Baw Baw Shire Council Trafalgar Flood Modelling & Drainage Strategy Project

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PROJECT DETAILS

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GLOSSARY OF TERMS

Annual Exceedance Probability (AEP)	Refers to the probability or risk of a rainfall event of a given magnitude (intensity and duration) occurring or being exceeded in any given year. A 90% AEP event has a high probability of occurring or being exceeded; it would occur quite often and would be a relatively minor rainfall event. A 1% AEP event has a low probability of occurrence or being exceeded; it would be rare but it would be likely to cause extensive damage.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level. Introduced in 1971 to eventually supersede all earlier datums.
Average Recurrence Interval (ARI)	Refers to the average time interval between a given flood magnitude occurring or being exceeded. A 10 year ARI flood is expected to be exceeded on average once every 10 years. A 100 year ARI flood is expected to be exceeded on average once every 100 years. The AEP is the ARI expressed as a percentage.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. Generally relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Design flood	A significant event to be considered in the design process; various works within the floodplain may have different design standards. A design flood will generally have a nominated AEP or ARI (see above).
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from elevated sea levels and/or waves overtopping coastline defences.
Flood damage	The tangible and intangible costs of flooding.
Flood hazard	Potential risk to life and limb caused by flooding. Flood hazard combines the flood depth and velocity.
Flood mitigation	A series of works to prevent or reduce the impact of flooding. This includes structural options such as levees and non-structural options such as planning schemes and flood warning systems.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Flood storages	Those parts of the floodplain that are important for the temporary storage, of floodwaters during the passage of a flood.
Freeboard	A factor of safety above design flood levels typically used in relation to the setting of floor levels or crest heights of flood levees. It is usually expressed as a height above the level of the design flood event.

Geographical information systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Intensity frequency duration (IFD) analysis	Statistical analysis of rainfall, describing the rainfall intensity (mm/hr), frequency (probability measured by the AEP), duration (hrs). This analysis is used to generate design rainfall estimates.
TUFLOW	A hydraulic modelling tool used in this study to simulate the flow of flood water through the floodplain. The model uses numerical equations to describe the water movement.
Ortho-photography	Aerial photography which has been adjusted to account for topography. Distance measures on the ortho-photography are true distances on the ground.
Peak flow	The maximum discharge occurring during a flood event.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a fuller explanation see Average Recurrence Interval.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequence and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
RORB	A hydrological modelling tool used in this study to calculate the runoff generated for design rainfall events.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Topography	A surface which defines the ground level of a chosen area.

EXECUTIVE SUMMARY

The Trafalgar Flood Modelling and Drainage Strategy Project had four main objectives, they are discussed individually below including the project's response and outcomes of each focus area;

1. *Determine the capacity of the existing drainage infrastructure for the current level of development, including the Strzelecki Views Estate*

This study established new hydrologic and hydraulic models representing the current land form (including the Strzelecki Views Estate) and the existing drainage infrastructure. New modelling was informed by recent investigations including:

- Stormwater Management Plan (SWMP) for 36 Hardy Drive, Trafalgar - Stormy Water Solutions;
- Trafalgar West Flood Study – Engeny Water Management; and
- Latrobe River Flood Study – WGCMA (Cardno).

In addition to the technical modelling, the project had a clear focus on using community knowledge of flooding to inform the results. This was achieved via two formal community consultation sessions and numerous informal discussions with interested community members via BBSC staff, WGCMA staff and Water Technology project staff.

With flood models constructed of the study area, the results were then validated by the community. The model results were reviewed to describe the capacity of the existing drainage infrastructure. The following was concluded:

5 year ARI system performance

5 year ARI flooding across Trafalgar is largely confined to defined drainage areas, roadways and areas not currently developed. The exception to this is the western edge of the township where ponding on the southern side of the highway is observed adjacent to both existing highway crossings. Flooding continues downstream from this point with breakouts between Reserve Road and Seven Mile Road (Willow Grove Road) resulting in overland flow moving through residential and commercial / industrial land. This overland flow tends to end up ponded behind Seven Mile Road

100 year ARI system performance

100 year ARI flooding across Trafalgar is extensive with many significant overland flow paths being engaged throughout the study area. The older part of the town (south of the Highway) is relatively free from extensive flooding, with only localised low points showing some ponding.

The majority of the new development to the east of town is flood proofed with the analysis indicating one breakout of flood waters between Berenger Avenue and Vileneuve Drive. This breakout is due to a small section of low embankment, which Council anticipates to rectify with modest works to alleviate the issue. Ponding behind the Princes Highway on the western portion of town is extensive (up to 0.8 m deep), with breakout flows north of the Princes Highway impacting much of the land from Reserve Road through to Seven Mile Road (Willow Grove Road). In 100 year ARI flooding, the capacity of Contour Drain is significantly compromised with several breakouts observed along its length. Flooding over the highway is observed in at least 3 locations during the peak 100 year ARI storm.

2. *Review the adequacy of the drainage infrastructure for future development and town expansion as outlined in current planning Strategies,*

Under existing conditions, flooding at the western edge of the township is extensive, with significant pressure put on the Reserve Road culvert crossing. The development proposed for the land immediately west of this area will need to be sensitive to these existing flooding problems. This result is contrasted with the east development, were the downstream conditions including development levels, tail water conditions and infrastructure beneath the highway and railway line are different. Any development west of the township will require a tailored and well thought out drainage solution.

3. *Provide mitigation options and cost estimates for the strategy,*

Many different mitigation options were trialled in this study. The majority of the options were recommended by the public through the community consultation process. Initially all flood mitigation options were tabled and ranked considering assumed effectiveness and cost. Quite quickly it was established that to flood proof the town for 100 year ARI flooding, significant works would be required. Consequently it was decided to split mitigation options analysis into a simple/practical options which would provide modest flood protection (up to 20 year ARI) and two more extensive options which would attempt to manage flooding up to 100 year ARI conditions. The adopted options were then further refined in a workshop held with BBSC on the 17th of October 2014.

Across all mitigation options a set of common works were applied, many of these works related to issues raised by the community through the consultation process.

Practical Solution

The practical solution provides the township flood protection up to and including the 20 year ARI event. It consists of all measures identified in the common works coupled with a small storage (13,700 m^3) on the western edge of the current township boundary (south side of the Highway). The small retarding basin utilises box culverts to attenuate the 20 year ARI flow back to a level where the culvert crossing at Reserve Road can more effectively convey flood water through to Contour Drain.

Under these conditions, 20 year ARI flooding is reduced to low hazard risk with most of the major flow paths and areas of ponding significantly reduced. It should be noted that the drainage system results for events greater than 20 year ARI would likely be closer to existing conditions as the basin volume was only designed to manage 20 year ARI flows. The estimated cost for the practical solution is of the order of $2M.

BBSC - Option 1

Option 1 involves construction of a small retarding basin on the south side of the Princes highway, as well as a drainage channel to direct runoff to the Contour Drain and eventually the Moe River. This option effectively ensures that runoff from the hill (to the south) does not contribute to inundation of the land recently rezoned RZ1 (east of Sunny Creek). It was determined that the proposed drainage channel works would be best located along the 80 m AHD contour. The capacity of this drain should be approximately 0.6 m^3/s.

Water Technology also assessed the proposal to construct a number of retardation basins located on the south side of the proposed drain to determine if the depth of inundation could be reduced further, however the retardation basins did not provide significant reduction in observed flooding.

While this option was found to be the cheapest ($1.3M), its effectiveness in reducing flooding was limited. Undertaking this analysis confirmed that to effectively mitigate flooding, flows from both the external (Strzelecki ranges) and the existing urban catchments need to be considered. Option 1 was able to effectively manage the external flows (from the Strzelecki ranges), however under these conditions the stormwater from the existing urban area begins to dominate flooding at the western edge of the township. This resulted in unacceptable flooding being observed on the western edge of town.

BBSC - Option 2

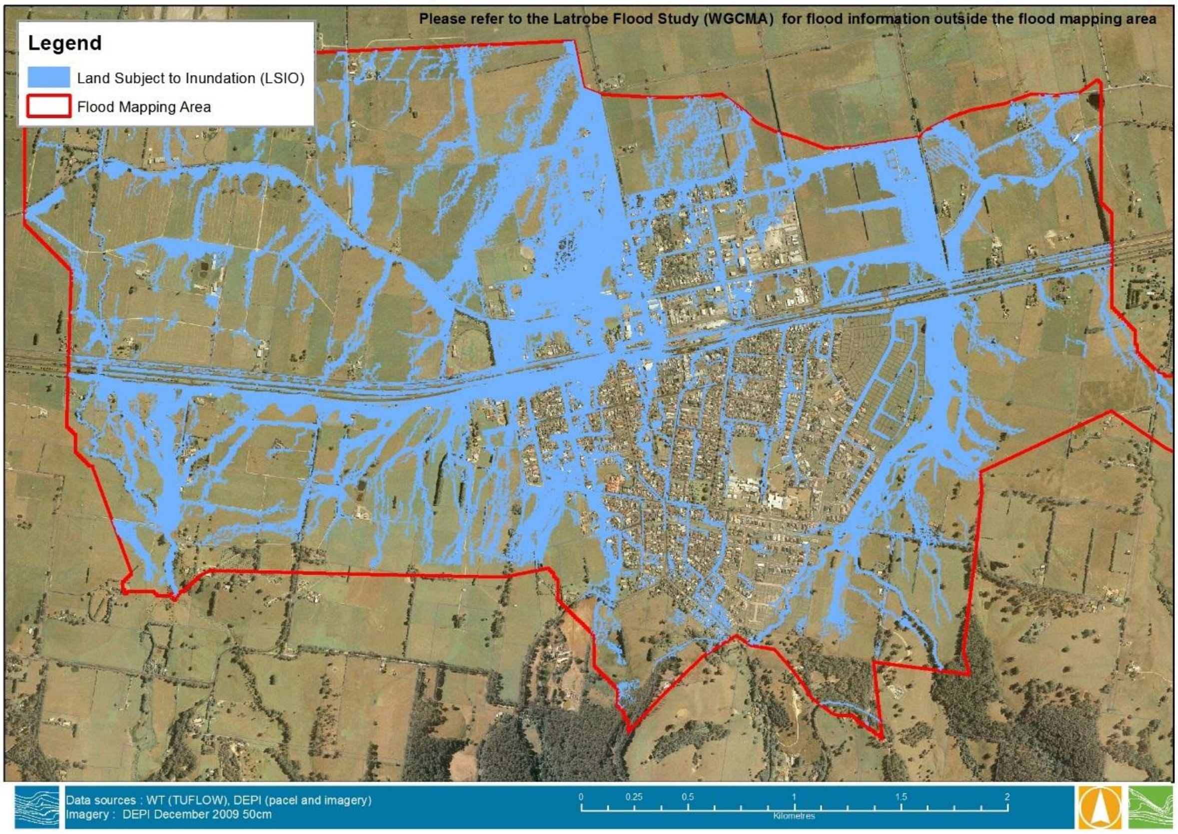
Option 2 included the construction of 16 deep culverts under the Princes Highway, the railway line and Waterloo Road to reduce the extent of inundation south of the highway. Council's reserve north of the Highway, bounded by Reserve Road, Contour Road and the Highway was to be used to provide retardation, noting that proposed playing fields may need to be raised to be flood proofed. The storage volume estimated approximately 200,000 m^3. It is anticipated that the retarding basin feature, would be coupled with Water Sensitive Urban Design features (such as wetlands) and water re-use systems to achieve an integrated solution for the township. The retarding basin was modelled with a nominal low flow outlet, it is anticipated this would need to be refined further if the mitigation option was to be further progressed.

An excavation adjacent the contour drain to just above the invert level including bunding (~0.6m high) has been included in concept to provide additional storage. This option also included the construction of major underground drainage within the existing residential development along School Road. These works inside the existing residential area were included to remove some of the overland flow away from the Reserve Road crossing.

This mitigation solution was significantly higher in cost ($23.4M) than the other options analysed but provided the most flood protection to the township.

4. *Provide flood mappings for Floodway and Land Subject to Inundation Overlays.*

The delineation of flood overlays was set out in accordance with the WGCMA – *"Guidelines for development in flood prone areas"* adopted by the WGCMA in 2013. Water Technology were advised by BBSC that the WGCMA only wished to apply the Land Subject to Inundation Overlay (LSIO) within Trafalgar with no allowance for a Flood Overlay (FO). Water Technology recommended the following shape (below) to be considered as LSIO layers within the Trafalgar study area. Currently there is no LSIO across the majority of this Land.



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1. INTRODUCTION

Historically (prior to settlement) much of the Trafalgar area was swamp land. In the 1880's the land was reclaimed (drained) through construction of the Moe Drain. Channel networks associated with this reclamation process are now dotted throughout the Yarragon to Moe floodplain, some of which remain as designated waterways today.

While the Trafalgar township topography is relatively flat, the external (southern) catchments flowing to the town includes the steeper terrain of the Strzelecki Ranges (slopes to 15% +). In large rainfall events, the relatively steep terrain of the ranges generates significant runoff.

Flooding can impact the township of Trafalgar by three mechanisms, there is:

- Local runoff (Stormwater) from in the township itself;
- Runoff from the Strzelecki Ranges - local catchment flows (Loch and Sunny Creeks and other smaller catchments); and,
- Riverine flooding (Moe drain) from Moe River catchment;
    - Typically this will impact the town by creating elevated levels in the receiving waterways (such as the Contour Drain) reducing the overall capacity of the system.

Describing each of these systems and representing them in conceptual model of the system was the key process in the Trafalgar Flood Modelling and Drainage Strategy Project. Understanding the interaction of the three flooding mechanisms helped describe existing flooding problems and set a sound basis to find mitigation solutions. The technical analysis was coupled with the invaluable feedback gained through the community engagement sessions held throughout the project to deliver a well-rounded assessment of the current and future flood risks and opportunities within the Trafalgar catchment.

2. PROJECT OBJECTIVES METHODOLOGY

Baw Baw Shire Council (BBSC) identified the purpose of the drainage modelling and strategy was to:

> *…conduct a comprehensive study to determine the capacity of the existing drainage infrastructure for the current level of development, including the Strzelecki Views Estate. The study is also required to review the adequacy of the drainage infrastructure for future development and town expansion as outlined in the Trafalgar 2030 Land Use Strategy, to provide mitigation options and cost estimates for the strategy, and to provide flood mappings for Floodway and Land Subject to Inundation Overlays.*

To achieve these project objectives Water Technology worked closely with BBSC and the West Gippsland Catchment Management Authority (WGCMA) to develop a project method which maximised the potential of available data and community feedback and integrated it into an appropriately detailed modelling platform.

The following project method was adopted in this study:

Task 1: Available information and site visit

Task 2: Hydrology – external catchments

- RORB model construction, calibration and determination of design flows for the 1%, 2%, 5%, 10% and 20% AEP events as well as the PMF.

Task 3: Hydraulic modelling – Trafalgar Township

- Construction of TUFLOW model to model and present the above design events.

Task 4: Mitigation option assessment

- Modification of the TUFLOW model to analyse and present the results of potential mitigation options, including cost estimation.

Task 5: LSIO and FO Processing

- Based on the outcomes of the above Tasks, LSIO and FO layers will be produced.

Two community engagement sessions were held in Trafalgar, one during Task 3 (Hydraulic modelling) and one during Task 4 (mitigation option assessment) to gain the invaluable knowledge and feedback from the local Trafalgar community. The outcomes of the community engagement sessions are discussed further in Section 4.

3. AVAILABLE INFORMATION REVIEW & SITE VISIT

3.1 Site Visit

A site visit was conducted on the 23rd of January 2014. The Water Technology project team were joined by Adam Dunn (Statutory Planning Manager) of the West Gippsland Catchment Management Authority (WGCMA). Key hydraulic structures / crossings, areas with recent development and areas of known flooding were visited.

Adam Dunn and Water Technology staff inspected local sites which were considered significant to the WGCMA. Throughout this process he described historic drainage conditions and noted recent and on-going flooding concerns from the perspective of the WGCMA.

This process provided invaluable input to the project. Gaining an understanding of the key areas of flooding early in the project was critical to determining the most appropriate methodology to move forward with. Water Technology staff also gathered information on the terrain, vegetation and soil characteristics of the study area, focusing on critical inputs to the modelling stages such as Manning's roughness coefficients, pipe and culvert locations and characteristics as well as key topographical influencers of overland flow paths.

3.2 Project Inception Meeting

A project inception meeting was held on the 23rd of January 2014. The meeting was attended by BBSC staff (Planning and Engineering), Victorian State Emergency Service (VicSES), WGCMA and key Water Technology project staff. The BBSC project manager, Tong Ung, provided a brief study background and then invited Water Technology staff to present the recommended project methodology to meeting attendees.

Prior to closing the meeting, all stakeholders were invited to give their opinion of what a successful study would look like to them and provide general feedback about the project to the Water Technology team. The following points were noted in the meeting minutes:

WGCMA

They noted the study will need to address waterway interface issues including:

- Development and flooding concerns associated with the Contour Drain;
- Proposed development west of Trafalgar in the Sunny Creek catchment;
- Latrobe (Moe Drain) Flood study showed no impacts on the Trafalgar township, confirming this with the higher resolution study would be a priority for WGCMA; and,
- Education of the Trafalgar community on the true factors causing flooding in the town (flood concurrence, etc.)

BBSC Planning Dept.

- Education of the community is paramount;
- Help BBSC decide if future development (west of the township) should mirror that to the east or should it be approached differently;
- Engaging land owners in the Sunny Creek catchment to understand their local catchment and development drainage pressures;
- Establish long term planning controls that are defensible and make sense to the community; and,
- Use the Trafalgar newsletter to engage with the community;

BBSC Engineering Dept.

- Quality mitigation options are a priority; and,
- Quality community consultation.

VicSES

- Flood mapping outputs which help VicSES manage flooding in the township including;
    - Hazard maps;
    - Properties inundated mapping; and,
    - Critical duration mapping.

These key outcomes and how they were achieved throughout the project are addressed in the conclusion of this report.

3.3 Data collation

To successfully develop a drainage strategy for Trafalgar a significant amount of data needed to be collected and reviewed. Data collected ranged from policy/strategy documents through to detailed survey. Following the inception meeting, a table detailing data required, expected formats and sources was developed. As data was received it was catalogued and ranked based on comments from BBSC as well as parties supplying the data.

3.4 Available data review

Several inputs were needed to be schematised in order for the drainage strategy to accurately represent both current and future conditions inside the study area. Some of these features were physical survey (e.g. levels, pipe sizes), while other were conceptual (location of proposed developments etc). In each case Water Technology used the data considered most relevant by BBSC.

Key data used in this investigation (and its source) is shown in Figure 3-1. The following Sections cover each area of focus in the investigation and nominate key data collected and how it was used.

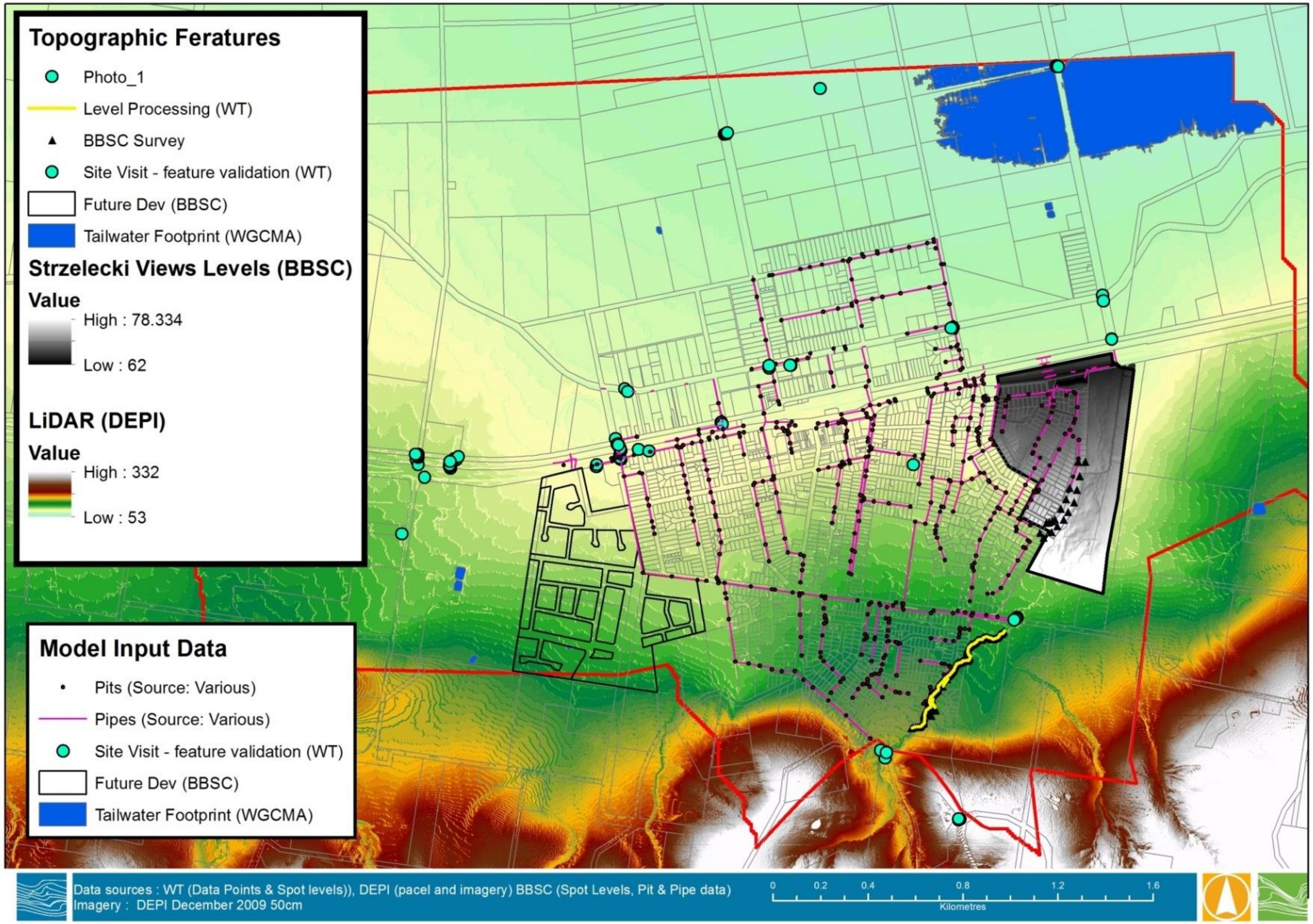


Figure 3-1 Key data used in the Trafalgar Drainage Strategy

3.4.1 External Catchment flows

Several data sets were analysed to help describe external flows (from the Strzelecki ranges) which impact the township of Trafalgar. They included:

GIS data:

- Topography - Hydrologically reinforced 10 m Digital Elevation Model (DEM) (sourced from satellite), supplied by DEPI;
- Geo-referenced aerial Image – Captured in 13/12/2009 at 50 cm resolution, supplied by DEPI; and,
- VicMap Base data – Land parcels, roads, designated waterway features, planning layers and overlays, etc., supplied by DEPI.

