.1% AEP	0.20% AEP
	PMF	1,330,000 (ML/D)	388,000 (ML/D)	622,000 (ML/D)	Note that Broken/Seven dominant events may show high Goulburn River flows to achieve some of the higher gauge levels at Shepparton.					

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6.1 Timing Sensitivity Analysis

Two preliminary design events were modelled using the timing methodology mentioned in Section 4.4.2. A further sensitivity analysis of the timing of the three peak inflows entering the model was undertaken to assess the water level differences experienced downstream of the confluences of the Goulburn River with the Seven Creeks and Broken River. While it is unlikely that a flood occurring in Shepparton would have the peak flow from the three river systems combining at the same time, it is important to assess the impact that a combination of this nature can have.

A comparison of the Goulburn River dominant and Broken River/ Seven Creeks dominant flood events with the adopted design hydrograph timing compared to the adopted design hydrographs phased so the peaks at the inflow locations align is shown in Figure 6-1. The impact at the Shepparton gauge for the aligned tributary peak scenario is shown in Table 6-3. Note that the tributary inflows could be phased so that the peaks at Shepparton aligned more closely and the impacts on level at the Shepparton gauge may be more pronounced than the scenario presented.

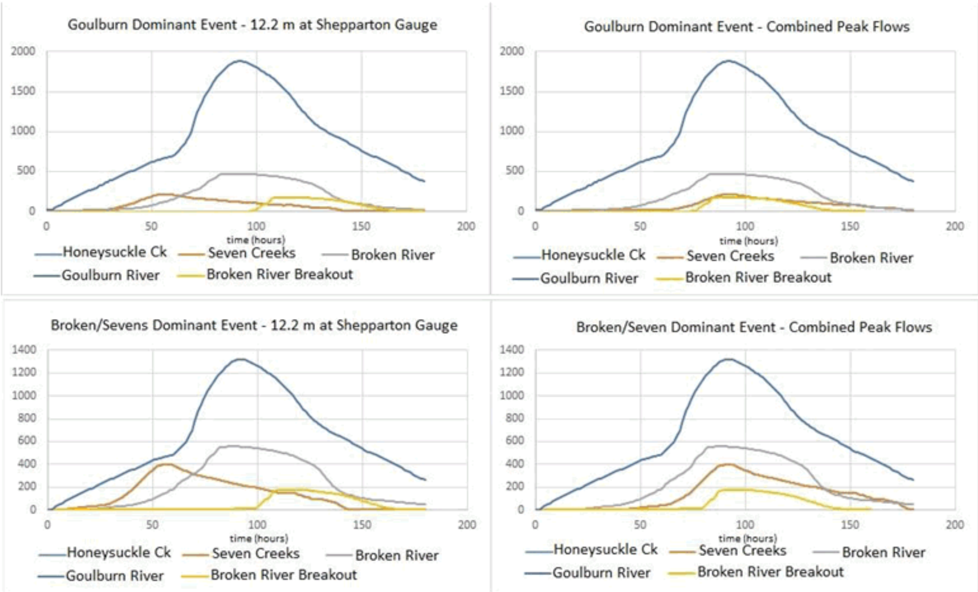


FIGURE 6-1 INFLOW HYDROGRAPHS FOR SENSITIVITY ANALYSIS OF TRIBUTARY TIMING

TABLE 6-3 IMPACTS OF TRIBUTARY TIMING AT THE SHEPPARTON GAUGE

Flow Event	Flood Level at Shepparton Gauge (m AHD)	Flow at Shepparton Gauge (ML/d)
Goulburn Dominant Design Event	112.28	222,100
Goulburn Dominant Combined Peak	112.38	241,800
Broken/Seven Dominant Design Event	112.21	205,718
Broken/Seven Dominant Combined Peak	112.36	237,600

As expected, more closely aligning the peaks of the inflows resulted in an increase in flood levels at Shepparton. It showed not only an increase downstream of the confluences but also back up the three tributary systems. The Broken/Seven dominant event showed a larger increase in flood levels (generally 100-200 mm) compared to the Goulburn dominant event (50-100 mm increase). The peak flows through the causeway increase significantly with the peaks aligned. Given the various catchment sizes of the contributing tributaries it is unlikely that they will align perfectly, and the design assumption is based on observations from historic events.

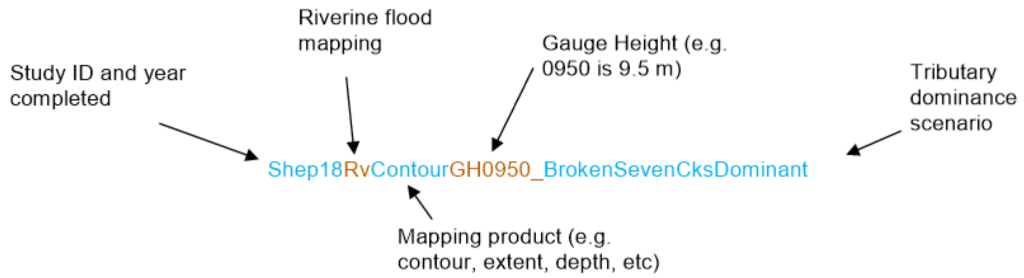
6.2 Design Flood Mapping

Flood mapping was produced for each of the gauge height increments for all three tributary dominance scenarios. For final design mapping of each gauge height increment, the three tributary dominance scenarios were combined, taking the maximum of the dominance scenarios.

Each scenario modelled was processed to produce mapping following the Victoria Flood Database (VFD) version 2 specifications. The VFD outputs included the following:

- Flood surface elevation contours at 200 mm intervals;
- Flood surface elevation grids (10 m grid resolution);
- Flood depth grids (10 m grid resolution);
- Flood velocity grids (10 m grid resolution);
- Flood hazard grids (velocity x depth at 10 m grid resolution);
- Flood extent polygons;
- Floor level survey points (9,355 floors); and
- Various VFD tables describing the study.

The VFD data was supplied as a geodatabase (Shep18Rv_VFD2_V9_Rev_07.gdb) to the Goulburn Broken CMA. The naming of the flood mapping products followed the naming convention below:



6.3 Online Flood Portal

To ensure that not only government agencies had access to the flood mapping developed during this study, but that community had access to the flood mapping, a cloud-based flood mapping portal was developed. At the time of writing this report the portal was online and accessible via www.floodreport.com.au but it is likely that the website will change in the near future to accommodate more townships to be displayed. This will see the addition of a landing page with easy links to the individual township flood mapping portals and possibly links to other sites of interest and general flood information.

The flood portal allows users to view flood depth maps across the range of events considered in this study, see Figure 6-2. Users can also click on a property parcel or search for an address and generate a property specific flood report, see Figure 6-3. This PDF report will generate a summary table of the water level, depth and velocity across the property, a 1% AEP flood map of the property of interest and a flood preparedness table which shows the water level at the property for all the modelled Goulburn River at Shepparton scenarios. If the property has a surveyed floor level, it will also show the depth of flooding above or below floor for that property. Note that not all properties within Shepparton have a recorded floor level. Floor levels were surveyed as part of the previous flood study (SKM, 2002), and since that time new developments should have been built with floor levels a minimum of 300 mm above the 1% AEP flood level. There is also the possibility that some buildings have been altered with raised floors, or have been demolished and built new, so floor levels may differ from that surveyed during the 2002 study.

The flood portal was developed by HydroLogic, the developers of the HydroNET platform. Water Technology is the Australian distributor of HydroNET.

A standalone user guide was developed to help users with the flood portal, the user guide can be accessed by clicking on the 'User Guide' link above the map.

Given the flood mapping is accessible via the flood portal, and the number of flood mapping scenarios mapped was so large, this report does not include any further flood mapping figures and the reader is encouraged to view the maps via www.floodreport.com.au.

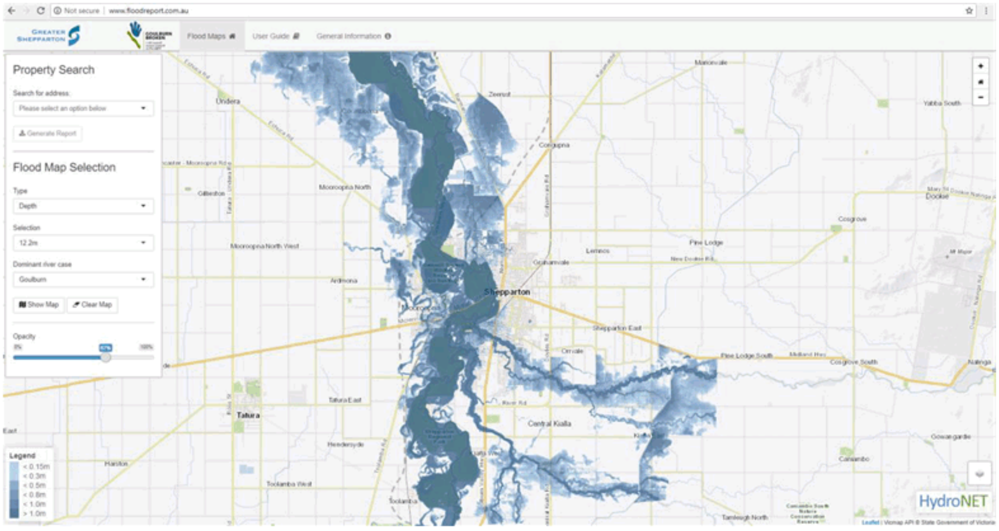


FIGURE 6-2 FLOOD REPORT PORTAL

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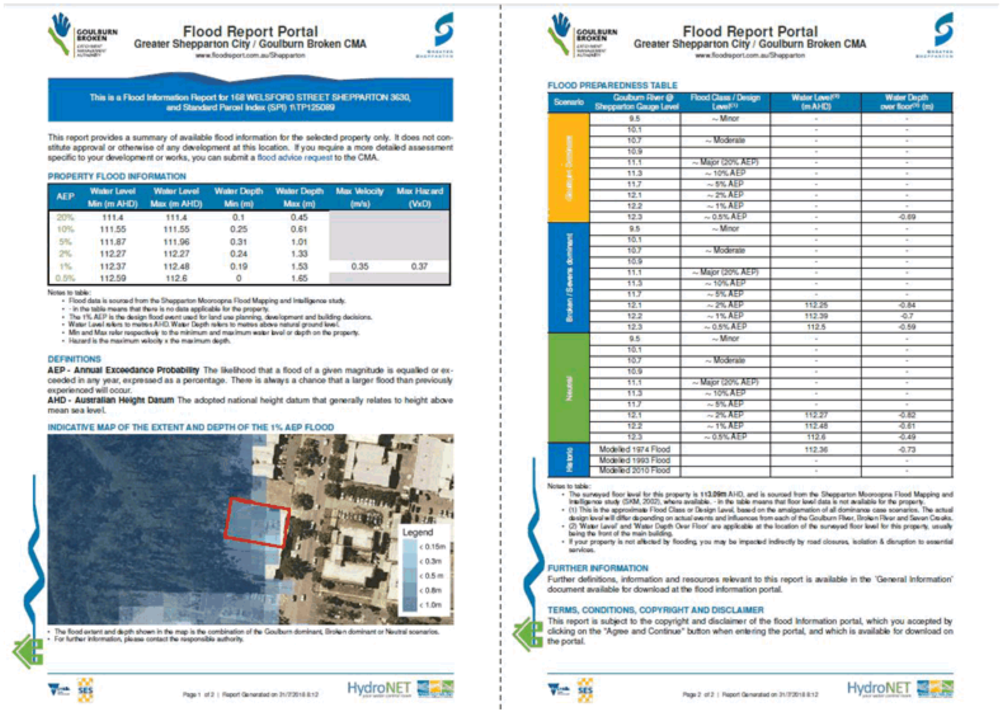

Flood Report Portal
Greater Shepparton City / Goulburn Broken CMA
www.floodreport.com.au/Shepparton

This is a Flood Information Report for 168 WELSFORD STREET SHEPPARTON 3630, and Standard Parcel Index (SPI) 1\TP125089

This report provides a summary of available flood information for the selected property only. It does not constitute approval or otherwise of any development at this location. If you require a more detailed assessment specific to your development or works, you can submit a flood advice request to the CMA.

PROPERTY FLOOD INFORMATION

AEP	Water Level Min (m AHD)	Water Level Max (m AHD)	Water Depth Min (m)	Water Depth Max (m)	Max Velocity (m/s)	Max Hazard (VxD)
20%	111.4	111.4	0.1	0.45		
10%	111.55	111.55	0.25	0.61		
5%	111.87	111.96	0.31	1.01		
2%	112.27	112.27	0.24	1.33		
1%	112.37	112.48	0.19	1.53	0.35	0.37
0.5%	112.59	112.6	0	1.65		

Notes to table:
- Flood data is sourced from the Shepparton Mooroopna Flood Mapping and Intelligence study.
- - in the table means that there is no data applicable for the property.
- The 1% AEP is the design flood event used for land use planning, development and building decisions.
- Water Level refers to metres AHD. Water Depth refers to metres above natural ground level.
- Min and Max refer respectively to the minimum and maximum water level or depth on the property.
- Hazard is the maximum velocity x the maximum depth.

DEFINITIONS
AEP - Annual Exceedance Probability The likelihood that a flood of a given magnitude is equalled or exceeded in any year, expressed as a percentage. There is always a chance that a larger flood than previously experienced will occur.
AHD - Australian Height Datum The adopted national height datum that generally relates to height above mean sea level.

INDICATIVE MAP OF THE EXTENT AND DEPTH OF THE 1% AEP FLOOD

- The flood extent and depth shown in the map is the combination of the Goulburn dominant, Broken dominant or Neutral scenarios.
- For further information, please contact the responsible authority.

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Flood Report Portal
Greater Shepparton City / Goulburn Broken CMA
www.floodreport.com.au/Shepparton

FLOOD PREPAREDNESS TABLE

Scenario	Goulburn River @ Shepparton Gauge Level	Flood Class / Design Level(1)	Water Level(2) (m AHD)	Water Depth over floor(2) (m)
Goulburn Dominant	9.5	~ Minor	-	-
	10.1		-	-
	10.7	~ Moderate	-	-
	10.9		-	-
	11.1	~ Major (20% AEP)	-	-
	11.3	~ 10% AEP	-	-
	11.7	~ 5% AEP	-	-
	12.1	~ 2% AEP	-	-
	12.2	~ 1% AEP	-	-
	12.3	~ 0.5% AEP	-	-0.69
Broken / Sevens dominant	9.5	~ Minor	-	-
	10.1		-	-
	10.7	~ Moderate	-	-
	10.9		-	-
	11.1	~ Major (20% AEP)	-	-
	11.3	~ 10% AEP	-	-
	11.7	~ 5% AEP	-	-
	12.1	~ 2% AEP	112.25	-0.84
	12.2	~ 1% AEP	112.39	-0.7
	12.3	~ 0.5% AEP	112.5	-0.59
Neutral	9.5	~ Minor	-	-
	10.1		-	-
	10.7	~ Moderate	-	-
	10.9		-	-
	11.1	~ Major (20% AEP)	-	-
	11.3	~ 10% AEP	-	-
	11.7	~ 5% AEP	-	-
	12.1	~ 2% AEP	112.27	-0.82
	12.2	~ 1% AEP	112.48	-0.61
	12.3	~ 0.5% AEP	112.6	-0.49
Historic	Modelled 1974 Flood		112.36	-0.73
	Modelled 1993 Flood		-	-
	Modelled 2010 Flood		-	-

Notes to table:
- The surveyed floor level for this property is **113.09m** AHD, and is sourced from the Shepparton Mooroopna Flood Mapping and Intelligence study (SKM, 2002), where available. - in the table means that floor level data is not available for the property.
- (1) This is the approximate Flood Class or Design Level, based on the amalgamation of all dominance case scenarios. The actual design level will differ depending on actual events and influences from each of the Goulburn River, Broken River and Seven Creeks.
- (2) 'Water Level' and 'Water Depth Over Floor' are applicable at the location of the surveyed floor level for this property, usually being the front of the main building.
- If your property is not affected by flooding, you may be impacted indirectly by road closures, isolation & disruption to essential services.

FURTHER INFORMATION
Further definitions, information and resources relevant to this report is available in the 'General Information' document available for download at the flood information portal.

TERMS, CONDITIONS, COPYRIGHT AND DISCLAIMER
This report is subject to the copyright and disclaimer of the flood Information portal, which you accepted by clicking on the "Agree and Continue" button when entering the portal, and which is available for download on the portal.

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FIGURE 6-3 PROPERTY SPECIFIC FLOOD REPORT

6.4 Comparison to Previous Design Flood Mapping

The flood mapping produced in this study has improved on the previous flood mapping through advancements in topography survey (LiDAR), significantly improved modelling approaches and computer software/hardware, better representation of levees, roads and channel embankments through the floodplain. All these improvements led to a very good calibration of three historic flood events (1974, 1993 and 2010), providing confidence in the model's ability to accurately describe flood behaviour throughout the study area. A greater understanding of tributary timing and breakouts from the Goulburn River, Broken River and Seven Creeks, and their interaction with the East Goulburn Main Channel has also improved model results.

When compared to the previous 1% AEP flood mapping, the new 1% AEP flood mapping shows a very similar extent across the floodplain, with the area of inundation reduced through Kialla West and Mooroopna due to the inclusion of more detailed representation of channel banks and roads which impact on the flood behaviour in those areas. The new 1% AEP flood mapping has therefore reduced the area of flood prone land in the Shepparton, Mooroopna and surrounding area.

The 1% AEP flood height at the Goulburn River at Shepparton gauge has not changed, it remains at 12.2 m. The flood level contours across the study area are similar to the previous flood mapping but vary slightly due to the improved representation of key features throughout the floodplain.

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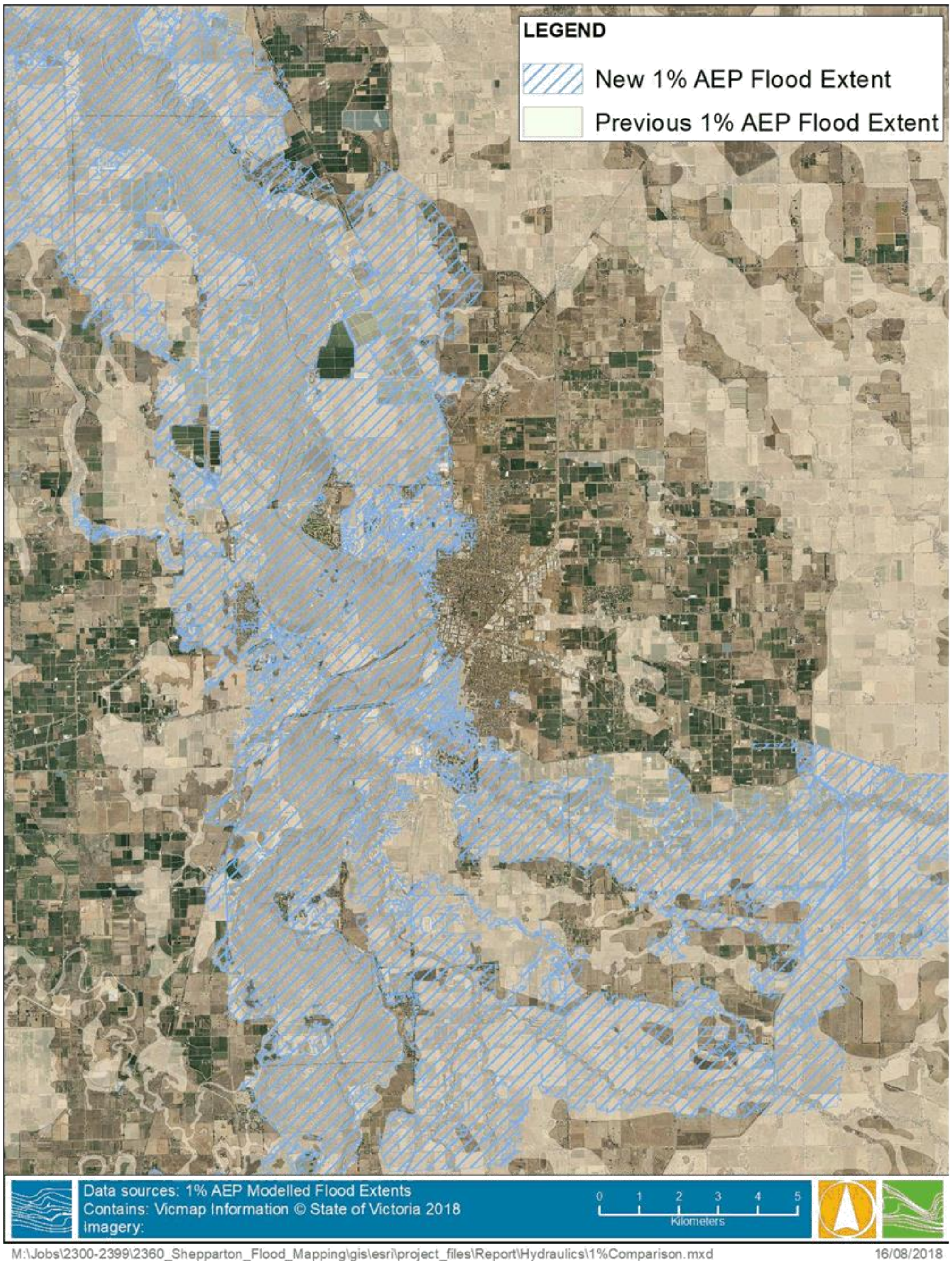

FIGURE 6-4 COMPARISON BETWEEN NEW AND PREVIOUS 1% AEP FLOOD MAPPING

7 FLOOD INTELLIGENCE

Water Technology partnered with Michael Cawood & Associates to develop flood intelligence information for the Shepparton-Mooroopna Flood Mapping and Flood Intelligence Study. The major flood intelligence deliverable was an update to the ***Greater Shepparton City Council Flood Emergency Plan: A Sub-Plan of the Municipal Emergency Management Plan***. The flood intelligence is summarised in this section, but readers are referred to the Flood Emergency Plan for more detail.

7.1 Flood Warning System and Flood Class Level Review

In 2006, Water Technology published a report as part of the Shepparton-Mooroopna Flood Warning and Emergency Management Project that reviewed the then flood warning arrangements and flood class levels for the study area and presented a draft Flood Forecast and Warning Service Charter (Water Technology, 2006). The Charter was founded on the Total Flood Warning System (TFWS) concept (EMA, 2009), but confined itself to the prediction, interpretation, message construction and review aspects of the TFWS for Shepparton and Mooroopna.

A TFWS (EMA, 2009), typically includes the following elements:

- **Data Collection and Collation** – rain and river gauges, data management and display systems.
- **Prediction** – estimating the flood magnitude and time of onset of particular levels of flooding.
- **Interpretation** – identifying the impacts of the predicted flood levels on the community at risk.
- **Flood Warning Message Construction** – defining the content of the message, describing what is happening, the expected impact and what action should be taken.
- **Message Communication** – disseminating warning information in a timely fashion to people and organisations likely to be affected by a flood.
- **Response** – generating appropriate and timely actions from the community and from the agencies involved.
- **Flood Awareness** – material aimed at raising awareness of flood risk and what to do in the lead up to and during a flood.
- **Review** – examining the various aspects of the system with a view to improving performance.

The Service Charter summarised the prediction requirement as follows:

> *To enable the maximum use of available flood intelligence and streamflow and rainfall data in the effective response to a flood event, flood predictions are required at the following gauges:*
>
> - *Goulburn River at Murchison;*
> - *Goulburn River at Arcadia Downs;*
> - *Goulburn River at Shepparton;*
> - *Seven Creeks at Kialla West; and*
> - *Broken River at Orrvale.*

The Service Charter went on to clarify agency roles and responsibilities in relation to flood predictions and, following a description of the flood inundation mapping available, outlined a process for selecting the most appropriate map set to inform emergency flood response. This was an important element of the Service Charter as Goulburn-Murray Water (G-MW) were keen to relinquish the lead role they had occupied for some considerable time in providing flood forecasts for Shepparton and the surrounding area.

Messaging requirements were outlined in the Service Charter and agency roles and responsibilities clarified. Of particular note is the requirement that:

> *"all warning information for the project area shall be contained in a set of single flood warning messages applicable to the entire project area. Rather than warning information…..being contained in separate….messages for the Goulburn River, Broken River and Seven Creeks respectively."*

Requirements relating to message content, warning lead times and update times were also documented. An operational review and update process for the Service Charter was also detailed.

7.1.1 Current Status of TFWS Elements

7.1.1.1 Data Collection and Collation

The current network of telemetered rain and river gauges upstream of Shepparton provide suitable information to support the TFWS for Shepparton and Mooroopna.

Rainfall data is available at 3-hourly intervals during smaller floods and more frequently during large floods. Weather radar also covers the area. River level data is available more frequently. Rain and river data, including the latest radar and satellite imagery, is available from the Bureau of Meteorology (BoM) website and through FloodZoom.

The City of Greater Shepparton is a contributing member of the Regional Surface Water Monitoring Partnership which ensures that all data is quality assured and stored in an accessible database, and that the gauge sites and equipment are covered by comprehensive routine and fault fix maintenance arrangements.

7.1.1.2 Prediction

BoM provide quantitative flood forecasts (BoM, 2015) for the following sites near Shepparton:

- Goulburn River at Murchison;
- Goulburn River at Shepparton;
- Seven Creeks at Kialla West; and
- Broken River at Orrvale.

A forecast is not provided for the Goulburn River at Arcadia Downs (also known as Goulburn River at Kialla West) site (AWRC 405270: BoMSN 581022), despite the requirement being documented and discussed in the Service Charter (Water Technology, 2006). Sometime after December 2011, but before the release of the first version of the Service Level Specification for Flood Forecasting and Warning Services for Victoria in 2013, the BoM dropped the flood class levels for this site, relegated it to data location status and began referring to it as Goulburn River at Kialla West rather than Goulburn River at Arcadia Downs. Before the site was relegated to data location status, BoM updated the flood class levels to reflect the levels specified in the Service Charter (Water Technology, 2006) and adopted those levels for operational use.

The requirement for a quantitative flood forecast for this site has increased following this study. The mapping requires a (forecast) level at the upstream forecast locations, including at the Goulburn River at Arcadia Downs (Kialla West) gauge, to enable determination of dominance and the most appropriate flood mapping set. This drives flood response, e.g. which roads will be affected first, which properties will be flooded, what community assets will be inundated, where sandbags will be required to minimise damage and disruption, etc.

It appears, based on experience during flood events over the past few years, that BoM have adopted a cautious approach to the issuing of flood forecasts for Murchison, Orrvale, Seven Creeks at Kialla West and Shepparton. To enable informed planning for evacuation etc. during an event (flooding causes substantial disruption within Shepparton's communities, there are more than 9,000 properties at risk of flooding, and upstream peak levels are key to determining flood dominance and therefore which inundation map set is most appropriate), an early "heads up" forecast is required. This is often left to a flood specialist in the Incident Control Centre (ICC) to develop, as the official BoM flood forecast is often issued much later, closer to the peak of the flood.

The flood class level review documented in the Service Charter was revisited as part of this review. While the updated modelling in this project has resulted in some changes to the water surface profiles through the study area, the flood class levels for all locations are still relevant. The triggering consequences in the definition for each class of flooding are occurring at about the same levels as identified previously even though the situation is complicated by which of the Goulburn, Broken-Seven or neutral dominance scenarios should be used for flood intelligence. It is evident that the flood class levels for each of the forecast locations do not need to change. The levels previously used for the Goulburn River gauge at Arcadia Downs (Kialla West) should be reinstated (i.e. 9 m, 10.4 m & 10.7 m). The naming of this gauge should also revert to Goulburn River at Arcadia Downs, so as not to confuse the gauge site with Seven Creeks at Kialla West.

A summary of the current flood class levels is provided in Table 7-1.

TABLE 7-1 FLOOD CLASS LEVELS

Flood Class Level	Goulburn River at Shepparton	Goulburn River at Arcadia Downs	Broken River at Orrvale	Seven Creeks at Kialla West
Minor	9.5 m	9.0 m	6.8 m	4.5 m
Moderate	10.7 m	10.4 m	7.2 m	5.0 m
Major	11.0 m	10.7 m	7.9 m	6.6 m

7.1.1.3 Interpretation

The Shepparton Municipal Flood Emergency Plan (MFEP) has been substantially updated to include flood intelligence from all recent flood and related studies. The work has included development of flood intelligence cards that include consequences across a range of flood levels, for key locations.

A companion spreadsheet of properties likely to be flooded over-ground and over-floor, with expected depths for various increments on the Shepparton gauge, has also been prepared.

The flood maps produced during this study are key to interpreting flood risk and consequences and when used in conjunction with the summary information contained in the MFEP, can inform the development of a targeted emergency response to flooding.

The part of the MFEP that deals with Shepparton, Mooroopna, Kialla and Kialla West includes a set of simple to apply flood forecast tools. These tools can be used to develop a heads-up flood forecast for Shepparton (and the upstream locations) before Benalla, Euroa or Goulburn Weir have peaked. This enables flood dominance to be determined and an appropriate flood map set to be selected at an early stage. This facilitates early planning for and implementation of flood response activities. It also informs community messaging.

To facilitate use of the latest MFEP within an ICC, it should be loaded to FloodZoom along with the spreadsheet of properties likely to be flooded and all flood mapping layers supplied to Goulburn Broken CMA as discussed in Section 6.2.

7.1.1.4 Flood Warning Message Construction

While BoM provide a standardised product, the matters raised through the Service Charter (Water Technology, 2006) have been mostly addressed. A gap does however exist in the value adding that could occur within an ICC to aid a community's understanding of what the BoM forecast flood height means in terms of local consequences. One way of closing this gap would be to develop, during non-flood periods, a suite of pre-scripted warning messages that include the value-added material for a range of gauge heights. The intelligence required to populate such messages is available in the MFEP and supported by the updated flood mapping. Keys and Cawood (2009) provides additional commentary on this subject.

7.1.1.5 Message Communication

BoM continues to use the wider media to disseminate flood warnings as does VicSES.

The demise of Xpedite, the message delivery system subscribed to by Greater Shepparton City Council in the mid-2000's to disseminate flood warnings to those at risk within Shepparton and Mooroopna, appeared initially to present a few problems. However, with Emergency Management Victoria (EMV) establishing the VicEmergency website and App, that service has been replaced. All warnings issued by BoM and VicSES are available on the website and are "pushed" to users of the App. Shepparton residents would be well advised to access the App and/or the website when flood threatens.

7.1.1.6 Response

With the adoption of AIIMS 4 and the inclusion of technical expertise in the ICC coupled with access to current flood intelligence through MFEP's and flood mapping available through FloodZoom, flood response has improved markedly over the past few years. Many of the issues raised by Comrie (2011) relating to this aspect of the TFWS have been addressed.

7.1.1.7 Flood Awareness

As part of this study, Water Technology has developed a web-based flood and property information portal for community use, www.floodreport.com.au. The portal enables flood maps to be visualised for the various dominance scenarios (e.g. neutral, Goulburn River dominant, Broken-Seven dominant) for a range of Goulburn River at Shepparton gauge heights, as well as allowing the download of a property specific flood report linking gauge heights to flood depths and floor levels.

The maps display the modelled inundation for 14 different river heights between 9.5 and 12.3 m on the Goulburn River at Shepparton (Dainton's Bridge) gauge. The flood information for a user-specified property is presented as a report that includes all available flood information for that property. See Section 0 for further information.

The maps and reports provide a means for community members to inform themselves of the likelihood of their property being inundated and the likely depths of inundation for a range of levels at the Shepparton gauge. The portal therefore replaces the property charts produced and disseminated in the early 2000's as well as the now out-dated on-line flood map viewing system hosted by Council since the mid-2000's.

Local Flood Guides (LFGs) have been developed and are available from VicSES for Shepparton and Mooroopna and for Murchison. LFGs need to be developed for all other locations for which flood studies have been completed (e.g. Kialla and Kialla West, East Shepparton, Tatura, Merrigum and the rural area upstream of Kialla West) as a step in raising awareness of flood risk in these areas. It is suggested that the Shepparton and Mooroopna LFGs could be updated with a link to the flood and property information portal once it is made public, to assist in raising community flood awareness.

7.1.1.8 Review

The review process that forms part of the Service Charter (Water Technology, 2006) has not been activated to date. It is apparent that there would be significant value in doing so as it would again draw stakeholder attention to matters that are crucial to improving the TFWS for Shepparton and Mooroopna.

TFWS performance during recent events (most recently in early December 2017) indicate that the TFWS is reasonably well developed. Operational processes seem to be working well with close cooperation between key agencies who openly share data and other information. There are however several actions that are considered key to further performance improvements:

- BoM to consider elevating the Goulburn River at Arcadia Downs (Kialla West) site from data location to forecast location. This is critical to improved flood response within Shepparton and Mooroopna.
- BoM to consider changing the name of the Goulburn River at Kialla West back to Goulburn River at Arcadia Downs (as it was previously known), to avoid confusion with Seven Creeks at Kialla West.
- BoM to consider providing earlier heads-up type forecasts for Shepparton and the immediate upstream locations so that flood response planning and community messaging can proceed with some lead time.
- Upload new flood intelligence information and flood mapping to FloodZoom so that it is available to inform future operations and messaging/warnings.
- Sharing of the updated flood mapping with the Shepparton community via the community web-based flood portal to raise flood awareness.
- Promotion of the VicEmergency website and App.
- Review exiting LFG's for accuracy and consistency with the MFEP, update to include information regarding the community web-based flood portal and produce additional LFG's for locations where studies have been completed.
- Develop a suite of pre-written value-added flood warning messages.

7.1.2 Suggested Actions Arising from this Review

The below section includes a series of suggested actions grouped by the responsible agency.

1. To maximise the value inherent in work done to date, it is suggested that the Greater Shepparton City Council, ideally in association with VicSES and with the support of DELWP, formally request that BoM consider the following:
   - Rename the Goulburn River at Kialla West to Goulburn River at Arcadia Downs, as it was previously known.
   - Add Goulburn River at Arcadia Downs (Kialla West) to the list of quantitative forecast locations;
   - Reinstate the previously adopted flood class levels for the Goulburn River at Arcadia Downs (Kialla West) gauge;
   - Provide initial flood predictions based on rainfall and observed / forecast river levels at upstream locations, aimed at maximising lead time without undue concern for forecast precision, for the following sites:

- Murchison – based on forecast outflows from Goulburn Weir;
- Goulburn River at Arcadia Downs (Kialla West) - based on the forecast level for Murchison;
- Seven Creeks at Kialla West - based on the forecast level for Euroa;
- Orrvale - based on the forecast level for Benalla;
- Shepparton - based on the above forecasts.

2. It is further suggested that Greater Shepparton City Council:
   - Arrange for the Shepparton MFEP to be loaded to FloodZoom together with the spreadsheet of properties likely to be flooded along with all flood mapping layers and associated reports.
   - In conjunction with VicSES, actively promote the VicEmergency website and App to the Shepparton, Mooroopna, Kialla and Kialla West communities as part of a flood preparedness and awareness program.
   - Promote the web-based flood portal, www.floodreport.com.au within the Shepparton and Mooroopna communities.
   - Prompt a review of the Shepparton flood forecast and warning service charter (Water Technology, 2006).
3. It is suggested that VicSES:
   - Review and update the LFGs for Shepparton, Mooroopna and Murchison so that there is consistency between the LFG's and the MFEP.
   - Produce and promote LFG's for other locations within the Municipality.
   - Promote the use of the flood portal for Shepparton and Mooroopna.
   - In conjunction with Greater Shepparton City Council, develop a suite of pre-written value-added flood warning messages.

7.2 Municipal Flood Emergency Plan (MFEP) Summary Information

The major flood intelligence deliverable was an update to the ***Greater Shepparton City Council Flood Emergency Plan: A Sub-Plan of the Municipal Emergency Management Plan***. The section below summarises some of the key flood intelligence findings included within the MFEP. For more details, the reader is referred to the MFEP.

7.2.1 Historic Flooding

The MFEP includes a good summary of historic flood events including gauge levels, flows and impacts within the Shepparton and Mooroopna communities, Table 7-2.

Many residents can relate to the October 1993 and September 2010 flood events, because they are recent events. A smaller number of longer term residents will remember the 1974 event. The March 2012 localised rainfall event, which caused small rural creeks to flood in the north-east region of the municipality (and a record flood along Broken Creek), has served to advise that any area may be subject to flooding. The heavy rain event of 27th and 28th February 2013 which resulted in severe flooding through East Shepparton reinforced that message.

TABLE 7-2 MAJOR FLOODS AT GOULBURN RIVER AT SHEPPARTON GAUGE

Flood / Year	Gauge Height (m)	Peak Discharge (ML/d)	Rank
September 1916	12.25	233,300	1
May 1974	12.08	214,000 #	2
1939		161,000	3
October 1993	11.72	160,500 ^	4
1956	11.42	121,000	5
1934		118,400	6
1975	11.24	105,000	7
1924		103,300	8
1958	11.21	103,000	9
1921		97,500	10
September 2010	11.09	81,328 *	11

The Goulburn River at Shepparton gauge has changed locations three times. It was located upstream of Dainton's Bridge from 1968 to 1986. It was moved to the current downstream location in 1986. There is about 100mm head loss through the bridge.

 # Historic streamflow record, this study has revised the peak flow to 191,000 ML/d.

^ Historic streamflow record, this study has revised the peak flow to 150,000 ML/d.

** Historic streamflow record, this study has revised the peak flow to 78,600 ML/d.*

7.2.2 Flood Travel Times

In the case of riverine flooding, the time of travel of a flood peak will be influenced by antecedent conditions. A flood on a 'dry' watercourse will generally travel more slowly than a flood on a 'wet' watercourse (e.g. the first flood after a dry period will travel more slowly than the second flood in a series of floods), and big floods tend to travel faster than small floods. Hence, the size of the flood, recent flood history, soil moisture and forecast weather conditions all need to be considered when using the following information to direct flood response activities.

The characteristics of the first flood after a dry period can be significantly altered by floodwater filling floodplain storage. This phenomenon is particularly important for the floodplain upstream of Shepparton and thus flood volume and dominance (i.e. whether the Broken – Seven Creeks system or Goulburn River or neither will dominate) is a key consideration in determining both travel times and flood attenuation.

Dominance and the timing of flows in the three key contributing catchments (i.e. Goulburn, Broken and Seven) is key to determining peak levels and thus impacts within Shepparton and Mooroopna. The Broken – Seven Creeks system appears to dominate most often with the Goulburn dominating least often.

The Goulburn River, Broken River and Seven Creeks waterways present a significant flood risk to the Shepparton/Mooroopna urban area and the immediate surrounds because their confluences are located within or adjacent to the urban area. A further significant flood risk arises from locally intense storms over urban and peri-urban areas, such as East Shepparton. The generally flat nature and poor drainage characteristics of the East Shepparton area make it particularly vulnerable to intense and heavy continuous rain.

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TABLE 7-3 RIVERINE FLOOD TIMING

Location From	Location To	Typical Travel Time	Comments
Riverine Flooding – Goulburn River			
Floods are characterised by steady rises, peaks that extend for a number of hours and recessions that are around one-half to one-third the rate of rise (i.e. takes around 2.5 to 3 times longer). The further down the catchment the longer the peak and the slower the recession. Flood volume determines rise and recession characteristics.			
Eildon	Seymour	48 hours	
Seymour	Goulburn Weir	30 to 40 hours	
Seymour	Murchison	40 to 60 hours	
Goulburn Weir	Murchison	9 to 18 hours	Generally, around 10 hours or a little less. Can be as short as 3 hours
Murchison	Kialla West (Goulburn River)	15 to 25 hours	In 1974, peak on Goulburn at Kialla West occurred 15 hours after the Broken at Orrvale peaked while in 1993 the difference was 60 hours.
Murchison	Shepparton	18 to 30 hours	20 hours or less if Goulburn dominant. 24 to 36 hours if Broken – Sevens dominant. In 1992 & 2010, travel time for peak from Murchison to Shepparton was ~1.5 days.
Kialla West (Goulburn)	Shepparton	Up to 12 hours	When Broken – Sevens dominant, peak at Shepparton can be at the same time or a little before peak at Goulburn at Kialla West.
Shepparton	McCoys Bridge	46 hours	
Shepparton	Echuca	7 days	
Riverine Flooding – Seven Creeks			
The recession at Kialla West is around one-third to one-quarter the rate of rise (i.e. takes around 3 to 4 times longer).			
Euroa	Kialla West (Mitchell Road)	26 to 50 hours	26 to 30 hours for floods ~6m and over at Kialla West. 35 to 48 hours if between 4.5m and 6m but 30 to 36 hours if 2nd flood in past 3 weeks or rain across lower catchment similar to upper catchment.
Kialla West (Seven Cks)	Shepparton	18 to ~60 hours	18 to 21 hours if Broken and Seven Creeks dominant. Time increases towards 30+ hours under neutral conditions but can be as high 60 hours.
Peak at Kialla West (the gauge is located immediately downstream from the Mitchell Road Bridge) occurs around 6 – 24 hours earlier than at the Broken River at Orrvale. Median time is around 15 hours but the usual range is 12-18 hours. In general terms, peak occurs at about the same time as at (or within a few hours of) the Broken River at Gowangardie. Travel time from Kialla West to Shepparton increases as Goulburn dominance builds.			
Riverine Flooding – Broken River			
After a slow peak, the recession at Orrvale is around one-third the rate of rise (i.e. takes around 2.5 to 3 times longer).			
Benalla	Casey's Weir	6 to 12 hours	Tends to cluster around 7 to 9 hours.
Benalla	Gowangardie Weir	18 to 37 hours	Think in terms of 26 to 30 hours but faster if good rain downstream from Benalla or 2nd flood.
Benalla	Orrvale	31 to 54 hours	Tends to cluster around 36 to 42 hours.
Casey's Weir	Gowangardie Weir	12 to 30 hours	Tends to cluster around 20 – 26 hours.

Location From	Location To	Typical Travel Time	Comments
Gowangardie Weir	Orrvale	10 to 18 hours	Usually in the 13-15 hour range (as per 2003) but ~24 hours in 1993 & 2010.
Orrvale	Shepparton	4 to 40+ hours	Generally, 8 to 14 hours with Broken River dominant. 20 to 28 hours as Goulburn flows increase (Murchison around 7.5m to 8.5m – neutral). 30+ hours with Goulburn dominant and Murchison above flood level.
In general terms, for a Broken – Seven Creeks dominant flood, the peak occurs at Gowangardie a few hours after the peak occurs at Kialla West on Seven Creeks. The difference between peak timings is longer (of order 12+ hours) for a neutral flood. Travel time from Orrvale to Shepparton increases as Goulburn dominance builds.			

To summarise, Shepparton and surrounds will have between 3 and 5 days' notice of the approach of major flooding within the river system. Flash flooding (e.g. East Shepparton) occurs within a few hours.

7.2.3 Flood Consequences

The MFEP contains tables with detailed flood consequence information for Shepparton, Mooroopna and surrounding communities. Those tables are not reproduced in this report. A summary of flood consequences is provided below. Detailed information is available in the MFEP. Emergency response agency staff are encouraged to use a combination of the flood mapping products available through FloodZoom, the MFEP, the excel spreadsheet of properties impacted, and this report, to fully understand likely flood impacts to implement appropriate emergency response actions. Shepparton and Mooroopna community members are encouraged to stay informed via their local emergency broadcaster and via the VicEmergency website and App. Community members are also encouraged to use the www.floodreport.com.au flood mapping portal to identify the likely impacts at their property of any flood levels forecast for the Goulburn River at Shepparton gauge.

7.2.3.1 Road Access

The main highways to Shepparton will begin to be inundated from around the start of major flooding (i.e. greater than 11.0 m at the Shepparton gauge). Details are provided in the Shepparton flood intelligence card of the MFEP.

- The Midland Highway will be impassable near the eastern boundary of the municipality when the Broken River breaks its banks at Gowangardie.
- The Midland Highway will be wetted in Mooroopna from around 11.66 m and may need to be closed.
- The Midland Highway in Shepparton begins to get wet between Mitchell and Florence Streets from around 12.05 m and may need to be closed.
- The Barmah – Shepparton Road will be wetted to the north of its intersection with the Goulburn Valley Highway from around 11.7 m and may need to be closed.
- The Goulburn Valley Highway will be inundated opposite Victoria Park Lake (north of the railway line) from around 11.4 m as well as north and south of the town.
- The Goulburn Valley Highway will be wetted at the Brauman Street – Pine Road intersection in North Shepparton from around 11.8 m.
- In December 2017, Castle Creek was against the underside of the lower Goulburn Valley Highway Bridge with the Castle Creek at Arcadia gauge showing 2.39 m.
- Some other roads will be closed at creek and river crossings – see the MFEP for details.

7.2.3.2 Evacuation Issues

The majority of properties have satisfactory egress in the event of rising floodwaters. However, there are three (3) locations that may present evacuation issues, if the residents are not notified early. These are:

- Kialla Settlement, Riverview Drive;
- Arcadia Downs Estate; and
- Kidstown Tourist facility.

Evacuation of areas close to the Goulburn River, Broken River and Seven Creeks waterways may be required once the Shepparton gauge is expected to exceed 11.1 m.

7.2.3.3 Caravan Parks

Caravan parks are also susceptible to flooding. The main sites in Shepparton and Mooroopna are:

- Victoria Lake Holiday Park, 536 Wyndham Street or Fitzjohn Road, Shepparton. The grounds begin to flood at around 11.18 m at Shepparton while the first floors begin to flood from about 11.4 m.
- Shepparton Riverside Cabin Park, 8049 Goulburn Valley Highway, Shepparton South. The grounds begin to flood at around 12.0 m at Shepparton.
- Big4 Shepparton Park Lane Holiday Park, 7835 Goulburn Valley Highway, Kialla. The grounds begin to flood at around 12.4 m at Shepparton
- Aspen Lodge Caravan Park, 1 Lawson Street, Mooroopna. The grounds begin to flood at around 11.4m at Shepparton while the first floors begin to flood from about 11.6 m.

7.2.3.4 Property Inundation

The property data on which the following count is based was collected as part of the SKM (2002) study and targeted all land parcels and buildings then determined to lie within the 1% AEP flood extent. It is assumed that all buildings constructed since 2002 have their floors at the 1% AEP flood level plus a minimum of 300 mm freeboard, therefore no further floor levels were collected as part of this study. There are likely to be other properties not included in the count of buildings inundated. Those buildings are likely to be above flood level but inundation on or surrounding the property may be observed. In addition, there may be some buildings which have been redeveloped since 2002 and no longer have the same floor level.

A summary of the number of properties and floors inundated at various levels at Shepparton is provided in Table 7-4.

A full list of all properties affected by flooding (including over-floor) was supplied as a separate Excel spreadsheet and was not added into the MFEP due to the large number of properties. The spreadsheet should be added to FloodZoom to be accessible by emergency flood response agencies. A summary of the properties first impacted by flooding is provided in the MFEP.

TABLE 7-4 PROPERTIES IMPACTED BY FLOODING IN STUDY AREA

	Shepparton gauge level (m)	Properties				Floors			
		Flooded and almost flooded	Flooded	Almost flooded	Number of properties not "flood affected"	Flooded and almost flooded	Flooded	Almost flooded	Number of floors not "flood affected"
	10.5	2	2	0	9353				
Moderate	10.7	15	11	4	9340	5	4	1	9350
10% AEP	10.9	31	23	8	9324	9	5	4	9346
Major	11	64	36	28	9291	14	9	5	9341
	11.1	163	99	64	9192	20	18	2	9335
5% AEP	11.3	308	193	115	9047	37	28	9	9318
~1993	11.5	498	322	176	8857	64	45	19	9291
	11.7	1311	862	449	8044	155	109	46	9200
2% AEP	11.9	4223	3578	645	5132	819	556	263	8536
~1974	12.1	5152	4537	615	4203	1129	765	364	8226
1% AEP	12.2	7329	6814	515	2026	2564	1778	786	6791
0.5% AEP	12.3	8376	8066	310	979	4489	3314	1175	4866
0.2% AEP	12.5	8903	8682	221	452	6351	5415	936	3004

Note: The count of floors flooded in the above table, uses data from the previous flood study (SKM, 2002). It does not include properties built in the floodplain since 2002 (but those buildings should have floor levels set at least 300 mm above the 1% AEP flood level. There may also be some buildings which have been redeveloped since 2002 and the floor levels may have changed.

7.2.3.5 Essential Services

During a flood event, ground level electrical substations are at extreme risk and will need to be protected with sandbags. Failure to protect the substations may result in shut down localised outages.

The water treatment plant is well protected but if the levees are breached, water supply will be affected; the town has only a single week's supply of treated water available if the plant were to become inoperable.

The sewerage system will become overloaded if floodwater can flow back into the system through private gully traps and such; all inlets must be closed.

Goulburn Valley Water, the responsible agency for water supply and sewerage management in the City of Greater Shepparton municipal area, has its own detailed response plan which includes details of tasks to be conducted when river levels rise. Their works commence when the level reaches 8.5 m at the Shepparton gauge. Their water treatment plant and sewerage pumps will be adversely affected at a river height of 11.9 m.

If the Shepparton gauge is forecast to reach levels above 12.0 m, the Municipal offices at 90 Welsford Street are impacted and the Municipal Emergency Coordination Centre should be relocated to 315 Doyles Road, Orrvale.

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7.2.4 Flood Mitigation

Shepparton, Murchison, Kialla and Undera regions have levees at strategic locations. However, these only provide protection up to just over the Shepparton major flood level of 11.0 m and have been overtopped twice in the past 40 years.

Penstocks are in place on most inlet pipes to the rivers, preventing backflow of floodwaters. The closing and opening of these penstocks is correlated closely to the levels recorded at the 3 major automated flood level gauges on the Broken, Sevens and Goulburn waterways.

There are large volume pumps at some locations to lift and discharge waters when penstocks are closed.

All new subdivisions are being developed with sufficient retardation basin capacity, to slow up the inflow of water into the town stormwater drainage systems.

7.2.5 Flood Forecasting

This study has reviewed and updated an early heads up forecasting procedure for Shepparton and Mooroopna based on upstream gauge levels or flows. The approach requires some knowledge of the catchment and is best used by an experienced flood analyst who knows the catchment. This procedure has not been developed to replace detailed flood forecasts provided by the Bureau of Meteorology. It is designed purely for an early heads up to begin planning for an oncoming flood event.

The approach is outlined in the MFEP and is not reproduced in this report.

8 CONSULTATION PROCESS

The Shepparton-Mooroopna Flood Mapping and Flood Intelligence Study was commissioned in 2012. The purpose of the study was to provide a technical review and update of the previous flood study (SKM, 2002), and to develop updated flood mapping and flood intelligence information for emergency managers and the broader community.

The project was completed in close consultation with Greater Shepparton City Council engineers, planners and emergency managers, Goulburn Broken CMA floodplain managers and the Victoria State Emergency Service.

Initially there were some major data gaps in topography that led to delays in the project. A major issue with the Goulburn River at Murchison streamflow gauge required additional work to improve the flow gauging. This led to the completion of a flood mapping and intelligence study for Murchison, which has provided additional benefit to understanding flood risk in the region. An extensive review and update to the regional hydrology of the Goulburn, Broken and Seven Creeks catchments also led to an improved understanding of design flood flows for the region, resolving some discrepancies which previously existed in prior knowledge. The flood portal was added to the project toward the end of the flood modelling component. Extensive consultation occurred with key stakeholders to ensure the product met their needs and would be flexible enough to allow other Councils to make use of the same service in the future.

Through the many deviations that this project has taken, Water Technology has kept close consultation with Greater Shepparton Council, Goulburn Broken CMA and Victoria State Emergency Service to ensure that the project delivered a high-quality product for the region.

Consultation included a series of technical project meetings either held in Shepparton or Melbourne. At these meetings study progress was reviewed, key data gaps were discussed along with deficiencies and required solutions. The meetings were also important for reaching agreement and sign-off at key decision points and discussing future timelines for delivery. At various stages these meetings included Council planners to ensure they were kept up to date on the study and were aware of the best available flood data for use in land use planning decisions.

During the flood modelling, Water Technology worked very closely with Goulburn Broken CMA to ensure the best possible calibration could be achieved. This involved many hours of sitting with knowledgeable CMA individuals to review and improve the flood mapping, both through calibration and design phases.

The hydrology and hydraulic flood modelling calibration was reviewed by an independent technical review panel process arranged by the Department of Environmental, Land, Water and Planning. This technical review provided increased confidence in the appropriateness of the study method.

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9 CONCLUSION AND RECOMMENDATIONS

The Shepparton-Mooroopna Flood Mapping and Flood Intelligence Study provides an improved understanding of flood behaviour through the study area. This will ensure future flood-related planning decisions are based on the best available flood risk information. The study has included:

- Collection and review of data relevant to flooding within the study area.
- A rigorous hydrologic analysis to develop robust design flood estimates for the study area including consideration for the timing and potential combinations of Goulburn River, Broken River and Seven Creeks riverine flooding.
- Development and calibration of a detailed hydraulic model that can predict flood impacts across the complex floodplain.
- Flood mapping of many potential design flood scenarios.
- Development of an online flood mapping portal, www.floodreport.com.au.
- Quantification of flood risk at a property specific level.
- Review of flood warning and emergency response, and an update to the Municipal Flood Emergency Plan.

The key findings and outcomes of the study are summarised below:

- Update to previous design hydrology of the Goulburn River basin, which has resulted in an improved understanding of design flooding throughout the system, including resolution of an earlier discrepancy in relation to the Murchison design flows. The Goulburn River at Murchison gauge rating curve has been updated, and this has officially been incorporated into the gauge rating for large flood flows.
- The hydraulic modelling in the Shepparton, Mooroopna and surrounding areas has been completed at a higher resolution using better topography data compared to the earlier SKM (2002) study. This has resulted in improved flood mapping for the area.
- The flood mapping data has been formatted into the Victoria Flood Database format and has been provided to Goulburn Broken CMA. The flood mapping portal, www.floodreport.com.au, has made the flood mapping accessible to anyone with internet access, and provided a means to obtain property specific flood information to assist in raising community flood awareness.
- A comprehensive review of the flood warning system was completed along with a major update to the Municipal Flood Emergency Plan for Shepparton, East Shepparton, Mooroopna, Kialla, Murchison, Tallygaroopna, Congupna, Katandra West, Tatura and Merrigum.

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

- **Goulburn Broken CMA**
  - Endorse the flood study and use the flood mapping data to inform floodplain risk management decisions.
  - Upload the Victoria Flood Database mapping data to FloodZoom
  - Work with Greater Shepparton City Council to define the specific criteria for defining flood planning layers using the flood modelling produced in this study. This may include investigation of higher resolution modelling and mapping of the Shepparton, Mooroopna and surrounding area.

- **Greater Shepparton City Council**
  - Endorse the flood study before putting it out for public comment with aim of adopting the flood study and implementing a planning scheme amendment to update the flood related planning overlays.
  - Arrange to load the updated MFEP and the excel spreadsheet of property inundation to FloodZoom (Goulburn Broken CMA may be able to assist).
  - Review the Shepparton flood forecast and warning service charter (Water Technology, 2006).
  - Request that the Bureau of Meteorology consider the following:
    - Rename Goulburn River at Kialla West to Goulburn River at Arcadia Downs, as it was previously known.
    - Add Goulburn River at Arcadia Downs (Kialla West) to the list of quantitative forecast locations.
    - Reinstate the previously adopted flood class levels for the Goulburn River at Arcadia Downs (Kialla West) gauge.
    - Provide initial flood predictions based on rainfall and observed / forecast river levels at upstream locations, aimed at maximising lead time for Goulburn River at Murchison, Arcadia Downs (Kialla West) and Shepparton, Seven Creeks at Kialla West, and Broken River at Orrvale.
  - Actively promote the use of the VicEmergency website and App and the flood portal www.floodreport.com.au to the community to improve flood preparedness and awareness.
- **Victoria State Emergency Service** with assistance from Goulburn Broken CMA and Greater Shepparton City Council:
  - Continue to engage the community through regular flood awareness programs such as the VICSES FloodSafe program.
  - Update the Local Flood Guides of Shepparton and Mooroopna and Murchison to reflect the new flood study data and to provide consistency across all documents.
  - Develop Local Flood Guides for other locations within the municipality using the updated information contained in this report and the MFEP.
  - Develop a suite of pre-written value-added flood warning messages.

10 ACKNOWLEDGEMENTS

Water Technology would like to acknowledge the contributions of Guy Tierney of Goulburn Broken CMA and Greg McKenzie of Greater Shepparton City Council in the completion of this study, and their ongoing commitment to reducing flood risk in the Shepparton, Mooroopna and surrounding areas. We would also like to acknowledge the contributions from our project partners, HydroLogic and Michael Cawood and Associates.

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Greater Shepparton City Council

Flood Emergency Plan

A Sub-Plan of the Municipal Emergency Management Plan

For Greater Shepparton City Council,
VICSES North East Region,
VICSES Unit Tatura and Murchison
and
Shepparton Search & Rescue Squad

Version 2.3 Draft July 2018

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5		MRM	
6		MERC (Shepparton Police Station)	
7		RERC	
8		VICSES North East (Hume) Benalla RHQ	
9		VICSES (Tatura unit)	
10		VICSES (Murchison unit)	
11		Goulburn Broken Catchment Management Authority	
12		Bureau of Meteorology (Flood Warning)	
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20		Power supplier (Powercor)	
21		Goulburn Murray Water	
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23		Shepparton Search & Rescue Squad (SS&RS)	
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Document Transmittal Form / Amendment Certificate

This Municipal Flood Emergency Plan (MFEP) will be amended, maintained and distributed as required by VICSES in consultation with Greater Shepparton City Council.

Suggestions for amendments to this Plan should be forwarded to VICSES Regional Office North East (Hume) Benalla.

Amendments listed below have been included in this Plan and promulgated to all registered copyholders.

Amendment Number	Date of Amendment	Amendment Entered By	Summary of Amendment
V2.0	March 2018	M Cawood	Update of flood intelligence (Appendices A, B, C, etc) drawing on recent events and flood studies – Shepparton-Mooroopna, East Shepparton, Murchison, Merrigum & Tatura. Checked and adjusted EMMV & VFMS references. Updated agency names as well as Section 4.3 re Animal Welfare. Added references. Selected Appendices reviewed by Ben Tate of Water Technology.
V2.1	June 2018	Ben Tate	As discussed with GSCC, GBCMA, VICSES, MCA – May 2018
V2.2	June 2018	M Cawood	Further edits based on discussion and feedback from GSCC, GBCMA, VICSES. Other minor edits.
V2.3	July 2018	M Cawood	Added flood intel and history for Congupna, Dainton's, Pine Lodge, O'Keefe & Gulfus creeks from the 27Feb2014 report from Greg Sidebottom to GSCC.

This Plan will be maintained on the www.ses.vic.gov.au and www.greatershepparton.com.au websites.

List of Abbreviations & Acronyms

The following abbreviations and acronyms are used in the Plan:

AEP	Annual Exceedance Probability
AHD	Australian Height Datum (the height of a location above mean sea level in metres)
AIIMS	Australasian Inter-service Incident Management System
AoCC	Area of Operations Control Centre / Command Centre
ARI	Average Recurrence Interval
ARMCANZ	Agricultural & Resource Management Council of Australia & New Zealand
AV	Ambulance Victoria
BoM	Bureau of Meteorology
CEO	Chief Executive Officer
CERM	Community Emergency Risk Management
CFA	Country Fire Authority
CMA	Catchment Management Authority
DEDJTR	Department of Economic Development, Jobs, Transport and Resources
DELWP	Department of Environment, Land, Water and Planning (successor body to DSE, DPI and DEPI)
DHHS	Department of Health and Human Services
DoI	Department of Infrastructure
EMMV	Emergency Management Manual Victoria
EMT	Emergency Management Team
EO	Executive Officer
FO	Floodway Overlay
FWS	Flood Warning System
UFZ	Urban Floodway Zone
IC	Incident Controller
ICC	Incident Control Centre
IMT	Incident Management Team
IMS	Incident Management System
EMLO	Emergency Management Liaison Officer
H&HS SEMC	The Health & Human Services State Emergency Management Centre
LSIO	Land Subject to Inundation Overlay
MECC	Municipal Emergency Coordination Centre
MEMP	Municipal Emergency Management Plan
MEMPC	Municipal Emergency Management Planning Committee
MERC	Municipal Emergency Response Coordinator
MERO	Municipal Emergency Resource Officer
MFB	Metropolitan Fire and Emergency Services Board
MRM	Municipal Recovery Manager
PMF	Probable Maximum Flood

RCC	Regional Control Centre
RDO	Regional Duty Officer
REOC	Regional Emergency Operations Centre
RERC	Regional Emergency Response Coordinator
RERCC	Regional Emergency Response Coordination Centre
SBO	Special Building Overlay
SCC	State Control Centre
SEWS	Standard Emergency Warning System
SS&RS	Shepparton Search and Rescue Squad
SHERP	State Health Emergency Response Plan
SOP	Standard Operating Procedure
VicPol	Victoria Police
VICSES	Victoria State Emergency Service

Part 1. INTRODUCTION

1.1 Municipal Endorsement

This Municipal Flood Emergency Plan (MFEP) has been prepared by the Shepparton MEMPC Flood Sub Committee and with the authority of the Greater Shepparton City Council MEMPC pursuant to Section 20 of the Emergency Management Act 1986 and Emergency Management Act 2013 (as amended)[1].

Greater Shepparton City Council has undertaken consultations with the Shepparton, Mooroopna, Murchison, Toolamba, Tatura, Tallygaroopna, Congupna and Katandra communities about the arrangements contained within this plan.

This MFEP is a sub plan to the Greater Shepparton City Council Municipal Emergency Management Plan (MEMP). It is consistent with the Emergency Management Manual Victoria (EMMV) and the Victorian Floodplain Management Strategy (DELWP, 2016), and takes into account the outcomes of the Community Emergency Risk Assessment (CERA) process undertaken by the Municipal Emergency Management Planning Committee (MEMPC).

The Municipal Flood Emergency Plan is consistent with the Regional Flood Emergency Plan and the State Flood Emergency Plan.

This Municipal Flood Emergency Plan is a result of the cooperative efforts of the Greater Shepparton City Council Flood Planning Committee (MFPC) and its member agencies.

This Plan is endorsed by the Greater Shepparton City Council MEMPC as a sub-plan to the MEMP.

Endorsement

....	
Keith O'Brien VICSES Regional Manager	Date 29 August 2014
....	
Kaye E. Thomson Municipal Emergency Manager Director Community.	Date 29 August 2014

[1] The 2013 Act operates concurrently with the *Emergency Management Act 1986* with the intention that the 1986 Act will ultimately be repealed.

1.2 The Municipality

An outline of the City of Greater Shepparton in terms of its location, demography and other general matters is provided in the MEMP. An outline of the flood threat is provided in Appendix A of this Plan.

1.3 Purpose and Scope of this Flood Emergency Plan

The purpose of this MFEP is to detail arrangements agreed for the planning, preparedness/prevention, response and recovery from flood incidents within the City of Greater Shepparton municipal area.

As such, the scope of the Plan is to:

- Identify the Flood Risk within the City of Greater Shepparton municipal area;
- Support the implementation of measures to minimise the causes and impacts of flood incidents within the City of Greater Shepparton municipal area;
- Detail Response and Recovery arrangements including preparedness, Incident Management, Command and Control;
- Identify linkages with Local, Regional and State emergency and wider planning arrangements with specific emphasis on those relevant to flood.

