WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

# Summary Report

## Teesdale Flood Risk Identification Study

### Golden Plains Shire

12 May 2023

## Document Status

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## Project Details

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Cover Image: Native Hut Creek in Flood, Teesdale, 1949



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# EXECUTIVE SUMMARY

Water Technology were engaged by Golden Plains Shire to deliver the Teesdale Flood Risk Identification Study. The project has been funded through the Risk and Resilience Grants Program, with equal parts funding from Local, State and Federal Government.

The study has reviewed the available flood data for Native and Hut Creek, and produced flood modelling and mapping in line with current industry best practices and the recommendations of Australian Rainfall and Runoff 2019. Flood modelling and mapping has been produced for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% and Probable Maximum Flood (PMF) events.

In addition to the flood modelling and mapping, flood intelligence products detailing the flood behaviour and impacts in Teesdale have been developed and included in a draft update to the Golden Plains Municipal Emergency Management Plan (MFEP). Intelligence products developed include the following:

- A rating table for a proposed gauge on Native Hut Creek at the Bannockburn-Shelford Road bridge
- Summaries of flood behaviour and impacts in concise tables;
- Flood peak timing estimates from the beginning of rainfall;
- A simple tool to link rainfall to potential flood impacts, and;
- Recommended Flood Class Levels for the proposed gauge in line with the Bureau of Meteorology's Flood Class definitions.

Additional components to improve the flood warning capability for Teesdale were recommended, with two additional gauges proposed to improve the town's flood monitoring capacity.

The Average Annual Damages (AAD) caused by flooding in Teesdale were assessed in line with industry standard methods. Flooding in Teesdale is estimated to cost, on average, $113,366 per year. Three mitigation options to reduce the AAD were investigated and their benefit/cost ratios estimated. The options investigated were raising Pantics Road, placing additional culverts under Bannockburn-Shelford Road, and clearing Native Hut Creek of vegetation. None of the options investigated achieved a favourable financial benefit/cost ratio.

Non-structural mitigation in the form of planning scheme mapping has also been developed and is recommended for inclusion in the Golden Plains Planning Scheme. The mapping is based on the 1% AEP flood with projected increased rainfall intensity to 2100 under Representative Concentration Pathway RCP8.5. Draft planning scheme amendment documentation has been provided to Council with the proposed mapping.

The study outputs will support floodplain management in Teesdale into the future by providing a sound basis for the implementation of planning controls to ensure development within the floodplain is appropriate and responds to the risk. Future flood events can be responded to in a more proactive way through utilisation of the intelligence products produced.

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# 1 INTRODUCTION

## 1.1 Overview

Water Technology has been commissioned by Golden Plains Shire Council (Council) to undertake the Teesdale Flood Risk Identification Study. The investigation area covers the Native Hut Creek and tributaries in the township of Teesdale, as shown in Figure 1-1. Teesdale is identified as a Priority Flood Risk Area in the Corangamite Regional Floodplain Management Strategy (2018), which identifies both riverine and flash flood risks for the town and states that "*flooding associated with Native Hut Creek has damaged several residential properties"*.

Previous flood investigations covering Teesdale include CCMA investigations undertaken in 2008 and 2019. The 2008 study utilised RORB hydrologic modelling and HEC-RAS one-dimensional hydraulic modelling, while the 2019 study utilised HEC-RAS two-dimensional hydraulic modelling. A regional flood study of the Barwon River catchment which covers the study area was also completed in 2016 (GHD, 2016).

The CCMA modelling completed in 2019 indicates that the current flood mapping which is the basis for the current Floodway Overlay (FO) and Land Subject to Inundation Overlay (LSIO) in the Golden Plains Planning Scheme understates the flood hazard in Teesdale. The Flood Risk Identification Study is being carried out to ensure that the planning scheme mapping accurately reflects flood hazard to ensure that growth in Teesdale is managed appropriately into the future. As such, updated flood mapping suitable for inclusion in the Golden Plains Planning Scheme is a key output requirement of the study.

In addition, the study will produce flood intelligence information for use in emergency management situations, assess the current flood impact/exposure in terms of annual average damages caused by flooding in Teesdale, investigate structural and non-structural mitigation options to reduce damages, investigate and make recommendations for establishing a flood warning system for the town.

This report is one of a series documenting the outcomes of the Teesdale Flood Risk Identification Study. Each reporting stage is shown below:

- R01 - Data Review and Validation
- R02 – Joint Validation Modelling Report
- R03 – Design Hydrology and Hydraulic Modelling Report
- R04 – Flood Intelligence and Flood Warning Report
- R05 – Flood Damages and Mitigation Assessment Report
- R06 – MFEP Documentation
- **R07 – Final Summary Report – This Report**

## 1.2 Study Area

Teesdale is located approximately 8.5 km north of Inverleigh and is situated on the banks of Native Hut Creek. The Native Hut Creek catchment begins approximately 22.5 km north of Teesdale near the town of Meredith. The creek meanders south across agricultural land, the vast majority of which has been historically cleared of large vegetation in line with its agricultural use.

The catchment within and upstream of the study area is mostly cleared agricultural land, and the main waterway (Native Hut Creek) has several onstream dams of varying size along its alignment. The Native Hut Creek catchment, draining to Teesdale is approximately 110 km$^2$. The entire catchment is located within the

Golden Plains municipal area. The study area is focussed on the township of Teesdale and includes the following waterway structures:

- Two large on-stream dams approximately 3km upstream of the township.
  - An indicative assessment of the impact of the upstream dams was completed in R01 – Data Collation and Validation. The assessment found the dams would have minimal impact on peak flow rate or flood levels in a significant storm event.
- Road crossings, formal and informal, at the following roads:
  - Tolson Road/Stones Road
  - Sutherland Street
  - Bannockburn-Shelford Road
  - Barkers Road
- Several off-stream dams throughout the town.

## 1.3 Previous Reporting

This report follows R01 to R06 and summarises the completed project. This summary report will not delve into technical detail, instead focussing on project outputs and deliverables produced by the study. Readers will be directed to individual reports should additional information be required. The chapters and sections of this report broadly follow the previous reporting from R01 to R06 with a summary of the key points in each detailed report.

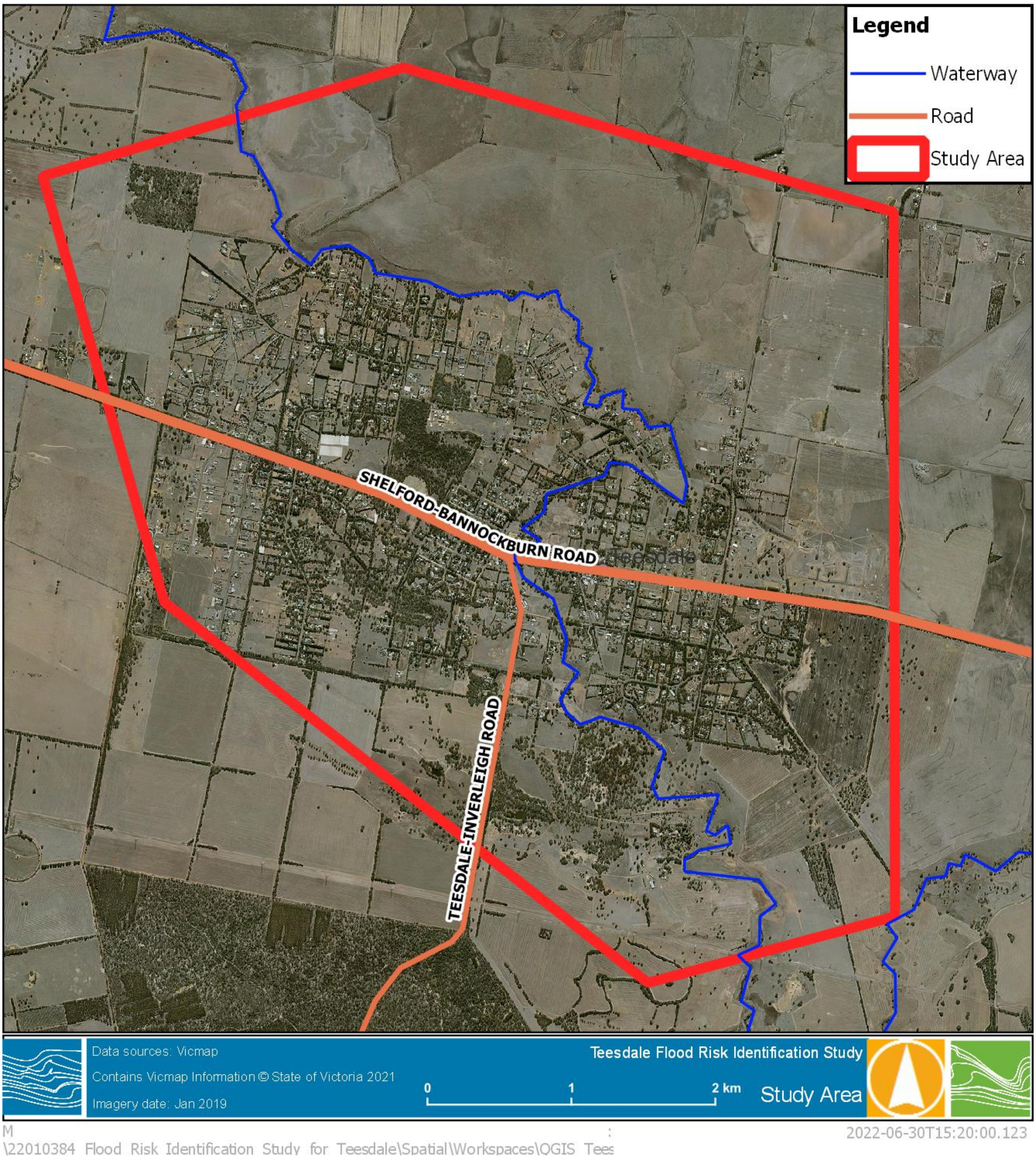


**Figure 1-1 Teesdale Flood Risk Identification Study - Study Area**

# 2 DATA COLLATION AND REVIEW

The first stage of the project included the collation and review of available data relevant to flooding in Teesdale. This included the following:

- Previous flood studies and reports covering the area (see Table 2-1 below)

**Table 2-1 Flood related studies completed in Teesdale and Native Hut Creek Region**

| Related Studies | Author | Year |
|---|---|---|
| Victorian Flood Data Transfer Project (2001) | DNRE/SKM | 2001 |
| Hydrologic and Hydraulic assessment (2008) | CCMA | 2008 |
| Regional Flood Mapping – Barwon River, Thompson Creek and Woady Yaloak Creek | GHD | 2016 |
| Updated Hydrologic and Hydraulic assessment (2019) | CCMA | 2019 |

- Historical flood events and accompanying anecdotal evidence
  - Anecdotal evidence was the best available data for historical floods – no surveyed or otherwise measured flood heights were uncovered as part of the study
  - Evidence was gathered for the February 1973, April 2001 and January 2011 events, which were then selected for validation modelling based on the information available.
- Recorded streamflow
  - The catchment has no streamflow gauges
- Recorded rainfall
  - Includes both daily and sub-daily rainfall
- Road and drainage infrastructure
  - Some data was supplied by council with gaps infilled by survey for major structures and site visits for minor structures
- Topographic data
  - Multiple LiDAR data sets were available and were verified against survey captured for the project

The initial community consultation session also formed part of the data collation aspect of the project. The consultation session was held at the Teesdale Community Hall and had 17 residents in attendance. Information relevant to the study was gathered during the session however was limited to anecdotal evidence of flood behaviour in historic events.