GIS data was used to describe the physical catchment conditions, these included catchment boundaries, slopes and relative imperviousness. This data was used to build the RORB hydrologic models.

Recent Studies:

- Stormwater Management Plan (SWMP) for 36 Hardy Drive, Trafalgar - Stormy Water Solutions; and,
- Trafalgar West Flood Study – Engeny.

This data was used for cross checking and comparative analysis, catchment delineation and modelling parameters. Peak flow estimates were compared to those determined by Water Technology.

3.4.2 Existing Conditions Rain-on-Grid modelling

Several data sets were analysed to help schematise the detailed rain-on-grid model of the main Trafalgar township. Key items that need to be represented in the modelling included:

Runoff Characteristics - GIS data:

- Geo-referenced Aerial Image – Captured in 13/12/2009 at 50 cm resolution, supplied by DEPI; and,
- VicMap Base data – Land parcels, roads, designated waterway features, planning layers and overlays etc., supplied by DEPI.

GIS data was used to describe the physical catchment conditions, these included, relative imperviousness and roughness.

Terrain data (topography);

- LiDAR (Light Detection and Aerial Ranging) 1 m DEM vertically accurate to +/- 0.1m, captured in 2008, supplied by DEPI;
    - Primary topographic data source.
- Strzelecki Views Digital Terrain Model (DTM), vertical accuracy unknown, supplied by BBSC;
    - Data used to represent developed surface east of the main Trafalgar township (Strzelecki Views subdivision); and,
- Spot levels collected via field survey by BBSC, 27 June 2014.

The above various terrain data sets were used to describe the physical catchment conditions including, spot levels, catchment boundaries and slopes. Ultimately, a study such as this is heavily reliant on quality terrain data. Consequently, Water Technology spent some time reviewing the aforementioned data considering its appropriateness to achieve the study objectives.

Asset Data (Pits, Pipes Crossings);

- *BBSC_Pipes_20140203.tab* and *BBSC_Pits_20140203.tab*, MapInfo GIS files showing pits and pipe features collected by Think Spatial up to February 2014, supplied by BBSC:

  - Primary asset data source;
- *Trafalgar Drains.dwg*, Auto CAD drawing file showing councils pit and pipe network;
  - Used as the first reference for Think Spatial data validation and data infill;
- Auto CAD sub-division drawings (various), supplied by BBSC:
  - Used as reference for asset data validation and data infill, and;
- PDF sub-division drawings (various), supplied by BBSC:
  - Used as reference for asset data validation and data infill.

As part of the Trafalgar Drainage Strategy project, a comprehensive data set representing stormwater pits, pipes as well as major waterway crossings has been developed, this process involves working with multiple dataset (described above). Despite the significant amount of data supplied by BBSC, in many cases data gaps exist. In most cases this was in the form of missing feature sizes and inverts. A copy of the adopted asset data was provided to BBSC for approval prior to the rain-on-grid modelling being undertaken.

3.4.3 Developed Conditions Rain-on-Grid modelling

As part of the Drainage Strategy, Water Technology were required to investigate the impacts of proposed development inside the study area. These developed conditions were represented in the rain–on-grid modelling to determine their impacts on flooding and to conceptualise mitigation solutions should any proposed development be realised. Both strategic (Council growth plans, etc.) and specific (actual proposed developments) were reviewed to help understand the nature and magnitude of proposed development inside the study area. The following data was reviewed:

Strategic Documents:

- Trafalgar settlement plan; supplied by BBSC;
- Recent Planning Scheme Amendments, supplied by BBSC; and,
- Trafalgar 2030 Land Use Strategy Plan, supplied by BBSC.

Development Plans

- Trafalgar West Flood Study – Engeny, supplied by BBSC; and,
- Overall Development Plan - Trafalgar West, Source unknown, supplied by BBSC.

4. COMMUNITY ENGAGEMENT

Two formal community engagement sessions were held throughout the project with other discussions with Trafalgar residents and land owners held at other times throughout the project, whether directly with Water Technology staff or with WGCMA or BBSC representatives. The objective of the community engagement sessions were to discuss the project with the community and to give the project team the opportunity to gather information from past experiences and current and future concerns of the residents and land owners within Trafalgar. The two formal engagement sessions were well represented by a diverse group of residents as well as staff from BBSC, WGCMA and Water Technology. Both sessions commenced with a presentation by Water Technology staff to inform the community of the progress to date in the project. The short presentation was then followed by forming break-out groups of 4-5 people to discuss in detail the community's experiences, ideas and concerns. The resounding outcome of both sessions was that the community of Trafalgar are passionate and have a thorough understanding of flooding mechanisms with exceptional ideas to create opportunities to reduce the risk of flooding within Trafalgar. Impressively, there was often the suggestion and understanding that 'hard engineering' solutions may not always be the best solution to reduce flood risk, with appropriate town planning and storm and flood awareness and education playing a very powerful role in the solution.

Key details of each of the formal community engagement sessions is presented below.

4.1 Community Engagement Session 1

Date: 8th April 2014

Location: Baw Baw Shire Council Service Centre, 107 Princes Highway, Trafalgar.

Key Outcomes:

4.1.1 Existing Flooding in Trafalgar

The following points were noted:

Loch Creek

- In major events water tends to back up behind the Princes Highway (south side);
- Water has broken out of the waterway channel and flowed west along the Princes Highway eventually flowing over the road around the location of the new wetland feature inside the Strzelecki Views estate. This occurred in the 2012 flood event ;
- Loch Creek tends to peak 12 hours prior to the Moe Drain peak; and,
- Downstream of Contour Road the drain (Loch Creek) is silted up, with significant vegetation present (including established trees), it is believed that lack of maintenance (particularly of this reach) makes flooding in the township worse.

Waterway immediately west of the main Trafalgar Township

- Water tends to back up behind the Princes Highway crossing causing flooding. Alto Motors has flooded up to front door in the past;
- Flow from the upstream catchment tends to combine with that from the township overwhelming the drainage infrastructure. In major events flow breakouts over the Highway between Reserve and Seven Mile Roads;
- Flow in Reserve Road Drain has to turn 90 degrees when it meets the Contour Drain, this causes drainage features to back up, breakout and flood properties;
- Water which flows under the Highway and down Reserve Road, regularly breaks out of the Contour Drain and flows due north through the township reserve, before flowing north east towards the Seven Mile Road Drain; and,

- Drainage east of Duggans Road tends to move through a swale drain at the northern boundary of the Trafalgar Reserve and combines with flows which break out of the Contour Drain exacerbating flooding for residents along Seven Mile Road.

Contour Drain

- Residents believe the Contour Drain tends to be full (at capacity) after only a moderate short burst of rain (around 1 inch) or a few days of sustained rain;
- Informal crossings in the Contour Drain between Reserve and Middle Road are believed to be under sized contributing to the observed flooding;
- A levee on the north side of the Contour Drain between Middle and Loch Creek Road could contribute to flooding outcomes;
- Clearing the Contour Drain (by BBSC) seems to have helped reduce flooding;
  - Weeds (such as Phragmites / Cumbungi) have since grown back;
- Crossing at Malady's Lane is blocked, this likely contributes to breakouts flowing north;
- Debris tends to get caught on crossings along the Contour Drain (such as the Middle Road culverts), this causes flooding. A resident showed us a photo of this occurring;
- Shed on Seven Mile Road (possibly number 35) flooded from breakout from the Contour Drain; and,
- Not much water flows east in the Contour Drain from the Sunny Creek. A high point immediately west of the football oval moves water west then north back to the Moe Drain floodplain.

Sunny Creek

- In major events water tends to back up behind the Princes Highway (south side);
- In 2012 flood water from Sunny Creek banked up on the south side of the railway line;
- Downstream of the Princes Highway some overland flow heads east towards the town; and,
- Some participants commented that this system doesn't tend to impact flooding outcomes in the Trafalgar township;

Moe Drain (Floodplain)

- Much of the historic drainage infrastructure (open drains, one way valves and culvert crossings) in the flood plain is failing or is unmaintained (choked with vegetation) ;
  - It is perceived that this is a significant contributor to existing flooding problems;
- When the Moe Drain breaks out onto the floodplain floodwater tends to pond for an extended period;
  - Farmers find this frustrating;
- Generally participants realised that flooding in the Trafalgar township and or the floodplain are disconnected, with some people nominating 12 hours as a typical gap between peaks in the two systems.

4.1.2 Possible Solutions to Flooding in Trafalgar

The following points were noted:

- Disconnecting the flood peaks from the Loch Creek and the waterway immediately west of the main Trafalgar township was a clear theme of proposed solutions.

4.1.3 New works / system upgrades

- Moving flood water away from the Contour Drain possibly to Gooding's Drain running west to east (north of the Contour Drain) could reduce flooding north of the Princes Highway;
  - This would require drainage reserves or large pipe solutions;
- Retarding basins were not particularly favoured by consultation participants;
- Allowing more water to pass under the Highway could relieve flooding of stakeholders upstream of the Princes Highway;

  - This creates challenges with more water impacting the stakeholders north of the Highway;
- Upgrading informal crossings along the Contour Drain to match flood flows;
- Reserve area north of Contour Drain could be used in mitigation works;
- There was a suggestion that a retarding basin be constructed at the eastern end of Settlement Road at Middle Road intersection) to divert flows away from the Contour Drain and limit interaction with the Loch Creek system; and,
- Earth works to formalise a diversion which ensures Sunny Creek flows don't interact with township and Loch Creek flows.

4.1.4 Maintenance

A clear focus by almost all stakeholders was that they believe a lack of maintenance of drainage assets (open drains, one way valves and culvert crossings) in the floodplain contributes to flooding problems in Trafalgar. Some specific locations where culvert capacity is jeopardised were noted, however most participants suggested the whole system could be overhauled.

4.2 Community Engagement Session 2

Date: 9th September 2014

Location: Baw Baw Shire Council Service Centre, 107 Princes Highway, Trafalgar.

Key Outcomes:

4.2.1 Review of Existing Conditions Model Results

The following points were noted:

Loch Creek

- Results were considered to be broadly accurate;
- Land owner downstream of the Highway crossing suggested some earth works in both Loch Creek and Contour Drain were probably not picked up in the LiDAR;
- People had concerns that the “basin” inside Strzelecki Views constantly had water in it;
    - As this feature is a constructed wetland it by design should hold permeant water, possibly some community education is warranted.

Trafalgar Township

- Ponding behind Highway is consistent with the communities observations (5 year and 100 year ARI event);
- Participants believe that the major crossings under the Highway have capacity problems and that flooding is not just because the land is low;
- It was noted that stormwater needs to be conveyed away from the Contour Drain for flooding on the southern side of the Highway to be relieved.

Contour Drain

- Flooding along the Contour Drain throughout town was considered accurate particularly where the breakout occurs between Contour / Reserve Road through to Seven Mile Road;
- Residents noted that back flooding from the Contour Drain can impact the Princes Highway particularly around Maladys Lane and Princes Avenue in the centre of town;
- One participant noted a levee on the southern bank (north west of the football oval) has been removed possibly changing some observed ponding on the southern side of the drain.

Waterway immediately west of the main Trafalgar Township

- The breakout which flows from the south side of the Princes Highway through to Seven Mile Road is consistent with the communities observations;
- Ponding inside the football oval has not been observed by the community; and,
    - Water Technology suspect the oval has internal drainage not included in the current modelling.
- Old flow path at the western edge of town (Alto Motors) was filled many years ago with a pipe installed to get water under the Highway;
    - The southern boundary now suffers from siltation behind the filled land;
    - The flood model results at this location was noted as being accurate.

Sunny Creek

- Participants were unsure if the total amount of breakout flow from Sunny Creek was accurate with a resident noting a crossing under the Highway (Rankins Road) was not in the current model;
    - A resident did note that he had seen overland flow “weir” over Rankins Road and head east towards town but suspected that was due to culverts under the Highway being blocked during the event.

Moe Drain (Floodplain)

- Ponding behind Seven Mile Road (Willow Grove Road) and Loch Creek Road was considered consistent with observed flooding.

4.2.2 Possible Solutions to Flooding in Trafalgar

Most of the mitigation discussion in the second community consultation session was focused on the functionality of the Contour Drain. With many participants believing the Drain could be modified to move the urban drainage away from town reducing observed ponding throughout the town. Proposed options to achieve this included:

- Generally increasing the capacity Drain by widening it where possible (deepening would not help as the channel already suffers from lack of grade);
- Sizing all crossing to convey 100 year ARI flows – it was noted that some of the private crossings over the Drain were assumed to be too small;
- Re-grading the western end of the Drain to encourage more of the township's runoff to flow west.
- Consider one-way valve system to stop back flooding of the Highway from the Contour Drain;
- Divert the eastern end of the Contour Drain (upstream of the Loch Creek confluence) to outfall downstream of the drop structure on Loch Creek Road (increasing the grade on the drain); and,
- Continue / expand the maintenance program along the Drain (vegetation removal).

Other mitigation options discussed included:

- Bunding on north side of Contour Drain;
- Moving the equestrian club, currently located on the corner of Settlement and Reserve Roads and using the land as storage; and,
- Dispersive pipes along Seven Mile Road, 300 mm diameter pipes at strategic locations to relieve the flooding backing up behind the road embankment.

4.3 Response to Community Engagement

The following key points were tabled from the two sessions with the projects responses shown in Table 4-1.

Table 4-1 Community consultation feedback and the study response

Community comment / feedback	Study response - how the feedback has been used
Current Flooding	
Contour Drain has conveyance issues from lack of maintenance	Contour Drain was modelled in an "as is" manner with conveyance reduced through topography applied.
Water which flows under the Highway and down Reserve Road, regularly breaks out.	This was observed in our existing conditions modelling and was reduced in our proposed mitigation solutions.
Ponding inside the football oval has not been observed by the community	Internal drainage inside the football oval was not included in our modelling, observed ponding was edited out of the flood modelling results.

Community comment / feedback	Study response - how the feedback has been used
Participants were unsure if the total amount of breakout flow from Sunny Creek was accurate.	Prince's highway between Sunny Creek Road and the western boundary of town was revisited and smaller culvert crossings under the Highway and Waterloo Road were included in our modelling.
People had concerns that the "basin" inside Strzelecki Views has permeant water in it.	As this basin as actually a wetland, it by design should have permanent water inside it. Education of local residents of the features purpose and how it works will alleviate the concerns.
Participants believe that the major crossings under the Highway have capacity problems.	Particular effort has been made to represent each crossing under the Highway as accurately as possible in the model. Analysis suggests that capacity constraints exist in the centre of town and at the western edge of the township.
Mitigation Options	
Disconnecting the flood peaks from the Loch Creek and the Waterway immediately west of the main Trafalgar township was a clear theme of proposed solutions	Several options were trialled to disconnect flows impacting Contour Drain. Getting overland flow under the Highway was the biggest challenge. The analyses indicate that retardation was more effective than simply disconnecting the Loch Creek and Sunny Creek flows.
Connecting Contour Drain to Gooding's Drain running west to east (north of the Contour drain) could reduce flooding north of the Princes Highway	
Upgrading informal crossings along the Contour Drain to match flood flows	Each crossing was included in the model. Recommendations were made on conveyance requirements along Contour Drain.
Retarding basin at the eastern end of Settlement Road near Middle Road intersection to divert flows away from the Contour Drain and limit interaction with the Loch Creek system	This option was modelled and found to be ineffective at reducing flooding in Trafalgar.
Earthworks to formalise a diversion which ensures Sunny Creek flows don't interact with township	Investigation has been carried out and the results are in Section 11.
Continue / expand the maintenance program along Contour Drain and Reserve Road rain	All mitigation options modelled by Water Technology included some form of increased channel maintenance program. Ultimately that is one of the study recommendations.

5. HYDROLOGICAL MODELLING – EXTERNAL CATCHMENTS

5.1 Overview

The purpose of the external catchment hydrologic modelling was to determine design flood hydrographs (flows) for input to the hydraulic modelling at designated locations. While the rainfall-on-grid modelling represented the rain falling directly on the township, the rainfall falling on the Strezleki Ranges required accurate and detailed representation in order to be adopted as inflows to the final flood model. RORB was employed as the principal tool for the upper catchment hydrologic modelling. Table 5-1 shows the modelled catchment conditions and the ARI events examined for this project.

Table 5-1 Modelled catchment conditions and design events (Refer to Figure 5-3)

Catchment	Catchment Characteristics		ARI Event (1 in x years probability)					
	Area (km²)	Imperviousness (%)	5	10	20	50	100	PMP
Sunny Creek	8.4	10	✓	✓	✓	✓	✓	✓
SC2 (Sunny Creek 2)	1.3	10	✓	✓	✓	✓	✓	✓
SC3 (Sunny Creek 3)	1.4	10	✓	✓	✓	✓	✓	✓
Loch Creek	9.5	10	✓	✓	✓	✓	✓	✓

5.2 Existing Model Reviews

Two existing RORB models were identified in the data review phase of the project. In each case the hydrologic modelling was undertaken to assist with proposed development within the urban fringe of Trafalgar.

5.2.1 Stormwater Management Plan (SWMP) for 36 Hardy Drive, Trafalgar

Stormy Water Solutions were engaged by Ross and Worth Pty Ltd to prepare a Stormwater Management Plan (SWMP) for 36 Hardy Drive, Trafalgar, known as “Strzelecki Views Subdivision”. The study included:

- Key drainage issues relating to the site;
- Details of the West Gippsland Catchment Management Authority’s requirements in regard to drainage infrastructure;
- A Surface Water Management Plan for the site;
- Details of the results of the flood flow and flood level analysis conducted for Loch Creek; and,
- Details the concept design requirements of the major sediment pond/wetland feature proposed within the subject site.

Of specific interest to this study are the external flow estimations in the Loch Creek catchment using RORB modelling. Figure 5-1 shows the Stormy Water Solutions RORB model sub-catchments and flow reach details. A high level review of the RORB modelling by Stormy Water Solutions suggested reasonably large sub catchment areas (2 km²) were applied, this was deemed unsuitable for the purpose of the Trafalgar Drainage study. Otherwise the model schematisation seems consistent with current best practice approaches.

RORB model catchment delineation and modelling parameters (shown in Table 5-2) were used by Water Technology as guide during their model schematisation. RORB model peak flow estimates (shown in Table 5-3) were not directly compared to those estimated in Water Technology's updated modelling. This was due to the different areas covered by each model and the specific locations where peak flow estimates were reported.

