WATER TECHNOLOGY
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Expert Opinion

Amendment C31 to the Central Goldfields Planning Scheme

North Central CMA

Panel Hearing

November 2020

Report Author:	Ben Tate
Title:	Expert Opinion Report
Location:	Central Goldfields Shire (specifically Carisbrook and Dunolly)
Report Prepared For:	North Central CMA
Instructed By:	Camille White
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Qualifications:

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

Affiliations:

- Member, Institution of Engineers Australia, Chartered Professional Engineer
- Member, River Basin Management Society
- Member, Floodplain Management Australia

Area of Expertise

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

- Assessment of drainage and flood related issues;
- Expert witness for drainage and flood related issues.

Statement of Expertise

With my qualifications and experience, I believe that I am well qualified to provide an expert opinion on drainage and flood matters relative to Amendment C31 to the Central Goldfields Planning Scheme.

2 SCOPE OF REPORT

In relation to Amendment C31 to the Central Goldfields Planning Scheme, I have been engaged to act as an independent expert on drainage and flooding issues relevant to the proposed amendment to the Land Subject to Inundation Overlay (LSIO) and Floodway Overlay (FO).

I have been asked to review and provide my opinion of the material provided to me in relation to the exhibited LSIO and FO layers, and to provide a summary of the *Carisbrook Flood and Drainage Management Plan (2013)* and the *Dunolly Flood Investigation (2014).* Specifically, I have been requested to:

- Provide an overview of both the Dunolly and Carisbrook Flood Studies, including a summary of the methodology, and statements regarding the accuracy of the modelling.
- Summarise the historical information used to calibrate the models, how well the model compared to the historical events, what consultation was undertaken with community to gather additional information.
- State the estimated likelihood of the 2010 and 2011 flood events.
- Summarise any changes to the modelling completed since the Carisbrook and Dunolly Flood Studies.
    - Describe any changes to the floodplain topography that may influence flood behaviour since the completion of the Flood Studies.
    - Describe the additional modelling that has been undertaken at Carisbrook to understand the impact of the physical works that has been constructed to date.
    - Document any changes to design flood estimation with the update of Australian Rainfall and Runoff since completion of the Flood Studies.
    - Are there any obvious areas that should be removed from the overlays at this time prior to the final stage 4 being completed.
- Describe the level of confidence you have that the proposed works at Carisbrook and Dunolly will mitigate the flood impact.
- Provide a review of the LSIO and FO mapping completed in the rural areas (upstream and downstream) of Carisbrook, and your opinion on its appropriateness to replace the existing LSIO.
- Provide a review of the rationale behind the selection of overlays and your opinion on the appropriateness of the methodology.
- Provide comments regarding each of the five unresolved submissions made by local residents.

3 BASIS OF THIS REPORT

This report is based on:

- Review of Amendment C31 to the Central Goldfields Planning Scheme supporting information and technical reports, including:
  - Central Goldfields C31 Explanatory Report
  - Central Goldfields C31 Amendment Maps Exhibited
  - Carisbrook Flood and Drainage Management Plan (Water Technology, 2013)
  - Dunolly Flood Investigation (Water Technology, 2014)
  - Updated Hydrology and Hydraulic Report – ARR2016: Carisbrook Flood Mitigation Modelling (Water Technology, 2019)
  - Rural Mapping – Tullaroop Creek (North Central CMA, 2019)
- Review of additional available information, including:
  - LiDAR (survey) and VicMap data
  - GIS flood mapping results
  - Dunolly and Carisbrook hydrology and hydraulic models
- Five unresolved Submissions received in respect to Amendment C31 to the Central Goldfields Planning Scheme:
  - Rinaldi, McCallum Street, Carisbrook
  - McIver, Landrigan Road, Carisbrook
  - Blazko, Curragh Moor Road, Carisbrook
  - Coutts, Carisbrook
  - Hodgkins, Bucknall Street, Carisbrook
- Relevant guidelines and standards, including:
  - DELWP's *Guidelines for Development in Flood Affected Areas* (2019)
  - Planning Practice Note 12 - Applying the Flood Provisions in Planning Schemes: A guide for Councils
- Council material, including:
  - Ordinary Council Meeting Minutes (26th November 2019)

This report has been prepared in accordance with the relevant procedures and practice notes applied by Planning Panels Victoria on Expert Evidence. I have read the "Guide to Expert Evidence" and am aware of my overriding duty to assist the Panel on matters relevant to my expertise.

I have had no direct input in the development of the C31 Central Goldfields Planning Scheme Amendment. I was Project Director on both the Carisbrook and Dunolly Flood Studies and the subsequent work completed at Carisbrook, so I am very familiar with the technical details of those studies.

My mother in law resides on the Carisbrook-Eddington Road, which under the C31 Central Goldfields Planning Scheme Amendment will have a small portion of grazing land covered by the proposed LSIO and FO.

4 INTRODUCTION

I have been instructed by North Central CMA on behalf of Central Goldfields Shire Council to provide expert evidence in relation to relevant drainage and flooding matters associated with the proposed Amendment C31 to the Central Goldfields Planning Scheme.

5 BACKGROUND

5.1 Locality

The C31 Amendment to the Central Goldfields Planning Scheme applies to 754 properties in Carisbrook, Dunolly and surrounding rural areas. The Amendment relates to riverine flood risk from Burnt Creek through Dunolly, McCallums and Tullaroop Creeks through Carisbrook, Tullaroop Creek in rural areas between Tullaroop Reservoir and Eddington. The Amendment also relates to flooding from major overland flow paths through Carisbrook and Dunolly.

As a result of the Carisbrook and Dunolly Flood Studies, physical flood mitigation works have already been constructed, with further works planned at Carisbrook. The proposed Amendment reflects the mitigation work already constructed but not the works yet to be completed at Carisbrook.

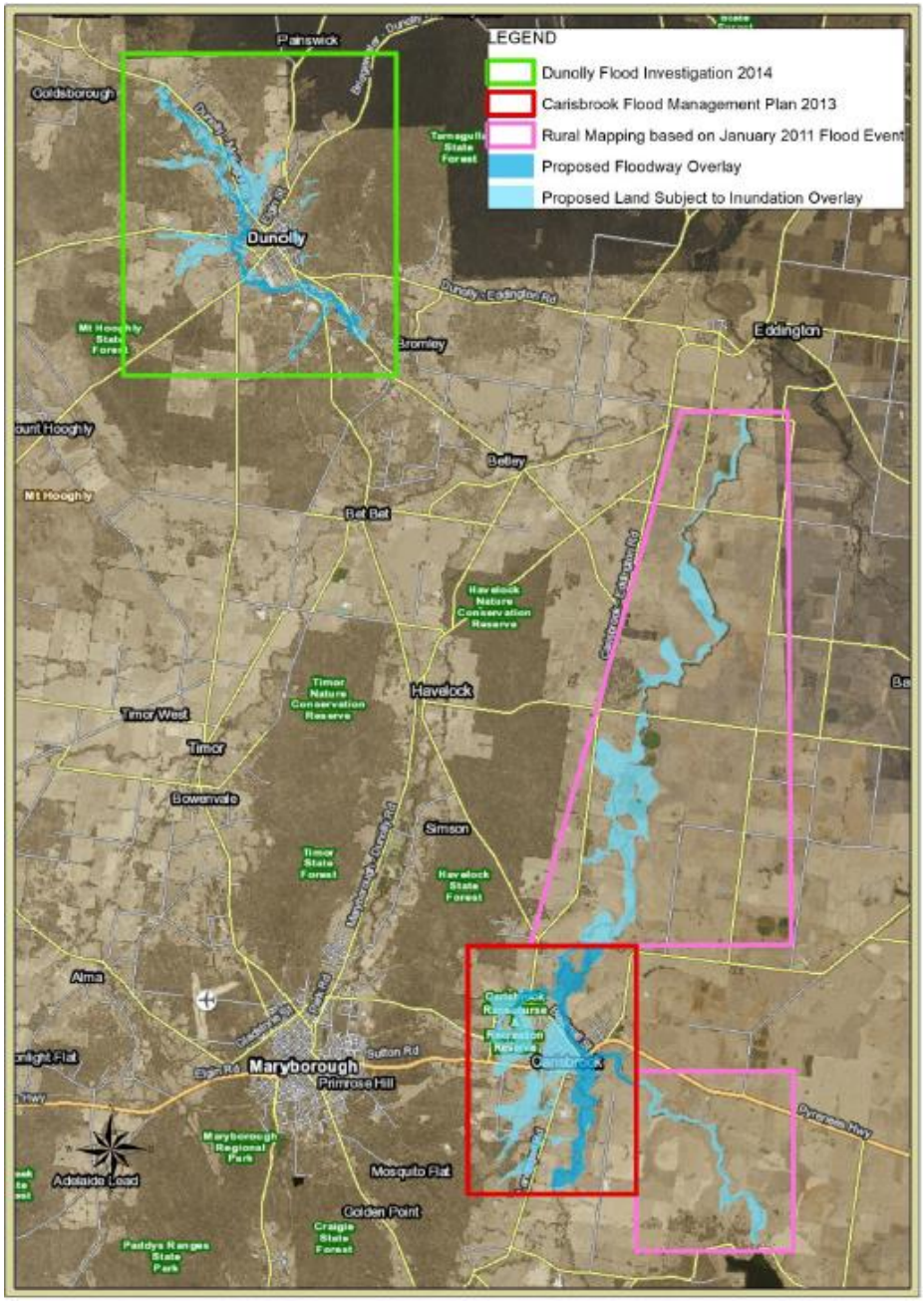

Figure 5-1 Area subject to Amendment

The Central Goldfields Planning Scheme currently has LSIO implemented, with no FO, Figure 5-2. This Amendment will introduce FO for the first time.