This Flood Emergency Plan document is complemented by two other guides which provide the public with additional information specific to their area:

a) Local Flood Guide (Appendix F)

b) Community Information Guide (Appendix G)

1.4 Municipal Flood Planning Committee (MFPC)

Membership of the Greater Shepparton City Council Flood Planning Committee (MFPC) will comprise of the following representatives from the following agencies and organisations:

- VICSES (i.e. Unit Controller & Regional Officer – Emergency Management) **(Chair)**,
- Greater Shepparton City Council,
- Victoria Police (i.e. Municipal Emergency Response Co-ordinator) (MERC),
- Goulburn Broken Catchment Management Authority,
- Department of Health and Human Services (DHHS) as required,
- Department of Environment Land Water and Planning (DELWP) as required,
- Goulburn Murray Water
- Goulburn Valley Water
- Shepparton Search & Rescue
- Other agencies as required

1.5 Responsibility for Planning, Review & Maintenance of this Plan

This Municipal Flood Emergency Plan must be maintained in order to remain effective.

VICSES through the Flood Planning Committee has responsibility for preparing, reviewing, maintaining and distributing this plan.

The MFPC will meet at least once per year.

The plans should be reviewed:

- Following any new flood study;
- Change in non-structural and/or structural flood mitigation measures;
- After the occurrence of a significant flood event within the Municipality to review and where necessary amend arrangements and information contained in this Plan.

1.6 Endorsement of the Plan

The MFEP will be circulated to the Greater Shepparton City Council Emergency Management Planning Committee to seek acceptance of the draft plan.

Upon acceptance, the plan is forwarded to the MEMPC for endorsement with the recommendation to include the MFEP as a sub-plan of the MEMP.

Additional supporting documents which focus on specific towns and areas are:

a) Local Flood Guide

b) Community Information Guide

Part 2. PREVENTION / PREPAREDNESS ARRANGEMENTS

2.1 Community Awareness for all Types of Flooding

Details of this MFEP will be released to the community through local media, the FloodSafe program, websites (www.ses.vic.gov.au and www.greatershepparton.com.au) upon formal adoption by the Greater Shepparton City Council.

VICSES with the support of Greater Shepparton City Council and Goulburn Broken Catchment Management Authority will coordinate community education programs for flooding within the council area. E.g., FloodSafe / StormSafe.

2.2 Structural Flood Mitigation Measures

The following summary of structural flood mitigation measures exist within the Council area:

- Levees in Murchison, Kialla, Mooroopna and Shepparton. These are on private and Crown land and maintenance responsibility is to be determined.
- Flood pumps are positioned at strategic locations to protect urban areas
- Penstocks are located along waterways to prevent backflow
- There are more than 70 retardation basins (47 in East Shepparton) across the municipality, owned and maintained by Council.

Refer to Appendix C for detailed information of structural flood mitigation measures.

2.3 Non-structural Flood Mitigation Measures

2.3.1 Exercising the Plan

Arrangements for exercising this Plan will be at the discretion of the MEMPC. This Plan should be regularly exercised, preferably on an annual basis.

2.3.2 Flood Warning

Arrangements for flood warnings are contained within the State Flood Emergency Plan, the EMMV (Part 7) and on the BoM website (see http://www.bom.gov.au).

Specific details of local flood warning systems and arrangements are provided in Appendix E.

2.3.3 Flood Observers

Community Observers provide local knowledge to VICSES and the Incident Control Centre regarding local insights and the potential impacts and consequences of an incident and may assist with the dissemination of information to community members.

Specific details of arrangements to capture local knowledge are provided in Appendix G.

Part 3. RESPONSE ARRANGEMENTS

3.1 Introduction

3.1.1 Activation of Response

Flood response arrangements may be activated by the Regional Duty Officer (RDO) VICSES North East (Hume) Region or Incident Controller.

The Incident Controller/RDO VICSES will activate agencies as required and documented in the State Flood Emergency Plan.

3.1.2 Responsibilities

There are a number of agencies with specific roles that will act in support of VICSES and provide support to the community in the event of a serious flood within the City of Greater Shepparton. These agencies will be engaged through the EMT.

The general roles and responsibilities of supporting agencies are as agreed within the Greater Shepparton City Council MEMP, EMMV (Part 7 'Emergency Management Agency Roles'), State Flood Emergency Plan and Regional Flood Emergency Plan.

3.1.3 Municipal Emergency Coordination Centre (MECC)

If established, liaison with the emergency coordination centre will be through the established Division/Sector Command and through Municipal involvement in the Incident EMT, in particular the Municipal Emergency Response Coordinator (MERC). The VICSES RDO / ICC will liaise with the MECC directly if no Division/Sector Command is established.

The function, location, establishment and operation of the MECC will be as detailed in the Greater Shepparton City Council MEMP.

3.1.4 Escalation

Most flood incidents are of local concern and an appropriate response can usually be coordinated using local resources. However, when these resources are exhausted, the State's arrangements provide for further resources to be made available, firstly from neighbouring Municipalities (on a regional basis) and then on a State-wide basis.

Resourcing and event escalation arrangements are described in the EMMV ('State Emergency Response Plan' – Part 3).

3.2 Strategic Control Priorities

To provide guidance to the Incident Management Team (IMT), the following strategic control priorities shall form the basis of incident action planning processes:

1. Protection and preservation of life is paramount - this includes:

    - Safety of emergency services personnel; and,
    - Safety of community members including vulnerable community members and visitors/tourists located within the incident area.

2. Issuing of community information and community warnings detailing incident information that is timely, relevant and tailored to assist community members make informed decisions about their safety.

3. Protection of critical infrastructure and community assets that supports community resilience;

4. Protection of residential property as a place of primary residence;

5. Protection of assets supporting individual livelihoods and economic production that supports individual and community financial sustainability; and

6. Protection of environmental and conservation values that considers the cultural, biodiversity, and social values.

Circumstances may arise where the Incident Controller is required to vary these priorities, with the exception being that the protection of life should remain the highest. This shall be done in consultation with the State Controller and relevant stakeholders based on sound incident predictions and risk assessments.

3.3 Command, Control & Coordination

The Command, Control and Coordination arrangements in this Municipal Flood Emergency Plan must be consistent with those detailed in State and Regional Flood Emergency Plans. For further information, refer to the State Emergency Response Plan, Part 3 of the EMMV.

The specific details of the Command, Control and Coordination arrangements for this plan are to be provided in Appendix C.

3.3.1 Control

Functions 5(a), 5(b) and 5(c) at Part 2 of *the Victoria State Emergency Service Act 2005* detail the authority for VICSES to plan for and respond to flood.

Part 7.1 of the EMMV prepared under the *Emergency Management Act 1986* and *Emergency Management Act 2013 (as amended)*, identifies VICSES as the Control Agency for flood. It identifies DELWP as the Control Agency responsible for "*dam safety, water and sewerage asset related incidents*" and other emergencies. A more detailed explanation of roles and responsibilities is provided in later sections of Part 7 of the EMMV.

All flood response activities within the City of Greater Shepparton municipal area including those arising from a dam failure or retardation basin / levee bank failure incident will therefore be under the control of the appointed Incident Controller, or their delegated representative.

3.3.2 Incident Controller (IC)

An Incident Controller (IC) will be appointed by the VICSES (as the Control Agency) to command and control available resources in response to a flood event on the advice of the Bureau of Meteorology (or other reliable source) that a flood event will occur or is occurring. The Incident Controller responsibilities are as defined in Part 3 of the EMMV

3.3.3 Incident Control Centre (ICC)

As required, the Incident Controller will establish an Incident Control Centre (ICC) from which to initiate incident response command and control functions. The decision as to if and when the ICC should be activated, rests with the Control Agency (i.e. VICSES).

Pre-determined Incident Control Centre locations are

- CFA Hume Region District 22 Office 195 – 205 Numurkah Road Shepparton.
- VICSES North East (Hume) Region 64 Sydney Road Benalla

  And / Or are listed in the North East (Hume) Regional Flood Emergency Plan.

3.3.4 Divisions and Sectors

To ensure that effective Command and Control are in place, the Incident Controller may establish Divisions and Sectors depending upon the complexity of the event and resource capacities.

The following Divisions and Sectors may be established to assist with the management of flooding within the Municipality:

Division	Sector
Tatura	Tatura, Murchison, Nagambie and Mooroopna
Shepparton	Shepparton, Kialla

Pre-determined Division Command locations are:

- Tatura Division Command location Corner Russell and Martin Street Tatura
- Shepparton S&R Division Command location 15 Dudley St Shepparton

Pre-determined Sector Command locations are:

- Tatura Sector Command location is Corner Russel and Martin Streets Tatura
- Shepparton S&R Sector Command location is 15 Dudley Street Shepparton
- Murchison Sector Command location is 10a Watson Street, Murchison
- Nagambie Sector Command location is Vine Street, Nagambie
- Kialla Sector Command location is Central Kialla Road, Kialla

3.3.5 Incident Management Team (IMT)

The Incident Controller will form an Incident Management Team (IMT).

Refer to the EMMV for guidance on IMTs and Incident Management Systems (IMSs).

3.3.6 Emergency Management Team (EMT)

The Incident Controller will establish a multi-agency Emergency Management Team (EMT) to assist the flood response. The EMT will consist of key personnel (with appropriate authority) from stakeholder agencies and relevant organisations who need to be informed of strategic issues related to incident control and who are able to provide high level strategic guidance and policy advice to the Incident Controller for consideration in developing incident management strategies.

Organisations, including Greater Shepparton City Council, required within the EMT will provide an Emergency Management Liaison Officer (EMLO) to the ICC if and as required as well as other staff and / or resources identified as being necessary, within the capacity of the organisation.

Refer to the EMMV for guidance on EMTs.

3.3.7 On Receipt of a Flood Watch / Severe Weather Warning

Incident Controller or VICSES RDO (until an incident controller is appointed) will undertake actions as defined within the flood intelligence cards (Appendix C). General considerations by the Incident Controller/VICSES RDO will be as follows:

- Review flood intelligence to assess likely flood consequences
- Monitor weather and flood information – www.bom.gov.au
- Assess Command and Control requirements.
- Review local resources and consider needs for further resources regarding personnel, property protection, flood rescue and air support
- Notify and brief appropriate officers. This includes Regional Control Centre (RCC) (if established), State Control Centre (SCC) (if established), Council, other emergency services through the EMT.
- Assess ICC readiness (including staffing of IMT and EMT) and open if required
- Ensure flood bulletins and community information are prepared and issued to the community
- Monitor watercourses and undertake reconnaissance of low-lying areas
- Develop media and community information management strategy
- Ensure flood mitigation works are being checked by owners
- Develop and issue incident action plan, if required
- Develop and issue situation report, if required

3.3.8 On Receipt of the First and Subsequent Flood Warnings

Incident Controller/VICSES RDO (until an incident controller is appointed) will undertake actions as defined within the flood intelligence cards (Appendix C). General considerations by the Incident Controller/VICSES RDO will be as follows:

- Develop an appreciation of current flood levels and predicted levels. Are floodwaters, rising, peaking or falling?
- Review flood intelligence to assess likely flood consequences. Consider:
    - What areas may be at risk of inundation
    - What areas may be at risk of isolation
    - What areas may be at risk of indirect affects as a consequence of power, gas, water, telephone, sewerage, health, transport or emergency service infrastructure interruption
    - The characteristics of the populations at risk

- Determine what the at-risk community need to know and do, as the flood develops.
- Warn the at-risk community including ensuring that an appropriate warning and community information strategy is implemented including details of:
  - The current flood situation
  - Flood predictions
  - What the consequences of predicted levels may be
  - Public safety advice
  - Who to contact for further information
  - Who to contact for emergency assistance
- Liaise with relevant asset owners as appropriate (i.e. water and power utilities)
- Implement response strategies as required based upon flood consequence assessment.
- Continue to monitor the flood situation – www.bom.gov.au/vic/flood/
- Continue to conduct reconnaissance of low-lying areas

3.4 Community Information and Warnings

Guidelines for the distribution of community information and warnings are contained in the State Flood Emergency Plan.

Community information and warnings communication methods available include:

- Emergency Alert;
- VicEmergency
- Phone messages (including SMS);
- Radio and Television;
- Two-way radio;
- Mobile and fixed public address systems;
- Sirens;
- Verbal Messages (i.e. Door knocking);
- Agency Websites;
- VICSES Flood Storm Information Line;
- Variable Message Signs (i.e. road signs);
- Community meetings;
- Newspapers;
- Email;
- Telephone trees;
- Community Flood Observers;
- Fax Stream;
- Newsletters;
- Letter drops;

- Social media and/or social networking sites (i.e. Twitter and/or Facebook).

Refer to Appendix E for the specific details of how community information and warnings are to be provided.

The release of flood bulletins and information with regard to response activities at the time of a flood event is the responsibility of VICSES, as the Control Agency.

Council has the responsibility to assist VICSES to warn individuals within the community including activation of flood warning systems, where they exist. Responsibility for public information, including media briefings, rest with VICSES as the Control Agency.

Other agencies such as CFA, DELWP and VicPol may be requested to assist VICSES with the communication of community flood warnings.

In cases where severe flash flooding is predicted, dam failure is likely or flooding necessitating evacuation of communities is predicted, the Incident Controller may consider the use of the Emergency Alert System and Standard Emergency Warning System (SEWS).

DHHS will coordinate information regarding public health and safety precautions.

3.5 Media Communication

The Incident Controller through the Information Unit established at the ICC will manage media communication. If the ICC is not established the RDO will manage all media communication.

3.6 Impact assessment

Impact assessments can be conducted in accordance with Part 3 section 5.2.5 of the EMMV to assess and record the extent and nature of damage caused by flooding. This information may then be used to provide the basis for further needs assessment and recovery planning by DHHS and recovery agencies.

3.7 Preliminary Deployments

When flooding is expected to be severe enough to cut access to towns, suburbs and/or communities the Incident Controller will consult with relevant agencies to ensure that resources are in place if required to provide emergency response. These resources might include emergency service personnel, food items and non-food items such as medical supplies, shelter, assembly areas, relief centres etc.

3.8 Response to Flash Flooding

Emergency management response to flash flooding should be consistent with the guideline for the emergency management of flash flooding contained within the State Flood Emergency Plan.

When conducting pre-event planning for flash floods the following steps should be followed, and in the order as given:

1. Determine if there are barriers to evacuation by considering warning time, safe routes, resources available and etc.;

2. If evacuation is possible, then evacuation should be the adopted strategy and it must be supported by a public information capability and a rescue contingency plan;

3. Where it is likely people will become trapped by floodwaters due to limited evacuation options safety advice needs to be provided to people at risk advising them not to attempt to flee by entering floodwater if they become trapped, and that it may be safer to seek the highest point within the building and to telephone 000 if they require rescue. This advice needs to be provided even when evacuation may be possible, due to the likelihood that not all community members will evacuate.

4. For buildings known to be structurally un-suitable an earlier evacuation trigger will need to be established (return to step 1 of this cycle).

5. If an earlier evacuation is not possible then specific preparations must be made to rescue occupants trapped in structurally unsuitable buildings either pre-emptively or as those people call for help.

During a flash flood it will often be difficult, due the rapid development of flooding, to establish evacuation (relief) centres ahead of actually triggering the evacuation as is normal practice but this is insufficient justification for not adopting evacuation.

3.9 Evacuation

The decision to recommend or warn people to prepare to evacuate or to evacuate immediately rests with the Incident Controller.

Once the decision is made VicPol are responsible for the management of the evacuation process where possible. VICSES and other agencies will assist where practical. VICSES is responsible for the development and communication of evacuation warnings.

VicPol and/or Australian Red Cross may take on the responsibility of registering people affected by a flood emergency including those who have been evacuated.

Refer to Part 3, Part 6 and Part 8 (Appendix 9) of the EMMV for further guidance on evacuations for flood emergencies. Agency roles and responsibilities are detailed in Part 7.

Refer to Appendix D of this Plan for detailed evacuation arrangements applying within the City of Greater Shepparton.

3.10 Flood Rescue

Victoria Police is the control agency for rescue of persons from water. VICSES may conduct flood rescues as directed by a Police rescue coordinator, during a large-scale flood event.

Appropriately trained and equipped VICSES units or other agencies that have appropriate training, equipment and support may carry out rescues.

Rescue operations may be undertaken where voluntary evacuation is not possible, has failed or is considered too dangerous for an at-risk person or community. An assessment of available flood rescue resources (if not already done prior to the event) should be undertaken prior to the commencement of Rescue operations.

Rescue is considered a high-risk strategy to both rescuers and persons requiring rescue and should not be regarded as a preferred emergency management strategy. Rescuers should always undertake a dynamic risk assessment before attempting to undertake a flood rescue.

Resources available for use for rescues to be carried out within the City of Greater Shepparton can be/are detailed in Appendix D.

3.11 Aircraft Management

Aircraft can be used for a variety of purposes during flood operations including evacuation, resupply, reconnaissance, intelligence gathering and emergency travel.

Air support operations will be conducted under the control of the Incident Controller.

The Incident Controller may request aircraft support through the State Air Desk located at the State Control Centre will establish priorities.

Suitable airbase facilities are located at:

- The Shepparton Aerodrome is located on Melbourne Road, Kialla; 5.5 kilometres south from the Shepparton CBD. It is at latitude S 36° 25'7", longitude E 145°a 23'6" and altitude 374 feet.

The following facilities at the Shepparton Aerodrome may be at risk of flooding during a 1 in 100 flood event:	
Facility Name Potential water level over land	Water Level
Terminal Building 7810 Goulburn Valley Highway KIALLA 3631	0.25 to 0.5m
Hangar 15 7810 Goulburn Valley Highway KIALLA 3631	0.25 to 0.5m
Emergency Equipment Shed 7810 Goulburn Valley Highway KIALLA 3631	0.25 to 0.5m

3.12 Resupply

Communities, neighbourhoods or households can become isolated during floods as a consequence of road closures or damage to roads, bridges and causeways. Under such circumstances, the need may arise to resupply isolated communities/properties with essential items.

When predictions/intelligence indicates that communities, neighbourhoods and/or households may become isolated, VICSES will advise businesses and/or households that they should stock up on essential items.

After the impact, VICSES can support isolated communities through assisting with the transport of essential items to isolated communities and assisting with logistics functions.

Resupply operations are to be included as part of the emergency relief arrangements with VICSES working with the relief agencies to service communities that are isolated.

3.13 Essential Community Infrastructure and Property Protection

Essential community infrastructure and property (e.g. residences, businesses, roads, power supply etc.) may be affected in the event of a flood.

The Greater Shepparton City Council maintains a small stock of sandbags at the Doyles Road Complex, 315 Doyles Road, Orrvale and back-up supplies are available through the VICSES Regional Headquarters. The Incident Controller will determine the priorities related to the use of sandbags which will be consistent with the strategic priorities.

If VICSES sandbags are becoming limited in supply, then priority will be given to protection of essential community infrastructure. Other high priorities may include for example the protection of historical buildings.

Property may be protected by:

- Sandbagging to minimise entry of water into buildings
- Encouraging businesses and households to lift or move contents
- Construction of temporary levees will be in consultation with the VICSES, Goulburn Broken CMA, LGA and VICPOL and within appropriate approval frameworks.

The Incident Controller will ensure that owners of essential community infrastructure are kept advised of the flood situation. Essential community infrastructure providers must keep the Incident Controller informed of their status and ongoing ability to provide services.

Refer to Appendix D for further specific details of essential infrastructure requiring protection and location of sandbag collection point(s).

3.14 Disruption to Services

Disruption to services other than essential community infrastructure and property can occur in flood events. Refer to Appendix C & D for specific details of likely disruption to services and proposed arrangements to respond to service disruptions in the City of Greater Shepparton.

3.15 Road Closures

The Greater Shepparton City Council and VicRoads will carry out their formal functions of road closures including observation and placement of warning signs, road blocks etc. to its designated local and regional roads, bridges, walking and bike trails. Greater Shepparton City Council staff may also liaise with and advise VicRoads as to the need or advisability of erecting warning signs and / or of closing roads and bridges under its jurisdiction. VicRoads are responsible for designated main roads and highways and Council is responsible for the designated local and regional road network.

VicRoads and the Greater Shepparton City Council will communicate community information regarding road closures.

3.16 Dam Failure

DELWP is the Control Agency for dam safety incidents (e.g. breach, failure or potential breach / failure of a dam), however VICSES is the Control Agency for any flooding that may result from such an incident.

Major dams and weirs with potential to cause structural and community damage within the Municipality are contained in Appendix A.

3.17 Waste Water related Public Health Issues and Critical Sewerage Assets

Inundation of critical sewerage assets including septic tanks and sewerage pump stations may result in water quality problems within the Municipality. Where this is likely to occur or has occurred the responsible agency for the critical sewerage asset (Goulburn Valley Water) should undertake the following:

- Advise VICSES of the security of critical sewerage assets to assist preparedness and response activities in the event of flood;
- Maintain or improve the security of critical sewerage assets;
- Check and correct where possible the operation of critical sewerage assets in times of flood;
- Advise the ICC in the event of inundation of critical sewerage assets.
- Advise the EMT, DHHS and the Health Commander within the ICC

It is the responsibility of the Greater Shepparton City Council's Environmental Health Team to inspect and report to the MERO and the ICC on any water quality issues relating to flooding.

3.18 After Action Review

VICSES will coordinate the after action review arrangements of flood operations as soon as practical following an event.

All agencies involved in the flood incident should be represented at the after action review.

Part 4. EMERGENCY RELIEF AND RECOVERY ARRANGEMENTS

4.1 General

Arrangements for recovery from a flood incident within the City of Greater Shepparton are detailed in the Greater Shepparton City Council MEMP and/or the Recovery Sub-plan.

4.2 Emergency Relief

Incident Controllers (appointed by the control agency for the incident - refer to State Emergency Relief and Recovery Plan (Part 4 of the EMMV)) are responsible for considering the current and potential impacts and consequences of an emergency, and advising the relevant emergency relief and recovery agencies as soon as possible.

The Emergency Management Team (which is established when an emergency requires a response by more than one agency - refer to the EMMV) includes provisions for a functional commander for recovery - a Recovery Commander. This position is competency-based and can be held by anyone who has the appropriate experience and training.

The Recovery Commander will be appointed at the discretion of the Regional Recovery Coordinator (Department of Health and Human Services).

Regardless of the appointee's normal role, they will represent all emergency relief and recovery agencies at the incident control level. This position will not be required for all emergencies but is most likely to be beneficial for emergencies with Tier 2 or 3 impacts as per the tiered approach to emergency relief and recovery coordination outlined below.

	Tier 0	Tier 1	Tier 2	Tier 3	Tier 3+
Likely Incidence	Frequent	Occasional	Rare	Very Rare	Extremely Rare
Complexity	Low-Medium	Medium	Medium-High	High	Extreme
Consequence	Low-Medium	Medium	Medium-High	High	Extreme
Population Effects	No Significant Disruptions	Minor Localised Disruptions	Moderate Short-Term Disruptions	Major Medium-Term Disruptions	Most or all usual activity Disruption
Activation	Normal Business Procedures	MEMPlans	Regional Plans	State Plans	State Plans (Possible Commonwealth Involvement)
Coordination Level	Local	Local	Regional	State	State
Coordination Point	None	MECC	REOC	H&HS SEMC	H&HS SEMC
Illustrative Examples	House fire or Car Accident	Gas leak in a block of flats	Widespread Hail Storm	Prolonged Flood Situation	Terrorist attack Or Significant Earthquake

The range and type of emergency relief services to be provided in response to a flood event will be dependent upon the size, impact, and scale of the flood. Refer to Part 4 of the EMMV for further information including on details of the range of emergency relief services that may be provided.

Details of the relief arrangements are available in the MEMP.

4.3 Animal Welfare

Refer to the Municipal Emergency Animal Welfare Plan if implemented.

Matters relating to the welfare of livestock, companion animals and wildlife (including feeding and rescue) are to be referred to DEDJTR. This includes requests for emergency supply and / or delivery of fodder to stranded livestock or for livestock rescue.

Matters relating to the welfare of wildlife are to be referred to DELWP.

Refer to Appendix D for animal shelter compound locations.

4.4 Transition from Response to Recovery

VICSES as the Control Agency is responsible for ensuring effective transition from response to recovery. Transition is detailed in the MEMP and is consistent with Part 4 of the EMMV.

APPENDIX A - FLOOD THREATS FOR THE CITY OF GREATER SHEPPARTON MUNICIPALITY

General - Goulburn and Broken Rivers and Seven Creeks

Shepparton and Mooroopna are situated on the Goulburn River downstream from the Seven Creeks[2] – Goulburn River confluence and a little downstream from where the Broken River[3] joins the Goulburn. Two other tributaries enter the Goulburn River between Murchison and Shepparton; Pranjip Creek at Moorilim and Castle Creek at Arcadia.

The Goulburn Broken catchment comprises the Goulburn and Broken River catchments and part of the Murray Valley and covers 2.4 million hectares, or 10.5% of Victoria[4]. It provides 11% of the Murray Darling Basin's stream flow although it occupies just 2% of the basin. It stretches from near the outskirts of Melbourne to the Murray River and includes the municipalities of Moira Shire Council, Benalla Rural City, Mansfield Shire Council, Mitchell Shire Council, Murrindindi Shire Council, Strathbogie Shire Council and the Greater Shepparton City Council. The Goulburn River stretches from the headwaters near Woods Point, and flows to the west through Lake Eildon, Alexandra and Yea. At Seymour it turns to the north and continues through Nagambie / Goulburn Weir, Murchison, and Shepparton to its confluence with the Murray River upstream of Echuca. The total length of the Goulburn River is 570 km. It has a mean annual discharge of 3,040 GL. This volume of water is approximately 14% of the total water discharge from Victoria (Goulburn Broken CMA, 2005).

The Goulburn Broken catchment produces approximately 11% of the Murray Darling Basin's water and is a key food producing area. Production from irrigation supports a large food processing industry, contributing to 25% of Victoria's export earnings, approximately 70% of the land has been cleared and public land makes up 28% of the catchment.

Major Floods

Major floods in the Shepparton-Mooroopna area generally occur after moderate to heavy widespread rainfall across the catchment. This can be the result of prolonged periods of regular rainfall or one or more significant storms. Due to the relatively large catchment area above Shepparton and the number of major tributary streams the timing and distribution of rainfall across the catchment can significantly influence the nature of flooding in and around Shepparton-Mooroopna. Apart from the base flow in the Goulburn River and tributaries prior to a major flood producing storm, the other factors such as Lake Eildon storage conditions and possible diversion operations at Goulburn Weir could affect the magnitude of flooding at the Shepparton gauge. These will be discussed further in the following sections.

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[2] Seven Creeks and Honeysuckle Creek join 1.8 km upstream of the Seven Creeks @ Kialla West gauge.

[3] During large events (i.e. more than about 18,000 ML/d or around 3.0 m at Benalla), the Broken River spills to the north into the Broken Creek catchment with a corresponding reduction in flow increases at Orrvale.

[4] The total catchment area of the Goulburn River at Shepparton is approximately 16,000 km^2. 2,525 km^2 in the Broken River catchment, 1,510 km^2 in the Seven Creeks/Honeysuckle Creek catchment, 800 km^2 in the Pranjip Creek catchment and 280 km^2 in the Castle Creek catchment (Water Technology, 2017).

There are several small ephemeral watercourses, structures, irrigation channels, levees, railways and roadways across the floodplain which all influence flood behaviour. The pipe drainage networks within Shepparton and Mooroopna also influence flood behaviour: some of the urban area is inundated due to backflow within these pipes.

Effect of Lake Eildon

Goulburn Murray Water (G-MW) operates Lake Eildon to ensure the safety of the structure while, as far as is possible within the operating rules of the structure, minimising peak flood outflows. Flood mitigation potential is greatest when there is storage capacity (i.e. air-space with the level below FSL) prior to a flood event.

The peak inflow to Lake Eildon during the October 1993 flood was estimated at 170,000 ML/d (Hydro Technology, 1995) with the peak outflow now estimated at 46,630 ML/d. The dam was operated to achieve a significant reduction in the peak outflow and thereby avoid more serious flooding at Seymour and downstream. This was achieved by surcharging the storage but is unlikely to occur in the future due to current G-MW policy.

The potential for Eildon to deliver indirect flood mitigation benefits to the Goulburn River immediately and further downstream of the dam is significant as demonstrated in October 1993. However, due to changes to G-MW operations policies this degree of attenuation is unlikely to be experienced again if conditions that occurred in 1993 were to be repeated.

Effect of Goulburn Weir & Waranga Basin Diversions

Low flood flows in the Goulburn River at Shepparton can be significantly influenced by the operation of Goulburn Weir and diversions to Waranga Basin via the Stuart Murray Canal (SMC) or Cattanach Canal (CC) where the combined diversion flow capacity is 7,290 ML/d.

For example, at the start of the June 1996 rain event the Goulburn Weir pool was well below full supply level (FSL) with close to maximum diversions via the SMC and CC to Waranga Basin occurring during the subsequent flood event. Whether diversions are occurring or not will depend on the status of Waranga Basin. If Waranga Basin is full or close to full then the diversion flow will be nil or very low. Even if diversions are occurring at the start of the flood they may cease during the flood event once Waranga Basin is full or reaches the interim FSL.

If heavy rain occurs following releases from Lake Eildon for irrigation purposes, there is a rapid and substantial reduction in the need for the water for irrigation. As a result, G-MW may need to rapidly increase discharge downstream of Goulburn Weir. This results in what G-MW call a “rain rejection event”. While the resulting flush is often well below minor flood level, there may be recreational users within the river bank who could be caught unawares and impacted by a rapid rise in river level. This is a problem more likely to occur during the summer months than at other times of the year.

G-MW has an arrangement with VICSES at Benalla to alert VICSES when a release of greater than 3,000 ML/d is expected from Goulburn Weir. While it is possible for these releases to have some impact on the Goulburn River in Shepparton-Mooroopna the full impact is more likely to occur upstream from Murchison. DELWP and Parks Victoria also are stakeholders in this issue.

Effect of Irrigation Channels

There are a number of irrigation channel banks within the Goulburn and Broken floodplains, all of which form hydraulic barriers across the floodplain of various size and effectiveness. In producing the flood mapping for the Shepparton Mooroopna Flood

Mapping and Flood Intelligence project (2017), Water Technology stamped the irrigation network onto the topography as thin break lines in the TUFLOW hydraulic model. Thus flood mapping produced by that study and available through FloodZoom and other means, reflects the influence on conveyance of the existing irrigation channel network.

Irrigation channel banks are designed to convey irrigation water, not act as flood levees. Channel banks may fail (or be deliberately breached) during a flood and inundation may differ during an event.

Historic Floods

The Shepparton-Mooroopna area has a long history of major flooding on the Goulburn River dating back to 1870. The largest flood in the recent past occurred in September 1916. It is difficult to rank the 1916 flood in terms of current conditions due to the Big Eildon Dam not being constructed at that time and because of major changes within the floodplain as well as to bridges and the causeway between Shepparton and Mooroopna.

Since the completion of the Eildon dam in 1955 there have been seven floods exceeding the Major Flood Level of 11.0 metres on the Shepparton gauge. These occurred in 1956, 1958, 1974, 1975, 1981, 1993 and 2010 resulting in a major flood on average every 7-8 years prior to the onset of major drought in late 1996.

Flooding at Shepparton is caused by a combination of Goulburn River, Broken River and Seven Creeks flows. Due to the rainfall patterns of any given event, each waterway is likely to respond differently. The May 1974 flood was a Goulburn River dominated event while the October 1993 and September 2010 floods were Broken River and Seven Creeks dominant events.

Specific flood information for the key flood gauges in the Shepparton-Mooroopna area is contained in the various Appendix C's to this document.

September 1916 Flood

The September 1916 flood on the Goulburn River at Shepparton is the highest flood on record with an estimated peak flow of 233,000 ML/d (SKM 2002) and a peak level at Shepparton of 12.25 m (SKP 1982). The rainfall ranged from 130 mm in the Broken River catchment, to 178 mm in the Goulburn above Seymour, with Seven Creeks catchment receiving around 170 mm. Rainfall accumulations were recorded over a six day period (SKP 1982, *Shepparton-Mooroopna Flood Study* Appendices, p B10).

May 1974 Flood

The flood in May 1974 reached 12.08 metres on the Shepparton gauge with a peak flow of 214,000 ML/d[5] (SKM, 2002). At Shepparton, it was the largest flood since 1955 when Eildon was completed (important as Eildon changed flow frequencies) and also the largest flood since 1916.

Around 600 residential and commercial buildings were inundated above floor due to large breakouts from the Goulburn River, Broken River and Seven Creeks (VICSES, 2013). If a flood of similar magnitude occurred now, it is estimated that around 7,000 residential, commercial and industrial properties are likely to be affected.

[5] The peak flow estimate for the 1974 event has changed a number of times since it was first published with revisions to the rating curve, the most recent estimate on the DELWP WIMS system is 191,000 ML/d (Water Technology, 2017).

This was a “Goulburn River dominated flood” in that flows in the Goulburn were larger than those in the Broken River and Seven Creeks system.

October 1993

The major flood of October 1993 reached 11.72 metres on the Shepparton gauge with a peak flow estimated at 150,000 ML/d. Around 30 residential and commercial buildings were inundated above floor (VICSES, 2013). If a flood of similar type and magnitude was to occur now, it is expected that around 2,700 residential, commercial and industrial properties would be affected.

The Goulburn River had sustained high water levels for the majority of September 1993. The Broken River and Seven Creeks were relatively low until they both received a big inflow that started around 3rd October and lasted until early on the 9th October. The Goulburn River peaked at Shepparton on the 6th October and stayed high until around the 16th when it finally receded. Even though the peak in the Goulburn River upstream of Shepparton wasn’t as high as in September (as most of the flow was contained within the lower floodplain), the combination of flows from the three systems caused a peak water level of 11.72 m at the Shepparton gauge on Wednesday 6th October.

Parts of Shepparton were inundated during the event and significant areas downstream of Shepparton were also inundated, particularly around the water treatment plant.

This event was a “Broken River and Seven Creeks dominated flood” in that flows in these watercourses were larger than in the Goulburn River, particularly in Seven Creeks where significant overbank flood flow occurred in surrounding low lying areas.

September 2010 Flood

The September 2010 flood reached 11.09 metres on the Shepparton gauge with a peak flow of 93,500 ML/d[6]. During this flood, 13 houses and 31 structures were damaged, 620 houses were isolated and more than 60 people attended the relief and recovery centre. While approx. 30 local roads were closed due to flooding, all major roads surrounding Shepparton remained open for the duration of the event.

Heavy rain fell across the north east of Victoria on Saturday 4th and Sunday 5th September 2010, particularly in the alpine areas including the upper Goulburn and Broken catchments. On Monday 6th September, the Seven Creeks at Kialla West peaked just above the major flood level of 6.6 m while the Broken River at Orrvale peaked overnight at 8.19 m, above the major flood level of 7.9 m. On Wednesday 8th September, the Goulburn River at Shepparton peaked just above the major flood level (11 m) at 11.09 m. Both Castle Creek and Pranjip Creek also flooded.

Low lying areas between Archer Road and the East Goulburn Main Channel along the Broken River were inundated as were parts of the lower Goulburn River floodplain. Areas outside the lower Goulburn River floodplain were not affected.

This event was a “Broken River dominated event” with significant contributing flows from the Broken River.

A report on this event and the subsequent floods in December 2010 and January 2011, has been drafted by the Goulburn-Broken Catchment Management Authority (GBCMA, 2012). Key data is documented along with assessment of “flood dominance”.

6 Water Technology (2017) quote a revised peak flow of 78,600 ML/d.

History of Flood Levels & Discharges

At Shepparton, the largest floods this century have occurred in 1916, 1939, 1974 and 1993[7]. These were ranked 1, 3, 2 and 4, respectively by HydroTechnology (1995) - see Table 1-1. However, Big Eildon Dam was not constructed prior to the 1916 and 1939 events, and it is estimated that it would have had some effect in reducing the peaks of those floods. Given that the estimated peak discharges in 1939 and 1993 were very similar, allowance for the effect of Eildon would likely elevate the 1993 flood to the third largest this century.

The effect of Eildon Reservoir in reducing flood peaks has been studied previously (SRWSC, 1981). It was estimated that at Shepparton the impact on flood peaks during large floods is approximately 7%. Nathan (1992) estimated a reduction of 27% in large floods in the Goulburn River at Murchison. The impact is larger in more frequent floods of smaller magnitude, and the impact is also greater further upstream near Eildon. The effect diminishes downstream because of the effect of unregulated tributary inflows and floodplain storage.

There is also fairly clear indirect evidence that a flood larger than any this century occurred in 1870. Although there were no gauges operating on the Goulburn at that time, the Murray River at Echuca peaked much higher in 1870 (and in 1867) than in 1916. It should be noted that the effect on flooding at Echuca from the Murray River downstream of Barmah is restricted by the effect of the Bama Sandhills, so that little more than the "choke" capacity of approximately 35,000 ML/d can pass along the Murray without forcing additional flow north along the Edward River into NSW. Therefore, the magnitude of flood peaks at Echuca above this capacity is very dependent on the magnitude of flows received from the Goulburn and Campaspe Rivers, and to a much lesser extent the Broken Creek.

A comparison of the highest ranked floods last century is presented in the following table for the Goulburn River at Shepparton. A continuous recorder has operated at this location since 1939. A staff gauge was observed daily from 1921 to 1939.

Magnitudes and Ranking of Major Floods at Shepparton

Flood / Year	Gauge Height (m)	Peak Discharge (ML/d)	Rank
September 1916	12:25	233,300	1
May 1974	12:08	214,000 [8]	2
1939		161,000	3
October 1993	11:72	160,500 [9]	4
1956	11:42	121,000	5
1934		118,400	6

[7] The Shepparton gauge was moved from upstream of Dainton's Bridge (built in the late 1960s) to the current downstream location in 1986. There is about 100mm head loss through the bridge.

[8] Water Technology (2017) quote a revised peak flow of 191,000 ML/d.

[9] Water Technology (2017) quote a revised peak flow of 150,000 ML/d.

Flood / Year	Gauge Height (m)	Peak Discharge (ML/d)	Rank
1975	11:24	105,000	7
1924		103,300	8
1958	11:21	103,000	9
1921		97,500	10
September 2010	11.09	81,328 [10]	11
The Goulburn River at Shepparton gauge has changed locations three times. It was located upstream of Dainton's Bridge from 1968 to 1986. It was moved to the current downstream location in 1986. There is about 100mm head loss through the bridge.			

At Shepparton, the October 1993 (11.72 m) and September 2010 (11.09 m) are the two floods that many residents can relate to because they were recent floods on the main rivers. However, the March 2012 localised rainfall event, which caused small rural creeks to flood in the north-east region of the municipality (and a record flood along Broken Creek), has served to advise that any area may be subject to flooding. The heavy rain event of 27th / 28th February 2013 which resulted in severe flooding through East Shepparton reinforced that message.

Magnitudes and Ranking of Major Floods at Murchison

Flood / Year	Gauge Height (m)	Peak Discharge (ML/d)	Rank
1916	12:22	178,180	1
1934	11.55	132,750	2
1956	11.38	123,200	3
1974	11.29	117,860	4
1917	11.28	117,030	5
1939	10.79	91,490	6
1923	10.67	84,870	7
1912	10.64	83,700	8
1993	10.57	80,010	9
1920	10.52	76,620	10

The table below provides a summary of most floods in the Goulburn since 1955 (i.e. since Big Eildon Dam was constructed). Peak flow data (ML/d) and peak level data has been extracted from available sources for the key gauging stations upstream of

[10] Water Technology (2017) quote a revised peak flow of 78,600 ML/d.

Shepparton. Note that a number of flow estimates have changed over time, with revisions to gauge rating curves. The 'WT quote….' comments in the table relate to.

Gauging Station, Site Number, Peak Flow, Peak Level M12/59542						
	Goulburn River Murchison	Goulburn River Arcadia Downs	Seven Creeks Kialla West	Broken River Orrvale	Goulburn River Shepparton	Flood Category / Dominance
Date	405200	405270	405269	404222	405204	
Aug-55	45,170 9.69				68,900 10.72	Moderate
Jul-56	123,200 11.38				121,000 11.42	Major
Aug-58	60,330 10.17				103,000 11.21	Major
Sep-60	512,750 9.97				77,600 10.86	Moderate
Oct-64	47,430 9.80				67,800 10.70	Moderate
Jun-68	41,460 9.53				55,900 10.47	Minor
Sep-73	42,490 9.57				54,400 10.47	Minor
May-74	111,000 WT quote 117,900 11.29	135,000 12.10	50,200 7.85	40,000 8.33	191,166 WT quote 191,000 12.08	Major / Goulburn
Sep-75	72,500 ~10.46				105,000 11.24	Major / Neutral
Aug-78	30,200 ~9.02	28,959 9.79			31,626 9.74	Minor / Goulburn
Oct-79	39,000 9.40	37,375 10.28	10,979 5.53	18,257 7.24	43,900 10.20	Minor / Neutral
Jul-81	49,690 9.87	59,352 10.70	40,230 7.48	30,061 7.99	87,300 11.00	Major / Broken-Seven
Sep-83	50,200 9.88	51,954 10.62	10,128 5.42	7,961 5.74	60,800 10.57	Minor / Goulburn
Oct-92	63,380 10.24	11.05	8,086 5.13	13,369 6.76	81,800 10.93	Moderate / Goulburn
Sep-93	80,010 10.57	11.33	19,097 6.32	15,936 7.01	95,667 11.12	Major / Goulburn
Oct-93	60,903 WT quote 63,500 10.26	11.08	68,000 8.23	43,852 WT quote 42,900 8.44	150,000 11.72	Major / Broken-Seven
Aug-96	47,220 9.80	10.74	15,348 6.02	12,140 6.56	60,183 10.56	Minor / Goulburn
Oct-96	44,010 9.69	10.66	15,384 6.02	27,155 7.86	58,156 10.52	Minor / Goulburn
Sep-10	58,237 WT quote 50,200 10.15	NA	19,653 WT quote 20,500 6.69	8.14 WT quote 27,300	81,328 WT quote 78,600 11.09	Major / Broken
Mar-12	18,619 7.13	NA	11,718 6.03	7.00	38,549 9.97	Major / NE creeks

Note: In the above table "WT quote" refers to Water Technology (2017) revised flows quoted in the Water Technology (2017) report, which have come from the latest DELWP WIMS streamflow data website.

Description of Major Waterways and Drains around Shepparton

Waterway	Description
Goulburn River	Emanates from the Great Dividing Range near Jamieson and is mitigated by Eildon and Goulburn weirs
Broken River	Rises in the Tolmie Highlands of the Great Dividing Range
Seven Creeks	Rises in the Strathbogie Ranges east of Euroa
Honeysuckle Creek	Emanates from the Strathbogie Ranges east of Violet Town
Castle Creek	Emanates from runoff upstream of Euroa
Congupna Creek	Emanates from farmland run-off near Cosgrove and is fed by Broken River, when it floods
Pine Lodge Creek	Emanates from farmland run-off near Pine Lodge and is fed by Broken River, when it floods
Dainton's Creek	Emanates from farmland run-off near Cosgrove and is fed by Broken River, when it floods
O'Keefe Creek	Emanates from farmland run-off near Pine Lodge and is fed by Broken River, when it floods

The Goulburn River around Shepparton-Mooroopna experiences localised flooding initially along Watts Road, the main alternative route and short cut from Mooroopna south to the Goulburn Valley Highway, once the Shepparton gauge exceeds 8.75 m. A series of levees are located on the east side of the Goulburn River from Knight Street in Shepparton to Furphy Avenue in Kialla and prevent flooding up to 10.98 m on the Shepparton gauge, just below the major flood level of 11.0 m.

Mitchell Road at Kialla West is the first area to be affected by flooding from Seven Creeks with the low-level bridge overtopped at about 4.5 m on the Kialla West gauge. Raftery Road becomes impassable after the Kialla West gauge exceeds 5.0 m with Seven Creeks breaking its bank at the floodway west of the bridge. The first residential properties to be flooded are located on Central Kialla Road in Kialla. These properties can be affected by either backwater flooding up Seven Creeks from the Goulburn River once the Shepparton gauge reaches 10.5 m, or by flooding directly from Seven Creeks after the Kialla West gauge has exceeded around 6.5 m.

Minor flooding of rural properties along Broken River upstream of Doyles Road commences once the Orrvale gauge reaches 6.8 m. The flooding of Gordon Drive (located in the Broken River anabranch) follows soon after and the major arterial road of Archer Street is overtopped by floodwater backing up across the floodway on the north side of the Broken River bridge.

The first house in Mooroopna to be flooded above floor level is on the Midland Highway when the Shepparton gauge approaches 11.1 m. Properties in The Boulevard area of North Shepparton can expect flooding above floor level to commence once the Shepparton gauge has reached 11.6 m.

The Midland Highway Causeway between Shepparton and Mooroopna also begins to be affected by floodwater around 12.0 m with higher flows progressively disrupting traffic along this vital road link. However, at the Mooroopna side of the Causeway (Chinaman's Gardens), the road is overtopped at a lower flood level (from about 11.6 m on the Shepparton gauge).

The first properties flooded by location:

Location	Street	Level on the Shepparton gauge at which inundation starts (m)
Kialla West	Archer Road	Between 10.5 & 10.7
Kialla	Central Kialla Road	As level approaches 10.5
Shepparton	Doyles Road	Between 10.5 & 10.7
Shepparton North	Daldy Road	Between 11.1 & 11.3
Bunbartha	Barmah-Shepparton Road & McCleland Road	Between 11.5 & 11.7
Mooroopna	Midland Highway	Between 10.7 & 10.9
Mooroopna North	Koenig Road	Between 11.5 & 11.7
Coomboona	Koenig Road	Between 11.5 & 11.7
Ardmona	Excelsior Avenue	Between 11.7 & 11.9

The first buildings flooded above floor by location:

Location	Street	Level on the Shepparton gauge at which inundation starts (m)
Bunbartha	Barmah-Shepparton Road	Between 11.7 & 11.9
Kialla West	Archer Road	Between 10.5 & 10.7
Kialla	Central Kialla Road	Between 10.5 & 10.7
Shepparton	The Boulevard, Wanganui Road and the Caravan Park on Fitzjohn Road	Between 11.3 & 11.5
Shepparton North	Daldy Road	Between 11.3 & 11.5
Mooroopna	Midland Highway	Between 11.0 & 11.1
Mooroopna North	Echuca Road	Between 11.7 & 11.9
Ardmona	Excelsior Avenue	Between 12.1 & 12.2

Dam Failure

Flooding resulting from failure of the following dams is likely to cause significant structural and community damage within the municipality.

Location	Owner	Dam Height	Dam Capacity (ML)	Comments
Eildon Dam	G-MW	84.25m	3,334,158	ANCOLD & AIIMS compliant Dam Safety Emergency Plan in place.
Lake Waranga Reservoir	G-MW	12.2m (ave)	432,260	ANCOLD & AIIMS compliant Dam Safety Emergency Plan in place.
Goulburn Weir	G-MW	13.7m (ave)	25,000	ANCOLD & AIIMS compliant Dam Safety Emergency Plan in place.
Lake Nillahcootie Reservoir	G-MW	35m (ave)	40,400	ANCOLD & AIIMS compliant Dam Safety Emergency Plan in place.
Caseys Weir	G-MW	3m	<150	
Gowangardie Weir	Committee of Management	3m	140	Stock & Domestic Committee from local farmers manage the flow from the weir. Greater Shepparton City Council assists with maintenance of the channels.

APPENDIX B - TYPICAL FLOOD PEAK TRAVEL TIMES

Definitive information on the time it takes flash flooding (i.e. resulting from heavy rainfall associated with severe weather or thunderstorm activity) to develop (i.e. to arrive at a location) following the start of heavy rain and the time it takes for the maximum water depth / extent to be reached is not available.

In the case of riverine flooding, the time of travel of a flood peak will be influenced by antecedent conditions. A flood on a 'dry' watercourse will generally travel more slowly than a flood on a 'wet' watercourse (e.g. the first flood after a dry period will travel more slowly than the second flood in a series of floods) and big floods tend to travel faster than small floods. Hence, the size of the flood, recent flood history, soil moisture and forecast weather conditions all need to be considered when using the following information to direct flood response activities. This first flood can be significantly altered by floodwater filling the floodplain storage. ***This phenomena is particularly important for the floodplain upstream of Shepparton and thus flood volume and dominance (i.e. whether the Broken – Seven Creeks system or Goulburn River or neither will dominate – the Broken and Seven Creeks appear to dominate most often with a neutral situation observed a little less often) is a key consideration in determining both travel times and flood attenuation.*** In very simplistic terms, due to the wide floodplain and opportunity for significant loss as well as friction, a flood on a wet floodplain will behave very differently from one on a dry floodplain.

Dominance and the timing of flows in the three key contributing catchments (i.e. Goulburn, Broken and Seven) is key to determining peak levels and thus impacts within Shepparton and Mooroopna. The Broken – Seven Creeks system appears to dominate most often with the Goulburn dominating least often.

The Goulburn, Broken and Sevens waterways present a significant flood risk to the Shepparton / Mooroopna urban area and the immediate surrounds because their confluences are located within or adjacent to the urban area. A further significant flood risk arises from locally intense storms over urban and peri-urban areas, such as East Shepparton. The generally flat nature and poor drainage characteristics of the East Shepparton area make it particularly vulnerable to intense and heavy continuous rain.

Location From	Location To	Typical Travel Time	Comments
RIVERINE FLOODING – Goulburn River – **see diagram below**			
Floods are characterised by steady rises, peaks that extend for a number of hours and recessions that are around one-half to one-third the rate of rise (i.e. takes around 2.5 to 3 times longer). The further down the catchment the longer the peak and the slower the recession. Flood volume determines rise and recession characteristics.			
Eildon	Seymour	48 hours	
Seymour	Goulburn Weir	30 to 40 hours	
Seymour	Murchison	40 to 60 hours	
Goulburn Weir	Murchison	9 to 18 hours	Generally around 10 hours or a little less. Can be as short as 3 hours
Murchison	Kialla West (Goulburn River)	15 to 25 hours	In 1974, peak on Goulburn at Kialla West occurred 15 hours after the Broken at Orrvale peaked while in 1993 the difference was 60 hours.

Location From	Location To	Typical Travel Time	Comments
Murchison	Shepparton	18 to 30 hours	20 hours or less if Goulburn dominant. 24 to 36 hours if Broken – Sevens dominant. In 1992 & 2010, travel time for peak from Murchison to Shepparton was ~1.5 days.
Kialla West (Goulburn)	Shepparton	Up to 12 hours	When Broken – Sevens dominant, peak at Shepparton can be at the same time or a little before peak at Goulburn at Kialla West.
Shepparton	McCoys Bridge	46 hours	
Shepparton	Echuca	7 days	
RIVERINE FLOODING – Seven Creeks – see diagram below			
The recession at Kialla West is around one-third to one-quarter the rate of rise (i.e. takes around 3 to 4 times longer).			
Euroa	Kialla West (Mitchell Road Bridge over Seven Creeks)	26 to 50 hours	26 to 30 hours for floods ~6m and over at Kialla West. 35 to 48 hours if between 4.5m and 6m but 30 to 36 hours if 2nd flood in past 3 weeks or rain across lower catchment similar to upper catchment.
Kialla West (Seven Cks)	Shepparton	18 to ~60 hours	18 to 21 hours if Broken and Seven Creeks dominant. Time increases towards 30+ hours under neutral conditions but can be as high 60 hours.
Peak at Kialla West (the gauge is located immediately downstream from the Mitchell Road Bridge) occurs around 6 – 24 hours earlier than at the Broken River at Orrvale. Median time is around 15 hours but the usual range is 12-18 hours. In general terms, peak occurs at about the same time as at (or within a few hours of) the Broken River at Gowangardie. Travel time from Kialla West to Shepparton increases as Goulburn dominance builds.			
RIVERINE FLOODING – Broken River – see diagram below			
After a slow peak, the recession at Orrvale is around one-third the rate of rise (i.e. takes around 2.5 to 3 times longer).			
Benalla	Casey's Weir	6 to 12 hours	Tends to cluster around 7 to 9 hours.
Benalla	Gowangardie Weir	18 to 37 hours	Think in terms of 26 to 30 hours but faster if good rain downstream from Benalla or 2nd flood.
Benalla	Orrvale	31 to 54 hours	Tends to cluster around 36 to 42 hours.

Location From	Location To	Typical Travel Time	Comments
Casey's Weir	Gowangardie Weir	12 to 30 hours	Tends to cluster around 20 – 26 hours.
Gowangardie Weir	Orrvale	10 to 18 hours	Usually in the 13-15 hour range (as per 2003) but ~24 hours in 1993 & 2010.
Orrvale	Shepparton	4 to 40+ hours	Generally 8 to 14 hours with Broken River dominant. 20 to 28 hours as Goulburn flows increase (Murchison around 7.5m to 8.5m – neutral). 30+ hours with Goulburn dominant and Murchison above flood level.
In general terms, for a Broken – Seven Creeks dominant flood, the peak occurs at Gowangardie a few hours after the peak occurs at Kialla West on Seven Creeks. The difference between peak timings is longer (of order 12+ hours) for a neutral flood. Travel time from Orrvale to Shepparton increases as Goulburn dominance builds.			
RIVERINE FLOODING – Congupna Creek			
Gowangardie Weir	Congupna	52 hours	Flooding in these creeks results from local runoff and from breakouts from the Broken River during major floods. Breakouts from near Casey's Weir occur when flow in the Broken River reaches approximately 18,000ML/d or around 3.0m at Benalla. At Casey's Weir the trigger flow is around 17,250ML/d (~200m^3/s) or at a water surface elevation of 158.73mAHD (around 1.81m at the gauge). Further details are provided in the Moira Shire MFEP.
RIVERINE FLOODING – Pine Lodge Creek			
Gowangardie Weir	Tallygaroopna	3.5 days	
RIVERINE FLOODING – Guilfus Creek			
Gowangardie Weir	Katandra West (rural areas to the west)	52 hours	

APPENDIX C1 – MURCHISON FLOOD EMERGENCY PLAN

Overview of Flooding Consequences

Murchison is a small rural town located on the Goulburn River 40 km from Shepparton and is within the Great Shepparton City Council. It is surrounded by countryside which contains orchards, vineyards and dairy farms. HM Prison Dhurringile is just down the road.

Murchison town centre has been developed on a land locked depression which could flood during a Goulburn River flood or a major rain event (flash flooding).

Around Murchison, the major flood risk is from the Goulburn River which can result in flooding which lasts from one (24hrs) to three days (72 hrs). When floods affect areas around Murchison, road access in and out of the area can be compromised, resulting in isolation for some areas.

River levels can rise within several hours of heavy rain, and during floods, floodwater can travel from Goulburn Weir to Murchison in 12 – 15 hours and from Seymour to Murchison in 40 to 60 hours (sometimes a little longer). Be aware that floods can affect properties before the peak arrives and no two floods are the same.

Areas likely to be affected:

- During "**Minor**" flooding the low lying rural properties upstream and downstream of Murchison are likely to be flooded. This may necessitate the removal of stock and equipment to higher ground and the closing of some local roads. Camping and fishing spots north of the Bridge will also need to be evacuated.
- During **"Moderate"** flooding, such as occurred in 2010 (10.15 m) people were moved to Murchison Relief centre in Watson Street and caravans were moved to higher ground.
- When **"Major"** flooding occurs (10.7 m and above), the area around High Road and River Haven Caravan Park will be impassable.
- At 11.92 m (the 1% AEP flood level) low lying areas are flooded including Willoughby Street, Phillip Lane, Hutchison Street, Gillam Streets and the cemetery

Caravan Parks likely to be affected

- **River Haven Caravan** Park, 88 High Road (or Low Road), Phone 03-5826 2403
  - Sites – 36 powered, 6 unpowered and cabins.
  - Low areas affected in Moderate flood event (10.2 m), and evacuation required in Major flood events (10.7 m).
- **River Road Caravan Park,** 101 River Road, Phone 03-5826 2546
  - Sites – 8 powered, 10 unpowered and 8 on-site cabins.
  - Not impacted by Goulburn River flooding up to 1916 flood event – levee protects.
- **Murchison Caravan Park,** 4925 Goulburn Valley Hwy, Phone 03-5826 2229
  - Sites – 20 powered, 48 unpowered and cabins.
  - Not impacted by Goulburn River flooding up to 1916 flood event.
- Campers regularly camp along the banks of the Goulburn Rivers at Murchison; they will need to be notified when high or flood waters are approaching.

How many properties.

During a Major Goulburn River flood:

- East of Willoughby Street and East on the Old Weir Road up to 6 properties may be affected by flooding.

- South along the old railway line up to 2 km may see flooding affects.
- River Haven Caravan Park on High Road will be affected during a major flood.

How much warning time

- The Goulburn River in flood will generally take somewhere between 40 and 60 hours to travel from Seymour to Murchison and half a day (12 to 15 hours) to travel from Goulburn Weir to Murchison. Murchison to Arcadia Downs (now referred to as Kialla West) will take approximately 1 day (15 to 25 hours).

Isolation risks

- Flooding in and around Murchison can last 1 to 3 days (24 to 72 hours). This depends on the amount of rain that has fallen around the area.

Major road closures

- Willoughby Street would be closed south of the town and Old Weir Road should be monitored for closure.
- The Causeway does not overtop until the river reaches 11.9 m.
- River Road appears to remain dry, even in very large floods, with modelling showing it dry up to and including at 12.22 m.

Locations where evacuation difficulties may occur (e.g. low flood islands)

- Evacuation of the River Haven Caravan Park could be difficult if the Goulburn River rises quicker than expected.
- Campers on the banks of the Goulburn River could be caught if there is a lot of rain which will prevent them from leaving their camp site.

Flood Mitigation

There are a number of rain and river gauges in the general vicinity and upstream of Murchison that can provide flood information for the town. For example:

- One at Murchison Bridge.
- Goulburn Weir.
- Seymour.
- Trawool.
- Ghin Ghin.
- Lake Eildon dam (downstream of the wall).
- Hughes Creek at Tarcombe Road and a rain gauge at Temagong which can provide early indications of rainfall intensity east of Seymour.
- Data from additional sites are available from the BoM website. FloodZoom also provides access to this and other data relevant to flooding at Murchison.

The following levees exist in Murchison:

- There is a 200 m long earthen levee, approximately 600 mm in height, along the bank of the Goulburn River north from High Street (Bendigo / Murchison Road) to the back of the playground. This levee protects from backwater flooding along the depression that runs past Stevenson Street back towards Watson Street. This levee has a minimum crest elevation of 121.04 m AHD, which provides a freeboard of 610 mm during a 1% AEP flood event (i.e. water level is 120.43 m AHD at this location) and a freeboard of 310 mm during a repeat of the 1916 flood.
- The River Road Caravan Park on River Road is protected by a levee that is not overtopped in a repeat of the 1916 flood (i.e. 12.22 m).

Details of any levee closure points such as railway crossing etc, which may need to be sandbagged.

- During an extreme flood event (i.e. from above 12.1 m or so and similar to what occurred in 1916) and as a consequence of a breakout from the Goulburn River upstream of Murchison establishing a flow path through the western side of the town, there is a possibility of flooding of the depression that runs through the town. Given the long lead times, sandbagging could prevent this flooding at the location shown on the figure below. The location is suggested as it is at a natural constriction and is where flows are the shallowest. However, as this location appears to be on private land, an arrangement with the landholder would need to be agreed. The matter is discussed further in Water Technology (2014).

Flood Mapping

A set of flood inundation maps for Murchison has been produced for emergency management and response purposes (Water Technology, 2014). Maps were produced for 12 incremental gauge heights from 9.0 to 12.2 m, including the 1% AEP gauge height (11.92 m)

Flood mapping is available of the Goulburn River from where the Stuart Murray Canal crosses under Old Weir Road downstream to Follett Rd. Flood mapping is available through FloodZoom. The study report (Water Technology, 2014) is also available through FloodZoom.

Flood Frequency

AEP	ARI (1 in X years)	Adopted Peak Flow (ML/d)	Gauge Height (m)
20%	5	49,100	9.9
10%	10	69,000	10.4
5%	20	90,900	10.8
2%	50	123,900	11.4
1%	100	152,600	11.9
0.5%	200	166,500	12.1
0.2%	500	196,900	12.4

Past Flood Experience – History

The highest flood recorded at Murchison was in 1916 when up to a meter of water flowed down the main street. Other floods above the major flood level (10.7 m on the Murchison Gauge) have occurred in the region in 1917, 1934, 1939 and 1974.

- Eildon Weir, built in 1956, and water diversions at Goulburn Weir now control most water flows including irrigation into the lower Goulburn River. Although Eildon Weir and Goulburn Weir were not specifically designed for flood mitigation, these weirs have reduced how often minor and moderate floods affect Murchison and the damage this causes. However, in a major flood these two weirs may not be able to reduce the impact of severe flooding on Murchison.
- Extreme heavy local rainfall between Eildon Weir and Murchison can also result in floods, such as in 1974, the highest floods since Eildon Weir and Lake Eildon were created.

Community or agency flood awareness material

SES in conjunction with the Greater Shepparton City Council has produced a “Local Flood Guide” for Murchison (see Appendix F). The Guide has been distributed to all residents in areas likely to be impacted by flood.

Community and agency knowledge

- To be identified:

Known or possible community infrastructure impacts including:

- Impacts on essential community infrastructure – still to be considered
- There are no known / identified groundwater wells likely to be inundated;
- Water treatment plants and water storage areas along with pumps and other service equipment etc likely to be inundated.