The Data Collation Report (R01) also confirmed and detailed the modelling methodology for the following stages of the project.

# 3 JOINT VALIDATION MODELLING

## 3.1 Overview

The Joint Validation Modelling Report (R02) describes in detail the hydrologic (RORB) and hydraulic (TUFLOW) model builds and parameter selection adopted for the study. The report also details the validation modelling of historic events. Model performance and alignment with the anecdotal evidence was utilised to determine the RORB routing parameter Kc. Other parameters were selected based in consideration of adopted values from nearby flood studies and regional approximations in the absence of local calibration data.

## 3.2 RORB Summary

### 3.2.1 Model Build

The RORB hydrologic model build followed the following steps:

1. Catchment delineation utilising 10m resolution Vicmap DEM based on a flow accumulation and tracing method
2. Subareas and reaches defined from the above, with nodes placed at or near the centroid of each subarea and the junction of reaches
3. Reach slopes defined from the LiDAR dataset, with reach types assigned as "excavated (unlined)" where a waterway was clearly visible on aerial imagery and LiDAR
4. Interstation areas delineated for two local catchments that flow through Teesdale where hydrographs and mapping were required
5. Fraction impervious (FI) assigned to zones in the planning scheme in accordance with Table 3-1 below

**Table 3-1 Adopted Fraction Impervious**

| Land Use/Zone | FI |
|---|---|
| Farming Zone | 0.01 - 0.05 |
| LDRZ | 0.2 |
| PCRZ/PPRZ | 0.01 (one area assigned 0.1 due to buildings on site) |
| PUZ | 0.05 – 0.5 (based on aerial imagery) |
| Roads | 0.7 |
| Township Zone | 0.4 |
| Transport Zone | 0.0 – 0.7 (based on aerial imagery) |

### 3.2.2 Model Parameters

RORB model parameters were assigned as follows:

- Initial and Continuing Loss were adopted from the ARR datahub after comparison with nearby calibrated losses
- The "m" parameter was left at the recommended 0.8

- A range of Kc values were selected for validation against historical events, with a Kc/Dav ratio of 1.25[1] selected for design modelling

### 3.2.3 Rainfall

#### 3.2.3.1 Historic Events

Validation events utilised daily rainfall records from available gauges surrounding the Native Hut Creek catchment. Sub-daily records were obtained from the Sheoaks station (87168) for the April 2001 and January 2011 events and from the Warrambine Basin No. 3 station (890094) for the February 1973 event. Daily records informed the spatial pattern and total rainfall across the catchment with the sub-daily record informing the temporal pattern of each event.

#### 3.2.3.2 Design Events

Design rainfall depths for the range of AEPs and durations were downloaded from the Bureau of Meteorology's IFD (Intensity-Frequency-Duration) Design Rainfall Data System[2]. Given the size of the catchment, spatial variation in design rainfall was considered by deriving the spatial pattern in accordance with the method shown in section 6.5.4 of ARR2019 Book 2 Chapter 6.

Pre-burst rainfall was accounted for by subtracting the median pre-burst depth from the storm initial loss (as provided by the ARR datahub and verified against nearby calibrated models) to produce the burst initial loss according to the below equation:

$$\mathrm{IL}_b = \mathrm{IL}_s - \text{pre-burst depth}$$

Consideration was given to the Victorian Specific Information of the ARR datahub, which recommends the use of 75th percentile pre-burst depths when applying datahub values for other hydrologic inputs[3]. The median pre-burst depth was selected for the following reasons:

- The catchment sits at the border between loss regions 2 and 3, and the Victorian Specific Information relates only to loss region 3.
- While the adopted losses came from the ARR Datahub, their adoption considered validated loss values from the neighbouring Inverleigh Flood Study, which is considered to be hydrologically similar.
- The adopted losses were reconciled with Regional Flood Frequency Estimation (RFFE).

[1] Pearse et al., 2002
[2] http://www.bom.gov.au/water/designRainfalls/revised-ifd/
[3] https://data.arr-software.org/vic_specific

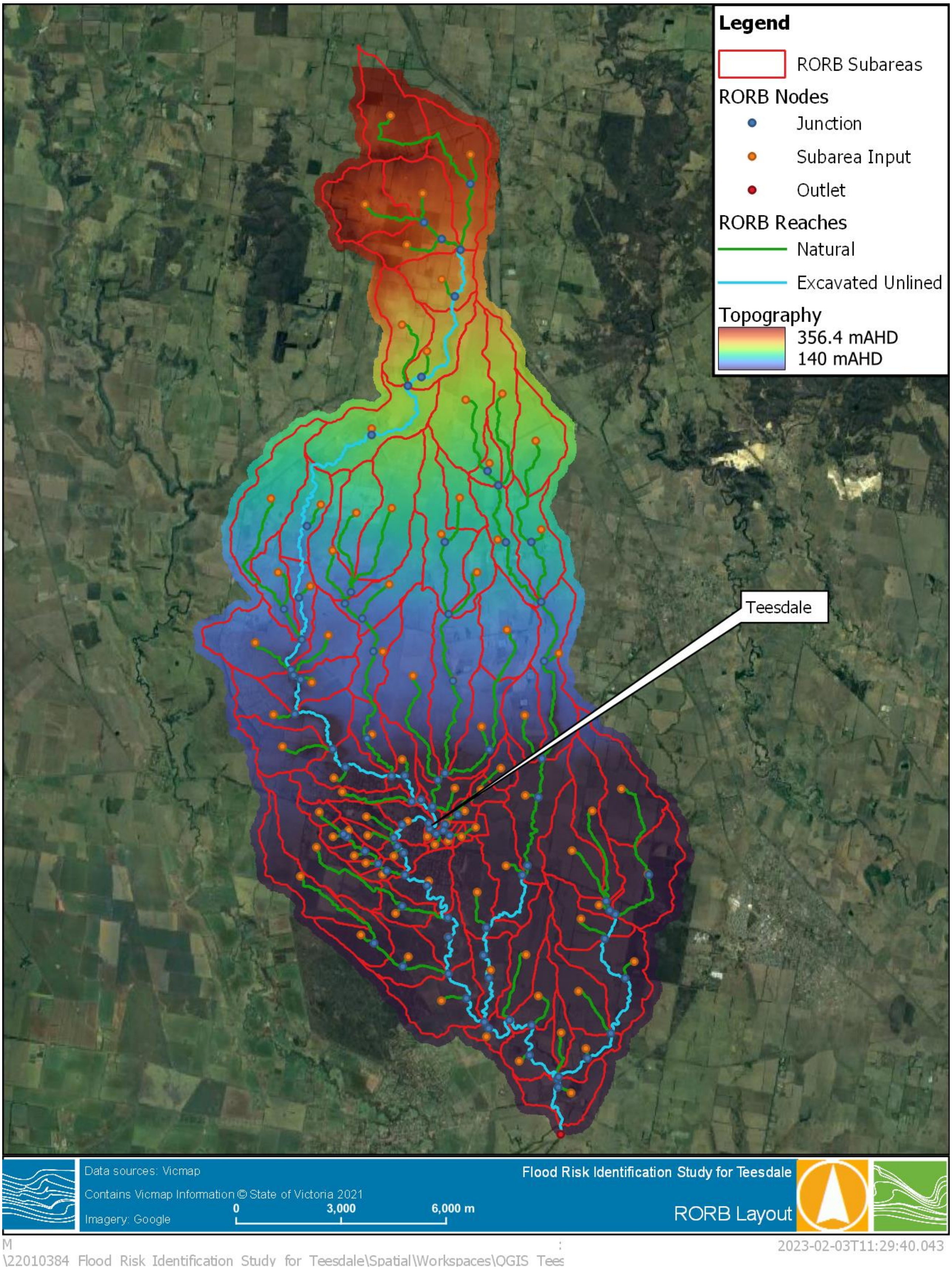


**Figure 3-1 RORB model layout**

## 3.3 TUFLOW Summary

### 3.3.1 Model Parameters and Design

The TUFLOW model design and parameter selection is described in detail in R02 – Joint Validation Report. A short summary of the modelling logic and selected parameters is provided below however readers wishing to know more about the model build should refer to the full report.

The key TUFLOW model parameters, along with the design approach for key components of the model, are shown in Table 3-2 below. The TUFLOW model extent and boundary areas are shown in Figure 3-2 below.

**Table 3-2 Key TUFLOW model parameters**

| Parameter | Value/Approach |
|---|---|
| Model Build | 2023-03-AA-iSP-w64 |
| Model Precision | Single Precision |
| Grid Cell Size | 3 metres |
| Sub Grid Sampling | Not adopted |
| Solution Scheme | HPC |
| Inflows | Source-Area boundaries coupled with streamlines |
| Outflow | Height-Flow Slope of 0.3% based on waterway slope |
| Hydraulic Roughness | Manning's 'n', varies with land use |
| 1-Dimensional elements | Culverts and pipes linked to 2-D domain |
| Topography | 2021 LiDAR dataset utilised after comparison and validation |
| Extent | The model extent was set such that the entire floodplain in Teesdale would be captured and main flow boundaries would be a sufficient distance from the town to have no influence on model results within the town |
| Roughness | Assigned based on land use (planning zones), see Table 3-3 |
| Hydraulic Structures | Culverts and pipes were represented as 1-dimensional elements linked to the 2-dimensional domain<br>Bridges were represented as layered flow constrictions within the 2-dimensional domain based on survey captured as part of the |

**Table 3-3 Hydraulic Roughness**

| Land use / Topographic description | Roughness coefficient (Manning's n) |
|---|---|
| Pasture and Grasses | 0.05 |
| Sealed Roads (entire reserve) | 0.02 |
| Unsealed Roads (entire reserve) | 0.03 |
| Township Zone | 0.20 |
| Low Density Residential | 0.06 |
| Medium Density Bushland | 0.08 |
| Vegetated Ephemeral Waterway (Native Hut Creek) | 0.07 |