Prior to the Carisbrook and Dunolly Flood Studies the flood controls were based on best estimates and hand drawn extents from knowledge of past floods and interpretation of available topography and aerial imagery. As a result, some areas of the existing LSIO are highly inaccurate.

The proposed LSIO and FO is based on the best available flood mapping data available in Carisbrook and Dunolly. The North Central CMA have extended the area of flood mapping coverage upstream and downstream of Carisbrook along Tullaroop Creek. These three flood mapping studies have been used this to develop the proposed LSIO and FO flood controls in this Amendment.

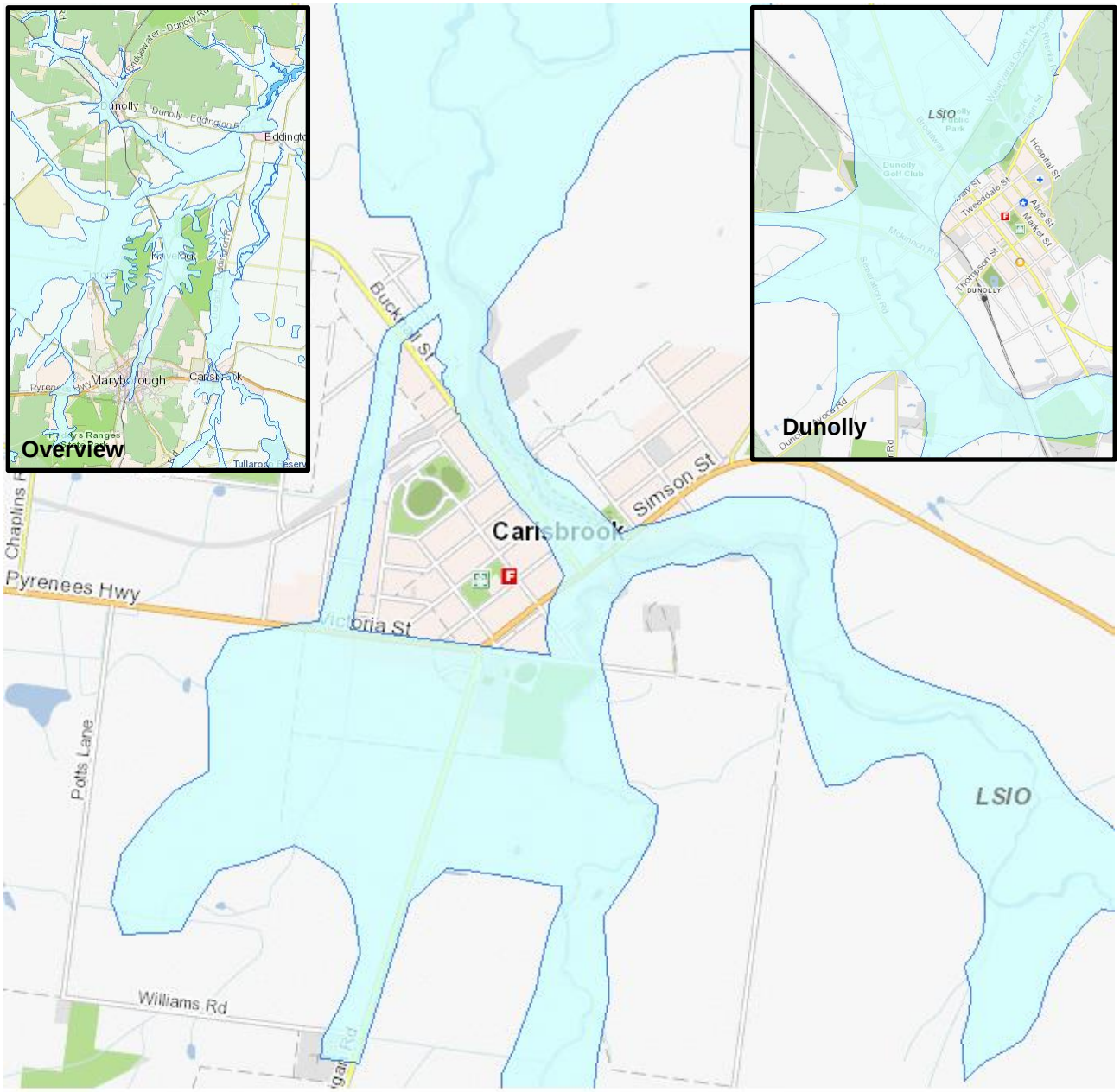

Figure 5-2 Current LSIO

5.2 Existing Flood Risk

The Carisbrook and Dunolly townships were known to be at risk of flooding prior to the 2010-11 flood events. The January 2011 event was one of the largest flood events on record throughout the region, with Carisbrook suffering significant damage (over 250 properties inundated). The majority of the Dunolly township was largely unimpacted (estimated that 20 houses inundated), but the town was once again isolated, with all road access cut, with the only way in and out along the raised railway line embankment.

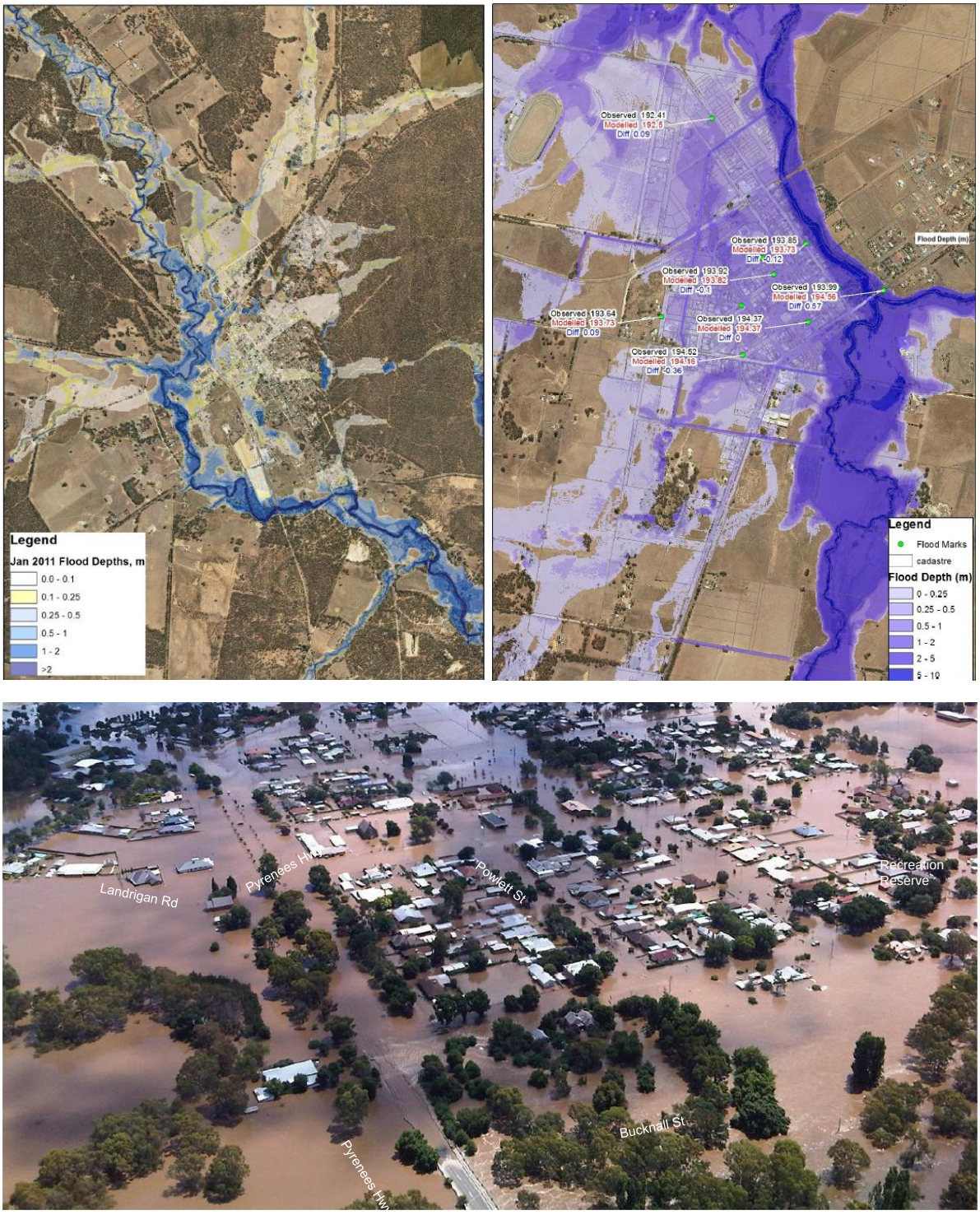

Figure 5-3 January 2011 Modelled Flooding Dunolly (top left) and Carisbrook (top right). Flood Imagery of Carisbrook in January 2011

As a result of the flood risk identified, the relevant authorities, namely North Central Catchment Management Authority (NCCMA) and the Central Goldfields Shire Council (CGSC), commissioned the following two studies:

- Carisbrook Flood and Drainage Management Plan (Water Technology, 2013)
- Dunolly Flood Investigation (Water Technology, 2014)

The two flood studies carried out detailed hydrological and hydraulic modelling of the catchment and floodplain, calibrated to historic events, modelled a range of flood magnitudes, assessed the flood risk and calculated flood damages, investigated mitigation options made flood warning recommendations, and consulted with the community on several occasions. Both studies had a community steering committee setup to oversee the studies, and particularly in the case of the Carisbrook study, the committee was very active and engaged.