GV Water	Murchison WTP	Water Treatment Plant	52 Stevenson St, Murchison
GV Water	Murchison WWTP	Waste water treatment plant	Murchison
GV Water	Murchison SPS 1	Sewer pump station	Watson Ave, Murchison
GV Water	Murchison SPS 2	Sewer pump station	McKenzie St, Murchison
GV Water	Murchison SPS 3	Sewer pump station	Station St, Murchison
GV Water	Murchison SPS 4	Sewer pump station	Meteorite St, Murchison
GV Water	Murchison SPS 5	Sewer pump station	Murray Lane, Murchison
GV Water	Murchison water tower	Water Tower	71 Stevenson St, Murchison
GV Water	Murchison WTP	Water Treatment Plant / Water Tower	Stevenson St (opposite water tower), Murchison

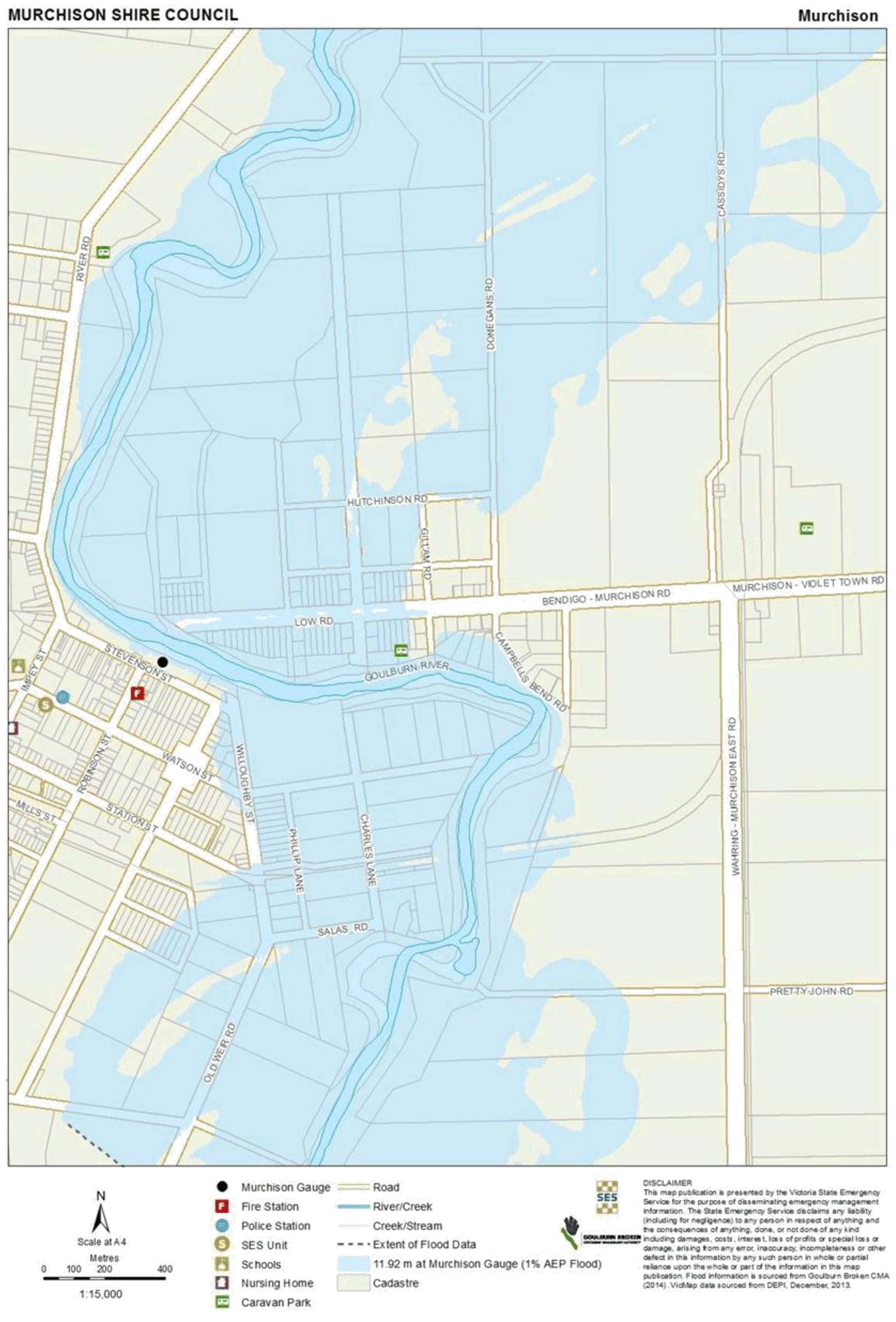
Command, Control and Coordination

VICSES will assume overall control of the response to flood incidents. Other agencies will be requested to support operations as detailed in this Plan. Control and coordination of a flood incident shall be carried out at the lowest effective level and in accordance with the State Emergency Response Plan (EMMV Part 3). During significant events, VICSES will conduct incident management using multi-agency resources.

Divisional Command will be located at the Hume Region Divisional Command Centre Shepparton and Tatura to manage the Murchison community.


Murchison Gauge
Fire Station
Police Station
SES Unit
Schools
Nursing Home
Camp Ground
River/Creek
Cadastre
1m WSE Contours
20cm WSE Contours
Flood Depth (m)
0 - 0.25
0.25 - 0.5
0.5 - 1
1 - 2
2 - 5
> 5m
STEVENSON ST
ROBINSON ST
WATSON ST
HIGH RD
MURCHISON - GOULBURN WEIR RD
Recommended Sandbag Location
Data sources : Vicmap Data, DEPI, October 2013
Imagery : DEPI, December 14, 2009
0
100
5/02/2014

Goulburn River 1% AEP Design Flood Extent (Map Shows revised 1% AEP))



Gauge Location: Goulburn River at Murchison Gauge

Note to convert gauge level to m AHD, add 108.679 (i.e. gauge zero is 108.679 m AHD)

River Height (m) and / or River Flow (ML/d)	Annual Exceedance Probability	Consequence / Impact	Action Actions may include (but not limited to) Evacuation, closure of road, sandbagging, issue warning and who is responsible
5.62	**Dec 2017 flood**	• Was a Seven Creeks – Broken River dominant flood	•
7.12	**March 2012 flood**	• Was a Seven Creeks – Broken River dominant flood	•
Minor flood level 9.0 m 34,900	50% AEP (<2 year ARI)	• Low lying rural properties upstream and downstream of Murchison are likely to be flooded. • Floodwater approaching the downstream side of High Road and Hutchison Road.	• Move stock and equipment to higher ground. • Close local roads adjacent to river. • Evacuate camping and fishing spots north of the bridge. • Note flood impacts for later update of this table.
9.40	**Oct 1979 flood**		•
9.57	**Sept 1973 flood**		•
9.43	**Nov 2011 flood**	• No significant impacts in Murchison.	•
9.791	**Dec 2010 flood**	• No significant impacts in Murchison.	•
9.80	**Aug 1996 flood**		•
9.87	**July 1981 flood**		•
9.88	**Sept 1983 flood**		•
9.93	**Jan 2011 flood**	• No significant impacts in Murchison.	•
10.15	**Sept 2010 flood**	• People were moved to Murchison Relief Centre in Watson Street and caravans were moved to higher ground.	•
Moderate flood level 10.2 62,600	12% AEP (8 year ARI)	• Overland flooding south of High Road covering western side of River Haven Caravan Park. • Extensive inundation of floodplain and shallow water over Willoughby Street south of Station Street. • High Road and Hutchison Road wet.	• Move caravans in River Haven Caravan Park to higher ground. • Willoughby Street – consider for closure. • High Road – consider for closure.
10.24	**Oct 1992 flood**	•	•
10.26	**Oct 1993 flood**	•	•
10.57	**Sept 1993 flood**	•	•

River Height (m) and / or River Flow (ML/d)	Annual Exceedance Probability	Consequence / Impact	Action Actions may include (but not limited to) Evacuation, closure of road, sandbagging, issue warning and who is responsible
Major flood level 10.7 86,400	6% AEP (18 year ARI)	• Shallow inundation of Hutchinson Road, Old Weir Road and more extensive inundation of Willoughby Street south of Station Street. • Water up against River Road downstream of town • Cemetery beginning to flood.	• Evacuate residents on Hutchinson Road • Evacuate River Haven Caravan Park • Close Willoughby Street south of Station Street • Old Weir Road – Consider for Closure
10.79	**1939 flood**	•	•
10.8 92,200	5% AEP (20 year ARI)	• Inundation of properties on east side of Willoughby Street, including cemetery, south of Station Street. • Water encroaching onto the foreshore opposite the CBD in Stevenson Street.	• Consider opening evacuation centre • Warn residents along Willoughby Street
11.0 103,500	3.3% AEP (30 year ARI)	• Inundation of several properties on east end of Willoughby Street near Watson Street. (i.e. properties east of McKenzie Street) • Phillip Lane wet.	• Consider closing Willoughby Street.
11.2 114,000	2.5 % AEP (40 year ARI)	• Inundation of Willoughby Street between Watson Street and Stevenson Street and adjacent properties. Water up to 1m deep. • Inundation of Watson Street east of Willoughby Street.	• Close Willoughby Street between Station Street and Stevenson Street • Close Watson Street near Willoughby Street
11.25	**1934 flood**		•
11.28	**1917 flood**		•
11.29	**May 1974 flood**		•
11.38	**July 1956 flood**		•
11.4 123,600	2% AEP (50 year ARI)	• Further inundation of properties east of Willoughby Street between Watson Street and Station Street. • Flow across Donegans Road north of Hutchinson Road – has broken out of the immediate floodplain downstream of town.	• Close Donegans Road
11.55	**Dec 1934 flood**		
11.6 134,700	1.4% AEP (70 year ARI)	• Flow across Watson Street west of Willoughby Street.	
11.8 147,700	1.1% AEP (90 year ARI)	• Inundation of additional property west of Willoughby Street between Watson Street and Stevenson Street. • Extensive flow across Donegans Road.	• Warn residents along McKenzie Street and Watson Street.

River Height (m) and / or River Flow (ML/d)	Annual Exceedance Probability	Consequence / Impact	Action Actions may include (but not limited to) Evacuation, closure of road, sandbagging, issue warning and who is responsible
11.92 152,600	1% AEP (100 year ARI)	• Flow will begin to overtop Murchison-Bendigo Road causeway.	• Monitor Murchison-Bendigo Road Causeway – consider closing
12.0 160,200	0.7% AEP (150 year ARI)	• Breakout flow across Gillam Road towards Hutchinson Road across several properties. • Intersection of Stevenson and McKenzie streets now wet. • Breakout immediately to the south of town will soon activate and the overland flow path begin flowing. Substantial property flooding and over-floor likely.	• Close Murchison-Bendigo Road Causeway. • Close Gillam Road. • Sandbag low area south of Station Street between Willoughby Street and Robinson Street –across the flow path of the breakout in order to prevent flooding through town. • Consider relocating VICSES and VicPol operations. • Warn residents in the overland flow path of possible / likely flooding.
12.22 175,300	**Sept 1916 flood** 0.3% AEP (300 year ARI)	• Breakout from river south of Station Street and the rail trail with flow path through town. Crosses Robinson Street south of Station Street, then across Station Street, Watson Street and Stevenson Street between Impey Street and Robinson Street. • Substantial number of properties, including in the CBD, wet. • Above floor flooding likely in properties along High, Station, Willoughby, Hutchison and Gillam streets, Phillip Lane and River Road. Intersection of Stevenson Street and High Road wet. • Extensive flooding of River Haven Caravan Park. • Significant number of rural properties isolated. • VICSES depot surrounded by water. • Police station surrounded by water.	• If not already done, sandbag low area south of Station Street between Willoughby Street and Robinson Street in order to prevent breakout and flooding through town.

APPENDIX C2– SHEPPARTON / MOOROOPNA and KIALLA FLOOD EMERGENCY PLAN

Overview of the Catchment and Flooding Consequences

Shepparton-Mooroopna lies at the confluence of three main river systems, the Goulburn River, the Broken River and Seven Creeks. Large floods can originate from any one of the three systems or from a combination of the three systems.

The total catchment area to Shepparton is 16,125 km^2.

The Goulburn River catchment at its confluence with Seven Creeks has an approximate catchment area of 12,000 km^2. The river rises in the Great Dividing Range above Jamieson. The upper catchment flows into Lake Eildon which has a storage capacity of 3,390,000 ML and provides irrigation supplies to a large part of northern and central Victoria. During floods, the storage may reduce flow peaks from the upper catchment. From Lake Eildon to Seymour, several tributaries including the Rubicon, Acheron and Murrindindi Rivers join the Goulburn as it flows to the west. From Seymour, the Goulburn River turns to flow in a northern direction to the Goulburn Weir near Nagambie. Downstream of Goulburn Weir, the river continues to flow in a northerly direction to Shepparton. Just upstream of Shepparton, the Goulburn River is joined by Seven Creeks and the Broken River. Downstream of Shepparton at Bunbartha, the Goulburn flows in a north westerly direction to join the River Murray upstream of Echuca.

The Broken River rises in the Tolmie highlands and flows to the west before flowing to the north into Lake Nillahcootie. Lake Nillahcootie has a storage capacity of 39,800 ML and is not large enough to have a significant effect on major floods (HydroTechnology 1995a). Nevertheless Cardno (2008) found that without Lake Nillahcootie, flood levels at Benalla would be up to 0.23m higher (a situation that could occur if Nillahcootie was at FSL at the start of a major flood event). Holland Creek joins the Broken River just upstream of Benalla. The river continues flowing north until downstream of Benalla where the river turns and flows west to join the Goulburn River. The catchment area of the Broken River at the Goulburn River confluence is 2,510 km^2. During large floods, the flow in the Broken River break out to the north in the vicinity of Casey's Weir and joins the Broken Creek system (see footnote [11] below, additional details are provided in the Moira Shire MFEP). Further breakouts to the north and south occur during large floods along the Broken River between Casey's Weir and Shepparton. About 10 km upstream of the Broken River's confluence with the Goulburn River, the East Goulburn Main Channel passes under the Broken River via a siphon. The channel causes a constriction in the floodplain and during major floods this constriction results in a ponding of water upstream of the channel. Flood flow may break out upstream of the channel and flow to the south to join Honeysuckle Creek, a tributary of Seven Creeks or to the north to the Broken Creek via a number of tributaries including Pine Lodge, Congupna and Dainton's creeks[3]. The breakouts and the floodplain storage result in a reduction of the peak flow for the Broken River from Benalla to its confluence with the Goulburn River.

Seven Creeks flows to the north-west from the Strathbogie Ranges through Euroa and to its confluence with the Goulburn River. The catchment area of Seven Creeks at the confluence

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[11] During major floods, flows spill into the Broken Creek catchment from the Broken River near Casey's Weir and downstream from Gowangardie Weir through minor watercourses such as Guilfus, Congupna, Dainton's, Pine Lodge and O'Keefe creeks and moves north across a broad area west of Gowangardie Weir. Extensive inundation of the surrounding land results. These creeks discharge into Nine Mile Creek downstream from Wunghnu and then into the Broken Creek between Numurkah and Walsh's Bridge

Breakouts from near Casey's Weir occur when flow in the Broken River reaches approximately 18,000 ML/d or around 3.0 m at Benalla. At Casey's Weir the trigger flow is around 17,250 ML/d (~200 m^3/s) or at a water surface elevation of 158.73 m AHD (or around 1.81 m at the gauge).

is about 1,550 km^2. Honeysuckle Creek is a tributary of Seven Creeks and joins just upstream of Kialla West. During major flood events in the Broken River, the flow may break out of the Broken River and flow to the south joining Honeysuckle Creek. Some exchange of flow from Seven Creeks to the Broken River may occur during major floods. This exchange occurs downstream of Kialla West, spilling across Riverview Drive toward Kalinga Park (Lincoln Drive).

Two other tributaries enter the Goulburn downstream from Murchison: Pranjip Creek at Moorilim and Castle Creek at Arcadia.

The Goulburn and Broken Rivers in particular have a number of tributary and effluent flow paths. These facilitate flow transfers during large floods which further complicates flood behaviours.

The City of Greater Shepparton is built on a floodplain and can expect flooding across the majority of the municipality from time to time. Historical records indicate that the areas directly adjacent to the major waterways are obviously most at risk from major floods; however, because of the flat terrain, most areas will experience localised 'flash flooding' from intense storms. See for example Appendix C3 for East Shepparton.

Generally Shepparton and surrounds will have between 3 and 5 days' notice of the approach of major flooding within the river system. Flash flooding (e.g. East Shepparton) occurs within a few hours.

The main highways to Shepparton will begin to be inundated from around the start of major flooding (i.e. greater than 11.0 m). Details are provided in the Shepparton flood intelligence card.

- The Midland Highway will be impassable near the eastern boundary of the municipality when the Broken River breaks its banks at Gowangardie.
- The Midland Highway will be wetted in Mooroopna from around 11.66 m and may need to be closed.
- The Midland Highway in Shepparton begins to get wet between Mitchell and Florence Streets from around 12.05 m and may need to be closed.
- The Barmah – Shepparton Road will be wetted to the north of its intersection with the Goulburn Valley Highway from around 11.7 m and may need to be closed.
- The Goulburn Valley Highway will be inundated opposite Victoria Park Lake (north of the railway line) from around 11.4 m as well as north and south of the town.
- The Goulburn Valley Highway will be wetted at the Brauman Street – Pine Road intersection in North Shepparton from around 11.8 m.
- Some other roads will be closed at creek and river crossings – see the table below giving the depth of water over the pavement and where "pink" indicates within 100 mm of over-topping.

In December 2017, Castle Creek was against the underside of the lower Goulburn Valley Highway Bridge with the Castle Creek at Arcadia gauge showing 2.39 m.

Evacuation issues

The majority of properties have satisfactory egress in the event of rising floodwaters. However, there are three (3) locations that may present evacuation issues, if the residents are not notified early. These are:

- Kialla Settlement, Riverview Drive
- Arcadia Downs Estate
- Kidstown Tourist facility

Depth of flooding at key creek and river crossings

	Depth of flooding over bridge deck or causeway for various levels at Shepparton gauge										
Bridge or Causeway name	**9.5m**	**10.1m**	**10.7m**	**10.9m**	**11.1m**	**11.3m**	**11.7m**	**12.1m**	**12.2m**	**12.3m**	**12.5m**
Watt Rd - Goulburn River	-	-	-	-	-	-	-	-		0.08	0.16
Shep - Euroa Rd - Broken River	-	-	-	-	-	-	-	-	-	-	-
Mitchell Rd - Seven Cks	0.36	1.30	2.62	2.89	3.18	3.46	3.84	4.09	4.09	4.17	4.44
GV Highway - Seven Cks	-	-	-	-	-	-	-	0.09	0.09	0.16	0.44
GV Highway River Rd	-	-	-	-	-	-	-	0.17	0.17	0.31	0.70
Doyles Rd - Broken River	-	-	-	-	-	-	-	-	-	-	-
Archer Rd - Broken River	-	-	-	-	-	-	-		0.08	0.21	0.50
GV Highway - Broken River	-	-	-	-	-	-	-	-		0.09	0.31
Railway - Goulburn River	-	-	-	-	-	-	-	-	-	-	-
Railway - Broken River	-	-	-	-	-	-	-	-	-	-	-
Chinamans Gardens Culvert	-	-	-	-	-	-	-	-	-	-	-
Causeway Br1	-	-	-	-	-	-	-	-	-	-	-
Causeway Br 2	-	-	-	-	-	-	-	-	-	-	-
Causeway Br 3	-	-	-	-	-	-	-	-	-		0.09
Causeway Br 4	-	-	-	-	-	-	-	-	-	-	-
Dainton's Br	-	-	-	-	-	-	-	-	-	-	-
Midland Hwy Culvert Mooroopna	-	-	-	-	-	-	-	0.36	0.73	0.99	1.14
Trevaskis Rd - Honeysuckle Ck	-	0.55	1.21	1.29	1.37	1.42	1.49	1.54	1.54	1.56	1.65
Central Kialla Rd - Honeysuckle Ck	-	-	-	-	-	-	-	-	-	-	-

Note – refer to the map on the following page for bridge and causeway locations.

Caravan parks are also susceptible to flooding. The main sites in Shepparton and Mooroopna are:

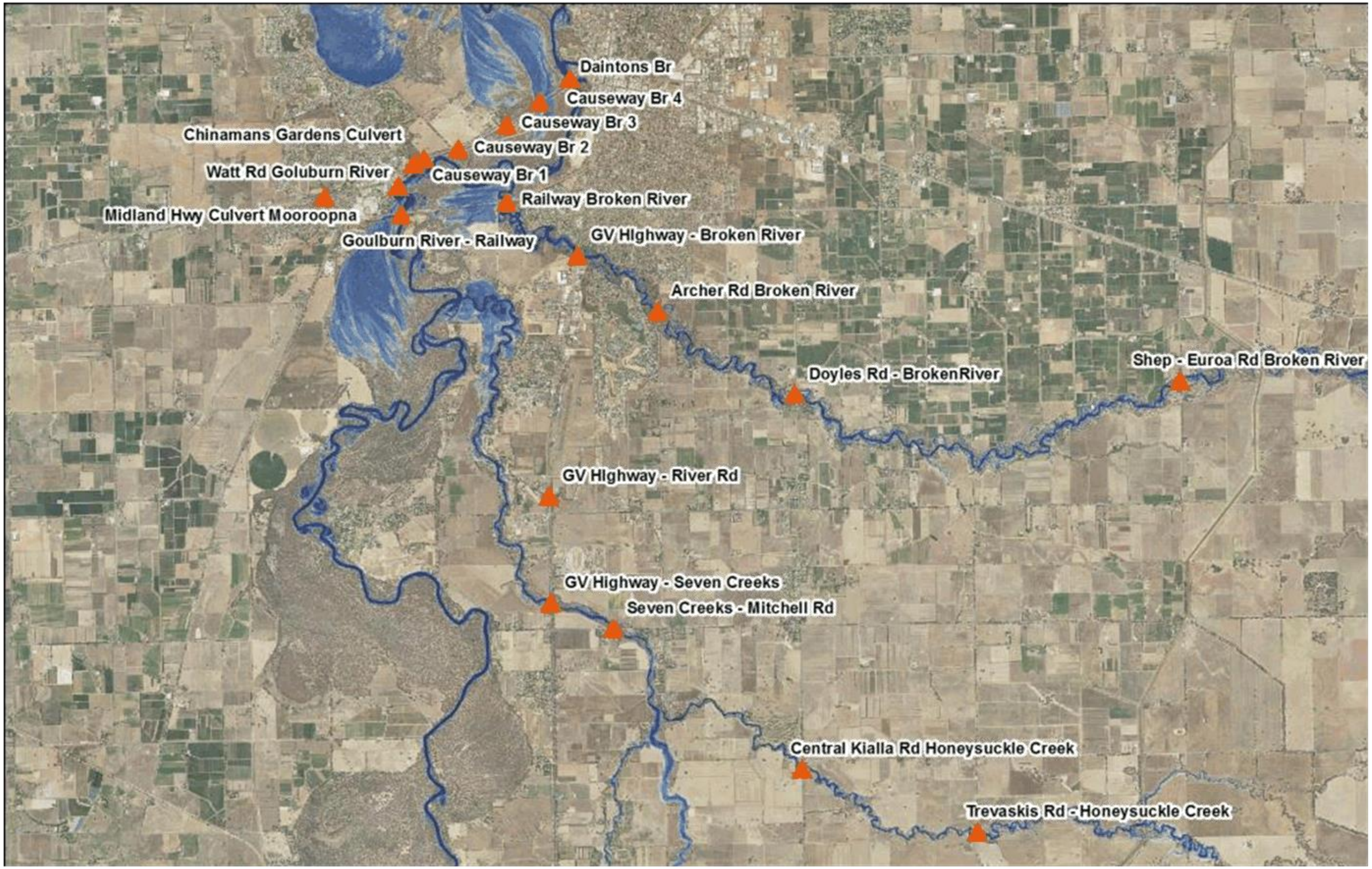
- **Victoria Lake Holiday Park**
  536 Wyndham Street or Fitzjohn Road, Shepparton Tel 03 5821 5431
  The grounds begin to flood at around 11.18m at Shepparton while the first floors begin to flood from about 11.4m.
- **Shepparton Riverside Cabin Park**
  8049 Goulburn Valley Highway, Shepparton South Tel 03 5823 1561
  The grounds begin to flood at around 12.0m at Shepparton.
- **Big4 Shepparton Park Lane Holiday Park**
  7835 Goulburn Valley Highway, Kialla Tel 03 5823 1576
  The grounds begin to flood at around 12.4m at Shepparton
- **Aspen Lodge Caravan Park**
  1 Lawson Street, Mooroopna Tel 03 5825 2245
  The grounds begin to flood at around 11.4m at Shepparton while the first floors begin to flood from about 11.6m.

Property Flooding

There are in excess of 9,000 properties within the current 1% AEP flood extent.

Property Data Summary

The property data on which the following count is based was collected as part of the 2002 study and targeted all land parcels and buildings then determined to lie within the 100 year ARI flood extent. It is assumed that all buildings constructed since 2002 have their floors at the 100-year ARI flood level plus a minimum of 300 mm freeboard, therefore no further floor levels have been collected as part of this study. So there are likely to be other properties not included in this list where buildings will be above flood level but inundation on or surrounding the property is observed. In addition to the above note, the property use may have changed.



Daintons Br
Causeway Br 4
Causeway Br 3
Chinamans Gardens Culvert
Causeway Br 2
Watt Rd Goluburn River
Causeway Br 1
Railway Broken River
Midland Hwy Culvert Mooroopna
Goulburn River - Railway
GV HIghway - Broken River
Archer Rd Broken River
Shep - Euroa Rd Broken River
Doyles Rd - BrokenRiver
GV HIghway - River Rd
GV Highway - Seven Creeks
Seven Creeks - Mitchell Rd
Central Kialla Rd Honeysuckle Creek
Trevaskis Rd - Honeysuckle Creek

For example, the building at 195-205 Numurkah Road is now occupied by the CFA and hosts the Shepparton ICC, and both the Mooroopna Police Station and Mooroopna Hospital are no longer located in McLennan Street).

The number of properties and buildings assessed as being subject to inundation has also changed due to updated flood extent and depth modelling. This is mostly due to the higher resolution of the recent study, incorporating the impacts of channel embankments in the modelling, reducing areas of inundation in some locations.

Number and type of properties within the 1% AEP flood extent

Building Type as at 2002	Total within 2002 study area	2017 study
Urban Residential	8,958	8505
Rural Residential (including farm buildings)	415	385
Commercial	453	379
Recreational	20	14
Industrial	27	23
Public	82	49
Total	**9,955**	**9355**

A summary of the number of properties and floors inundated at various levels at Shepparton is provided in the following table (Water Technology, 2017).

Number of properties and floors flooded at various levels

		Properties				Floors			
	Shepparton gauge level (m)	Flooded and almost flooded	Flooded	Almost flooded	Number of properties not "flood affected"	Flooded and almost flooded	Flooded	Almost flooded	Number of floors not "flood affected"
	10.5	2	2	0	9353				
Moderate	10.7	15	11	4	9340	5	4	1	9350
10% AEP	10.9	31	23	8	9324	9	5	4	9346
Major	11	64	36	28	9291	14	9	5	9341
	11.1	163	99	64	9192	20	18	2	9335
5% AEP	11.3	308	193	115	9047	37	28	9	9318
~1993	11.5	498	322	176	8857	64	45	19	9291
	11.7	1311	862	449	8044	155	109	46	9200
2% AEP	11.9	4223	3578	645	5132	819	556	263	8536
~1974	12.1	5152	4537	615	4203	1129	765	364	8226
1% AEP	12.2	7329	6814	515	2026	2564	1778	786	6791
0.5% AEP	12.3	8376	8066	310	979	4489	3314	1175	4866
0.2% AEP	12.5	8903	8682	221	452	6351	5415	936	3004

Properties likely to be first affected by flooding

The following list has been compiled from a combination of local knowledge and the property listings produced by the 2017 study. Levels at which key public buildings and services are impacted along with a more detailed listing of flood consequences is included in the Flood Intelligence Card included in this Appendix.

A listing of properties affected by flooding (including over-floor) is not included in this document but is available as a separate Excel spreadsheet from which will be added to FloodZoom along with this MFEP document.

685 DOYLES ROAD, KIALLA
The property begins to be affected from 6.3 m at Orrvale. The house is a fair bit higher (approx. 1 m) with levels known by the owner. Does not need to be sandbagged until Orrvale likely to approach 7.3 m.

68 DOYLES ROAD, KIALLA
When the Broken River reaches 7.8 m at Orrvale there will be water lapping at the house

SHEPPARTON VILLAGES
Ensure that the chief project officer and management of Tarcoola Village and Waranga Drive Village are advised of predicted flood levels so that they can activate their flood response plan for both sites.

470 MADILL ROAD, UNDERA
Levee banks in the area of his farm will over-top when we have a flood in excess of approximately 11.2 m on the Shepparton gauge.

95 JAMIESON ROAD, ORRVALE
The Broken River will flood up around the house at around 7.8 m at Orrvale; they need a Road Closed sign at Channel Road to stop people driving down there.

25 FURPHY AVENUE, KIALLA
Will always ring to find out what is going on because she lives in the deepest part of Furphy Avenue. Property starts to flood around 11.2 m at Shepparton with over-floor flooding likely to start from approx. 11.4 m

3 & 5 McLENNAN STREET, MOOROOPNA
Right beside the river in the service road. Both properties start to flood around 11.0 m at Shepparton. No 3 will be flooded over-floor to a depth of around 10mm at 11.1 m at Shepparton while the lower level of No 5 will begin to flood as the river exceeds 11.1 m.

489 ARCHER ROAD, KIALLA
Owns the house and land at the floodway south of Kialla Lakes Drive, on the east side of Archer Road. Knows it is his responsibility to keep the floodway, watercourse clear and has assisted us with his tractor to rescue stranded motorists when Archer Road flooded.

60 HOOPER ROAD, KIALLA
The property will start to be flooded if the Broken River reaches 7.7 m at Orrvale as the anabranch will flow out from the Broken across to the Archer Road culverts.

56, 60 & 100 HOOPER ROAD, KIALLA
All properties begin to flood from about 10.8 m at Shepparton with over-floor flooding at No 60 likely of Shepparton exceeds 11.5 m.

360 & 370 CENTRAL KIALLA ROAD, KIALLA
These are the first properties flooded in Kialla from around 10.4 m at Shepparton.

966, 970 & 980 ARCHER ROAD, KIALLA WEST
These are the first properties flooded in Kialla West from around 10.6 m at Shepparton. Nos 966 & 980 are also likely to begin experiencing over-floor flooding around this level.

650 DOYLES ROAD, SHEPPARTON
The first property flooded in Shepparton from around 10.6 m.

118 MCPHEES ROAD & 89 MALCOLM CRESCENT, SHEPPARTON
These two properties are likely to be the first to suffer over-floor flooding in Shepparton, beginning from around 11.8 m.

7275 MIDLAND HIGHWAY, MOOROOPNA
The first property flooded in Mooroopna from around 10.8 m at Shepparton.

3 MCLENNAN STREET, MOOROOPNA
This is the first property likely to suffer over-floor flooding in Mooroopna, beginning from around 11.0 m at Shepparton.

Essential Services

Essential services such as **electricity supply** (Powercor) will be impacted by floodwaters. Ground level electrical substations are at extreme risk and will need to be protected with sandbags; otherwise they will have to be shut down; causing localised outages.

The water treatment plant is well protected but if the levees are breached, **water supply** will be affected; the town has only a single week's supply of treated water available, if the plant were to become inoperable due to floodwater damage. The **sewerage system** will become overloaded if floodwater is allowed to flow back into the system through private gully traps and such; all inlets must be closed. **Goulburn Valley Water** who is the responsible agency for water supply and sewerage management in the City of Greater Shepparton municipal area, has its own detailed response plan which includes details of tasks to be conducted when river levels rise. Their works commence when the level reaches 8.5 m at the Shepparton gauge. Their water treatment plant and sewerage pumps will be adversely affected at a river height of 11.9 m.

Flood Mitigation

- Shepparton, Murchison, Kialla and Undera regions have levees at strategic locations; however, these only provide protection up to just over the Shepparton major flood level of 11.0 m and have been overtopped twice in the past 40 years.
- Penstocks are in place on most inlet pipes to the rivers, preventing backflow of floodwaters. The closing and opening of these penstocks is correlated closely to the levels recorded at the 3 major automated flood level gauges on the Broken, Sevens and Goulburn waterways.
- There are large volume pumps at some locations to lift and discharge waters when penstocks are closed.
- All new subdivisions are being developed with sufficient retardation basin capacity, to slow up the inflow of water into the town stormwater drainage systems.
- Greater Shepparton City Council manages and maintains floodwater infrastructure.

Flood Impacts and Required Actions

Totems for the Goulburn and Broken Rivers and Seven Creeks waterways display the impacts and actions required when the waterways reach certain levels. They were developed in 1994 using historical data and reviewed after each flood event for the past 18 years to refine and improve Council's preparedness.

Flood reaction 'totems' have recently been prepared for local communities at Tallygaroopna, Congupna and Katandra; these will need to be checked for practical function during future events.

Note – In Flash Flood areas without gauges, it will only be possible to provide a general description of likely flood impacts.

Flood Mapping

A comprehensive set of riverine flood inundation maps for Shepparton-Mooroopna has been produced for emergency management and response purposes (Water Technology, 2017) for Goulburn dominant, Broken – Seven Creeks dominant and neutral flood scenarios. Maps were produced for the design event combinations shown in the table below from the minor flood level (9.5 m at Shepparton) up to the 0.2% AEP (500-year ARI) event (12.5 m at Shepparton). Each map set comprises:

- Flood extent;
- Flood depth in metres;
- Flood level in m AHD;
- Velocity;
- Hazard;
- Flood affected properties and those flooded over-floor (these are the properties listed in the separate Excel spreadsheet referred to on the previous page).

Mapping is available through FloodZoom. The study reports (Water Technology, 2017) are also available through FloodZoom.

A matrix has been developed for each of the modelled and mapped flood (or dominance) scenarios. The matrix comprises flood levels at each of the Broken River at Orrvale, Seven Creeks at Kialla West and Goulburn River at Kialla West gauges, that in combination produce the listed key levels at the Goulburn River at Shepparton gauge for each of the mapped scenarios. The matrix is provided at the end of this Appendix.

Shepparton gauge heights for flood inundation map sets

Event	Goulburn River @ Shepparton Gauge Height (m AHD)	Goulburn River @ Shepparton Gauge Level (m)
Minor Flood	109.627	9.5
20-10%	110.227	10.1
Moderate Flood	110.827	10.7
10%	111.027	10.9
Major Flood 2010	111.127	11.0
10-5%	111.227	11.1
5%	111.427	11.3
5-2%	111.627	11.5
1993	111.827	11.7
2%	112.027	11.9
1974	112.227	12.1
1%	112.327	12.2
0.5%	112.427	12.3
0.2%	112.627	12.5
PMF		

Flood Class Levels

Flood levels	Goulburn River gauge at Shepparton	Goulburn River gauge at Arcadia Downs	Broken River gauge at Orrvale	Seven Creeks gauge at Kialla West
Minor Flood Level	9.5 m	9.0 m	6.8 m	4.5 m
Moderate Flood Level	10.7 m	10.2 m	7.2 m	5.0 m
Major Flood Level	11.0 m	10.5 m	7.9 m	6.6 m

Using the flood inundation map sets

The first step in using the flood mapping data sets is to determine which dominance scenario applies (i.e. Broken–Seven Creeks, neutral or Goulburn). This will dictate which map set is appropriate to determine flood extents and consequences in the vicinity of each of Orrvale, Seven Creeks at Kialla West, Goulburn River at Kialla West and Shepparton. The appropriate map and summary of likely consequences (read from the flood intelligence card for each gauge) at a location will be the one that matches the expected level at that location.

As the event progresses and peak level forecasts are refined, the appropriateness of map sets being used and thus likely consequences should be reviewed and adjustments made as necessary.

While a conservative approach would be to use the maximum extent map sets, on-ground flood impacts will in general be less than expected in some locations. See for example, the 1% AEP flood extent maps below for each of the dominance scenarios.

Getting a heads-up of likely flood severity and impacts

Tools and instructions for their use are provided at the end of this Appendix to enable a user to quickly determine an indication of likely flood severity and consequences through the lower reaches of the Broken - Seven Creeks - Goulburn system.

The earliest an initial heads-up of the expected peak level at Shepparton can be determined is after a forecast peak level is available for Benalla and Euroa and a peak outflow forecast (or estimate) is available for Goulburn Weir (i.e. a peak level for the Goulburn Weir tail gauge). The use of actual flood peaks will generally result in more accurate estimates.

The tools provide an estimate of the likely flood peak. They are not infallible and are unlikely to be as precise as BoM flood forecasts.

Use of FloodZoom and other tools is encouraged in order to better inform the early heads-up estimate and assist response activity planning and implementation.

Past flood experience

The City of Greater Shepparton has a history of flooding including major floods (i.e. above 11 m) in 1870, 1916, 1939, 1974, 1981, 1993 and more recently in 2010, recent moderate floods in 1981 and 1983 and minor floods in 1996 and 2016.

- 1974 was a Goulburn River dominant flood.
- 1993 was a Broken River dominant flood.
- 2010 was a flood which saw gauges on the Goulburn, Broken and Seven Creeks peak at major level. During this flood, 13 houses and 31 buildings were flooded in Shepparton, 620 houses were isolated and approx. 40 houses inundated in Kialla and more than 60 people attended the relief and recovery centre.

Flooding from the rivers and creeks in this area usually lasts about four to seven days depending on the rainfall. Roads and properties can also flood due to water backing up in the stormwater drain system.

Flash flooding caused by heavy rainfall can also occur in low-lying areas, especially in the industrial and business areas of Mooroopna and Shepparton East and around the Doyle's Road-Midland Highway roundabout. These flash floods only last a few hours but can be dangerous and cause extensive damage.

Community Education

An important deliverable from the Shepparton-Mooroopna Flood Mapping and Intelligence Study (Water Technology, 2017) was a web-based flood and property information portal for community use. The portal enables flood maps for the various dominance scenarios (e.g. neutral, Goulburn River dominant, Broken-Sevens dominant) to be displayed as well as flood related information for a user-specified property.

The maps display the projected inundation for a variety of river heights: from 9.5, 10.1, 10.7, 10.9, 11.0, 11.1, 11.3, 11.5, 11.7, 11.9, 12.1, 12.2 and 12.3 m; as measured on the Goulburn River at Shepparton (Dainton's Bridge) gauge.

The flood information for a user-specified property is presented as a report that includes all available flood information for that property.

The maps and reports provide a means for community members to inform themselves of the likelihood of their property being inundated and the likely depths of inundation for a range of levels at the Shepparton gauge.

A typical map is included in Appendix G.

The web-based flood and property information portal can be accessed http://www.floodreport.com.au/

The full range of flood inundation maps for the Shepparton area are kept electronically on Greater Shepparton City Council's Crisisworks and the VICSES G drive: G:\Data\AAA North East Operations\Flood Management\Flood Intelligence and Planning\Shepparton-Mooroopna Flood maps will also be available via FloodZoom.

Local Flood Guides are available for all residents within the City of Greater Shepparton to assist them in preparing for future flood events. Refer to Appendix F for a sample. These Local Flood Guides need to be kept current, and should consider the latest flood information and the web-based flood and property information portal.

Command, Control and Coordination

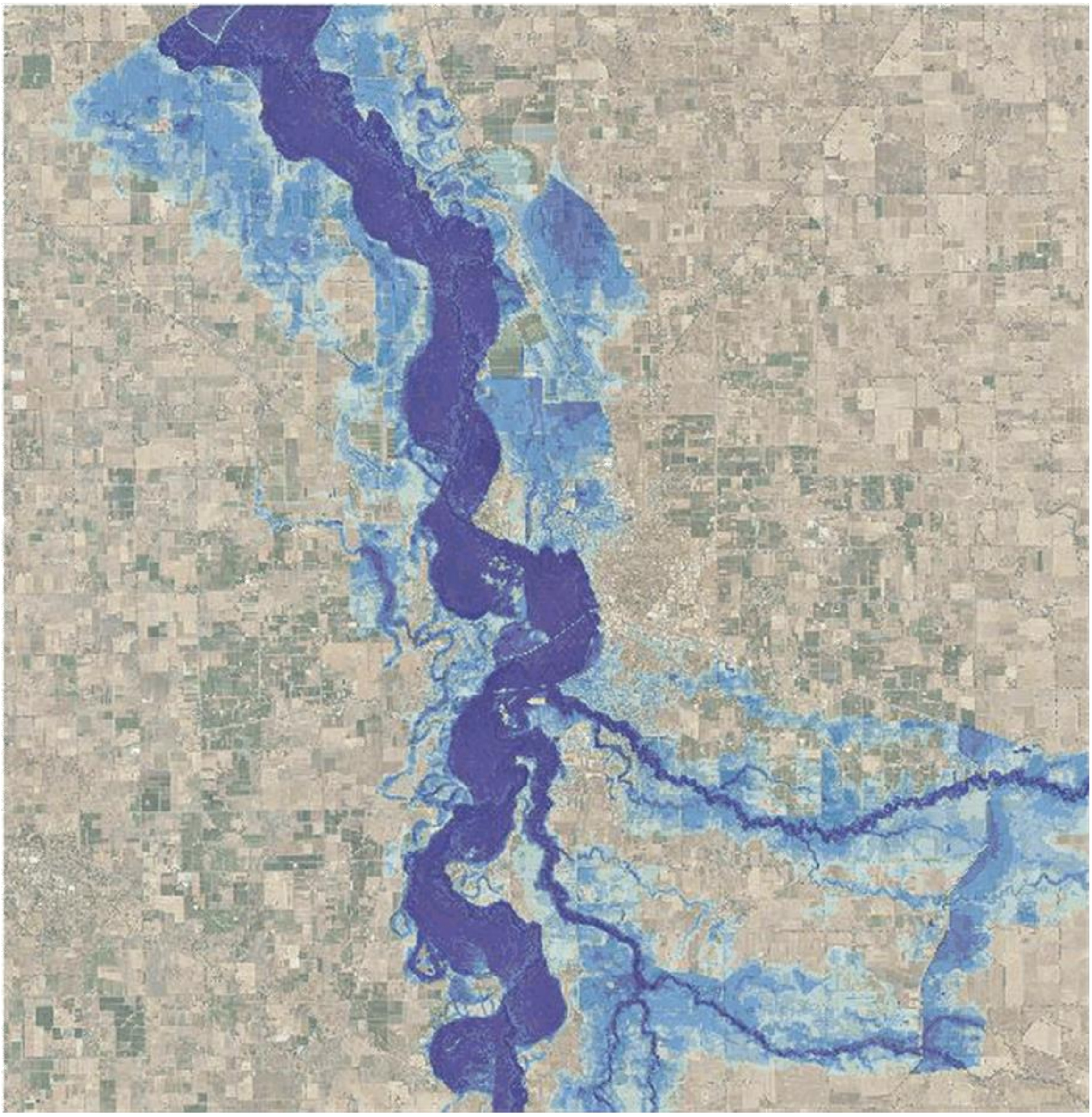
The responsible agency for the Command, Control and Coordination of floods is the Victorian State Emergency Service (VICSES).

VICSES will assume overall control of the response to flood incidents. Other agencies will be requested to support operations as detailed in this Plan. Control and coordination of a flood incident shall be carried out at the lowest effective level and in accordance with the State Emergency Response Plan (EMMV Part 3). During significant events, VICSES will conduct incident management using multi-agency resources.

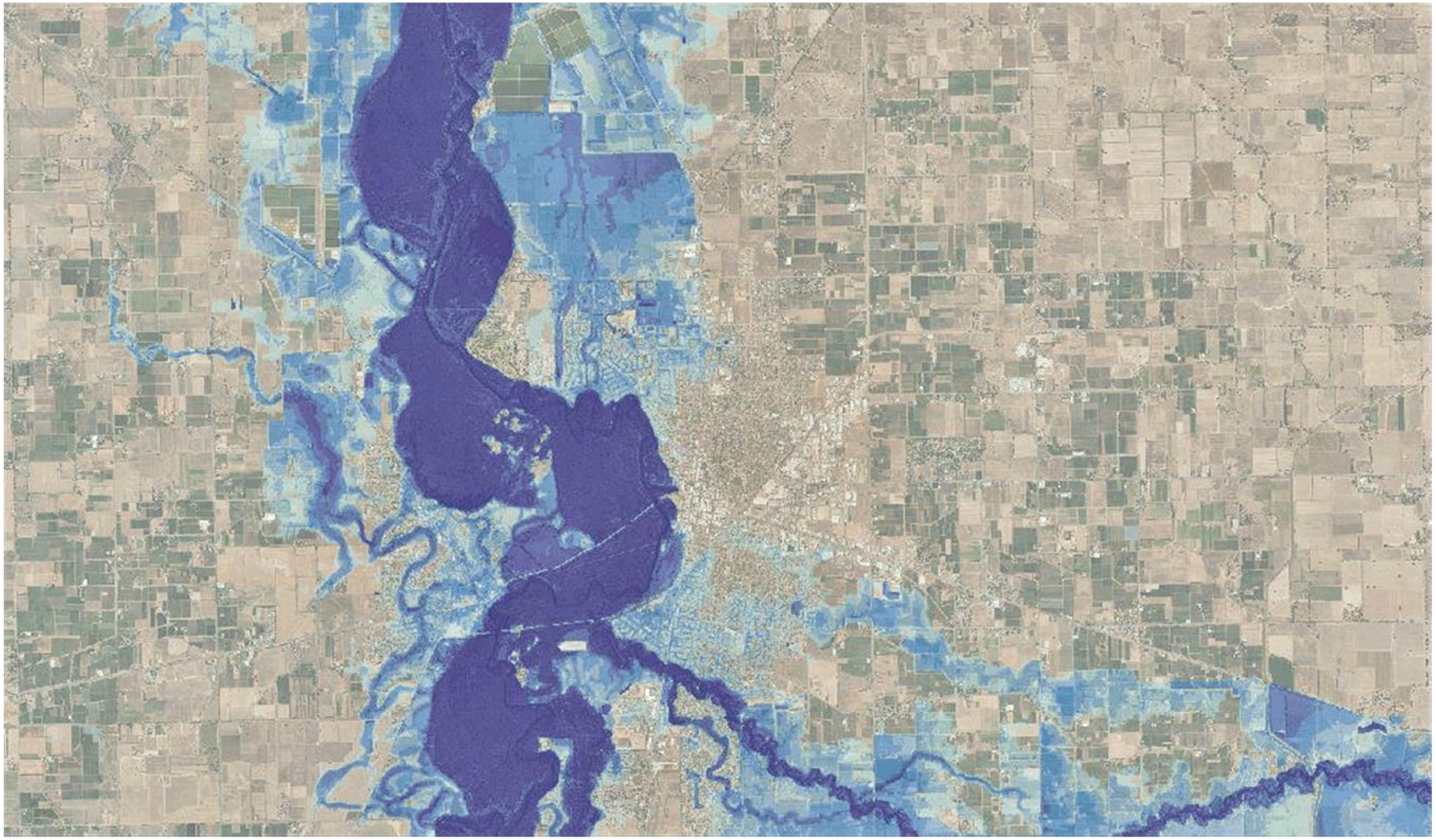
Divisional Command will be located at the Hume Region Divisional Command Centre Shepparton and Tatura to manage the Shepparton community.

The Incident Control Centre (ICC) for management of floods is located at the CFA Headquarters, 195 Numurkah Road, North Shepparton or at the VICSES North East Regional Headquarters, 64 Sydney Road, Benalla.

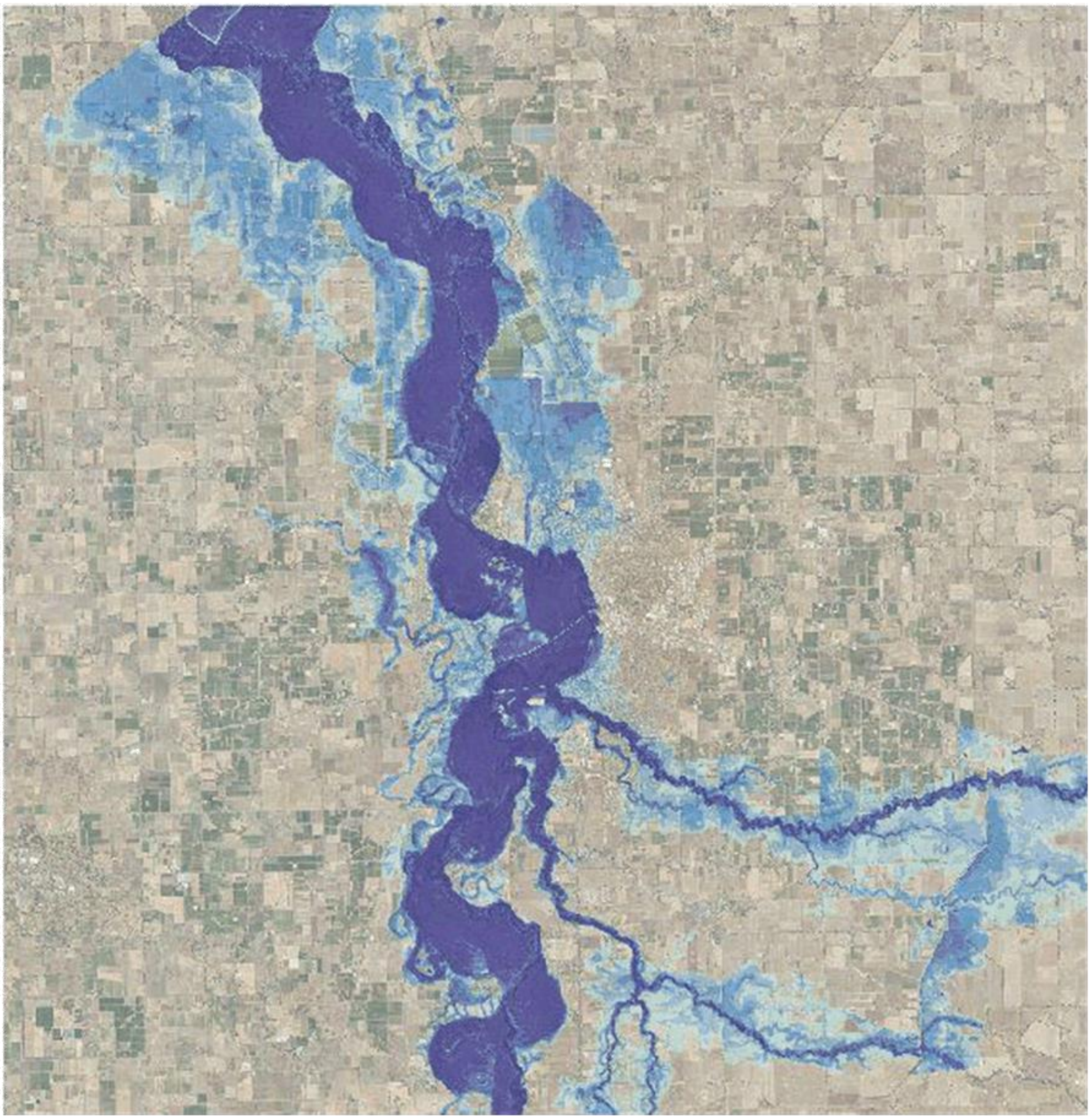
1% AEP flood extent for Broken River and Seven Creek dominant – view 1



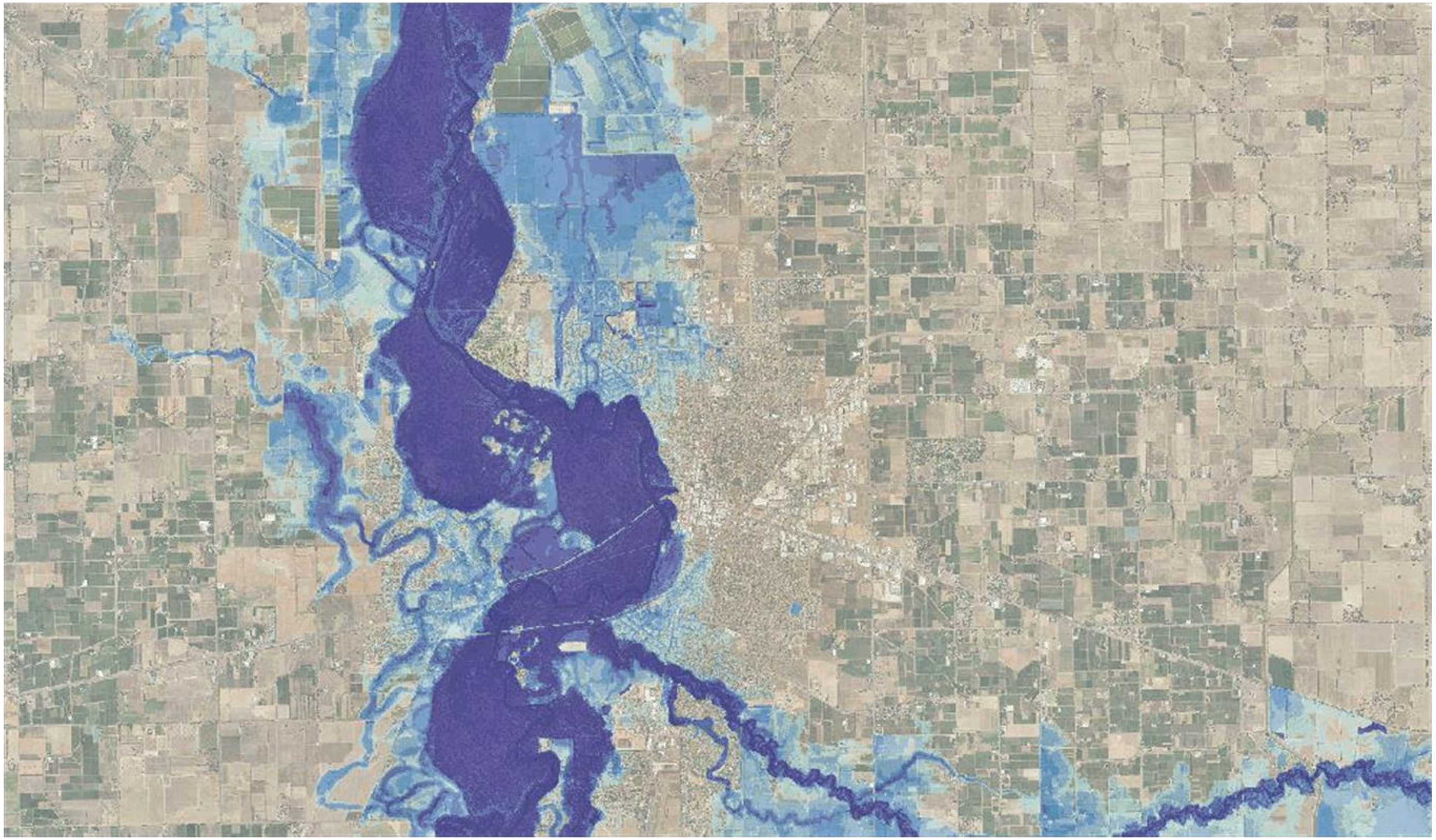
1% AEP flood extent for Broken River and Seven Creek dominant – view 2 – zoomed in



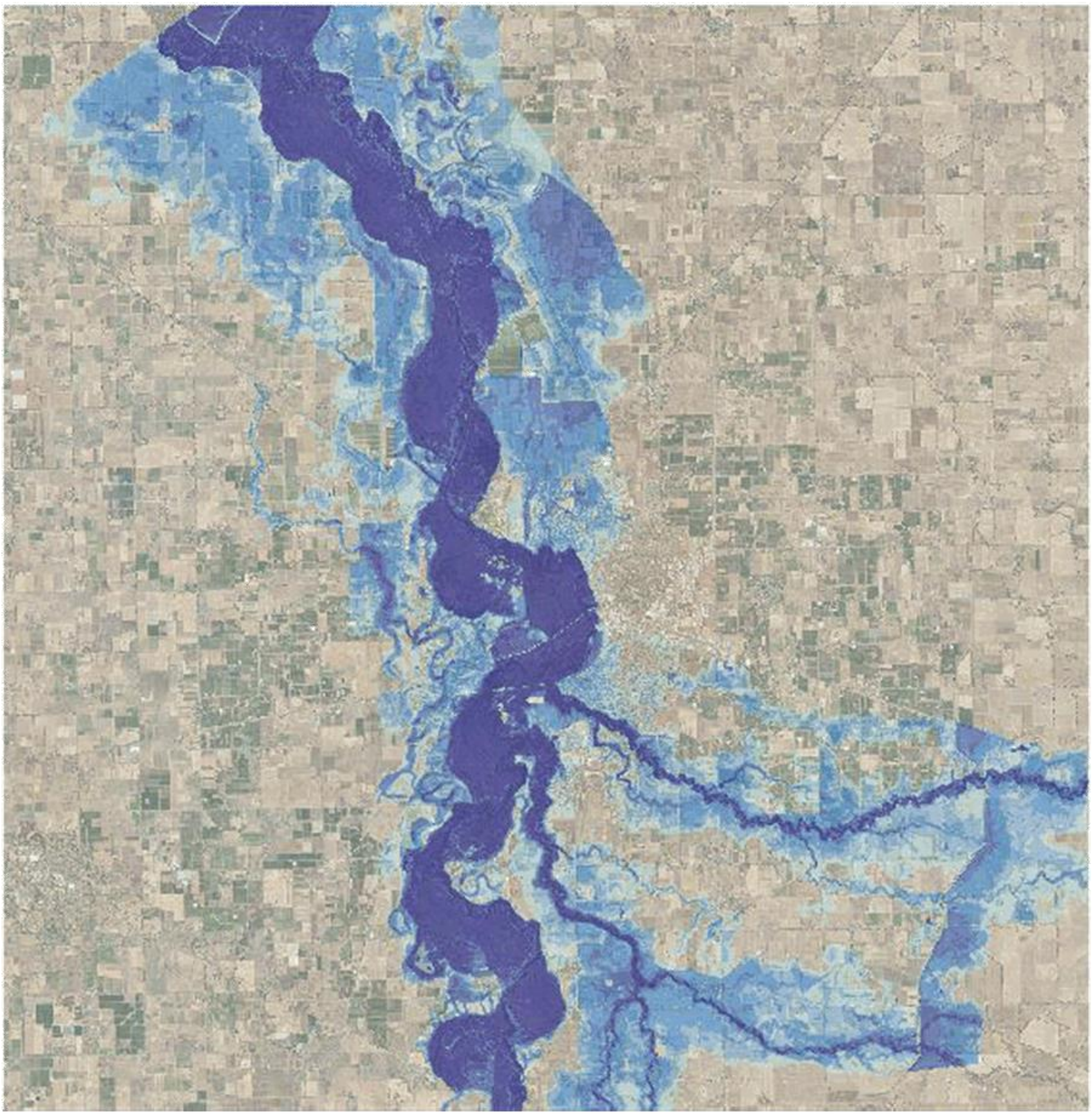
1% AEP flood extent for Goulburn River dominant – view 1



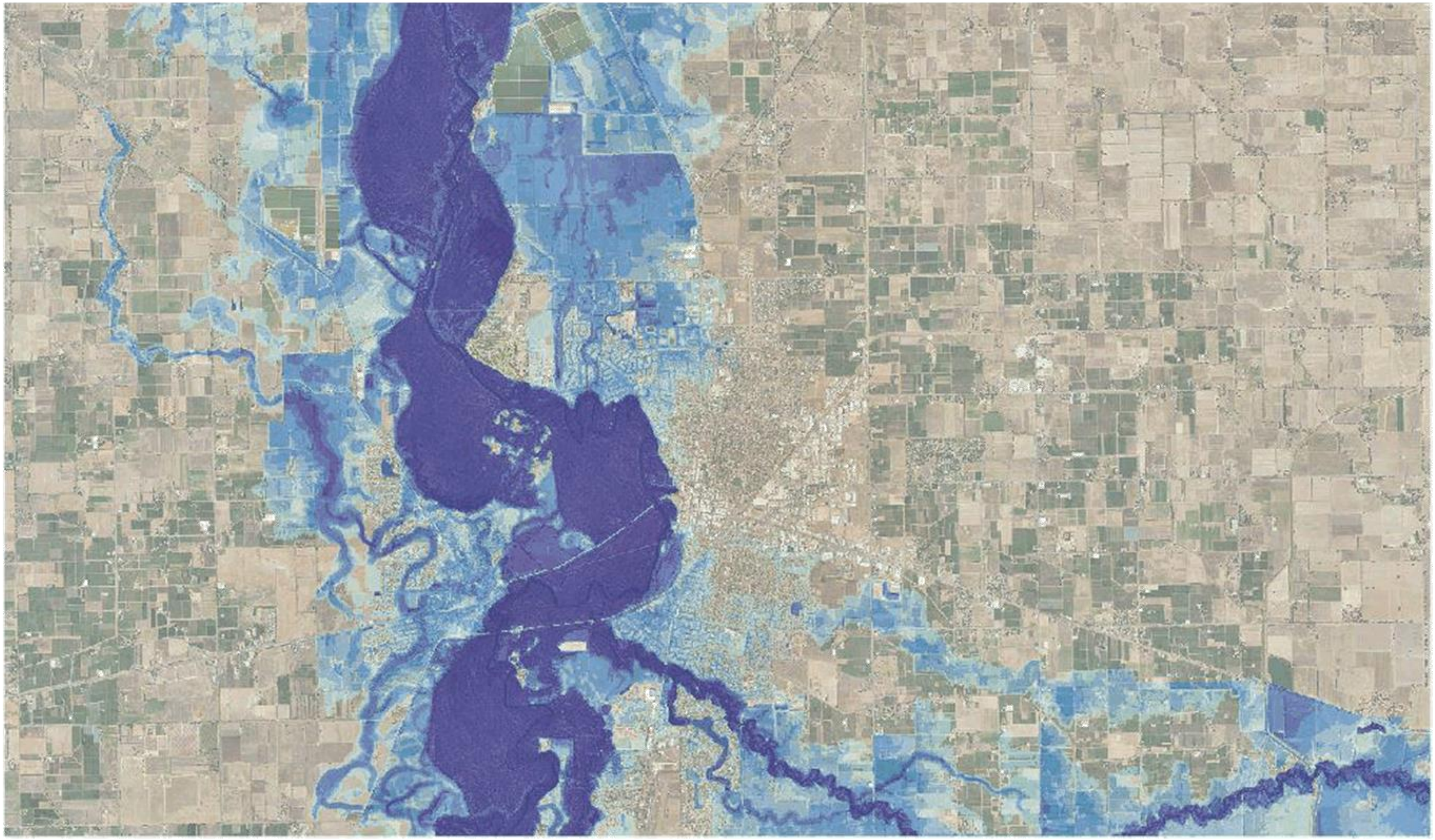
1% AEP flood extent for Goulburn River dominant – view 2 – zoomed in



1% AEP flood extent for neutral scenario – view 1



1% AEP flood extent for neutral scenario – view 2 – zoomed in



GOULBURN RIVER

Gauge Location: Goulburn River at Shepparton

River Height (m) and / or River Flow (ML/d)	Annual Exceedance Probability	Consequence / Impact	Action Actions may include (but not limited to) evacuation, closure of road, sandbagging, issue warning and who is responsible
Refer to the spreadsheet of addresses of flooded properties and buildings – covers Kialla, Kialla West, Kialla Lakes, Shepparton, Mooroopna and nearby areas			
7.93m		• Princess Park north end beside bike path, near end of Knight Street	• First Penstocks to be closed • Note flood impacts for later update of this table.
8.54m		• Macguire Reserve north end near Jetty; Penstock is in the middle of the bike path	• Close penstock
8.70m			• Greater Shepparton City Council internal Flood Management Group Briefing
8.75m		• Watt Road (back road or alternative route to Mooroopna) flooded. The trigger for this is when the Goulburn River @ Kialla West reaches 9.0m. • Raftery Road at the bridge through to Edgewater Road flooded.	• Close Watt Road • Close Raftery Road at the bridge through to Edgewater Road. • Monitor conditions for variation of flood flow down each river/creek. • Monitor Toolamba Bridge Road for need to close.
8.92m	**Dec 2017 event**	•	•
9.15m		• Welsford St behind Lawn Tennis Court	• Check that pump is operating
9.45m		• Hassett Street near Lincoln Drive • Princess Park south end near BOCCE Club	Check all OK
9.50m	**Minor flood level** <50% AEP (<2yr ARI)		• Greater Shepparton City Council internal Flood Management Group Briefing. • VICSES may coordinate an EMT meeting / teleconference and briefing regarding flood predictions and or actions. • If an ICC has not been established or an EMT has not been conducted, contact with the VICSES RDO should be considered (1800 899 927 requesting the NEDO be paged with your name and contact details).
9.80m			• McFarlane Road – consider for closure • Lenne Street Penstock to be closed • If rain continues in Mooroopna will need to monitor pump on Toolamba Road pipe (it is a manual pump)
9.97m	**March 2012 flood**		
10.1m	20% - 10% AEP (5yr – 10yr ARI)		

River Height (m) and / or River Flow (ML/d)	Annual Exceedance Probability	Consequence / Impact	Action Actions may include (but not limited to) evacuation, closure of road, sandbagging, issue warning and who is responsible
Refer to the spreadsheet of addresses of flooded properties and buildings – covers Kialla, Kialla West, Kialla Lakes, Shepparton, Mooroopna and nearby areas			
10.20m			• Creek Street (Kialla Park) - Check the gate is closed
10.21m			• Newton Street Pump Station (Turn on pump and pump out well) • 58 The Boulevard - pit behind house
10.30m		• The Boulevard at Kittles Road	• Close Tom Collins Drive to traffic at Fitzjohn Road and at Aquamoves entrance
10.36m		• Loch Gary Regulator Operates - G-MW will commence removing bars and they are responsible for advising the farms downstream of Loch Garry	• All bars are removed at 36ft / 10.96m
10.37m			• Provide flexi-pump to Manager of Victoria Lake Caravan Park. • Tom Collins Drive on drain into Caravan Park. • There are 2 penstocks along this levee.
10.40m		• First properties flooded at Kialla – 360 & 370 Centre Kialla Road, Kialla	•
10.50m		• In North Shepparton, Goulburn is about to break-out into the overland flow path that travels north from near the corner of The Boulevard and Hovell Court.	• Penstock – Carr Crescent in Mooroopna • Penstock – Lenne Street, Mooroopna; check operation of pump • If rain continues in Mooroopna will need to close Penstock on the Gange Estate. • Check River Road Toolamba, • Operate Echuca Road pump near Ann Street • Check levels at Gemmill's Swamp and consider closing Gange Estate Penstock.
10.52m			• Balaclava Road / The Boulevard roundabout on Parkside drain
10.60m		• First property flooded in Shepparton – 650 Doyles Road. • First properties flooded at Kialla West – 966, 970 & 980 Archer Road. Nos 966 & 980 close to over-floor flooding. • Properties in Adams Road, Watt Road and Watt Road, Kialla wetted.	•
10.70m	**Moderate flood level**	• Flooding of Watt Road and along Victoria Park more extensive.	• Consider opening Evacuation Centres • Check Echuca Road north of Mooroopna in anticipation of closure • Briefing MERC, MERO, MRM & Support Agencies listed
10.80m		• Balmoral Street Estate flooding will occur • East end McLennan Street, Mooroopna both sides of Highway • Properties at 56, 60 & 100 Hooper Road, Kialla begin to flood • First property flooded in Mooroopna – 7275 Midland Highway • Properties in Doyles Road & Hoopers Road in Kialla wetted • Goulburn Valley Highway properties at Kialla & Kialla West wetted	• Turn on Creek Street pump, if it is still raining. • Car park opposite old Mooroopna hospital – McLennan Street south side block pit inside levee. • Main drain outlet or Main drain near Fairway Drive • Block culverts under railway line from Mooroopna Station to Pyke Road.