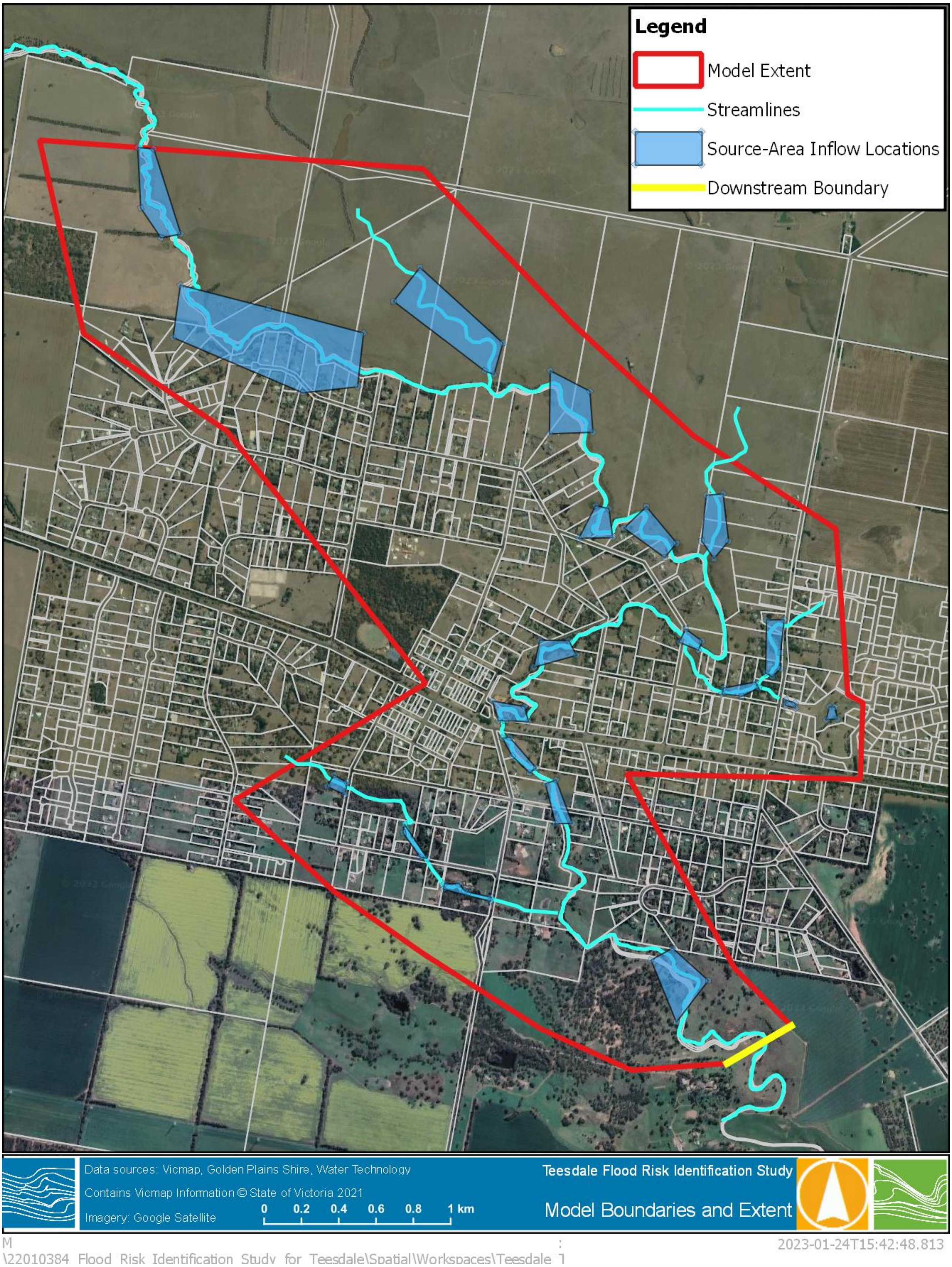


**Figure 3-2 TUFLOW Extent and Model Boundaries**

## 3.4 Validation Modelling Results

The results of the validation modelling were used to ensure the models were performing as expected, and to inform the selection of the RORB parameter Kc. The model results were presented to community members at the second community consultation session held in March 2023. Feedback gathered during the session clearly supported the use of a Kc/Dav ratio of 1.25 over the lower ratio utilised in nearby modelling by the CCMA for the January 2011 and April 2001 events. Little feedback was gathered for the February 1973 event other than a photograph showing widespread flooding near Pantics Road.

Community feedback is summarised as follows:

- The January 2011 event was contained within the bed and banks of the waterway, with photographic evidence demonstrating no breakout at 75 Sutherland Street.
- Strong anecdotal evidence suggested only shallow inundation of Turtle Bend during April 2001.
- A community member recalled Bannockburn-Shelford Road was closed during April 2001, however this was not recreated in the model. Other participants informed the modelling team that after April 2001, a creek clean up removed significant amounts of rubbish and debris from the waterway occurred. As a result it is possible that the bridge was partially blocked, or that the road closure was a result of runoff rather than riverine inundation.

Modelling results for the April 2001 and January 2011 events are shown below.

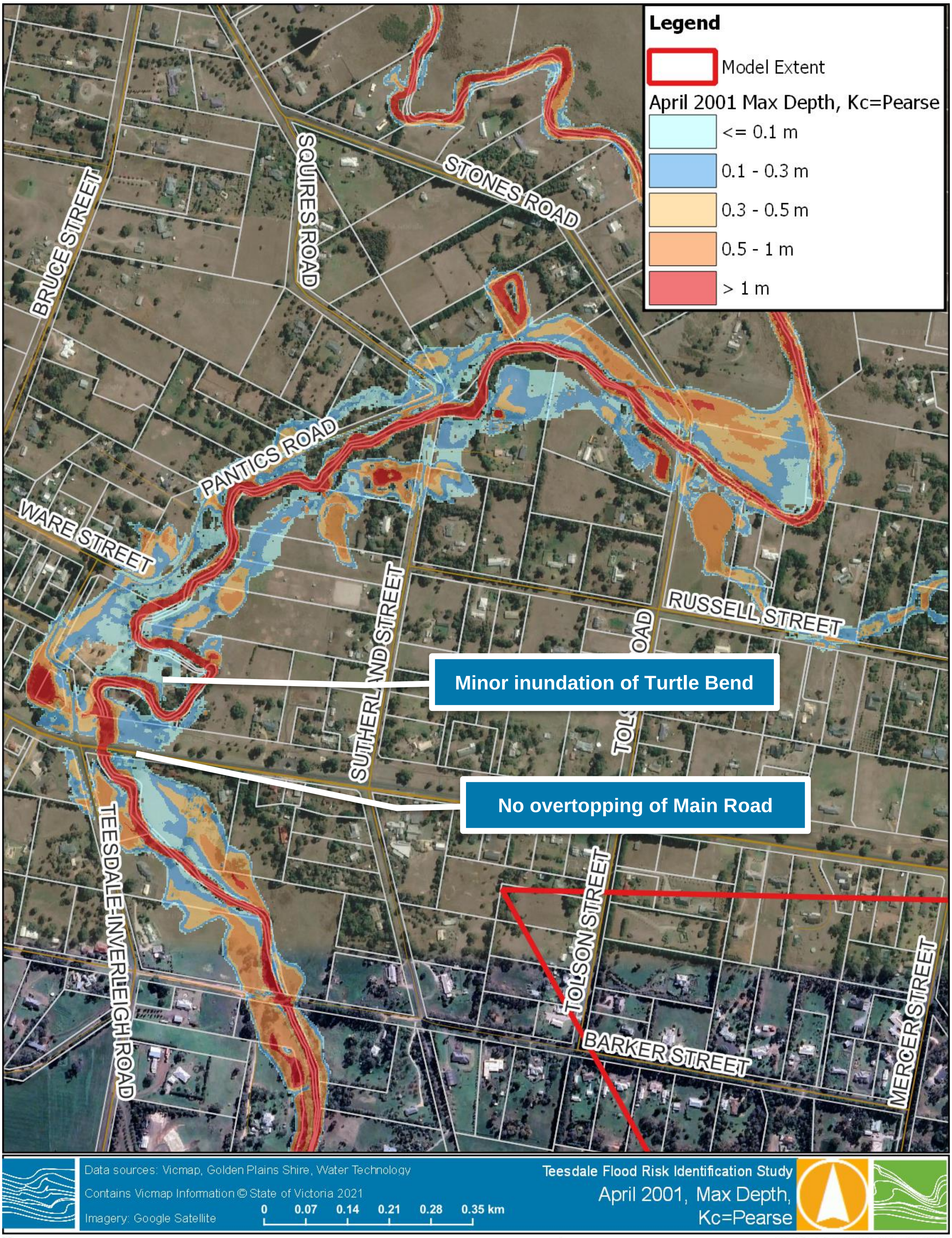


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**Figure 3-3 April 2001 Flood Depths, $K_c$=Pearse (Township)**

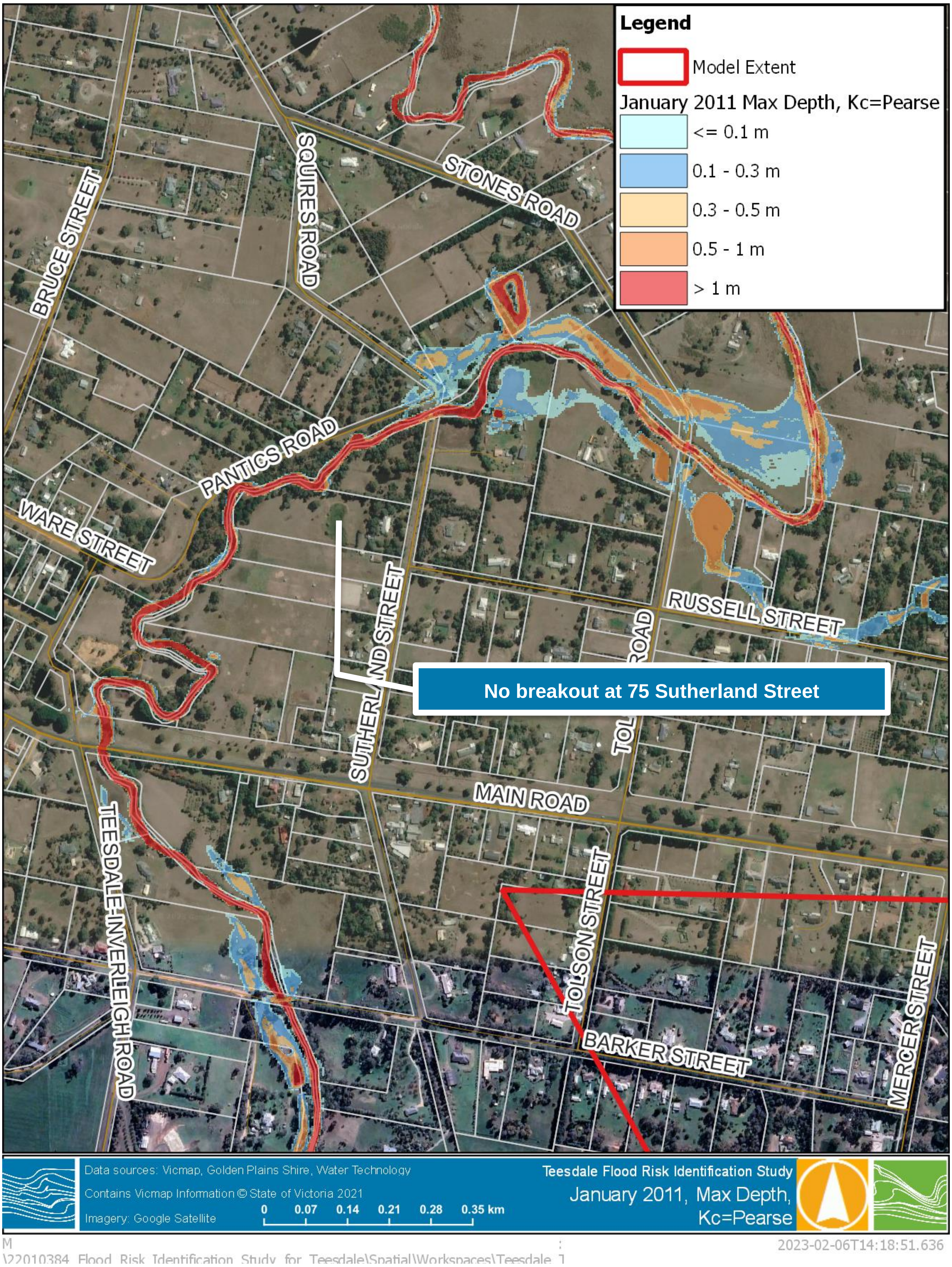


Figure 3-4 January 2011 Flood Depths, $K_c$=Pearse (Township)