Since the studies, further relevant investigations have been completed, including:

- Carisbrook detailed design (Entura, 2016)
- Updated Hydrology and Hydraulic Report – ARR2016: Carisbrook Flood Mitigation Modelling (Water Technology, 2019)
- Rural Mapping – Tullaroop Creek (North Central CMA, 2019)

North Central CMA managed works to clear a section of Tullaroop Creek of invasive woody tree species and thin out some of the native River Red Gums to provide less resistance to flood waters.

Council completed works, upgrading a flood mitigation contour channel at Dunolly and a small retarding basin to reduce the risk of inundation from local overland flows at Dunolly. Council also has completed the first stages of a larger flood mitigation project at Carisbrook, reinstating a cut of drain south of Carisbrook between Landrigans Road and McCallums Creek, and constructing levees and drains along Belfast Road and the northern end of Pleasant Street. The next stage of works is currently in progress, with components of the western levee part way through construction, which will protect the town from overland runoff from the catchment to the west.

5.3 Proposed Amendment

The C31 Central Goldfields Planning Scheme Amendment proposes to update the flood related planning controls to reflect the current best available flood mapping information. The Amendment will:

- Update the LSIO in the rural areas between Tullaroop Reservoir and Eddington based on mapping completed by North Central CMA.
- Update the LSIO in Carisbrook and Dunolly based on flood mapping completed by Water Technology. This will reflect the already constructed flood mitigation works but will not include impact of mitigation works not yet completed at Carisbrook.
- Introduce FO in areas of higher hazard based on the results of the flood mapping byNorth Central CMA and Water Technology.
- Associated changes to Schedules and Clauses as described in the C31 Explanatory Report.

6 OVERVIEW OF THE FLOOD STUDIES

6.1 Dunolly Flood Investigation

Following the 2010 and 2011 flooding, the North Central CMA in conjunction with Central Goldfields Shire Council commissioned Water Technology to complete a flood investigations at Dunolly, including Burnt Creek and the upstream catchment. The below sections summarise the relevant components of the study in relation to the flood mapping produced, which is relied upon for the C31 Central Goldfields Planning Scheme Amendment.

6.1.1 Data Availability

The first stage of any flood study involves data collation and review because this to a large extent will determine the flood modelling approach and will guide the selection of historic events to calibrate the modelling to.

6.1.1.1 Streamflow Gauging

Unfortunately, there is no streamflow gauging on Burnt Creek, but some data exists for the Bet Bet Creek at Bet Bet outside of the study area. Burnt Creek is a tributary to Bet Bet Creek. The hydrology modelling included both Burnt Creek and the Bet Bet Creek catchment so that the modelling could be calibrated to streamflow gauging on Bet Bet Creek as a means to validate the model parameters for use on the ungauged Burnt Creek.

The Bet Bet Creek at Bet Bet streamflow gauge has records from 1943 to current, but has periods of missing data. There was no streamflow data available for the Bet Bet Creek at Bet Bet streamflow gauge in the January 2011 event, but data was available for the September 2010 event.

Although not ideal to have no streamflow data within the Burnt Creek catchment, this is not uncommon in flood studies. With the Bet Bet Creek gauge and the observed flood levels for January 2011, there was enough data to form a robust estimate of streamflow within Burnt Creek and the tributaries upstream of Dunolly.

6.1.1.2 Rainfall Gauging

Rainfall data at twenty five nearby daily rainfall gauges was collated along with ten sub-daily rainfall gauges. These gauges were used to provide historic rainfall data for model calibration. The daily gauges were used to provide rainfall totals across the catchment, with the sub-daily gauges used to provide the pattern of the rainfall intensity during the storm.

Only two of the daily rainfall gauges are located within the Burnt Creek catchment, with another at Moliagul just outside of the catchment boundary. No sub-daily rainfall gauges are located within the Burnt Creek catchment but the gauge at Bet Bet is reasonably close.

In the January 2011 event up to 230 mm of rainfall was recorded over a 5 day period, with the maximum daily rainfall recorded exceeding 90 mm.

In the September 2010 event around 85 mm was recorded over 4 days with most of the rainfall falling overnight on Friday 3rd September.

The rainfall data available was appropriate to develop a good understanding of rainfall patterns across the catchment.

6.1.1.3 Topography and Feature Survey

The flood modelling relied heavily on the available LiDAR (aerial laser survey) topography data. The LiDAR was captured in 2011 and has a stated vertical and horizontal accuracy of 0.1 and 0.2 m respectively. To verify

the LiDAR, detailed field survey was undertaken along two transects. This showed that the LiDAR was accurate, with a mean difference to the field survey of just 54 mm.

Feature survey of over 20 waterway structures including bridges and culverts was undertaken, including details of the invert levels, pipe diameters, pier widths, etc.

Both the LiDAR and the feature survey of structures was used in the development of the hydraulic flood model to enable an accurate representation of the floodplain topography.

Floor level survey was captured for flood impacted dwellings to assist with the flood damages assessment and flood intelligence products for emergency planning.

6.1.1.4 Flood Data

Eight surveyed flood heights based on debris marks from the January 2011 flood event were available along Burnt Creek.

Early on in the study a request for information was published in the local newspaper. The response was very helpful, with many community members providing anecdotal accounts of historic flooding, rainfall data, sketched up flood extents, time stamped photos and historic newspaper articles. During the study, the community was engaged several times.

In addition, some earlier flood estimates for Burnt Creek completed by the Rural Water Commission in 1986, a VICSES debriefing report following the January 2011 event, and a rapid impact assessment by the Office of the Emergency Services Commissioner for the January 2011 flood, were also very useful.

6.1.2 Flood Modelling

The modelling approach adopted for the study followed industry best practice approaches at the time the study was completed. A combination of RORB catchment modelling to estimate streamflow in Burnt Creek and tributaries upstream of Dunolly, with MIKE FLOOD hydraulic modelling to determine flood extents, depths, and velocities was used. The models were calibrated to historic events and the calibrated models were then used for design flood modelling of events with a range of flood magnitudes.

6.1.2.1 Calibration

The September 2010 flood event was used to calibrate the RORB catchment model to the Bet Bet Creek at Bet Bet gauge. A good model calibration was achieved, using model parameters that are within the expected range.

The January 2011 event was then modelled using the calibrated RORB catchment model to generate streamflow hydrographs for input into the hydraulic model. The hydraulic model was compared to historic flood marks and the extent of inundation was presented to the project steering committee. Local residents and members of the local VICSES confirmed the flood extent along Burnt Creek provided a good match to observations, but that local overland flooding from the catchment to the east of town was overestimated. A dilapidated contour channel running through the forest to the east of town intercepts this local catchment runoff and bypasses the town, outfalling into Burnt Creek downstream of town. The contour channel was walked along its length, and the model was updated to reflect its current condition and embankment heights.

The January 2011 model was rerun, with the extents providing an improved match to local observations.

The January 2011 model calibration was determined to provide a good agreement with surveyed flood marks along Burnt Creek, with the model being on average just 16 cm higher than surveyed marks. The flood extents across town were accepted by the community members and local VICSES team on the Steering Committee and were accepted by the broader community during a community engagement event.

6.1.2.2 Design

The calibrated hydrology and hydraulic model was then adopted for design purposes. It is noted that the design modelling approach used the Australian Rainfall and Runoff (1987) methods. These methods have since been updated in 2016 and again in 2019. The changes in Australian Rainfall and Runoff do represent a significant shift in the design modelling approach. Although the design modelling approach would be different if the study was done today, it is not to say that the results would be significantly different.

To provide confidence in the design flood modelling approach adopted for the Dunolly Flood Investigation, several design estimate verifications and comparisons to previous work were made. While there is a lot of variability in the design flow estimates across the different approximation equations and past studies, they are all within an expected range, and this provides confidence that the Dunolly design flood estimates are appropriate.

A comparison of the best estimates of the January 2011, September 1983 and April 1959 peak flows to that of the design flood estimates is provided in Table 6-1, with the design flood extents shown in Figure 6-1.

Table 6-1 Burnt Creek Design Flow Compared to Best Estimate of Historic Events

Event	Peak Flow (m^3/s)
20% AEP	20
10% AEP	42
September 1983	45
5% AEP	71
2% AEP	106
January 2011	107
1% AEP	145
April 1959	160
0.5% AEP	188

Despite the fact that the Australian Rainfall and Runoff design flood estimation approaches have now been updated, the Dunolly Flood Investigation provides the most current and best design flood mapping information available for the study area.