River Height (m) and / or River Flow (ML/d)	Annual Exceedance Probability	Consequence / Impact	Action Actions may include (but not limited to) evacuation, closure of road, sandbagging, issue warning and who is responsible
Refer to the spreadsheet of addresses of flooded properties and buildings – covers Kialla, Kialla West, Kialla Lakes, Shepparton, Mooroopna and nearby areas			
10.82m			• Set up pump and pump out drain in Vaughan Street west of Welsford Street. Use 8" diameter centrifugal pump.
10.81m	**2010 flood**		
10.90m	10% AEP (10yr ARI)	• Grounds of swimming pool on Tom Collins Drive about to be wetted. Will need to remove electric motors if flood likely to be ~250mm higher.	• Activate Flood Operations Centre
10.98m		• Macguire Reserve Levee overtopped near Dainton's Bridge • Fitzjohn Road at Tom Collins Drive • Break-out from the Goulburn into Mooroopna near the intersection of Toolamba Road and Lenne Street about to commence.	• Warn property owners in Welsford Street, adjacent to Macguire Reserve of levee breach. Rear yards and their car parking area only should be affected. • Set up pump and pump out Wilmot Road drain
11.00m	**Major flood level** **July 1981 flood**	• Flooding of properties at 3 & 5 McLennan Street, Mooroopna about to start with 3 McLennan Street and 7275 Midland Highway about to be flooded over-floor. • Properties in Cameron Avenue, McPhees Road & Newton Street in Shepparton about to be flooded • Properties in Riverview Drive, Kialla about to be flooded • Main Highways into Shepparton begin to be inundated. First affected is the Midland Highway near the Municipality's eastern boundary when the Broken River breaks out at Gowangardie.	• Open Flood Information Centre at Welsford Street Offices • Assess need to place levee across Alternate Route at Channel No. E.G. 16/10 in Doyles Road to stop water from flowing west from here and inundating residential areas of South Shepparton. • Penstock – Archer Street • Penstock – Ardmona Cannery – Railway Yard • Ardmona Cannery Office Penstock (Cannery usually control) • Mooroopna Waterworks Trust Office (Trust usually control) • Consider need to close the Midland Highway to the east of Shepparton
11.06m		• Premises at 3 McLennan Street, Mooroopna about to be flooded over-floor	
11.09	**Sept 2010 flood**		

River Height (m) and / or River Flow (ML/d)	Annual Exceedance Probability	Consequence / Impact	Action Actions may include (but not limited to) evacuation, closure of road, sandbagging, issue warning and who is responsible
Refer to the spreadsheet of addresses of flooded properties and buildings – covers Kialla, Kialla West, Kialla Lakes, Shepparton, Mooroopna and nearby areas			
11.10m	10%-5% AEP (10yr – 20yr ARI)	• Furphy Ave overtopped. • Balmoral Estate levee is overtopped. • Lower level of 5 McLennan Street, Mooroopna about to be flooded over-floor • In North Shepparton, a second break-out is about to activate from the Goulburn into the overland flow path near Watters Reserve at intersection of The Boulevard and Kittles Road. • First property on The Boulevard is about to be flooded	• Gemmill Crescent outlet – block at Gemmill Crescent • Centennial Drive outlet – block on high ground • Outlet on Echuca Road south of Paisley Crescent – block in Paisley Crescent • Paisley Crescent & Wishaw Court outlet – block in street by sandbagging perimeter of pits • Operate Lenne Street pump and manipulate rural inflow from the south to keep Lenne Street area dry. May need to bank to restrict rural flow entering Lenne Street area • Penstock – Lenne Street penstock. Lift pit lid on river side of railway line so as to release pressure on pipeline. • Monitor drain culvert under railway line at Ferguson Road, close as necessary • Warn G.V. Estate area. • McFarlane Road, Mooroopna drain near Rodney Park • Assess need to sandbag Echuca – Mooroopna Road in low section near Gange Estate and houses in Carr Crescent. Sand to be stockpiled at Recreation Reserve • Baker Crescent Mooroopna outfall; block at outlet • Consider / commence evacuation of Balmoral Estate • Warn The Boulevard, Wanganui Estate and Tassicker Estate properties and DECA of break-out.
11.13m			• Close Penstocks at:
11.18m		• Victoria Park Lake Levee overtopped • Victoria Lake Holiday Park (536 Wyndham Street / Fitzjohn Road) begins to flood.	• Warn Tennis Club • Close Fitzjohn Road at Wyndham Street • Remove electric motors from pool pumps and lake pumps • Turn off sewerage pumps and plug sewer at Caravan Park and Aquamoves. • Evacuate Victoria Lake Caravan Park and remove all equipment • Close Welsford Street at Sobroan Street • Consider need to evacuate Victoria Lake Holiday Park

River Height (m) and / or River Flow (ML/d)	Annual Exceedance Probability	Consequence / Impact	Action Actions may include (but not limited to) evacuation, closure of road, sandbagging, issue warning and who is responsible
Refer to the spreadsheet of addresses of flooded properties and buildings – covers Kialla, Kialla West, Kialla Lakes, Shepparton, Mooroopna and nearby areas			
11.20m		• Lincoln Drive at Varcoe Street • Lincoln Drive at Gourlay Street • Lincoln Drive at Abernethy Street • Lincoln Drive at Coppin Crescent • Levees at the farm at 470 Madill Road, Undera about to be overtopped. • Water onto property at 25 Furphy Avenue, Kialla (at lowest part of the road) • River breaks its banks near Watters Reserve at intersection of The Boulevard and Kittles Road and floods north	• Check sewers and plug or shut down pumps affected as required. • Evacuate houses in lower lying areas as necessary.
11.30m	5% AEP (20yr ARI)	• Broken River breaks its banks near Railway Bridge	• Warn Taylors Estate (western end), Halls Estate and Longstaff Street area. • Evacuate houses in western end of Halls Estate not built to current 1% AEP flood level. • Consider / commence evacuating The Boulevard and Wanganui Estate. • GVW will check sewers and plug or shut off as required.
	Summary of flood characteristics for the 20yr ARI event:		
		▪ Large amount of inundation along the Broken River upstream of the East Goulburn Main Channel and a transfer of flow to Honeysuckle Creek. Shallow flow overtops the channel with constriction at Beckham Road and Central Avenue directing flow up to the north. Flows through Kialla Lakes. ▪ Flow along Seven Creeks confined to the adjacent floodplain downstream of Mitchell Road. Immediately upstream, flows extend from the No 6 Main Channel to the Goulburn Valley Highway. Further upstream, flows again confined generally to the immediate floodplain. ▪ Goulburn River adjacent to Arcadia Downs generally confined to the floodplain. ▪ Floodplain flow constricted at the railway and Midland Highway. ▪ Flow breaking out into Mooroopna through some private properties. Further downstream, flow breaking out to the Echuca - Mooroopna Road north of Homewood Drive, some private property inundated. Flow heading through the floodway to the north. ▪ In North Shepparton, flow breaking out over The Boulevard to the north inundating some private property. Overland flow constricted by Wanganui Rd and Channel No. 7. Flows extend to alongside the Barmah – Shepparton Road.	
11.38m		• Broken River breaks its banks at Gourlay Street and Wyndham Street (GVH) bridge	• Warn area east of Wyndham Street between Broken River and railway line, Riverpark Estate and Housing Commission area. • Consider evacuation - check area for necessity to evacuate particular houses – refer to spreadsheet of addresses of flooded properties and buildings. • GVW will check sewers and pump stations.

River Height (m) and / or River Flow (ML/d)	Annual Exceedance Probability	Consequence / Impact	Action Actions may include (but not limited to) evacuation, closure of road, sandbagging, issue warning and who is responsible
Refer to the spreadsheet of addresses of flooded properties and buildings – covers Kialla, Kialla West, Kialla Lakes, Shepparton, Mooroopna and nearby areas			
11.40m		• Water about to flood over-floor at 25 Furphy Avenue, Kialla (at lowest part of the road) • The first house flooded over-floor on The Boulevard • Goulburn Valley Highway in Shepparton north of the railway line / opposite Victoria Park Lake about to get wet. Highway also wet north & south of town • The lowest floors at Victoria Lake Holiday Park (536 Wyndham Street / Fitzjohn Road) begin to flood. • Grounds of Aspen Lodge Caravan Park (1 Lawson Street, Mooroopna) begin to flood	• Consider need to close Goulburn Valley Highway in Shepparton north of the railway line / opposite Victoria Park Lake. • Consider need to evacuate Aspen Lodge Caravan Park.
11.50m	5% - 2% AEP (20yr -50yr ARI)	• Premises at 60 Hooper Road, Kialla about to flood over-floor. • Flooding around GVW asset at 35 McLennan Street, Mooroopna	• Check Riverside Cabin Park • Grant Street drain at Fairway Drive – may need to sand bag perimeter of pits in Ann Street, Harding Street etc.
11.53m		• Further break-out from the Goulburn at the Boulevard / Balaclava Road roundabout	• Warn all residents north of Balaclava Road and west of Numurkah Road. • Evacuate Tarcoola Retirement Home • Check sewers and pump stations.
11.60m		• The lowest floors at Aspen Lodge Caravan Park (1 Lawson Street, Mooroopna) begin to be wetted	
11.66m		• Princess Park Levee overtopped • Midland Highway in Mooroopna beginning to get wet • The grounds of Wanganui Park Primary School are about to be wetted:	• Warn Shepparton Swans Football Club and Shepparton United Cricket Club and property owners adjoining Princess Park • Consider evacuating the Princess Park Sports Complex • Remove sewerage ejector pump. • Consider need to close Midland Highway in Mooroopna • Close the school?
11.70m		• Grounds of swimming pool at 24 Morrell Street, Mooroopna will be wetted if water rises further. Will need to remove electric motors if flood likely to reach 11.9m. • Grounds of (old) Mooroopna Police Station at 119 McLennan Street flooded • Grounds of the old Hospital at 2-8 McLennan Street, Mooroopna flooded. Access may be an issue. • Flooding outside and over-floor at Goulburn Medical Centre at 113 – 115 McLennan Street, Mooroopna • Grounds of the Wastewater Treatment Plant on McCracken Road in North Shepparton begin to flood • Grounds of the Wastewater Treatment Plant at 5440 Barmah-Shepparton Road, Bunbartha begin to flood • Adams Road, Kialla is impassable • The Barmah – Shepparton Road will be wetted to the north of its intersection with the Goulburn Valley Highway.	• Make sure Adams Road, Kialla is closed • Consider closing the Barmah – Shepparton Road

River Height (m) and / or River Flow (ML/d)	Annual Exceedance Probability	Consequence / Impact	Action Actions may include (but not limited to) evacuation, closure of road, sandbagging, issue warning and who is responsible
Refer to the spreadsheet of addresses of flooded properties and buildings – covers Kialla, Kialla West, Kialla Lakes, Shepparton, Mooroopna and nearby areas			
11.71m	**October 1993 flood**		
11.80m		• First premises about to be flooded over-floor in Shepparton – 118 McPhees Road & 89 Malcolm Crescent • Water outside the Mooroopna Fire Station in Ann Street, Mooroopna • Abernethy Street is impassable • The grounds of these schools are about to be wetted: ➢ Gowrie Street Primary School ➢ Guthrie Street Primary School ➢ Mooroopna Primary School • The Goulburn Valley Highway will be wetted at the intersection of Brauman Street & Pine Road in North Shepparton.	• Make sure Abernethy Street is closed • Close schools? • Consider closing the Goulburn Valley Highway through North Shepparton.
11.81m	**August 1939 flood**	•	•
11.9m	2% AEP (50yr ARI)	• Welsford Street - Water Treatment plant and sewerage pumps affected • Floors of Swimming pool at 24 Morrell Street, Mooroopna just being wetted. • Grounds of Shepparton Police Station at 195 Welsford Street flooded • Grounds of Valley Residential Aged Care Facility, 195-205 McLennan Street, Mooroopna flooded • Floor of the Mooroopna Fire Station in Ann Street beginning to flood • Over-floor flooding at the Wastewater Treatment Plant at 5440 Barmah-Shepparton Road, Bunbartha • Over-floor flooding of GVW asset at 35 McLennan Street, Mooroopna • Flooding around GVW asset at 242 Riverview Drive, Kialla • Flooding around GVW pump station at 104 Numurkah Road, Shepparton	• GVW plans implement to address WTP and sewerage pump issues. • Remove electric motors from pool pumps.
	Summary of flood characteristics for the 50yr ARI event:		
		▪ Large amount of inundation along the Broken River upstream of the East Goulburn Main Channel. Break-outs to the north well established. ▪ Inundation occurs in South Shepparton (Lincoln & Broken River Drives) ▪ Increased Goulburn River flow through Arcadia Downs but still predominantly contained within the general floodplain. ▪ A large amount of flow heading through Mooroopna inundating the majority of the private properties in the eastern parts. ▪ In North Shepparton, increased flow breaking out over The Boulevard inundating many properties to the north. Overland flow constricted by Channel No. 7. ▪ Increased flood extent to the east and around Coomboona. ▪ Flooding extends across the Barmah - Shepparton Road. ▪ Flood depths and extent increase as move downstream.	
12.00m		• A large part of North Shepparton north from around Mason Street & Balaclava Road is flooded • Grounds of Shepparton Riverside Cabin Park (8049 Goulburn Valley Highway) begin to flood • The Midland Highway and the P.R Edwards Causeway flooded – loss of connection between Shepparton and Mooroopna (east & west)	• Close the Midland Highway at the Causeway

River Height (m) and / or River Flow (ML/d)	Annual Exceedance Probability	Consequence / Impact	Action Actions may include (but not limited to) evacuation, closure of road, sandbagging, issue warning and who is responsible
Refer to the spreadsheet of addresses of flooded properties and buildings – covers Kialla, Kialla West, Kialla Lakes, Shepparton, Mooroopna and nearby areas			
12.05m		• Midland Highway in Shepparton between Mitchell & Florence Streets about to get wet	• Consider need to close Midland Highway in Shepparton
12.09m	**May 1974 flood**		
12.10m		• Access to the CFA (and ICC) facility at 195-205 Numurkah Road, Shepparton is about to be compromised as surrounding access roads get flooded	• Relocate the ICC
12.20m	1% AEP (100yr ARI) **1916 flood event**	• Old Mooroopna Police Station at 119 McLennan Street inundated (below floor). Police Station rebuilt since floor level survey was captured. • Old Mooroopna Hospital at 2-8 McLennan Street, Mooroopna flooded over-floor. • The Valley Residential Aged Care Facility, 195-205 McLennan Street, Mooroopna flooded over-floor • The car park of the Hospital off Graham Street, Shepparton beginning to get wet. Surrounding roads get wetter as levels increase. Access increasingly becoming an issue. • Over-floor flooding of GVW asset at 242 Riverview Drive, Kialla • Over-floor flooding of GVW pump station at 104 Numurkah Road, Shepparton	
12.3m	0.5% AEP (200yr ARI)	• Shepparton Police Station at 195 Welsford Street flooded over-floor • The CFA (and ICC) facility at 195-205 Numurkah Road, Shepparton is flooded over-floor	
12.40m		• Grounds of the Big4 Shepparton Park Lane Holiday Park (7835 Goulburn Valley Highway, Kialla) begin to flood	
12.5m	0.2% AEP (500yr ARI)	• Council offices in Welsford Street surrounded by mostly shallow water	
x.xxm	Probable Maximum Flood (PMF)		

Note: Flood intelligence records are approximations. This is because no two floods at a location, even if they peak at the same height, will have identical impacts. Flood intelligence cards detail the relationship between flood magnitude and flood consequences. More details about flood intelligence and its use can be found in the Australian Emergency Management Manuals flood series.

BROKEN RIVER

Gauge Location: Broken River at Orrvale Gauge

River Height (m) and / or River Flow (ML/d)	Annual Exceedance Probability	Consequence / Impact	Action Actions may include (but not limited to) Evacuation, closure of road, sandbagging, issue warning and who is responsible
		• The Midland Highway near the Municipality's eastern boundary is flooded when the Broken River breaks out at Gowangardie.	• Close Midland Highway to the east of Shepparton • Note flood impacts for later update of this table.
4.90m	**Dec 2017 flood**	•	
6.30m		• 685 Doyles Road begins to be wetted but house is about 1m higher with levels known by owner. Sandbagging not required until ~7.3m.	Place "water over road" signs and monitor for closures.
6.80m	**Minor flood level**	• Rural properties upstream of Doyles Road flooded.	
7.00m	**March 2012 flood**	•	
7.15m		• Gordon Drive (Broken River anabranch) will be over-topped at western end by waters flowing out of Lake Kialla. Affects Gordon Drive.	
7.20m	**Moderate flood level**	• Lake Amaroo will over top and flow under the new Kialla Lakes Drive bridge. • Kialla Lakes Drive likely to be wetted. • Traffic disruption in and around Kialla Lakes residential area.	• Monitor for road closures.
7.30m		• Archer Street at Oxbow Court. • Floodway on Archer Street about to be over-topped by the Broken River. • Kialla Lakes Drive likely to be impassable.	• Close boom gate at Oxbow Court and open the gate into Kensington Gardens; their Manager has a key. • Consider closing Archer Street. • Close Kialla Lakes Drive.
7.50m		• First properties flooded at Kialla West – 966, 970 & 980 Archer Road. Nos 966 & 980 close to over-floor flooding. • Gordon Drive likely to be impassable.	• Close Gordon Drive.
7.61m	**October 2016 flood**	•	•
7.70m		• Inundation of land beginning at 56, 60 & 100 Hooper Road, Kialla • Water over northern causeway on Archer Street around 500mm deep.	• Inundation at 60 Hooper road premises starts to occur. • No access over causeway.
7.80m		• 68 Doyles Road – starting to flood over-floor • 95 Jamieson Road – starting to flood over-floor	• Sandbag houses at 68 Doyles Road and 95 Jamieson Road and / or assist residents. • Close Jamieson Road at Channel Road
7.85m		• Archer Road, south of Kialla Lakes Drive, about to be over-topped by overflow from Broken River anabranch.	• Consider closing Archer Road as over-topped by anabranch flow • 4WD access only at this stage

River Height (m) and / or River Flow (ML/d)	Annual Exceedance Probability	Consequence / Impact	Action Actions may include (but not limited to) Evacuation, closure of road, sandbagging, issue warning and who is responsible
7.86m 27,155ML/d	**October 1996 flood**		
7.90m	**Major flood level** 10% AEP (10 year ARI)	• Likely that residents north and east of Lake Kialla and east of Lake Amaroo are isolated.	
7.99m	**July 1981 flood**	•	
8.10m 33,032ML/d	20% AEP (5 year ARI)	• First homes in Guthrie, Nicholls and Abernathy begin flooding	
8.14m		• Kialla Lakes Drive	• Engineers estimate that the new bridge will start to over-top at this water level. • To be confirmed at next event
8.19m	**Sept 2010 flood**	•	
8.33m 40,000ML/d	2% AEP (50 year ARI) **May 1974 flood**	•	
8.41m	**October 1993 flood**	• Water over southern causeway on Archer Road approaching 500mm deep.	• No access over causeway.
8.44m 43,852ML/d	1% AEP (100 year ARI)	•	
8.50m 48,300ML/d	0.5% AEP (200 year ARI)	• Over-floor flooding at 60 Hooper Road, Kialla.	

SEVEN CREEKS

Gauge Location: Seven Creeks at Kialla West

River Height (m) and / or River Flow (ML/d)	Annual Exceedance Probability	Consequence / Impact	Action Actions may include (but not limited to) Evacuation, closure of road, sandbagging, issue warning and who is responsible
4.50m	**Minor flood level**	• Floodwater will overtop Mitchell Road Bridge and road floods between the Goulburn Valley Highway and Archer Road	• Consider closing road • Note flood impacts for later update of this table.
5.00m	**Moderate flood level**	• Raftery Road will be over-topped between the bridge and Edgewater Road. Also occurs when the Goulburn River @ Kialla West gauge reaches 10.4m.	• Detour traffic
5.46m	**October 2016 flood**	•	•
6.02m	**October 1996 flood** **March 2012 flood**	•	•
6.03m	**June 1995 flood**	•	•
6.33m	**July 1981 flood** **Dec 2017 flood**	•	•
6.5m		• First properties flooded in Kialla – 360 & 370 Centre Kialla Road.	•
6.60	**Major flood level** 1% AEP (5 year ARI)	• First residential floor flooded in Balmoral Estate • Over-floor flooding at 360 & 370 Central Kialla Road, Kialla • Also occurs when Goulburn River @ Kialla West reaches 10.7m	• Consider evacuation of Balmoral Estate.
6.70m	**Sept 2010 flood**	•	•
6.90m	1% AEP (10 year ARI)	• Houses flood in Archer Road South	• Advise residents • Close Archer Road South at Mitchell Road
7.25m		• First residential floors flooded in Kialla West – 966 & 980 Archer Road	•
7.40m		• Water onto property at 25 Furphy Avenue, Kialla (at lowest part of the road)	•
7.50m		• Water about to flood over-floor at 25 Furphy Avenue, Kialla (at lowest part of the road)	•
7.66m		• Properties in Riverview Drive, Kialla about to be flooded	•
7.85m	1% AEP (35 year ARI) **May 1974 flood**	•	•
8.23m	1% AEP (100 year ARI) **October 1993 flood**	•	•

Flood Forecast Tools and How to Use Them

The purpose of the following flood forecast tools is to enable an early heads-up of likely flood severity and consequences through the lower reaches of the Broken - Seven Creeks - Goulburn system.

It is important to be fully aware that the tools provide an estimate of the likely flood peak. They are not infallible and are unlikely to be as precise as BoM flood forecasts. While they should not be used to generate competition with BoM, they may provide a basis for informed discussion with BoM about the flood forecasts for Seven Creeks at Kialla West, Broken River at Orrvale and Goulburn River at Shepparton.

Use of FloodZoom and other tools is encouraged in order to better inform the early heads-up and assist response activity planning and implementation.

The earliest an initial heads-up of the expected peak level at Shepparton can be determined is after a forecast peak level is available for Benalla and Euroa and a peak outflow forecast (or estimate) is available for Goulburn Weir (i.e. a peak level for the Goulburn Weir tail gauge). The use of actual flood peaks will generally result in more accurate estimates.

To repeat the above as a word of caution. The following flood forecast tools provide estimates of the likely flood peaks and timings at Orrvale, Seven Creeks at Kialla, and the Goulburn River at both Kialla West and Shepparton. Those estimates and the associated timings are unlikely to be exact but will be sufficiently accurate to indicate, when used in conjunction with the flood intelligence tables and flood mapping, likely consequences and to guide and inform early response planning and related activity.

1. Determine the expected peak level for Seven Creeks at Kialla West using the Euroa peak level. The relationship implicitly includes an allowance for Stony and Honeysuckle Creek flows. If these are exceptionally high (look at data from Tamleugh and U/S Violet Town) and noting the comment on the tool about upper and lower catchment rainfall, increase the level suggested by the tool up by 100 mm or so (i.e. bias to the upper side of the curve).
2. Determine the expected peak level for Orrvale using either the Benalla peak level and / or the Gowangardie Weir peak level. The relationship implicitly accommodates the flow transfers to the Broken Creek system that occur from a level at Casey's Weir of around 1.81 m.
3. Determine the expected peak level for the Goulburn at Kialla West using either Goulburn Weir tail gauge peak level and / or the Murchison peak level.
4. Using information at Appendix B, determine likely timings for all locations, including Shepparton. If and as appropriate and in order to increase confidence in estimated timings, use FloodZoom to look at relative timings in similar past events (i.e. similar in terms of rainfall distributions and / or levels at key gauges).
5. Determine dominance: Broken – Seven Creeks, neutral or Goulburn. This will dictate which map is appropriate to determine flood extents and consequences in the vicinity of each of Orrvale, Seven Creeks at Kialla West, Goulburn River at Kialla West and Shepparton. The appropriate map and summary of likely consequences (read from the flood intelligence card) at a location will be the one that matches the expected level at that location.

   As the event progresses and peak level forecasts are refined, the appropriateness of map sets being used and thus likely consequences should be reviewed and adjustments made as necessary.

While a conservative approach would be to use the maximum extent maps, the resulting expected peak level for Shepparton is likely to be incorrect.

6. Determine the expected peak level for Shepparton. Two approaches are suggested.

   a. **APPROACH 1**: Using the dominance scenario matrix (see below) and the following rules. This involves extracting the Shepparton value associated with the expected peak at each of Orrvale, Seven Creeks at Kialla West and Goulburn River at Kialla West for the selected dominance scenario. This will always give you 3 values.

   IMPORTANT NOTE: If the results of the following give at least 2 Shepparton values that are less than 9.5 m, the peak at Shepparton will be below the minor flood level (i.e. less than 9.5 m) unless Murchison is above minor flood level (i.e. 9.0 m) in which case Shepparton will almost certainly exceed minor flood level (i.e. 9.5 m). If only 1 of the values is less than 9.5 m, that value should be changed to 9.5 m.

      i. If the expected peak at Seven Creeks at Kialla West is GREATER THAN 6 m, use the NEUTRAL matrix to determine the 3 Shepparton values. Add these 3 values together and divide by 3. The result is the expected peak at Shepparton. It can generally be expected to be within +/- ~100 mm of the actual peak.

      ii. If the expected peak at Seven Creeks at Kialla West is LESS THAN 6 m and the expected peak at Murchison is GREATER THAN 8 m, use the GOULBURN dominant matrix. Add the Shepparton values associated with the expected peaks at Orrvale and Seven Creeks at Kialla West and divide by 2. If the expected peak at Orrvale is GREATER THAN 7 m, add 100 mm to the above result otherwise add 50 mm. This is the expected peak at Shepparton. It can generally be expected to be within +/- ~100 mm of the actual peak.

      iii. At all other times (unless the Goulburn is clearly dominant) use the Broken – Seven Creeks dominant matrix. Add the Shepparton values associated with the expected peaks at Orrvale and Seven Creeks at Kialla West and divide by 2. This is the expected peak at Shepparton.

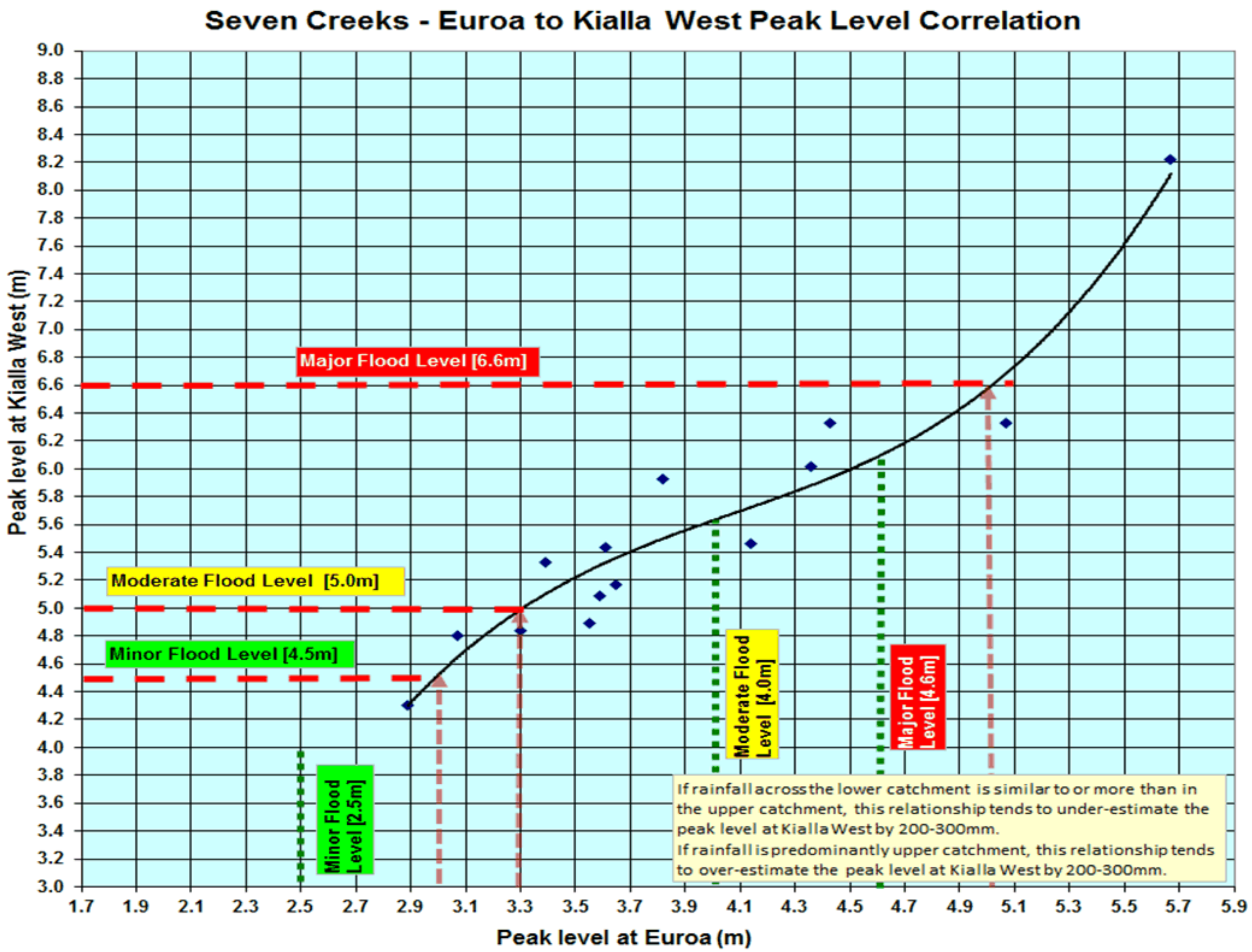
   b. **APPROACH 2**: Using current rating tables for each of Orrvale, Seven Creeks at Kialla West, Goulburn River at Kialla West and Shepparton.

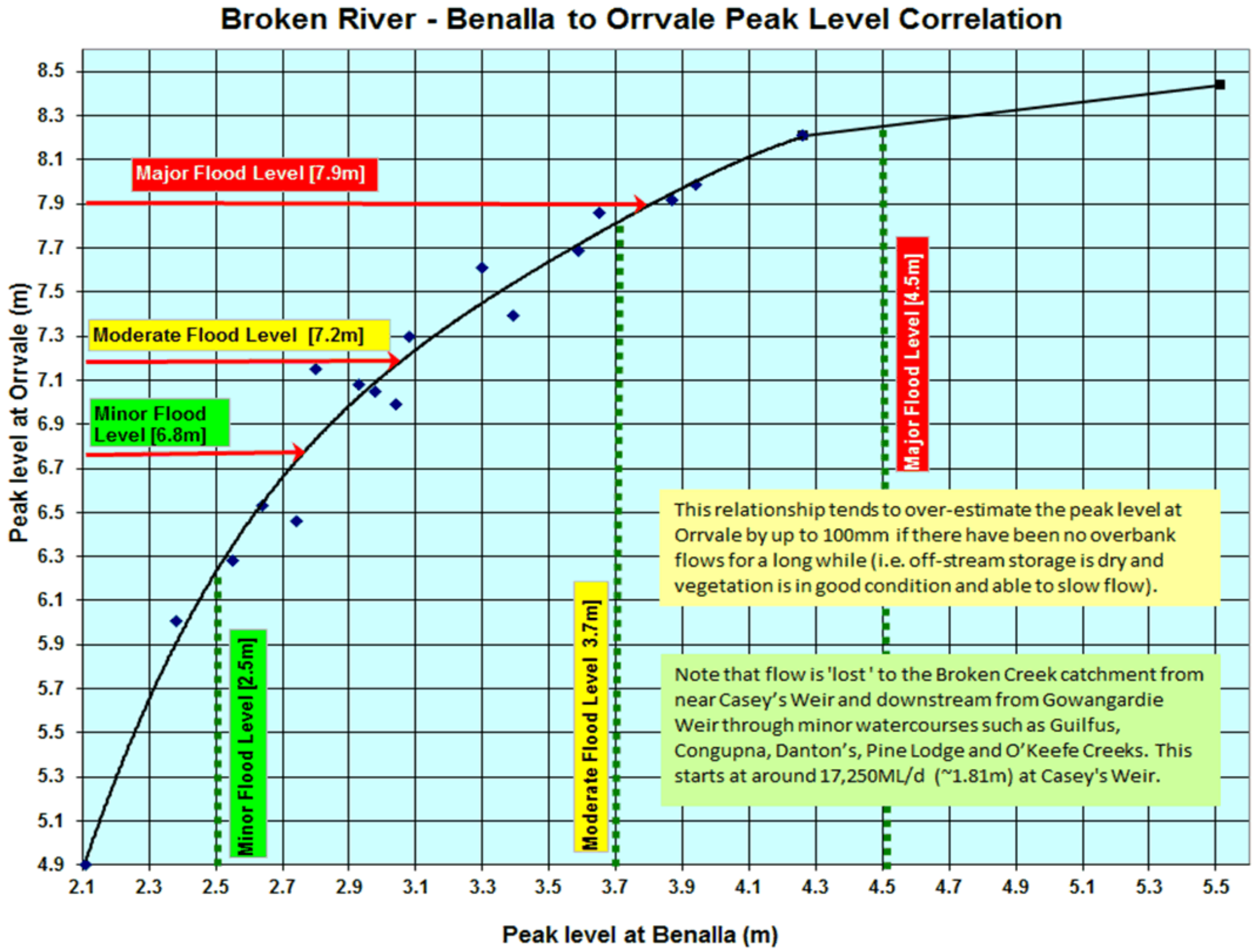
      i. Determine the expected peak flows at Orrvale, Seven Creeks at Kialla West and Goulburn River at Kialla West.

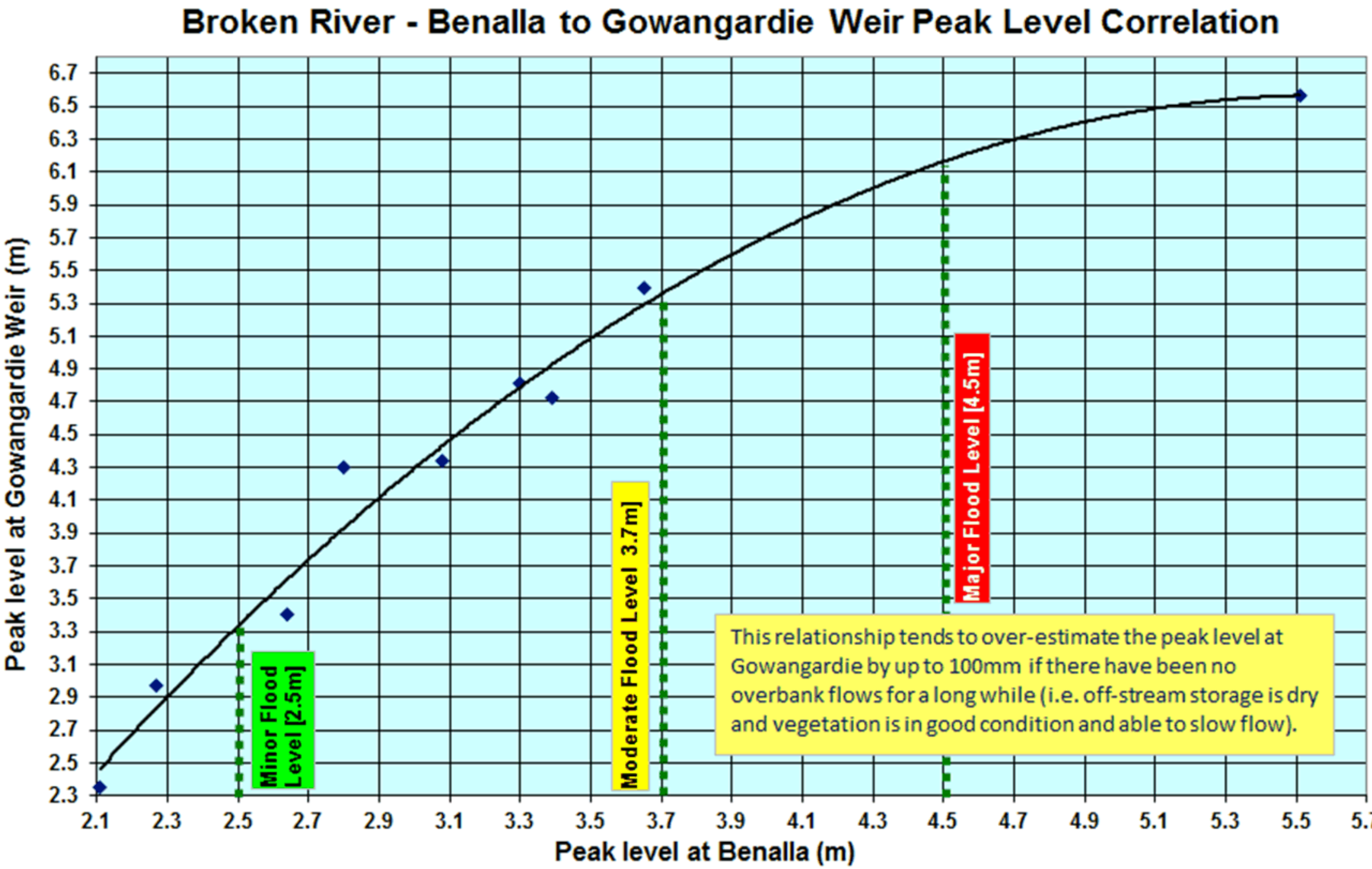
      ii. Add these flows and reduce by between 10% and 20%.

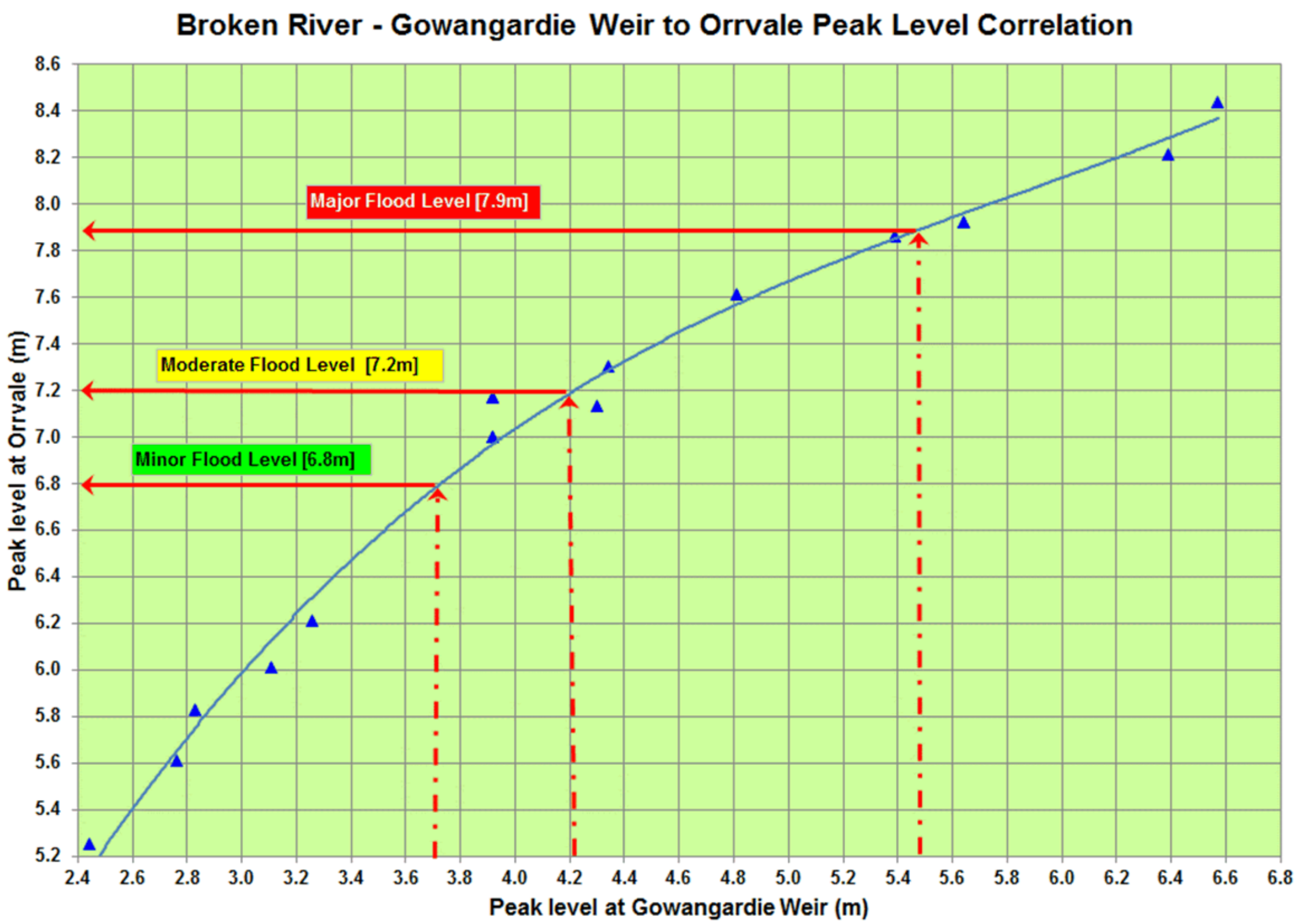
      Use 20% when the floodplain and off-stream storage are dry and waterways are running at normal levels (i.e. not elevated).

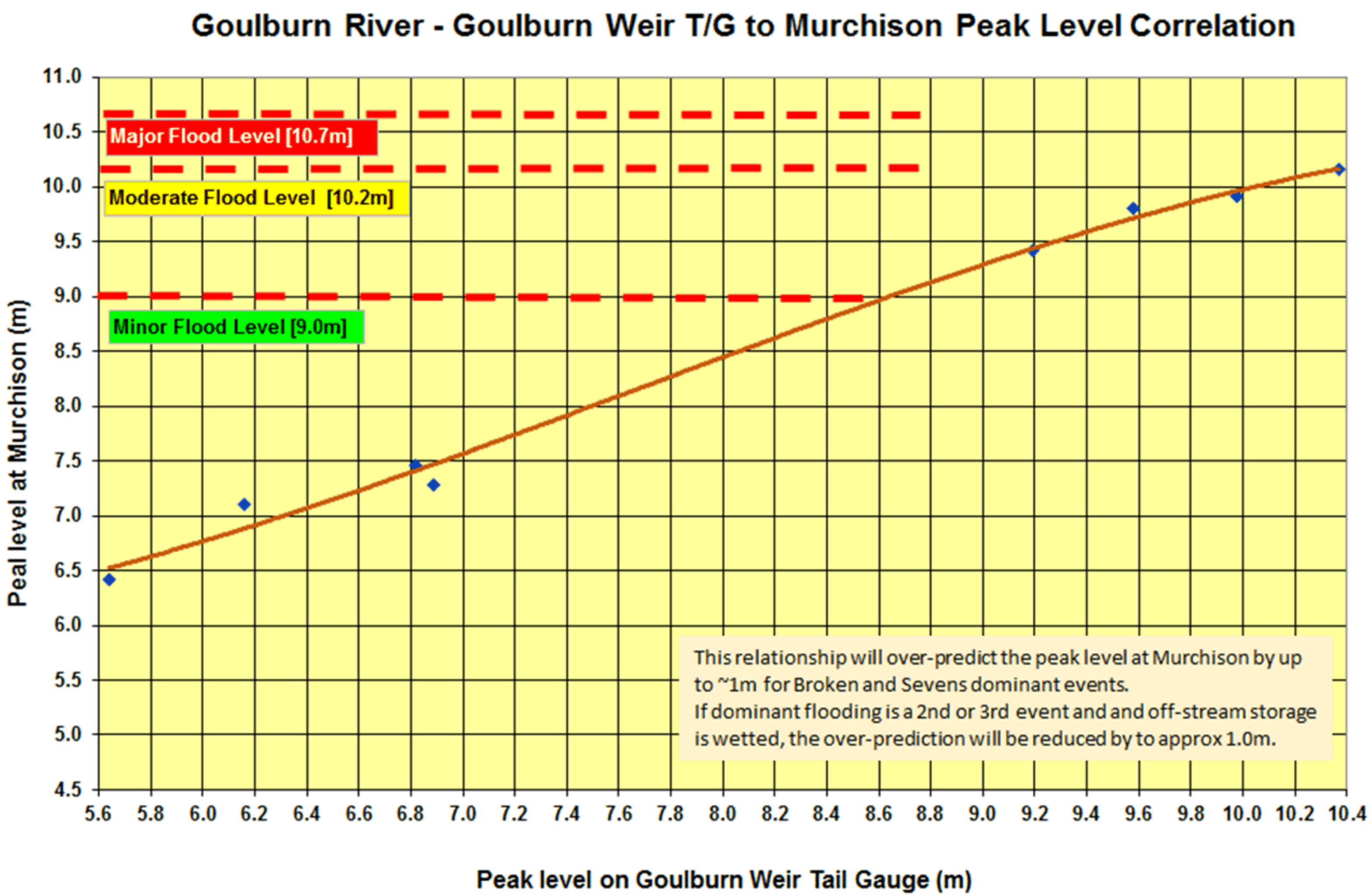
      Reduce by 10% if the area is wet and / or this is a follow-on flood with off-stream floodplain storage wetted and elevated levels in waterways.

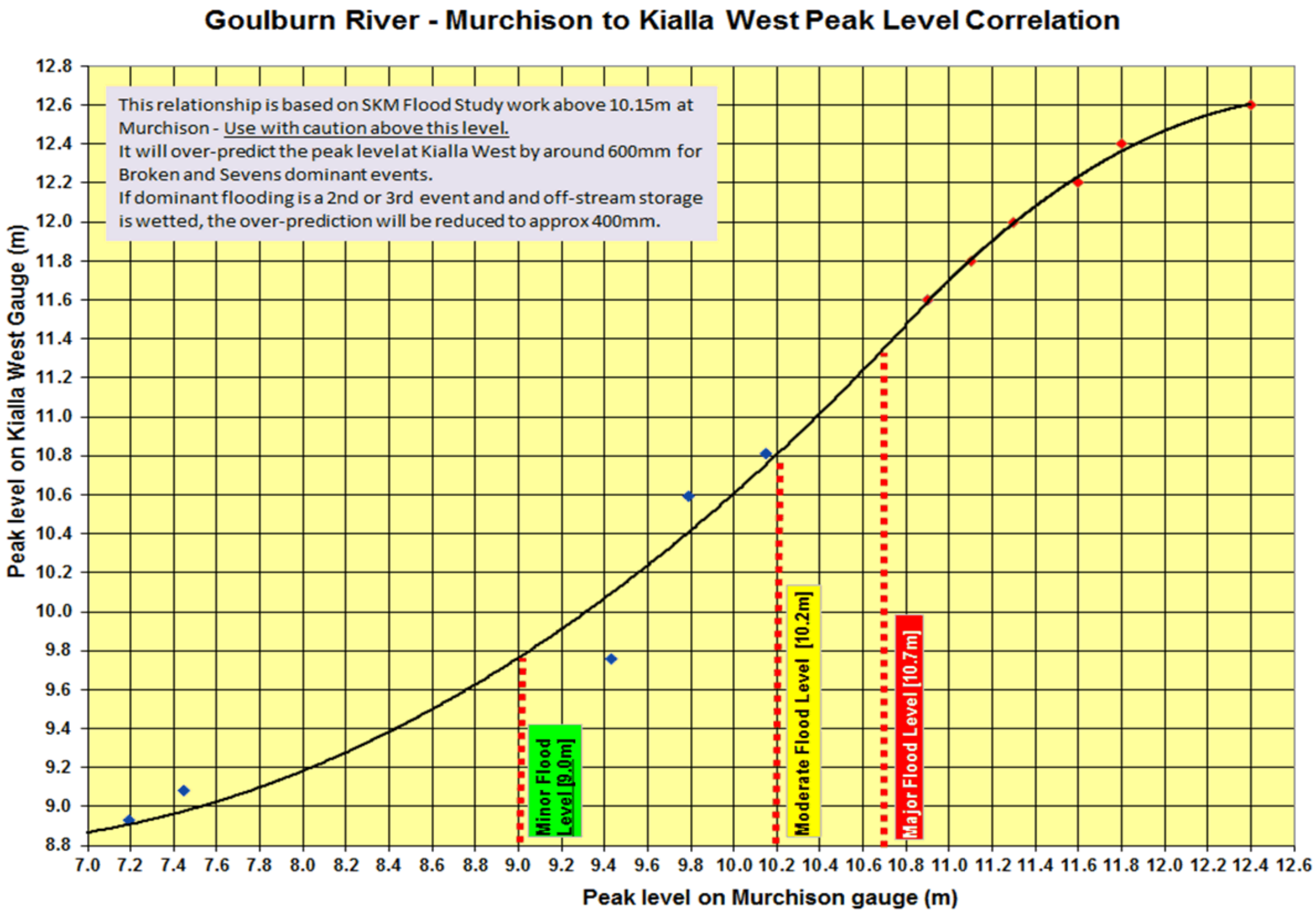

Seven Creeks - Euroa to Kialla West Peak Level Correlation
Peak level at Kialla West (m)
Peak level at Euroa (m)
Major Flood Level [6.6m]
Moderate Flood Level [5.0m]
Minor Flood Level [4.5m]
Minor Flood Level [2.5m]
Moderate Flood Level [4.0m]
Major Flood Level [4.6m]
If rainfall across the lower catchment is similar to or more than in the upper catchment, this relationship tends to under-estimate the peak level at Kialla West by 200-300mm.
If rainfall is predominantly upper catchment, this relationship tends to over-estimate the peak level at Kialla West by 200-300mm.


Broken River - Benalla to Orrvale Peak Level Correlation
Peak level at Orrvale (m)
Peak level at Benalla (m)
8.5
8.3
8.1
7.9
7.7
7.5
7.3
7.1
6.9
6.7
6.5
6.3
6.1
5.9
5.7
5.5
5.3
5.1
4.9
2.1
2.3
2.5
2.7
2.9
3.1
3.3
3.5
3.7
3.9
4.1
4.3
4.5
4.7
4.9
5.1
5.3
5.5
Major Flood Level [7.9m]
Moderate Flood Level [7.2m]
Minor Flood Level [6.8m]
Minor Flood Level [2.5m]
Moderate Flood Level 3.7m]
Major Flood Level [4.5m]
This relationship tends to over-estimate the peak level at Orrvale by up to 100mm if there have been no overbank flows for a long while (i.e. off-stream storage is dry and vegetation is in good condition and able to slow flow).
Note that flow is 'lost' to the Broken Creek catchment from near Casey's Weir and downstream from Gowangardie Weir through minor watercourses such as Guilfus, Congupna, Danton's, Pine Lodge and O'Keefe Creeks. This starts at around 17,250ML/d (~1.81m) at Casey's Weir.


Broken River - Benalla to Gowangardie Weir Peak Level Correlation
Peak level at Gowangardie Weir (m)
6.7
6.5
6.3
6.1
5.9
5.7
5.5
5.3
5.1
4.9
4.7
4.5
4.3
4.1
3.9
3.7
3.5
3.3
3.1
2.9
2.7
2.5
2.3
2.1
2.3
2.5
2.7
2.9
3.1
3.3
3.5
3.7
3.9
4.1
4.3
4.5
4.7
4.9
5.1
5.3
5.5
5.7
Peak level at Benalla (m)
Minor Flood Level [2.5m]
Moderate Flood Level 3.7m]
Major Flood Level [4.5m]
This relationship tends to over-estimate the peak level at Gowangardie by up to 100mm if there have been no overbank flows for a long while (i.e. off-stream storage is dry and vegetation is in good condition and able to slow flow).


Broken River - Gowangardie Weir to Orrvale Peak Level Correlation
Major Flood Level [7.9m]
Moderate Flood Level [7.2m]
Minor Flood Level [6.8m]
Peak level at Orrvale (m)
Peak level at Gowangardie Weir (m)
8.6
8.4
8.2
8.0
7.8
7.6
7.4
7.2
7.0
6.8
6.6
6.4
6.2
6.0
5.8
5.6
5.4
5.2
2.4 2.6 2.8 3.0 3.2 3.4 3.6 3.8 4.0 4.2 4.4 4.6 4.8 5.0 5.2 5.4 5.6 5.8 6.0 6.2 6.4 6.6 6.8


Goulburn River - Goulburn Weir T/G to Murchison Peak Level Correlation
Major Flood Level [10.7m]
Moderate Flood Level [10.2m]
Minor Flood Level [9.0m]
Peal level at Murchison (m)
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
5.6 5.8 6.0 6.2 6.4 6.6 6.8 7.0 7.2 7.4 7.6 7.8 8.0 8.2 8.4 8.6 8.8 9.0 9.2 9.4 9.6 9.8 10.0 10.2 10.4
This relationship will over-predict the peak level at Murchison by up to ~1m for Broken and Sevens dominant events.
If dominant flooding is a 2nd or 3rd event and and off-stream storage is wetted, the over-prediction will be reduced by to approx 1.0m.
Peak level on Goulburn Weir Tail Gauge (m)


Goulburn River - Murchison to Kialla West Peak Level Correlation
This relationship is based on SKM Flood Study work above 10.15m at Murchison - Use with caution above this level.
It will over-predict the peak level at Kialla West by around 600mm for Broken and Sevens dominant events.
If dominant flooding is a 2nd or 3rd event and and off-stream storage is wetted, the over-prediction will be reduced to approx 400mm.
Minor Flood Level [9.0m]
Moderate Flood Level [10.2m]
Major Flood Level [10.7m]
Peak level on Kialla West Gauge (m)
Peak level on Murchison gauge (m)
12.8
12.6
12.4
12.2
12.0
11.8
11.6
11.4
11.2
11.0
10.8
10.6
10.4
10.2
10.0
9.8
9.6
9.4
9.2
9.0
8.8
7.0 7.2 7.4 7.6 7.8 8.0 8.2 8.4 8.6 8.8 9.0 9.2 9.4 9.6 9.8 10.0 10.2 10.4 10.6 10.8 11.0 11.2 11.4 11.6 11.8 12.0 12.2 12.4 12.6

Dominance scenario matrix – PART 1							
Broken - Sevens dominant				Goulburns dominant			
Gauge levels in metres				Gauge levels in metres			
Goulburn River @ Shepparton	Broken River @ Orrvale	Seven Creeks @ Kialla West	Goulburn River @ Kialla West	Goulburn River @ Shepparton	Broken River @ Orrvale	Seven Creeks @ Kialla West	Goulburn River @ Kialla West
9.5 (minor)	6.15	4.98	9.73	9.5 (minor)	5.55	4.58	10.20
9.7				9.7			
9.9				9.9			
10.1	7.53	5.92	10.58	10.1	6.77	5.93	10.90
10.5				10.5			
10.7 (moderate)	7.97	7.25	11.09	10.7 (moderate)	7.32	5.95	11.46
10.9 (10% AEP)	8.16	7.52	11.18	10.9 (10% AEP)	7.35	5.95	11.53
11 (major)				11 (major)			
11.1	8.37	7.81	11.40	11.1	7.75	6.36	11.76
11.3 (5% AEP)	8.45	8.09	11.62	11.3 (5% AEP)	7.94	6.60	11.93
11.5	8.52	8.32	11.81	11.5	8.06	6.86	12.09
11.7	8.57	8.46	12.08	11.7	8.23	7.12	12.30
11.9 (2% AEP)				11.9 (2% AEP)			
12.1	8.67	8.61	12.47	12.1	8.44	7.17	12.75
12.2 (1% AEP)	8.71	8.61	12.74	12.2 (1% AEP)	8.55	7.64	12.84
12.3 (0.5% AEP)	8.80	8.80	12.87	12.3 (0.5% AEP)	8.56	8.17	12.92
12.5 (0.2% AEP)				12.5 (0.2% AEP)			

Dominance scenario matrix – PART 2

Neutral scenario

Gauge levels in metres			
Goulburn River @ Shepparton	Broken River @ Orrvale	Seven Creeks @ Kialla West	Goulburn River @ Kialla West
9.5 (minor)	5.97	4.82	9.91
9.7			
9.9			
10.1	6.90	5.92	10.76
10.5			
10.7 (moderate)	7.32	5.95	11.46
10.9 (10% AEP)	7.38	7.15	11.48
11 (major)			
11.1	7.79	7.44	11.77
11.3 (5% AEP)	7.91	7.44	11.82
11.5	8.14	7.58	12.05
11.7	8.26	7.76	12.20
11.9 (2% AEP)			
12.1	8.57	8.57	12.60
12.2 (1% AEP)	8.70	8.72	12.90
12.3 (0.5% AEP)	8.76	8.79	13.05

Maximum envelope

Gauge levels in metres			
Goulburn River @ Shepparton	Broken River @ Orrvale	Seven Creeks @ Kialla West	Goulburn River @ Kialla West
9.5 (minor)	6.15	4.98	10.20
9.7	6.45	5.11	10.44
9.9	6.77	5.11	10.48
10.1	7.53	5.93	10.90
10.5	7.33	6.60	11.20
10.7 (moderate)	7.97	7.25	11.46
10.9 (10% AEP)	8.16	7.52	11.53
11 (major)	8.25	7.66	11.65
11.1	8.37	7.81	11.77
11.3 (5% AEP)	8.45	8.09	11.93
11.5	8.52	8.32	12.09
11.7	8.57	8.46	12.30
11.9 (2% AEP)	8.62	8.59	12.63
12.1	8.67	8.72	12.75
12.2 (1% AEP)	8.71	8.72	12.90
12.3 (0.5% AEP)	8.80	8.80	13.05
12.5 (0.2% AEP)	9.02	9.06	13.31

APPENDIX C3 – EAST SHEPPARTON FLOOD EMERGENCY PLAN

Overview of Flooding Consequences

Land use through East Shepparton is mainly residential and agricultural (e.g. orchards) with some industrial and commercial.

The area drains through an extensive network of man-made open drains rather than a natural drainage system – see figure on following page. The area is generally flat with raised irrigation channels forming barriers to overland flows. Drainage is relatively poor. Large portions of the area take considerable time to drain after a flood with many requiring the water to be pumped away.

East Shepparton is susceptible to widespread and generally shallow slow moving flooding following heavy rain. While flooding is extensive across the area, it is generally confined to the road reserves, particularly within the urban portion. Flood depths within the road reserves are typically between 250mm and 400mm with isolated areas up to 1.0m. Depths greater than 1.0m only occur within the 47 retarding basins within the area (see list below).

Where flooding occurs within residential or commercial properties, the depth of inundation is typically shallow (i.e. less than 250mm) and slow moving.

The Goulburn Valley Highway acts as a hydraulic control as it holds back some of the overland flow in North Shepparton. Water levels are therefore elevated on the upstream side.

In the rural and farm areas of East Shepparton, flooding is widespread at even the 20% AEP (5 year ARI) event with floodwater filling local depressions and backing up behind roadways or other ridges through the catchment. Flood depths are typically shallow and rarely exceed 500mm, even in the 1% AEP (100 year ARI) event.

As the area is generally quite flat with widespread shallow flooding, flood velocities are typically slow, rarely exceeding 0.25m/s. They are a bit higher but mostly less than 0.5m/s in the road reserves within urban areas. Across residential and commercial properties they are typically less than 0.1m/s.

With the exception of the 47 retarding basins throughout the area, at a small number of roadways and within a small number of road reserves in the urban areas, the flood risk (as per ARR 2016) is low for adults, children and vehicles.

The Drainage Network (see figure on following page)

Goulburn-Murray Water Main Drain No 2 flows west from the East Goulburn Main Channel and drains agricultural land between the Midland Highway and the Broken River as well as some urban areas. It is 12.5km long. It discharges into the Broken River between Archer Street and McPhees Road.

Goulburn-Murray Water Main Drain No 3 flows for 20km north-west from the East Goulburn Main Channel, crossing Central Avenue, Doyles Road and the Goulburn Valley Highway before discharging into the Goulburn River at Reedy Swamp.

Open drains from agricultural properties combine with Main Drain No 2 and Main Drain No 3 to form a dense drainage network.

In addition to the Main Drain catchments, there are a number of small urban catchments that drain directly to the Broken and Goulburn rivers through the urban drainage system.

The Midland Highway forms a significant ridge which largely prevents cross-flows between the areas contributing flow to Main Drain No 2 and Main Drain No 3.

There are 47 retarding basins spread through East Shepparton. 5 are privately owned with the remaining 42 owned by Greater Shepparton City Council. Due to the general lack of grade across the area, all but 3 of these basins are pumped (or balanced) and as such operate as depression storages rather than the more typical gravity outlet controlled retarding basin. See table below. Further details are provided in WBM (2017).