**Figure 3-5 Photo provided by the residents of 75 Sutherland Street Teesdale during the 2011 flood showing flows contained within Native Hut Creek**

# 4 DESIGN MODELLING RESULTS

## 4.1 Hydrology

The RORB hydrologic model was ran for the 50%, 20%, 10%, 5%, 2%, 1%, 0.5%, 0.2% and PMF events. Critical event hydrographs at the Bannockburn-Shelford Road bridge for the design events (excluding the PMF) are shown in Figure 4-1 below.

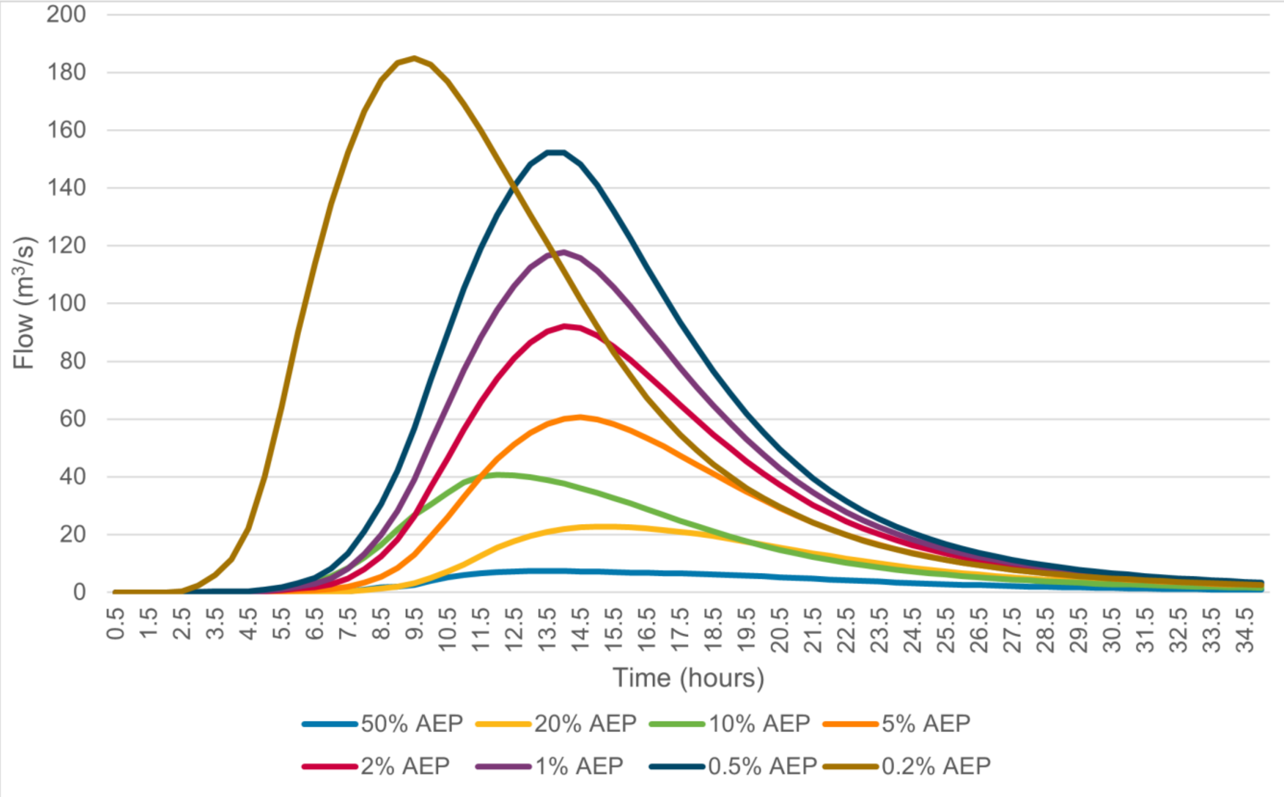


**Figure 4-1 Design hydrographs, Native Hut Creek at Bannockburn-Shelford bridge**

The impact of increased rainfall intensity associated with climate change was investigated for the 10% and 1% AEP events, with four scenarios modelled for both AEPs:

- Projected flows to 2050 under RCP4.5
- Projected flows to 2100 under RCP4.5
- Projected flows to 2050 under RCP8.5
- Projected flows to 2100 under RCP8.5

The resultant impact on flows at the Bannockburn-Shelford Road bridge are shown in Table 4-1 below. The 1% AEP flows under an RCP8.5, 2100 scenario are increased 44% and are between present day 0.2% and 0.5% AEP flows. Similarly, the 10% AEP flows for the same climate scenario are increased 59% and are between present day 5% and 2% AEP flows.

**Table 4-1 Climate change assessment summary**

| 10% AEP | RCP4.5 2050 | RCP4.5 2100 | RCP8.5 2050 | RCP8.5 2100 |
|---|---|---|---|---|
| IFD Rainfall (mm) | 54.11 | 54.11 | 54.11 | 54.11 |
| % Increase | 5.4% | 7.8% | 7.3% | 18.4% |
| Projected Rainfall Depth (mm) | 57.03 | 58.33 | 58.06 | 64.06 |
| Peak Flow at Bridge | 46.79 | 50.06 | 49.50 | 64.66 |
| Increase in Flow (%) | 15.19 | 23.24 | 21.85 | 59.17 |
| **1% AEP** | **RCP4.5 2050** | **RCP4.5 2100** | **RCP8.5 2050** | **RCP8.5 2100** |
| IFD Rainfall | 85.06 | 85.06 | 85.06 | 85.06 |
| % Increase | 5.4% | 7.8% | 7.3% | 18.4% |
| Projected Rainfall Depth (mm) | 89.65 | 91.69 | 91.27 | 100.71 |
| Peak Flow at Bridge | 137.39 | 142.97 | 141.83 | 169.21 |
| Increase in Flow (%) | 16.75 | 21.49 | 20.52 | 43.79 |

## 4.2 Hydraulics

Hydrographs extracted from the RORB model at locations corresponding to the source-area inflow locations shown in Figure 3-2 were applied to the TUFLOW model. Peak flood depths for the 1% AEP and the 2100 1% AEP under RCP8.5 are shown in Figure 4-2 and Figure 4-3 below.

Figure 4-4 shows the difference in flood levels between the existing conditions 1% AEP event and the 2100 1% AEP under RCP8.5. In the township, flood levels increase in the order of 0.15 to 0.25 metres upstream of the bridge where the floodplain is relatively wide. Downstream of the bridge, increases in flood levels are between 0.4 and 0.5 metres, where the floodplain is more confined.