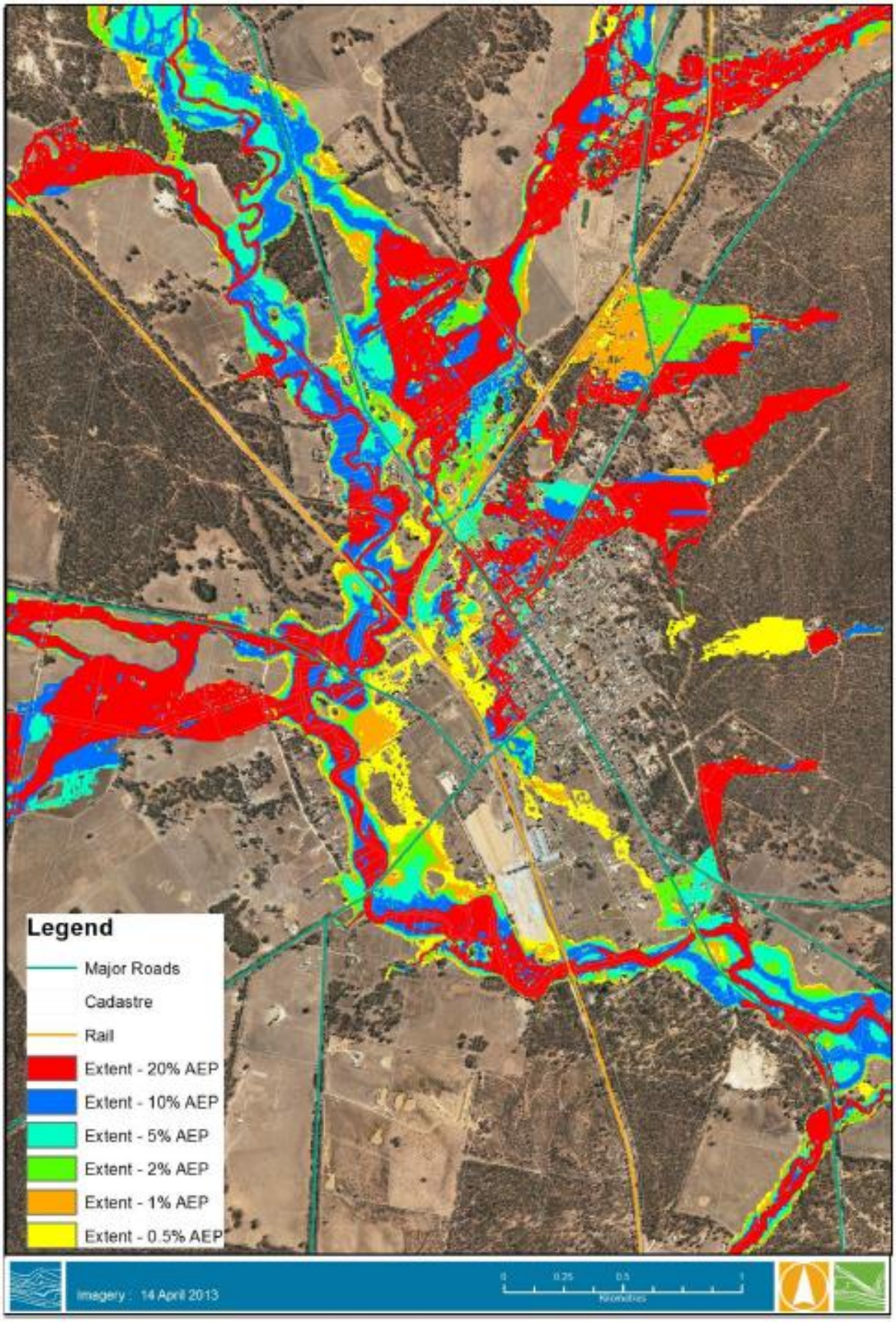

Figure 6-1 Design Flood Extents for Dunolly.

6.1.2.3 Community Engagement

Community engagement throughout the study provided very useful information to help improve the quality of the study, and the feedback and concerns raised shaped some of the technical analysis completed. An initial media release and engagement session uncovered a lot of anecdotal information used during the model calibration. Community ideas regarding mitigation were assessed, and concerns regarding a local water storage was investigated in detail.

Feedback on the draft flood mapping was sort, with the mapping updated to reflect some community observations regarding the overland inundation from the catchment to the east of Dunolly. Positive feedback was received regarding the final flood mapping and the recommended flood mitigation measures.

6.1.3 Changes in Floodplain Since Study

Since the completion of the flood study the Council has completed works to upgrade the contour channel which intercepts the overland flow from the catchment to the East of Dunolly, and formalised a small retarding basin associated with the contour channel. In addition, vegetation removal along the channel and minor earthworks have been completed. The works completed should prevent overland flooding from the eastern catchment from inundating the township.

These works do not impact the broader flooding from Burnt Creek.

The flood mapping completed of the recommended flood mitigation package has been used in the determination of the proposed LSIO and FO for the C31 Central Goldfields Planning Scheme Amendment. This is appropriate as it best represents the current conditions of the floodplain.

6.2 Carisbrook Flood and Drainage Plan

Water Technology completed the Carisbrook Flood and Drainage Plan on behalf of North Central CMA and in conjunction with Central Goldfields Shire Council in 2013. This formed the first major flood investigation at Carisbrook, and greatly improved the understanding of flood risk for the town. Flooding at Carisbrook is a result of two different flood mechanisms; riverine flooding from McCallum and Tullaroop Creeks, and overland flooding from the catchment to the west of Carisbrook.

The Carisbrook Flood and Drainage Plan recommended a series of works to reduce the flood risk, largely associated with preventing inundation from the overland flooding from the west of town. Some vegetation removal works to improve the conveyance of the creek through town was also recommended.

The Carisbrook Flood and Drainage Plan was reviewed by a State Government appointed independent expert reviewer. Comments and feedback were incorporated into the modelling approach and study report.

In 2013 Council had the report reviewed by AAECOM. They provided a series of comments regarding the study and the results, which were responded to and appropriately resolved.

Vegetation removal works were carried out after the study was completed, with Water Technology reviewing the works in 2016 and concluding that the works were in line with the recommendations and would achieve the recommended conveyance improvements.

A series of works were completed including a levee and drain upgrade at Belfast Road and at Williams Road to the south of Carisbrook. These works intercept overland flows from the south west and divert them back to McCallum Creek.

Council appointed Entura to complete a detailed design of the recommended mitigation works in 2016.

In 2017 Council appointed Jacobs to review the Carisbrook Flood and Drainage Plan along with works completed at the time. Their review was to recommend what investigations and physical works still need to be completed to finalise the flood mitigation scheme. They recommended an update of the hydrology, bringing it inline with the recent 2016 updates to design flood modelling practices in Australian Rainfall and Runoff.

Water Technology subsequently completed an update of design hydrology to the current Australian Rainfall and Runoff, which did result in improvements to the design flood mapping in Carisbrook. The update also included modelling to incorporate the mitigations works constructed at the time. This update resulted in changes in the flood extents for the 1% AEP event. It is this updated flood mapping that has been used in preparing the proposed LSIO and FO for the C31 Central Goldfields Planning Scheme Amendment.

The below sections summarise the relevant data and approaches to developing the flood mapping used for deriving the proposed LSIO and FO for the C3 Central Goldfields Planning Scheme Amendment.

6.2.1 Data Availability

6.2.1.1 Streamflow Gauging

Streamflow gauges exist upstream of Carisbrook on Tullaroop Creek at Clunes and at the Tullaroop Reservoir, and on McCallum Creek at Carisbrook.

Unfortunately, gauge data for the McCallum Creek gauge was missing for the September 2010 and January 2011 events as the gauge was damaged during the floods.

Gauge data was available for the Tullaroop Creek at Tullaroop Reservoir for both the September 2010 and January 2011 events, and was used for calibration of the RORB catchment model.

As well as the streamflow data, data on the Tullaroop Reservoir was used to understand the impact it has on flood events. Prior to the September 2010 flood the reservoir was at 60% capacity, whereas prior to January 2011 it was close to full capacity. Even when spilling, the reservoir attenuated the January 2011 peak flow by an estimated 20,000 ML/d due to the restriction in the spillway capacity.

6.2.1.2 Rainfall Gauging

Over twenty five daily rainfall gauges spread across the catchment and in nearby catchments were used to establish historic rainfall distributions for the September 2010 and January 2011 storms events. Sub-daily rainfall data was available at Maryborough, Clunes, Bendigo and Ballarat, and was used to assess the temporal rainfall intensity across the two historic events.

The rainfall records across the upper catchment vary. At Clunes the September 2010 and January 2011 rainfall totals are summarised as follows:

- September 2010 – approximately 90 mm over 24 hours, with most of that falling over a 10 hour period.
- January 2011 – approximately 180 mm over a 4 day period, with 80 mm over a 20 hour period.

The rainfall data available was appropriate to develop a good understanding of rainfall patterns across the catchment.

6.2.1.3 Topography and Feature Survey

Two LiDAR topography datasets were available for the study area. These were compared to detailed field survey to validate their accuracy. One of the LiDAR datasets was adjusted to match the survey and match the other preferred LiDAR dataset. The two datasets were combined to provide full coverage of the study area.

Several bridge and culvert structures were identified as important to incorporate into the model to accurately represent flood behaviour. For major bridge structures engineering plans were supplied from VicRoads, VicTrack or Council, with smaller culverts measured on site.