There are no flow or water level gauges in any of the channels in East Shepparton.

Basin Name	Ownership	Outfall from Basin
Big 4 Shepparton	Private	
The Boulevard	GSCC	Pumped
Channel Road Estate (Support Basin)	GSCC	Balance pipe
Connolly Park Estate	GSCC	Pumped
Connolly Park (Support Basin)	GSCC	Balance pipe
Crestwood Estate	GSCC	Pumped
Ducat Reserve (Relief Basin)	GSCC	Gravity
Enterprise Drive	GSCC	Pumped
Grammar Park Estate	GSCC	Pumped
Ivanhoe	GSCC	Pumped
Kensington Gardens	Private	Pumped
Kialla Greens	GSCC	Gravity
Kialla Lakes (Lake Kialla)	GSCC	
Kialla Lakes (Lake Amaroo)	GSCC	Balance pipe
Kialla Lakes (Lowanna Waters)	GSCC	Balance pipe
Lifestyle Communities	GSCC	Pumped
Lifestyle Communities (Support Basin)	GSCC	Balance pipe
Market Place	Private	Pumped
Mercury Drive	GSCC	Pumped
Orchard Circuit	GSCC	Pumped
Parkside Gardens Estate (Wetland Basin)	GSCC	Pumped
Parkside Gardens Estate (Support Basin 1)	GSCC	Balance pipe
Parkside Gardens Estate (Support Basin 2)	GSCC	Balance pipe
Parkside Gardens Estate (Support Basin 3)	GSCC	Balance pipe
Parkside Gardens Estate (Support Basin 4)	GSCC	Balance pipe
Perrivale	GSCC	Pumped
Perrivale (Support Basin)	GSCC	Balance pipe
Pine Park Estate	GSCC	Pumped
River Rise Estate	GSCC	
Riverview Estate	GSCC	Pumped
Ross Alan Drive	GSCC	Pumped
Seven Creeks Estate	GSCC	
Shepparton East Drainage Scheme	GSCC	Pumped
Sherbourne Estate	GSCC	Pumped
Sherbourne Estate (Support Basin)	GSCC	Balance pipe
Smythe Street	GSCC	Gravity
Sofra Drive	GSCC	Pumped

Basin Name	Ownership	Outfall from Basin
Southdown Estate	GSCC	Pumped
Southdown Estate (Support Basin)	GSCC	Balance pipe
Telford Drive	GSCC	Pumped
Telford Drive (Support Basin)	GSCC	Balance pipe
Vision Australia	Private	
Windsor Park Estate	GSCC	Pumped
Windsor Park Estate (Support Basin 1)	GSCC	Balance pipe
Yakka Estate	GSCC	Pumped
Zurcas Lane	GSCC	Pumped
405 Goulburn Valley Highway	Private	Pumped

Properties at Risk of Flooding

An estimate of the number of properties at risk from flooding was produced by WBM (2017) using a simplified schema. A number of assumptions underpin the approach as surveyed floor levels were not available to the study team.

Due to the flat nature of the area (and absence of floor level data), the majority of properties have been categorised at the highest risk category (category 5). This is because the assessment is based on property boundaries and as such if any water, no matter how shallow or expansive, is on more than 5% of the property it is deemed at risk.

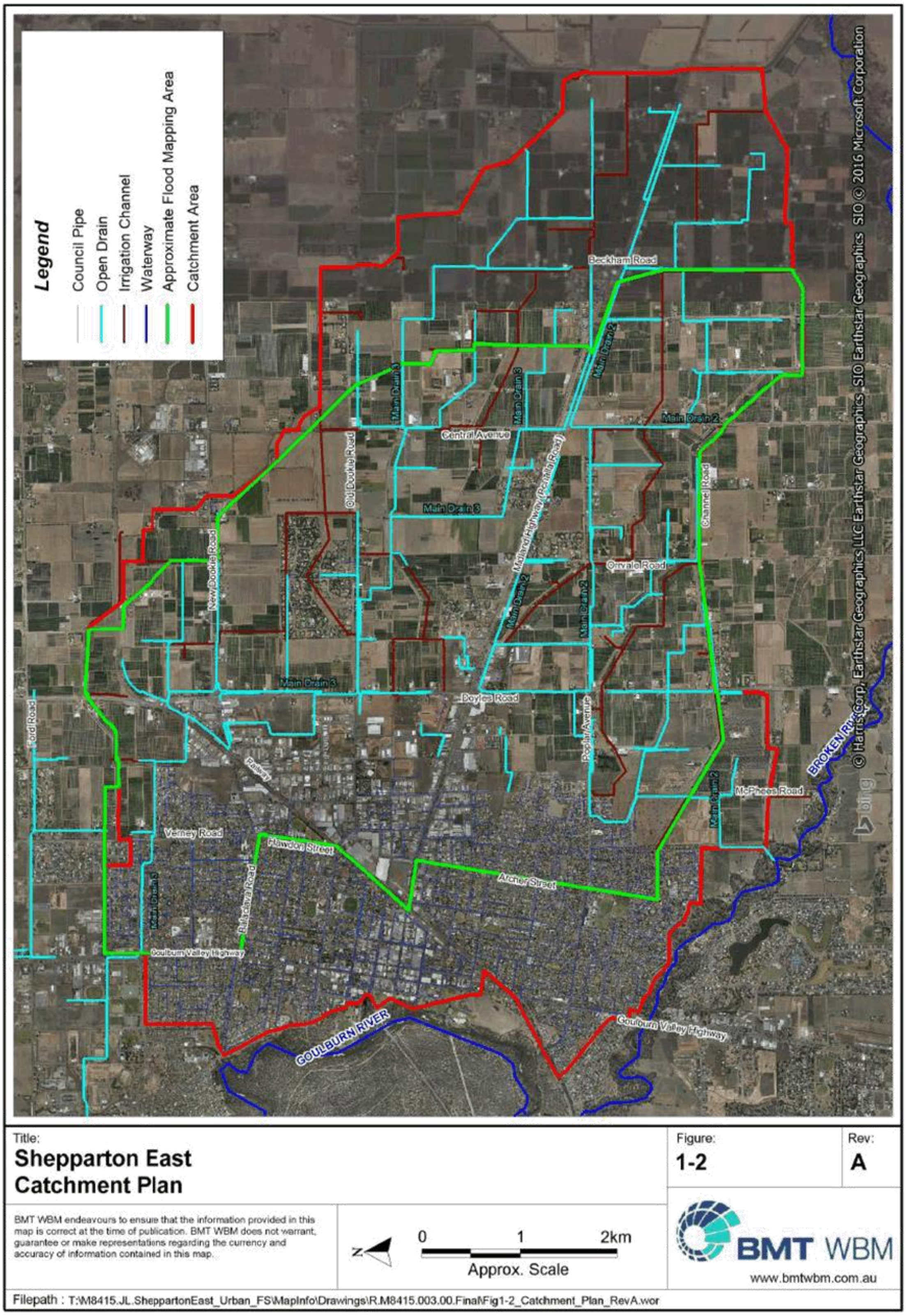
Schema:
Category 1 – the property is above the 2% AEP but below the 1% AEP flood level
Category 2 – the property is above the 5% AEP but below the 2% AEP flood level
Category 3 – the property is above the 10% AEP but below the 5% AEP flood level
Category 4 – the property is above the 20% AEP but below the 10% AEP flood level
Category 5 – the property is below the 20% AEP

Existing conditions	Category 1	Category 2	Category 3	Category 4	Category 5
No of properties within category	321	564	408	279	1,585
Flood size	Up to 1% AEP	Up to 2% AEP	Up to 5% AEP	Up to 10% AEP	Up to 20%AEP
No of properties at risk of flooding	3,157	2,836	2,272	1,864	1,585

Past Floods

A significant rain and flood event occurred on 27th & 28th February 2013. The flood was estimated by WBM (2017) as between a 0.5% and 0.2% AEP (200 to 500 year ARI) event. Peak discharges at key locations and the approximate AEPs are listed in the table below.

- ABC Shepparton reported that "*Flash flooding has inundated homes, closed roads and caused the evacuation of residents from an aged-care facility in the Goulburn Valley. Official rainfall gauges* (the BoM AWS at Shepparton airport) *say 50 to 65 millimetres of rain has fallen in Shepparton since yesterday afternoon however some residents have reported over 100 millimetres of rainfall.*"



East Shepparton drainage network

- One resident reported that the rain started at 5 o'clock. By 7 o'clock there was 98mm in the gauge and by morning it had a further 42mm in it (a total of 140mm).
- Further local rainfall recordings are provided in the table below.
- SES reported 4 houses inundated with water above the floor boards.
- The following roads were closed in Shepparton:
  - Drummond Road
  - King Richard Drive
  - Ross Allen drive
  - Kakadu Drive
  - Matilda Drive
  - Mehmet Drive
  - Orchard Circuit
  - Grace Road between Barmah Road and Shepparton Zeerust Road
  - Pine Road
  - Merino Drive
  - Byass Street

LOCAL RAINFALL DATA – COLLECTED AFTER THE EVENT						
Collected by:	**Easting**	**Northing**	**Reading 1**	**Reading 2**	**Reading 3**	**Total**
Trevor Birch 47 Archer St, Solar City Market	357700	5972680	to 5:15pm 45mm	to ~7pm 65mm	to 10:45pm 25mm	135mm
Megan McFarlane 1300 Midland Hwy East Shepparton	368800	5968080	to 7pm 102mm	to 7am (28.02.2013) 50mm		152mm
Don Colbert 1 Bregan Court, Grahamvale)	360410	5973210	to 8:30pm 170mm	Said it stopped raining for ~15mins at ~6:30 to 7pm	Neighbour's gauge overtopped at 150mm	170mm
Lorraine and Gordon Threlfull 14 Dobson Road Grahamvale 0427214627	360570	5973710	4pm to 7:15pm 114mm	7:15pm to 8am (28.02.2013) 48mm		162mm
Owen Power 27 Hicken Cres. 58214195	356090	5974950	4pm to 8am 125mm			125mm
Helen Williams 65 Ebbott Road 58292522	364800	5969260	4pm to 7am 140mm			140mm
Helen Williams 535 Old Dookie Rd 58292522	363290	5973300	4:10pm to 7:15pm 75mm	7:15pm to 9pm 50mm	9pm to 7am (28.02.2013) 10mm	135mm
Dimits Orchard 223 Doyles Road	359420	5972210	to 6pm 96mm	6pm to 9pm 44mm	9pm to 7am (28.02.2013) 16mm	156mm
Sue Wallington 6 Holstein Court	357780	5976220	4pm to 9am (28.02.2013) 136.9mm			136.9mm

<table>
<tr><th colspan="7">LOCAL RAINFALL DATA – COLLECTED AFTER THE EVENT</th></tr>
<tr><th>Collected by:</th><th>Easting</th><th>Northing</th><th>Reading 1</th><th>Reading 2</th><th>Reading 3</th><th>Total</th></tr>
<tr><td>Graeme Jackson
Unit 100 / 80 Channel Road, Kensington Gardens
5831 5877</td><td>358070</td><td>5969480</td><td>5pm to 7:30am (28.02.2013)
66mm</td><td></td><td></td><td>66mm</td></tr>
<tr><td rowspan="2">Dennis Collins
590 Old Dookie Road</td><td rowspan="2">363780</td><td rowspan="2">5972970</td><td>Total to the following day
140mm</td><td></td><td></td><td>140mm</td></tr>
<tr><td colspan="4">(same rainfall depth recorded by his neighbours at 710 Old Dookie Road and at 285 Boundary Road)</td></tr>
<tr><td rowspan="2">Brett Laws
365 Hosie Road
0419144351</td><td rowspan="2">366480</td><td rowspan="2">5970840</td><td>4:30pm to 6:30pm
100mm</td><td>6:30pm to 7am (28.02.2013)
72mm</td><td></td><td>172mm</td></tr>
<tr><td colspan="4">(same rainfall depth recorded by his brother at 339 Hosie Road)</td></tr>
<tr><td>Ron Davies
405 Midland Hwy
58292323</td><td>360330</td><td>5971600</td><td>4:30pm to 6:30pm
100mm</td><td>6:30pm to 7am (28.02.2013)
60mm</td><td></td><td>160mm</td></tr>
<tr><td>Ross Reddrop
540 New Dookie Road, Lemnos
0412606341</td><td>363140</td><td>5974380</td><td colspan="2">Has an AWS</td><td></td><td>128mm</td></tr>
<tr><td>Peter Moller
Rubicon Water
8 Grammar Court
5820 8851</td><td></td><td></td><td></td><td></td><td></td><td>130mm</td></tr>
<tr><td>Charles DuBourg
Kialla
0428210477</td><td>360643.1</td><td>5966723.7</td><td colspan="2" rowspan="2">Guy Tierney at GBCMA has Excel spreadsheet of weather station data</td><td></td><td>59mm</td></tr>
<tr><td>IK Caldwell
Grahamvale
0428210477</td><td>360098.7</td><td>5974651.5</td><td></td><td>150mm</td></tr>
</table>

Estimated flow and AEP of the flood at key locations							
Location	**Beckham Road**	**Central Avenue**	**Doyles Road**	**Main Drain No 2 Outlet**	**314 Old Dookie Road**	**Railway**	**Main Drain No 3 Outlet**
Peak flow (m^3/s)	17.8	16.2	20.9	20.1	25.9	36.4	35.6
AEP	>0.2%	0.5% - 0.2%	~0.5%	~1%	~0.5%	0.5% - 0.2%	0.5% - 0.2%

Rain to Flood and Peak – Typical Response Times

Under heavy continuing rain conditions, floods develop and rise quickly across East Shepparton, more so when the area is wet. Warning times are short with flooding likely to develop within an hour or so of heavy rain starting.

MAIN DRAIN No 2				
Location	Time from start of heavy rain			
	To start of rise	To inundation	To peak	To reduced flows
Beckham Road	45 - 60 minutes	60 - 75 minutes	65 - 90 minutes	~6 hours
Central Avenue	~1 hour	~90 minutes	~ 2 hours	~10 hours
Doyles Road	~1 hour	~90 minutes	3.5 - 4 hours	10 - 15 hours
Outlet	~2 hours	2.5 - 3 hours	4 - 6 hours	18+ hours

MAIN DRAIN No 3				
Location	Time from start of heavy rain			
	To start of rise	To inundation	To peak	To reduced flows
314 Old Dookie Rd	~60 minutes	75 minutes	2 – 4 hours	~8 hours
Railway	~2 hours	3 - 4 hours	8 – 10 hours	~15 hours
Outlet	1 - 2 hours	2 to 3 hours	~10 hours	15 – 20 hours

Flood Mapping

A comprehensive set of flood inundation maps has been produced for East Shepparton (WBM, 2017) – see Appendix F. Maps were produced for the 20%, 10%, 5%, 2%, 1%, 5% and 0.2% AEP flood events under existing conditions. While future conditions including climate change scenarios were modelled and mapped, those results are not presented or discussed herein. Each map set comprises:

- Flood extent;
- Flood depth in metres;
- Flood level in m AHD;
- Velocity; and
- Hazard.

Mapping is available from Council, GBCMA and through FloodZoom. The study reports (WBM, 2017) are also available through FloodZoom.

Command, Control and Coordination

The responsible agency for the Command, Control and Coordination of floods is the Victoria State Emergency Service (VICSES).

VICSES will assume overall control of the response to flood incidents. Other agencies will be requested to support operations as detailed in this Plan. Control and coordination of a flood incident shall be carried out at the lowest effective level and in accordance with the State Emergency Response Plan (EMMV Part 3). During significant events, VICSES will conduct incident management using multi-agency resources.

Divisional Command will be located at the Hume Region Divisional Command Centre Shepparton and Tatura to manage the Shepparton community.

The Incident Control Centre (ICC) for management of floods is located at the CFA Headquarters, 195 Numurkah Road, North Shepparton or at the VICSES North East Regional Headquarters, 64 Sydney Road, Benalla.

Indicative Flood / No Flood Guidance Tool for East Shepparton

As the BoM does not currently provide flash flood forecasts other than in very general terms, all actions must be driven by rain and / or observations of elevated flows in drain and the start of overland flows.

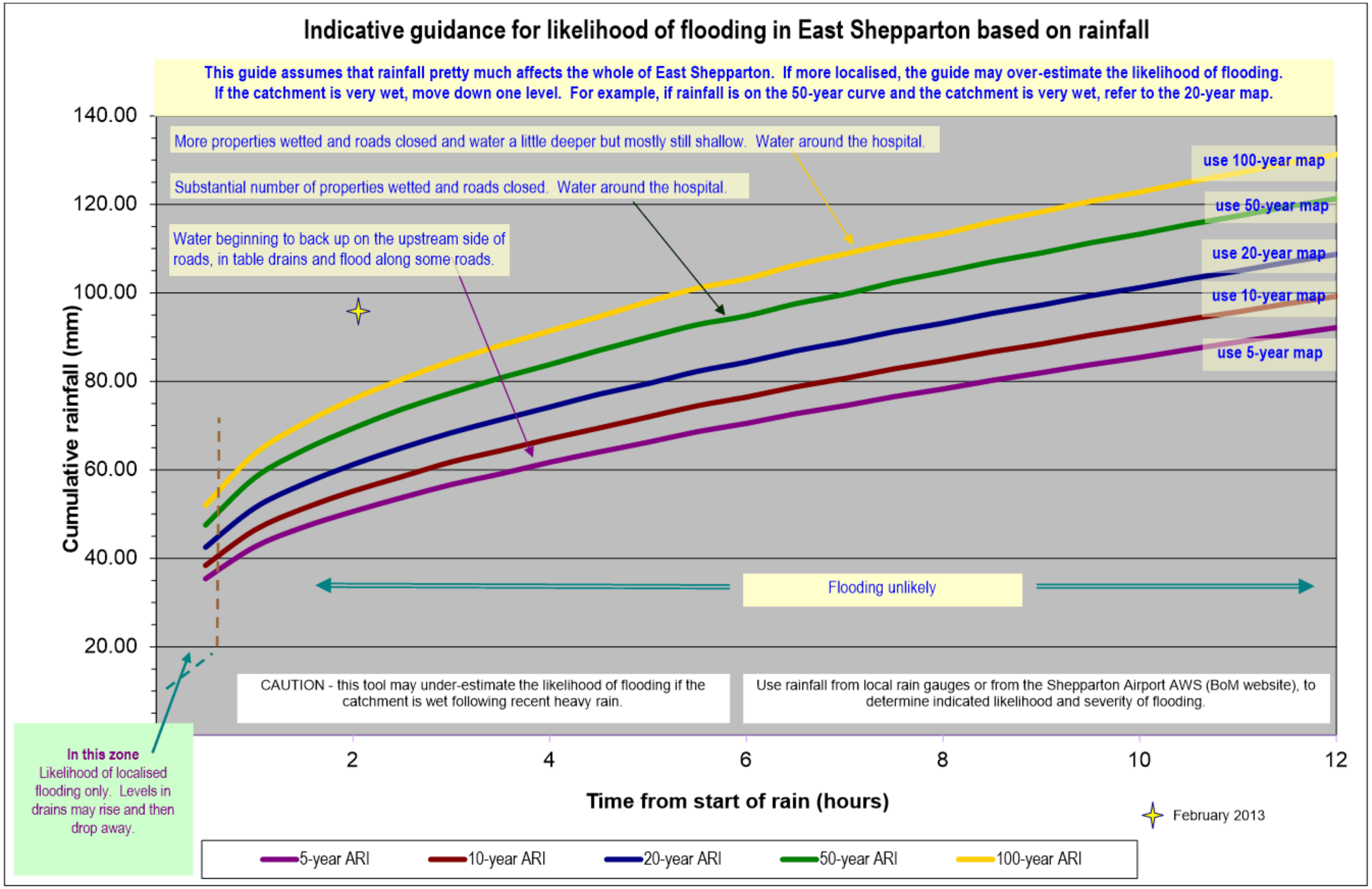
It is suggested that the indicative quick look 'flood / no-flood' tool developed for East Shepparton (see below) will provide an initial heads-up of the likelihood and scale of possible flooding. **Local rainfall data** determined from local reports or from an **interpretation of BoM weather radar images** can be used to determine an appropriate rainfall depth for use in the tool. Rainfall reported from the **Shepparton Airport AWS** (available from the BoM website at 30 minute intervals and occasionally more frequently) will provide near real-time data as well as a basis for calibration of radar imagery.

It should be noted that the tool provides indicative guidance only that can then be related to the flood inundation maps (and GIS datasets) produced by WBM (2017), a sub-set of which is provided in Appendix F. The flood extent mapping and report are also available through FloodZoom.

The rainfall that produces each new flood event should be added to the indicative tool as a dot along with the date. It is also suggested that information about the area over which the rainfall occurred and the consequences should be added to the *past floods* and *flooding consequences* sections of this Appendix C.

Local Data

Source local knowledge (e.g. collect private rain gauge data).



Indicative guidance for likelihood of flooding in East Shepparton based on rainfall
This guide assumes that rainfall pretty much affects the whole of East Shepparton. If more localised, the guide may over-estimate the likelihood of flooding. If the catchment is very wet, move down one level. For example, if rainfall is on the 50-year curve and the catchment is very wet, refer to the 20-year map.
More properties wetted and roads closed and water a little deeper but mostly still shallow. Water around the hospital.
Substantial number of properties wetted and roads closed. Water around the hospital.
Water beginning to back up on the upstream side of roads, in table drains and flood along some roads.
use 100-year map
use 50-year map
use 20-year map
use 10-year map
use 5-year map
Flooding unlikely
CAUTION - this tool may under-estimate the likelihood of flooding if the catchment is wet following recent heavy rain.
Use rainfall from local rain gauges or from the Shepparton Airport AWS (BoM website), to determine indicated likelihood and severity of flooding.
In this zone
Likelihood of localised flooding only. Levels in drains may rise and then drop away.
Cumulative rainfall (mm)
140.00
120.00
100.00
80.00
60.00
40.00
20.00
2
4
6
8
10
12
Time from start of rain (hours)
February 2013
5-year ARI
10-year ARI
20-year ARI
50-year ARI
100-year ARI

APPENDIX C4 - TALLYGAROOPNA FLOOD EMERGENCY PLAN

Overview of Flooding Consequences

The township of Tallygaroopna is located 15 km north of Shepparton. The 2007 census recorded a population of 270 people while the 2016 census recorded 579 people in the Tallygaroopna Census area. The town itself encompasses a total land area of approximately one square kilometre and is defined by the railway line and Goulburn Valley Highway to the west and general farmland to the east.

Three distinct waterways flow around the town itself:

- The Pine Lodge Creek flows approximately 3 kilometres to the south,
- Dainton's and Congupna Creek flow north-westerly past the town to the east.

Essentially rural in character, the town has a Primary School and a significant recreation reserve which services a number of different sports.

Greater Shepparton City Council has a pump and retarding basin on the northern side of the town near the silos.

Flood history.

- The Tallygaroopna area has a history of flooding with big floods recorded in 1919, 1939, 1956, 1974, 1993 and 2012. The highest recorded flood in Tallygaroopna occurred in 1993.
- The Tallygaroopna area has a flat landscape with grades of approximately a slope of 1 metre per kilometre.
- Tallygaroopna has experienced flash flooding caused by heavy rain over a short period of time (generally greater than 75mm in a 24 hour period).
- March 2012 – substantial flooding occurred due to very intense rainfall (up to 300mm occurring to the east of Tallygaroopna over three days).
- October 1993 - there was a slow onset flood caused primarily by the Broken River spilling over its banks at Gowangardie; which resulted in significant overland flows reaching Tallygaroopna and the surrounding districts.
- Tallygaroopna has experienced some inconvenience caused by overflowing of the Pine Lodge, Dainton's and Congupna Creek systems. These systems are sometimes filled by waters flowing out of the Broken River when it is in flood, which then take up to 3 days to peak in Tallygaroopna.
- There are no regulated water storages (e.g. dams) or large wetlands in this area.
- Large pockets of water can collect in low-lying areas before slowly draining away/drying out.
- Road closures are likely to include Victoria Road, Goulburn Valley Highway (north and south bound), Bowey Road and Tallygaroopna West / Bunbartha Road.

Aerial view of flooding at Tallygaroopna in March 2012
(source: Tallygaroopna Local Flood Guide, December 2016)

Slow onset flooding

The township has experienced slow moving flooding in the past primarily from the overflow of the Broken River via its creek system, which may last for one or more weeks, or even months on some occasions.

There are three water level gauges located on the Broken River at different points including:

- Broken River at Benalla
- Broken River at Casey's Weir
- Broken River at Orrvale near Shepparton (does not affect Tallygaroopna)

Flood warnings from the Broken River Gauges at Benalla and Casey's Weir will give an indication of the possibility and potential size of a flood based on historical records.

Flash flooding

Severe storm warnings will usually give an indication of what rainfall to expect during the storm event. The BoM may also issue warnings that include mention of flash flooding for particular areas depending on the estimated intensity of the expected rainfall.

HISTORIC FLOOD LEVELS AND FLOW ASSUMPTIONS

Note that no two floods are ever the same. Water flows and impacts of weather can be highly variable, especially after changes to the floodplain (road works, laser levelling).
The following levels and information are provided as a guide only and should be considered flexible and changeable according to the conditions at the time of an event.

The emergency service providers will be in charge of determining what actions to take according to information and data provided to them at the time by BoM and the Goulburn Broken CMA. The following information can assist in their decision making, however it should be noted that this may not be appropriate for the circumstances at the time of the event.

The following assumptions about flooding in the Tallygaroopna area are based on historic observations and the past behaviour of our river and creek systems as they peak at varying times. Historic records indicate that flooding usually occurs when;

- Generally there has not been any significant rain recorded in previous days,
- The catchments are saturated,
- The rainfall intensity has been evenly spread over a 24 hour period.

When the Broken River floods, it can spill over its banks in many places. If it spills over near Gowangardie Weir (from about 1km east of Gowangardie Weir through to Pine Lodge at the East Goulburn Main Channel), the water usually flows in a generally north easterly direction into five waterways:

- Congupna Creek
- Dainton's Creek
- Pine Lodge Creek
- Guilfus Creek
- O'Keefe Creek.

All five creeks flow toward the Tallygaroopna area as per the map.

A number of staff gauges have been installed along these creeks. See map of gauge locations, photos of gauges, key data and local contacts at Appendix I. A summary of data collected for these gauges is provided below.

	Gauge reading				
	Centreline of road	1993	2010	2012	
Benalla		5.50	4.43	N/A	
Caseys Weir		4.18	3.6	N/A	
O'Keefe Creek (refer to Appendix I)					
New Dookie Road 1.7km west of Pine Lodge North Road	2.078	2.34	1.71	1.82	
Pine Lodge Creek (refer to Appendix I)					
New Dookie Road 0.6km east of Pine Lodge North Road Road first covered 20m west of bridge	1.623	2.578	1.838	1.948	
Lemnos North Road 0.2km north of Congupna East Road	2.283	2.358	1.965	2.208	
Katamatite-Shepparton Road 1.9km north of Congupna East Road Road first covered 30m south of bridge	2.328	2.448	2.050	2.300	
Dainton's Creek (refer to Appendix I)					
New Dookie Road 0.3km east of Sidebottom Road	1.850	1.855	1.326	1.436	
Congupna East Road 0.3km west of Hudson Road	1.995	2.500	2.109	2.218	
Congupna Creek (refer to Appendix I)					
New Dookie Road 0.3km west of Kellows Road Road first covered 15m west of bridge	1.900	2.065	1.536	1.646	
Tungamah-Boundary Road 0.2km east of Sidebottom Road	2.074	2.938	2.409	2.519	
Katamatite-Shepparton Road 0.3km south of Thompsons Road Road first covered 20m north of bridge	2.125	2.585	2.176	2.235	
Guilfus Creek (refer to Appendix I)					
Katandra Main Road 0.8km east of Boundary Road Road first covered 20m west of bridge	2.050	2.025	1.495	1.795	
	[shaded]	Indicates road is wet across the centreline			

River Level (metres)	Gauge	Significant flood event	Impact on Tallygaroopna township
Not applicable	Benalla Gauge Gowangardie Weir Gauge	**March 2012**	Flash Flood: This flood was caused by localised intense rainfall of 300mm over a period of 3 days; not from the Broken River.
4.26m **6.39m**	Benalla Gauge Gowangardie Weir Gauge	**September 2010**	Tallygaroopna township was not flooded.

River Level (metres)	Gauge	Significant flood event	Impact on Tallygaroopna township
3.87m **5.64m**	Benalla Gauge Gowangardie Weir Gauge	**December 2010**	Tallygaroopna township was not flooded.
5.51 **6.57**	Benalla Gauge Gowangardie Weir Gauge	**October 1993**	Slow Onset flood – overland from creek system. Township flooded.

Possible Rainfall impacts based on local knowledge

The following rainfall measurements are based on readings from local resident rainfall gauges.

Bureau of Meteorology warnings are not in place on these systems.

- The first 50mm or so of localised rainfall should not cause any significant flooding; for example, 28 mm of rainfall was accumulated at the Numurkah gauge (15.3 km from Tallygaroopna) in the 24 hours to 09:00 on 4 September 2010 and no flooding was recorded.
- 75mm+ over a wide area may cause minor flooding; for example, 73 mm of rainfall was accumulated at the Numurkah gauge in the 48 hours prior to 09:00 on 9 December 2010.
- 125mm+ of localised rainfall event may cause widespread minor to moderate flooding
- 150mm+ of localised rainfall event may cause moderate flooding and some major
- 200mm+ of localised rainfall event will most likely result in major flooding; for example, 300mm of rainfall accumulated over a period of 3 days lead to flash flooding at Tallygaroopna.

If the above rainfall amounts happen over a shorter time frame; it is likely localised flash flooding will occur

ESTIMATED FLOOD TRAVEL TIMES

The flood travel times are estimates based on local resident knowledge and observations at previous events. These times were not provided from a formal source or Authority.

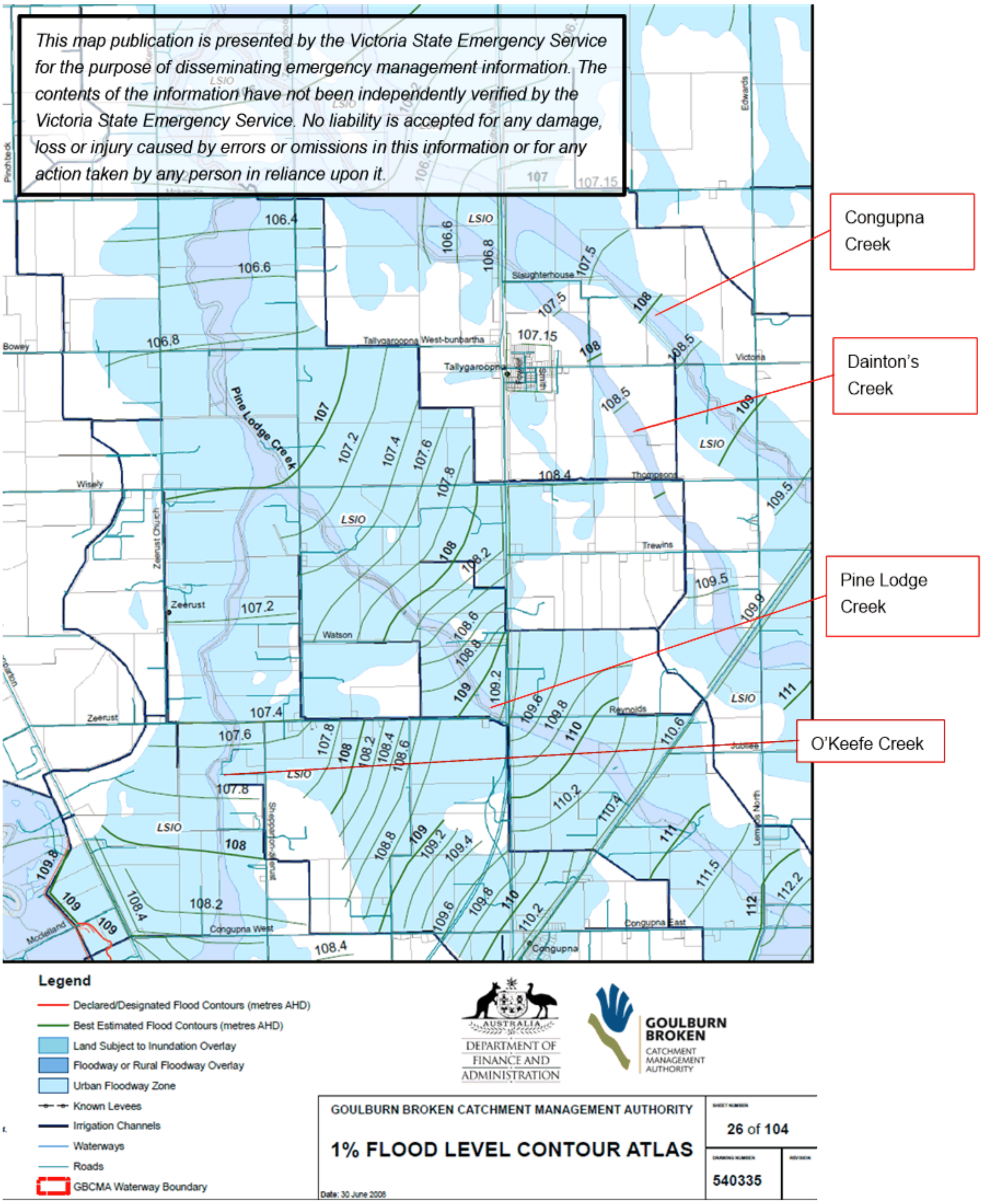
BENALLA TO GOWANGARDIE WEIR	Varies but 29 hours is a reasonable estimate – see Appendix B
GOWANGARDIE WEIR TO NEW DOOKIE ROAD	12 HOURS
NEW DOOKIE ROAD TO CONGUPNA EAST ROAD	1 DAY
CONGUPNA EAST ROAD TO KATAMATITE ROAD	1 DAY
KATAMATITE ROAD TO TALLYGAROOPNA	1 DAY
Between staff gauges at bridges over the Creeks – see Appendix I	

For the 1993 flood the passage of the flood peak from Gowangardie to Tallygaroopna took approximately 2.5 days.

Note: These flow times are based on observations from previous floods and may vary considerably depending on the weather and other conditions at the time of the event.

AUTOMATIC GAUGE READINGS

Tallygaroopna has no automatically monitored flood gauges.
The Broken River Gauge at Benalla can help to provide a guide as to the potential for floodwater that may come this way. Refer to Bureau of Meteorology website for River Heights
http://www.bom.gov.au/cgi-bin/wrap_fwo.pl?IDV60150.html


This map publication is presented by the Victoria State Emergency Service for the purpose of disseminating emergency management information. The contents of the information have not been independently verified by the Victoria State Emergency Service. No liability is accepted for any damage, loss or injury caused by errors or omissions in this information or for any action taken by any person in reliance upon it.
Congupna Creek
Dainton's Creek
Pine Lodge Creek
O'Keefe Creek
Pine Lodge Creek
Tallygaroopna
Zeerust
Congupna
Legend
Declared/Designated Flood Contours (metres AHD)
Best Estimated Flood Contours (metres AHD)
Land Subject to Inundation Overlay
Floodway or Rural Floodway Overlay
Urban Floodway Zone
Known Levees
Irrigation Channels
Waterways
Roads
GBCMA Waterway Boundary
AUSTRALIA
DEPARTMENT OF FINANCE AND ADMINISTRATION
GOULBURN BROKEN CATCHMENT MANAGEMENT AUTHORITY
GOULBURN BROKEN CATCHMENT MANAGEMENT AUTHORITY
1% FLOOD LEVEL CONTOUR ATLAS
26 of 104
540335
Date: 30 June 2008

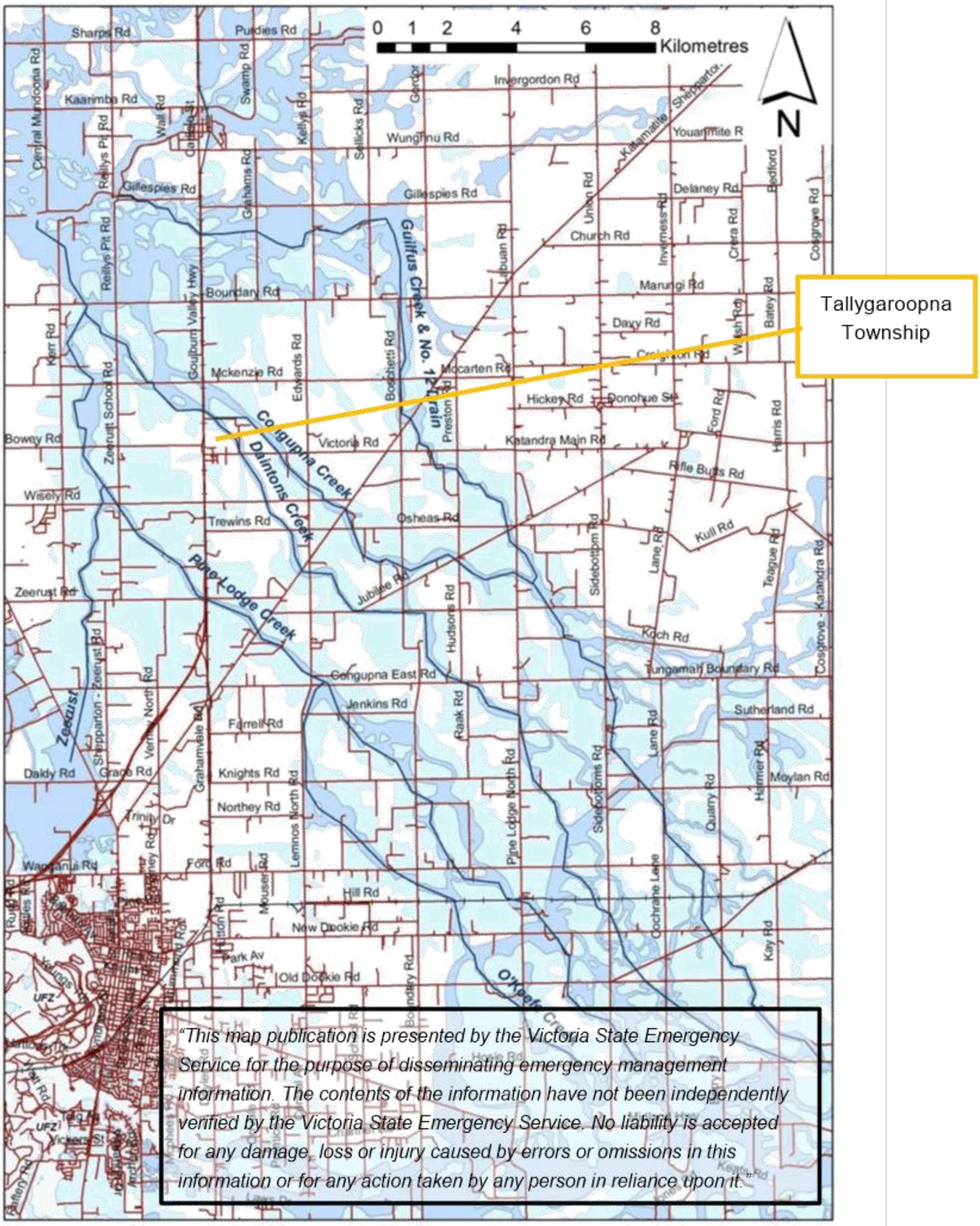
River level / rainfall gauge prompts and actions

River Level (metres)	Gauge location	General Information	General Action	Drain/Penstock/ Other Action	Roads
NA	**Localised Heavy rainfall or Thunderstorms may cause widespread minor to moderate flash flooding**	Flash flooding can occur at any time with short notice. Can only be guided for likelihood of flooding by BoM heavy rainfall /storm warnings.	Monitor BoM weather sites for rainfall indicators and flash flooding warnings. Source local knowledge (e.g. collect private rain gauge data). Creek level markers have been installed which may assist authorities in assessing the risk of flood. **Refer to Appendix I.**		
5.51 **6.57**	**Benalla Gauge** **Gowangardie Weir Gauge** **(Oct 1993 event level)**	Water overflow from Broken River at Gowangardie Weir will affect New Dookie Road at the Congupna, Dainton's, Pine Lodge and O'Keefe Creeks. Based on past events, the estimated flow time is 3 days to Tallygaroopna.	Consider delivery of 120m^3 sand and 3000 sandbags to car park beside Tallygaroopna CFA building	Communicate with G-MW to consider the possibility of directing flood flow into the East Goulburn Main Channel where there is capacity	Midland Highway possibly closed by VicRoads New Dookie Road possibly closed the next day
		First farm vulnerable properties to be affected are in Edwards, Trewins and Thompsons Roads.	Ensure VICSES is aware of vulnerable properties. Ensure residents/ landholders are advised of situation.		
		First township vulnerable properties to be affected are in North, Fowler, Church and Victoria Streets	Ensure VICSES is aware of vulnerable properties. Ensure residents/ landholders are advised of situation.		
			Inspect retardation basin pump and the outfall to ensure pump is operating.	Table drain pipes in Tallygaroopna West Road are clear to be checked to ensure clean and clear.	Council to provide road closure signs at appropriate locations by advised.

River Level (metres)	Gauge location	General Information	General Action	Drain/Penstock/ Other Action	Roads
		4 x 150mm pumps were deployed in 2012	Consider installing flood pumps at this railway bridge site as necessary. Contact VicTrack, V-Line and VicRoads to ensure they are aware of the emergency situation and imminent installation of flood pumps on Congupna Creek.	Check the outlet pipe and penstock into Congupna Creek at the railway bridge to ensure positive flow. Close this penstock once Congupna Creek exceeds the inflow level and positive flow is no longer possible.	
		1 x 150mm pump was deployed in 2012	Consider installing additional flood pump at retardation basin if town streets are not clearing quickly enough.		
				Request G-MW to review inlet gates into Congupna Creek at the end of Slaughterhouse Lane and others to ensure positive flow; otherwise these gates are to be closed	
				Consult with G-MW to consider opening channel gates along Thompson's Rd until positive flow no longer possible, then close.	Consider closing Thompsons & Trewins Roads to deter sightseeing traffic.
				Consult with G-MW to consider opening channel gates at Trewins and Reynolds Roads until positive flow is no longer possible then close.	

River Level (metres)	Gauge location	General Information	General Action	Drain/Penstock/ Other Action	Roads
			Monitor channel bank on Congupna Creek on Edwards Road adjacent to Bagley property.	Consider installing slides either side of Edwards Rd when Congupna Creek is full; 100mm Pump to be located on Congupna Creek Bank to discharge water from table drains into creek.	
			Consult with G-MW monitoring the gates at back of Maddison property in Edwards Road on Channel 17, 400m north of Trewins Road; Request G-MW to consider installing 150mm Pumps x2 to allow discharge of Dainton's Creek water into Channel 17.	Consult with G-MW to consider opening channel gates into this channel until positive flow is not possible, and then close. Ask G-MW to consider the possibility of lowering the level of the channel to accept this water.	
			Channel bank 5/17 east of Tallygaroopna to be monitored for integrity.		
			Consider sandbagging across Victoria Road itself on the 5/17 channel, 400m east of Slaughterhouse Lane.		Consider closing Victoria Road if required.
			Consider sandbagging across Victoria Road at Slaughterhouse Lane to direct water down the Lane.		
			Check that Congupna Creek (Drain 2/11) flows within its banks and does not surcharge back toward the township.		
			Consider sandbagging at Trewins/Edwards Road corner.		

Creek names and locations



APPENDIX C5 – CONGUPNA FLOOD EMERGENCY PLAN

Overview of Flooding Consequences

Community spirit in Congupna. Photo taken by Carolyn Allen.

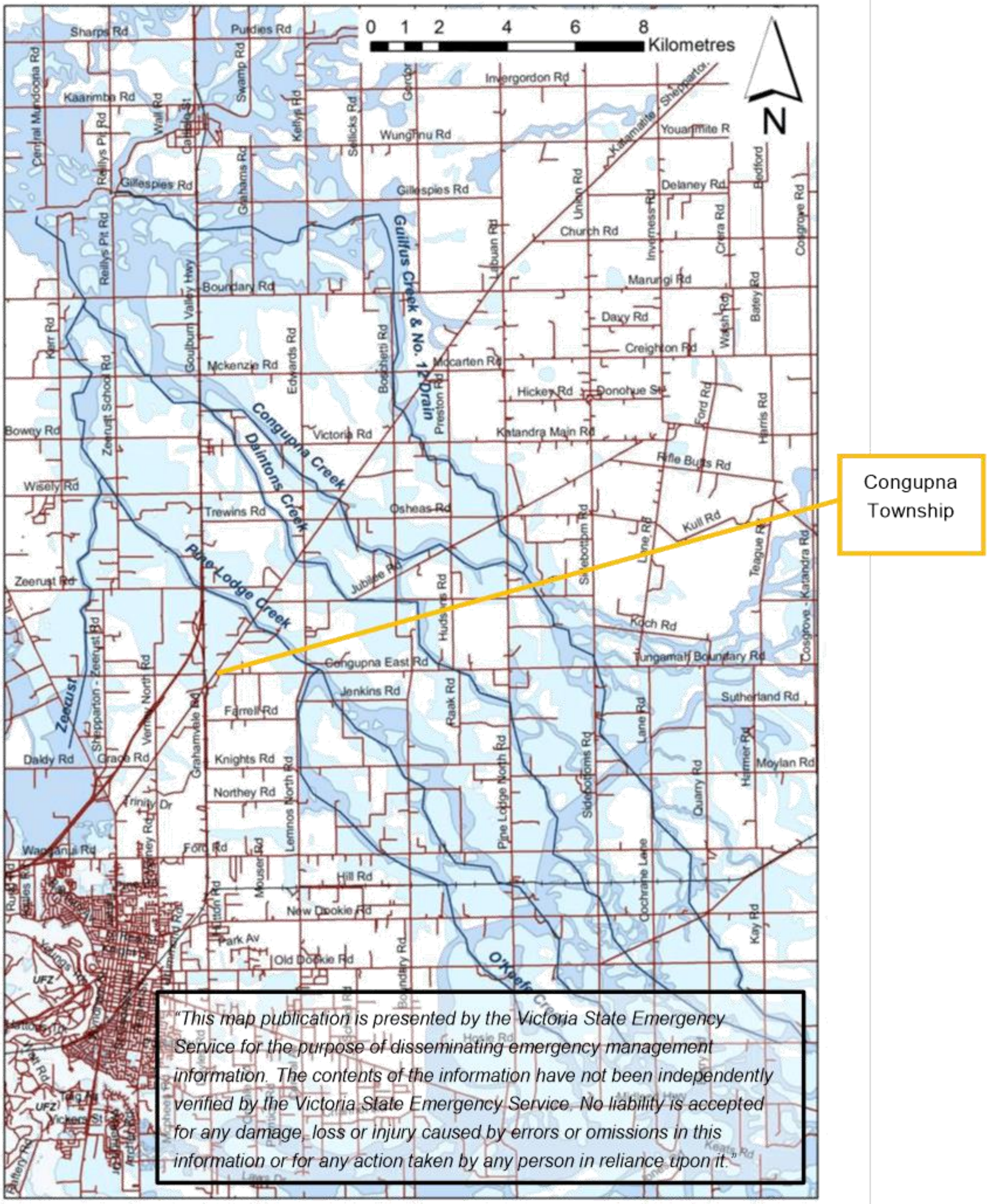
The township of Congupna is located 8 km north of Shepparton and has a population of 230 people (605 for Congupna Census area, 2016).

The town itself only encompasses a total land area of approximately one square kilometre and is situated at the crossroads of Goulburn Valley Highway and Katamatite-Shepparton Road and is surrounded by farmland on all sides

There are no distinct waterways that flow through the town itself, with over land run-off being the major source of floodwater. However, the Pine Lodge Creek will flood and threaten farming properties approximately 2 kilometres to the north and east of the town; with O'Keefe Creek also contributing to these flows.

Essentially rural in character, the town has a Primary School and a significant recreation reserve which services a number of different sports.

The map on the next page outlines the areas and river and creek systems, relative to the Shepparton urban development.



Flood level maps are available on the Goulburn Broken CMA website:
http://www.gbcma.vic.gov.au/default.asp?ID=floodplain_and_drainage

Are you at risk of flood?

- Congupna Township has had a significant history of flash flooding. Heavy rain over a short period of time (generally greater than 75mm in a 24 hour period) will result in the urban drainage network being overwhelmed, causing streets to flood for many hours.
- There are approximately six homes in the town itself which will be inundated during extreme events.
- In times of flood, five homes adjacent to Pine Lodge Creek will also experience some inconvenience through inundation. This creek system is often charged by waters flowing out of the Broken River when it is in flood, which then take up to two days to peak in the Congupna area.
- Road closures are likely to include Wallace Street and Katamatite-Shepparton Main Road.
- Congupna has a flat landscape with grades of approximately a slope of one metre per kilometre across the region.
- There are no regulated water storages (e.g. dams) or large wetlands in this area.
- Large pockets of water can collect in low-lying areas before slowly draining away/drying out.

Slow onset flooding

The township has experienced slow moving flooding in the past from the overflow of the Broken River via its creek system, which may last for one or more weeks, or even months on some occasions.

There are three water level gauges located on the Broken River at different points including:

- Broken River at Benalla
- Broken River at Casey's Weir
- Broken River at Orrvale near Shepparton (does not affect Congupna)

Flood warnings from the Broken River Gauges at Benalla and Casey's Weir will give an indication of the possibility and potential size of an overland slow onset flood based on historical records.

Flash flooding

Severe storm warnings will usually give an indication of what rainfall to expect during a storm event. The BoM may also issue warnings that include mention of flash flooding for particular areas depending on the estimated intensity of the expected rainfall.

HISTORIC FLOOD LEVELS AND FLOW ASSUMPTIONS

Note that no two floods are ever the same. Water flows and impacts of weather can be highly variable, especially after changes to the floodplain (road works, laser levelling).
The following levels and information are provided as a guide only and should be considered flexible and changeable according to the conditions at the time of an event.

The emergency service providers will be in charge of determining what actions to take according to information and data provided to them at the time by BoM and the Goulburn Broken CMA. The following information can assist in their decision making, however it should be noted that this may not be appropriate for the circumstances at the time of the event.

The Congupna area has a history of flooding with big floods recorded in 1919, 1939, 1956, 1974, 1993 and 2012.

Aerial view of flooding at Congupna in March 2012
(source: Congupna Local Flood Guide, December 2016)

The following assumptions about flooding in the Congupna area are based on historic observations and the past behaviour of our river and creek systems as they peak at varying times. Historic records indicate that flooding usually occurs when;

- Generally there has not been any significant rain recorded in previous days,
- The catchments are saturated,
- The rainfall intensity has been evenly spread over a 24 hour period.

When the Broken River floods, it can spill over its banks in many places. If it spills over near

Gowangardie Weir (from about 1km east of Gowangardie Weir through to Pine Lodge at the East Goulburn Main Channel), the water usually flows in a generally north easterly direction into five waterways:

- Congupna Creek
- Dainton's Creek
- Pine Lodge Creek
- Guilfus Creek
- O'Keefe Creek.

NB. Only Pine Lodge and O'Keefe Creeks flow toward Congupna area (see previous map).

A number of staff gauges have been installed along these creeks. See map of gauge locations, photos of gauges, key data and local contacts at Appendix I. A summary of data collected for these gauges is provided below.

	Gauge reading				
	Centreline of road	1993	2010	2012	
Benalla		5.50	4.43	N/A	
Caseys Weir		4.18	3.6	N/A	
O'Keefe Creek (refer to Appendix I)					
New Dookie Road 1.7km west of Pine Lodge North Road	2.078	2.34	1.71	1.82	
Pine Lodge Creek (refer to Appendix I)					
New Dookie Road 0.6km east of Pine Lodge North Road Road first covered 20m west of bridge	1.623	2.578	1.838	1.948	
Lemnos North Road 0.2km north of Congupna East Road	2.283	2.358	1.965	2.208	
Katamatite-Shepparton Road 1.9km north of Congupna East Road Road first covered 30m south of bridge	2.328	2.448	2.050	2.300	
Dainton's Creek (refer to Appendix I)					
New Dookie Road 0.3km east of Sidebottom Road	1.850	1.855	1.326	1.436	
Congupna East Road 0.3km west of Hudson Road	1.995	2.500	2.109	2.218	
Congupna Creek (refer to Appendix I)					
New Dookie Road 0.3km west of Kellows Road Road first covered 15m west of bridge	1.900	2.065	1.536	1.646	
Tungamah-Boundary Road 0.2km east of Sidebottom Road	2.074	2.938	2.409	2.519	

	Gauge reading				
	Centreline of road	1993	2010	2012	
Katamatite-Shepparton Road 0.3km south of Thompsons Road Road first covered 20m north of bridge	2.125	2.585	2.176	2.235	
Guilfus Creek (refer to Appendix I)					
Katandra Main Road 0.8km east of Boundary Road Road first covered 20m west of bridge	2.050	2.025	1.495	1.795	
		Indicates road is wet across the centreline			

River Level (metres)	Gauge	Significant Flood event	Impact on Congupna township
Not applicable	Benalla Gauge Gowangardie Weir Gauge	**March 2012**	Flash Flood: This flood was caused by localised intense rainfall of 300mm over a period of 3 days; not from the Broken River.
4.26m **6.39m**	Benalla Gauge Gowangardie Weir Gauge	**September 2010**	Congupna township was not flooded.
3.87m **5.64m**	Benalla Gauge Gowangardie Weir Gauge	**December 2010**	Congupna township was not flooded.
5.51 **6.57**	Benalla Gauge Gowangardie Weir Gauge	**October 1993**	Slow onset flood – overland from creek system. Township flooded.

Possible Rainfall impacts based on local knowledge

The following rainfall measurements are based on readings from local resident rain gauges. Bureau of Meteorology warnings are not in place on these systems. In general the following totals over around 12 hours:

- 50mm or so of localised rainfall should not cause any significant flooding
- 75mm+ over a wide area may cause minor flooding
- 125mm+ of localised rainfall may cause widespread minor to moderate flooding
- 150mm+ of localised rainfall may cause moderate flooding and some major
- 200mm+ of localised rainfall will most likely result in major flooding

If the above rainfall amounts happen over a shorter time frame; it is likely localised flash flooding will occur

ESTIMATED FLOOD TRAVEL TIMES

The flood travel times are estimates based on local resident knowledge and observations at previous events. These times were not provided from a formal source or Authority.

BROKEN RIVER BENALLA TO GOWANGARDIE WEIR	Varies from 18 to 37 hours but 29 hours is a reasonable first estimate – see Appendix B
BROKEN RIVER BREAKOUT GOWANGARDIE WEIR TO NEW DOOKIE ROAD	~12 HOURS
BROKEN RIVER BREAKOUT NEW DOOKIE ROAD TO CONGUPNA EAST ROAD	~1 DAY
BROKEN RIVER BREAKOUT CONGUPNA EAST ROAD TO KATAMATITE ROAD	~1 DAY
BROKEN RIVER BREAKOUT KATAMATITE ROAD TO TALLYGAROOPNA	~1 DAY
Between staff gauges at bridges over the Creeks – see Appendix I	

For the 1993 flood the passage of the flood peak from Gowangardie to Tallygaroopna took approximately 2.5 days so would be less for Congupna.

Note: These flow times are based on observations from previous floods and may vary considerably depending on the weather and other conditions at the time of the event.

AUTOMATIC GAUGE READINGS

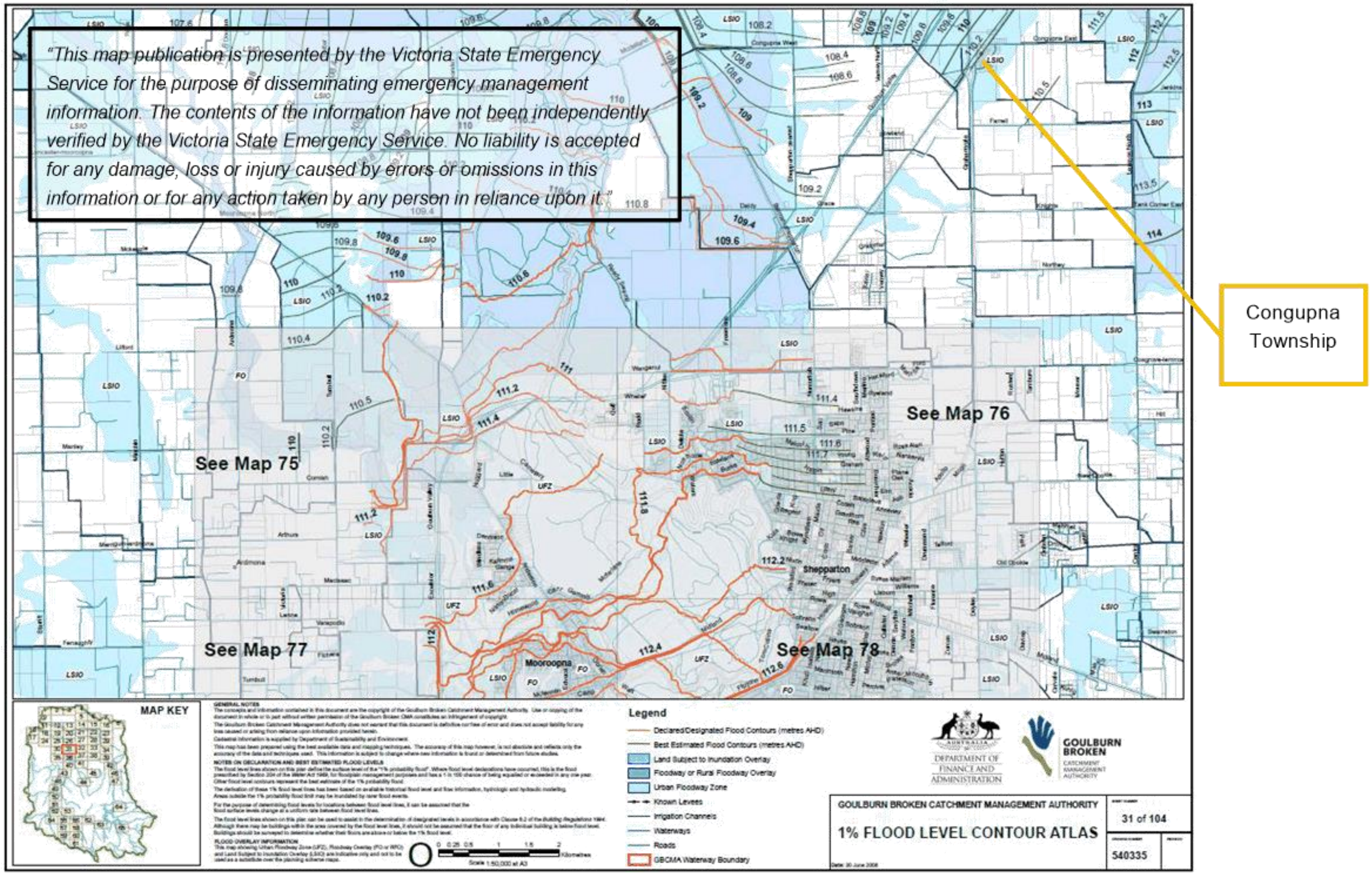
Congupna has no automatically monitored flood gauges.

The Broken River Gauge at Benalla can help to provide a guide as to the potential for floodwater that may come this way. Refer to Bureau of Meteorology website for River Heights **http://www.bom.gov.au/cgi-bin/wrap_fwo.pl?IDV60150.html**

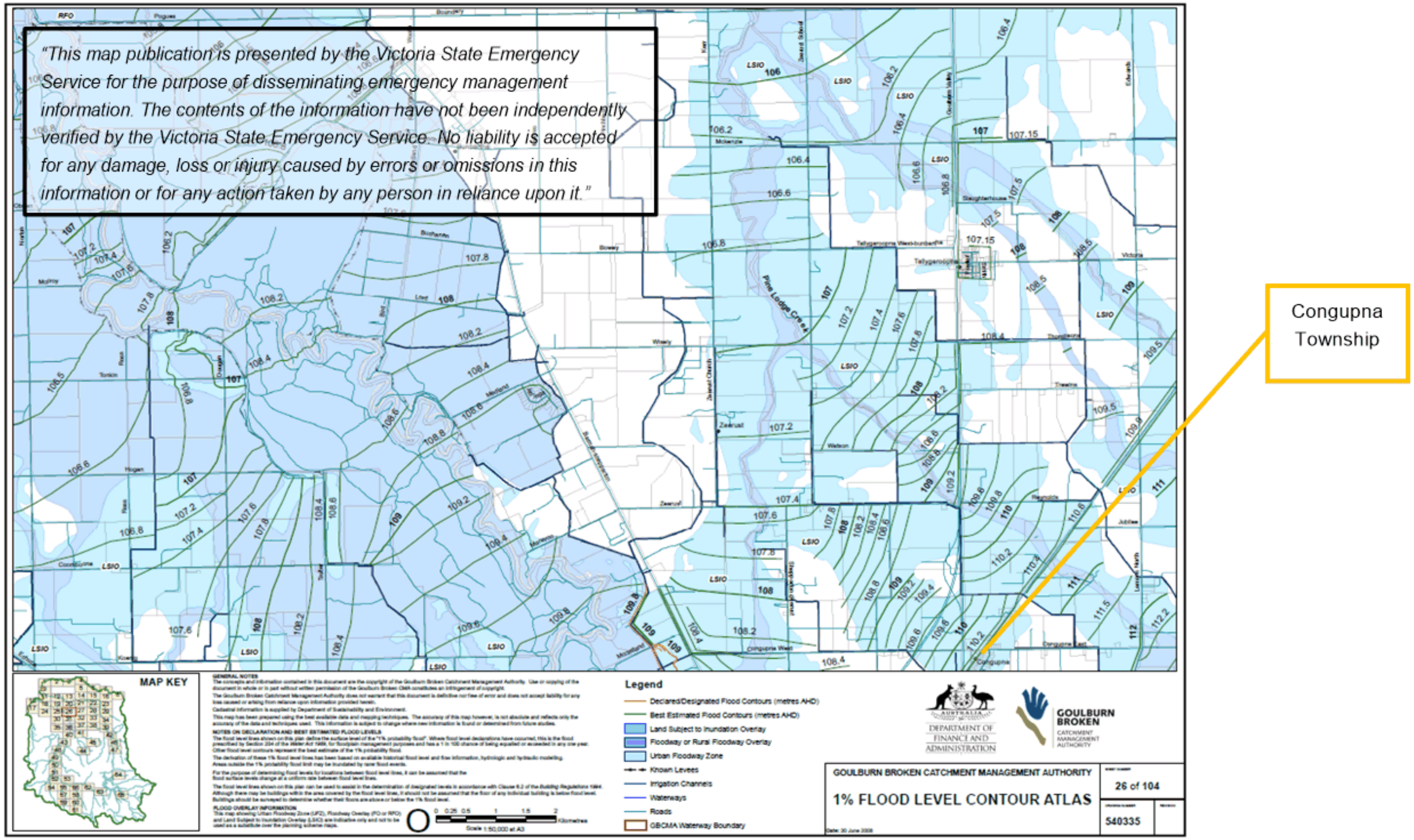
River level / Creek marker prompts and actions

River Level	Location	General Information / Impact	General Action	Drain/Penstock Other Action	Roads
	Localised Heavy rainfall or Thunderstorms may cause widespread minor to moderate flash flooding	Flash flooding can occur at any time with short notice. Can only be guided for likelihood of flooding by BoM heavy rainfall warnings.	Monitor BoM weather sites. Source local knowledge (e.g. collect private rain gauge data). Creek level markers have been installed which may assist authorities in assessing the risk of flood. **Refer to Appendix I.**		
5.51 **6.57**	**Benalla Gauge** **Gowangardie Weir Gauge** **(Oct 1993 event level)**	New Dookie Road is likely to over-top at Pine Lodge and O'Keefe Creeks which gives approximately 28 hours' notice to Congupna & 22 hours to Lemnos North	Ensure VICSES is aware of vulnerable properties in Congupna and Lemnos North. Ensure residents/landholders are aware of the situation.	Communicate with G-MW to inspect outfall pipe into G-MW drain, 600m north of the township to ensure it is clear and positive flow occurring. This pipe/penstock should be closed when negative flow occurs and install a high flow pump.	VicRoads will have closed Midland Highway and then New Dookie Road the next day.
			Consider delivery of 60m^3 sand and 1000 sandbags to Congupna recreation reserve; behind the goals at eastern end of oval.		Consider closing Old Dookie and Lemnos-Cosgrove Roads
			Consider sandbagging across Lemnos North Road at the flood flap pipes as necessary.	Consult with to G-MW to consider opening the gates into G-MW channels to the East of township until positive flow ceases and then close these gates.	Consider closing Lemnos North Road

River Level	Location	General Information / Impact	General Action	Drain/Penstock Other Action	Roads
				In consultation with G-MW, inspect outfall pipe into G-MW drain, 600m north of the Congupna township to ensure it is clear and positive flow occurring (this is an on-going maintenance issue). This flood flap will close when negative flow occurs and there is a need to consider installing a high flow pump.	
			Consider installing pumps at each end of Wallace Street to remove further rainfall; if necessary.	Check Penstocks in Wallace Street and keep open until positive flow ceases; then close.	
			Consider blocking 12 inch pipe/drain at South side of Congupna East Road. 400-500 metres from the corner of Lemnos North Road. That may help impede a small flow west to the Congupna Township.	Consult with G-MW to consider to opening gates into G-MW channels to the East of town until positive flow ceases and then close these gates.	Monitor Lemnos North and Congupna East Roads and prepare for closure.
			Consider sandbagging across Old Grahamvale Road where the pipe goes under the railway line.		Consider closing Old Grahamvale Road.
			It was noted that Drains need to be maintained and kept clear of weeds and debris to lessen the impact of floods.		