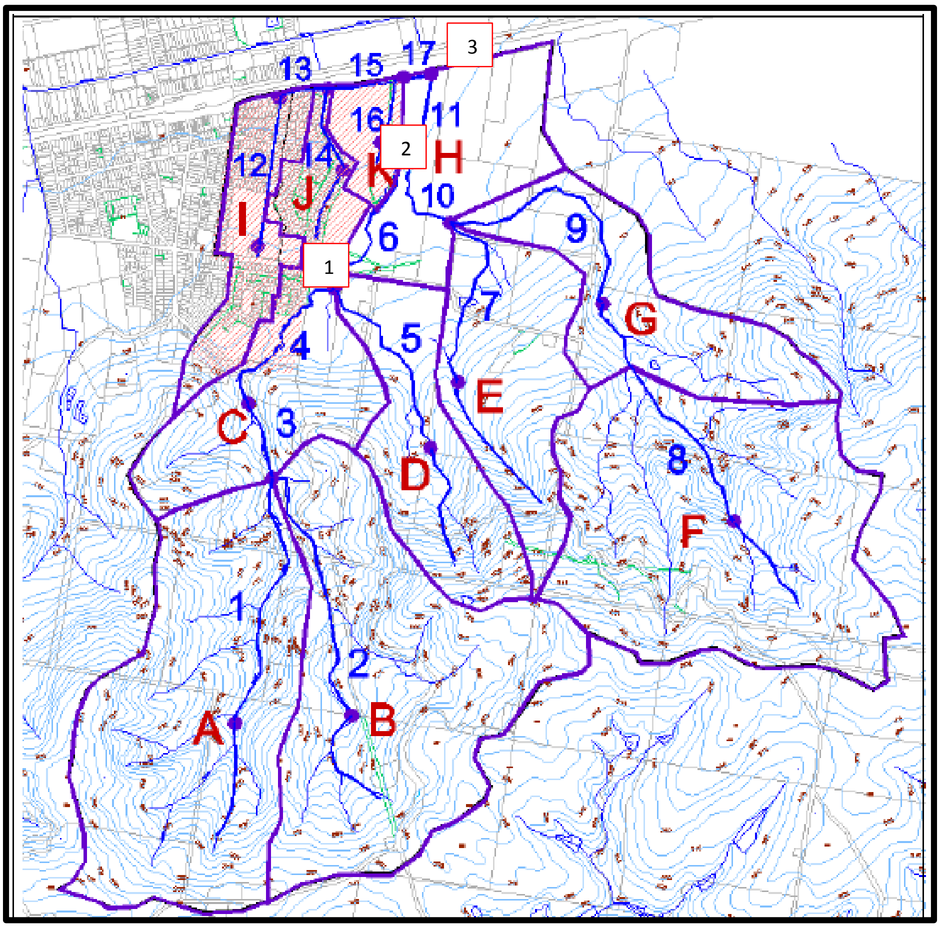


Figure 5-1 Loch Creek RORB model by Stormy Water Solutions

Table 5-2 Loch Creek RORB modelling parameters

Kc	m	Initial Loss (mm)	RoC Q_{100}	RoC Q_2
6.00	0.80	10.00	0.60	0.20

Table 5-3 Loch Creek RORB model by Stormy water Solutions Results

Location		ARI	
		2 years	100 years
1*	Loch Creek at School Road – Upstream End of Reach 6	2.3 m^3/s (12 hr)	17.1 m^3/s (9 hr)
2*	Loch Creek - Upstream End of Reach 11	3.5 m^3/s (12 hr)	26.1 m^3/s (9 hr)
3*	Loch Creek at Princes Hwy – Reach 17 + Reach 11	4.1 m^3/s (9 hr)	29.2 m^3/s (9 hr)

* Location number referenced to Figure 5-1, critical storm durations shown in brackets following the peak flow values.

5.2.2 Trafalgar West Flood Study

Engeny were engaged by Ross and Worth Pty Ltd to investigate the surface water issues arising from the proposed rezoning of an area on the west side of Trafalgar (residential development). The investigation has considered the West Gippsland Catchment Management Authority (CMA) and Baw

Baw Shire requirements associated with the rezoning of land on the west side of Trafalgar. The study included:

- Data collection and review;
- Site assessment;
- Consultation, West Gippsland CMA and Baw Baw Shire;
- Flood flow and flood level analysis; and,
- Concept design requirements of the major sediment pond/wetland feature proposed within the subject site.

Of specific interest to this study are the external flow estimations in the Sunny Creek catchment using RORB modelling. Figure 5-2 shows Engeny's RORB model sub-catchments. A high level review of the RORB modelling by Engeny showed the model schematisation appeared generally consistent with current best practice approaches.

RORB model catchment delineation and modelling parameters (shown in Table 5-4) were used by Water Technology as guide during model schematisation. RORB model peak flow estimates (shown in Table 5-5) were not directly compared to those estimated in Water Technology's updated modelling. This was due to the different areas covered by each model and the specific locations where peak flow estimates were reported.

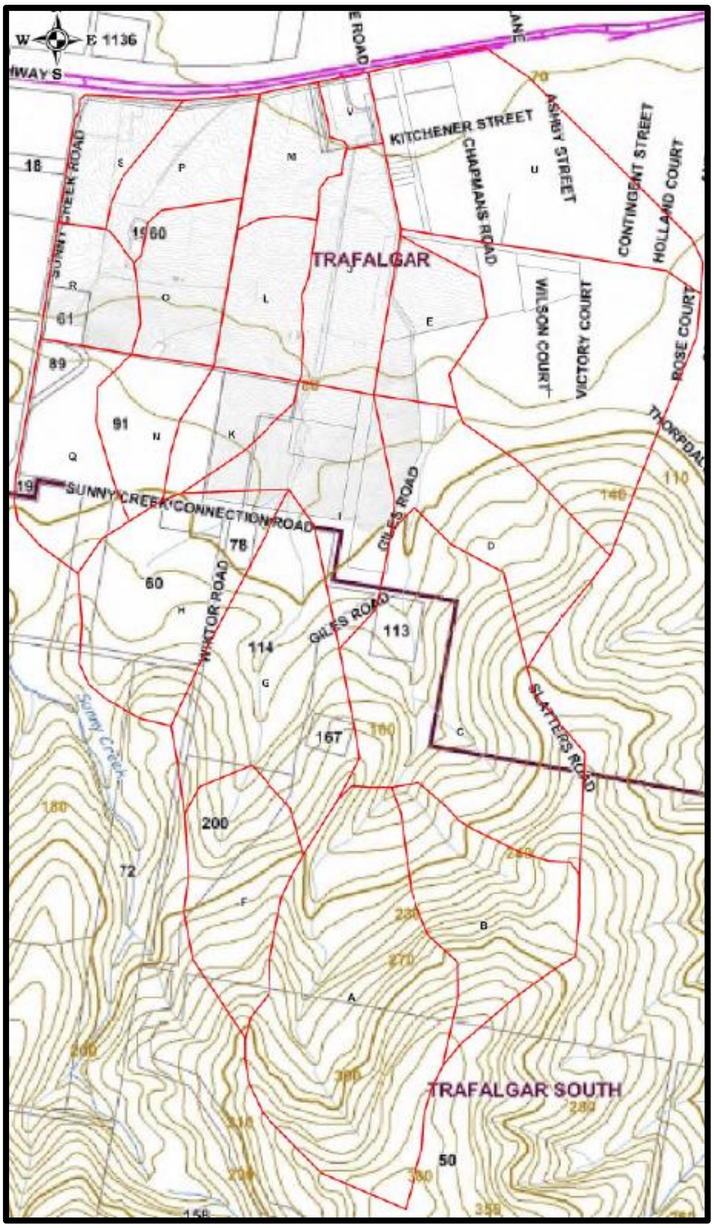


Figure 5-2 Sunny Creek RORB model by Engeny

Table 5-4 Sunny Creek RORB modelling parameters

Kc	m	Initial Loss (mm)	RoC Q_{100}
3.51	0.80	15.00	0.60

Table 5-5 Sunny Creek RORB model by Engeny

Location	ARI
	100 years
Downstream of Princes Highway	16.23 m³/s (9hr)

5.3 Fraction Impervious Data

Fraction impervious values were calculated for each individual RORB sub-catchment. Fraction impervious values were assigned based on the Planning Scheme Zones with the typical fraction impervious value for each zone type applied as detailed in *Melbourne Water's MUSIC Guidelines* (MWC, 2010a).

The fraction impervious values were then reviewed and adjusted if necessary following a general review of aerial photography and on site observations from a site visit conducted in January, 2014. Given the rural nature of all of the external catchments, uniform fraction impervious value 0.1 (10 %) was applied to all catchments.

5.4 Peak Flow Estimate Calculations

5.4.1 Overview

A Rational Method estimate was required for reconciliation in four catchments in the Trafalgar Drainage Strategy RORB Modelling. The four catchments considered are colour coded in Figure 5-3 below.

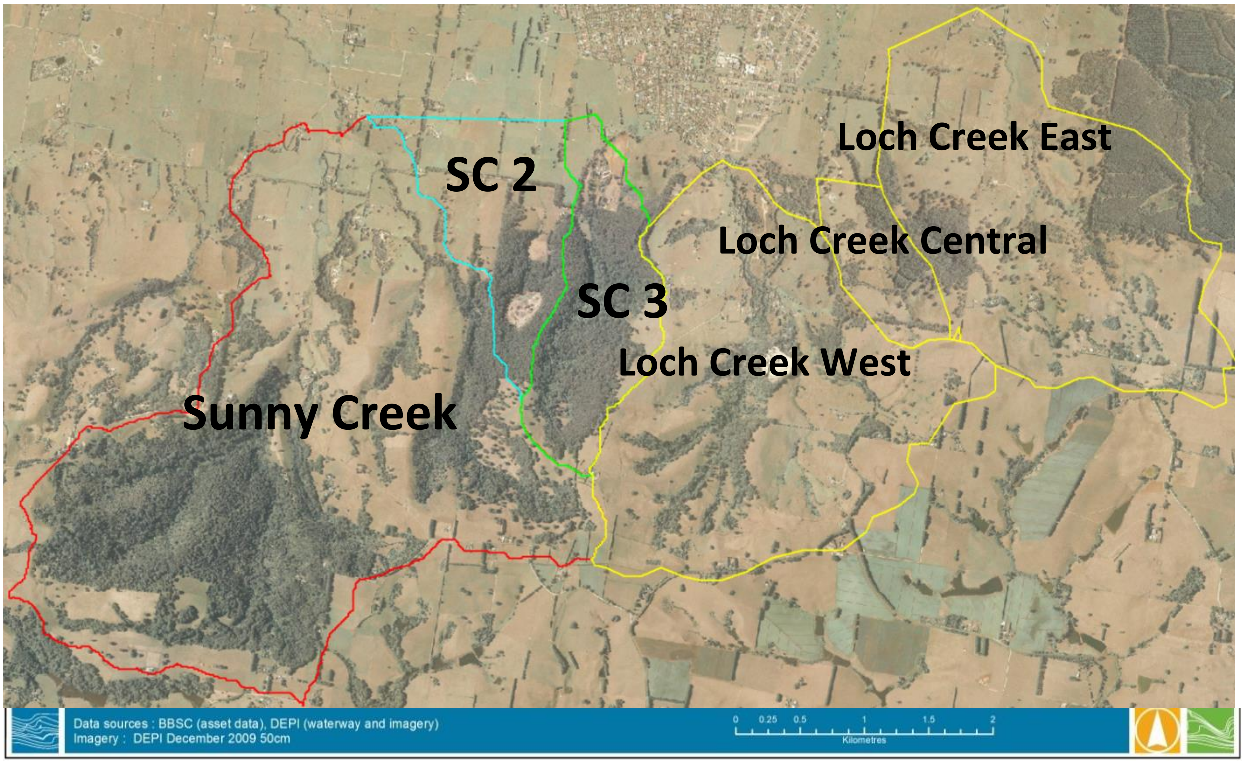


Figure 5-3 Rational Method Reconciliation Catchments

5.4.2 IFD Parameters and Rainfall Intensities

An Intensity-Frequency-Duration (IFD) chart specific to Trafalgar was created based on parameters from the Bureau of Meteorology as shown in Table 5-6. The IFD values are the key input into RORB to specify the various storm intensities and temporal patterns.

Table 5-6 IFD Parameters for Trafalgar

2y 1h (mm/h)	2y 12h (mm/h)	2y 72h (mm/h)	50y 1h (mm/h)	50y 12h (mm/h)	50y 72h (mm/h)	Skew	F2 Value	F50 Value
18.45	4.0	1.15	35.61	7.47	2.32	0.37	4.24	15.09

5.4.3 Rational Method Peak Flow Estimates

A Rational Method analysis was undertaken for each reconciliation location in accordance with the methodology outlined in Book 2 of Australian Rainfall and Runoff (*IEAust, 1997*). The equation is as follows:

$Q_{100} = C.I.A/360$

Where:

- Q_{100} is the flow in m^3/s for the 100 year ARI design event;
- C is the runoff coefficient;
- I is the rainfall intensity specific to the area, corresponding to the t_c (time of concentration of the catchment); and,
- A is the area of the catchment in hectares.

Using the travel time and design rainfall estimates, rainfall intensities for the time of concentration were interpolated via methods prescribed in Australian Rainfall and Runoff and a Rational Method Estimate (Q) was calculated as shown in Table 5-7.

Table 5-7 100 year Rational Method Calculations

Location	FI	I (mm/hr)	tc (mins)	Fy	C_{10}	Total Area (km²)	Q_{100} (m^3/s)
Sunny Creek	0.1	31.4	102.5	1.2	0.203	8.43	**17.9**
SC_2	0.1	49.1	50.5	1.2	0.203	1.31	**4.4**
SC_3	0.1	48.5	51.5	1.2	0.203	1.38	**4.5**
Loch Creek W	0.1	36.1	82.1	1.2	0.203	4.71	**11.5**
Loch Creek C	0.1	59.3	38.0	1.2	0.203	0.62	**2.5**
Loch Creek E	0.1	37.1	78.7	1.2	0.203	4.20	**10.5**

5.4.4 Other Peak Flow Estimates

Two other methods were employed to estimate design flows for the four external catchments which impact Trafalgar, they were:

- Australian Regional Flood Frequency Model (Australian Rainfall and Runoff Project- 2012)
- Flood Regression Curves for Victoria produced by the Department of Conservation and Natural Resources.
    - $Q = 4.67 \times A^{0.763}$, where Q is the 100 year design flow (m³/s) and A is the catchment area in km².

Results of these estimates are shown in Table 5-8, it was noted that the Rational Method peak flow estimates produced the lowest design flows, while Regional Flood Frequency and Flood Regression Curves estimates were broadly closer to each other. Given this study is generally following the Melbourne Water best practice flood modelling approach, and to remain consistent with previous flood modelling and mapping completed by BBSC, it was concluded that RORB models would be reconciled against Rational Method peak flow estimates.

Table 5-8 100 year Peak Flow estimates

Location	FI	Total Area (km²)	Rational Method Q_{100} (m³/s)	Regional Flood Frequency Q_{100} (m³/s)	Flood Regression Curves Q_{100} (m³/s)
Sunny Creek	0.1	8.43	**17.9**	**28.0**	**23.8**
SC_2	0.1	1.31	**4.4**	**9.3**	**5.7**
SC_3	0.1	1.38	**4.5**	**9.6**	**6.0**
Loch Creek W	0.1	4.71	**11.5**	**19.9**	**15.2**
Loch Creek C	0.1	0.62	**2.5**	**6.0**	**3.2**
Loch Creek E	0.1	4.20	**10.5**	**18.6**	**14.0**

5.5 RORB Model Development

Four independent RORB models were created in RORB Version 6.0. Sub-Catchment and reach delineation was under taken in the MiRORB GIS software package. MiRORB allows catchment characteristics to be interrogated and ultimately viewed spatially in the RORB GUI (Graphical User Interface). As the RORB model is being used to generate inflows to the TUFLOW model, RORB is reconciled to the Rational Method and set-up to replicate the conditions in a Rational Method estimate.

5.5.1 Subareas

Spatial drainage line processing software (ArcHydro) was initially used to delineate major catchment boundaries, this analysis used a 10 m Digital Elevation Model as the primary topographic resource. Outputs from ArcHydro were then modified into sub-catchments which met catchment specific requirements of this study.

The catchments were broken into sub-areas considering the overall catchment size and design output locations, Table 5-9 shows the relative number of sub-areas applied in each of the four RORB models.

Table 5-9 RORB Model Sub-Areas

Location	Total Area (km²)	No. of Sub-Catchments
Sunny Creek	8.43	17
SC_2	1.31	10
SC_3	1.38	5
Loch Creek W	4.71	7
Loch Creek C	0.62	5
Loch Creek E	4.20	11

5.5.2 Reach Types

Reach types were assigned based on the overland flow conditions along that reach. As the majority of the catchments consisted of open grassed areas or natural waterways, the majority of reaches were all assigned 'Type 1'. 'Type 5' dummy reaches were used throughout the models also to create hydrographs in desirable locations.

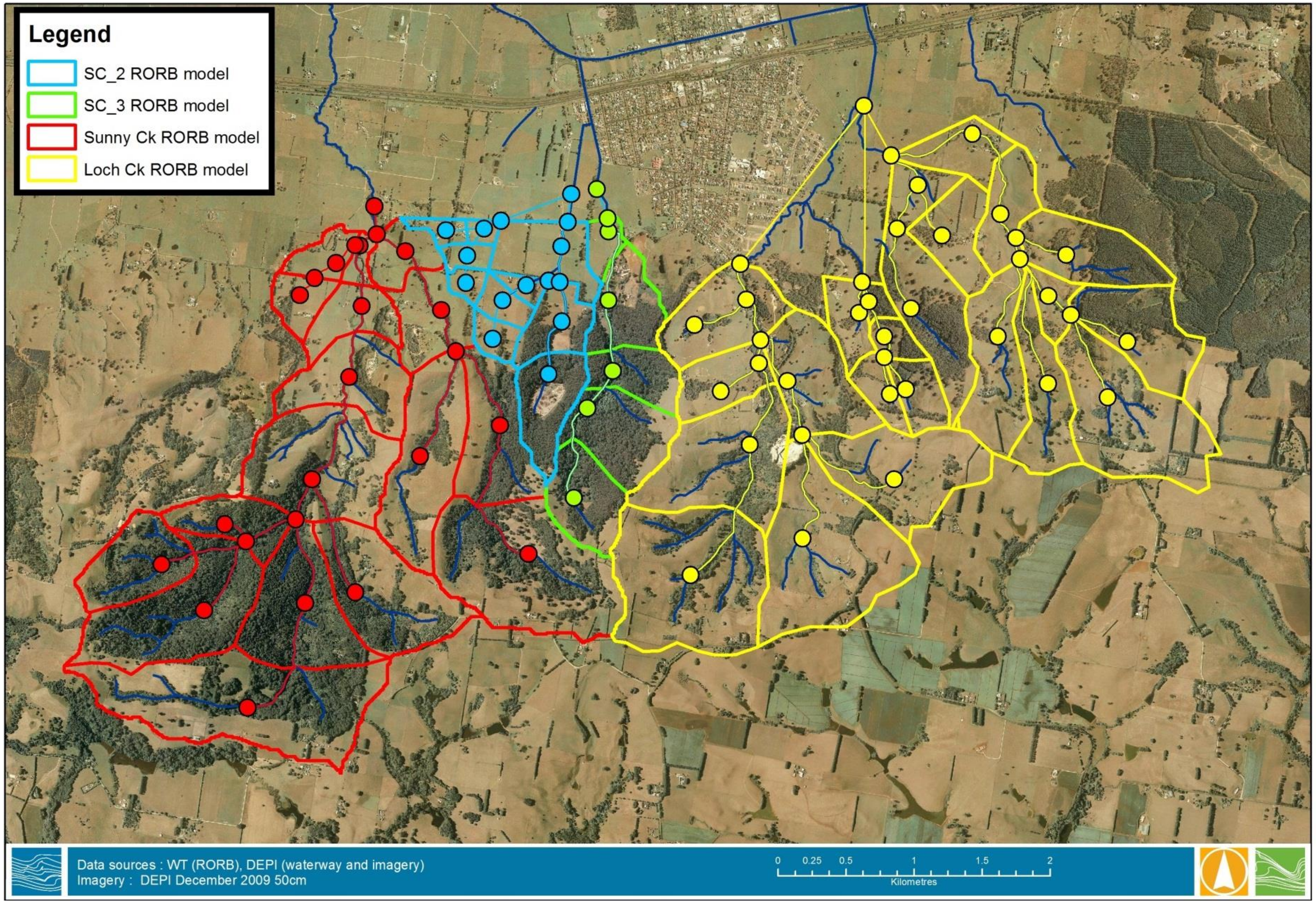


Figure 5-4 Trafalgar Drainage Strategy RORB Model Structures

5.5.3 RORB Parameters

The RORB model was run with AR&R 1987 method with an aerial reduction factor (reduction to the rainfall intensity applied to larger catchments to account for the application of a single point IFD relationship over a large catchment) area of 0.0 km^2. The Initial Loss applied was 20 mm (based on rural catchments). Temporal patterns were fully filtered. Runoff coefficients used are shown in Table 5-10.

Table 5-10 Runoff Coefficient for ARI events

ARI Event	Runoff Coefficient
5 Year	0.25
10 Year	0.35
20 Year	0.45
50 Year	0.55
100 Year	0.60

RORB parameter files were created and supplied with the RORB model to BBSC.