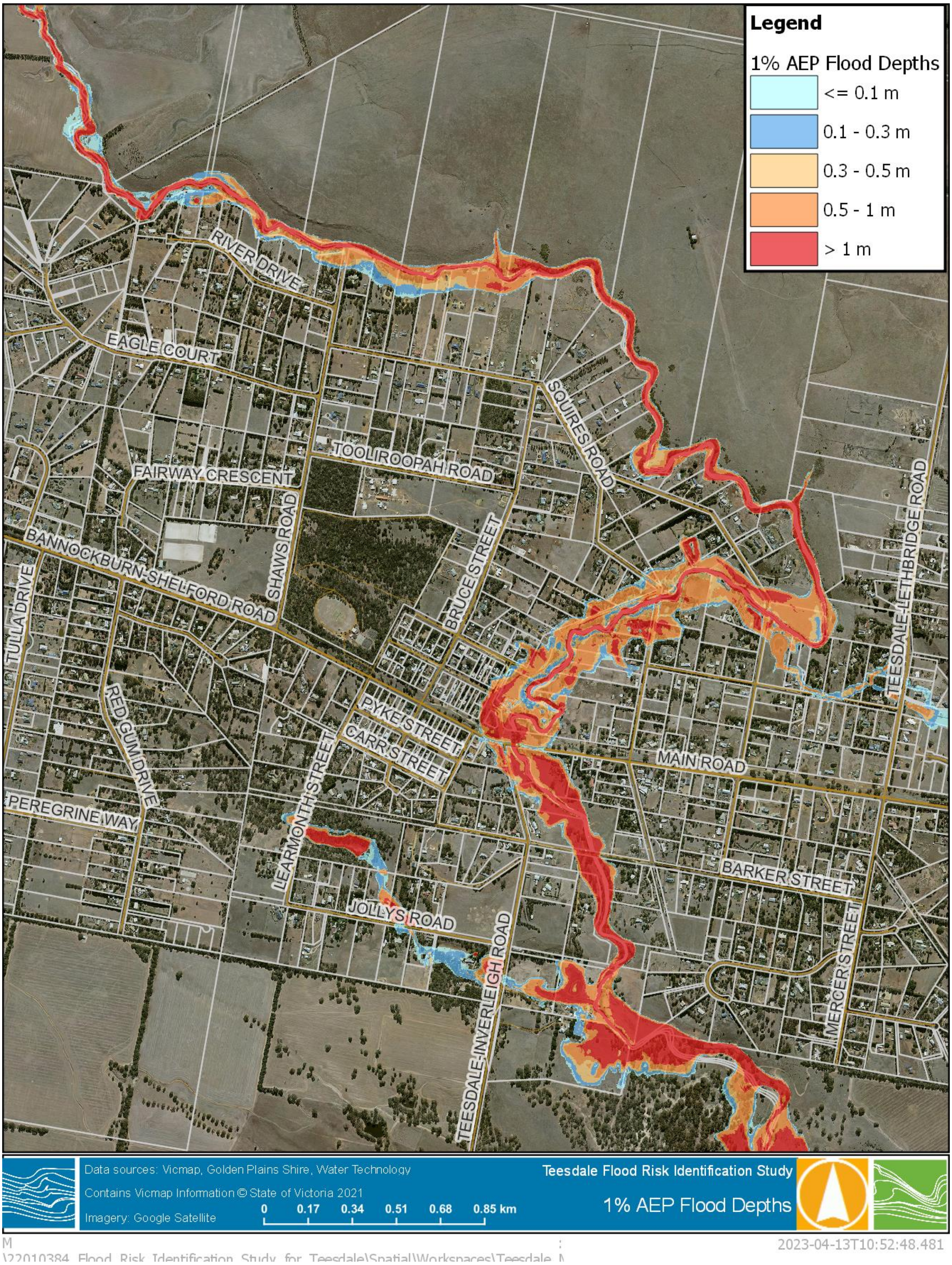


**Figure 4-2 1% AEP Flood Depths in Teesdale (Existing Conditions)**

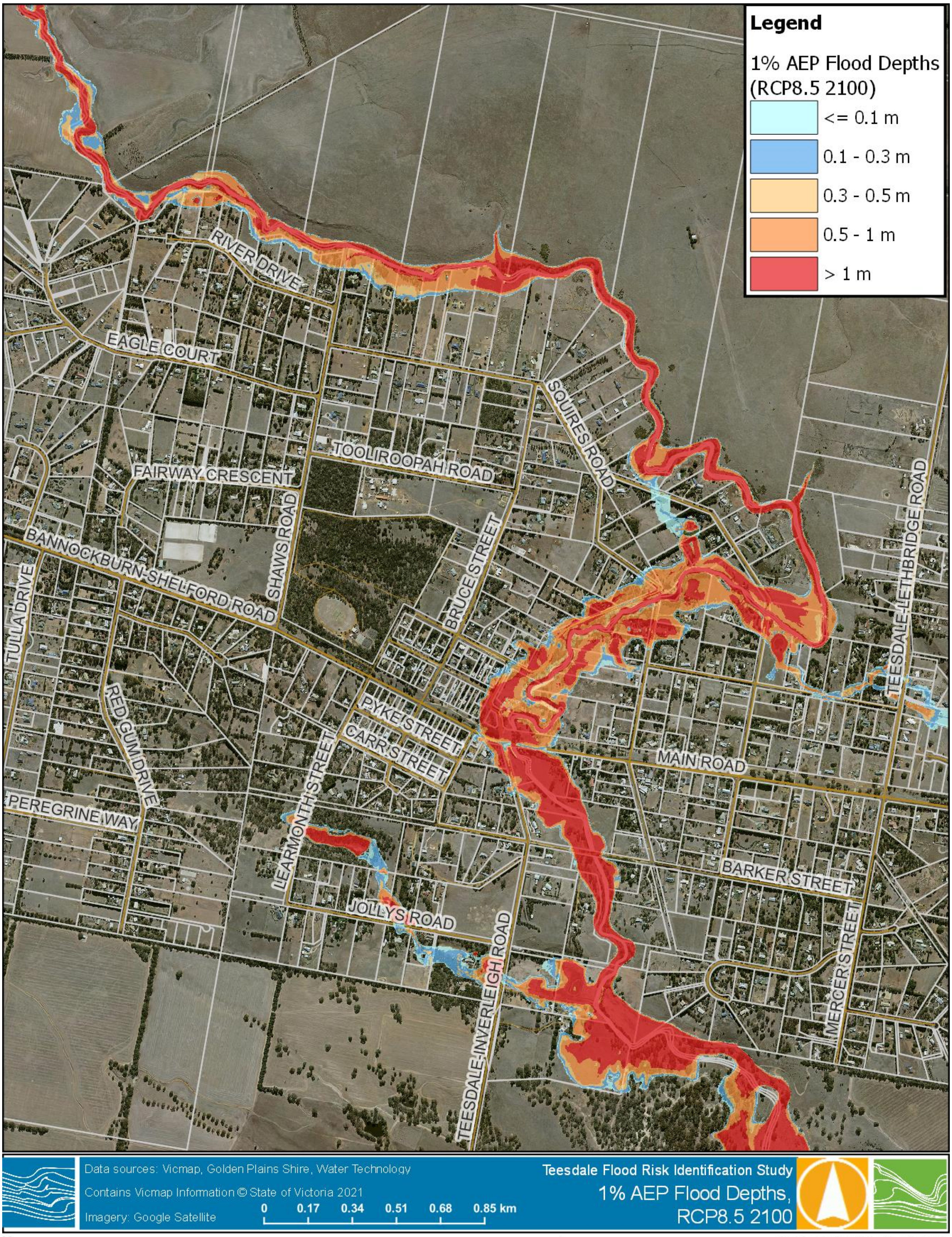


**Figure 4-3** **1% AEP Flood Depths in Teesdale under projected RCP8.5 to 2100**

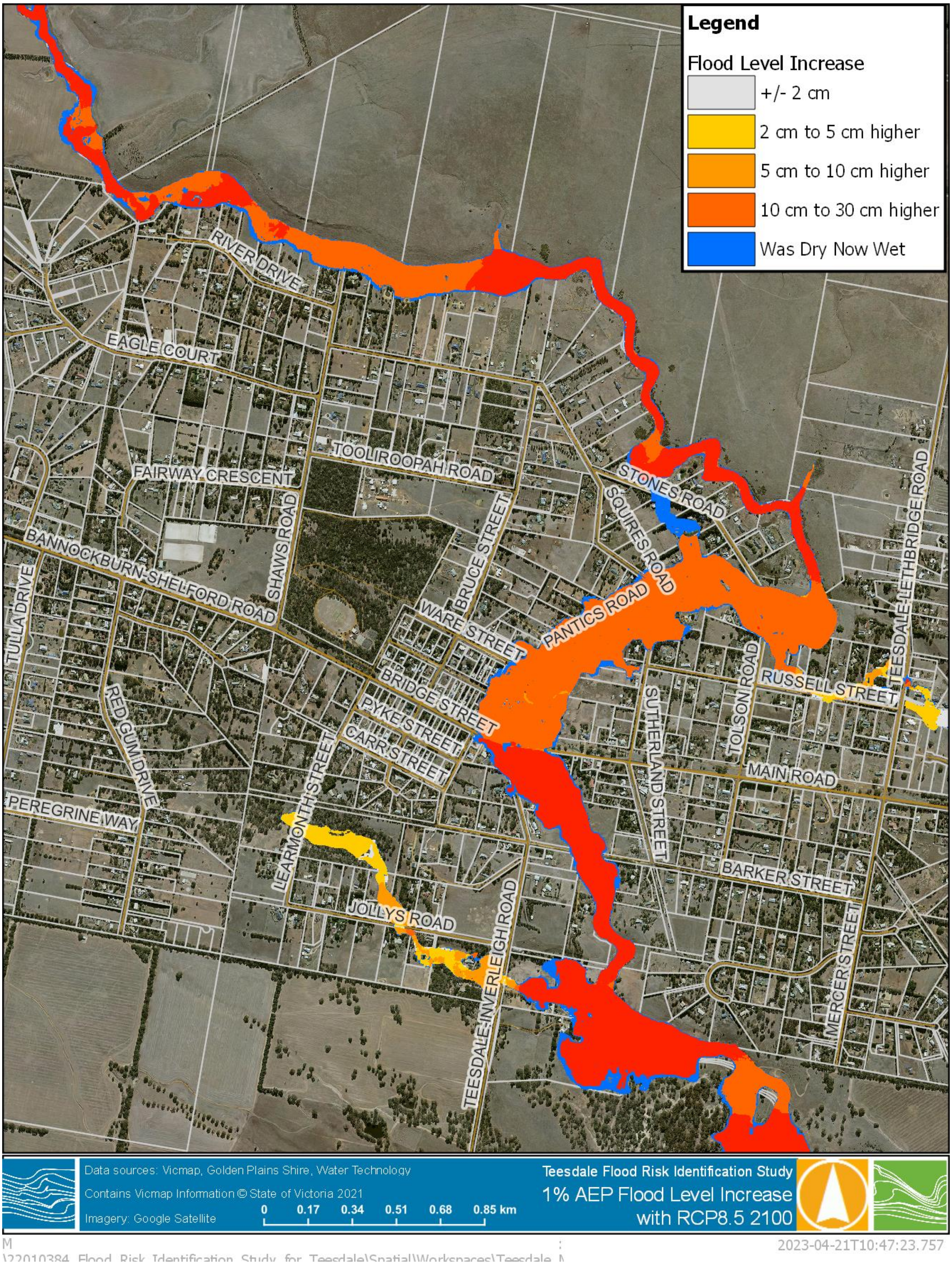


Figure 4-4 Flood level increase under RCP8.5 projections to 2100 for the 1% AEP event

## 4.3 Sensitivity Testing

Model sensitivity testing was conducted on the hydrologic and hydraulic models for the following parameters:

- Losses (hydrology)
- Hydraulic roughness
- Structure (bridge) blockage
- Boundary conditions (slope)

The models were shown to be sensitive to continuing loss and hydraulic roughness. Reducing continuing loss from 3.3 to 1 mm/hr caused a 40.3% increase in flows for the 1% AEP event. Alterations to hydraulic roughness impacted flood levels across the modelling area. The area upstream of the Bannockburn-Shelford Road bridge appears to be the least sensitive area in the model to changes in roughness. This is indicative of the influence the road and bridge has on flood behaviour in that area as well as the width of the flow path. Flood levels upstream of the bridge increased in the order of 0.1 to 0.2 metres in the high roughness scenario, compared to raises of around 0.4 metres downstream of the bridge. The low roughness scenario resulted in lower flood levels of around 0.1 metres upstream and 0.2 metres downstream of the bridge.

# 5 FLOOD INTELLIGENCE AND WARNING

## 5.1 Overview

In line with the project brief, components of the Total Flood Warning System were assessed, and additional components recommended with the aim of improving flood warning and monitoring capability for Teesdale. The following flood intelligence products were produced:

- A rating curve for a potential gauging station on Native Hut Creek at the Bannockburn-Shelford Road bridge.
- Summary table of flood behaviour, impacts and roads inundated.
- Average flood peak travel time estimations.
- "Flood/No Flood" tool, providing a rough link between observed rainfall and flood magnitude.
- Recommended Flood Class Levels for Teesdale based on the potential gauging station.

The majority of the products were included in a draft update to the Golden Plains Municipal Flood Emergency Plan in addition to the Flood Intelligence and Warning Report (R04). The flood impacts summary table, flood peak travel time estimates and Flood/No Flood tool have been reproduced herein for reference.