Flood level maps are available on the Goulburn Broken CMA website: *http://www.gbcma.vic.gov.au/default.asp?ID=floodplain_and_drainage*



"Floods can go higher than the 100-year flood level. In Australia, the flood planning level is usually defined by the 100-year flood. This is not a flood which happens once every 100 hundred years but one which has a 1 in 100 or 1% chance of occurring in each and every year. In a 70 year lifetime there is a 50/50 chance of a 1 in 100 flood being exceeded at any location." Text sourced from Flood Victoria Website: http://www.floodvictoria.vic.gov.au/centric/faq/common_misconceptions_about_flooding.jsp

APPENDIX C6 – KATANDRA WEST FLOOD EMERGENCY PLAN

Overview of Flooding Consequences

The Rath family property in Katandra Main Road, Katandra. Taken by Tori Rath.

The township of Katandra West is located 20km north east of Shepparton and has a population of 230 people (476 in Katandra West Census area, 2016).

The town itself only encompasses a total land area of approximately one square kilometre and is situated at the crossroads of Hickey and Sidebottom's Roads and is surrounded by farmland on all sides.

There are no distinct waterways that flow close to the town itself; with farmland run-off being the major source of floodwater. The Guilfus Creek will flood and threaten farming properties approximately 2 kilometres to the west of the town.

It is important to recognise that Guilfus Creek impacts the rural areas west of the Katandra West township, and not the township itself. The township of Katandra West is primarily impacted by direct rainfall. It is not impacted directly by riverine flooding at all.

Essentially rural in character, the town has a Primary School and a significant recreation reserve which services a number of different sports.

Greater Shepparton City Council has:

- A pump and basin in the grounds of the Katandra Football ground, Hickey Road.; and
- A pump in Black Street Katandra West (pumps into a nearby drain).

The map below outlines the areas and river and creek systems, relative to Katandra West and the Shepparton urban development.

Flood History

- The Katandra West district experienced flooding in 1919, 1939, 1956, 1974, 1993 and in March 2012.
- During significant events, the nearby Congupna and Guilfus creeks will flood the surrounding area and threaten farming properties to the west of town.
- Congupna and Guilfus creeks also flood if heavy rain falls in the Dookie Hills, as occurred in March 2012.
- The 2012 event overwhelmed the town's drainage network causing Black Street, Coleman Street, Burgman Street, Hickey Road, Donohue Street and King Street to flood for several days. Flooding in the Labuan Road area lasted longer than in the town
- Katandra West township has not had a significant history of flash flooding; however, heavy rain over a short period of time (generally greater than 75mm in a 24 hour period) will result in the urban drainage network being overwhelmed, causing streets to flood for a few hours.
- Generally no homes in the town should be inundated; however, the water will flow to the west and has flooded two houses on Labuan Road in the past.
- In times of flood, homes adjacent to Guilfus Creek may experience some inconvenience. This creek system is often charged by waters flowing out of the Broken River when it is in flood, which then take up to 2 days to peak in the Katandra West area.
- Katandra West has a flat landscape with an approximate slope of 1 metre per kilometre across the region.
- The township of Katandra West is only at risk of overland flooding from local storm events.
- There are no regulated water storages (e.g. dams) or large wetlands in this area, meaning that large pockets of water can collect in low-lying areas before slowly draining away / drying out.

Significant Flood Events

March 2012 – substantial flash flooding occurred due to very intense rainfall (300mm occurring to the east of Katandra West over three days).

October 1993 - was a flood caused primarily by the Broken River breaking its banks at Gowangardie; which resulted in significant overland flows reaching the rural areas west of the Katandra West township.

Aerial view of flooding at Katandra West in March 2012
(source: Katandra West Local Flood Guide, December 2016)

Slow onset flooding

The township has experienced slow moving flooding in the past primarily from the overflow of the Broken River via its creek system, which may last for one or more weeks, or even months on some occasions.

There are three water level gauges located on the Broken River at different points including:

- Broken River at Benalla
- Broken River at Casey's Weir
- Broken River at Orrvale near Shepparton (does not affect Katandra West)

Flood warnings from the Broken River Gauges at Benalla and Casey's Weir will give an indication of the possibility and potential size of a flood based on historical records.

Flash flooding warnings

Severe storm warnings will usually give an indication of what rainfall to expect during the storm event. The BoM may also issue warnings that include mention of flash flooding for particular areas depending on the estimated intensity of the expected rainfall.

HISTORIC FLOOD LEVELS AND FLOW ASSUMPTIONS

Note that no two floods are ever the same. Water flows and impacts of weather can be highly variable, especially after changes to the floodplain (road works, laser levelling).
The following levels and information are provided as a guide only and should be considered flexible and changeable according to the conditions at the time of an event.

The emergency service providers will be in charge of determining what actions to take according to information and data provided to them at the time by BoM and the Goulburn Broken CMA. The following information can assist in their decision making, however it should be noted that this may not be appropriate for the circumstances at the time of the event.

The following assumptions about flooding in the Katandra West area are based on historic observations and the past behaviour of our river and creek systems as they peak at varying times. Historic records indicate that flooding usually occurs when;

- Generally there has not been any significant rain recorded in previous days,
- The catchments are saturated,
- The rainfall intensity has been evenly spread over a 24 hour period.

When the Broken River floods, it can spill over its banks in many places. If it spills over near Gowangardie Weir (from about 1km east of Gowangardie Weir through to Pine Lodge at the East Goulburn Main Channel), the water usually flows in a generally north easterly direction into five waterways:

- Congupna Creek
- Dainton's Creek
- Pine Lodge Creek
- Guilfus Creek
- O'Keefe Creek.

Nb. Only the Congupna and Guilfus Creeks flow toward the Katandra West area.

A number of staff gauges have been installed along these creeks. See map of gauge locations, photos of gauges, key data and local contacts at Appendix I. A summary of data collected for these gauges is provided below.

	Gauge reading				
	Centreline of road	1993	2010	2012	
Benalla		5.50	4.43	N/A	
Caseys Weir		4.18	3.6	N/A	
O'Keefe Creek (refer to Appendix I)					
New Dookie Road 1.7km west of Pine Lodge North Road	2.078	2.34	1.71	1.82	
Pine Lodge Creek (refer to Appendix I)					
New Dookie Road 0.6km east of Pine Lodge North Road Road first covered 20m west of bridge	1.623	2.578	1.838	1.948	
Lemnos North Road 0.2km north of Congupna East Road	2.283	2.358	1.965	2.208	
Katamatite-Shepparton Road 1.9km north of Congupna East Road Road first covered 30m south of bridge	2.328	2.448	2.050	2.300	
Dainton's Creek (refer to Appendix I)					
New Dookie Road 0.3km east of Sidebottom Road	1.850	1.855	1.326	1.436	
Congupna East Road 0.3km west of Hudson Road	1.995	2.500	2.109	2.218	
Congupna Creek (refer to Appendix I)					
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Tungamah-Boundary Road 0.2km east of Sidebottom Road	2.074	2.938	2.409	2.519	
Katamatite-Shepparton Road 0.3km south of Thompsons Road Road first covered 20m north of bridge	2.125	2.585	2.176	2.235	
Guilfus Creek (refer to Appendix I)					
Katandra Main Road 0.8km east of Boundary Road Road first covered 20m west of bridge	2.050	2.025	1.495	1.795	

	(shaded)	Indicates road is wet across the centreline

River Level (metres)	Gauge	Significant Flood event	Impact on Katandra West township
Not applicable	Benalla Gauge Gowangardie Weir Gauge	**March 2012**	Flash Flood: This flood was caused by localised intense rainfall of 300mm over a period of 3 days; not from the Broken River.
4.26m **6.39m**	Benalla Gauge Gowangardie Weir Gauge	**September 2010**	Katandra West township was not flooded.
3.87m **5.64m**	Benalla Gauge Gowangardie Weir Gauge	**December 2010**	Katandra West township was not flooded.
5.51 **6.57**	Benalla Gauge Gowangardie Weir Gauge	**October 1993**	The rural areas west of the Katandra West township were flooded from breakouts from the Broken River

Possible Rainfall impacts based on local knowledge

The following rainfall measurements are based on readings from local resident rain gauges. Bureau of Meteorology warnings are not in place on these systems. In general the following totals over around 12 hours:

- 50mm or so of localised rainfall should not cause any significant flooding
- 75mm+ over a wide area may cause minor flooding
- 125mm+ of localised rainfall may cause widespread minor to moderate flooding
- 150mm+ of localised rainfall may cause moderate flooding and some major
- 200mm+ of localised rainfall will most likely result in major flooding

If the above rainfall amounts happen over a shorter time frame; it is likely localised flash flooding will occur

ESTIMATED FLOOD TRAVEL TIMES

The flood travel times are estimates based on local resident knowledge and observations at previous events. These times were not provided from a formal source or Authority.

BROKEN RIVER BENALLA TO GOWANGARDIE WEIR	Varies from 18 to 37 hours but 29 hours is a reasonable first estimate – see Appendix B
BROKEN RIVER BREAKOUT GOWANGARDIE WEIR TO NEW DOOKIE ROAD	~12 HOURS
BROKEN RIVER BREAKOUT NEW DOOKIE ROAD TO CONGUPNA EAST ROAD	~1 DAY
BROKEN RIVER BREAKOUT CONGUPNA EAST ROAD TO KATAMATITE ROAD	~1 DAY
BROKEN RIVER BREAKOUT KATAMATITE ROAD TO TALLYGAROOPNA	~1 DAY
Between staff gauges at bridges over the Creeks – see Appendix I	

For the 1993 flood the passage of the flood peak from Gowangardie to Tallygaroopna took approximately 2.5 days.

Note: These flow times are based on observations from previous floods and may vary considerably depending on the weather and other conditions at the time of the event.

AUTOMATIC GAUGE READINGS

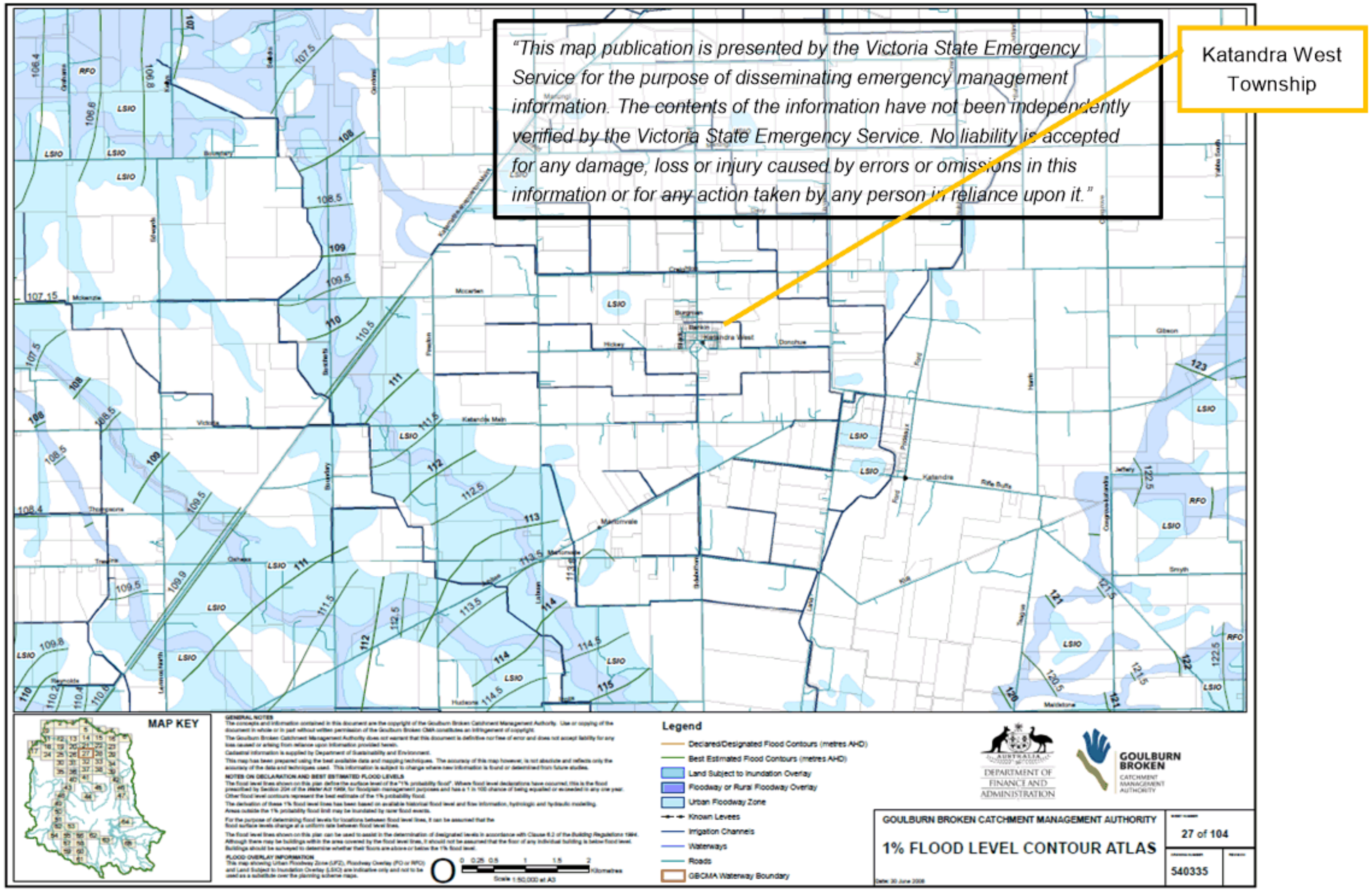
Katandra West has no automatically monitored flood gauges.

The Broken River Gauge at Benalla can help to provide a guide as to the potential for floodwater that may come this way. Refer to Bureau of Meteorology website for River Heights

http://www.bom.gov.au/cgi-bin/wrap_fwo.pl?IDV60150.html

River level / Creek marker prompts and actions

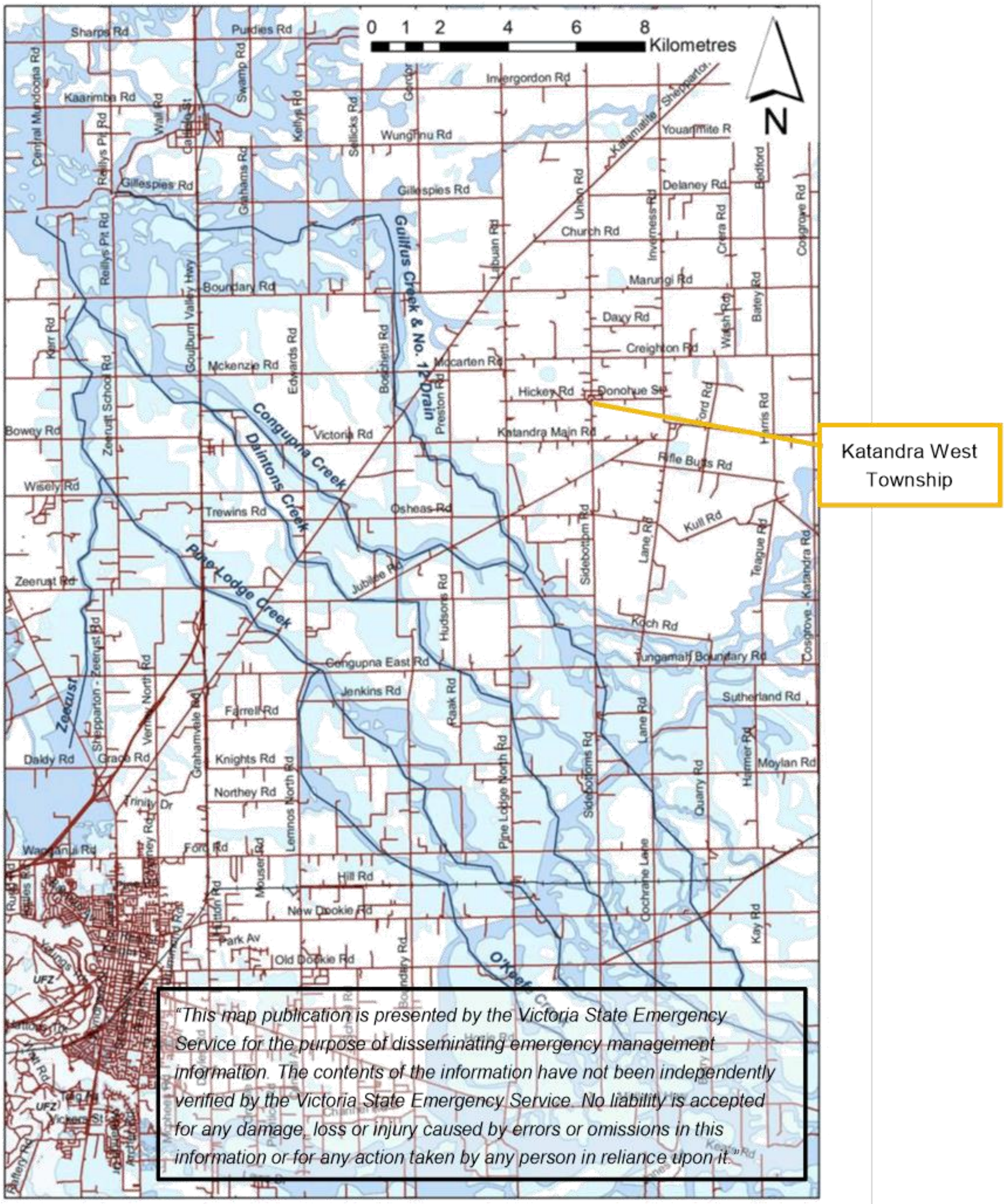
River Level	Gauge	General Information	General Action	Drain/Penstock/Other Action	Roads
	Localised Heavy rainfall or Thunderstorms may cause widespread minor to moderate flash flooding	Flash flooding can occur at any time with short notice. Can only be guided for likelihood of flooding by BoM heavy rainfall warnings.	Monitor BoM weather sites for rainfall indicators and flash flooding warnings. Source local knowledge (e.g. collect private rain gauge data). Creek level markers have been installed which may assist authorities in assessing the risk of flood. **Refer to Appendix I.**		
5.51 **6.57**	**Benalla Gauge** **Gowangardie Weir Gauge** **(Oct 1993 event level)**	New Dookie Road will over-top at Congupna, Dainton's, Pine Lodge and O'Keefe Creeks which gives just over 2 days' notice to Katandra West.		Communicate with G-MW to consider the possibility of directing flood flow into the East Goulburn Main Channel where positive flow is possible	VicRoads will most likely close Midland Highway and then New Dookie Road the next day
			Alert vulnerable properties in Sidebottom, Hickey, Labuan Roads and township	Check the drain from the retardation basin discharge point, to the west is clear	Consider placing "Road Closed" signs at these sites in preparation for closing
			Consider delivery of 80m3 sand and 2000 sandbags to the car park in front of the Recreation Reserve pavilion	Check pump is running in Bankin Street retardation basin. Check the outlet to the north is also clear.	
			Ensure appropriate channel banks are secure in Hickey Street	Check the pump is running in Hickey Street retardation basin	
As above				Flood flap on pipe in Union Road, north of the town to be closed to avoid any negative flow back south toward the township	



Flood level maps are available on the Goulburn Broken CMA website: *http://www.gbcma.vic.gov.au/default.asp?ID=floodplain_and_drainage*

"Floods can go higher than the 100-year flood level. In Australia, the flood planning level is usually defined by the 100-year flood. This is not a flood which happens once every 100 hundred years but one which has a 1 in 100 or 1% chance of occurring in each and every year. In a 70 year lifetime there is a 50/50 chance of a 1 in 100 flood being exceeded at any location." Text sourced from Flood Victoria Website: http://www.floodvictoria.vic.gov.au/centric/faq/common_misconceptions_about_flooding.jsp

Locality Creek System Map



APPENDIX C7 - TATURA FLOOD EMERGENCY PLAN

Overview of the Catchment

Tatura lies 17km south-west of Shepparton and 20km directly north of Murchison within the Mosquito Depression East Arm floodplain. In turn, the Depression is within the Deakin Basin. The eastern boundary of the Basin parallels the east side of the Depression's route.

The Mosquito Depression East Arm is a sub-catchment of the Mosquito Depression which originates south of Tatura in the general vicinity and to the west of Murchison. It drains into the Deakin Main Drain about 15km upstream from where the Drain outfalls into the Murray River, east (i.e. upstream) of Echuca.

The Mosquito Depression East Arm drains a highly modified 6.15km^2 catchment of rural pasture and orchards to Tatura. It comprises a network of shallow and wide interconnecting drainage paths on a low grade. Important features of the upstream catchment include agricultural storages / farm dams, irrigation channels, flood protection levees, road and rail embankments and culverts, and shallow interconnecting floodways. These features substantially attenuate flows.

Upstream of Tatura, the Mosquito Depression East Arm exists as two distinct branches, one from the south, the other from the east. The two branches are of similar length and have comparable catchment areas. However, agricultural storages and levees in the Eastern Branch impede the arrival of flood peaks at the town boundary by days.

The branches converge at Tatura to form a series of meandering and interlinked shallow depressions. Floodwaters enter the town via four flow paths from the south and east and drain through the town to the northwest before joining the main branch of Mosquito Depression.

Downstream from Tatura and on its way past Merrigum, the Depression winds through the catchment as a series of defined ephemeral flow paths although drainage is generally via the Mosquito Depression Drain, an open trapezoidal earth lined channel.

An extensive underground pipe network drains runoff from the developed areas of Tatura to the Southern and Eastern Branches of the Mosquito Depression East Arm. While drainage reserves have been designated along the Eastern Branch, significant development has occurred within the flood prone Southern Branch.

Tatura is cut diagonally by the Toolamba - Echuca railway embankment, which acts as a constriction to flows along the Southern Branch. Flows are conveyed via an underpass (~3.2m wide and 1.8m high). The majority of the town's flood prone properties are located along the Southern Branch in the area upstream of the embankment.

Flood History

Tatura's first experience with suburban flooding occurred in March 1950, when floodwaters rose rapidly in the area that is now Lake Bartlett and broke across Martin Street flooding shops and businesses in the Depression's natural course. Flooding occurred again in 1955, 1956, May 1974 and October 1993.

The 1955 flood is considered to be the largest on record. The May 1974 flood was not as severe and was contained by locals using portable and tractor-mounted pumps to pump flows down Service Street and into the Eastern Branch.

Large amounts of fill became available as the town's sewerage system was constructed and many low lying allotments within the floodplain were raised. Concern about development in the floodplain led to planning controls being put in place and construction by Council of banks of culverts within the Eastern Branch. A flood management plan was also implemented. The Plan utilised penstocks at Lake Bartlett to hold back flows in the Southern Branch while flows within town receded. Once sufficient capacity had returned within the town's drainage network, the penstocks were to be opened to allow Southern Branch flows to drain away via the natural depression. Local flood management has also involved cutting through roads and the deployment of pumps once the capacity of penstocks has been exceeded.

There is no rainfall or stream gauge data available for any flood producing storms within the catchment in the vicinity of Tatura.

Flood Behaviour

Flooding at Tatura has two sources: high intensity short duration storms that lead to localised rapid onset stormwater flooding within the township and long duration (36 hours or so) rainfall events that cause elevated flows within Mosquito Depression.

Overland flows through Tatura follow multiple flow paths with interconnections controlled by a range of constructed and natural features. For example, topography is flat, sinuosity is high, and there are numerous culverts, crossings and both natural and man-made levees. Further, the underground (trunk) stormwater drainage system can potentially convey a considerable portion of flow during some events as there are no restrictions on the exchange of water between the underground drainage network and overland flow paths. As a result, individual flow paths (and their relationship with others) are not always easily defined or predictable.

Localised stormwater flooding within town due to capacity constraints within the minor drainage network occurs, in general, much earlier, and is much smaller in magnitude, than resulting from flows in the Mosquito Depression East Arm.

Five electric pumps remain on standby at the Margaret Street Pumping Station to lift flows over an embankment into the Cussen Park Wetland once stormwater enters the Margaret Street pump well. The combined capacity of the pumps is approx. 3.4m^3/s (294ML/d).

The depth of flooding along drainage lines and in flood storage areas can be substantial. However, grades are flat and flows sluggish within the Depression. Floods travel slowly along the Depression and through Tatura with the result that the rise and recession are also slow. It can take several days for a flood to reach a peak and many more for it to drain. In the lower reaches, flooding can persist for anywhere from 14 days to 2 months.

Flood risk (based on depths and velocities as per ARR 2016) outside the drainage lines and storage areas is consider to be low for adults, children and vehicles

Blockages at drainage infrastructure, particularly in the vicinity of the railway bypass, will increase flood levels and extents.

A remote pocket of flooding will begin to develop in the vicinity of Hunter Street and between Unilever Foods and William Street as flood levels approach the 10% AEP (10yr ARI) event. This is backwater flooding caused by elevated water levels at the railway underpass pushing water back up the minor stormwater drainage network. It could be prevented by placing sandbags at drain outlets north and south of the railway embankment (i.e. those that drain the area affected) after any local runoff has escaped via the drainage network and before the peak of the flood passes through town.

Flood Impacts

Overview

Flood impacts in and around Tatura can be significant: multiple road closures, loss of access for residents, disruption to schools, child care centres and the hospital, property isolation, over-floor flooding, risks to emergency personnel during sand bagging and evacuation operations, and damage to buildings constructed below flood level. During major floods, there are also likely to be substantial rural and infrastructure flood damages.

Properties at Risk of Flooding

The number of properties at risk of flooding along with the number of buildings (those that are habitable: does not include garages or carports) at risk of over-floor flooding was calculated by WBM (2006). A summary of that analysis is provided in the table below.

ARI (years)	AEP	Number of properties at risk	
		Flooded above ground level	Flooded above floor level
10	10%	163	32
20	5%	220	46
50	2%	312	92
100	1%	399	132
500	0.2%	483	201

Caravan Parks

The Tatura Caravan Park is inundated from around the 10-year ARI (10% AEP) event.

Known or possible community infrastructure impacts including:

- Telstra exchange
- CFA Fire Station / Incident Command Centre
- Hospital and Aged Care Facility
- Schools and Child Care Centres
- Ovals and sporting facilities including the bowls club, tennis courts and swimming pool

Road closures

These are listed in the Flood Intelligence Card below and can also be determined from the flood mapping delivered by WBM (2006). See also FloodZoom.

Flood Mapping

A set of flood inundation maps for Tatura (depth and water surface elevation) has been produced for emergency management and response purposes (WBM, 2006). Maps were produced for 5 design events (i.e. 10, 20, 50, 100 & 500 year ARI).

Mapping is available from Council, GBCMA and through FloodZoom. The study report (WBM, 2006) is also available through FloodZoom.

Command, Control and Coordination

VICSES will assume overall control of the response to flood incidents. Other agencies will be requested to support operations as detailed in this Plan. Control and coordination of a flood incident shall be carried out at the lowest effective level and in accordance with the State Emergency Response Plan (EMMV Part 3). During significant events, VICSES will conduct incident management using multi-agency resources.

Divisional Command will be located at the Hume Region Divisional Command Centre Shepparton and Tatura to manage the local community.

Flood Intelligence and Action Table for Tatura

Introduction

Flood impacts described in the following tables relate primarily to flooding from the Mosquito Depression. It should be noted that local impacts, or impacts in excess of those indicated, may occur, especially in the event of locally heavy rain in and around Tatura, especially if that rain coincides with high flows within the Depression. Similarly, local increases in flood levels and impacts may result from local factors such as blockages at culverts and from obstructions within overland flow paths.

Notes:

1. While flood intelligence cards provide guidance on the relationship between flood magnitude and flood consequences, flood intelligence records are approximations. This is because no two floods at a location, even if they peak at the same height, will have identical impacts. Further, the hydrologic and hydraulic modelling that underpins much of the intell detailed below is informed by a number of assumptions and approximations that are unlikely to be replicated exactly during a flood event. Actual impacts under similar rainfall conditions are therefore expected to be similar but may not be exactly the same: there are likely to be some differences. Additional details about flood intelligence and its use can be found in the Australian Emergency Management Manuals flood series at http://www.ema.gov.au and in particular in Manual 20 "Flood Preparedness".
2. All levels, impacts and actions listed in the following flood intelligence card may need to be adjusted to better reflect experience.

Flood Intelligence Card

Observed Rainfall	~AEP of flood	Consequence / Impact at Tatura Refer to FloodZoom and to maps at Appendix F	Action Actions may include (but not limited to) evacuation, closure of roads, sandbagging, issue of warnings and who is responsible
▪ It is important that sand and sandbags are delivered to Tatura and made available to residents as soon as possible after it becomes apparent that flooding is likely. Sandbags are only likely to be efficient for masonry or brick buildings on a concrete slab. All others should concentrate on lifting furniture and other valuables. ▪ Consider how best to assist nursing staff attend the Tatura Public Hospital and Parkvilla Aged Care Facility in Hunter Street if flooding more severe than 10 year ARI is considered likely.			
USING THIS INTELLIGENCE CARD. The observed rainfall range and duration is provided as a guide only. Greater depths of rainfall over a shorter period may also lead to rises and possible flooding along the Mosquito Depression and through Tatura. While heavy short duration rainfall may lead to localised flash stormwater flooding within Tatura, the consequences of that are not detailed in this intelligence card. Rainfall reported from the **Tatura AWS** (available from the BoM website at 30 minute intervals and occasionally more frequently and also from FloodZoom) or from local gauges (or perhaps from the Castle Creek at Arcadia gauge - available from the BoM website and FloodZoom)) will provide near real-time data for use herein in order to determine the approximate flood severity. Consider the appropriate flood inundation map remembering that water will rise slowly and travel slowly. Review all consequences and actions in this table, from the first row down to the approximate expected severity of flooding. Initiate all actions in a logical sequence. Some actions may need to be initiated in an order that is different from their relative placement in this table.			
~50 to 70mm in 24hrs ~55 to 80mm in 36hrs	<10% AEP (<10yr ARI)	▪ Flow in Mosquito Depression through Tatura. ▪ Heavy local rain resulting in stormwater flooding and / or high flows within the stormwater drainage network.	▪ Manage the penstocks at Lake Bartlett as per the Flood Management Plan. ▪ Periodically check that the 5 electric pumps at the Margaret Street Pumping Station are operating as required and lifting water over the embankment into the Cussen Park Wetland. ▪ Check drainage infrastructure, particularly in vicinity of the railway bypass for blockages and clean out as necessary. This could include removing any build-up of soil in the culverts at Gowie St and Hogan St.

Observed Rainfall	~AEP of flood	Consequence / Impact at Tatura Refer to FloodZoom and to maps at Appendix F	Action Actions may include (but not limited to) evacuation, closure of roads, sandbagging, issue of warnings and who is responsible
~55mm in 12hrs ~70mm in 24hrs ~80mm in 36hrs	10% AEP (10yr ARI)	*The 12 hour rainfall is likely to cause some increase in flows but no real flooding issues in Tatura.* ▪ Flooding into the racecourse and into Cussen Park Wetland. ▪ Frank Howley Oval and adjacent oval flooded. ▪ Tatura Caravan Park flooded by up to 300mm deep. Both Hastie St and Galloway St are also flooded to a similar depth. ▪ Hunter St flooded in front of the Tatura Public Hospital and Parkvilla Aged Care Facility to around 300mm depth. ▪ VICSES Tatura unit HQ is dry but there water is close to Martin St either side. ▪ Flooding of a number of roads, mostly less than 300mm depth but up to 500mm: Albert St, Alexander Av, Bartlett St, Brown St, Casey St, Cussen St, Dhurringile Rd, Edgar St, Francis St, Fraser St, Gowie Park Rd, Johnstone Rd, Kerford St, Galloway St, Hampton Rd, Hastie St, Hogan St, Hunter St, Langdon Rd, Martin St, Murton Rd, O'Reilly Rd, Park St, Pyke St, Ross St, Serra Ct, Service St, Taylor Rd. ▪ 163 properties flooded along these roads and 32 buildings flooded over-floor. ▪ Most of the over-floor flooding is in the properties immediately downstream from Lake Bartlett: 55-59 Albert St, 28-35 Francis St, 11-17 Fraser St, 47 Hastie St, 16 Hunter St, 22-30 Kerford St, 103-142 Martin St, 100 O'Reilly Rd, 22-34 Service St. ▪ Water banked up on the upstream side of Pyke Road north of town. ▪ Water through George Reilly Park and Lions Park Playground. ▪ **This flood will pass through Merrigum. Is there anything that can be done now to assist response? For example, advice re likely flood size? See Appendix C8 of this MFEP.**	▪ Consider delivering sand and sandbags (60m3 and 1,000 respectively?) into Tatura to the nominated collection point (where is it?) sufficient for the expected severity of flooding. *Note that the Shire Depot on Cussen St remains mainly dry but that access is about to be compromised / it becomes isolated.* ▪ Evacuate Tatura Caravan Park. ▪ Review road flooding, place "Water over road" signs and consider closing roads as necessary. ▪ Place sandbags at drain outlets north and south of the railway embankment (i.e. those that drain Hunter Street and the area between Unilever Foods and William Street) after any local runoff has escaped via the drainage network and before the peak of the flood passes through town in order to prevent backwater flooding into this pocket. ▪ Sandbag or otherwise assist household likely to flood over-floor. Refer to the 10% AEP flood map for Tatura at Appendix F of this MFEP. ▪ Monitor water levels. ▪ Check drainage infrastructure, particularly in vicinity of the railway bypass for blockages and clean out as necessary. This could include removing any build-up of soil in the culverts at Gowie St and Hogan St. ▪ Review evacuation plan and prepare for implementation noting that there are very few shrinking islands but that the likelihood of isolation does increase as flood severity increases. A number of properties do become isolated – see flood depth maps available through FoodZoom. ▪ With the ICC and Goulburn Broken CMA, raise the possibility of installing one or more PALS in Mosquito Depression upstream of, at, and downstream from Tatura. The intention is to collect height data to enable development of more robust flood guidance tools. ▪ Record flood levels and impacts for later update of this table. This information could assist the development of a flood warning / prediction system for Merrigum.
~64mm in 12hrs ~81mm in 24hrs ~92mm in 36hrs	5% AEP (20yr ARI)	*The 12 hour rainfall is likely to cause some increase in flows but no real flooding issues in Tatura.* ▪ Flooding into the Bowls Club and alongside the Netball courts in Hastie St. ▪ Shallow water on Casey St in front of the CFA fire station (also local incident command centre). ▪ Tatura telephone exchange in Casey St surrounded by water. ▪ Tatura Public Hospital and Parkvilla Aged Care Facility may be isolated. ▪ Mostly shallow flooding though the majority of the CBD in Casey St. ▪ All flow paths are running deeper and a bit wider with a few more roads now	▪ Review road flooding, place "Water over road" signs and consider closing roads as necessary. ▪ Sandbag or otherwise assist household likely to flood over-floor. Refer to the 10% AEP flood map for Tatura at Appendix F of this MFEP. ▪ Consider how to assist nursing staff maintain access to the hospital and aged care facility in Hunter St. ▪ Monitor water levels. ▪ Check drainage infrastructure, particularly in vicinity of the railway bypass for blockages and clean out as necessary. This could include removing any build-up

Observed Rainfall	~AEP of flood	Consequence / Impact at Tatura Refer to FloodZoom and to maps at Appendix F	Action Actions may include (but not limited to) evacuation, closure of roads, sandbagging, issue of warnings and who is responsible
		flooded (e.g. Elizabeth St, Erica Av, Davey St, Hughes St, Margaret St, Peter Av, Thomson St, Toro Ct, William St). Velocities still slow. ▪ 220 properties flooded and 46 buildings flooded over-floor.	of soil in the culverts at Gowie St and Hogan St.
~76mm in 12hrs ~99mm in 24hrs ~112mm in 36hrs	2% AEP (50yr ARI)	*The 12 hour rainfall is likely to cause some increase in flows but no real flooding issues in Tatura.* ▪ All flow paths are running a bit deeper and a bit wider. Velocities still slow. ▪ 312 properties flooded and 92 buildings flooded over-floor. ▪ Tatura Public Hospital and Parkvilla Aged Care Facility isolated. ▪ Water just beginning to overtop Pyke Rd downstream / north of town.	▪ Review road flooding, place "Water over road" signs and consider closing roads as necessary. ▪ Sandbag or otherwise assist household likely to flood over-floor. Refer to the 10% AEP flood map for Tatura at Appendix F of this MFEP. ▪ Monitor water levels. ▪ Check drainage infrastructure, particularly in vicinity of the railway bypass for blockages and clean out as necessary. .
~85mm in 12hrs ~111mm in 24hrs ~128mm in 36hrs	1% AEP (100yr ARI)	*The 12 hour rainfall is likely to cause some increase in flows but no real flooding issues in Tatura.* ▪ All flow paths are running deeper and a bit wider with a few more roads now flooded. Velocities still slow. Flood depths on roads now between 300mm and 800mm. ▪ Buildings in the Tatura Caravan Park are flooded over-floor. ▪ Water up against the Tatura library building in Casey St. ▪ Water surrounds the CFA Fire Station in Casey St. ▪ 399 properties flooded and 132 buildings flooded over-floor. ▪ Over-floor flooding is concentrated in: ➢ The block surrounded by O'Reilly Rd, Hastie St, Albert St & Davey St. ➢ The area immediately downstream from Lake Bartlett through to the railway embankment. ➢ Hunter St and Park St either side of the railway embankment.	▪ Sandbag or otherwise assist household likely to flood over-floor. Refer to the 1% AEP flood map for Tatura at Appendix F of this MFEP. ▪ Review road flooding, place "Water over road" signs and consider closing roads as necessary. ▪ Sandbag or otherwise assist household likely to flood over-floor. Refer to the 10% AEP flood map for Tatura at Appendix F of this MFEP. ▪ Monitor water levels. ▪ Check drainage infrastructure, particularly in vicinity of the railway bypass for blockages and clean out as necessary.
	0.2% AEP (500yr ARI)	▪ All flow paths are running deeper and a bit wider. Velocities still slow. ▪ 483 properties flooded and 201 buildings flooded over-floor. ▪ The hospital grounds are partially flooded. ▪ VICSES unit HQ is dry but there is water across Martin St either side.	▪ Review road flooding, place "Water over road" signs and consider closing roads as necessary. ▪ Monitor water levels. ▪ Check drainage infrastructure, particularly in vicinity of the railway bypass for blockages and clean out as necessary.

APPENDIX C8 - MERRIGUM FLOOD EMERGENCY PLAN

Overview of the Catchment

Merrigum lies approx. 25km west of Shepparton and 12km north-west of Tatura within the Mosquito Depression floodplain. In turn, the Depression is within the Deakin Basin. The eastern boundary of the Basin parallels the east side of the Depression's route.

The Mosquito Depression originates south of Tatura. It drains into the Deakin Main Drain about 15km upstream from where the Drain outfalls into the Murray River, east (i.e. upstream) of Echuca.

The catchment upstream of Merrigum consists of a mix of around 228km^2 of irrigated and non-irrigated crops, orchards and pastoral land. The Depression winds through the catchment as a series of defined ephemeral flow paths although drainage is generally via the Mosquito Depression Drain, an open trapezoidal earth lined channel. The Drain was originally cut in the mid-1890's and extended in the early 1990's. Further minor extensions occurred during the 2000's.

The Drain has a design capacity of 150ML/d (1.8m^3/s), the flow estimated to result from a 2-year ARI (50% AEP) design storm of 50mm over a period of 24 hours. In comparison, the 10-year ARI (10% AEP) design storm delivers around 75mm in 24 hours.

Embankments were added to the floodway between Waverley Avenue and the railway embankment (through the urban area of Merrigum) in 1994 with crest levels set at 500mm above the 1993 flood levels.

Upstream of Tatura there are many obstructions in the Depression, all of which impact on flow conveyance (see Appendix C7). Between Tatura and Merrigum, there are substantially fewer obstructions (only 15 or so).

The local relatively small upper Byrneside – Merrigum catchment contributes to flows in the Depression at Merrigum upstream of the railway line. These flows arrive in the Depression well ahead of flows from further upstream.

There is significant storage within the catchment upstream of Merrigum, including wetlands upstream of Tatura, Cussen Park Wetland and Lake Bartlett at Tatura, a number of other named storages in other parts of the catchment, and swampy areas between Tatura and Merrigum.

Approximately 5km downstream from Tatura, there is a diversion out of the Depression to the north into the Rodney Main Drain system. Capacity is around 240ML/d (2.8m^3/s).

An underground pipe network drains stormwater runoff from the developed areas of Merrigum to the Mosquito Depression Drain.

Flood History

Flooding is known to have occurred at Merrigum in May 1974 and October 1993. Community feedback (WBM, 2005) also identified flooding in 1950, 1954, 1955, 1956 and 1982.

The '74 and '93 events resulted in inundation of roads and properties within the town (see photos below). Both events are thought to be around the 10-year ARI (10% AEP) level.

There is no rainfall or stream gauge data available for any flood producing storms within the catchment in the vicinity of Merrigum.

Flooding in Waverley Avenue, October 1993 (source: WBM, 2005)

Flooding at corner of Judd and Waverley Avenues, October 1993 (source: WBM, 2005)

Flood Behaviour

Flooding at Merrigum has two sources: high intensity short duration storms that lead to localised rapid onset stormwater flooding within the township and long duration (36 hours or so) rainfall events that cause elevated flows within Mosquito Depression.

The nature of flooding in Merrigum is influenced by the very flat grade and meandering nature of the Depression, the railway embankment and associated bridges and culverts, and the Waverly Avenue culverts. Irrigation channels contained by levees affect flood flows outside the town.

Grades are flat and flows sluggish within the Depression. Floods travel slowly with the result that the rise and recession are also slow. It can take several days for a flood to reach a peak and many more for it to drain. In the lower reaches, flooding can persist for anywhere from 14 days to 2 months.

At Merrigum, an initial rise is likely at around 24 to 36 hours after the start of rain. Peak flow could be expected around 4 days later with a return to "non-flood" conditions in a further 5 to 7 days.

Velocities are up to 0.2m/s on the floodplain, 0.2 to 0.5m/s in the natural depression, and up to 1.0m/s in the confined and straightened sections of the Drain.

The depth of flooding along drainage lines and in flood storage areas is generally in the range 1.5m to 2m. Depth on the floodplain varies but is generally less than 500mm.

Flood risk (based on depths and velocities as per ARR 2016) outside the drainage lines and storage areas is consider to be low for adults, children and vehicles

Localised stormwater flooding within town due to capacity constraints within the minor drainage network occurs, in general, much earlier, and is much smaller in magnitude, than resulting from flows in the Mosquito Depression. Similarly, local catchments contribute flows to the Depression ahead of upstream flows. These give the initial rises.

Blockages at drainage infrastructure will increase flood levels and extents.

Flood Impacts

Overview

Flood impacts in and around Merrigum can be significant: multiple road closures, loss of access for residents, disruption to school and child care centre, property isolation, over-floor flooding, risks to emergency personnel during sand bagging and evacuation operations, and damage to buildings constructed below flood level. During major floods, there are also likely to be substantial rural and infrastructure flood damages.

Properties at Risk of Flooding

The majority of the buildings in Merrigum are residential with a small number of commercial and industrial. WBM (2005) noted 218 buildings in Merrigum and a population of around 470.

The number of habitable buildings at risk of being flooded over-floor flooding was calculated by WBM (2005). A summary of that analysis is provided in the table below.

Depth of over-floor flooding (m)	Number of buildings flooded over-floor				
	10% AEP (10yr ARI)	5% AEP (20yr ARI)	2% AEP (50yr ARI)	1% AEP (100yr ARI)	0.2% AEP (500yr ARI)
0 – 0.10	4	8	12	17	
0.10 – 0.60	3	9	22	32	
0.60 – 1.50	0	0	1	1	
>1.5	0	0	0	0	

TOTAL	7	17	35	50	73

Caravan Parks

The northern half of the Merrigum Caravan Park begins to be inundated from somewhere between the 100 and 500-year ARI (1% to 0.2% AEP) event.

Known or possible community infrastructure impacts including:

- Telstra exchange
- CFA Fire Station
- Primary school and kindergarten
- Judd Memorial Park including the tennis courts, swimming pool and oval
- Merrigum Golf Course
- Public Hall

Road closures

These are listed in the Flood Intelligence Card below and can also be determined from the flood mapping delivered by WBM (2005). See also FloodZoom.

Flood Mapping

A set of flood inundation maps for Merrigum (depth and water surface elevation) has been produced for emergency management and response purposes (WBM, 2005). Maps were produced for 5 design events (i.e. 10, 20, 50, 100 & 500 year ARI).

Mapping is available from Council, GBCAMA and through FloodZoom. The study report (WBM, 2005) is also available through FloodZoom.

Command, Control and Coordination

VICSES will assume overall control of the response to flood incidents. Other agencies will be requested to support operations as detailed in this Plan. Control and coordination of a flood incident shall be carried out at the lowest effective level and in accordance with the State Emergency Response Plan (EMMV Part 3). During significant events, VICSES will conduct incident management using multi-agency resources.

Divisional Command will be located at the Hume Region Divisional Command Centre Shepparton and Tatura to manage the local community.

Flood Intelligence and Action Table for Merrigum

Introduction

Flood impacts described in the following tables relate primarily to flooding from the Mosquito Depression. It should be noted that local impacts, or impacts in excess of those indicated, may occur, especially in the event of locally heavy rain in and around Tatura, especially if that rain coincides with high flows with the Depression. Similarly, local increases in flood levels and impacts may result from local factors such as blockages at culverts and from obstructions within overland flow paths.

Notes:

3. While flood intelligence cards provide guidance on the relationship between flood magnitude and flood consequences, flood intelligence records are approximations. This is because no two floods at a location, even if they peak at the same height, will have identical impacts. Further, the hydrologic and hydraulic modelling that underpins much of the intell detailed below is informed by a number of assumptions and approximations that are unlikely to be replicated exactly during a flood event. Actual impacts under similar rainfall conditions are therefore expected to be similar but may not be exactly the same: there are likely to be some differences. Additional details about flood intelligence and its use can be found in the Australian Emergency Management Manuals flood series at http://www.ema.gov.au and in particular in Manual 20 "Flood Preparedness".
4. All levels, impacts and actions listed in the following flood intelligence card may need to be adjusted to better reflect experience.

Flood Intelligence Card

Observed Rainfall	**~AEP of flood**	**Consequence / Impact at Tatura** Refer to FloodZoom and to maps at Appendix F	**Action** Actions may include (but not limited to) evacuation, closure of roads, sandbagging, issue of warnings and who is responsible
USING THIS INTELLIGENCE CARD. The observed rainfall range and duration is provided as a guide only. Greater depths of rainfall over a shorter period may also lead to rises and possible flooding along the Mosquito Depression and through Merrigum. While heavy short duration rainfall may lead to localised flash stormwater flooding within Merrigum, the consequences of that are not detailed in this intelligence card. Rainfall reported from the **Tatura AWS** (available from the BoM website at 30 minute intervals and occasionally more frequently and also from FloodZoom) or from local gauges (or perhaps from the Castle Creek at Arcadia gauge - available from the BoM website and FloodZoom)) will provide near real-time data for use herein in order to determine the approximate flood severity. Consider the appropriate flood inundation map remembering that water will rise slowly and travel slowly. Review all consequences and actions in this table, from the first row down to the approximate expected severity of flooding. Initiate all actions in a logical sequence. Some actions may need to be initiated in an order that is different from their relative placement in this table.			
~50 to 70mm in 24hrs ~55 to 80mm in 36hrs	<10% AEP (<10yr ARI)	▪ Flow in Mosquito Depression. ▪ Heavy local rain resulting in stormwater flooding and / or high flows within the stormwater drainage network.	▪ Check drainage infrastructure for blockages and clean out as necessary. ▪ Check for flooding over the Merrigum – Ardmona Road town side of Ryan Road and close as necessary. ▪ Check for flooding over Waverly Av north of Judd Av and close as necessary.
~55mm in 12hrs ~70mm in 24hrs ~80mm in 36hrs	10% AEP (10yr ARI)	*The 12 hour rainfall is likely to cause some increase in flows but no real flooding issues in Merrigum.* ▪ Merrigum Golf Course is flooded and access compromised. ▪ Flooding of all road in town and immediately upstream (i.e. to the east), mostly less than 300mm depth with the exception of the Merrigum – Ardmona Rd which is up to 600mm deep along the edges and Waverly Rd which is up to 500mm deep: Judd Av, Merrigum - Ardmona Rd, Palmer Ct, Ryan Rd, Waverley Av,	▪ Close the Merrigum – Ardmona Road and Morrissey Av if not already done. ▪ Review road flooding and adjust signage and closures as necessary. ▪ Sandbag or otherwise assist household likely to flood over-floor. Refer to the 10% AEP flood map for Merrigum at Appendix F of this MFEP. ▪ Monitor water levels. ▪ Check drainage infrastructure for blockages and clean out as necessary.

Observed Rainfall	~AEP of flood	Consequence / Impact at Tatura Refer to FloodZoom and to maps at Appendix F	Action Actions may include (but not limited to) evacuation, closure of roads, sandbagging, issue of warnings and who is responsible
		Wilson Av. ▪ A number of buildings flooded over-floor along Waverley Rd. ▪ 2 buildings flooded over-floor in Judd Av. ▪ Water is encroaching on the Merrigum CFA site at the corner of Morrissey St and Waverley Av with 2 buildings wetted over-floor. The site will soon be fully wet. ▪ Merrigum telephone exchange surrounded by water. ▪ Kindergarten surrounded by water. ▪ 7 buildings flooded over-floor, 3 up to a depth of 600mm.	▪ Review evacuation plan and prepare for implementation noting that water will soon cover the entire town if it continues rising to the 5% AEP flood level. ▪ With the ICC and Goulburn Broken CMA, raise the possibility of installing one or more PALS in Mosquito Depression upstream of, at, and downstream from Merrigum. The intention is to collect height data to enable development of more robust flood guidance tools. ▪ Record flood levels and impacts for later update of this table. This information, when used in conjunction with similar information from Tatura, could assist the development of a flood warning / prediction system for Merrigum.
~64mm in 12hrs ~81mm in 24hrs ~92mm in 36hrs	5% AEP (20yr ARI)	*The 12 hour rainfall is likely to cause some increase in flows but no real flooding issues in Merrigum.* ▪ All flow paths are running a bit deeper and a bit wider. Velocities still slow. ▪ Most of the town on the upstream (i.e. east) side of the railway line is now wet. ▪ 17 buildings flooded over-floor, 9 up to a depth of 600mm. ▪ Primary school flooded and access along Judd Av compromised. ▪ Water beginning to pond on the upstream (i.e. east) side of No 7 channel on the east side of Byrneside - Kyabram Rd. ▪ Isolation likely to become an issue.	▪ Consider evacuating the town if flooding likely to get any worse. ▪ Review road flooding and adjust signage and closures as necessary. ▪ Sandbag or otherwise assist household likely to flood over-floor. Refer to the 10% AEP flood map for Tatura at Appendix F of this MFEP. ▪ Consider how to assist nursing staff maintain access to the hospital and aged care facility in Hunter St. ▪ Monitor water levels. ▪ Check drainage infrastructure, particularly in vicinity of the railway bypass for blockages and clean out as necessary. This could include removing any build-up of soil in the culverts at Gowie St and Hogan St.
~76mm in 12hrs ~99mm in 24hrs ~112mm in 36hrs	2% AEP (50yr ARI)	*The 12 hour rainfall is likely to cause some increase in flows at Merrigum with the possibility of some flooding.* ▪ All flow paths are running a bit deeper and a bit wider. Velocities still slow. ▪ The Judd Memorial Park and oval, tennis courts and public pool are beginning to flood – the recreational facilities on the west side of the railway line. ▪ Public Hall surrounded by water. ▪ 35 buildings flooded over-floor, 22 up to 600mm and 1 up to a depth of 1.5m. ▪ Water has broken over No 7 channel and is flowing across the Byrneside - Kyabram Rd.	▪ Review road flooding and adjust signage and closures as necessary. ▪ Sandbag or otherwise assist household likely to flood over-floor. Refer to the 10% AEP flood map for Tatura at Appendix F of this MFEP. ▪ Monitor water levels. ▪ Check drainage infrastructure, particularly in vicinity of the railway bypass for blockages and clean out as necessary. .
~85mm in 12hrs ~111mm in 24hrs ~128mm in 36hrs	1% AEP (100yr ARI)	*The 12 hour rainfall is likely to cause some increase in flows at Merrigum with the possibility of some flooding.* ▪ All flow paths are running a bit deeper and a bit wider. Velocities still slow. ▪ 53 buildings flooded over-floor, 32 up to 600mm and 1 up to a depth of 1.5m. ▪ All buildings along Waverley Av and around the corner into Morrissey St are flooded over-floor.	▪ Sandbag or otherwise assist household likely to flood over-floor. Refer to the 1% AEP flood map for Tatura at Appendix F of this MFEP. ▪ Review road flooding and adjust signage and closures as necessary. ▪ Sandbag or otherwise assist household likely to flood over-floor. Refer to the 10% AEP flood map for Tatura at Appendix F of this MFEP. ▪ Monitor water levels. ▪ Check drainage infrastructure, particularly in vicinity of the railway bypass for

Observed Rainfall	~AEP of flood	**Consequence / Impact at Tatura** Refer to FloodZoom and to maps at Appendix F	**Action** Actions may include (but not limited to) evacuation, closure of roads, sandbagging, issue of warnings and who is responsible
		▪ Most of the buildings on Judd Av and Wilson Av and 1 in Palmer Ct are flooded over-floor. ▪ Railway station is wet and railway line is flooded.	blockages and clean out as necessary.
	0.2% AEP (500yr ARI)	▪ All flow paths are running deeper and a bit wider. Velocities still slow. ▪ 73 buildings flooded over-floor. ▪ Skate park flooded.	▪ Move caravans and other assets from the northern half of the Caravan Park to higher ground. ▪ Review road flooding and adjust signage and closures as necessary. ▪ Monitor water levels. ▪ Check drainage infrastructure for blockages and clean out as necessary.

APPENDIX D - FLOOD EVACUATION ARRANGEMENTS

Phase 1 - Decision to Evacuate

The Incident Controller may make the decision to evacuate an at-risk community under the following circumstances:

- Properties are likely to become inundated;
- Properties are likely to become isolated and occupants are not suitable for isolated conditions;
- Public health is at threat as a consequence of flooding and evacuation is considered the most effective risk treatment. This is the role of the Health Commander of the incident to assess and manage. Refer to the State Health Emergency Response Plan (SHERP) for details);
- Essential services have been damaged and are not available to a community and evacuation is considered the most effective risk treatment.

The following should be considered when planning for evacuation:

- Anticipated flood consequences and the timing and reliability of predictions;
- Size and location of the community to be evacuated;
- Likely duration of evacuation;
- Forecast weather;
- Flood Models;
- Predicted timing of flood consequences;
- Time required to conduct the evacuation;
- Time available to conduct the evacuation;
- Evacuation priorities and evacuation planning arrangements;
- Access and egress routes available and their potential flood liability;
- Current and likely future status of essential infrastructure;
- Resources required to conduct the evacuation;
- Resources available to conduct the evacuation;
- Shelter including Emergency Relief Centres, Assembly Areas etc.;
- Vulnerable people and facilities;
- Transportation;
- Registration
- People of CALD background and transient populations;
- Safety of emergency service personnel;
- Different stages of an evacuation process.

The decision to evacuate is to be made in consultation with the MERO, MERC, DHHS, Health Commander and other key agencies and expert advice (CMAs and Flood Intelligence specialists).

The table below details evacuation triggers levels for the Goulburn River at Shepparton gauge, if these heights are predicted or are likely to occur, evacuation should be considered

Sector	Gauge	Trigger
Balmoral Estate	Shepparton Seven Creeks	11.10 6.60
Victoria Lake Caravan Park	Shepparton	11.18
The Boulevard & Wanganui Estate	Shepparton	11.30
Taylors & Halls Estate	Shepparton	11.30
Riverpark Estate	Shepparton	11.38
Tarcoola Retirement Homes	Shepparton	11.53
Princess Park Sports Complex	Shepparton	11.66

The table below details time required to door-knock properties to advice of the need to evacuate established areas.

Sector	Likely time required for evacuation (including resource assumptions)
Balmoral Estate	8 hours
Victoria Lake Caravan Park	24 hours
The Boulevard & Wanganui Estate	48 hours
Taylors & Halls Estate	20 hours
Riverpark Estate	40 hours
Tarcoola Retirement Homes	24 hours
Princess Park Sports Complex	10 hours

Phase 2 – Warning

Warnings may include a warning to prepare to evacuate and a warning to evacuate immediately. Once the decision to evacuate has been made, the at-risk community will be warned to evacuate. Evacuation warnings can be disseminated via methods listed in part 3 of this plan.

Evacuation warning messages will be developed and issued by VICSES in consultation with the MERO, MERC, DHHS and other key agencies and expert advice (CMAs and Flood Intelligence specialists).

Phase 3 – Evacuation

Evacuation will be coordinated by VICPOL. VICSES will provide advice regarding most appropriate evacuation routes and locations for at-risk communities to evacuate to, etc.

VICSES, CFA, AV and Local Government will provide resources where available to support VICPOL/VICROADS with route control and may assist VICPOL in arranging evacuation transportation.

VICPOL will control security of evacuated areas.

Evacuees will be encouraged to move using their own transport where possible. Transport for those without vehicles or other means will be arranged by the MERO.

Possible Evacuation Routes to be used:

Sector	Evacuation Route	Evacuation route closure point and gauge height of closure
Balmoral Estate	Goulburn Valley Highway	Balmoral Street/GV Highway; 11.10m
Victoria Lake Caravan Park	Goulburn Valley Highway	Fitzjohn Street & GV Highway 11.18m
The Boulevard & Wanganui Estate	Balaclava Road, Parkside Drive, Wanganui Road	Balaclava Road, Parkside Drive, Wanganui Road 11.28m
Taylors & Halls Estate	Goulburn Valley Highway	Guthrie and Longstaff Streets 11.30m
Riverpark Estate	Goulburn Valley Highway	Macintosh & Wilmot Roads and Lachlan Crescent 11.38m
Tarcoola Retirement Homes	Balaclava Road	Balaclava Road/The Boulevard 11.53m
Princess Park Sports Complex	Nixon Street	Nixon and Marungi Streets 11.66m

Landing zones for helicopters are located at:

- Shepparton Airport (Greater Shepparton City Council: Shepparton Aerodrome Manager)
- Sports fields (as necessary)

The electronic Vulnerable Persons Register has been implemented on the state 'Crisisworks' software. Responsibility to refer to this register resides with Victoria Police.

A list of local facilities where vulnerable people are likely to be situated is coordinated and maintained by council. This list includes hospitals, schools, aged care facilities and child care centres. An updated copy of this document is maintained and available to Victoria Police on council's Crisisworks software.

The Greater Shepparton City Council MEMP includes further information including township profiles and social characteristics, transient populations and vulnerable persons.

Phase 4 – Shelter

Relief Centres and/or assembly areas which cater for people's basic needs for floods may be established to meet the immediate needs of people affected by flooding. This is detailed in the Greater Shepparton City Council MEMP.

VICPOL in consultation with VICSES will liaise with Local Government and DHHS (where regional coordination is required) via the relevant control centre to plan for the opening and operation of emergency relief centres. This can best be achieved through the Emergency Management Team (EMT).

Animal Shelter

Animal shelter compounds will be established for domestic pets and companion animals of evacuees. These facilities may be located at locations detailed below and coordinated by the MERO and Council's Animal Control Officers.

Sector	Animal Shelter (include address)	Comments
Greater Shepparton	Municipal Pound Wanganui Road, Shepparton 5821 2813	Pets and other small animals

Greater Shepparton	Municipal Saleyards New Dookie Road, Shepparton 5821 4462	Large animals and livestock

Phase 5 – Return

Return will be consistent with the Strategic Plan for the Return of Community

The Incident Controller in consultation with VicPol will determine when it is safe for evacuees to return to their properties and will arrange for the notification of the community.

VicPol will manage the return of evacuated people with the assistance of other agencies as required.

Considerations for deciding whether to evacuate include:

- Current flood situation;
- Status of flood mitigation systems;
- Size and location of the community;
- Access and egress routes available and their status;
- Resources required to coordinate the return;
- Special needs groups;
- Forecast weather;
- Transportation particularly for people without access to transport

Disruption to Services

Disruption to a range of services can occur in the event of a flood. This may include road closures affecting school bus routes, water treatment plant affecting potable water supplies, etc.