A series of bluestone drains throughout the site were identified and were determined to be too narrow to appropriately represent within the 2D hydraulic model. 1D channels were incorporated into the model using cross-sections of the channels from the detailed 1m LiDAR and measurements made on site.

6.2.1.4 Flood Data

Surveyed flood marks were available for the two historic calibration events, including 11 surveyed marks for September 2010 and 10 surveyed flood marks for the January 2011 event. A comparison of the surveyed levels for both events revealed suspected inaccuracies in the surveyed levels for several points. This is not uncommon when surveying debris marks, that take some judgement to assess peak water level from.

Several aerial flood photos and video from SES during both events were very helpful in calibrating the hydraulic model.

In addition, large amounts of information (written, verbal, photographs, etc) was made available from North Central CMA, Council, CFA, SES and community members, comprising a great deal of information to calibrate the models to.

6.2.2 Flood Modelling

6.2.2.1 Calibration

The modelling approach adopted for the study followed industry best practice approaches at the time the study was completed. RORB catchment modelling to estimate streamflow in Tullaroop and McCallum Creeks and the local overland catchment flows was used in combination with MIKE FLOOD hydraulic modelling to determine flood extents, depths, and velocities. The models were calibrated to historic events and the calibrated models were then used for design flood modelling of events with a range of flood magnitudes.

The modelling matched the survey levels reasonably well for both events although the survey was suspected to have some inaccuracies for several of the points. But with good aerial imagery, the survey marks alone were not solely relied upon for calibration, and the modelled extents matched the aerial imagery closely.

In addition, the feedback received from the community regarding the calibration was very positive, with large numbers of community members turning out to each community engagement event.

6.2.2.2 Design

As discussed previously, the Carisbrook Flood and Drainage Plan utilised the current best practice design flood estimation approaches at the time from Australian Rainfall and Runoff (1987). These approaches were subsequently updated and released in 2016 and again in 2019.

The updated design rainfall depths for various AEPs and storm durations in the catchment has generally reduced, with the critical 24 hour duration, 1% AEP event seeing a reduction in the rainfall depth of 8%. Several other significant changes in the latest Australian Rainfall and Runoff approaches to design hydrology have all contributed to a reduction in design flow at Carisbrook for the 1% AEP event.

The design flood modelling was subsequently updated in 2019 following the new updated approaches. This resulted in an improved design flood estimates for both the riverine flows on Tullaroop and McCallum Creeks and the local overland catchment flows. The combined 1% AEP flow downstream of the Tullaroop and McCallum Creeks confluence was reduced by approximately 18% using the new updated design hydrology approaches. This resulted in reductions in the 1% AEP flood level of between 5-10 cm. The more frequent events did not change significantly.

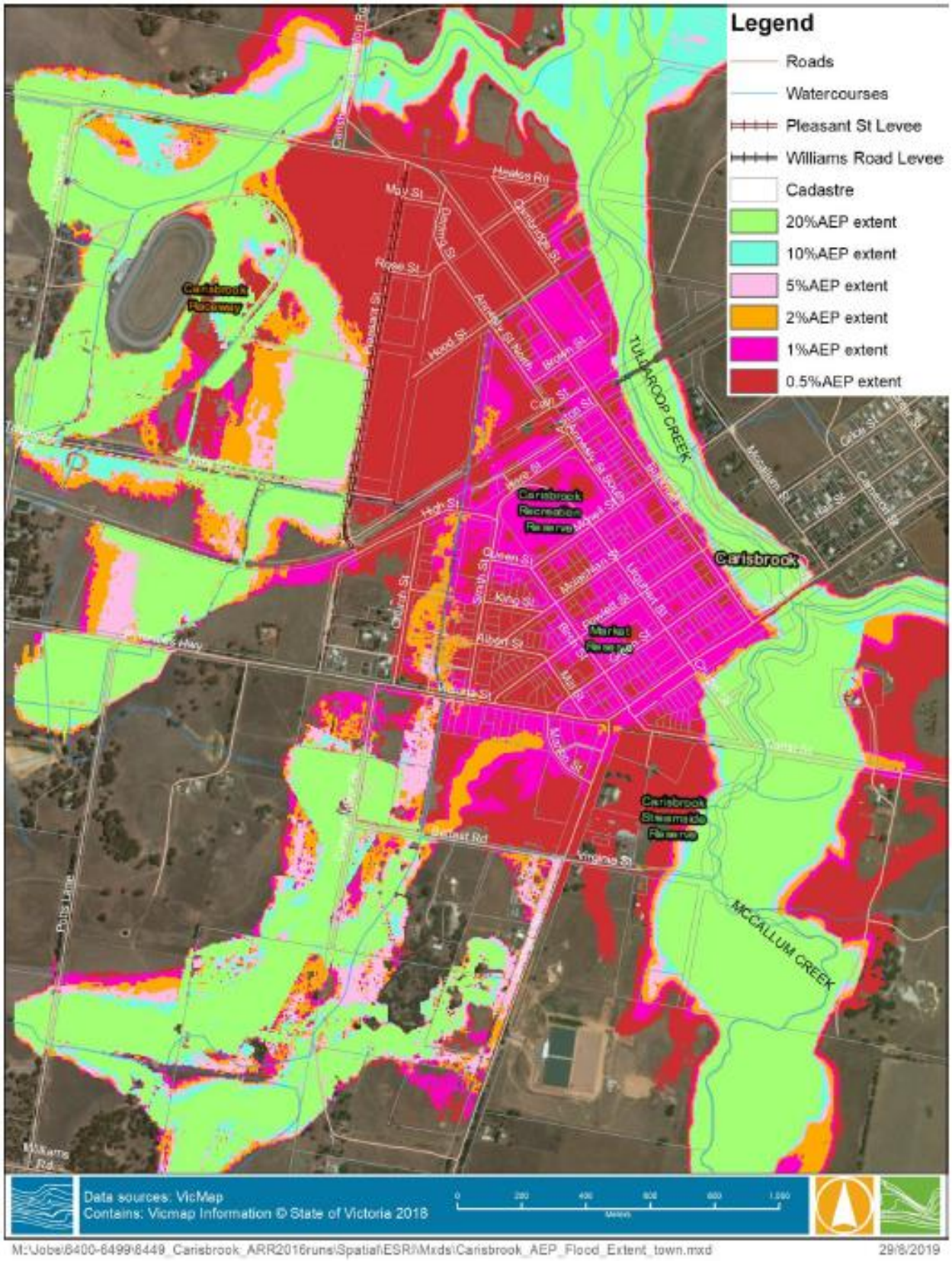

Figure 6-2 Design Flood Extents for Carisbrook with Updated Design Hydrology and Constructed Works

Design flood extents with the updated Australian Rainfall and Runoff hydrology are shown above in Figure 6-2 for the existing conditions incorporating the constructed mitigation works. The updated design flows for Tullaroop Creek downstream of the Tullaroop and McCallum Creeks confluence is

Table 6-2 Updated Design Flood Flows for Tullaroop Creek Downstream of Confluence, with Previous Estimates from Carisbrook Flood and Drainage Plan (2013) in Brackets

Event	Rainfall	Peak Flow (m^3/s)	Critical Duration (hours)
20% AEP	47 mm in 12 hr 61 mm in 24 hr	113 (129)	12 (9)
10% AEP	56 mm in 12hr 72 mm in 24 hr	235 (220)	12 (18)
5% AEP	65 mm in 12 hr 83 mm in 24 hr	374 (352)	12 (18)
2% AEP	77 mm in 12 hr 98 mm in 24 hr	555 (617)	12 (6)
September 2010	~75 mm in 10 hr ~90 mm in 24 hrs	779	
1% AEP	87 mm in 12 hr 110 mm in 24 hr	718 (882)	12 (6)
January 2011	~180 mm in 4 days ~80 mm in 20 hrs	1,000	

6.2.2.3 Community Engagement

The Carisbrook community was highly engaged during the Carisbrook Flood and Drainage Plan. A community led Steering Committee garnered a lot of interest in the project, and owing to the impact the January 2011 flood event had on the town, this study continues to be a topic of conversation and regularly appears in the local newspaper.

Initial community engagement events saw large numbers of people coming to voice their opinions, hear about what was to be done, and share information that could be used during the development of the study. With myself having family living on the outskirts of Carisbrook, I made time to visit some of the local community members who showed specific interest, to discuss the past flood events and keep them up to date with what was happening on the study.

While the study has seen some controversy, and at times has become a political topic, the community showed positive support for the model calibration and the proposed recommended mitigation. 113 submission were received regarding the recommended mitigation, with 100 of them supporting it, and 13 not supporting it or unsure.

6.2.3 Changes in Floodplain Since Study

Since the Carisbrook Flood and Drainage study, the following works have been completed which has slightly altered flood behaviour:

- Clean out of bluestone drains.
- Council completed several drainage upgrades around town that will impact local flows in storm events but unlikely to have major impacts on larger magnitude events.
- Vegetation removal works along McCallum and Tullaroop Creek between Camp Street and the Railway line.
- Upgrade of Belfast Rd levee and drainage channel.
- Upgrade of Williams Road drainage channel.
- Construction of Pleasant Street levee north of the railway line.
- Culvert under Pleasant Street at Wills Street removed.
- Floodway crossing over Wills St adjacent to the Pleasant Street levee constructed.
- Open drain along Wills Street draining to the dam near the Racecourse.