Table 5-1 Flood Impacts Summary

| Flood Event | Characteristics – Flood Behaviour | Roadways Inundated |
|---|---|---|
| **50% AEP**<br>~600 ML/d<br>~7.4 m$^3$/s<br>99.99 m AHD at Bannockburn-Shelford Road bridge | Breakout occurs upstream of Stones Road, flowing along the north side of Native Hut Creek and filling local depressions. The breakout rejoins Native Hut Creek at Pantics Road. | ▪ Learmonth St (<0.1m)<br>▪ Stones Road (<0.3m)<br>▪ Barker Street (<0.3m)<br>▪ Russel St (<0.1m) |
| **20% AEP**<br>~1,950 ML/d<br>~23 m$^3$/s<br>101.05 m AHD at Bannockburn-Shelford Road bridge | Breakout upstream of Stones Road becomes more significant with deep flows on the north side of Native Hut Creek. Breakout from dam at 95 Tolson Road flows over paddocks south of Native Hut Creek, rejoining before Sutherland Street. Stones Road and Barker Street flooded to hazardous depths.<br>Minor breakouts on west side of Native Hut Creek, north and south of Bannockburn-Shelford Road.<br>Significant breakouts around and downstream of Barker Street and around Native Hut Drive. | ▪ Learmonth St (<0.1m)<br>▪ Stones Road (>0.5m)<br>▪ Pantics Road (<0.1m)<br>▪ Barker Street (>0.5m)<br>▪ Russel St (~0.1m) |
| **10% AEP**<br>~3,400 ML/d<br>~40.5 m$^3$/s<br>101.53 m AHD at Bannockburn-Shelford Road bridge | Floodplain fully engaged with breakout flows on both sides of Native Hut Creek throughout the town.<br>Turtle Bend inundated with isolated islands.<br>**Teesdale Kindergarten driveway and carpark inundated.** Access via community hall possible.<br>**87 Pantics Road inundated above floor.** | ▪ Learmonth St (<0.1m)<br>▪ Stones Road (>0.5m)<br>▪ Mercer Tce (~0.5m)<br>▪ Pantics Road (<0.3m)<br>▪ Barker Street (>1m)<br>▪ Sutherland Street (~0.3m)<br>▪ Russel St (<0.3m) |

| Flood Event | Characteristics – Flood Behaviour | Roadways Inundated |
|---|---|---|
| **5% AEP**<br>~5,200 ML/d<br>~60.5 $m^3/s$<br>101.78 m AHD at Bannockburn-Shelford Road bridge | Generally as above with deeper, faster flowing water. Hazardous depths across floodplain.<br><br>**Teesdale Kindergarten driveway and carpark inundated to hazardous depths. Access via community hall possible.** | ▪ Learmonth St (<0.1m)<br>▪ Stones Road (~1m)<br>▪ Pantics Road (>0.3m)<br>▪ Mercer Tce (~0.9m)<br>▪ Barker Street (>1.0m)<br>▪ Sutherland Street (~0.5m)<br>▪ Teesdale-Inverleigh Road (<0.3m)<br>▪ Russel St (<0.3m) |
| **2% AEP**<br>~7,950 ML/d<br>~92 $m^3/s$<br>102.08 m AHD at Bannockburn-Shelford Road bridge | Generally as above with deeper, faster flowing water. Hazardous depths across floodplain.<br><br>Bannockburn-Shelford Road overtopped.<br><br>**844 Teesdale-Inverleigh Road inundated above floor.** | ▪ Learmonth St (~0.1m)<br>▪ Bannockburn-Shelford Road (<0.1m)<br>▪ Jollys Road (<0.1m)<br>▪ Stones Road (>1m)<br>▪ Pantics Road (>0.5m, ~750m length)<br>▪ Mercer Tce (>1m)<br>▪ Barker Street (>1.0m)<br>▪ Sutherland Street (~0.8m)<br>▪ Teesdale-Inverleigh Road (~0.4m)<br>▪ Russel St (<0.3m) |
| **1% AEP**<br>~10,150 ML/d<br>~118 $m^3/s$<br>102.25 m AHD at Bannockburn-Shelford Road bridge | Generally as above with deeper, faster flowing water. Hazardous depths across floodplain. | ▪ Learmonth St (~0.1m)<br>▪ Bannockburn-Shelford Road (<0.3m)<br>▪ Jollys Road (<0.1m)<br>▪ Stones Road (>1m)<br>▪ Pantics Road (>0.5m, ~750m length)<br>▪ Mercer Tce (>1m)<br>▪ Barker Street (>1.0m)<br>▪ Sutherland Street (>1m)<br>▪ Teesdale-Inverleigh Road (~0.6m)<br>▪ Russel St (<0.3m) |

| Flood Event | Characteristics – Flood Behaviour | Roadways Inundated |
|---|---|---|
| **0.5% AEP**<br>~13,100 ML/d<br>~ 52 $m^3/s$<br>102.48 m AHD at Bannockburn-Shelford Road bridge | Bannockburn-Shelford Road overtopped to depths greater than 0.3 metres.<br><br>Generally as above with deeper, faster flowing water. Hazardous depths across floodplain. | ▪ Learmonth St (~0.1m)<br>▪ Bannockburn-Shelford Road (>0.3m)<br>▪ Jollys Road (<0.1m)<br>▪ Stones Road (>1m)<br>▪ Pantics Road (>0.5m, ~750m length)<br>▪ Mercer Tce (>1m)<br>▪ Barker Street (>1.0m)<br>▪ Sutherland Street (>1m)<br>▪ Teesdale-Inverleigh Road (~0.9m)<br>▪ Russel St (<0.3m)<br>▪ Teesdale-Lethbridge Road (<0.1m) |
| **0.2% AEP**<br>~16,000 ML/d<br>~185 $m^3/s$<br>102.67 m AHD at Bannockburn-Shelford Road bridge | Generally as above with deeper, faster flowing water. Hazardous depths across floodplain. | ▪ Learmonth St (~0.1m)<br>▪ Bannockburn-Shelford Road (<0.5m)<br>▪ Jollys Road (<0.1m)<br>▪ Stones Road (>1m)<br>▪ Pantics Road (>0.5m, ~750m length)<br>▪ Mercer Tce (>1m)<br>▪ Barker Street (>1.0m)<br>▪ Sutherland Street (>1m)<br>▪ Teesdale-Inverleigh Road (>1m)<br>▪ Teesdale-Lethbridge Road (<0.1m) |

**Table 5-2 Flood peak timing for Teesdale**

| Location From | Location To | Typical Travel Time | Comments | Duration |
|---|---|---|---|---|
| Teesdale (Native Hut Creek) | | | | |
| Start of rainfall (catchment) | Teesdale | 2 - 5 hours | Begin to rise from normal levels | Generally <24 hours |
| Start of rainfall (catchment) | Teesdale | 7 - 30 hours | To peak – may be longer dependent on rainfall temporal pattern | |

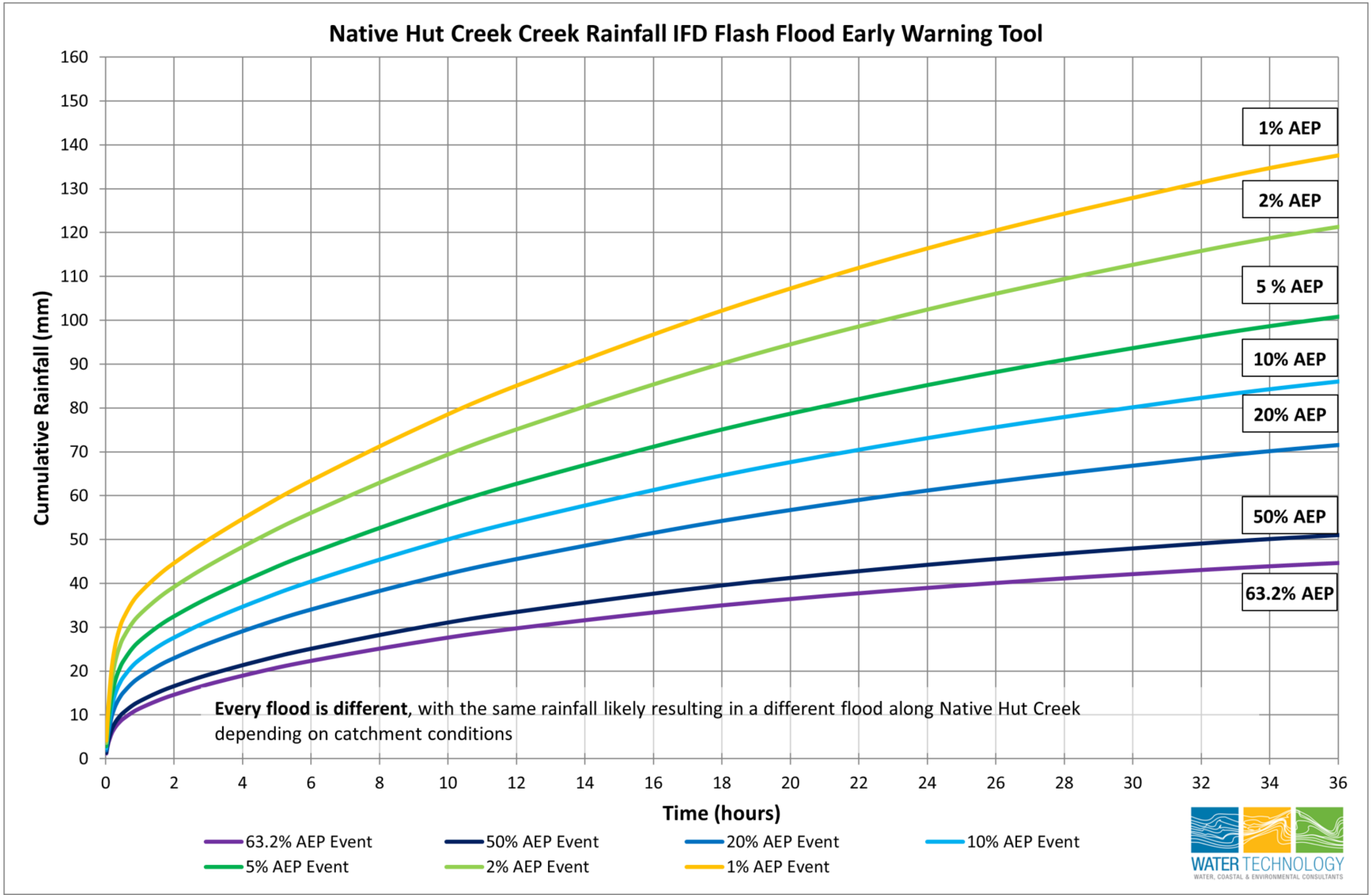


**Figure 5-1 Teesdale Flood/No Flood Tool**

# 6 FLOOD DAMAGES AND MITIGATION

## 6.1 Flood Damages Summary

Following completion of draft design modelling, floor level survey was commissioned for houses within or close to the draft 0.2% AEP flood extent. Flood model results for the range of existing conditions events were processed to calculate the Average Annual Damages (AAD) for Teesdale, which totals $113,366. The damages figure takes into account flooding of roads, properties and buildings. The damages assessment table is shown in Figure 6-1 below.