5.6 RORB Model Reconciliation

The four RORB models were reconciled to match the 100 year peak flow estimates from the Rational Method calculation shown above at each reconciled location. This was achieved by varying the Kc parameter which dictates the hydrograph lag over the average reach lengths upstream of the reconciliation location. All run parameters are shown in Table 5-11.

Table 5-11 RORB model reconciliation and parameters

Reconciliation Location	Kc	IL (mm)	RoC	m	Critical storm duration	Q RORB m^3/s	Q Rational Method m^3/s	Difference in Q m^3/s
Sunny Creek	5.28	20	0.6	0.8	12 h	17.9	17.9	0.0
SC_2	1.53	20	0.6	0.8	9 h	4.4	4.4	0.0
SC_3	1.98	20	0.6	0.8	9 h	4.5	4.5	0.0
Loch Creek W	4.55	20	0.6	0.8	9 h	11.5	11.5	0.0
Loch Creek C	0.89	20	0.6	0.8	9 h	2.5	2.5	0.0
Loch Creek E	3.90	20	0.6	0.8	9 h	10.5	10.5	0.0

5.7 RORB Model Design Flood Hydrograph Estimation

The ultimate purpose of RORB modelling in this study is to estimate external inflows from the Strzelecki Ranges which impact the township of Trafalgar. Given the topographic features/boundaries inside each of the 4 catchments analysed and the focus area of the Rain on Grid modelling, 7 locations have been identified as direct inflow points in the detailed modelling. These points are shown in Figure 5-5.

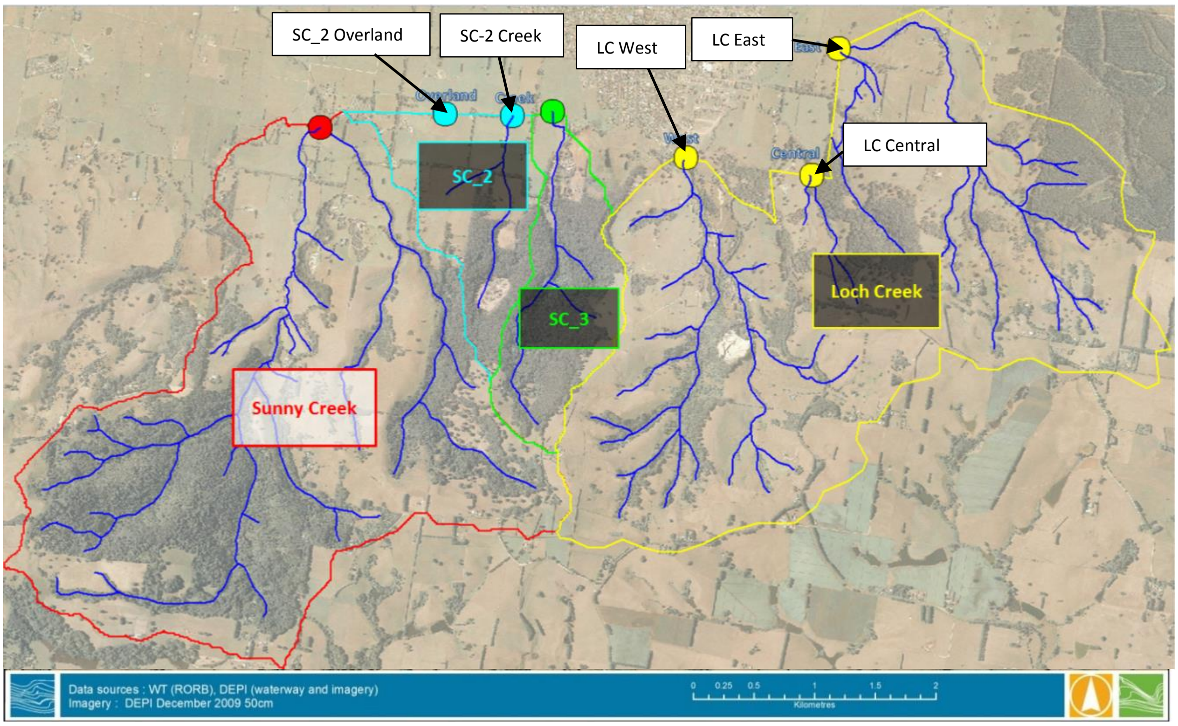


Figure 5-5 Direct Inflow locations

5.7.1 Sunny Creek Results

Table 5-12 and Figure 5-6 show key RORB modelling results on the Sunny Creek catchment.

Table 5-12 Sunny Creek RORB modelling results

AEP	ARI	Peak Flow (m^3/s)	Critical Duration (hrs)	Kc	IL	RoC
20%	5	3.71	36*	5.28	20	0.25
10%	10	5.8	12			0.35
5%	20	9.2				0.45
2%	50	14.06				0.55
1%	100	17.9				0.60

* 12h event peak flow 3.45 m^3/s

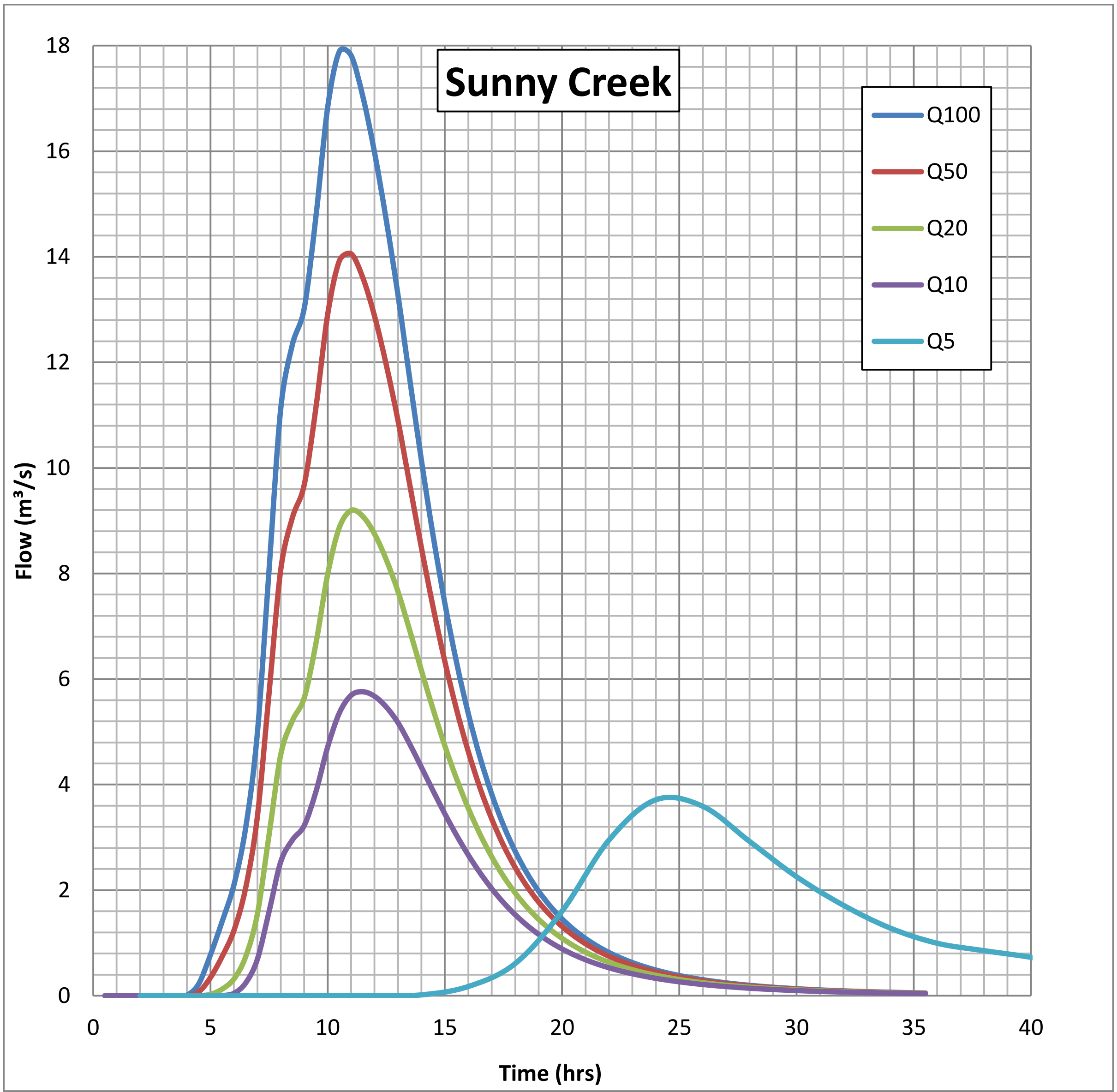


Figure 5-6 Sunny Creek – Critical duration hydrograph results

5.7.2 SC_2 Results

To accurately represent flows in this catchment, two hydrographs were extracted from the RORB model. One to represent the flows from the clearly defined waterway feature (creek) and the other to represent the smaller catchment to the west (overland flows). Model output locations for both flows are shown in Figure 5-5.

Table 5-13 and Figure 5-7 show key RORB modelling results on the SC_2 catchment.

Table 5-13 SC_2 RORB modelling results

AEP	ARI	Peak Flow (m^3/s)	Critical Duration (hrs)	Kc	IL	RoC
20%	5	0.893	12*	1.53	20	0.25
10%	10	1.46	9			0.35
5%	20	2.31				0.45
2%	50	3.46				0.55
1%	100	4.36				0.60

* 9hr Result 0.888

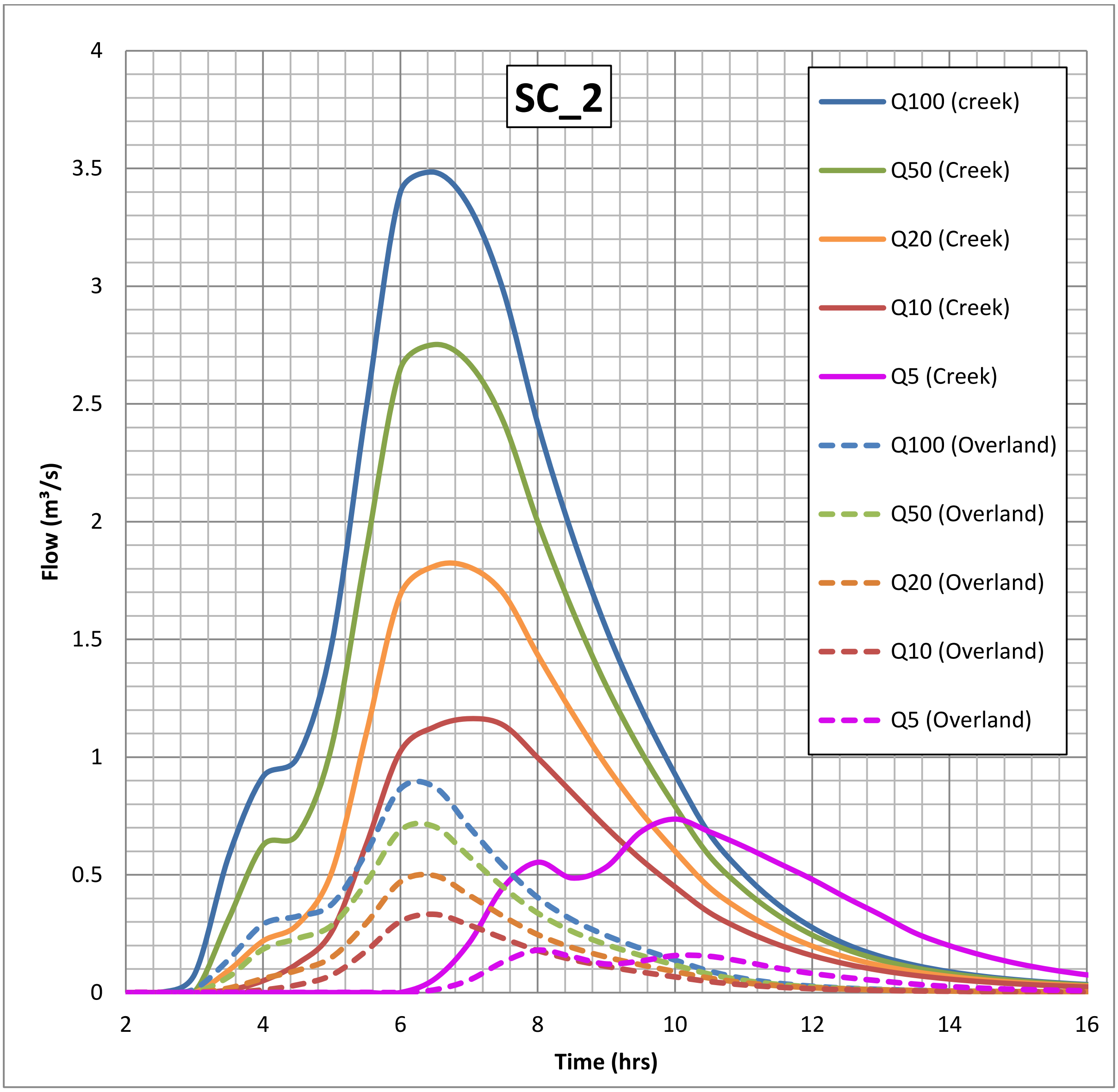


Figure 5-7 SC_2 – Critical duration hydrograph results

5.7.3 SC_3 Results

Table 5-14 and Figure 5-8 show key RORB modelling results on the SC_3 catchment.

Note that there are no overland flows in the SC_3 catchment. Refer to Figure 5-5 for this location.

Table 5-14 SC_3 RORB modelling results

AEP	ARI	Peak Flow (m^3/s)	Critical Duration (hrs)	Kc	IL	RoC
20%	5	0.93	9	1.98	20	0.25
10%	10	1.53				0.35
5%	20	2.36				0.45
2%	50	3.56				0.55
1%	100	4.51				0.60

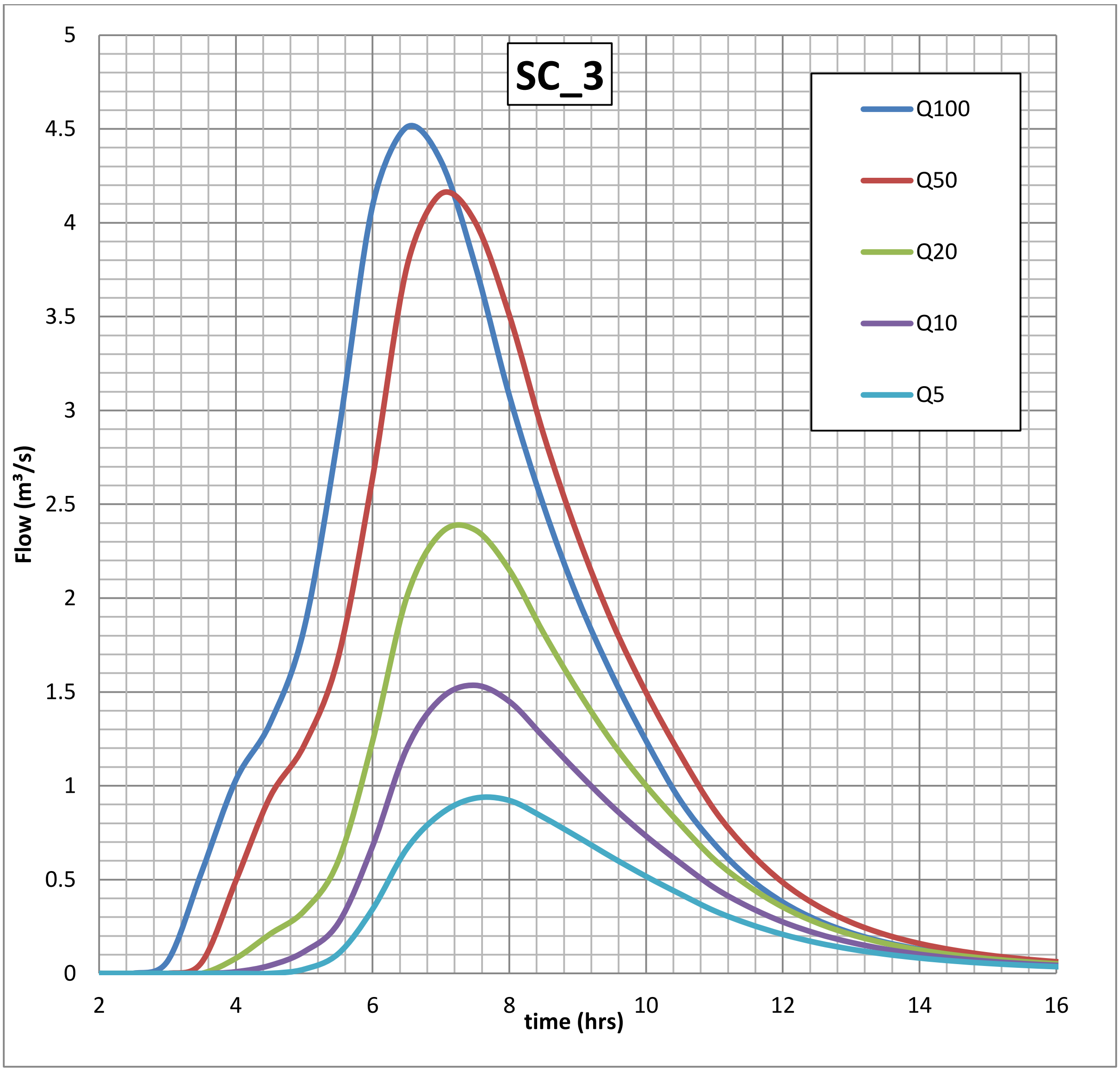


Figure 5-8 SC_3 – Critical duration hydrograph results

5.7.4 Loch Creek W (West) Results

Table 5-13 and Figure 5-7 show key RORB modelling results on the Loch Creek W (West) catchment.

Table 5-15 Loch Creek W RORB modelling results

AEP	ARI	Peak Flow (m^3/s)	Critical Duration (hrs)	Kc	IL	RoC
20%	5	2.3	36*	4.55	20	0.25
10%	10	3.7	12			0.35
5%	20	5.7	12			0.45
2%	50	8.9	9			0.55
1%	100	11.5	9			0.60

* 12hr Result 2.33

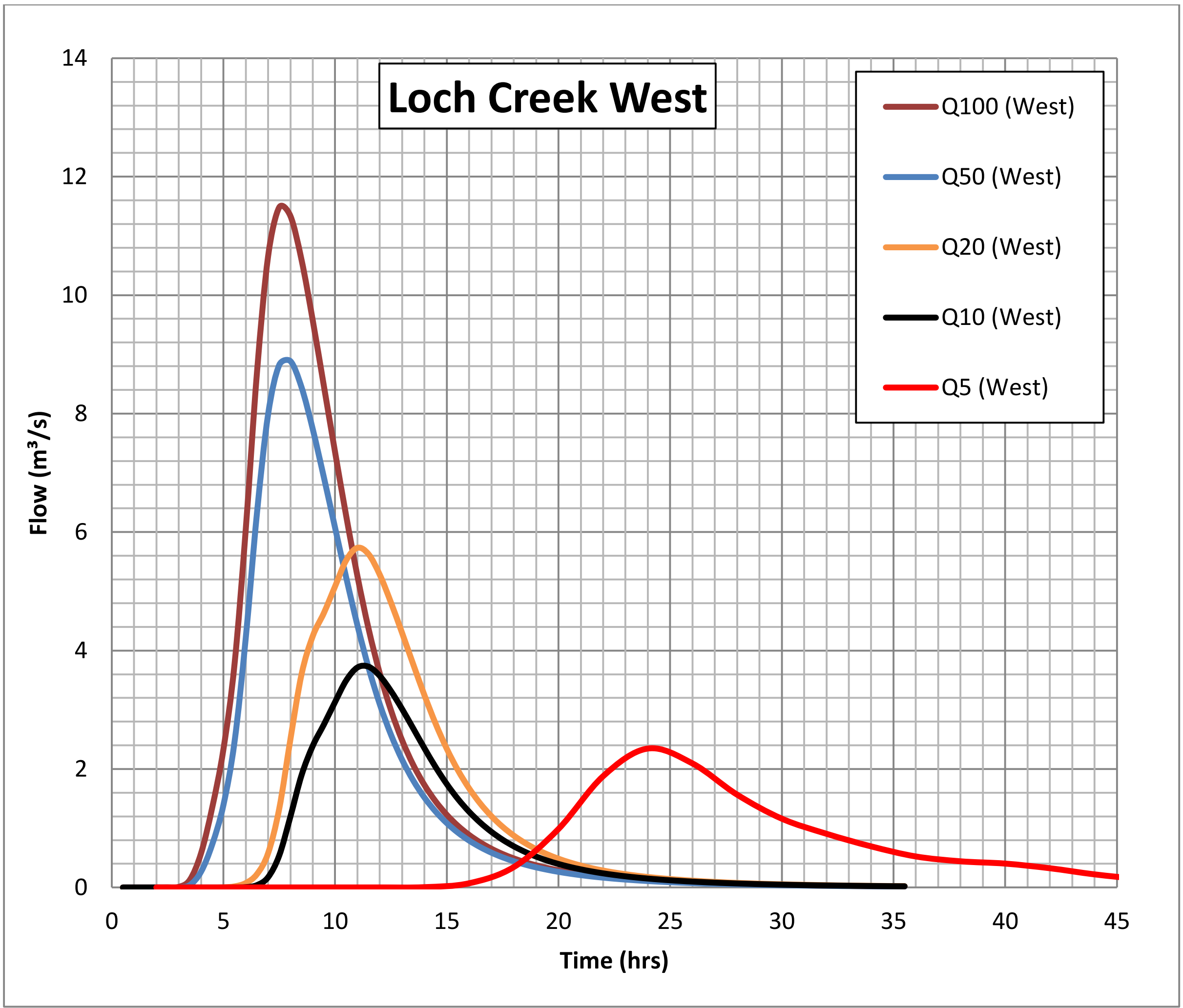


Figure 5-9 Loch Creek W – Critical duration hydrograph results

5.7.5 Loch Creek C (Central) Results

Table 5-16 and Figure 5-10 show key RORB modelling results on the Loch Creek C (Central) catchment.