The above constructed works have been incorporated into the most recent modelling and mapping which was used as the basis of the proposed LSIO and FO for the C31 Central Goldfields Planning Scheme Amendment.

The railway line is no longer in operation but there has been no changes to the culverts under the railway as yet. Equally no upgrades to culverts under the Pyrenees Highway have been made.

Work has begun on the remainder of the recommended Western Levee mitigation option but is not yet complete.

The Western Levee once complete will reduce the flood impacts on Carisbrook from local overland flooding from the western catchments. The vegetation removal works has lowered flood levels along Tullaroop Creek, but does not prevent rare floods like January 2011 from inundating the township.

6.3 Rural Mapping of Tullaroop Creek

The North Central CMA have completed flood modelling and mapping of the January 2011 flood event for Tullaroop Creek downstream of Tullaroop Reservoir through to Eddington. The January 2011 event was modelled, with hydrographs extracted from the RORB model developed in the Carisbrook Flood and Drainage Management Plan (Water Technology, 2013).

The January 2011 event was greater than a 1% AEP event on Tullaroop Creek, and closer to 0.5% AEP. This suggests that flood levels along Tullaroop Creek generated in this rapid Rural Mapping study by North Central CMA are likely to be conservative for the purposes of the planning scheme, i.e. they are based on a flood larger than a 1% AEP.

The flood modelling approach utilised a two-dimensional HEC-RAS model, which is appropriate for this rapid flood mapping study.

The modelling was validated against aerial imagery from the January 2011 event, and showed a good comparison. This is to be expected as the floodplain is very well defined through this reach, with some downstream areas breaking out across a wider floodplain. Even if the modelled flood heights are slightly conservative, having adopted the January 2011 event, it is unlikely that the flood extents would change dramatically, suggesting that the LSIO and FO layers are appropriate.

When comparing the modelled results to the current LSIO overlay, it is clear that the modelling from this study represents a significant improvement in the description of flood risk along this reach of Tullaroop Creek and is appropriate to use for the C31 Central Goldfields Planning Scheme Amendment.

7 REVIEW OF PROPOSED OVERLAYS

In my opinion the flood mapping that has been utilised to develop the proposed planning scheme overlays represents the best available flood mapping and is entirely appropriate to be used as the basis for setting LSIO and FO overlays in the C31 Central Goldfields Planning Scheme Amendment.

It is understood that North Central CMA has followed the following approach for determining the LSIO and FO overlays.

- Used the best available flood mapping, representative of the current conditions, which has included:
  - 1% AEP flood mapping updated with revised ARR2019 method, including the constructed flood mitigation works at Carisbrook. It does not include the works currently being constructed or the ultimate Western Levee option.
  - 1% AEP flood mapping including the recommended mitigation modelling from the Dunolly Flood Investigation.
  - January 2011 flood mapping of the rural areas along Tullaroop Creek from Tullaroop Reservoir to Eddington.
- LSIO
  - Adopted the flood extents based on the above mapping as the LSIO extent.
  - Manually filled in some “islands” within the 1% AEP flood mapping for Carisbrook.
- FO
  - Adopted areas of 1% AEP depth greater than or equal to 0.5 m as FO extent.
  - Checked that there were no additional areas that should be included as FO based on hazard (VxD >= 0.4) or additional areas inundated in 10% AEP.

The above method of setting LSIO and FO is appropriate and consistent with other flood related Planning Scheme Amendments I have observed across Victoria.

Further specific discussion points regarding Dunolly, Carisbrook and the rural areas are provided below.

7.1 Dunolly

The proposed overlays have used the recommended mitigation model results from the Dunolly Flood Investigation. The resulting LSIO and FO appear to be consistent with the modelling, with some infilling of islands. On review there are potentially some further islands within the LSIO that could be infilled. Other than this observation the LSIO and FO overlays seem consistent with the flood modelling and mapping, and reasonable to me.

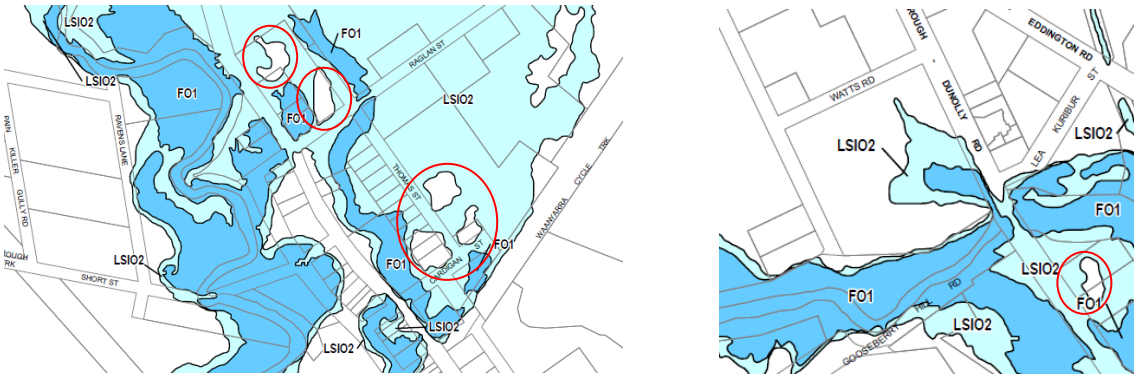

Figure 7-1 Possible areas of islands in LSIO that could be infilled

7.2 Carisbrook

The proposed overlays have used the latest 1% AEP flood mapping incorporating the Australian Rainfall and Runoff (2019) updates, and constructed mitigation works. It has not included the components of the western levee still to be constructed. Whilst this modelling and mapping best represents the flood risk in a 1% AEP flood event today, it is likely that with the levee soon to be constructed, that large areas inside the levee will be protected from flooding in a 1% AEP event.

The flood mapping used for determining the proposed LSIO and FO layers in the C31 Central Goldfields Planning Scheme Amendment is appropriate for today, and is likely to be conservative for the future, after the construction of the Western Levee. The proposed LSIO has infilled large “islands” in the existing 1% AEP flood extent, again providing a conservative LSIO. Figure 7-2 shows the proposed LSIO and the Existing Conditions 1% AEP flood depths that it is based on.

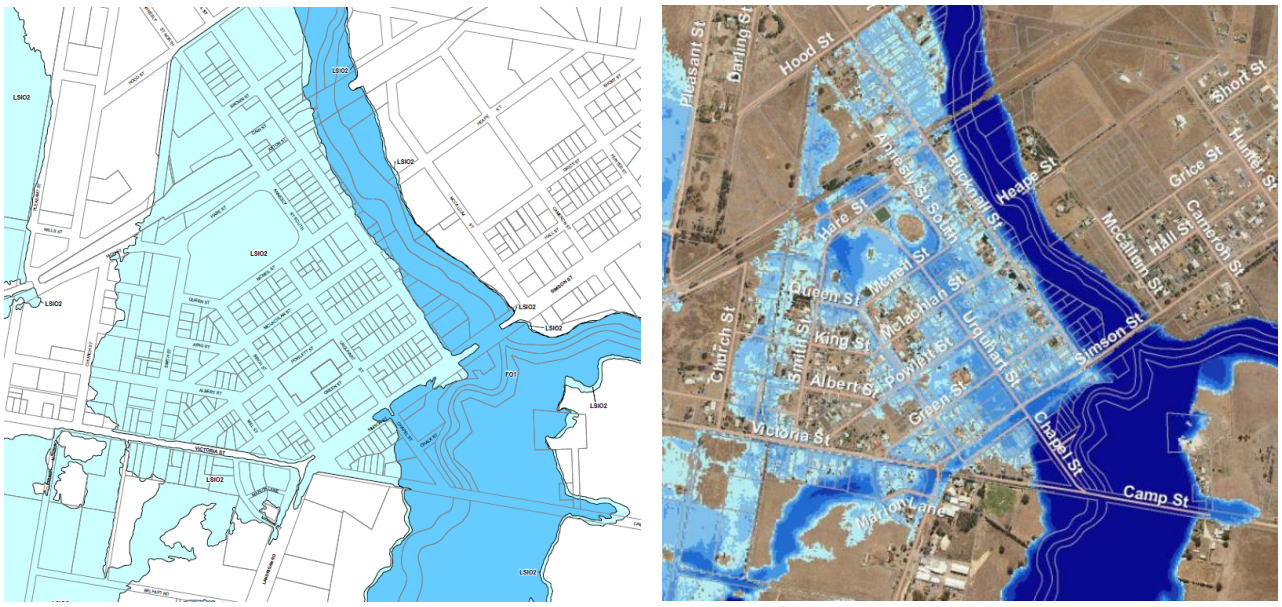

Figure 7-2 Proposed LSIO and FO (left), and Existing Conditions 1% AEP Flood Depths (right)

Adopting this conservative approach of existing conditions may be appropriate given that we know that the January 2011 event which significantly impacted the town was greater than a 1% AEP, closer to a 0.5% AEP, and resulted in wider flood extents. Figure 7-3 shows the pink areas that would be protected by the Western Levee in a 1% AEP, which could be used to argue that large areas will be protected by the levee and could be removed from the LSIO. Figure 7-3 also shows the 0.5% AEP flood depths under mitigation conditions, showing that there is a large incremental increase in flood extent within the urban area of Carisbrook for larger events like January 2011. It is for this reason I believe adopting the wider LSIO extent as proposed in the C31 Central Goldfields Planning Scheme Amendment is appropriate.