**EXISTING CONDITIONS**

| ARI (years)<br>AEP | PMF<br>0.00001 | 500yr<br>0.002 | 200yr<br>0.005 | 100yr<br>0.01 | 50yr<br>0.02 | 20yr<br>0.05 | 10yr<br>0.1 | 5yr<br>0.2 | 2yr<br>0.5 |
|---|---|---|---|---|---|---|---|---|---|
| Residential Buildings Flooded Above Floor | 16 | 2 | 2 | 2 | 2 | 1 | 1 | 0 | 0 |
| Commercial Buildings Flooded Above Floor | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Properties Flooded Below Floor | 164 | 119 | 119 | 114 | 109 | 101 | 98 | 76 | 64 |
| **Total Properties Flooded** | **182** | **121** | **121** | **116** | **111** | **102** | **99** | **76** | **64** |
| Direct Potential External Damage Cost | $1,582,730 | $643,420 | $583,954 | $521,971 | $470,489 | $402,605 | $319,425 | $179,678 | $87,892 |
| | | | | | | | | $0 | $0 |
| Direct Potential Residential Damage Cost | $2,173,478 | $197,000 | $185,013 | $170,988 | $160,202 | $81,321 | $73,152 | $0 | $0 |
| Direct Potential Commercial Damage Cost | $418,468 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Total Direct Potential Damage Cost** | **$4,174,676** | **$840,420** | **$768,967** | **$692,959** | **$630,691** | **$483,926** | **$392,577** | **$179,678** | **$87,892** |
| **Total Actual Damage Cost** *(0.8*Potential)* | **$3,339,741** | **$672,336** | **$615,174** | **$554,367** | **$504,553** | **$387,141** | **$314,062** | **$143,742** | **$70,314** |
| **Infrastructure Damage Cost** | **$198,267** | **$102,406** | **$96,149** | **$83,456** | **$71,859** | **$53,936** | **$46,225** | **$15,463** | **$11,352** |
| Indirect Clean Up Cost | | | | | | | | | |
| Indirect Residential Relocation Cost | | | | | | | | | |
| Indirect Emergency Response Cost | | | | | | | | | |
| **Total Indirect Cost** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** | **$0** |
| **Total Cost** | **$3,538,008** | **$774,742** | **$711,323** | **$637,823** | **$576,412** | **$441,077** | **$360,287** | **$159,206** | **$81,665** |
| | | | | | | | | | |
| **Average Annual Damage (AAD)** | $113,366 | | | | | | | | |

**Figure 6-1 Existing Conditions Average Annual Damages (AAD)**

## 6.2 Flood Mitigation

### 6.2.1 Overview

Three options for structural flood mitigation were tested in the hydraulic model for all AEP events, and the resultant impact on flood damages assessed. Reductions in AAD (i.e. savings) were discounted by 6% per year over 30 years, with the total net present value of savings in that period compared to the estimated capital and maintenance costs of the mitigation works. The resultant total project cost was then produced along with a benefit/cost ratio to determine if the concept is financially sound.

The options tested are as follows:

- Raising of Pantics Road to above the 1% AEP flood level with 300mm freeboard;
- Additional culverts under Bannockburn-Shelford Road adjacent to the bridge; and
- Clearing Native Hut Creek of vegetation and large wood.

Each option is discussed below along with the results of the benefit/cost analysis.

### 6.2.2 Option 1: Raising of Pantics Road

For this option, raising of Pantics Road to 300mm above the 1% AEP flood level was investigated. The raised road is intended to act as a levee, preventing flooding of both the road and properties on the west side of the road. The impact of the raised road on 1% AEP flood levels is shown in Figure 6-2 below.

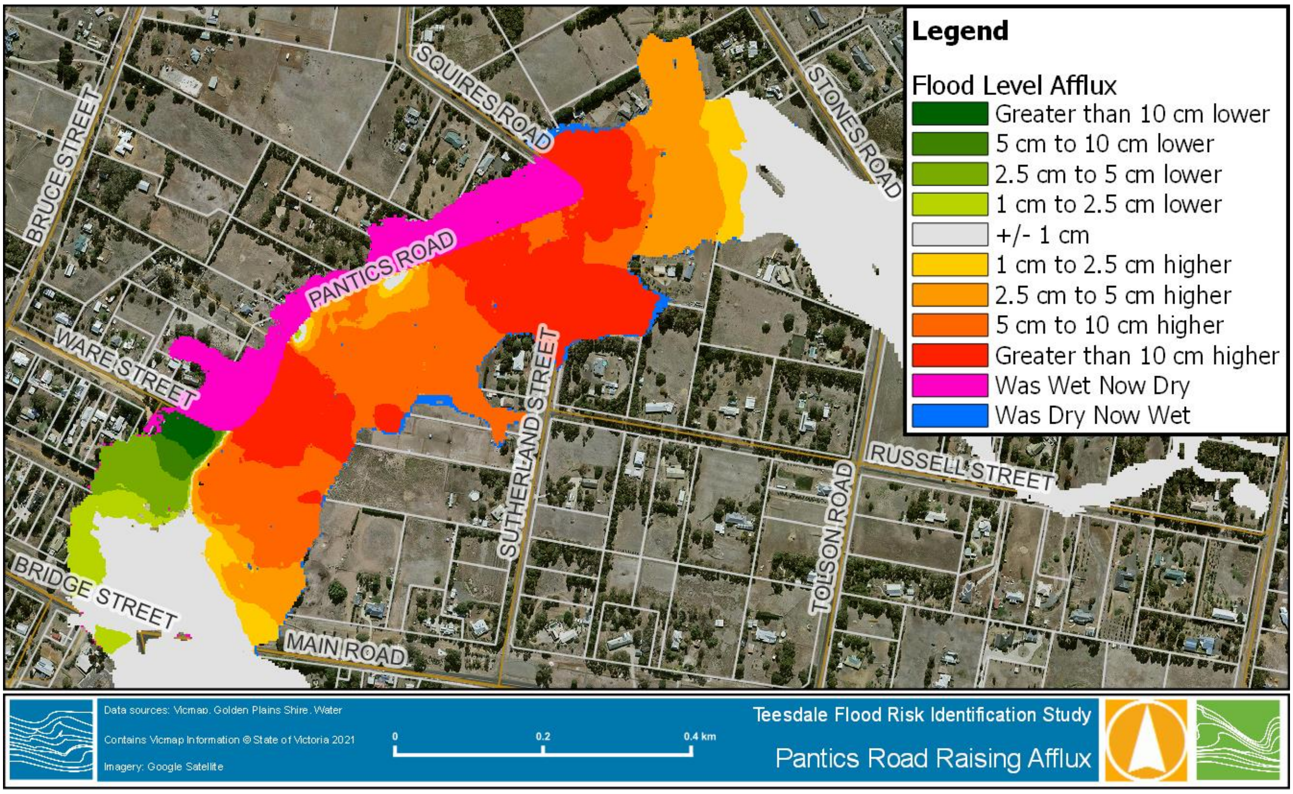


**Figure 6-2 1% AEP Flood Level Afflux – Raising of Pantics Road**

The raised road successfully prevents flooding of the trafficable surface and area to the west, however in doing so flood levels are raised for more properties than are protected by the levee. While a dwelling is protected from above floor flooding in events between a 10% AEP and 0.2% AEP, a different dwelling floods above floor in the 0.2% AEP event (where it does not in the existing conditions).

The resultant AAD under option 1 was $100,819 per year, providing an annual reduction of $12,547. The reduction in AAD is a result of seven properties now having flood immunity for events up to and including a 0.5% AEP flood.

The option is estimated to require capital investment of $905,556. The resultant net present value for option 1 was -$732,848.66, meaning the project will cost more than it will save, on average, over a 30-year period.

### 6.2.3 Option 2: Additional culverts under Bannockburn-Shelford Road

This option was iteratively modelled to attempt to alleviate flooding of Bannockburn-Shelford Road in the 2% and 1% AEP events. After several iterations, a new bank of culverts was included under the road on the east side of Native Hut Creek. The new bank consisted of 20 x 2.1m x 0.9m culverts, and also involved some manipulation of ground levels to allow flow to reach the new culverts.

The new culverts had little impact on flood levels and were unable to prevent overtopping of the road in the 1% or 2% AEP events. The impact of the culverts on 1% AEP flood levels is shown in Figure 6-3 below.

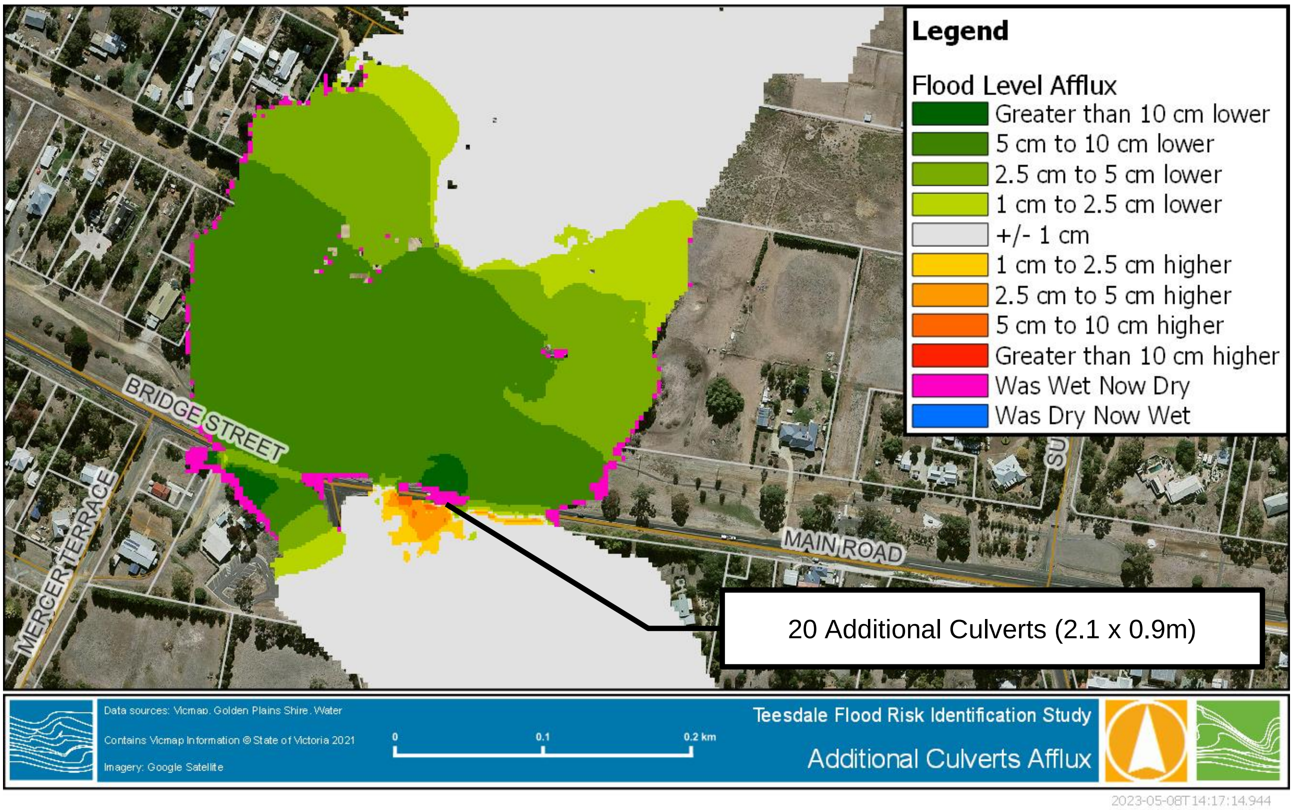


**Figure 6-3 1% AEP Flood Level Afflux – Additional Culverts**

The assessed reduction in AAD associated with Option 2 is $538 per year. This is a miniscule amount and reflects the lack of significant change the culverts were able to produce, with the road remaining overtopped in the same events as existing conditions. Slight reductions in extent and flood levels result in the minor reduction in AAD.