Table 5-16 Loch Creek C RORB modelling results

AEP	ARI	Peak Flow (m³/s)	Critical Duration (hrs)	Kc	IL	RoC
20%	5	0.6	9	0.89	20	0.25
10%	10	0.9				0.35
5%	20	1.4				0.45
2%	50	2.05				0.55
1%	100	2.5				0.6

* 12hr Result 2.33

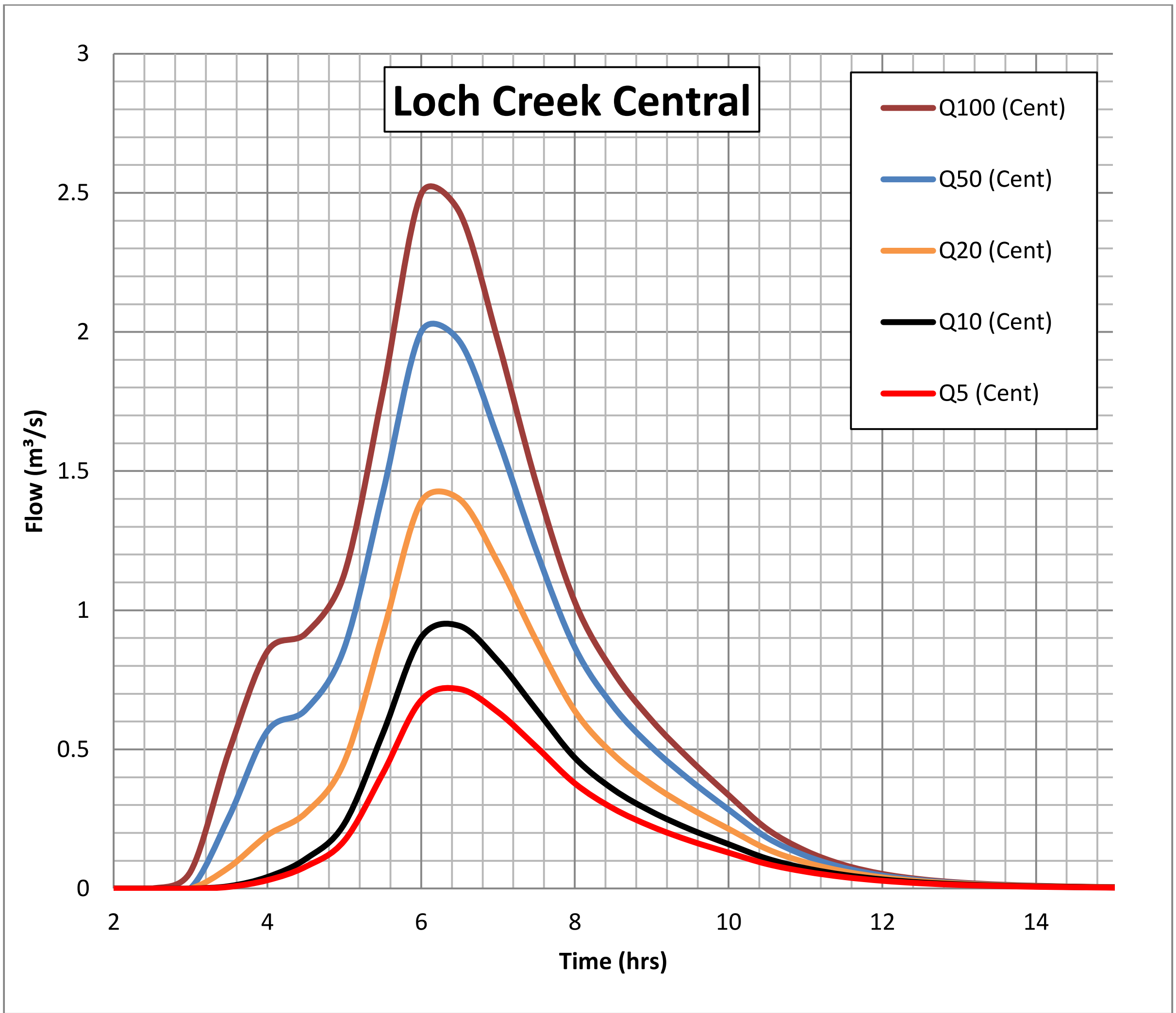


Figure 5-10 Loch Creek C – Critical duration hydrograph results

5.7.6 Loch Creek E (East) Results

Table 5-17 and Figure 5-11 show key RORB modelling results on the Loch Creek E (East) catchment.

Table 5-17 Loch Creek E RORB modelling results

AEP	ARI	Peak Flow (m^3/s)	Critical Duration (hrs)	Kc	IL	RoC
20%	5	2.2	36*	0.89	20	0.25
10%	10	3.5	12			0.35
5%	20	5.3	12			0.45
2%	50	8.2	9			0.55
1%	100	10.5	9			0.6

* 12hr Result 2.141

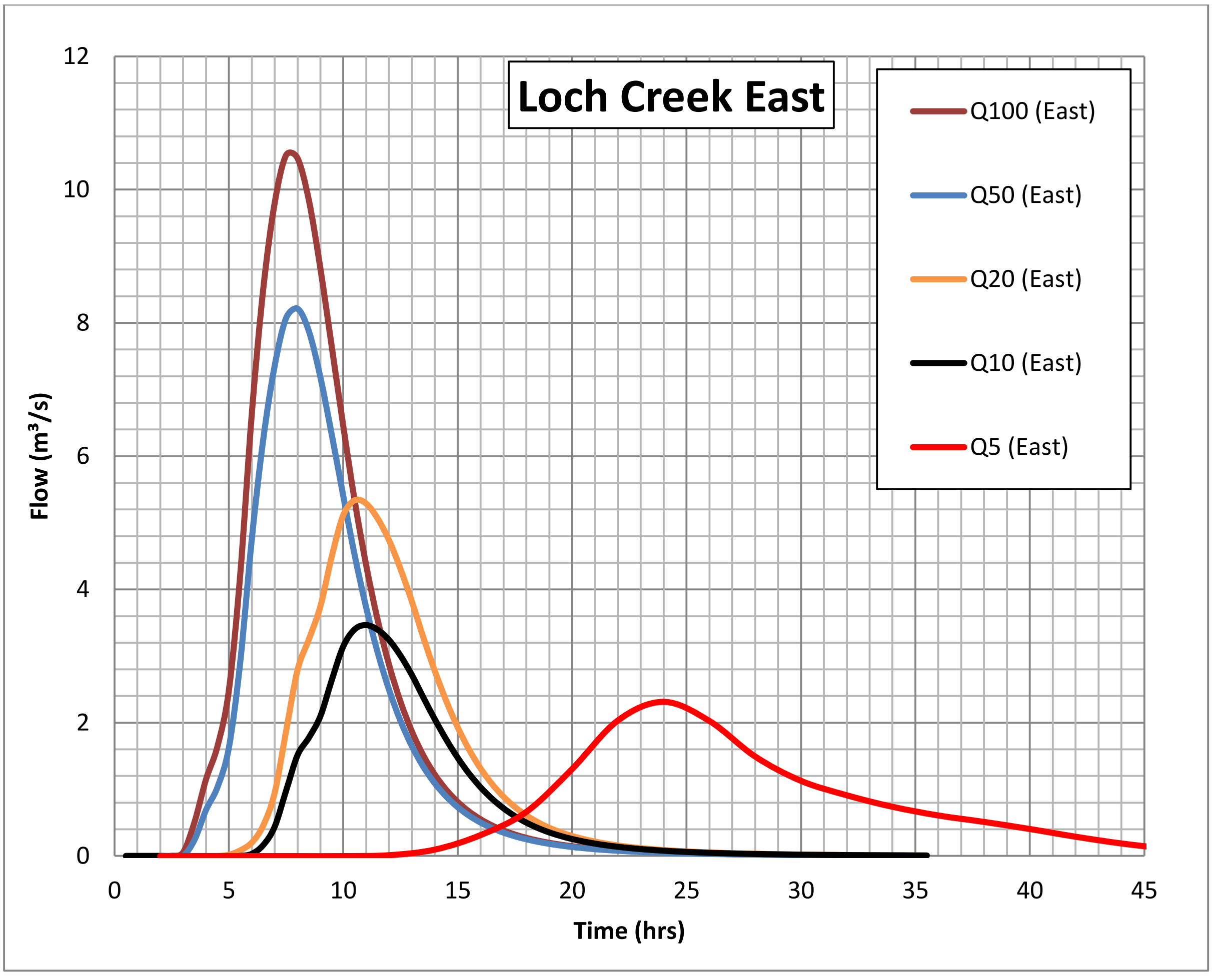


Figure 5-11 Loch Creek E – Critical duration hydrograph results

6. ESTIMATION OF PROBABLE MAXIMUM PRECIPITATION

The Probable Maximum Precipitation (PMP) for the Trafalgar study area was determined using the Generalised Short-Duration Method (Bureau of Meteorology, 2003). The key results of this method are outlined in Table 6-1, while the final calculated mean rainfall depths are in Table 6-2.

Table 6-1 GDSM method: summary results for Trafalgar

Step	Result	Calculations
Duration limits	6 hours	Trafalgar is located in the 6 hour zone in Figure 6-1.
Terrain category	Rough (R = 1, S = 0)	Areas where the catchment elevation commonly changes by 50 m or more within horizontal distances of 400 m are classified as rough. This is the case for the Trafalgar RORB sub-catchments.
Elevation Adjustment Factor (EAF)	EAF = 1	This catchment has a mean elevation of less than 1500 m.
Moisture Adjustment Factor (MAF)	MAF = 0.55	Trafalgar is located close to the 0.55 contour in Figure 6-2.
PMP estimations	Refer Table 6-2. Results rounded to the nearest 10 mm.	The PMP estimates for a range of durations were then calculated using the following formula: $\text{PMP Value} = (S \times D_S + R \times D_R) \times MAF \times EAF$ Where: S = a factor for smooth terrain (from 0 – 1) D_S = the initial rainfall depth for smooth terrain R = a factor for rough terrain (from 0 – 1) D_R = the initial rainfall depth for rough terrain MAF = Moisture Adjustment Factor EAF = Elevation Adjustment Factor The initial rainfall depths were read from the graph of Depth-Duration Area Curves for Short Duration Rainfall the study area (33.83 km^2). The equation for this catchment reduces to: $\text{PMP Value} = (1 \times D_R) \times 0.55 \times 1$ or $\text{PMP Value} = 0.55 \times D_R$
Positioning of convective storm cell PMP ellipses	Refer Figure 6-3.	The centroid of the ellipses was positioned over the centre of the four RORB sub-catchments.
Mean rainfall depth	Refer Table 6-3.	The calculation of the mean rainfall depth between successive ellipses involved a series of calculations. First, the area of catchment between successive ellipses was then determined, as was the area of catchment enclosed

		by each ellipse. From there, the initial mean rainfall depth enclosed by each ellipse was determined using the tables provided in Bureau of Meteorology (2003) for rough catchments. The mean rainfall depth enclosed by each ellipse was then adjusted by the MAF and EAF. The volume of rain enclosed by each ellipse was then computed, followed by the volume of rain between successive ellipses and then the mean rainfall depth between successive ellipses. This series of calculations was performed for each of the storm durations.

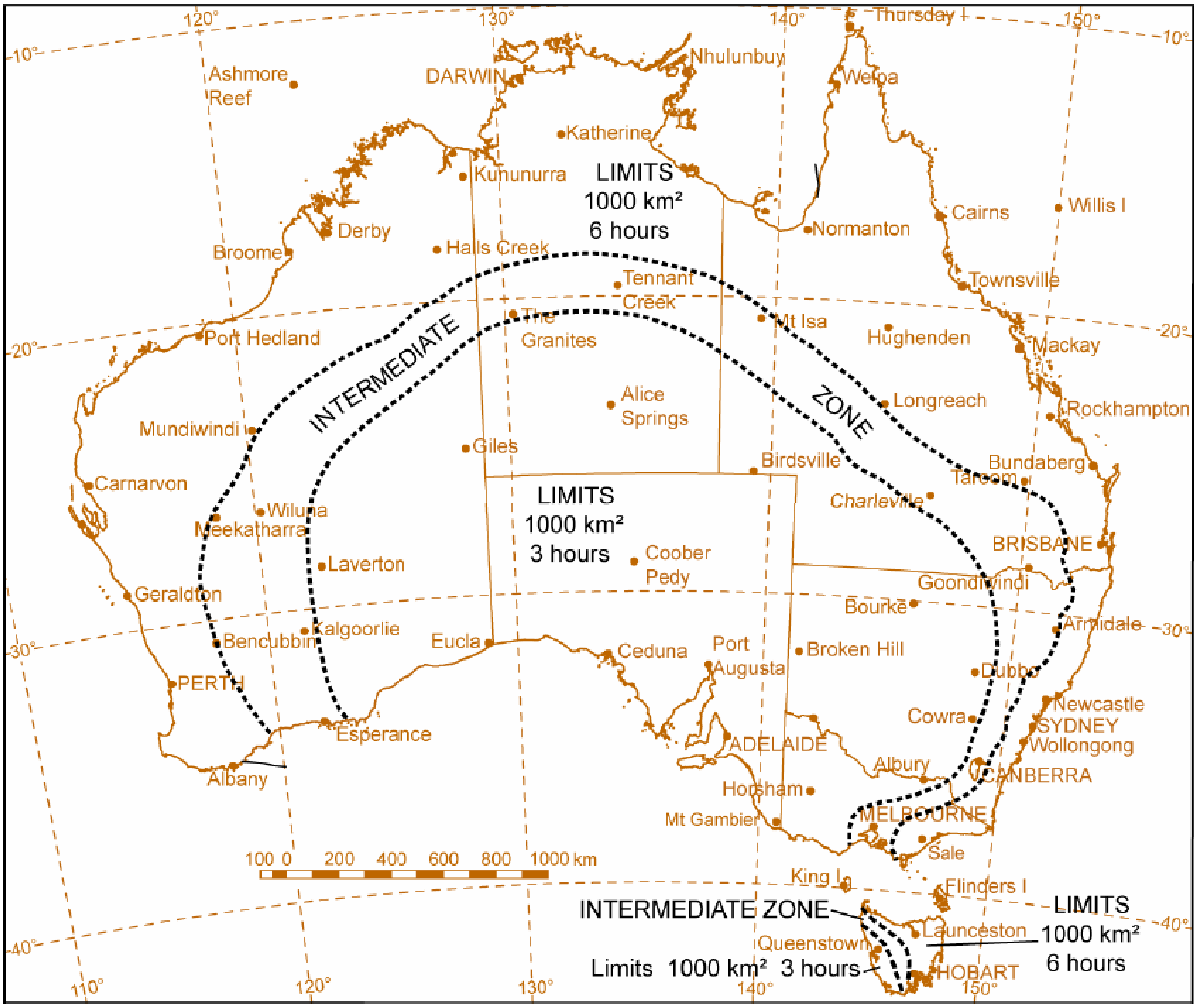


Figure 6-1 **GSDM zones (from Bureau of Meteorology, 2003).**

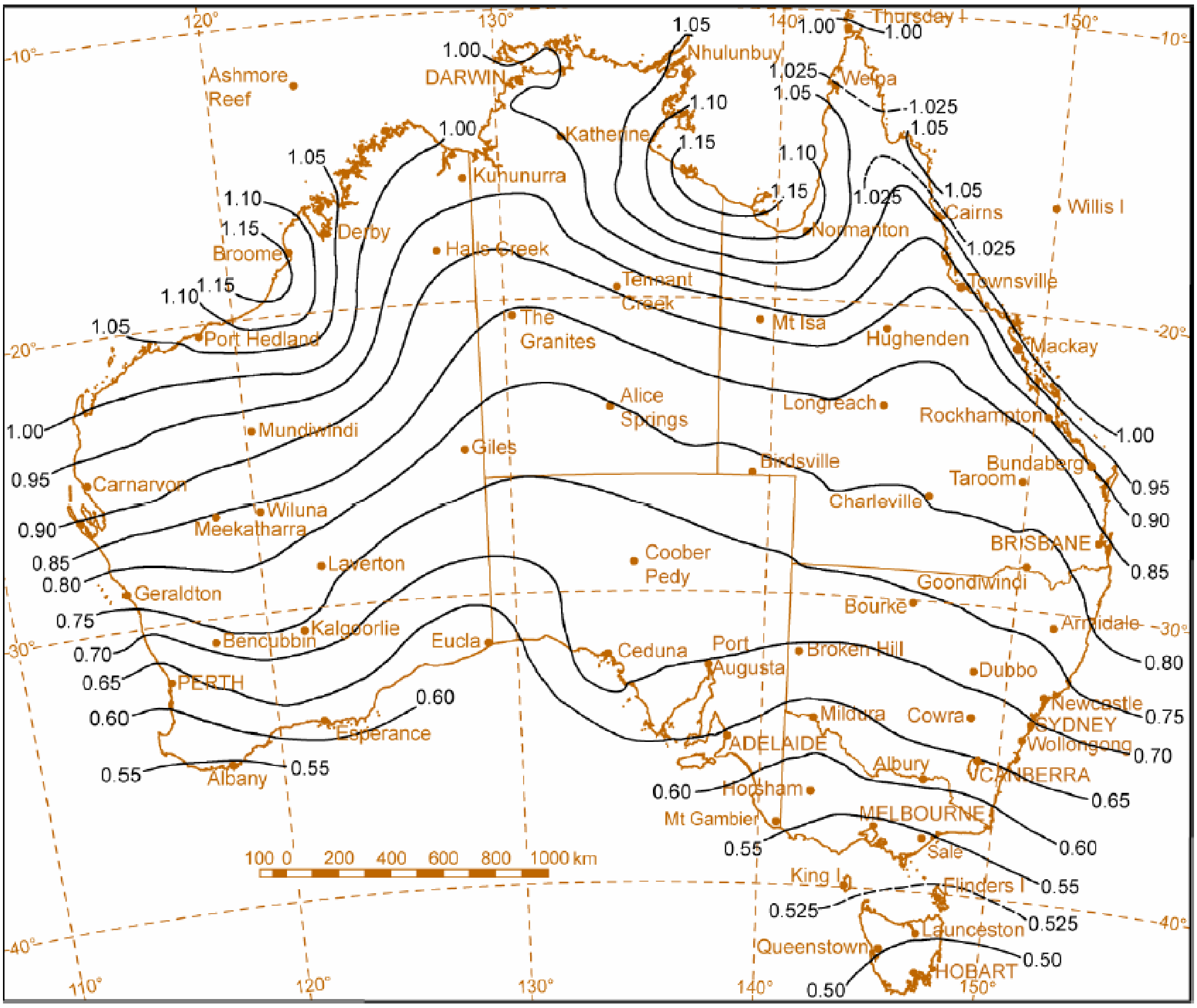


Figure 6-2 MAF zones (from Bureau of Meteorology, 2003).