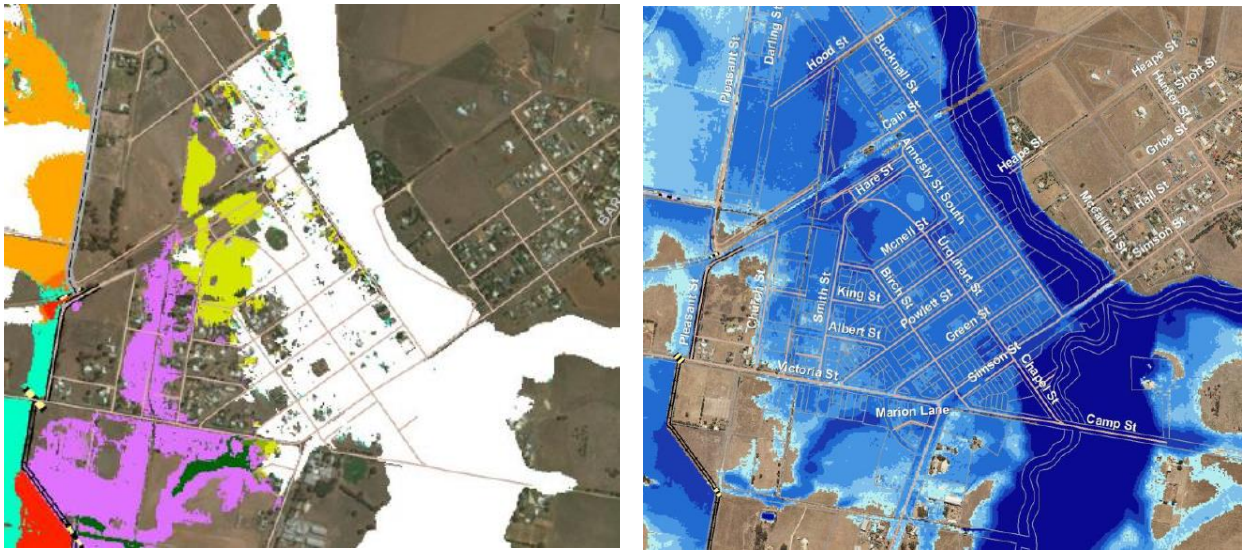

Figure 7-3 Difference Plot (Mitigation - Existing Conditions) 1% AEP (left); Mitigation Conditions 0.5% AEP Flood depths (right)

7.3 Tullaroop Creek Rural Areas

The rural flood mapping could potentially be over-estimating the 1% AEP flood levels, because it has adopted the January 2011 hydrographs which we know are larger than a 1% AEP event. But I consider this appropriate given that the proposed LSIO and FO mapping represents a significant improvement in flood controls along this reach of Tullaroop Creek, with the proposed overlays reducing the area impacted significantly as compared to the current LSIO.

The zoning along this rural section of Tullaroop Creek is Farm Zone, with the land adjoining the creek typically having larger blocks, with higher ground setback away from the creek. It is therefore unlikely that the proposed overlays being conservative in these rural areas will impact on future development applications.

8 SUBMISSIONS

I have responded to issues raised by the five unresolved objections related to Amendment C31, as relevant to my expertise.

8.1 Rinaldi, McCallum Street, Carisbrook

Mr Rinaldi's submission suggests that the proposed flood extents should be reduced on the property at 33 McCallum St as shown in Figure 8-1. Interpretation of aerial flood imagery from January 2011 indicates that flooding on this property covered a wider area than that suggested by Mr Rinaldi. Given that the flood extents are based on LiDAR data which accurately represents the land surface, and that the calibration of the flood model was accepted by the community as a good match, it is expected that the flood extents in this area will be reasonably accurate.

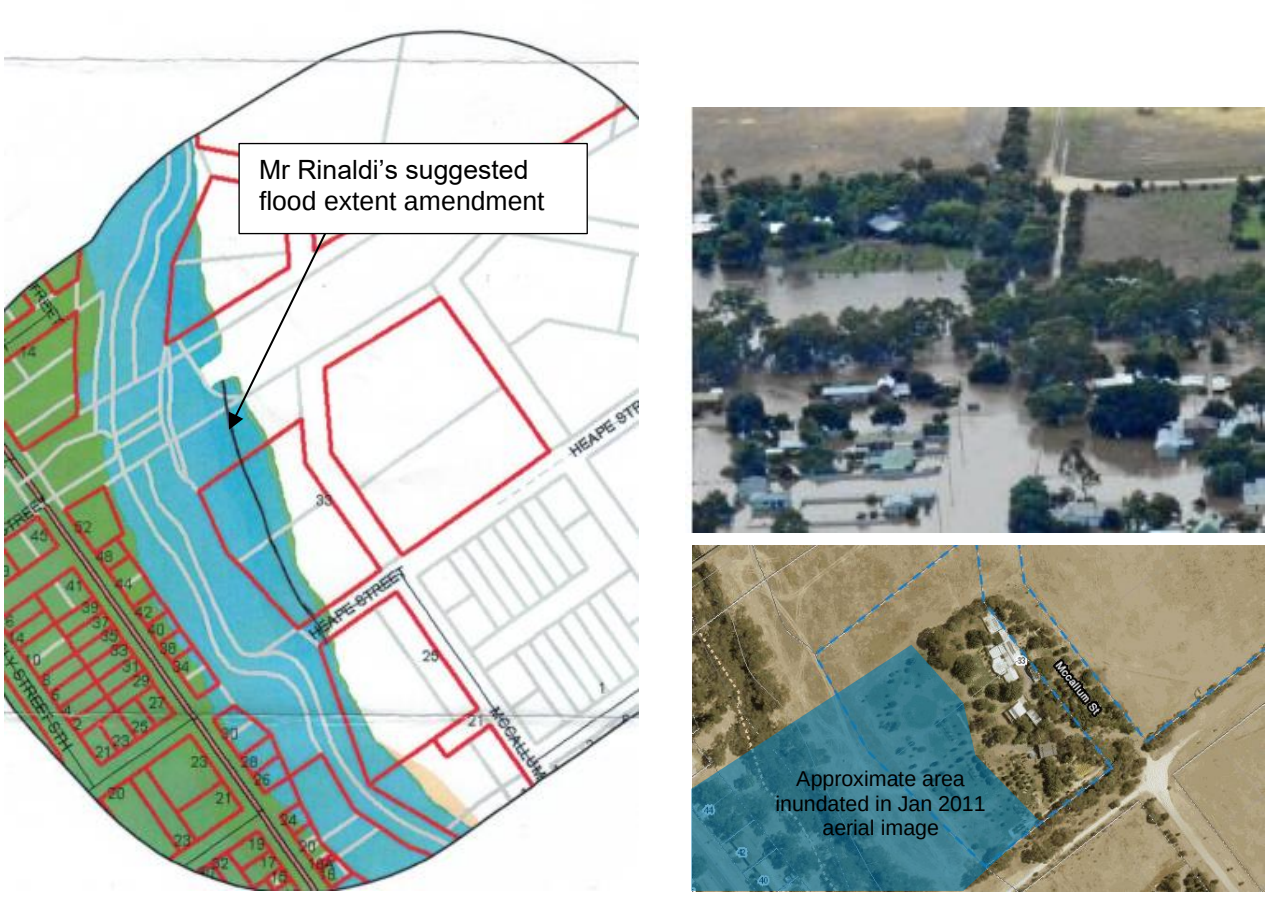

Figure 8-1 Submission of Mr Rinaldi (left); January 2011 aerial flood photo (top right); interpreted January 2011 flood extent from aerial photo (bottom right)

It is my opinion that the proposed LSIO and FO in this area are appropriate.

8.2 McIver, Landrigan Road, Carisbrook

Mr McIvor states in his submission that his house at 70 Landrigan Road was not inundated in the previous January 2011 event. The flood modelling from the Carisbrook Flood and Drainage Plan and the updated modelling with the revised hydrology and constructed mitigation works corroborates this statement.

Mr McIver's concerns relate to drainage along the nature strip adjacent to Landrigans Road. From available imagery of the front of Mr McIvor's residence it appears that crossovers into Mr McIvor's property do not have culverts underneath them, effectively blocking any roadside drainage. Culvert crossovers are the responsibility of the landowner.

It is my opinion that Mr McIvor's submission has no bearing on the C31 Central Goldfields Planning Scheme Amendment and is a mater of local drainage for Mr McIvor to discuss further with Council's Engineering Department.

8.3 Blazko, Curragh Moor Road, Carisbrook

Mr Blazko in his submission suggests that the flood mapping was based purely by a desktop exercise with no site inspections or validation. This is incorrect. Several site inspections were completed during the course of the study. In addition I have spent a considerable amount of time in Carisbrook as I have family who live in Carisbrook.

The area Mr Blazko suggests should be inundated (Mr Jacksons land), was not inundated in the January 2011 flood by evidence of the aerial flood image in Figure 8-2. I know this area and I can confirm that there is a slight rise in the topography in the area Mr Blazko believes should be inundated. LiDAR information confirms slightly elevated land in this area.