Service	Impact	Trigger Point for action	Strategy/Temporary Measures
Victoria Lake Caravan Park Sewerage system	Possible backflow of sewerage	11.18m	Turn off pumps and plug the sewer
Victoria Park Lake filling & recycle pumps	Damage to pumps if flooded	11.18m	Remove the electric motors
Sewerage to The Boulevard, Wanganui and Tassiker Estates	Inflow of floodwater into sewerage system-overload	11.28m	GVW to plug sewer system
Sewerage to Taylors Estate and surrounds	Inflow of floodwater into sewerage system-overload	11.30m	GVW to plug sewer system
Midland Highway access across causeway to Mooroopna	Loss of access	12.00m	VicRoads to manage access for emergency vehicles only

Essential Community Infrastructure and Property Protection

Essential Community Infrastructure and properties (e.g. residences, businesses, roads, power supply etc.) that require protection are:

Facility	Impact	Trigger Point for action	Strategy/Temporary Measures
Municipal Offices 90 Welsford Street	Loss of MECC	12.00m	Relocate MECC to 315 Doyles Road, Orrvale
Power supply	Loss of electricity, safety	300mm of water around ground level substations	Powercor to sandbag
GVW Treatment Plant	Treatment plant issues, but production will continue.	11.9m	GVW have detailed action plan

Greater Shepparton City Council will establish sandbag collection points at:

- Shepparton Showgrounds, Thompson Street, Shepparton
- Council depot in Mooroopna Recreation Reserve, Midland Highway, Mooroopna

Rescue

Known high-risk areas/communities where rescues might be required include:

1. **Kialla Settlement, Riverview Drive**
2. **Arcadia Downs Estate**
3. **Kidstown Tourist facility**

APPENDIX E - FLOOD WARNING SYSTEMS

Flood Warning

Flood Warning products and Flood Class Levels can be found on the BoM website. Flood Warning Products include Severe Thunderstorm Warnings, Severe Weather Warnings, Flood Watches and Flood Warnings.

Flood warnings are also available via the VicEmergency App and from the VicEmergency website (https://emergency.vic.gov.au/respond/).

Flood Bulletins

VICSES distributes flood emergency information to the media through "Flood Bulletins". Flood Bulletins provide BoM Flood Warning information as well as information regarding possible flood consequences and safety advice, not contained in BoM Flood Warning products. VICSES uses the title Flood bulletin to ensure emphasis is placed upon BoM Flood Warning product titles.

The relevant VICSES Region Headquarters or the established ICC will normally be responsible for drafting, authorising and issuing Flood Bulletins through the One Source, One Message system (OSOM).

Flood Bulletins should refer to the warning title within the Bulletin header, for example Flood Bulletin for Major Flood Warning on the Goulburn River.

Flood Bulletins should follow the structure below:

- What is the current flood situation;
- What is the predicted flood situation;
- What are the likely flood consequences;
- What should the community do in response to flood warnings;
- Where to seek further information;
- Who to call if emergency assistance is required.

It is important that the description of the predicted flood situation is consistent with and reflects the relevant BoM Flood Warning.

Flood Bulletins should be focused on specific gauge (or in the absence of gauges, catchment) reference areas, that is the area in which flood consequences specifically relate to the relevant flood gauge.

Flood Bulletins should be prepared and issued after receipt of each Flood Watch and Flood Warning from the BoM, or after Severe Weather or Thunderstorm Warnings indicating potential for severe flash flooding.

To ensure flood bulletins are released in a timely manner, standardised flood bulletins may be drafted based on different scenarios, prior to events occurring. The standardised flood bulletins can then be adapted to the specifics of the event occurring or predicted to occur.

Local Flood Warning System Arrangements

G-MW monitors levels and flows at gauging stations on the Goulburn River and tributaries upstream of Lake Eildon, between Lake Eildon and Goulburn Weir and downstream of Goulburn Weir to meet its core business requirements and in the past has also provided considerable assistance in flood predictions for Shepparton.

A 1925 agreement established the Loch Garry Flood Protection District to reduce the frequency of flooding to downstream landholders. The operating rules for Loch Garry were developed in 1932 and have until recently changed little in the interim. The original rules required a staged removal of drop bars from the Loch Garry regulator to commence 24 hours after the Goulburn River at Shepparton reached 10.36 m (34 feet). If the river continued to rise at Shepparton, drop bars would be progressively removed until all bars were removed by the time the river reached 10.97 m (36 feet) at Shepparton. Drop bars would be replaced in reverse order when the flood peak at Shepparton has passed.

The operation of the Loch Garry regulator requires timely forecasts of river level at Shepparton to mobilise and deploy work crews and provide sufficient notification to landholders to enable stock to be removed from land that will be flooded.

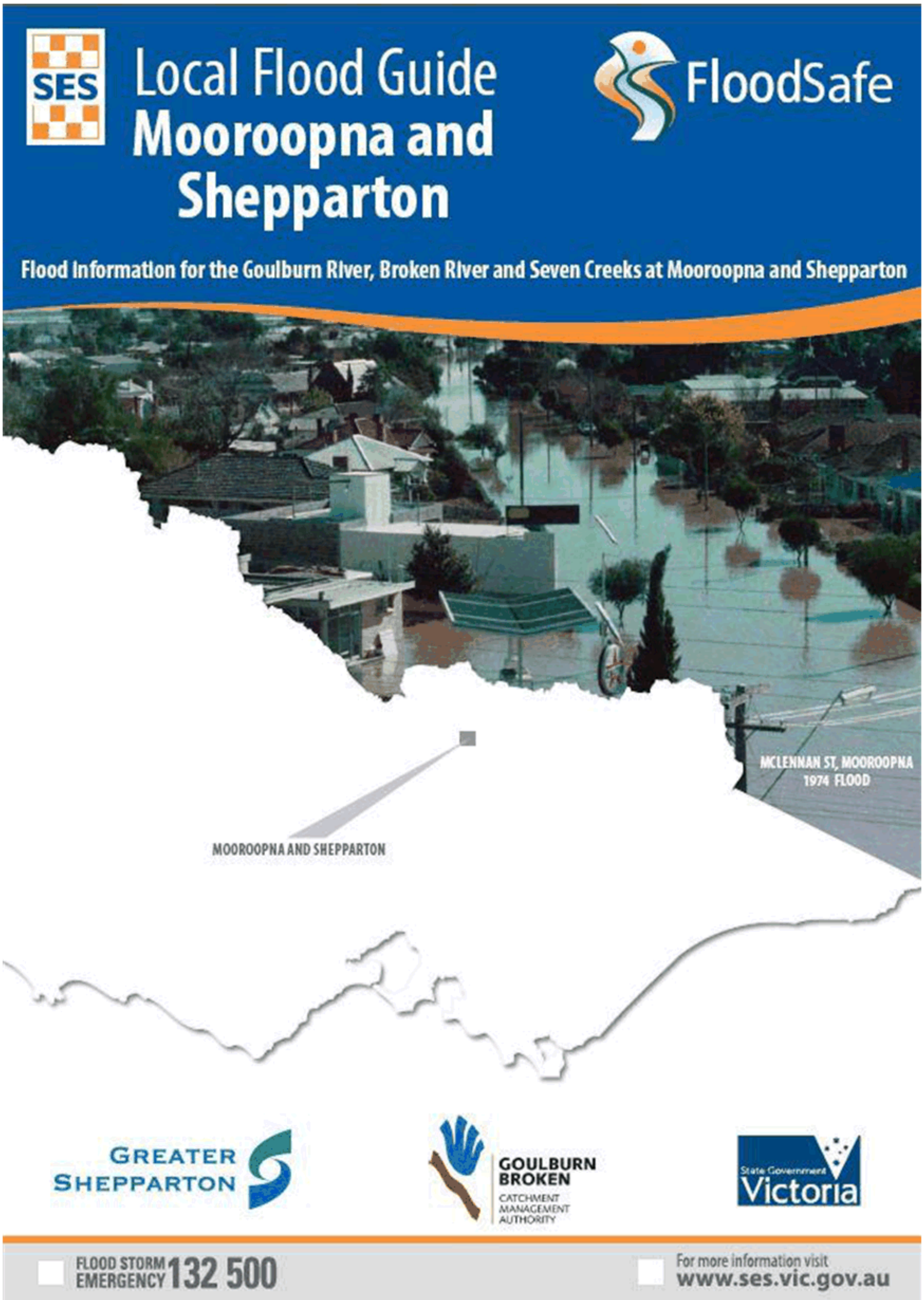
A review by G-MW in early 2006 identified safety issues associated with night time operation of the existing Loch Garry regulator. As a consequence of this review, G-MW has decided to confine operation of the Loch Garry regulator in its current form to daylight hours. As far as is possible, G-MW will operate the Loch Garry regulator to preserve the intent of the 1932 operating rules.

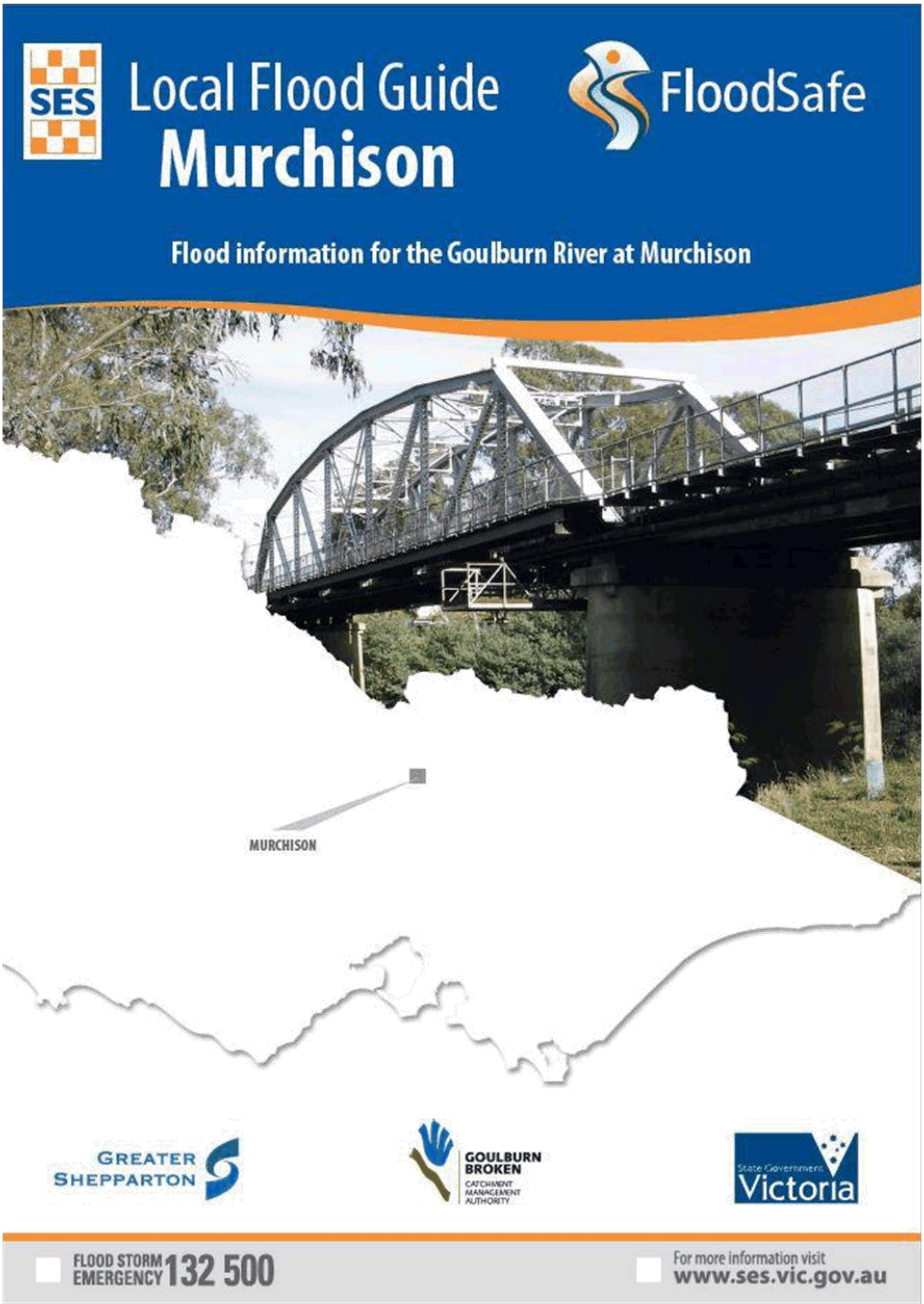
G-MW's existing flood prediction technique for the Goulburn River at Shepparton involves manual extraction of river level data obtained from a variety of telephone based telemark and synthesised voice recorders. The flow for each site is then manually derived from rating tables and entered on a spread sheet where forecasts of peak flows and river levels at Shepparton are produced by lagging flows and making appropriate allowance for losses on the floodplain.

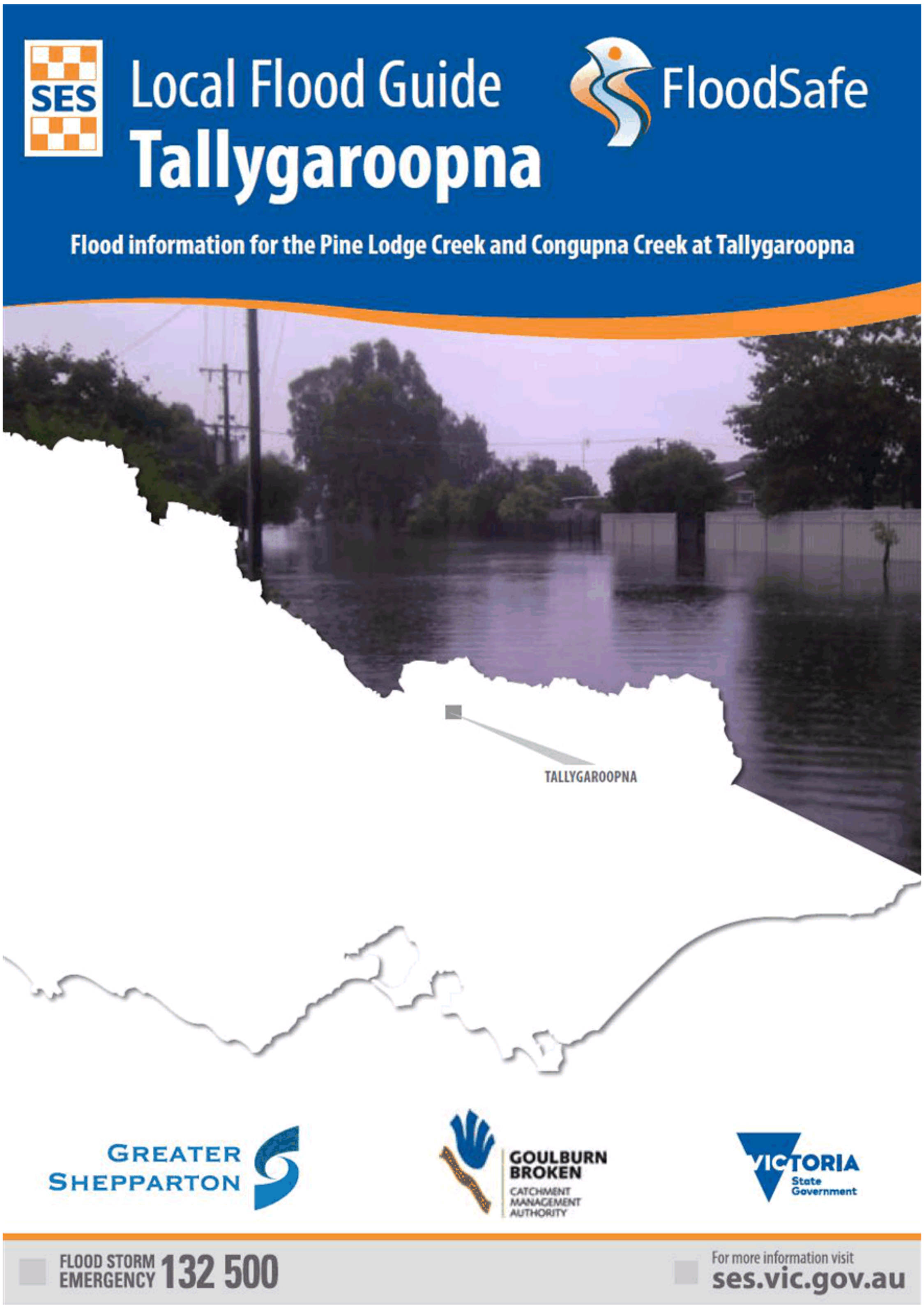
While this flood forecast spread sheet technique has been updated and refined since 2004, including a graphical component, the method is cumbersome, labour intensive and requires a considerable amount of skill to arrive at a reliable estimate of the peak flood level at Shepparton. G-MW believes that it is no longer appropriate for G-MW to provide a flood prediction service for Shepparton, and this role better rests with the Bureau of Meteorology. G-MW is also of the view that the development of a suite of rainfall-runoff models by the Bureau of Meteorology for the Goulburn River and tributaries utilising an enhanced data collection network and sophisticated computer models will render G-MW's present flood forecasting role redundant.

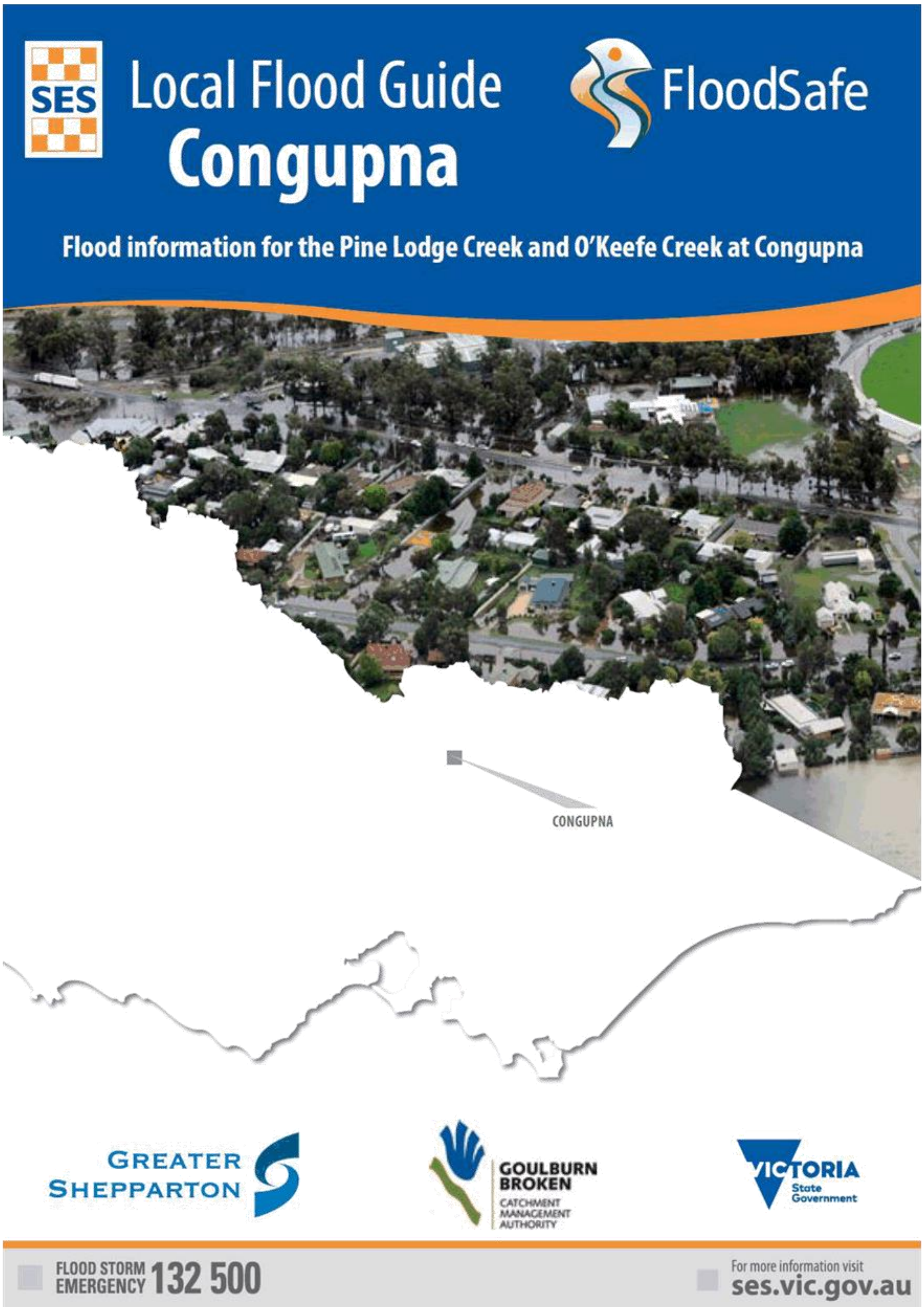
In an exchange of letters G-MW, Bureau of Meteorology and Greater Shepparton City Council have agreed that G-MW will as from 1 July 2006 cease providing a flood forecasting service and the Greater Shepparton City Council has agreed to rely on flood forecasts provided by the Bureau of Meteorology.

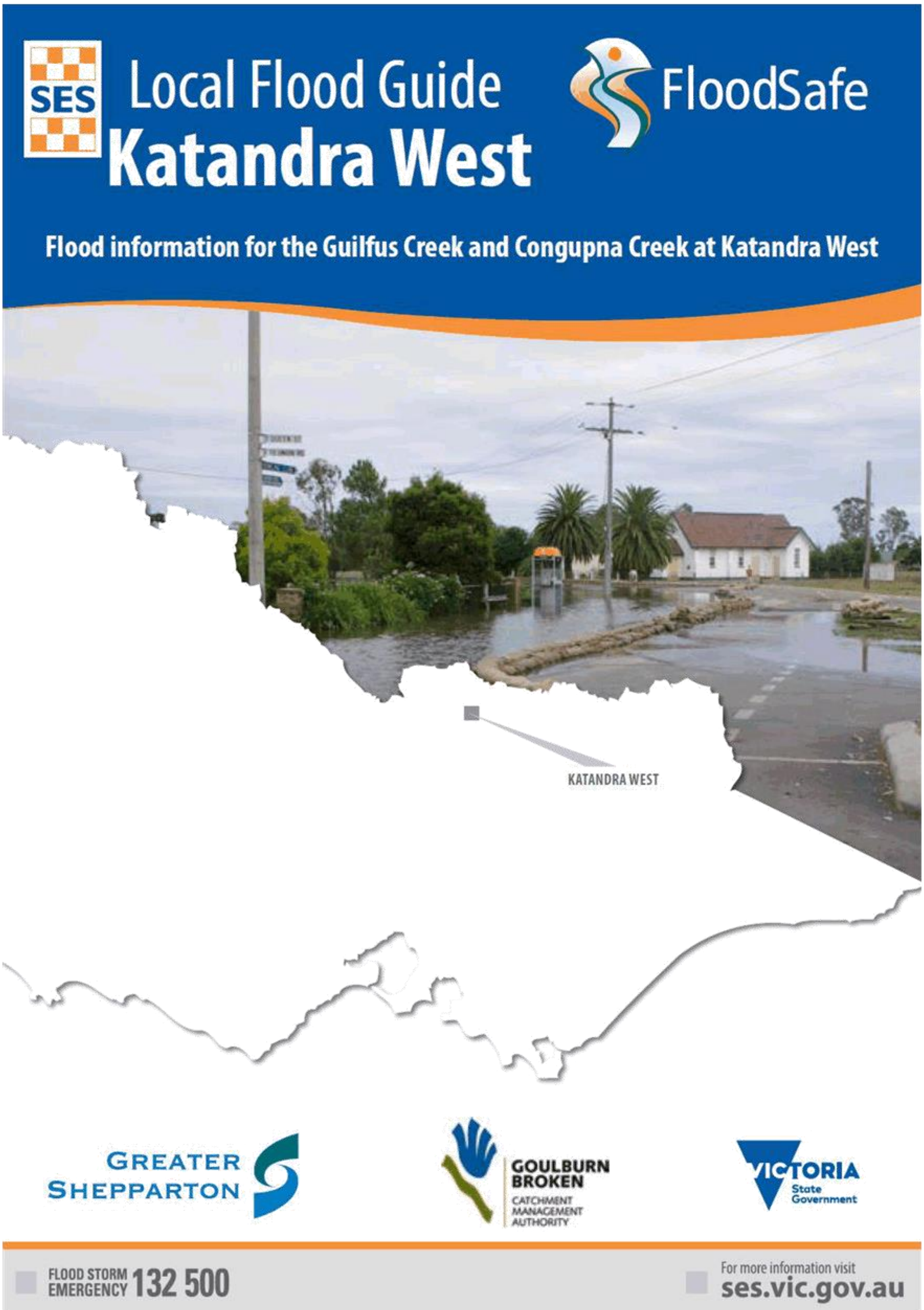
APPENDIX F – LOCAL FLOOD GUIDES




SES
Local Flood Guide
Murchison
FloodSafe
Flood information for the Goulburn River at Murchison
MURCHISON
GREATER SHEPPARTON
GOULBURN BROKEN CATCHMENT MANAGEMENT AUTHORITY
State Government Victoria
FLOOD STORM EMERGENCY 132 500
For more information visit www.ses.vic.gov.au


SES
Local Flood Guide
Tallygaroopna
FloodSafe
Flood information for the Pine Lodge Creek and Congupna Creek at Tallygaroopna
TALLYGAROOPNA
GREATER SHEPPARTON
GOULBURN BROKEN CATCHMENT MANAGEMENT AUTHORITY
VICTORIA State Government
FLOOD STORM EMERGENCY 132 500
For more information visit ses.vic.gov.au


SES
Local Flood Guide
Congupna
FloodSafe
Flood information for the Pine Lodge Creek and O'Keefe Creek at Congupna
CONGUPNA
GREATER SHEPPARTON
GOULBURN BROKEN CATCHMENT MANAGEMENT AUTHORITY
VICTORIA State Government
FLOOD STORM EMERGENCY 132 500
For more information visit ses.vic.gov.au


SES
Local Flood Guide
Katandra West
FloodSafe
Flood information for the Guilfus Creek and Congupna Creek at Katandra West
KATANDRA WEST
GREATER SHEPPARTON
GOULBURN BROKEN
CATCHMENT MANAGEMENT AUTHORITY
VICTORIA
State Government
FLOOD STORM EMERGENCY 132 500
For more information visit
ses.vic.gov.au

APPENDIX G – LOCAL KNOWLEDGE ARRANGEMENTS

As control agency for flood in Victoria, VICSES is committed to ensuring the incorporation of local knowledge in decision making before, during and after incidents.

Information from community sources including but not limited to observations, historical information and information about current and possible consequences of an incident may be utilised to help inform the process of incorporating local knowledge into decision making during an incident. **[Community observers, Local Information Officers (LIOs) and other agency networks] identified in [this plan/xxx register]** will help support this process.

LIOs provide a key communication interface to community observers and other sources of local knowledge.

For the **[Enter Location - Community/Municipality/River system]** community observers identified are:

Community Observer Name	Community Observer contact details	LIO Contact	Key Areas of local knowledge expertise
[Enter Name]	[Enter contact details]	[Enter name of LIO key point of contact]	[Enter key areas of local knowledge expertise that is consistent with the Local Knowledge Policy arrangements]
[Enter Name]	[Enter contact details]	[Enter name of LIO key point of contact]	[Enter key areas of local knowledge expertise that is consistent with the Local Knowledge Policy arrangements]

For the **[Enter VICSES unit location]** the Local Information Officer identified is:

LIO Name	LIO contact details	Community Observer contacts
[Enter Name]	[Enter contact details]	[Enter names of Community observer and other key local knowledge points of contact]

For the **[Enter Location - Community/Municipality/River system]** other agency networks identified are:

- **[Enter other relevant agency network details including the capability and management of these networks and the contact details if appropriate]**

Important Notes:

These arrangements do not permit community observers and existing agency networks any responsibility for operational decisions and do not permit community observers and existing agency networks to direct operational activity, including the management of flood levees.

Information provided from sources of local knowledge must be processed and validated before it can become intelligence to inform decision making.

APPENDIX H – MAPS

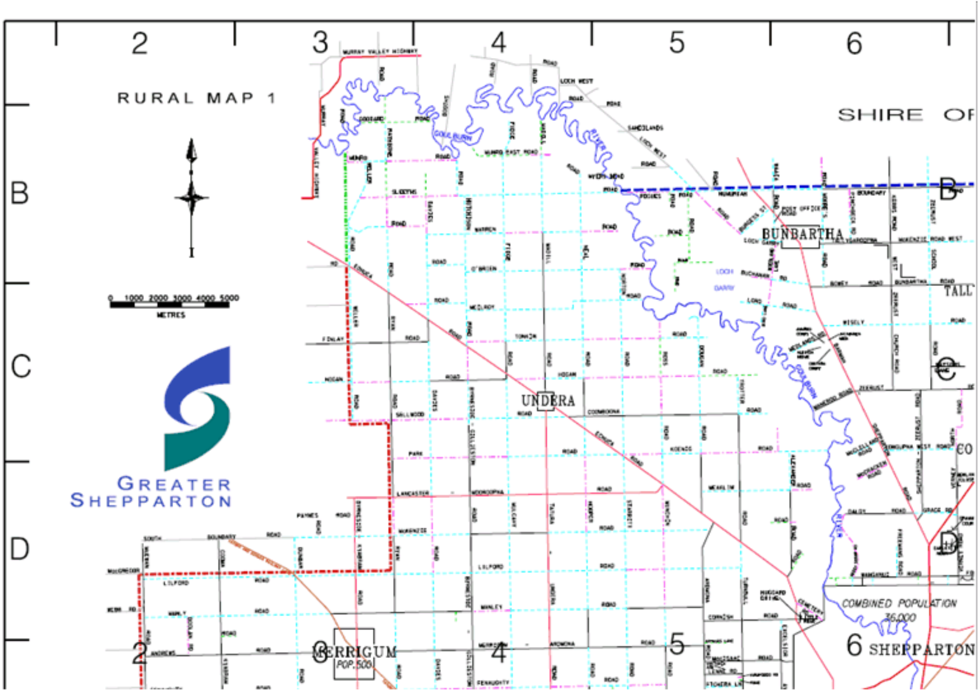
Maps are provided, detailing likely affected areas including roads, emergency relief centres etc.


Murray River
SHEPPARTON IRRIGATION REGION
Cobram
Lake Mulwala
Yarrawonga
Nathalia
Numurkah
Echuca
Goulburn River
Broken Creek
Kyabram
Shepparton
Broken River
Tatura
Waranga Reservoir
Rushworth
BROKEN GOULBURN REGION
Benalla
Broken River
Lake Nagambie
Euroa
Nagambie
Lake Nillahcootie
Lake Eildon
Mansfield
Seymour
Goulburn River
Mt Buller
Broadford
Yea
Alexandra
Kilmore
Jamieson
Marysville
Woods Point
1:1,000,000
0 10 20 Kilometers

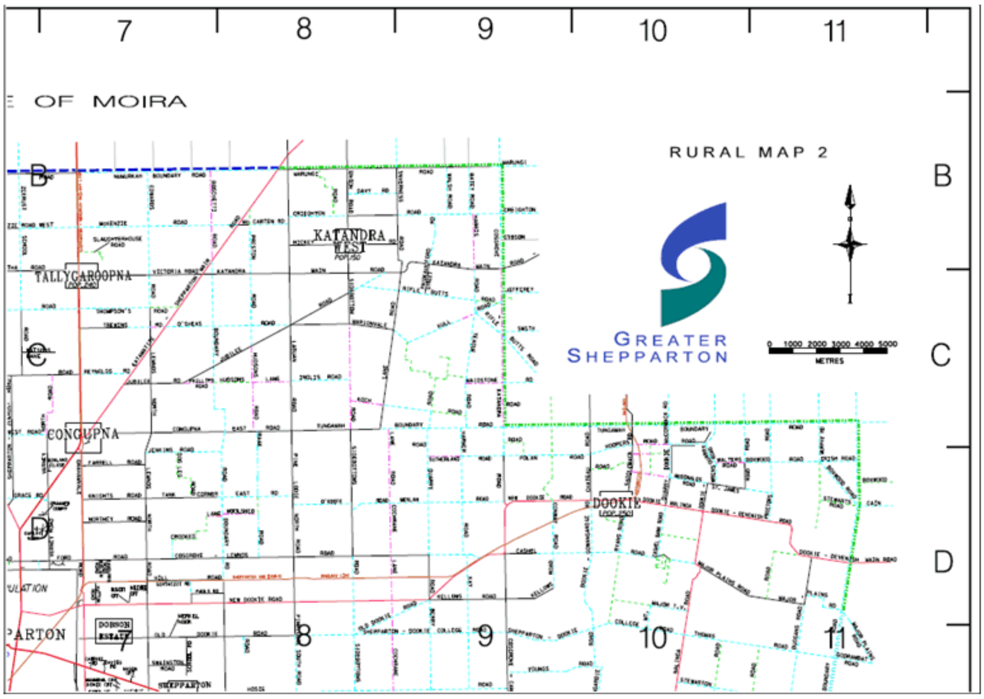
Catchment

Catchment with Roads and other waterways

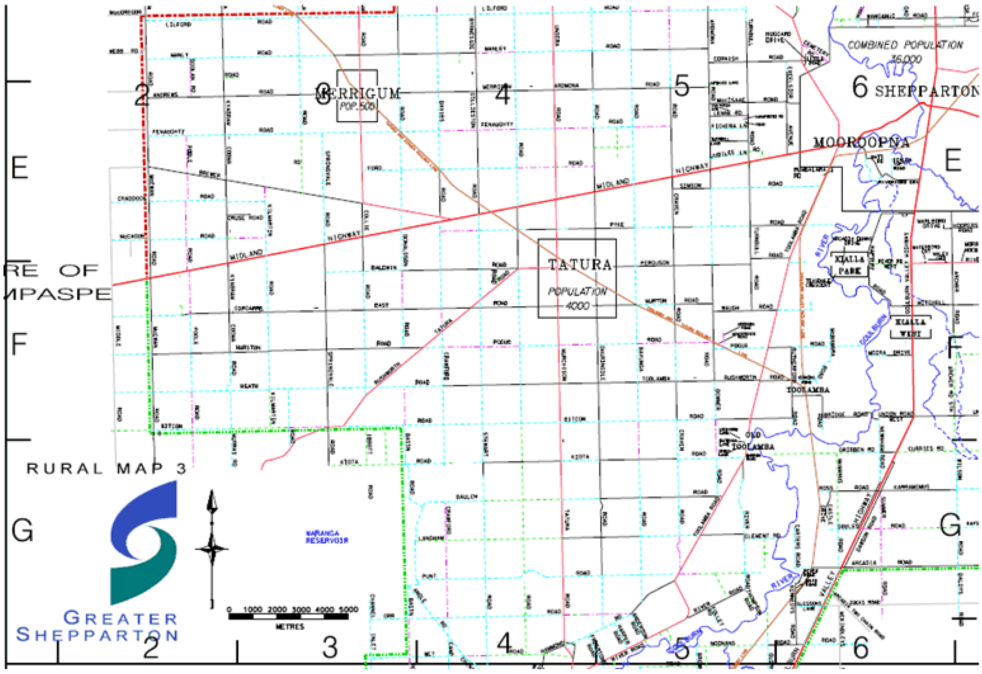
Rural map 1 - Merrigum, Undera, Bunbartha



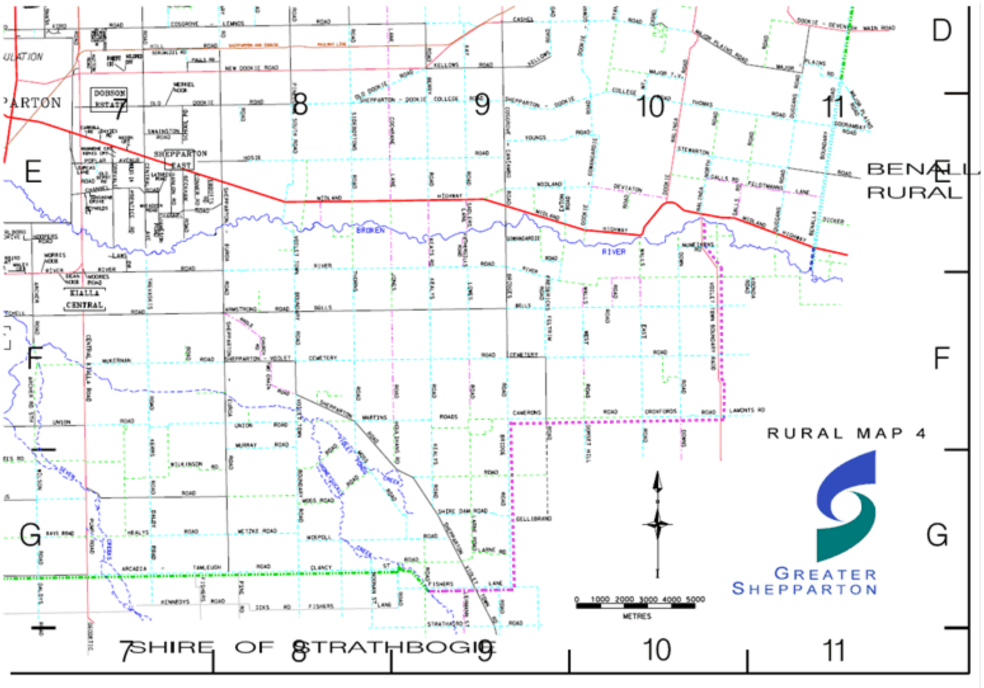
Rural map 2 - Congupna, Tallygaroopna, Katandra, Dookie



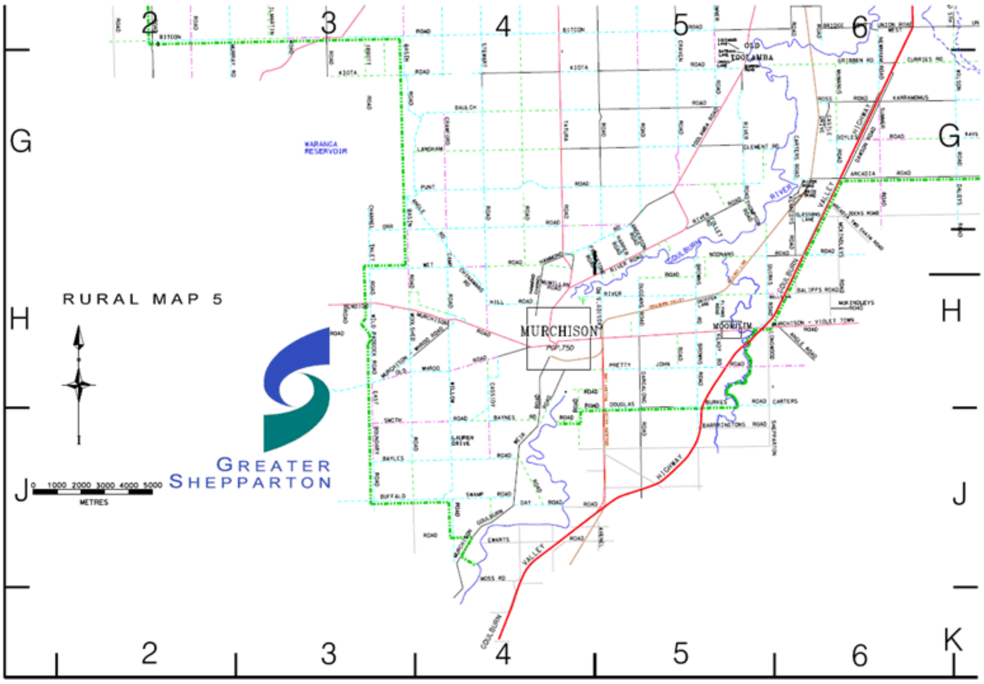
Rural map 3 - Merrigum, Tatura, Kialla Park, Kialla West, Toolamba, Old Toolamba



Rural map 4 - Kialla Central, Shepparton East

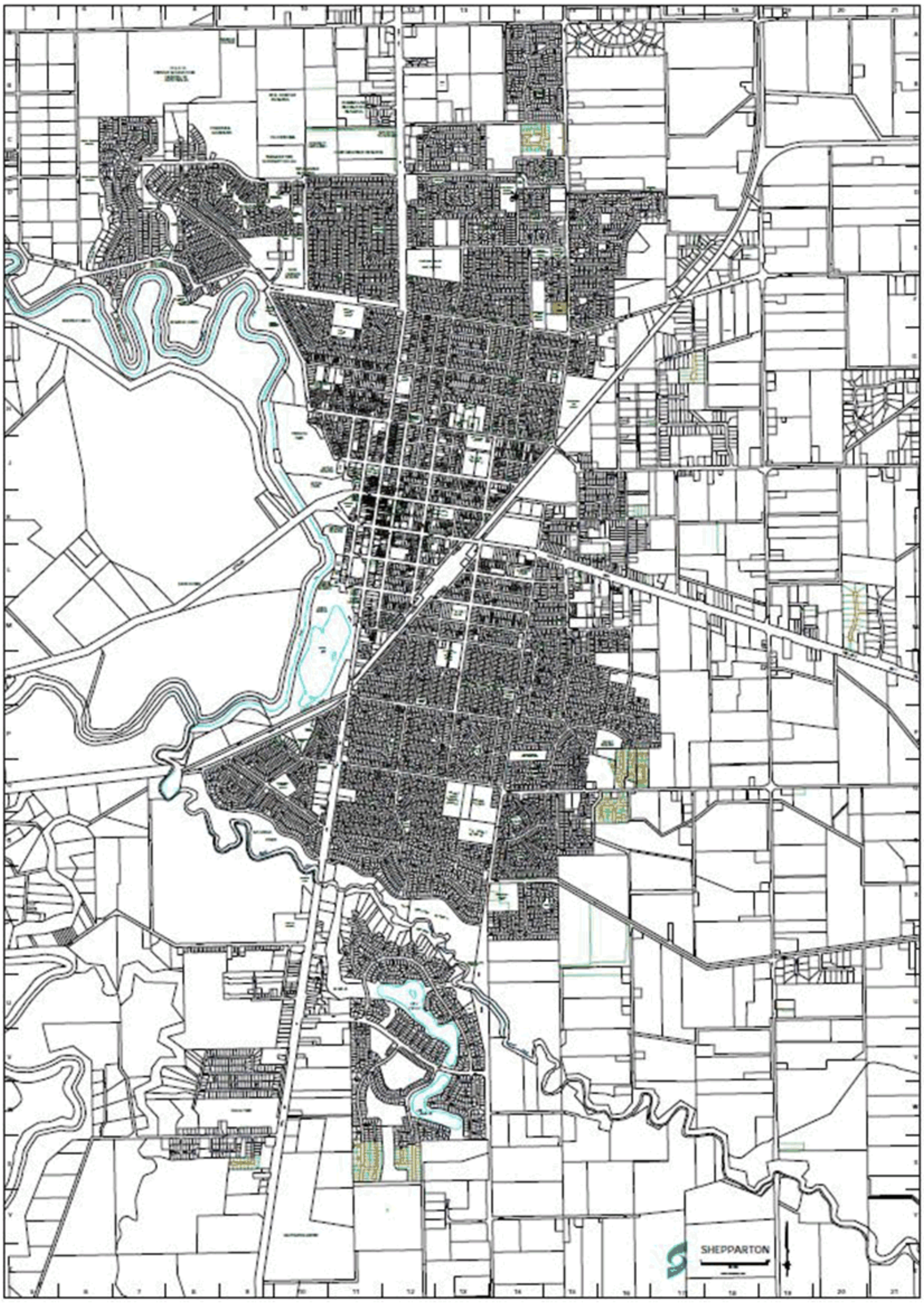


Rural map 5 - Murchison, Old Toolamba, Moorilim



Rural map 6 - Arcadia Downs Estate

Shepparton



The Shepparton Mooroopna Flood Mapping and Flood Intelligence project (Water Technology, 2017) produced a suite of flood maps for each flow dominance scenario (e.g. Goulburn River dominant, Broken River/Seven Creeks dominant, and a neutral or no dominance scenario) that include maximum depth, velocity, water surface and flood hazard, similar to the one above. The suite comprises mapping for seventeen (17) different heights at the Goulburn River at Shepparton gauge. The approximate gauge heights are 9.5 (minor flood level), 9.7, 9.9, 10.1, 10.5, 10.7 (moderate flood level), 10.9, 11.0 (major flood level), 11.1, 11.3, 11.5, 11.7, 11.9, 12.1, 12.2, 12.3 and 12.5 m. There are a total of 204 maps.

All of the flood maps (and reports) are available through FloodZoom.

Further, a deliverable from the study was a web-based flood and property information portal for community use. The portal enables flood maps for the various dominance scenarios (e.g. neutral, Goulburn River dominant, Broken-Sevens dominant) to be displayed as well as flood related information for a user-specified property. That information is presented as a report that includes all available flood information for that property.

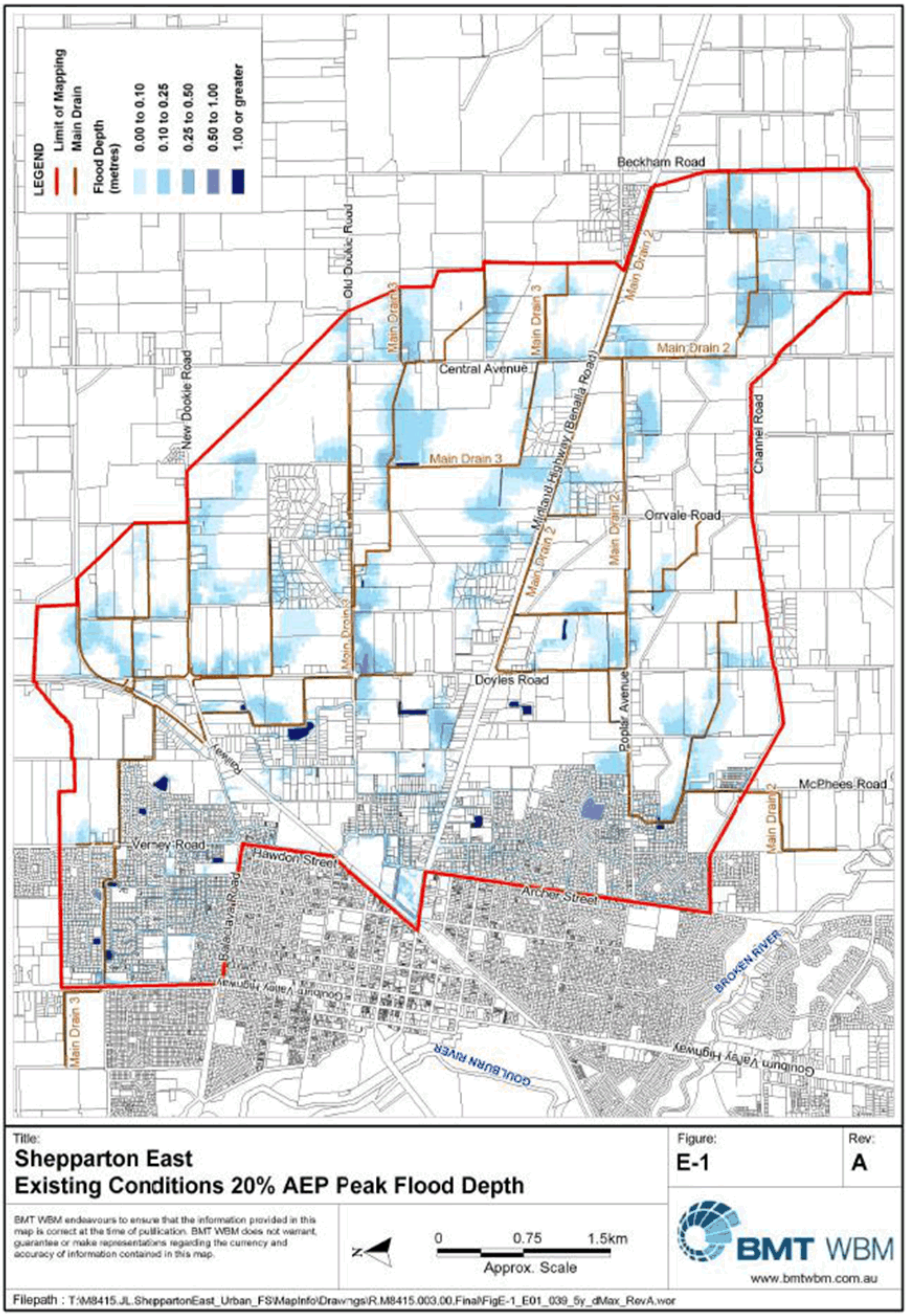
The maps and reports provide a means for community members to inform themselves of the likelihood of their property being inundated and the likely depths of inundation for a range of levels at the Shepparton gauge.

The web-based flood and property information portal can be accessed at http://www.floodreport.com.au/

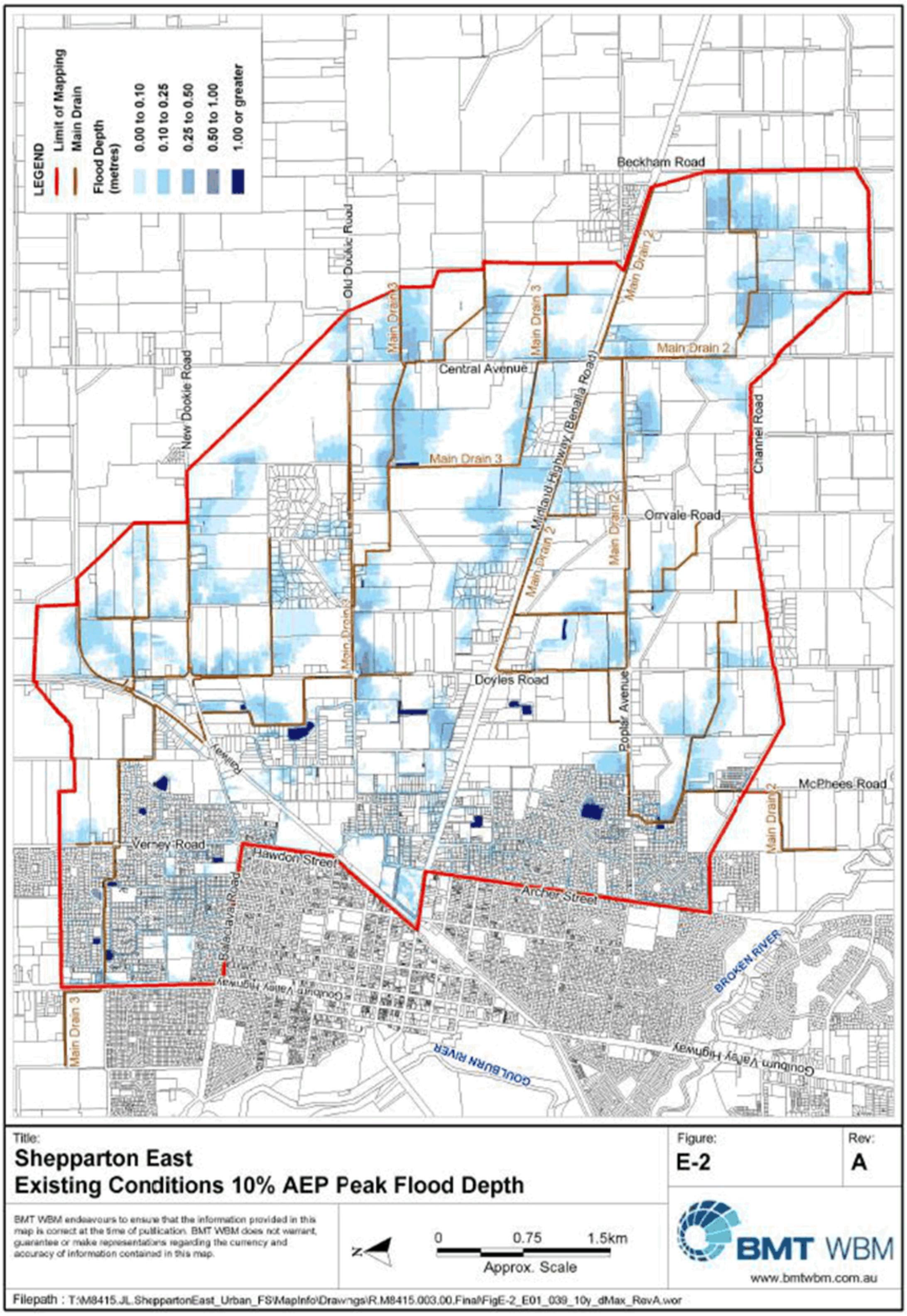
The full range of flood inundation maps for the Shepparton area are kept electronically on Greater Shepparton City Council's Crisisworks and the VICSES G drive: G:\Data\AAA North East Operations\Flood Management\Flood Intelligence and Planning\Shepparton-Mooroopna

Flood mapping is also available through FloodZoom (this will be uploaded on completion of the study).

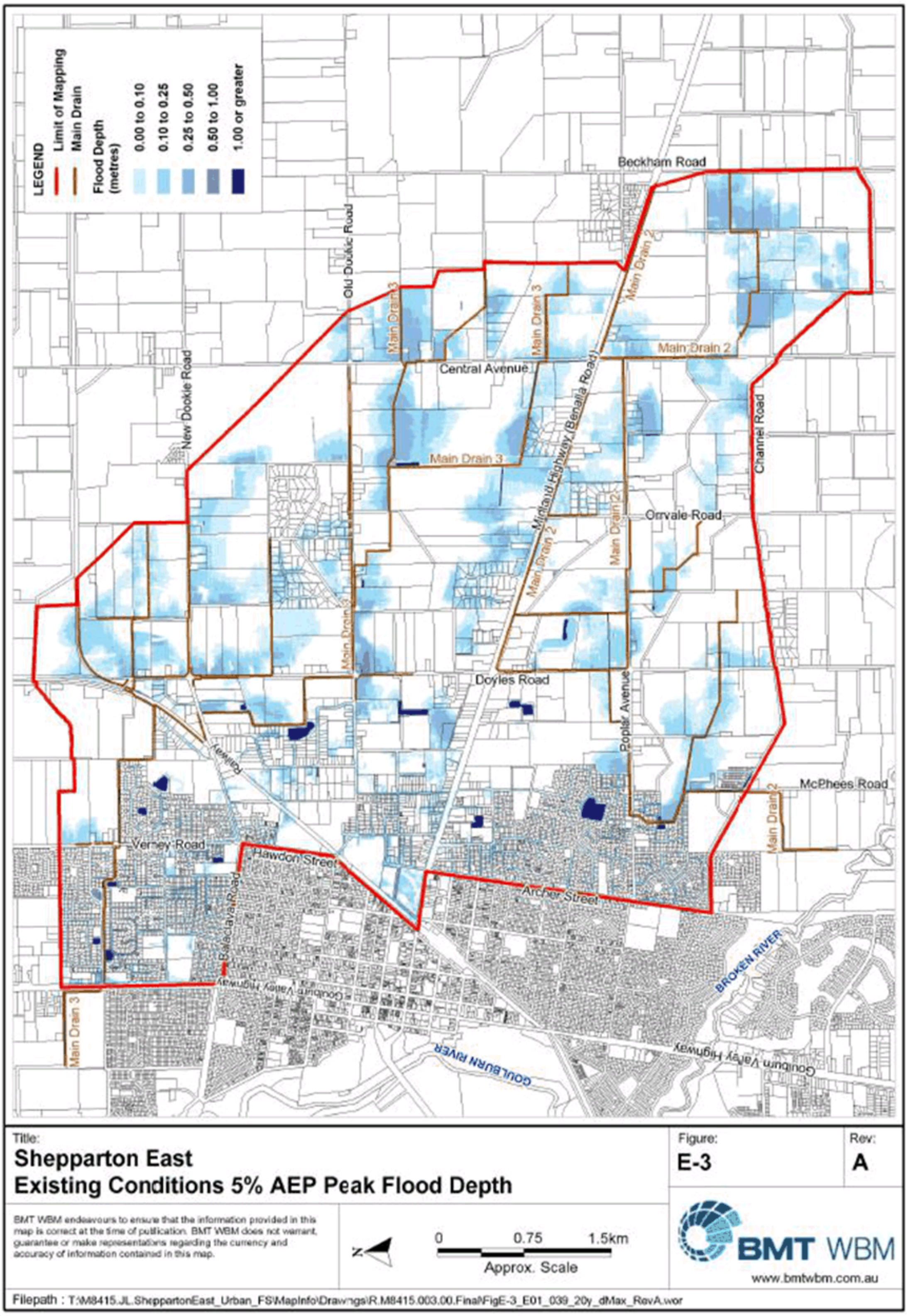
Local Flood Guides are available for all residents within the City of Greater Shepparton to assist them in preparing for future flood events. Refer to Appendix F for a sample.