Table 6-2 Calculated PMP values for a series of durations up to 6 hours

Duration (mins)	D_R (mm)	PMP (mm)
15	190	100
30	280	150
45	360	200
60	425	230
90	545	300
120	630	350
150	705	390
180	765	420
240	870	480
300	957	530
360	1020	560

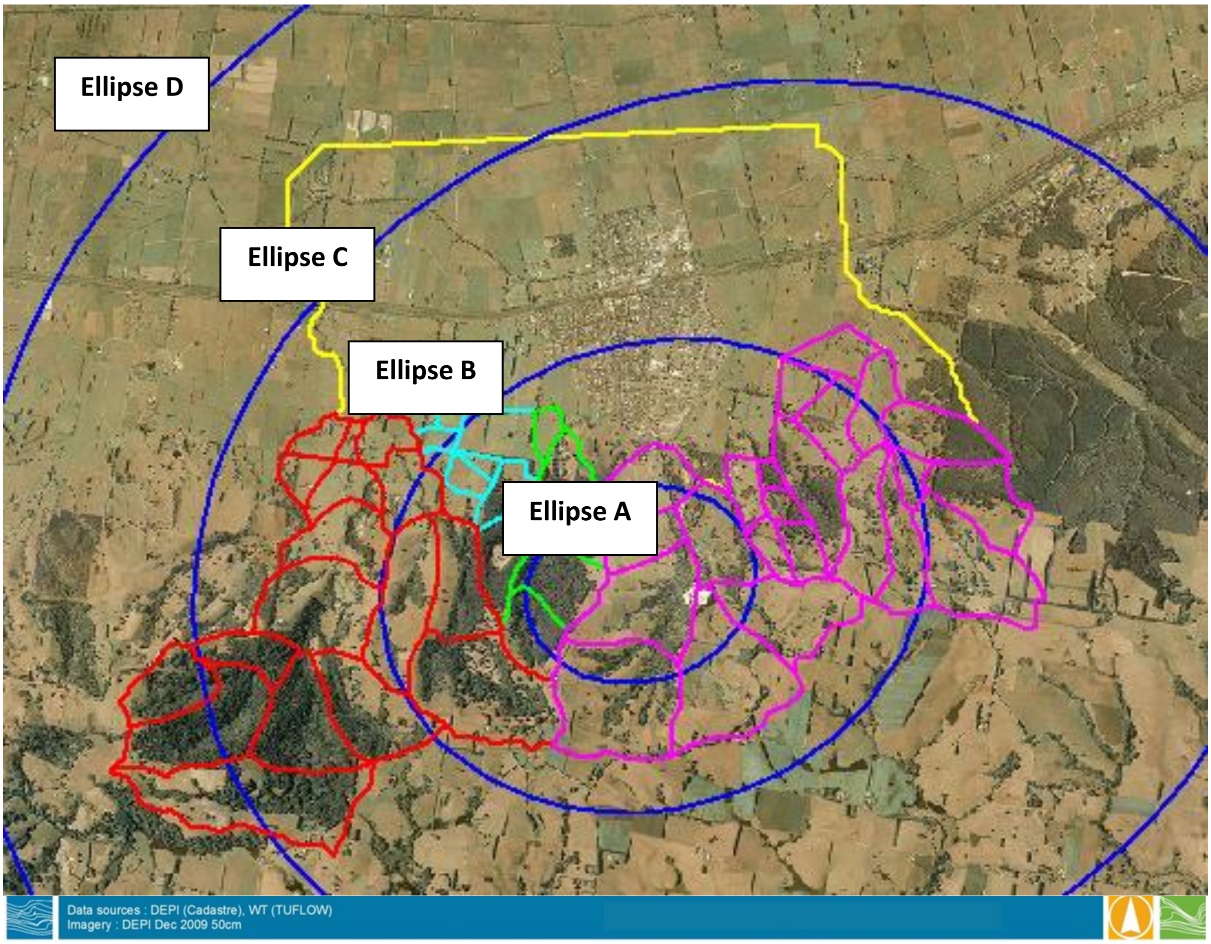


Figure 6-3 Convective storm cell PMP ellipses (dark blue) positioned over the four RORB sub-catchments (red, light blue, green and pink) for the study area (yellow).

Table 6-3 Mean rainfall depths (in mm) per ellipse for a series of durations

	Duration (hr)										
Ellipse	**0.25**	**0.5**	**0.75**	**1**	**1.5**	**2**	**2.5**	**3**	**4**	**5**	**6**
A	127	184	233	271	349	408	451	494	565	623	658
B	111	164	208	245	313	366	404	441	504	554	590
C	102	151	191	228	293	340	379	411	467	513	547
D	97	143	181	218	281	324	365	394	446	489	522

6.1 PMP RORB Model Design Flood Hydrograph Estimation

Likely rainfall characteristics determined using the GDSM method for each external catchment were used to generate RORB rainfall files (15 minute through to 6 hour event durations). The calibrated RORB models for each catchment were then run using the model input parameters shown in Table 6-4. RORB models were run for all durations with the 3 hour event found to be the critical duration. Peak flows generated in the PMP event are shown in Table 6-4. With comparisons to 100 year ARI flows shown for context. Generally the PMP hydrology generated peak flows 12 times that in the 100 year ARI event.

Table 6-4 PMP RORB model parameters & results

Reconciliation Location	Kc	IL (mm)	RoC	m	Critical storm duration	Q PMP RORB m^3/s	Q 100 RORB m^3/s	Magnitude of increase from Q100 results (times)
Sunny Creek	5.28	10	0.9	0.8	3h	222	18	12.4
SC_2 Creek	1.53	10	0.9	0.8	3h	45	3	12.8
SC Overland	1.53	10	0.9	0.8	3h	10	1	9.5
SC_3	1.98	10	0.9	0.8	3h	60	5	11.9
Loch Creek W	4.55	10	0.9	0.8	3h	140	12	11.7
Loch Creek C	0.89	10	0.9	0.8	3h	32	3	10.7
Loch Creek E	3.90	10	0.9	0.8	3h	140	11	12.8

7. HYDRAULIC MODELLING – STUDY AREA

7.1 Overview

The Direct Rain on Grid Method utilises the capability of the hydraulic modelling software to incorporate rainfall into the hydraulic model, requiring minimal hydrological input in form of hyetographs. After subtracting initial losses, the hyetographs are applied directly on the 2D domain in the hydraulic model. Fraction Impervious (FI) and Runoff Coefficient (RoC) values are applied inside the hydraulic model.

There are a number of advantages of the Direct Rain on Grid Method compared with traditional methods and these include:

- A rainfall-runoff hydrologic model such as a RORB model is not required nor is a detailed analysis of sub-catchments;
- Flows are applied to the model at all points and so there is no reliance on empirical relationships; and,
- Catchment storage areas are more accurately defined.

7.2 Methodology

The basic hydrologic model provided design rainfall hyetographs for input to the hydraulic modelling as part of the Direct Rainfall on Grid method. The hyetographs were extracted from AusIFD Software and Microsoft Excel spread sheets. Table 5-1 shows the modelled Scenarios.

Table 7-1 Modelled catchment conditions and climate scenarios

Modelling Scenario		Fraction Impervious	ARI Event (years)					
			5	10	20	50	100	PMP
A	**Base Case**	Calculated based on existing conditions	✓	✓	✓	✓	✓	✓
B	**Option 1 - Mitigated Conditions Existing FI** Mitigation measures to rectify existing flooding up to Q 100 year event	Calculated based on existing conditions	✓				✓	
C	**Option 2 - Mitigated Conditions Existing FI** Mitigation measures to rectify existing flooding up to Q 100 year event	Calculated based on existing conditions	✓				✓	
D	**Practical Mitigated Conditions** A practical mitigation solution which may not provide Q 100 year protection	Calculated based on existing conditions	✓		✓			

7.2.1 IFD Parameters

IFD Parameters were determined at the centroid of the catchment using the Bureau of Meteorology IFD Program. Parameters for Trafalgar are consistent with those shown in the external catchment hydrology section of this report (Table 5-6).

AusIFD Software used IFD parameters to generate hyetographs for each required ARI event and duration. These were then converted to an appropriate format for the TUFLOW hydraulic model input.

7.2.2 Fraction Impervious

The Fraction Impervious (FI) values across the study area were determined using BBSC's planning zones and Melbourne Water guidelines. The land use zones were checked against recent aerial imagery to ensure that the applied FI values were appropriate.

A summary of the FI breakup within the study area is shown in Table 7-2 below.

Table 7-2 Fraction Impervious Values

Zone	Fraction Impervious	
	Existing Conditions	Developed Conditions
Residential	Varies	Varies
Industrial (IN3Z)	Varies	Varies
Business	Varies	Varies
Public Use	Varies	Varies
Commonwealth Land	0.2 - 0.7	0.2 - 0.7
Special Use	0.1	0.1 - 0.6
Farm Zone	0.1	0.1
Road Zone	0.6 - 0.9	0.6 - 0.9

Existing Conditions FI

FI values for residential zones were based on the average block area. A typical relationship between FI and lot size has been developed with reference to current industry guidelines. Manual FI checks were undertaken for a number of residential lots across the study area, using a recent aerial image.

It is noted that within the residential areas, fraction impervious values were assigned based on the lot size, i.e. light green lots are greater than 800 m^2 and therefore have an FI of 0.45, while the yellow lots are within the 500 – 800 m^2 range, and therefore have an FI of 0.6.

Manual checks were also undertaken using the aerial image to identify areas that are zoned residential but are currently vacant, single residential parcels with multiple units and zoned residential areas that are used for other purposes such as reserves or ovals. For these cases the FI values were calculated manually. Figure 7-1 shows the fraction impervious values adopted across the study area.

Table 7-3 Relationship between Fraction Impervious and Lot Size

Lot Size (m^2)	Fraction Impervious
0 – 350	0.85
350 – 500	0.75
500 – 800	0.60
> 800	0.45

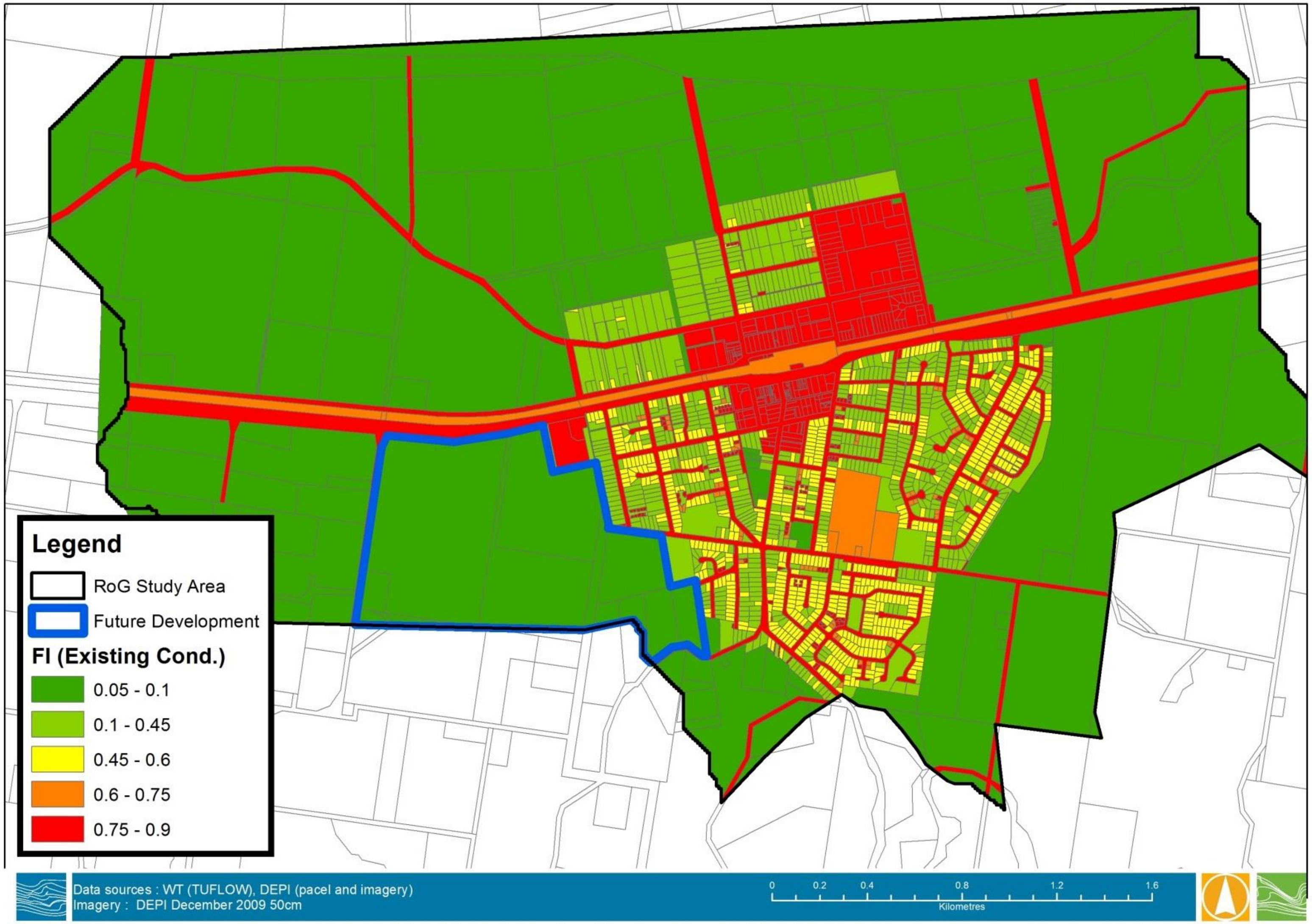


Figure 7-1 Existing Fraction Impervious Values

Developed Conditions FI

To reflect ultimate developed conditions in the catchment, the existing FI values were updated with future developments identified (industrial and residential precincts).

A summary of the updated FI values for the future developed conditions is shown in Table 7-4 below.

Table 7-4 Future Development FI Values (Beyond the Next 2 Years)

Region	Estate Name/Development Type	Timing	Zone	FI Comments
West of Town	Ross and Worth Development	3 – 5 years	R1Z (~700 m^2)	Set to 0.60
North Eastern Edge of town Available Industrial Zoned Land	Industrial 3 Zone	N/A	IN3Z	Set to 0.80

Figure 7-2 shows the future developed conditions FI values for the Trafalgar catchment.

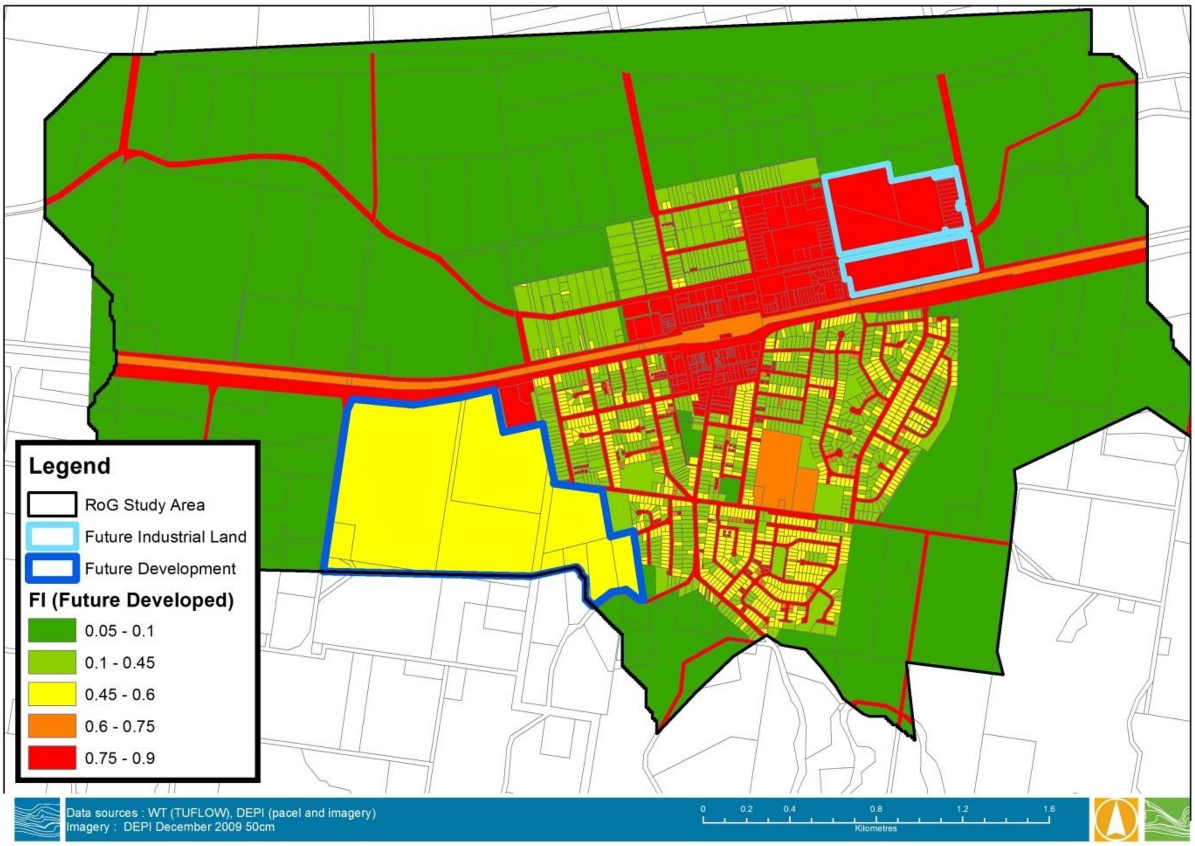


Figure 7-2 Developed Fraction Impervious Values

7.2.3 Losses

Rainfall losses were incorporated in the modelling in two forms, initial loss (IL) and Runoff Coefficient (RoC). Rainfall Runoff coefficients were set in accordance with Melbourne Water guidelines (MWC, 2010). The IL values are consistent with that used for other flood mapping in similar catchments within the BBSC municipality (such as Warragul).

Losses applied to the study area were less than that applied to external catchment hydrology estimations. This reflects the differences in catchments characteristics between the rural external catchments and the semi-rural study area.

The IL values as in agreement with BBSC for design storm events are presented in Table 7-5.

Table 7-5 Initial loss values

Storm Event (ARI)	Initial Losses (mm)	RoC
5 years	10	0.25
10 years	10	0.35
20 years	10	0.45
100 years	10	0.60

Rainfall Runoff coefficients were calculated in accordance with Melbourne Water guidelines (MWC, 2010).

8. HYDRAULIC MODELLING

8.1 Overview

There were no existing high resolution hydraulic models within the study area therefore a new TUFLOW model was constructed using a combination of direct inflow and the rainfall on grid methodology.

TUFLOW is widely used software that is suitable for the analysis of overland flows in urban areas. The TUFLOW models are used to apply rainfall and then route flows through the catchment both overland in a 2D domain and underground through a 1D pipe network. The pipe network (1D links), is dynamically linked to the 2D domain via pits. Water passing in and out of the underground pipe network is computed at every modelling time step. Where the 1D network is full, flows surcharge onto the surface and are routed overland in the 2D domain across a terrain, forming flood flow extents, depths and velocities.

The direct rainfall on grid method by TUFLOW has the following key inputs:

- Topography data;
- Rainfall data;
- Site roughness;
- Boundary conditions; and,
- 1D network.

The model extent for the catchment was extended out beyond the delineated sub-catchment boundary to ensure all flows into the catchments were captured. Figure 8-1 below shows the final TUFLOW model build with Figure 8-2 showing the Manning's Roughness coefficients used across the model.