Figure 8-2 January 2011 Flood Image

It is my understanding that the material Mr Blazko has commented on as being dumped at the Curragh Moor Road extension, is material that is currently being used to construct the Western Levee, and will soon be repurposed to build the levee.

Mr Blazko makes comment regarding errors in the flood mapping on his property, but without further information I can't formulate a response.

8.4 Coutts, Carisbrook

Mrs Coutts has questioned the basis of the proposed LSIO and FO mapping for the C31 Central Goldfields Planning Scheme Amendment. The mapping is based on the latest 1% AEP flood mapping incorporating the currently completed mitigation works. It does not include the Western Levee works that have just started construction. Further, the 1% AEP event is much smaller than the January 2011 event, thus the area surrounding the School, Leisure Centre and Chaff Mill are not shown as inundated.

In the development of the LSIO, North Central CMA have taken the approach of filling in large islands in the 1% AEP existing conditions mapping in the residential area of town between the Pyrenees Highway, Church Street and Urquhart Street, as shown in Figure 8-3. It is my opinion that this filling of islands in the LSIO is appropriate because in larger events such as the January 2011 event, there is a significant step change in the flood risk, inundating the majority of the residential area covered by the proposed LSIO.

The matter of the School and Chaff Mill not being included is relevant. The reason it has not been included in the LSIO is because it is outside of the 1% AEP flood extent. Mrs Coutts is correct that this area was inundated in the January 2011 event.

Mrs Coutts' comments suggesting that areas in Victoria Street are only flooded because the old Carisbrook Reservoir has been breached in a past event are misleading. Since the reservoir was breached as an emergency measure during a past event, the township has experienced two of the largest floods on record in the area. The reason for the inundation during September 2010 and January 2011 is the magnitude of the storm event, not because of the reservoir breach.

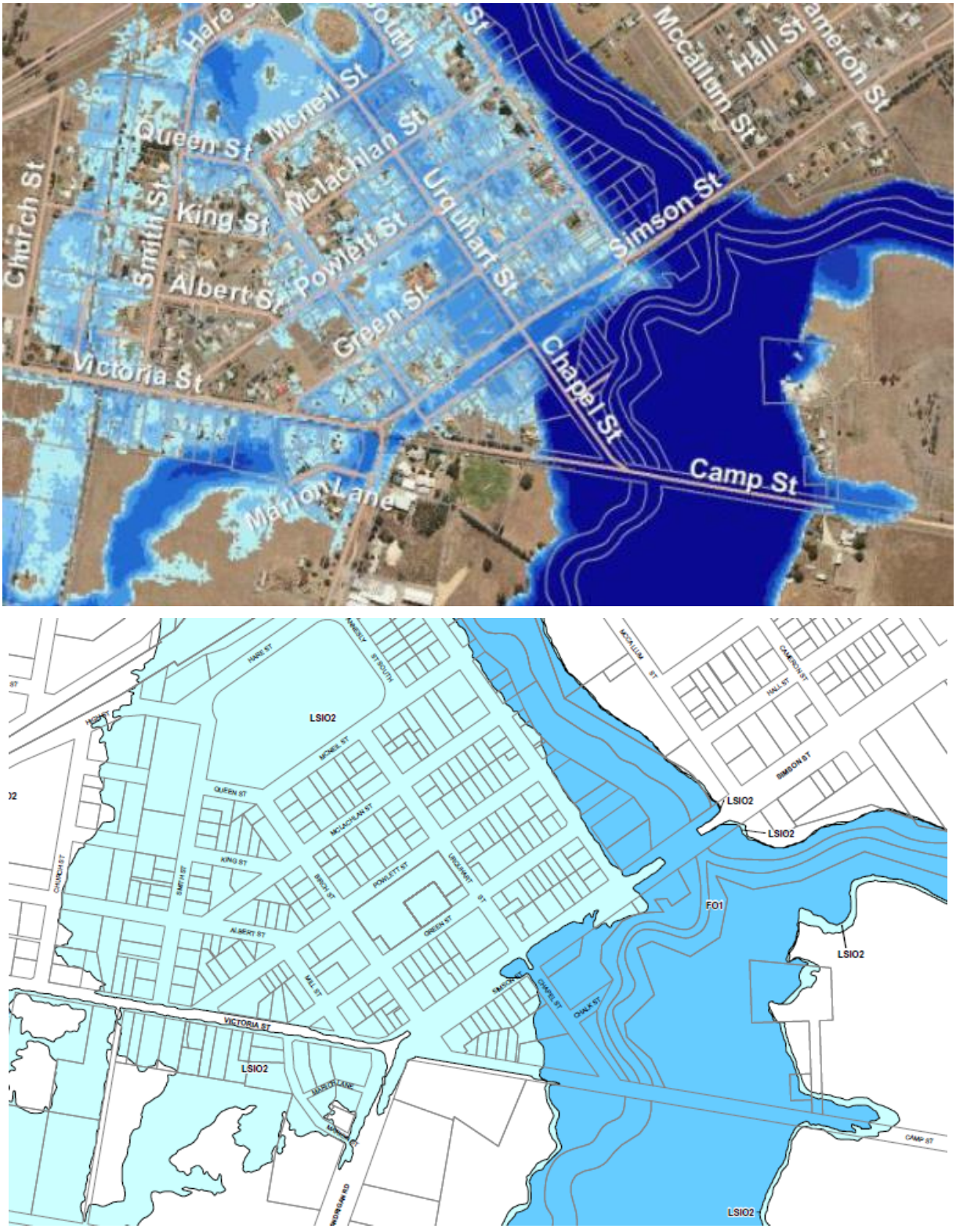

Figure 8-3 1% AEP Flood Depths for Existing Conditions (top); Proposed LSIO and FO (bottom)

8.5 Hodgkins, Bucknall St, Carisbrook

Mr Hodgkins states that his historic building at 9 Bucknall Street is over 150 years old, with the rear being constructed of mud brick, and that this suggests that it is not frequently flooded, because the mud brick had not previously deteriorated as it did in the January 2011 event. There is no doubt that the January 2011 event is one of, if not the largest flood event experienced since Mr Hodgkins building was constructed. In my opinion the fact the building is mud brick and is still standing does not provide any credible evidence that the flood study has understated the likelihood of the January 2011 event or the design 1% AEP event.

The Carisbrook Flood and Drainage Plan considered a range of levee options. The difficulty in constructing levees in developed areas, is that as soon as you prevent flood waters from spreading across the floodplain, you increase flood flows and raise flood levels in another area. A levee along the Pyrenees Highway and along the creek side of Bucknall Street was considered, but the impacts on existing properties were too great, and the Steering Committee decided they did not wish to recommend those options. Vegetation removal works along the creek hav been constructed and demonstrated to have reduced flood levels.

Planning Schemes will continue to be updated into the future, as to if or when the Carisbrook flood controls would again be updated, there is no set timeline for this happening. However, the LSIO and FO overlays in the Planning Scheme are used as a trigger for referral to North Central Catchment Management Authority as the relevant floodplain Authority. The North Central CMA then uses the current best available flood risk information to provide advice on development applications, and this would include the impact of any future flood mitigation works.

9 CONCLUSIONS

With respect to the proposed C31 Central Goldfields Planning Scheme Amendment, I make the following conclusions.

- The flood mapping used to form the basis of the proposed LSIO and FO is the best available flood mapping for the area.
  - The proposed LSIO and FO at Dunolly is based on 1% AEP flood mapping representative of the current floodplain conditions, including the constructed mitigation works on the contour channel and retarding basin. These works intercept overland flow, preventing it from inundating the township in a 1% AEP event. There are potentially some minor areas of LSIO islands that could be infilled.
  - The proposed LSIO and FO at Carisbrook is based on updated 1% AEP flood mapping with the latest Australian Rainfall and Runoff (2019) approaches, improving on the mapping produced during the Carisbrook Flood and Drainage Plan (2013). The flood mapping used for the LSIO and FO represents the current level of mitigation works constructed, noting that additional works on the Western Levee are underway but have not been incorporated. Further, the LSIO has infilled large islands in the existing conditions mapping through the township. It is my opinion that this is appropriate, given that in a larger event such as January 2011 there is a significant increase in the flood risk and the majority of the area represented by the LSIO will be inundated.
  - The proposed LSIO and FO for the rural areas along Tullaroop Creek between Tullaroop Reservoir and Eddington have used the January 2011 event as the basis for the flood modelling, which is larger than a 1% AEP. Given this reach is predominantly rural Farm Zone land and the floodplain is very confined, this conservative approach is in my opinion appropriate.
- The method used to delineate between LSIO and FO is appropriate and comparable to other flood related Planning Scheme Amendments elsewhere in the State.
- Compared to the current LSIO, the proposed Amendment represents a significant improvement in the representation of flood risk.

In relation to the five unresolved objections, I make the following conclusions:

- I do not believe any of the five unresolved objections require changes to the proposed LSIO or FO mapping.

10 DECLARATION

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

Benjamin Tate

B.E. (Hons), B.Sc.

Senior Principal Engineer, Regional General Manager, National Practice Lead of Flooding

Water Technology Pty Ltd

15 Business Park Drive, Notting Hill, VIC 3168

20 November 2020

APPENDIX A – CV