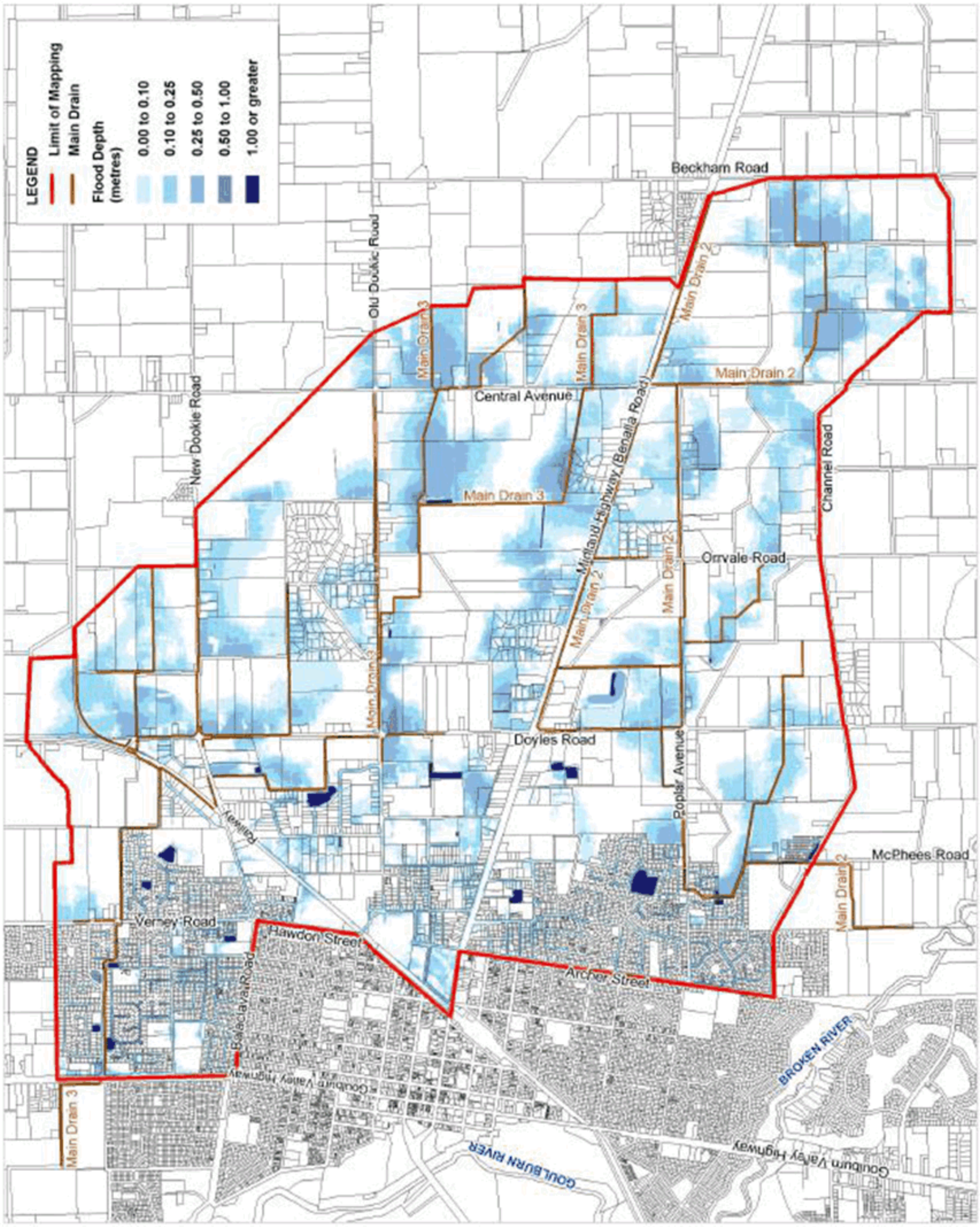
East Shepparton – 20% AEP peak flood depths



East Shepparton – 10% AEP peak flood depths



East Shepparton – 5% AEP peak flood depths



Title:
Shepparton East
Existing Conditions 2% AEP Peak Flood Depth

Figure: E-4 Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

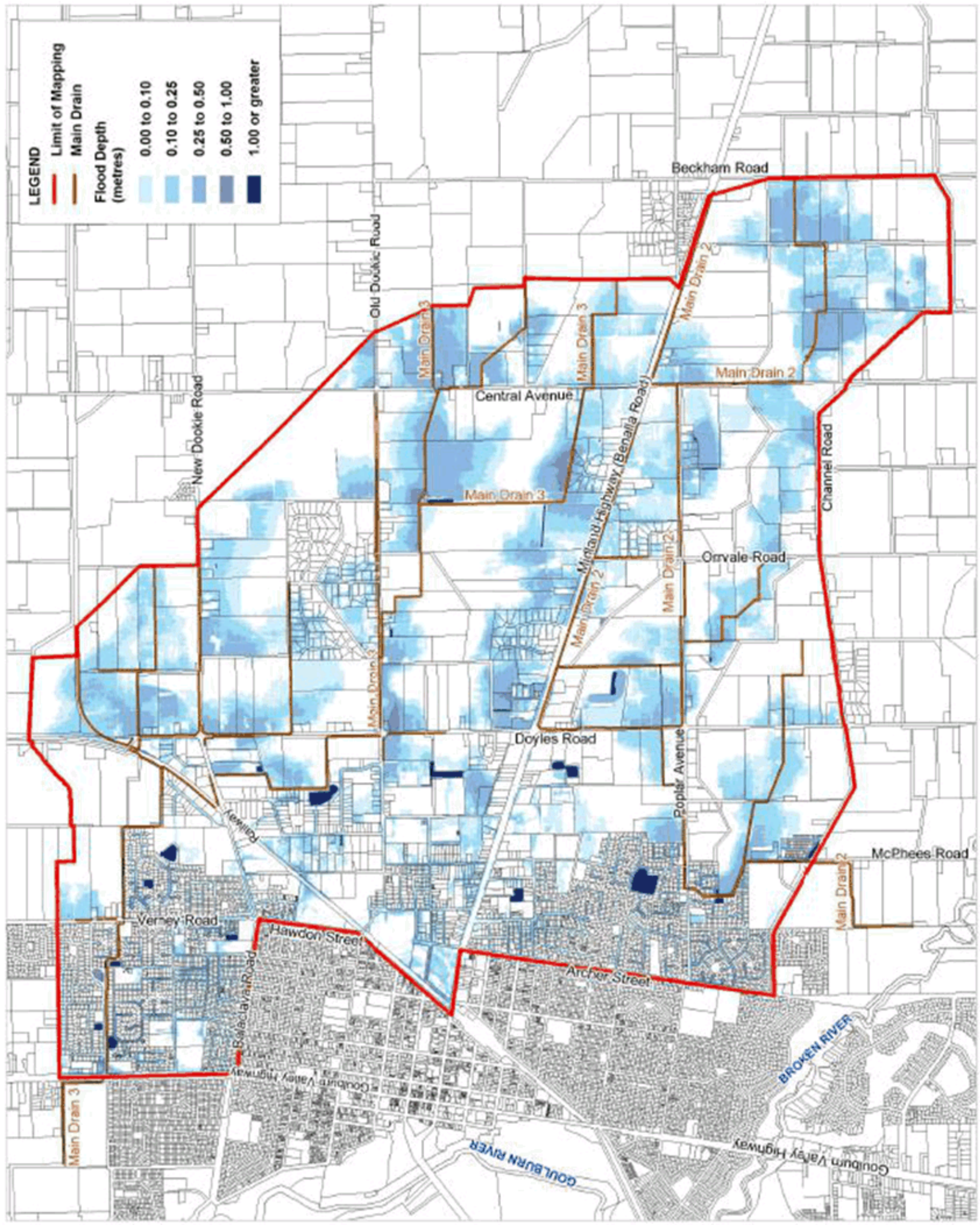
0 0.75 1.5km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : T:\M8415.JL.SheppartonEast_Urban_FS\MapInfo\Drawings\R.M8415.003.00.Final\FigE-4_E01_039_50y_dMax_RevA.wor

East Shepparton – 2% AEP peak flood depths

Greater Shepparton City Council Flood Emergency Plan – A Sub-Plan of the MEMP
- 158 -



Title:
Shepparton East
Existing Conditions 1% AEP Peak Flood Depth

Figure: **E-5**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

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Approx. Scale

BMT WBM
www.bmtwbm.com.au

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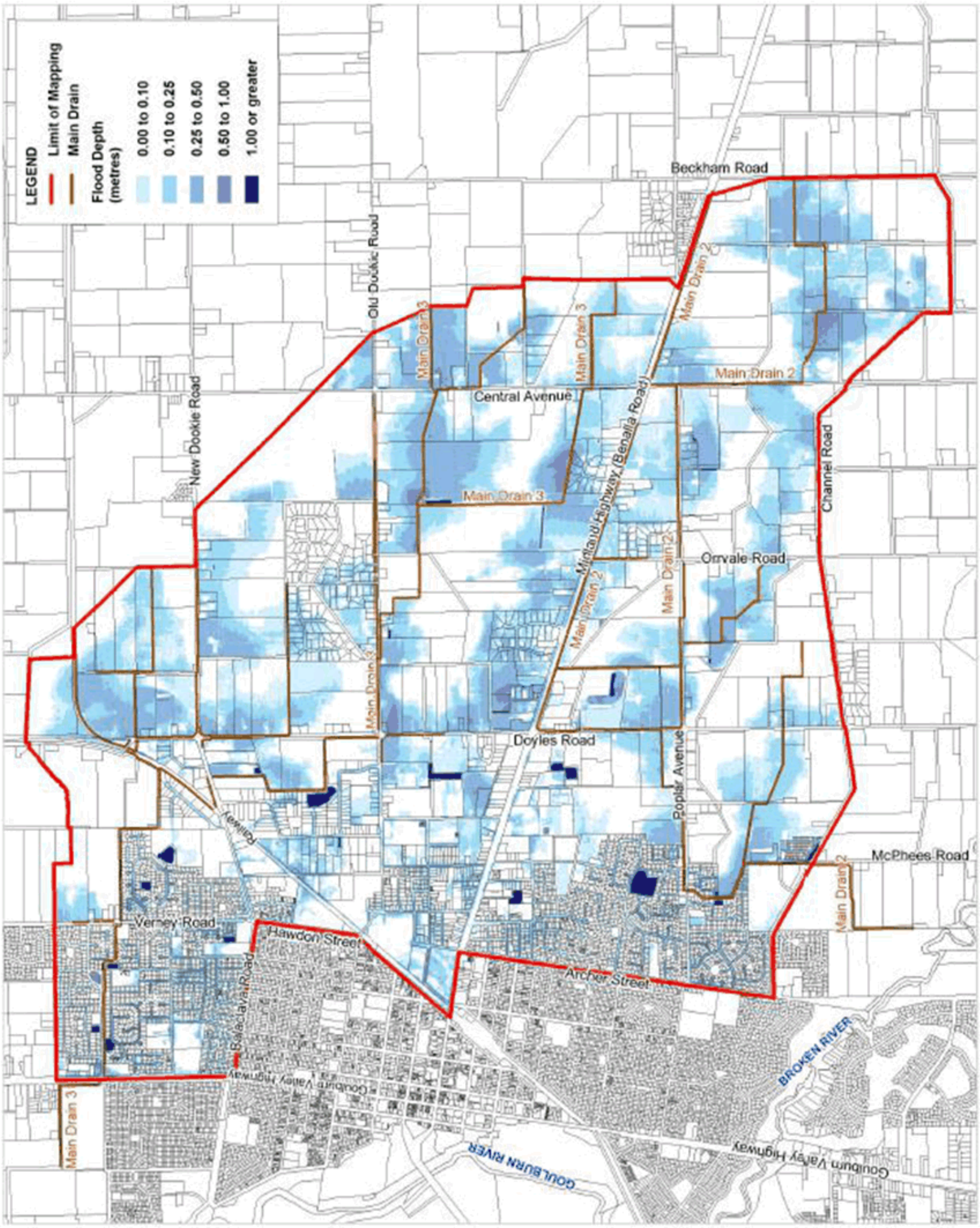
East Shepparton – 1% AEP peak flood depths



Title:

Shepparton East
Existing Conditions 0.5% AEP Peak Flood Depth

Figure: E-6

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 0.75 1.5km

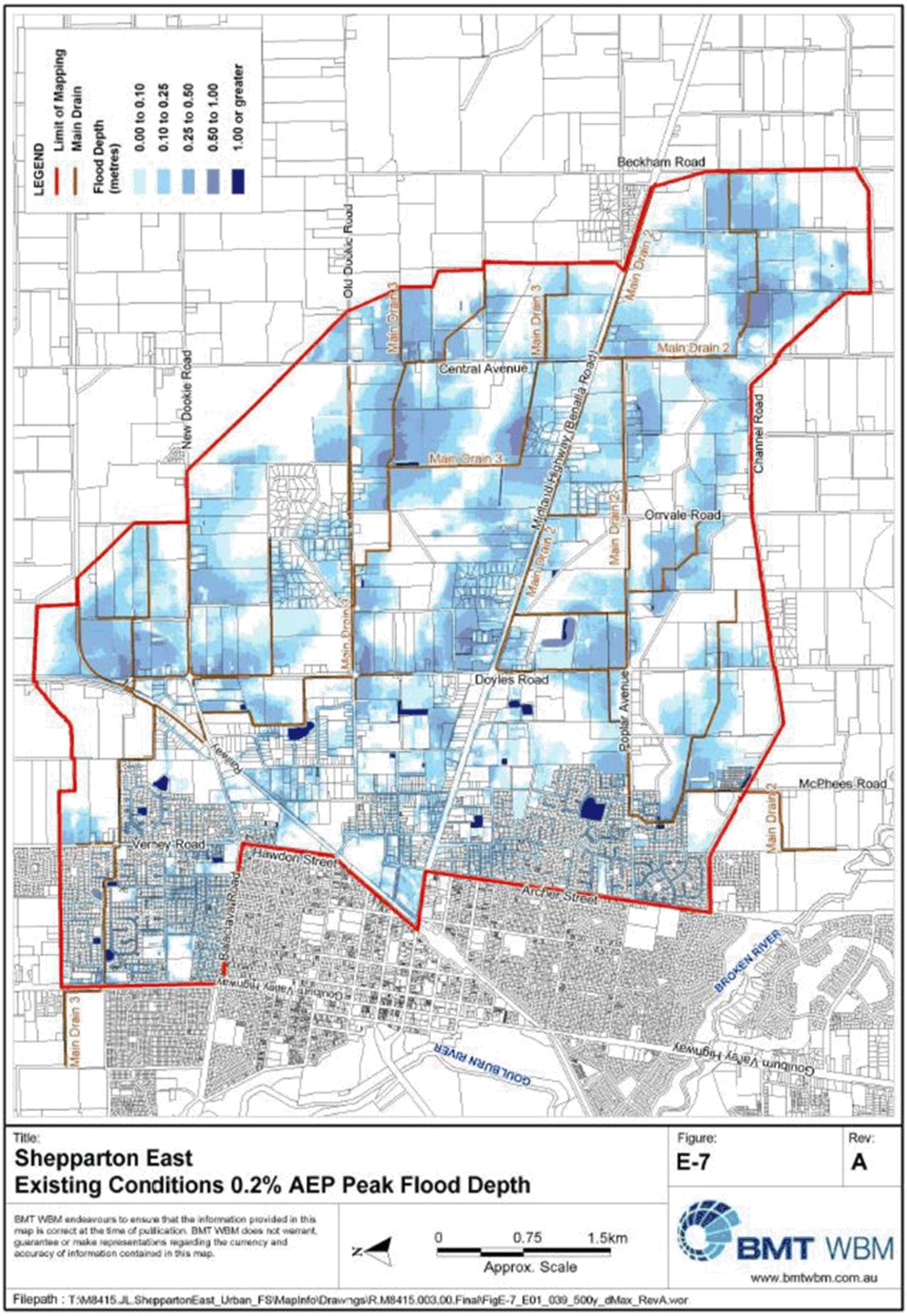
Approx. Scale

BMT WBM

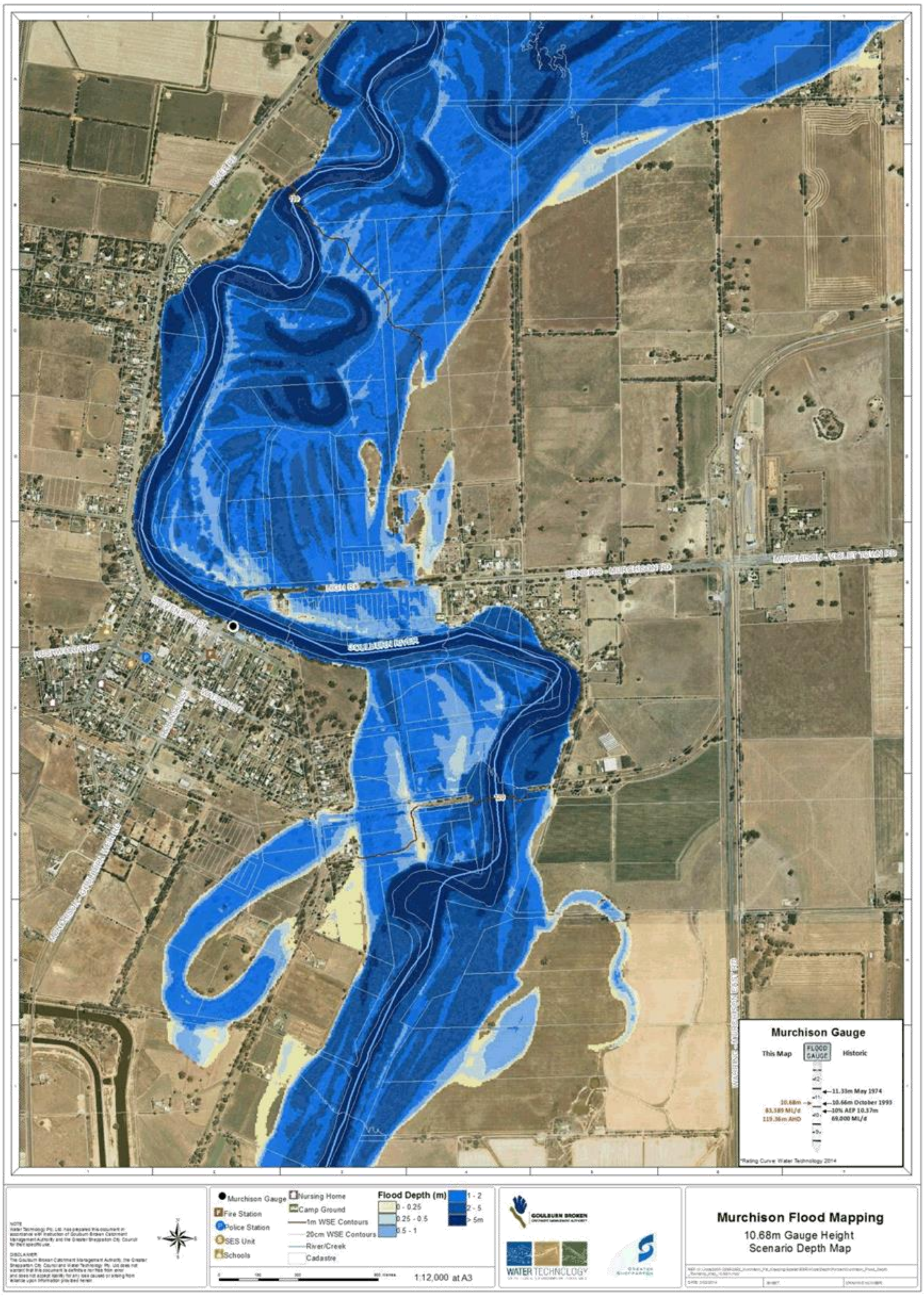
www.bmtwbm.com.au

Filepath : T:\M8415.JL.SheppartonEast_Urban_FS\MapInfo\Drawings\R.M8415.003.00.Final\FigE-6_E01_039_200y_dMax_RevA.wor

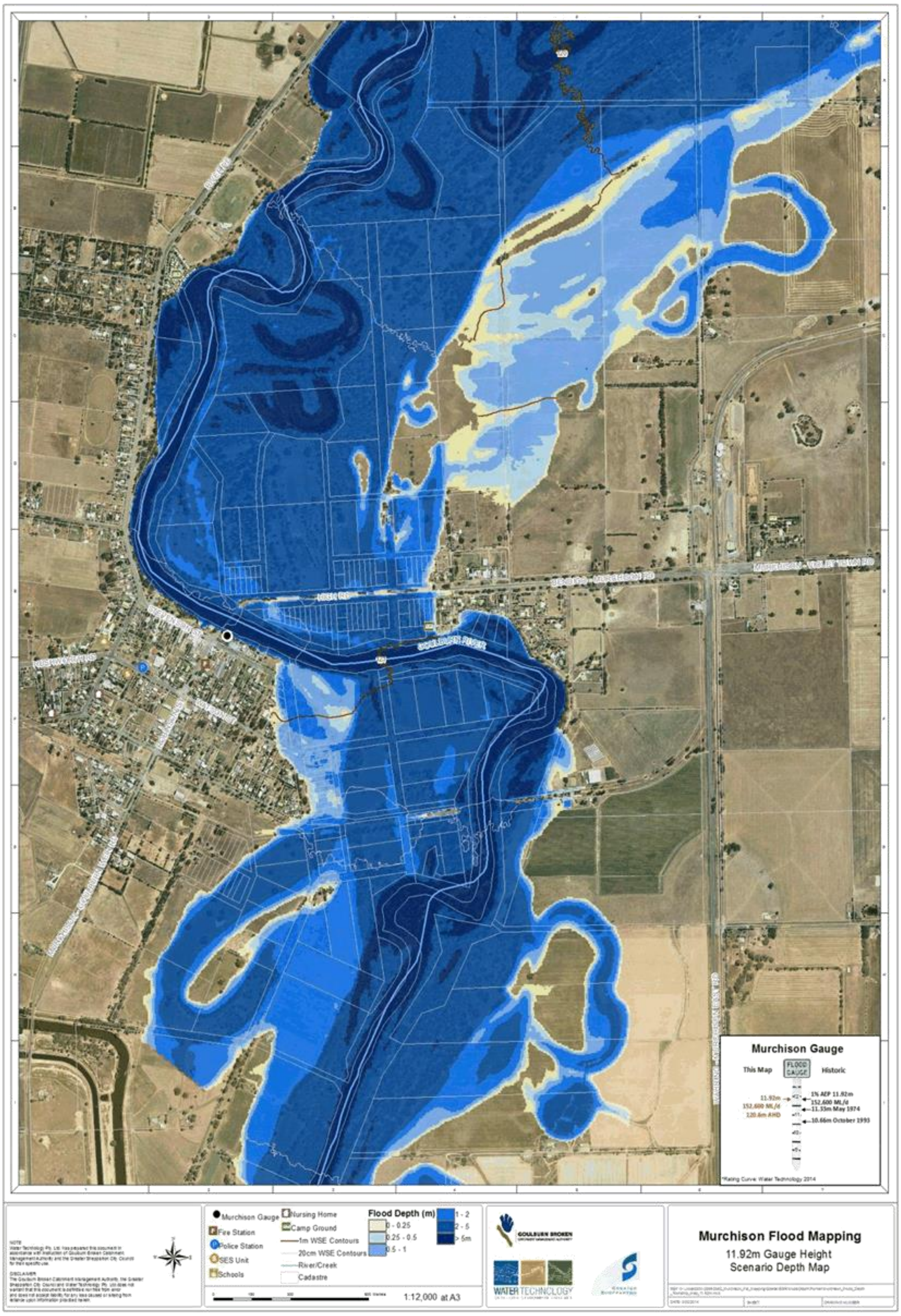
East Shepparton – 0.5% AEP peak flood depths



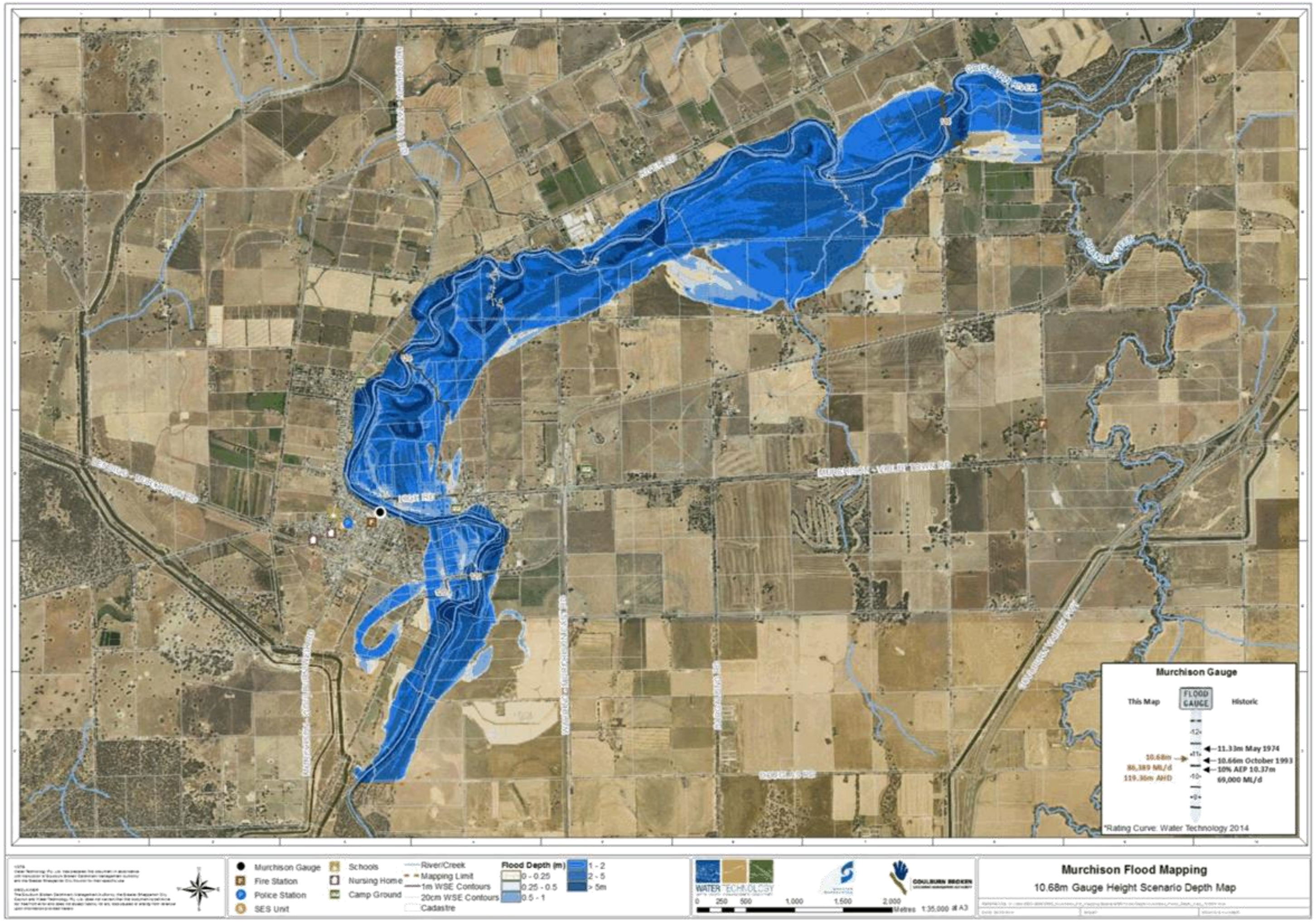
East Shepparton – 0.2% AEP peak flood depths



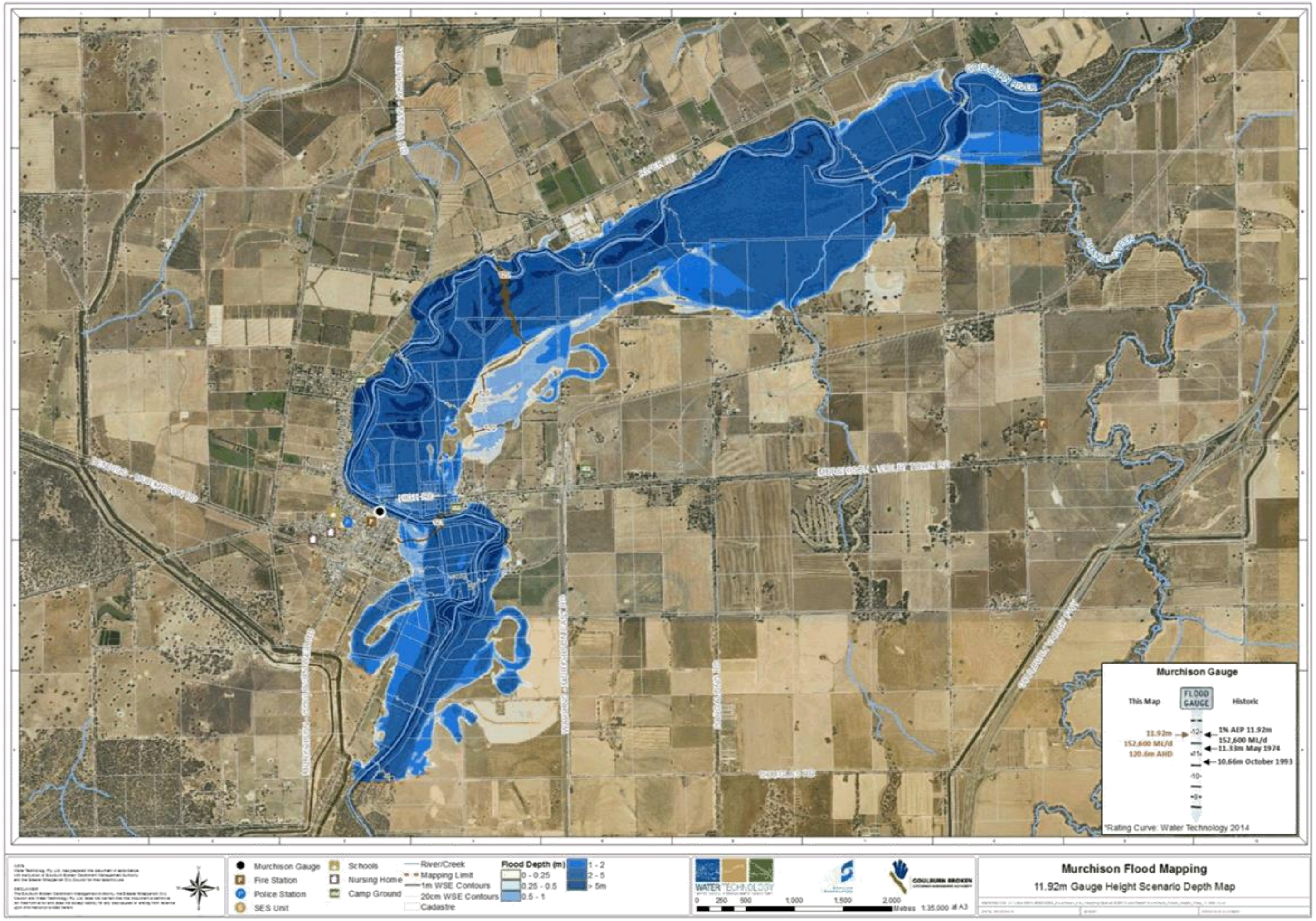
Murchison Township Map 3 – Major Flood Event



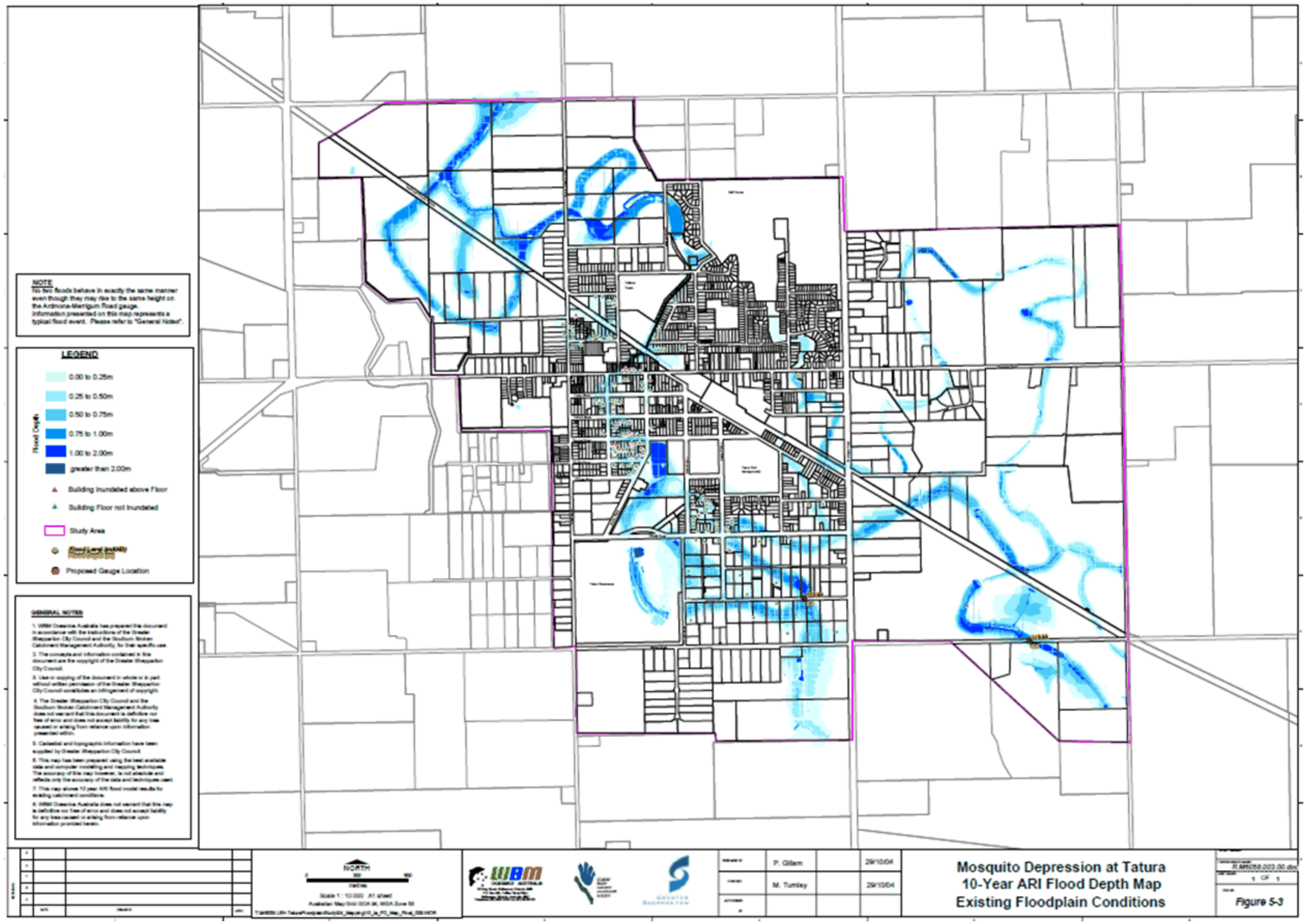
Murchison Township Map 4 – 1% AEP Flood Event



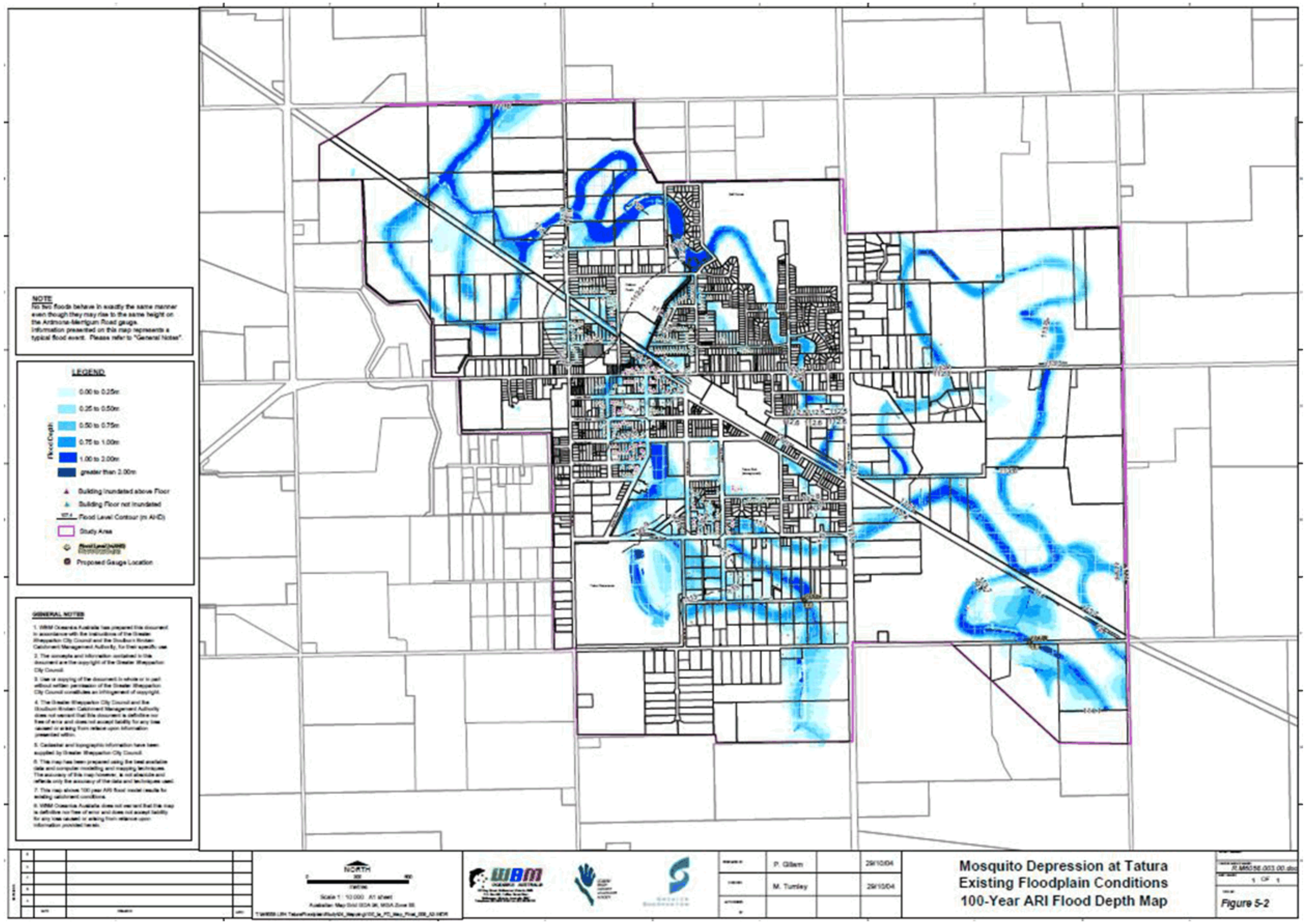
Murchison Rural Map 1 – Major Flood Event



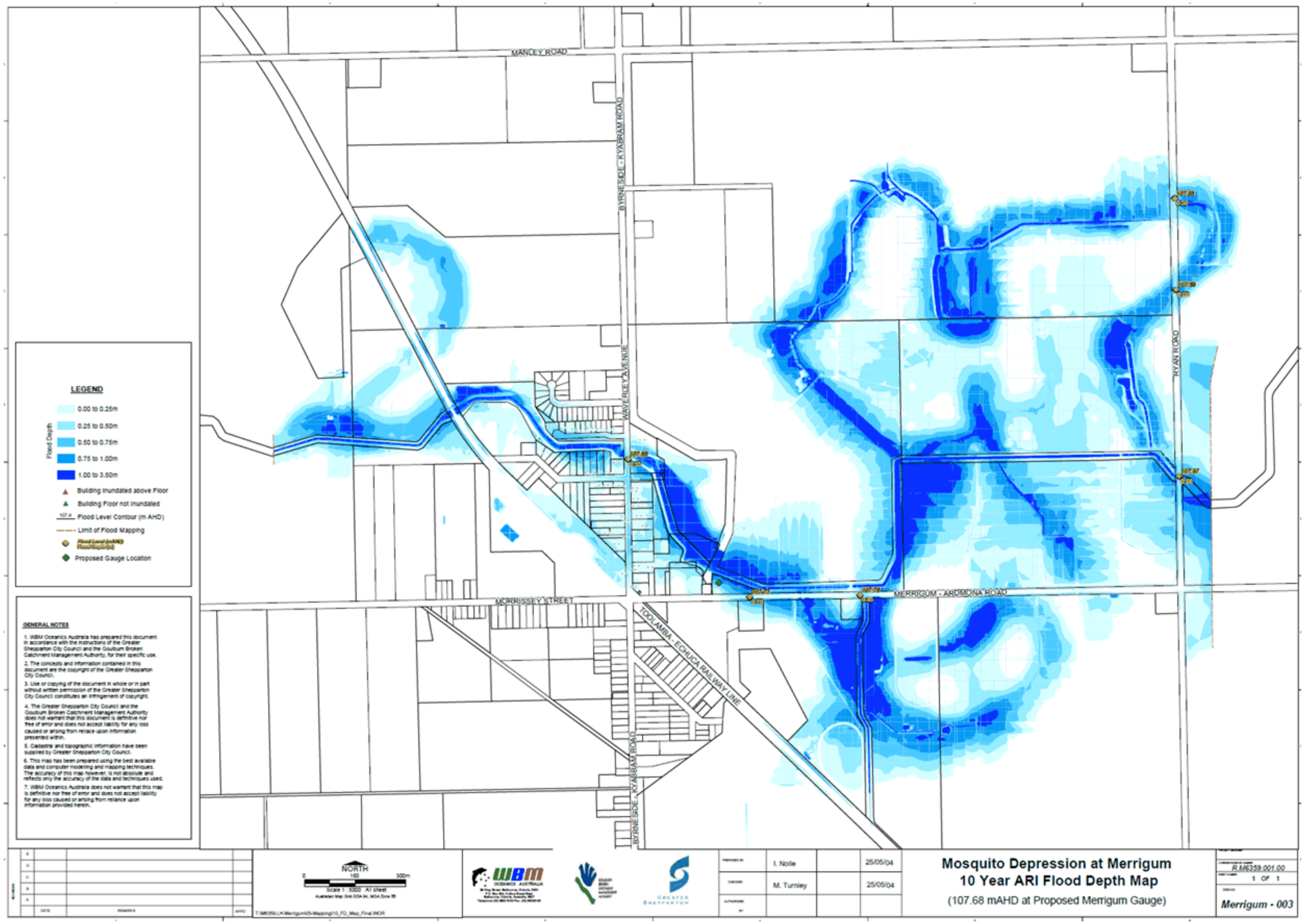
Murchison Rural Map 2 – 1% AEP Flood Event

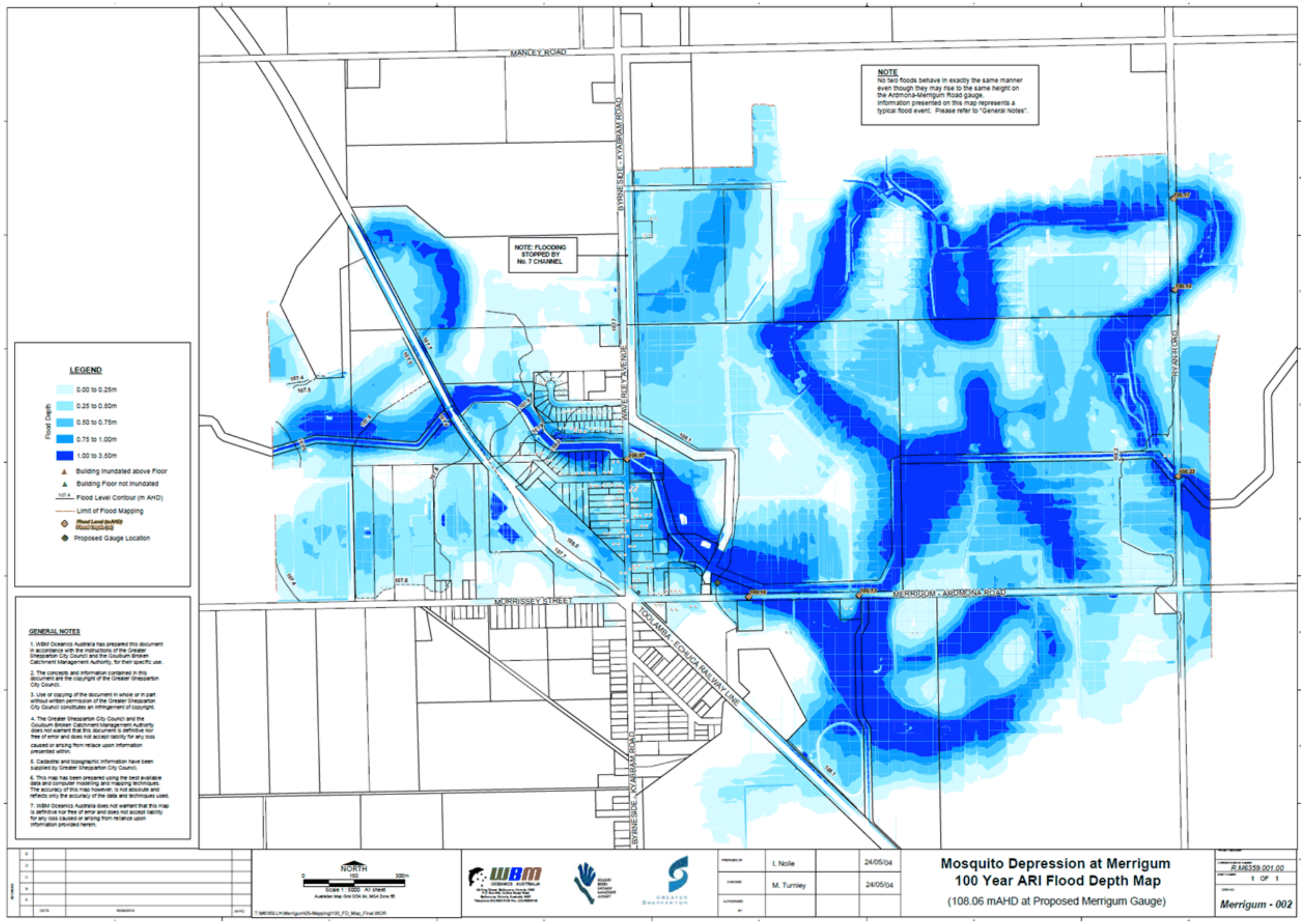


Greater Shepparton City Council Flood Emergency Plan – A Sub-Plan of the MEMP
- 166 -



Greater Shepparton City Council Flood Emergency Plan – A Sub-Plan of the MEMP
- 167 -


MANCEY ROAD
BYRNESIDE - KYABRAM ROAD
WAVERLEY AVENUE
RYAN ROAD
MORRISSEY STREET
MERRIGUM - ARDMONA ROAD
TOOLAMBA - ECHUCA RAILWAY LINE
LEGEND
Flood Depth
0.00 to 0.25m
0.25 to 0.50m
0.50 to 0.75m
0.75 to 1.00m
1.00 to 3.50m
Building Inundated above Floor
Building Floor not Inundated
Flood Level Contour (m AHD)
Limit of Flood Mapping
Proposed Gauge Location
GENERAL NOTES
NORTH
I. Nolle
M. Turnley
25/05/04
25/05/04
Mosquito Depression at Merrigum
10 Year ARI Flood Depth Map
(107.68 mAHD at Proposed Merrigum Gauge)
R.M6359.001.00
1 OF 1
Merrigum - 003


MANCEY ROAD
NOTE
No two floods behave in exactly the same manner even though they may rise to the same height on the Ardmona-Merrigum Road gauge. Information presented on this map represents a typical flood event. Please refer to "General Notes".
NOTE: FLOODING STOPPED BY No. 7 CHANNEL
BYRNESIDE - KYABRAM ROAD
WAVERLEY AVENUE
RYAN ROAD
MORRISSEY STREET
MERRIGUM - ARDMONA ROAD
TOOLAMBA - ECHUCA RAILWAY LINE
LEGEND
Flood Depth
0.00 to 0.25m
0.25 to 0.50m
0.50 to 0.75m
0.75 to 1.00m
1.00 to 3.50m
Building Inundated above Floor
Building Floor not Inundated
107.4 Flood Level Contour (m AHD)
Limit of Flood Mapping
Proposed Gauge Location
GENERAL NOTES
1. WBM Oceanics Australia has prepared this document in accordance with the instructions of the Greater Shepparton City Council and the Goulburn Broken Catchment Management Authority, for their specific use.
2. The concepts and information contained in this document are the copyright of the Greater Shepparton City Council.
3. Use or copying of the document in whole or in part without written permission of the Greater Shepparton City Council constitutes an infringement of copyright.
4. The Greater Shepparton City Council and the Goulburn Broken Catchment Management Authority does not warrant that this document is definitive nor free of error and does not accept liability for any loss caused or arising from reliance upon information presented within.
5. Cadastral and topographic information have been supplied by Greater Shepparton City Council.
6. This map has been prepared using the best available data and computer modelling and mapping techniques. The accuracy of this map however, is not absolute and reflects only the accuracy of the data and techniques used.
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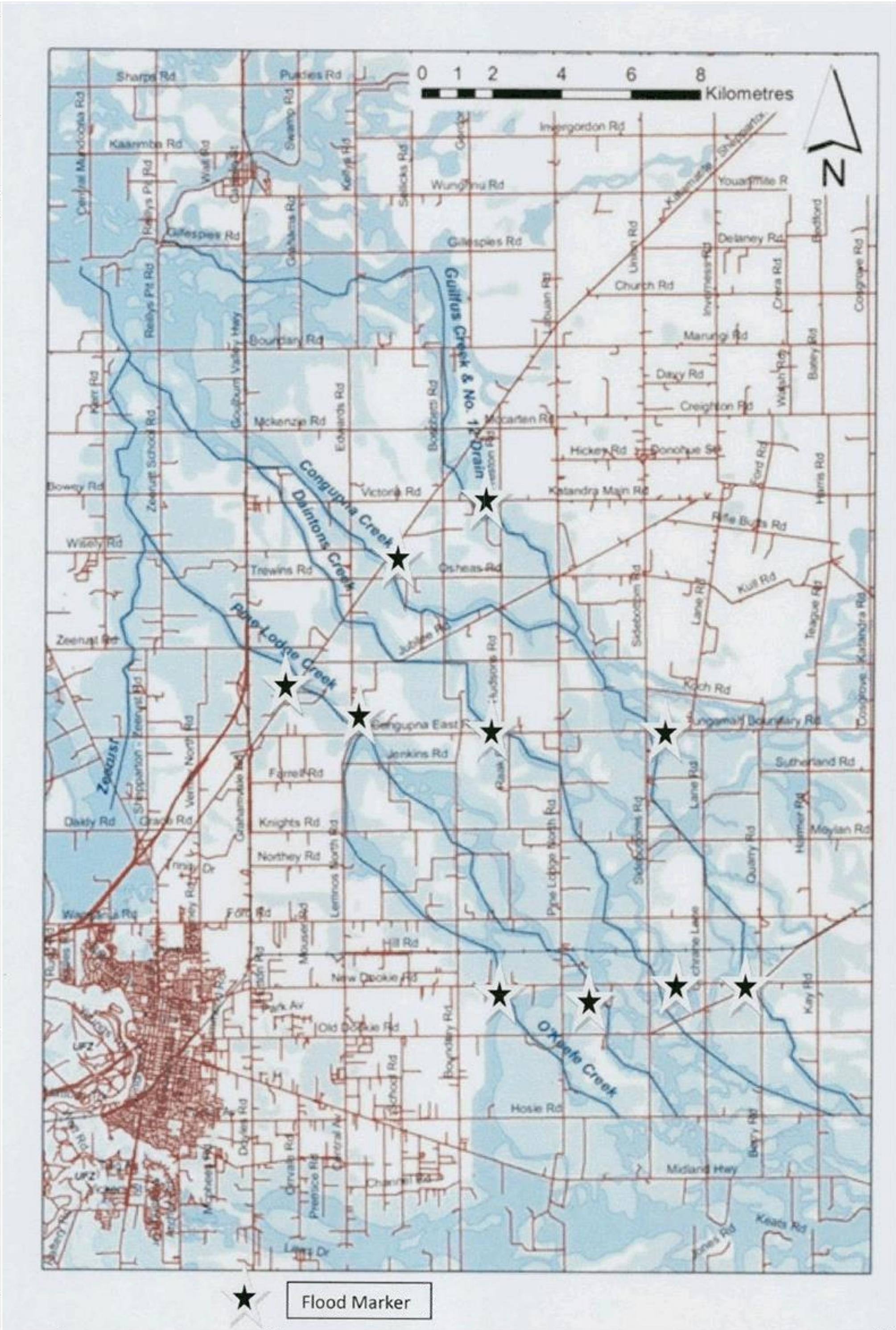
NORTH
I. Nolle 24/05/04
M. Turnley 24/05/04
Mosquito Depression at Merrigum
100 Year ARI Flood Depth Map
(108.06 mAHD at Proposed Merrigum Gauge)
R.M6359.001.00
1 OF 1
Merrigum - 002

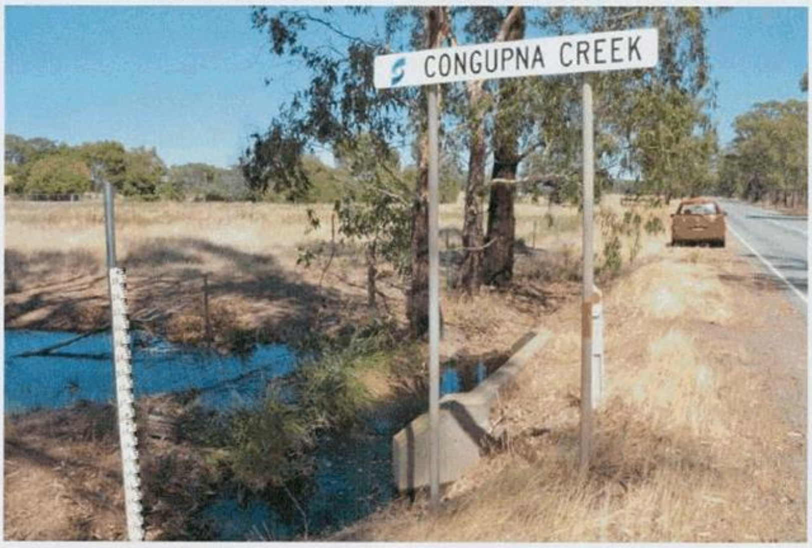
APPENDIX I – STAFF GAUGES ON THE CREEKS

A number of staff gauges (flood markers) have been installed along Congupna, Dainton's, Pine Lodge, O'Keefe and Guilfus creeks as shown on the following maps.



CONGUPNA CREEK

NEW DOOKIE ROAD, 0.3km WEST OF KELLOWS ROAD

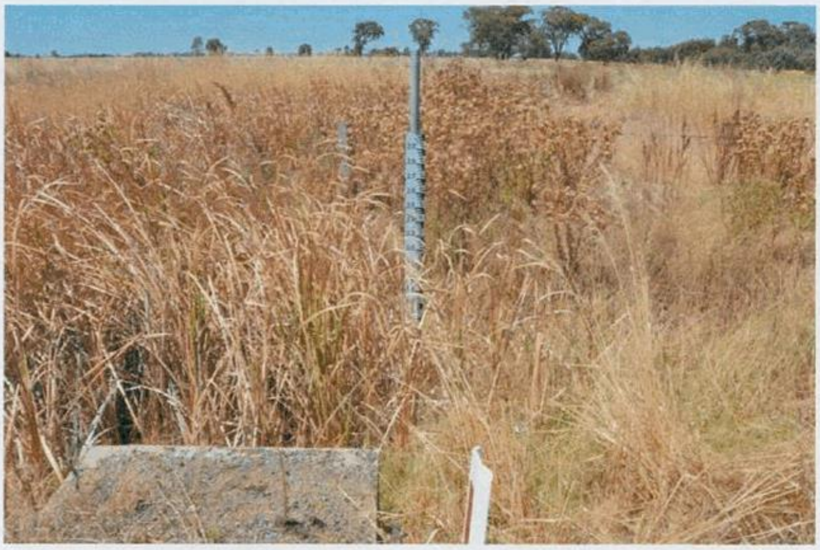


	Gauge Reading	Benalla Gauge
October 1993	2.065	5.500
September 2010	1.536	4.430
March 2012	1.646	Not applicable

- Water will peak at this gauge approximately 41 hours after peaking in Benalla
- Road will be first covered 15m west of the bridge at 1.900m on the gauge

CONGUPNA CREEK

TUNGAMAH-BOUNDARY ROAD 0.2km EAST OF SIDEBOTTOM ROAD



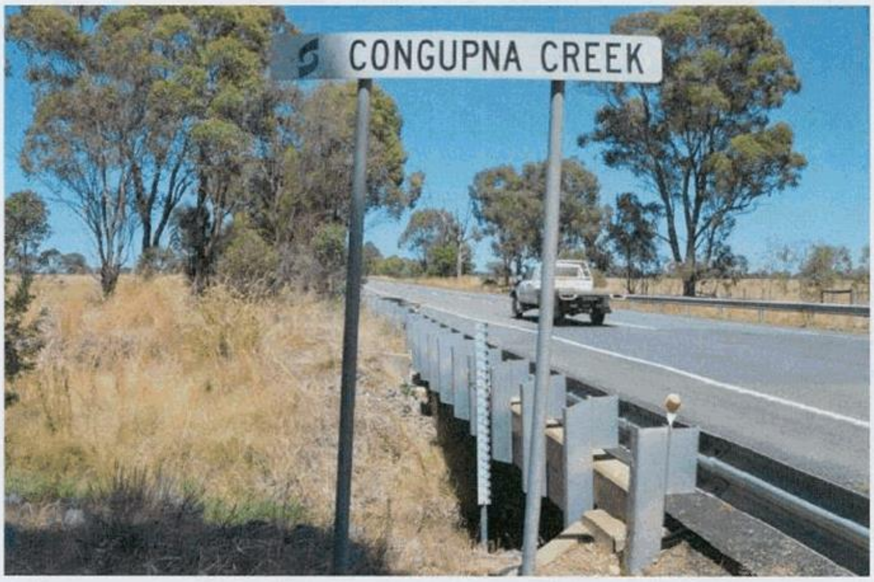
	Gauge Reading	Benalla Gauge
October 1993	2.938	5.500
September 2010	2.409	4.430
March 2012	2.519	Not applicable

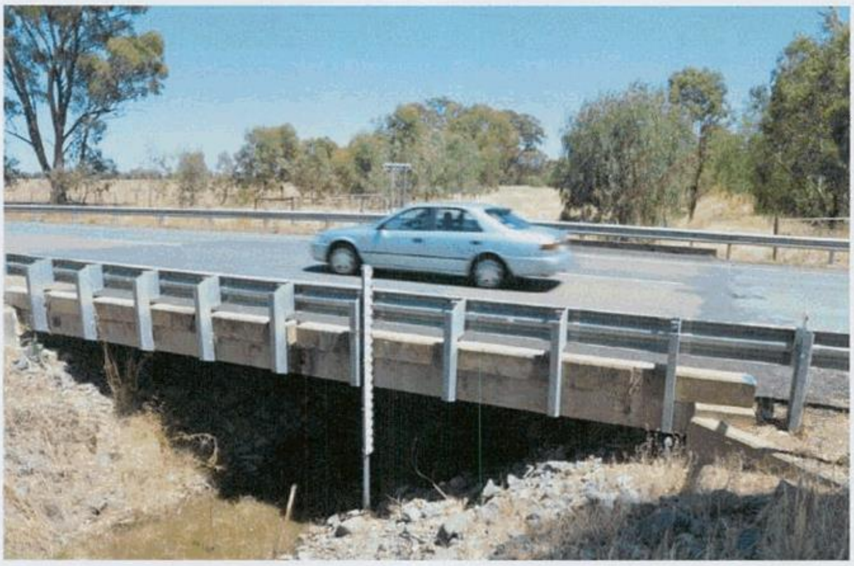
- Water will peak at this gauge approximately 53 hours after peaking in Benalla
- Road will be first covered at 2.074m on the gauge

Greg Howard	340 Tungamah Boundary Road	5828 8353	0428 387462

CONGUPNA CREEK

KATAMATITE-SHEPPARTON ROAD 0.3km SOUTH OF THOMPSONS ROAD





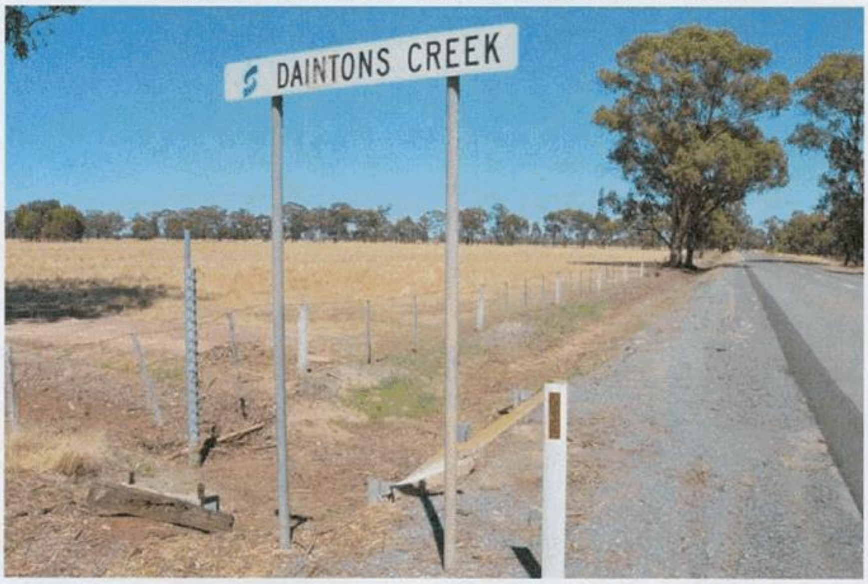
	Gauge Reading	Benalla Gauge
October 1993	2.585	5.500
September 2010	2.176	4.430
March 2012	2.235	Not applicable

- Water will peak at this gauge approximately 77 hours after peaking in Benalla
- Road will be first covered 20m north of the bridge at 2.125m on the gauge

Pegasus Lodge Stud (Sarah)	Katamatite-Shepparton Road	0431 987535

DAINTONS CREEK

NEW DOOKIE ROAD 0.3km EAST OF SIDEBOTTOM ROAD



	Gauge Reading	Benalla Gauge
October 1993	1.855	5.500
September 2010	1.326	4.430
March 2012	1.436	Not applicable

- Water will peak at this gauge approximately 43 hours after peaking in Benalla
- Road will be first covered at 1.850m on the gauge

Ron & Sandra Anstee	1340 New Dookie Road	5828 8227

DAINTONS CREEK

CONGUPNA EAST ROAD 0.3km WEST OF HUDSON ROAD

	Gauge Reading	Benalla Gauge
October 1993	2.500	5.500
September 2010	2.109	4.430
March 2012	2.218	Not applicable

- Water will peak at this gauge approximately 59 hours after peaking in Benalla
- Road will be first covered at 1.995m on the gauge

Alan Reynolds	585 Congupna east Road	5829 9256

PINE LODGE CREEK

NEW DOOKIE ROAD 0.6km EAST OF PINE LODGE NORTH ROAD (CHURCH)

	Gauge Reading	Benalla Gauge
October 1993	2.578	5.500
September 2010	1.838	4.430
March 2012	1.948	Not applicable

- Water will peak at this gauge approximately 51 hours after peaking in Benalla
- Road will be first covered 20m west of bridge at 1.623m on the gauge

Grant Dainton	1110 New Dookie Road	5828 8311 (w)

PINE LODGE CREEK

LEMNOS NORTH ROAD 0.2km NORTH OF CONGUPNA EAST ROAD

	Gauge Reading	Benalla Gauge
October 1993	2.358	5.500
September 2010	1.965	4.430
March 2012	2.208	Not applicable

- Water will peak at this gauge approximately 72 hours after peaking in Benalla
- Road will be first covered at 2.283m on the gauge

John Edwards	765 Lemnos North Road	5829 9101	0459 299101

PINE LODGE CREEK

KATAMATITE-SHEPPARTON ROAD 1.9km NORTH OF CONGUPNA EAST ROAD

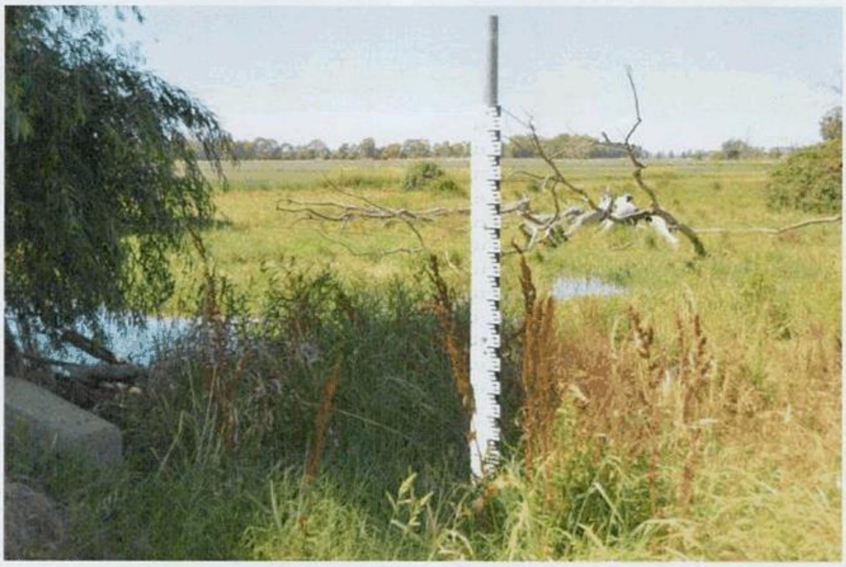
	Gauge Reading	Benalla Gauge
October 1993	2.448	5.500
September 2010	2.050	4.430
March 2012	2.300	Not applicable

- Water will peak at this gauge approximately 78 hours after peaking in Benalla
- Road will be first covered 30m south of the bridge at 2.328m on the gauge

Rob & Liz Grant	3390 Katamatite-Shepparton Road	5829 9206

O'KEEFE CREEK

NEW DOOKIE ROAD 1.7km WEST OF PINE LODGE NORTH ROAD (CHURCH)



	Gauge Reading	Benalla Gauge
October 1993	2.340	5.500
September 2010	1.710	4.430
March 2012	1.820	Not applicable

- Water will peak at this gauge approximately 55 hours after peaking in Benalla
- Road will be first covered at 2.078m on the gauge

Maree & Adrian Fitzsimmons	835 New Dookie Road	0418 358516

GUILFUS CREEK

KATANDRA MAIN ROAD 0.8km EAST OF BOUNDARY ROAD

	Gauge Reading	Benalla Gauge
October 1993	2.025	5.500
September 2010	1.495	4.430
March 2012	1.795	Not applicable

- Water will peak at this gauge approximately 80 hours after peaking in Benalla
- Road will be first covered 20m west of the bridge at 2.050m on the gauge

Henry Humphreys	Katandra Main Road	5829 8245	0428 298245

APPENDIX J – REFERENCES AND INTEL SOURCES

The following studies may be useful in understanding the nature of flooding within the City of Greater Shepparton.

- **FLOODZOOM** – for all available flood extent, depth and related mapping, studies reports and MFEPs as well as cadastral and related information
- http://planningschemes.dpcd.vic.gov.au/index.html Department of Planning and Community Development for planning scheme flood maps
- http://www.vicwaterdata.net/vicwaterdata/home.aspx for historical data on water quality, river heights and flows
- http://www.bom.gov.au Bureau of Meteorology for river gauge readings and flood warnings
- http://www.floodvictoria.vic.gov.au for information on historic floods in Victoria
- http://www.ses.vic.gov.au Victoria State Emergency Service
- http://www.ema.gov.au Emergency Management in Australia
- http://www.delwp.vic.gov.au/fire-and-other-emergencies Department of Environment Land Water and Planning emergency management.
- Cardno Lawson Treloar Pty Ltd (2008): *Lake Nillahcootie Flood Study.* Benalla Rural City, December 2008
- COUNCIL and VICSES Geographical Information System (GIS) – these contain layers showing drainage assets, flooding extents, flood related call-out locations, roads, title boundaries and other useful information.
- Goulburn-Broken Catchment Management Authority (2012). *Goulburn-Broken Basin Flood Summary Report: September 2010 - December 2010 - January 2011.* Draft, September 2012
- Greg Sidebottom (2014). *Flood History. Congupna, Dainton's, Pine Lodge, O'Keefe and Guilfus Creeks.* A report to Greater Shepparton City Council, 27th February 2014
- HydroTechnology (1995). *Documentation and Review of the 1993 Victorian Floods, Volume 5 (Lower Goulburn).* Department of Conversation and Natural Resources, Victoria, March 1995
- Nathan, R and Weinmann, E (1992). *Practical aspects of at-site and regional flood frequency analyses.* Transactions of the Institution of Engineers, Australia. Civil Engineering. Vol CE34, Issue 3
- Sinclair Knight & Partners Pty Ltd (SKP) (1982). *Shepparton – Mooroopna Flood Study.* Prepared for the for State Rivers and Water Supply Commission of Victoria, the City of Shepparton, the Shire of Rodney and the Department of National Development and Energy, June 1982
- Sinclair Knight Merz (SKM) (2002). *Shepparton Mooroopna Floodplain Management Study.* Prepared for the Greater Shepparton City Council, October 2002
- State Rivers and Water Supply Commission Victoria (SRWSC) (1981). *Lake Eildon: Effect on Flood Frequencies.* August 1981
- VICSES, (2013). *Remembering the 1993 Floods.* http://www.ses.vic.gov.au/media/news/news-items/remembering-the-1993-floods, accessed June 2015
- Water Technology (2014). *Murchison Flood Mapping Study Report.* May 2014
- Water Technology (2017). *Shepparton Mooroopna: Flood Mapping and Flood Intelligence.* April 2017
- Water Technology (in preparation). *Granite Creeks Regional Flood Mapping.* Prepared for the Department of Environment, Land, Water and Planning.
- WBM (2005). *Merrigum Flood Study – Final Report.* September 2005

- WBM (2006). *Tatura Floodplain Management Plan.* January 2006
- BMT WBM (2017). *Shepparton East Overland Flow Urban Flood Study – Final Report.* March 2017