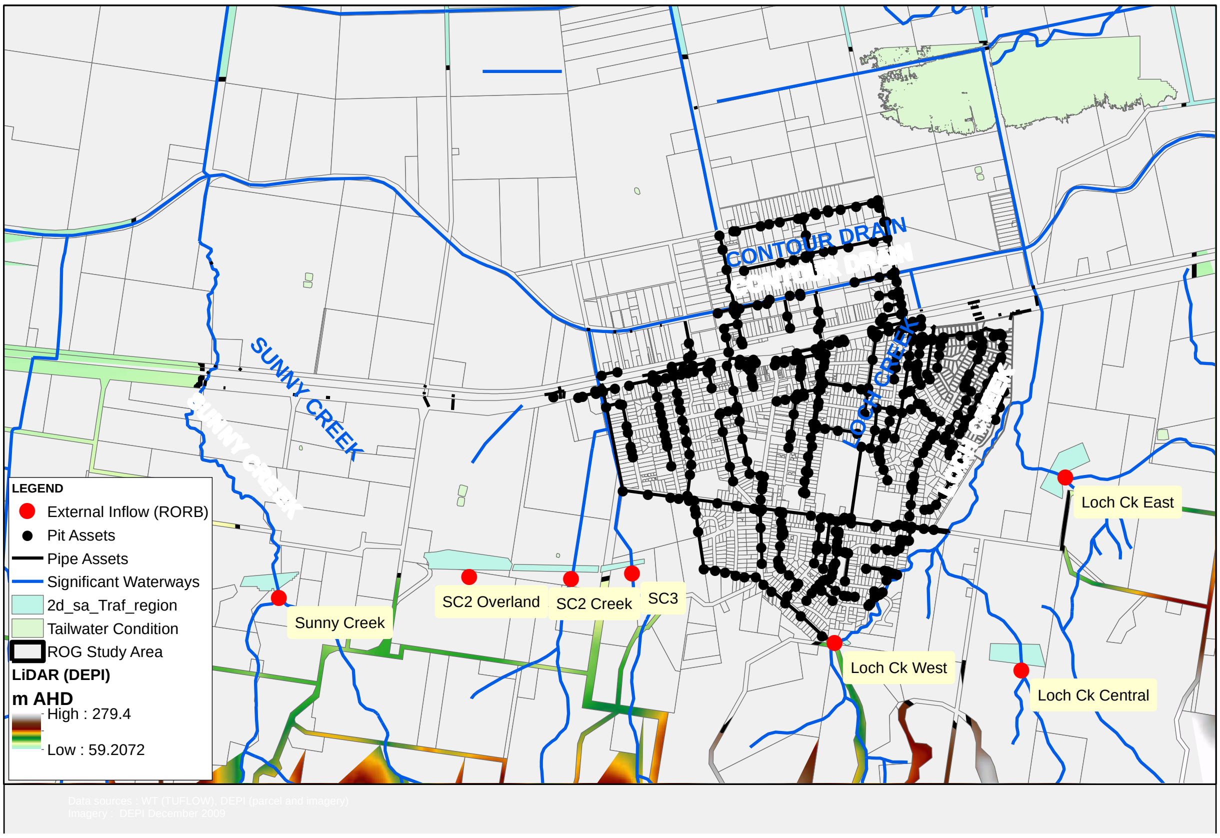


Figure 8-1 Hydraulic Model (Small diameter pipes not shown)

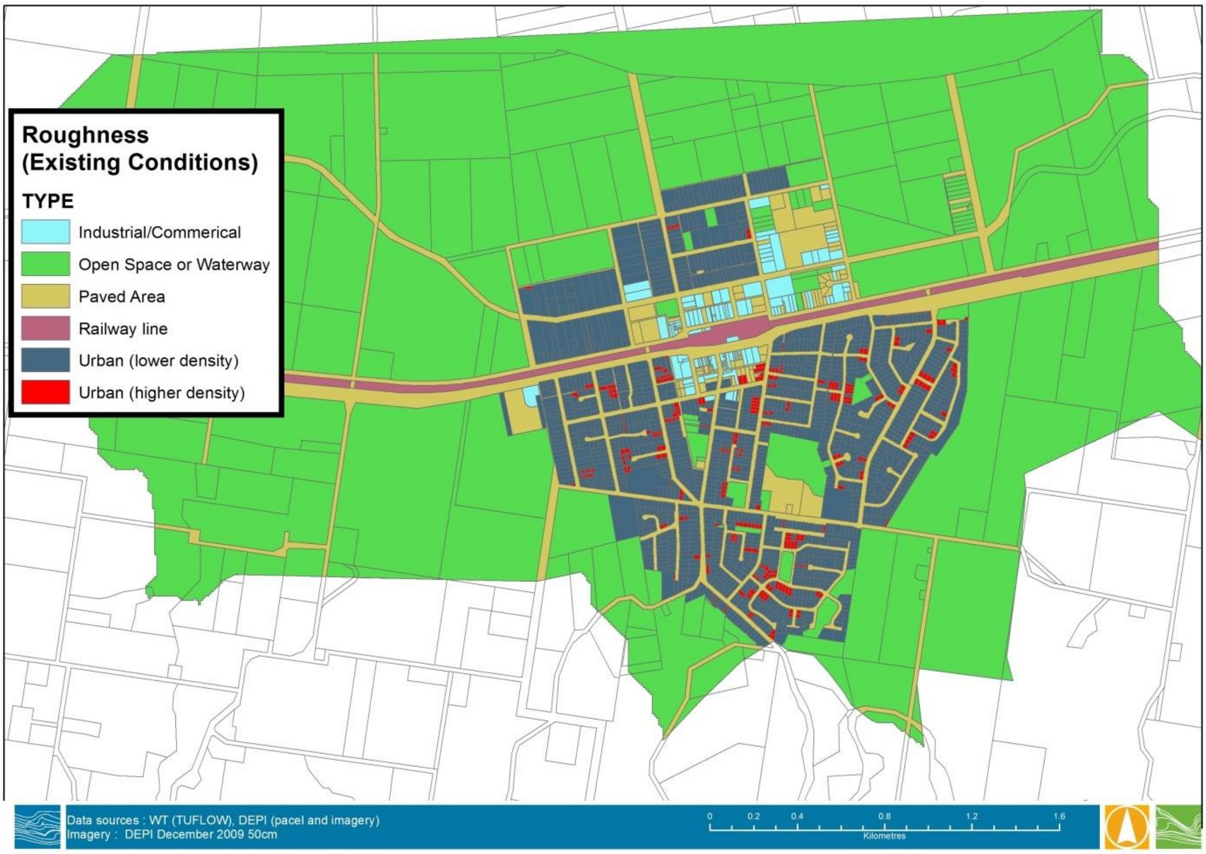


Figure 8-2 Hydraulic Roughness – Existing Conditions

8.2 Hydraulic Model Construction and Parameters

The TUFLOW model was constructed using MapInfo V11.5 and executive commands in form of text files. The models were built in conjunction with technical requirements documented in the Project Brief. This section details key elements and parameters of the TUFLOW models.

Model Version

The double precision version of the latest TUFLOW release was used for all simulations (TUFLOW Version: 2012-05-AC-iDP-w64).

2D Grid and Topography

The primary Digital Elevation Model (DEM) was created using the LiDAR. This data was supplemented at the eastern edge of town with survey provided by BBSC covering the Strzelecki Views development. The topography data was input to TUFLOW by directly interrogating the source DEM to set the TUFLOW Z-point elevations.

The grid size for the model was selected based on site specific features such as width of waterway and other conveyance features (such as roads), and model run times considering the overall project objective of creating a highly accurate flood model of the township and its surrounds. A grid size of 4 meters was discussed with BBSC and adopted for the study. At particular locations throughout the study area the 4 m grid levels were overwritten by TUFLOW Z-shapes which forced the model to adopt a maximum or minimum level (not the resampled elevation).

Examples of this included along the invert of the Loch creek, where at some locations the true creek invert was lost by vegetation and LiDAR post processing. Similarly along the left bank of the Loch Creek it was found the resampling of the LiDAR from 1 m to 4 m resulted in the bank height being lowered to a point where breakouts were noted. When the true bank heights (from the 1 m LiDAR) were included in the modelling, the breakouts no longer occurred.

1d Network

Pipes were modelled as 1D links using the pipe/pit CAD dataset provided by BBSC. Missing pipe/pit infrastructures were identified and added into the 1D network using engineering judgement. The data was read into TUFLOW via '1d_nwk' files.

The key waterway crossings were modelled using the structure details provided by BBSC or site visit observations. The data was read into TUFLOW via '1d_nwk' and '1d_nwke' files.

Roughness

Site roughness has important effects to flood velocities, flow paths, flood depths and extents. Site roughness values were derived from the BBSC planning zone data and refined based on site visits and aerial photography.

- For the 2D domain, '*2d_mat*' files were produced based on land use zones, with further refinement through the use of high-resolution aerial photographs and findings from the site visits. The Manning's values are specified in the .tmf TUFLOW model file.
- Manning's 'n' roughness coefficient values were adopted from Melbourne Water Guidelines (MWC, 2010) and are listed in Table 8-1.

- For the 1D domain, roughness values were applied directly to the 1d_nwk file, representing the internal roughness of pipes or 1-d structures.

Table 8-1 Manning's n Roughness Coefficients

Land Use	Manning's n Roughness Coefficient
Residential - Urban (higher density) - when building footprints and remainder of parcel are modelled together (with one roughness value)	0.350
Residential - Urban (lower density) - when building footprints and remainder of parcel are modelled together (with one roughness value)	0.150
Industrial/Commercial or large buildings on site	0.300
Significant Drainage Easement (regardless of zone type)	0.050
Open Space or Waterway - minimal vegetation	0.040
Car park/pavement/wide driveways/roads	0.020
Railway line	0.125
Pipes	0.013

Pit Configuration

- Pits along the 1D pipe section were connected to the 2D using the "SXL" option for the *'1d_nwk pit Conn_2D'* attribute. This option automatically lowered the 2D cells connected to the pits by 0.1 m, specified in the *'1d_nwk'* file, so that more surface water is forced into the pits and pipes.
- Weir Pits were used and uniformly given a width of 2 m to ensure more water is forced into the pits and pipes. This resulted in the pipe characteristics being the principle limiting factor to water entering the 1D network. This is a typical methodology when detailed survey information of pit inlet types is not available.

Pipe and Pit Losses

Pipe and pit losses were calculated in TUFLOW through the use of the Engelhund method. Where appropriate, these losses were manually overwritten by the modeller. Losses applied were reviewed to ensure consistency with industry best practice.

Boundary Conditions

The Rainfall-On-Grid method requires the outlet boundary to be determined. The tail water conditions at the outlet boundary for the project were determined following a review of the Latrobe River (Moe Drain) Flood Study completed by Cardno in 2013. Table 8-2 below shows tail water conditions for various modelling scenarios.

Where required, 'HQ' (the specification of a WSE at a given flow rate) boundaries were used to convey overland flow out of the catchment in a steady manner. Where the models overland flow interacted with the tail water of the Moe drain, 'HT' (the specification of a WSE at a given time) boundary types were applied. 'HT' boundaries ensure a water level is maintained by regulating the volume of flow leaving the model.

External flows (from the Strzelecki ranges) were included in the TUFLOW model via 'SA' (inflow source over an area) polygons. Polygons were schematised considering the likely overland flow characteristic at the inflow locations (wide polygons where shallow sheet overland flow occurs and smaller polygons where flow paths were clearly defined such as a watercourse). The location of the external in flow points are shown in Figure 8-1. Peak flows applied at each inflow point are shown in Table 8-3.

Table 8-2 Tail-water conditions

	Hydrology	Tail water Level (m AHD)	Fraction Impervious
Current Conditions	Existing rainfall intensity 100yr ARI 50yr ARI & 20Yr ARI	10 yr existing level: = 58.44 m AHD Moe Drain Floodplain	Calculated based on existing conditions
Current Conditions	Existing rainfall intensity 10yr ARI & 5yr ARI	Nominal Water level: = 58.00 m AHD Moe Drain Floodplain	Calculated based on existing conditions

Table 8-3 External Inflows from RORB modelling

AEP	ARI	Peak flow from RORB (m^3/s)						
		Loch Creek			SC 3	SC 2		Sunny Creek
		West	Central	East		Creek	Overland	
20%	5	2.30	0.60	2.20	0.93	0.73	0.18	3.71
10%	10	3.70	0.90	3.50	1.53	1.16	0.33	5.80
5%	20	5.70	1.40	5.30	2.36	1.81	0.50	9.20
2%	50	8.90	2.05	8.20	3.56	2.75	0.70	14.06
1%	100	11.50	2.50	10.50	4.51	3.48	0.87	17.90

Rainfall

Rainfall data is read in TUFLOW in form of hyetographs. Time-steps for hyetographs are often less than 5 minutes, and in the case of this investigation, 1 minute. Hyetograph .csv (comma separated variable) files were created for each rainfall ARI and duration. The rainfall losses were set as follows.

Initial Loss

Initial losses were removed from the hyetograph via the “2d_mat” option (linked to the Manning’s Roughness values applied). An initial loss of 10 mm was applied uniformly across the study area.

Runoff Coefficient Loss

A '*2d_rf*' rainfall file was produced in MapInfo for each ARI event, consisting of rainfall polygons. Each polygon contains a field listing the desired hyetograph and a 'final runoff coefficient'. The 'final runoff coefficients' for each rainfall polygon was calculated using the following equation:

$$ROC_{final} = (FI \times 0.9) + ((1 - FI) \times ROC_{x\ years\ ARI})$$

Where: $\mathrm{ROC_{final}}$ = Polygon runoff coefficient for ARI of x years

FI = Fraction Impervious of rainfall polygon (section 7.2.2)

$\mathrm{ROC_{x\ years\ ARI}}$ = Volumetric Runoff Coefficient for ARI of x years (Section 7.2.3)

Each individual property was hence assigned **its own** final runoff coefficient based on the storm event and given fraction impervious.

Initial Water Levels

Beyond the tailwater polygon, initial water levels were assigned for all the dams, storages and lakes at full capacity. This is a conservative approach which assumes that such storages would be full at the time of a significant storm event, omitting potential excess runoff storage effects of the water bodies.

8.3 TUFLOW model checks

The TUFLOW model was run for a suite of storm durations for each of the required durations in the Existing Conditions. The following checks were undertaken on TUFLOW model parameters and outputs:

- **2D grid size**: The 2-d grid size was 4 meters, suitable for the terrain features to be identified in conjunction with strategically used TUFLOW z-shape alterations.
- **2D timestep**: The 2-d timestep was 2, half of the grid size and hence within industry standards when considering the 2-d grid size.
- **1D timestep**: the 1-d timestep was x, and was again within industry standards with the given grid size and 2-d timestep.
- **Errors and warning messages**: None
- **Pipe flow**: In all the models, pipes flow full at downstream sections, as was expected.
- **2D Model extent**: All produced flood extents are not impacted by the edge of the TUFLOW model's active area.

8.3.1 TUFLOW and Rational Method Verification

Overview

Verification of the TUFLOW model flow results to an estimate from the Rational Method is important to ensure that catchment losses and conveyance are appropriately accounted for in the TUFLOW model. As the TUFLOW model is able to take many more catchment characteristics into account, it is not expected that the results from the TUFLOW model should exactly match the estimate from the Rational Method. Instead, the Rational Method is used as a check to ensure that the flows seen in the TUFLOW model are of the order expected. As the TUFLOW models are quite sensitive to the runoff coefficients and initial loss parameters applied, the Rational Method estimate also serves as a good check that appropriate values are being used.

Selected Areas

An area was identified within the catchment that was suitable for Rational Method calculation and TUFLOW model verification. The selected areas had well defined catchment boundaries and a single and distinctive outlet where comparison between the estimated flowrate from the Rational Method estimation could be compared to the TUFLOW model output. The selected area of the Trafalgar Catchment is shown in Figure 8-3

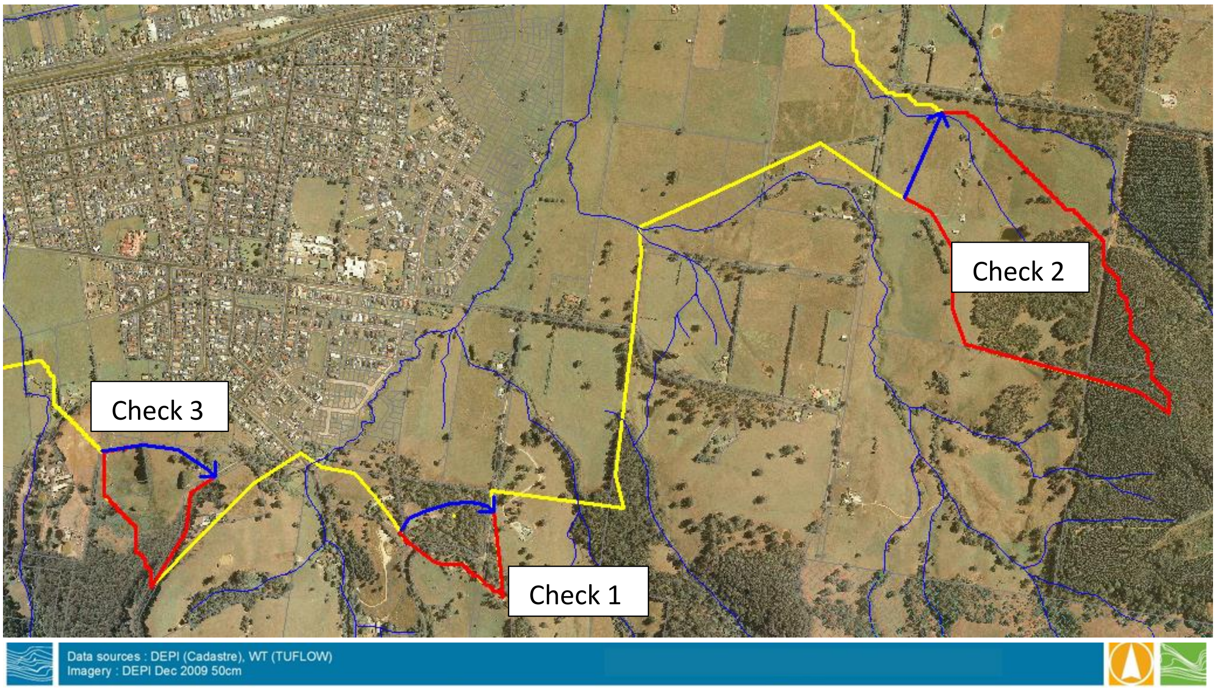


Figure 8-3 Selected area for Rational Method verification

Rational Method Estimate

A Rational Method estimate was completed for the selected area to estimate the peak 100 year ARI flow at the point of interest.

- The Fraction Imperious (FI) values were applied as detailed in Section Figure 7-1.
- The Time of Concentration (tc) was calculated using Adams Method, as shown below:

$$tc = t_{ini} + 0.76A^{0.36}$$

Where A = catchment area (km^2)

t_{ini}= initiation time , taken as 7 minutes

- The Rational Method flowrate was estimated at the outlet using Rational Method equation shown below:

$$Q = \frac{C.I.A}{360}$$

Where Q = 100 year ARI peak flow rate (m^3/s)

C= Runoff coefficient, based on FI values and ARI storm events.

A=Catchment area (ha)

I =Rainfall intensity of the storm with duration of tc

TUFLOW Model Outputs

Overland flows were extracted from the TUFLOW models at the same locations as the Rational Method estimates as shown in Figure 8-3 . The PO_line command in TUFLOW was utilised to record overland flow rates.

Verification

The Rational Method flow was compared to the TUFLOW output for 100 year ARI storms. Successful verification was judged to be no more than ±10% difference between the TUFLOW and Rational Method estimate peak flows.

The flow calculation and comparison are shown in Table 8-4 and Table 8-5

Table 8-4 Rational Method 100 Year ARI Flow Estimates

Sub Area	Selected Area (ha)	% Impervious	Tc* (minutes)	C_{100yr}	I (mm/hr)	Rational Method $Q^R(m^3/s)$
Check 1	6.3	10	6	0.243	125.3	**0.7**
Check 2	41.45	10	34	0.243	65.5	**1.8**
Check 3	9.54	10	7	0.243	154	**1.0**

* Bransby Williams Formula used for tc calculation

Table 8-5 TUFLOW and Rational Method Comparison

Sub Area	Critical Storm	Tuflow (m^3/s)	Rational method $Q^R(m^3/s)$	Difference (%)
Check 1	1h	0.8	**0.7**	**12.5**
Check 2	2h	1.7	**1.8**	**5.5**
Check 3	2h	1.1	**1.0**	**9.1**

Table 8-5 indicate that the results extracted from the TUFLOW model reconcile well to the Rational Method estimates completed. Water Technology considers the verification to be successful based on the results above.

8.3.2 GIS Processing

The raw model output data was processed in order for it to be easily viewed in GIS. Processing occurred in two stages – firstly processing the raw data using TUFLOW utilities and then processing the resulting data within a GIS environment. These processes are detailed below.

TUFLOW Data Processing

TUFLOW contains a number of utilities for processing output data. The following utilities were used:

- Dat_to_dat.exe: This utility has a number of functions and in this instance was used to extract the maximum value for depth, velocity and water elevation at each grid point across the twelve durations for each event. The maximums values are then placed into a new data file.
- TUFLOW_to_GIS.exe: This utility converts TUFLOW data into GIS formats and in this instance was used to convert TUFLOW data into the MapInfo mid/mif interchange format.

Results Processing

MapInfo was used to import and then compile the data into an appropriate format. Initially the depth, velocity, water surface elevation and duration layers were amalgamated into a single layer for each event. Final maps were produced from ASCII plots in Arc-GIS v10.

Data Integrity Checks

The results were checked to ensure that larger events corresponded with increased depths, flood level and velocity in each cell.

Depth results must conform to the following: 100 year > 50 year >20 year>10 year>5 year

Filtering of Results

The model results were filtered according to the following criteria, in accordance with MW requirements:

- Minimum Depth Threshold – any flooded cells with depths less than 0.02 m were removed; and
  Velocity * Depth Criteria – The results were filtered to remove any cells where both the depth is less than 0.10 m and the V*D is less than 0.008.

All cells considered as flooded after the application of the above filters (1 and 2) are then combined into a flood extent that connects neighbouring cells. Any flooded areas that are less than 100 m^2 are then removed.

8.3.3 Hydraulic model review

An initial review of the 100 year and 5 year ARI modelling results was undertaken by BBSC. Identified flooding was then discussed internally at council to determine if the results bear resemblance to historical flooding observations. The 100 year and 5 year ARI modelling results were also presented to the Trafalgar community in the second Community Engagement session.

Comments were supplied back to Water Technology from this process allowing for refinement of the model (specifically the pit and pipe network) and in certain cases augmented, before the revised results were again provided to the BBSC. The process was then repeated a second time before BBSC nominated they were comfortable with the 100 And 5 year ARI results. Following this process, the remaining ARI and Scenario events were completed.

9. HYDRAULIC MODELLING RESULTS

9.1 Existing Conditions Overview

The flood mapping deliverables consisted of a series of flood extents along with maximum depth, velocity and hazard plots for a range of ARI events. Figure 9-1 to Figure 9-4 show various mapping outputs from the study for existing conditions. Further flood depth and water surface elevation plots are shown in Appendix B for the scenarios and events listed in Table 5-1.