Option 2 is estimated to require capital investment of $681,620. The resultant net present value for option 2 was $674,213.27, meaning the project will cost more than it will save, on average, over a 30-year period.

### 6.2.4 Option 3: Waterway Vegetation Clearing

Option three tested a commonly perceived attitude in some flood affected communities: that clearing the waterway of vegetation and large wood will allow water to pass through faster and prevent inundation of properties. The option was tested by lowering the hydraulic roughness applied to Native Hut Creek in the model. Approximately 11km of waterway were "cleared" in the model by reducing the hydraulic roughness across the entire waterway corridor.

As shown during sensitivity testing, the model is highly sensitive to selection of the hydraulic roughness parameter. Reducing roughness to simulate waterway clearing therefore had a significant impact on flood levels in Teesdale. Flood levels were lowered by around 0.2 to 0.3 metres in confined areas of the waterway. The works had less impact in areas of engaged floodplain where a greater proportion of flow is outside the waterway corridor. Flood levels in the area between the Stones/Tolson Road breakout and the Bannockburn-Shelford Road bridge were lowered by less than 0.1 metres. Downstream of the bridge, flood levels were lowered between 0.1 and 0.25 metres generally.

The increased waterway conveyance benefits the two dwellings liable to above floor inundation. 87 Pantics Road is no longer inundated above floor in a 10% AEP event (although is still above floor in a 5% AEP event) while 844 Teesdale Inverleigh Road is now inundated above floor in the 1% AEP event but not the 2% AEP event.

The 1% AEP flood level afflux results are shown in Figure 6-4 below.

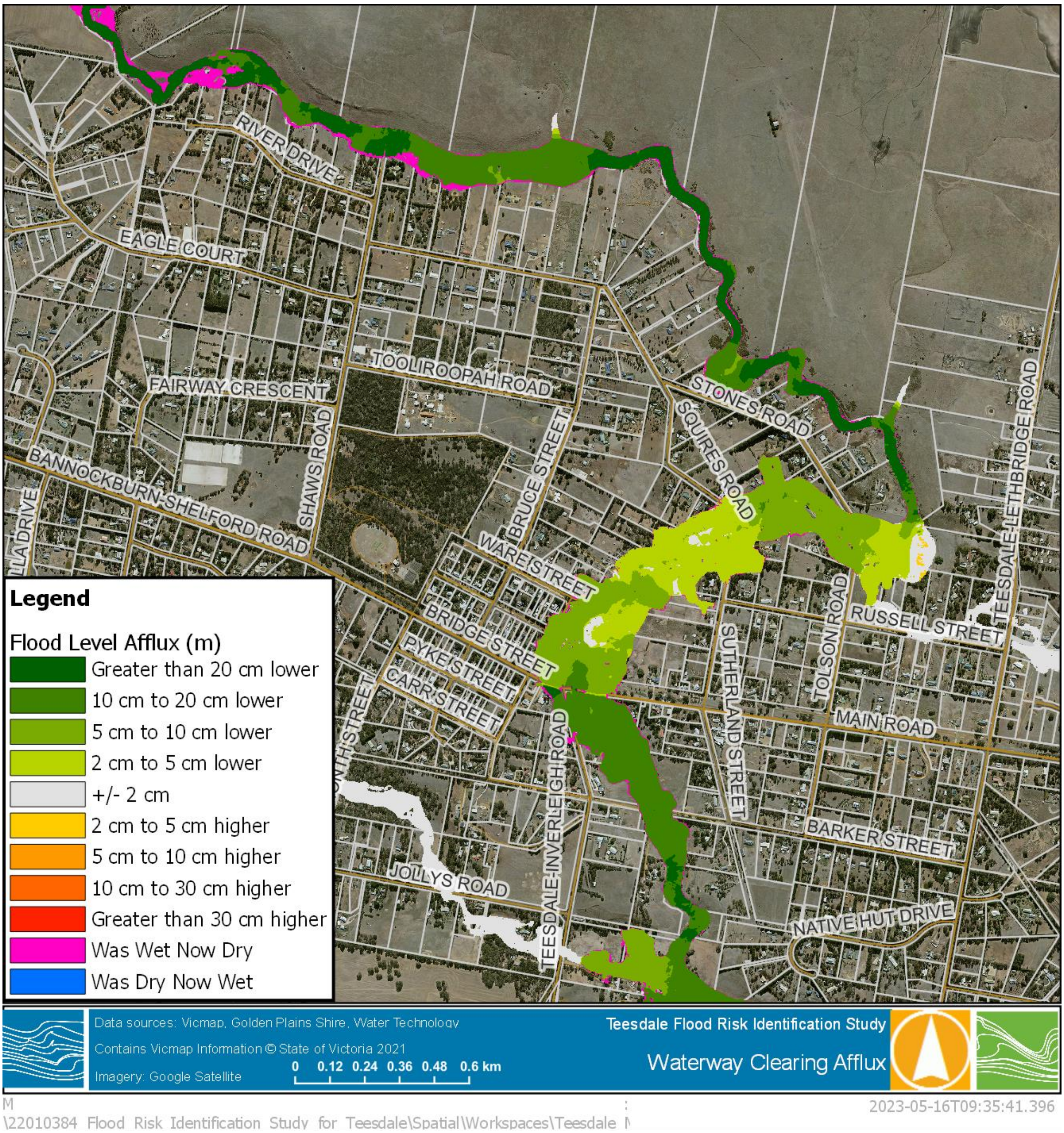


**Figure 6-4 1% AEP Flood Level Afflux – Clearing of Native Hut Creek**

The resultant reduction in assessed AAD is $17,363 per year. The works have been estimated to cost $4,394,473 upfront with maintenance of $38,500 per year in follow up vegetation management. The cost estimate includes the physical excavation works and makes allowances for required permits and native vegetation offsets which are significant and represent the bulk of the cost.

Given the estimated maintenance costs more per year than the amount saved in AAD, the project can not reach a positive cost/benefit ratio. The resultant net present value for option 3 was -$4,685,420.44, meaning the project will cost more than it will save, on average, over a 30-year period. Removing the ongoing maintenance cost reduces the NPV to -$4,155,474.44 which is still a significant deficit.

Notwithstanding the significant financial cost associated with the project, there remains a potentially insurmountable hurdle of permitting and approvals required prior to undertaking the works. Clearing of the waterway is likely to destroy significant habitat, which would need to be quantified. In addition, waterway clearing often creates ongoing erosion issues which can threaten private land when the waterway course and shape changes. Sediment deposition downstream also contributes to further habitat degradation.

#### 6.2.5 Cost-Benefit Summary

Table 6-1 summarises the three mitigation methods assessed from financial performance. For each option the benefit/cost ratio has been calculated as the sum of AAD reductions in present value terms minus the capital and maintenance cost in present value terms. A benefit/cost ratio of 1 equates to a net present value of $0. Ideally cost benefit ratio should be greater than 1, however it should be acknowledged that achieving high CBR for flood mitigation works is highly unlikely and should not be the only factor considered. Community safety, resilience and vulnerability must also be taken into account.

**Table 6-1 Cost-Benefit Summary**

| | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| Capital Cost ($) | $730,345.20 | $478,712.50 | $4,394,473.20 |
| Maintenance Cost ($/year) | $0.00 | $0.00 | $38,500.00 |
| Reduction in AAD ($/year) | $12,547.00 | $538.00 | $17,363.00 |
| Net Present Value ($, total) | -$557,637.86 | -$471,307.02 | -$4,155,474.44 |
| Benefit/Cost Ratio | 0.236 | 0.015 | 0.054 |

Table 6-1 clearly demonstrates that none of the mitigation methods investigated achieve favourable financial outcomes. None of the options are recommended for further investigation.

### 6.3 Planning Scheme Mapping

Inclusion of flood mapping in the planning scheme is a key non-structural mitigation measure to prevent flood risk from increasing into the future. The project has produced flood mapping suitable for inclusion in the planning scheme, as shown in Figure 6-5 below.

The mapping has been based on the 2100, RCP8.5 1% AEP event. Floodway delineation is based on the following criteria based on the Corangamite Catchment Management Authority's preferred delineation:

- Flood depths ≥ 0.3 metres, and/or
- Flood velocities ≥ 2.0 m/s, and/or
- Product of depth and velocity ≥ 0.3 $m^2/s$

The resultant draft planning scheme mapping is shown in Figure 6-5 below.


Figure 6-5 Draft Planning Scheme Mapping

# 7 SUMMARY

The Teesdale Flood Risk Identification Study has produced detailed flood modelling of Native Hut Creek through Teesdale. The mapping produced is fit for the purposes of flood emergency planning and response, statutory and strategic planning in the town. The study has also investigated the current flood impacts in terms of average annual damages and investigated structural mitigation to reduce those damages. Flood intelligence products have been produced and included in a draft update to the Golden Plains Municipal Emergency Management Plan. Options for improving flood warning and intelligence gathering have been recommended, with two additional gauges suggested for consideration.

The following actions are recommended for consideration by Golden Plains Shire and Corangamite Catchment Management Authority:

- That the findings of the study be considered by the relevant authorities;
- The additions to the draft Municipal Flood Emergency Plan are adopted into a working version of the plan;
- Flood mapping produced by the study is shared with the community;
- The draft planning scheme mapping is considered for adoption in the Golden Plains Shire planning scheme;
- Community education regarding flood damages and risk is carried out;
- The viability of additional gauges as recommended in the Flood Warning assessment are investigated in partnership with the Bureau of Meteorology;
- The model files and other deliverables of the study are filed by both authorities for future use.

Future flood events in Native Hut Creek should be monitored carefully and compared to the results of this study, with flood levels marked and surveyed where possible. Where flood behaviour appears to disagree with the findings of the study, the reason for the discrepancy should be investigated and an update to the study should be considered.

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