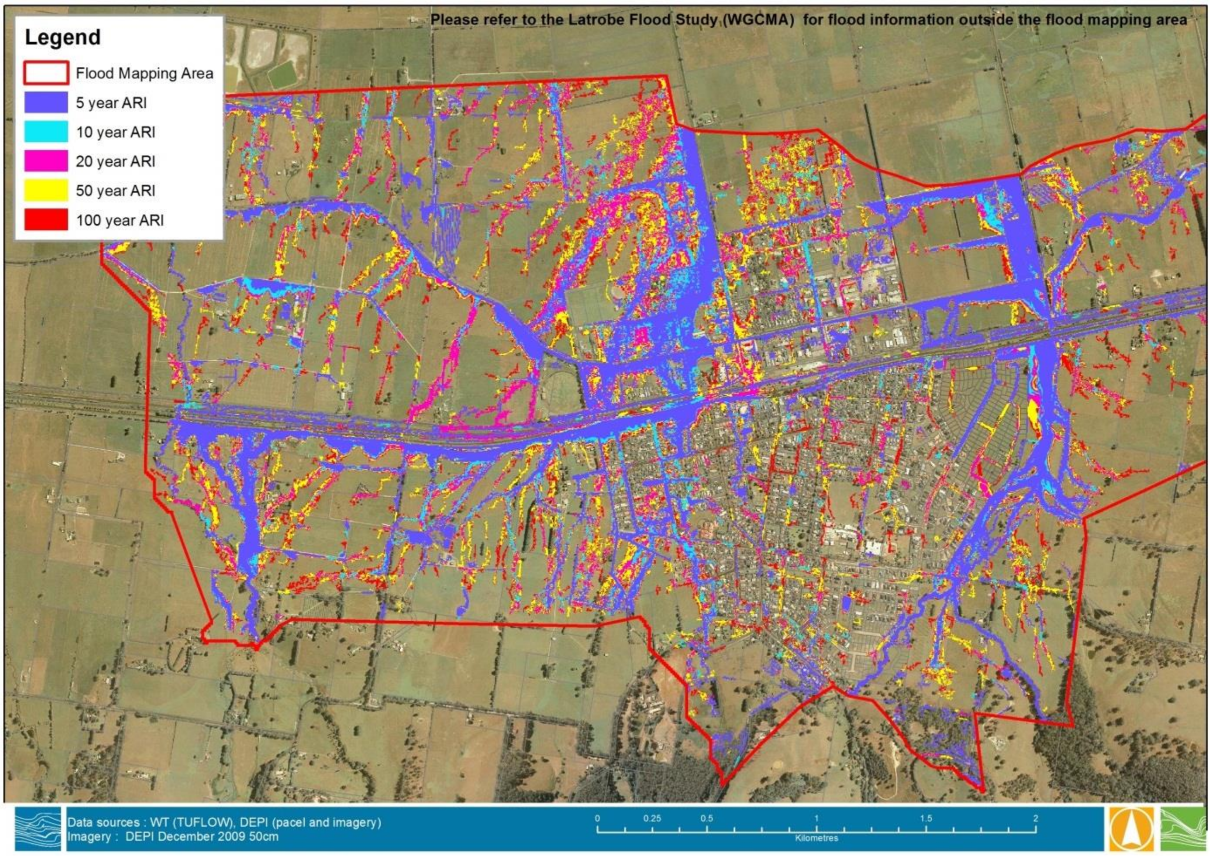


Figure 9-1 Flood Extents 5 year, 10 year, 20 year, 50 year and 100 year ARI

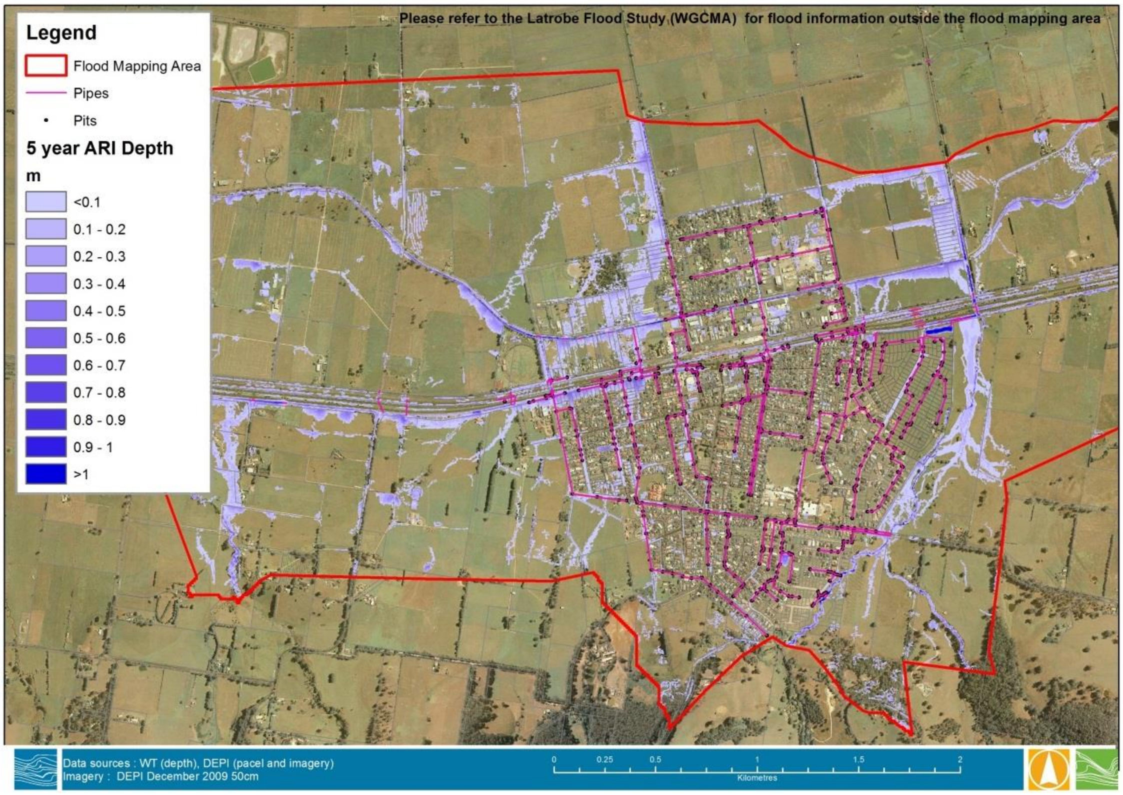


Figure 9-2 5 Year ARI Flood Extent

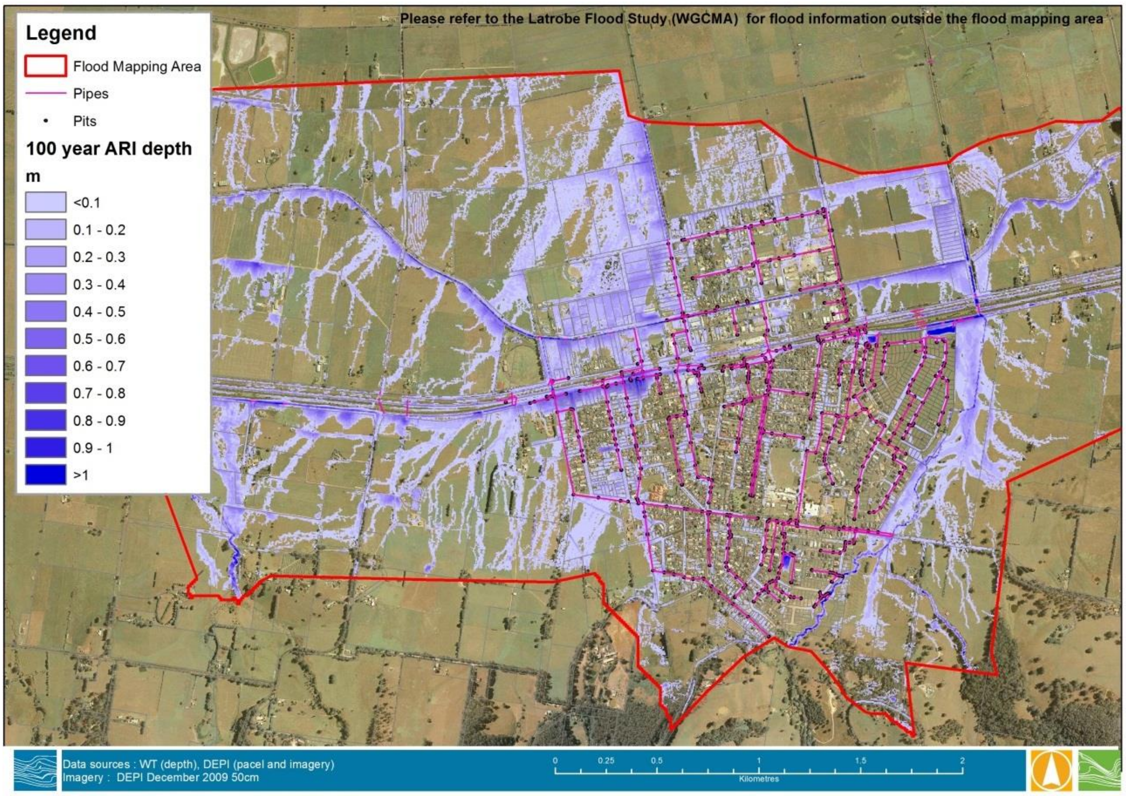


Figure 9-3 100 Year ARI Flood Extent

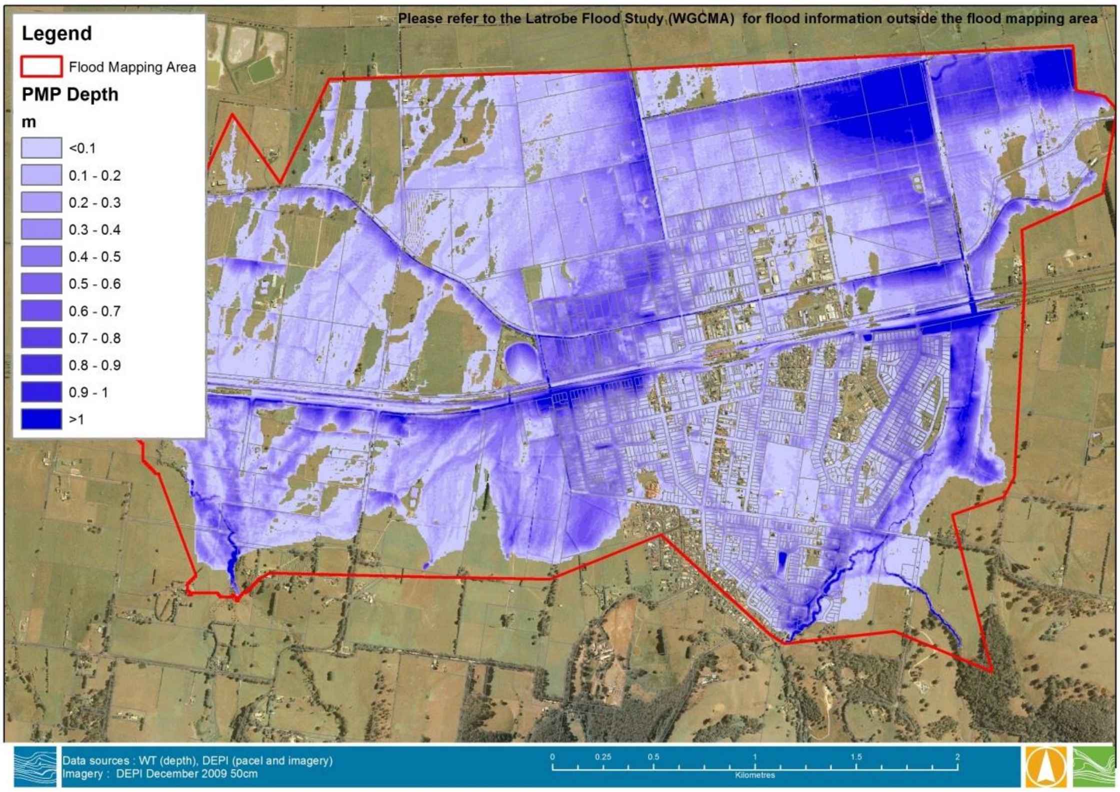


Figure 9-4 PMP Flood Extent

9.2 5 year ARI

5 year ARI flooding across Trafalgar is largely confined to defined drainage areas, roadways and areas not currently developed. The exception to this is the western edge of the township where ponding on the southern side of the highway is observed adjacent to both existing highway crossings. Flooding continues downstream from this point with breakouts between Reserve Road and Seven Mile Road (Willow Grove Road) resulting in overland flow moving through residential and commercial / industrial land. This overland flow tends to end up ponded behind Seven Mile Road.

9.2.1 5 year ARI flooding at the eastern edge of town

The eastern edge of the town (much of which has recently been developed) is practically protected from Loch Creek flooding. Lock Creek flood waters are constrained to the remnant floodplain. 5 year ARI flows from the Loch Creek can flow under the Princess Highway without causing any impacts to traffic on the Princes Highway. North of the Highway the Loch Creek channel (the manmade channel running parallel with Loch Creek Road) does not have sufficient capacity to convey the 5 year ARI flow with breakouts into the farm land on the left bank observed. This section of the system is clearly influenced by concurrent flood levels in the Moe Drain, particularly if the one-way outlet system is failing at the end of Loch Creek Road.

9.2.2 5 year ARI flooding through the centre of town

As discussed earlier, the most significant flooding observed in the 5 year ARI event occurs on the western edge of town through to Seven Mile Road. Significant ponding behind the Highway stretches from Dodemaides Road through to Ashby Street. An area of approximately 1.8 Ha has peak flood depths recorded >= 0.2 m deep (~0.3 Ha of this area is greater than 0.4 m deep). Ponding on the south side of the Highway can be up to 50 meters back from the median strip and impact homes which front the service road.

North of the Highway breakout flows originating from the two Highway major crossings move overland towards Seven Mile Road. Some of this overland flow is picked up by the Contour Drain however already being at capacity it tends to breakout from the Contour Drain also exacerbating flooding behind Seven Mile Road. At least one of these breakouts along Contour Road appears to be the result of insufficient crossing capacity over the Contour Drain. Flooding north of Contour Drain is mostly less than 200 mm deep and is not expected to inundate any homes in this area above their floor level.

9.2.3 5 year ARI flooding From Sunny Creek (West of town)

5 year ARI flood mapping shows flows from Sunny Creek breaking out at the ends of Sunnyburn Road and Rankins Roads. No culvert crossing was included in this area in the flood model but the topography was modified to encourage flow to remain in the primary channel. Even with these modifications, similar breakout behaviour was observed. In the 5 year ARI event this breakout appears to largely be contained by Sunny Creek Road and does not exacerbate flooding at the western edge of the township.

9.3 100 year ARI

100 year ARI flooding across Trafalgar is extensive with many significant overland flow paths being engaged throughout the study area. Comparatively speaking, the older part of the town (south of the Highway) is relatively free from extensive flooding, with only localised low points showing some ponding. It is assumed that the steady grade back to the Highway helps manage some of this flooding.

The majority of the new development to the east of town is flood proofed with only one breakout noted between Berenger Avenue and Vileneuve Drive. As with the 5 year ARI event, ponding behind the Princes Highway on the western portion of town is extensive (up to 0.8 m deep). Again, breakout flows north of the Princes Highway impact much of the land from Reserve Road through to Seven Mile Road (Willow Grove Road). In 100 year ARI flooding, the capacity of Contour Drain is significantly compromised with several breakouts observed along it length. Flooding over the highway is observed in at least 3 locations during the peak 100 year ARI storm.

9.3.1 100 year ARI flooding at the eastern edge of town

With the exception of the small breakout between Berenger Avenue and Vileneuve Drive, the new development on the eastern edge of the town is practically protected from Loch Creek flooding. Lock Creek flood waters are largely constrained to the remnant floodplain. North of the highway the Loch Creek channel (the manmade channel running parallel with Loch Creek Road) does not have sufficient capacity to convey the 100 year ARI flow with breakouts into the farm land on both sides of the road observed.

9.3.2 100 year ARI flooding through the centre of town

The most significant flooding observed in the 100 year ARI event occurs on the western edge of town through to Seven Mile Road. Significant ponding behind the highway stretches from Dodemaides Road through to Ashby Street. An area of approximately 7.3 Ha has peak flood depths recorded >= 0.2 m deep (~3.3 Ha of this area is greater than 0.4 m deep). Ponding on the south side of the Highway would likely cut the road and can be up to 100 meters back from the median strip and impact homes which front the service road.

North of the highway breakout flows originating from the two Highway major crossings move overland towards Seven Mile Road. In the 100 year ARI event, the Contour Drain has little effect on moving flood water away with breakouts occurring along its length, exacerbating flooding behind Seven Mile Road. Flooding north of Contour drain is mostly less than 200 mm deep but has deeper regions (~10 Ha) up to 0.4 m deep both south and north of Contour Drain. Many homes and business would be expected to be inundated above their floor levels in this region.

9.3.3 100 year ARI flooding From Sunny Creek (West of town)

100 year ARI flood mapping shows flows from Sunny Creek breaking out at the ends of Sunnyburn Road and Rankins Roads. In this event, more overland flow appears to head east towards town. A portion of this overland flow weirs over Sunny Creek Road and continues to the western edge of town exacerbating the flooding observed at Reserve Road through to Seven Mile Road.

10. DEVELOPED CONDITIONS MODELLING

After preliminary developed conditions flood modelling runs, it was decided that presenting the results of unmitigated developed conditions in Trafalgar would add little value to the project. When the hydraulic model was run with two areas in town proposed to be developed (west of town RZ1 and north east of INZ1 as shown in Figure 7-2) flooding was found to be significantly increased. In reality, this type of development would never be approved by BBSC or the WGCMA without significant works to retard flows back to existing conditions.

While some preliminary information was available for the arrangements inside the western development, they were not progressed to a point where they could be easily integrated into the hydraulic modelling. Preliminary subdivisional design including retarding basin locations, volumes and major overland flow paths were trailed in the hydraulic modelling but were found to not adequately manage the developed flows. Discussions were also held with the proposed developer of this land throughout the study and advice was provided.

11. MITIGATION

11.1 Overview

Mitigation modelling by Water Technology was a collaborative effort using council and community ideas coupled with the enhanced understanding of current flooding obtained through the flood modelling works. Initially all flood mitigation options were tabled and ranked considering assumed effectiveness and cost. Quite quickly it was established that to flood proof the town for 100 year ARI flooding, significant works would be required. Consequently it was decided to split mitigation options analysis into a simple/practical options which would provide modest flood protection (up to 20 year ARI) and a two more comprehensive options which would consider current and future conditions and would attempt manage flooding up to 100 year ARI conditions. Table 11-1 documents the options analysed and the ARI events modelled.

Table 11-1 Modelled mitigation conditions

Scenario	Fraction Impervious	ARI Event (years)					
		5	10	20	50	100	PMP
Practical Mitigated Conditions A practical mitigation solution which may not provide 100 year ARI protection	Calculated based on existing conditions	✓		✓			
Option 1 - Mitigated Conditions Mitigation measures to rectify existing flooding up to 100 year ARI event	Calculated based on estimated future conditions	✓				✓	
Option 2 - Mitigated Conditions Mitigation measures to rectify developed conditions flooding up to 100 year ARI event	Calculated based on developed conditions	✓				✓	

11.2 Common Works

Most mitigation solutions require multiple measures to achieve acceptable results. In this study it was found that the following common works were required to mitigate flooding;

1. Creation of a small bund between Berenger Avenue and Vileneuve Drive to prevent Loch Creek flows entering the Strzelecki Views Estate;
    a. This bund needed to be approximately 300 mm high (+ freeboard) and sit above 74.25 m AHD to flood proof the area.
2. Modest bunding along the current western town boundary, following School Road and west of Dodemaids Road (behind Alto Motors). This feature prevents significant overland flows entering the urban portion of town channelling them to the western edge of town;
3. Manipulating the topography of Contour Drain in order to simulate improved maintenance. This essentially involved flattening the base of the Drain between the two banks in order to increase the capacity;
4. Manipulating the topography of Contour Drain to represent culvert upgrades at each of the crossings. This was achieved through removing each crossing from the model topography, which effectively assumes that culvert upgrades would have the capacity to convey the 100 year ARI flow without causing any afflux (upstream flooding);
5. Modify the elevation of the Contour Drain to convey greater runoff to the west, and;
6. Increasing the capacity in the Reserve Road Drain and table drain running along the northern highway service road, again through manipulation of the existing topography.

11.3 Practical Mitigated Condition

The practical mitigation option consisted of all measures identified in the common works list (described in Section 11.2) coupled with a small storage (13,700 m³) on the western edge of the current township boundary (south side of the Highway). The small retarding basin used 2 x 1200 mm x 600 mm box culverts to attenuate the 20 year ARI flow back to a level (~ 5 m³/s) where the culvert crossing at Reserve Road could more effectively convey flood water through to the Contour Drain. A concept design of these works is shown in Figure 11-1. The modest bunding in Figure 11-1 shows the most likely alignment should this mitigation option be adopted. Mitigation modelling by Water Technology used a simplified alignment to prove the concept was viable. It is noted further Engineering design would be required to integrate such features into the landscape.

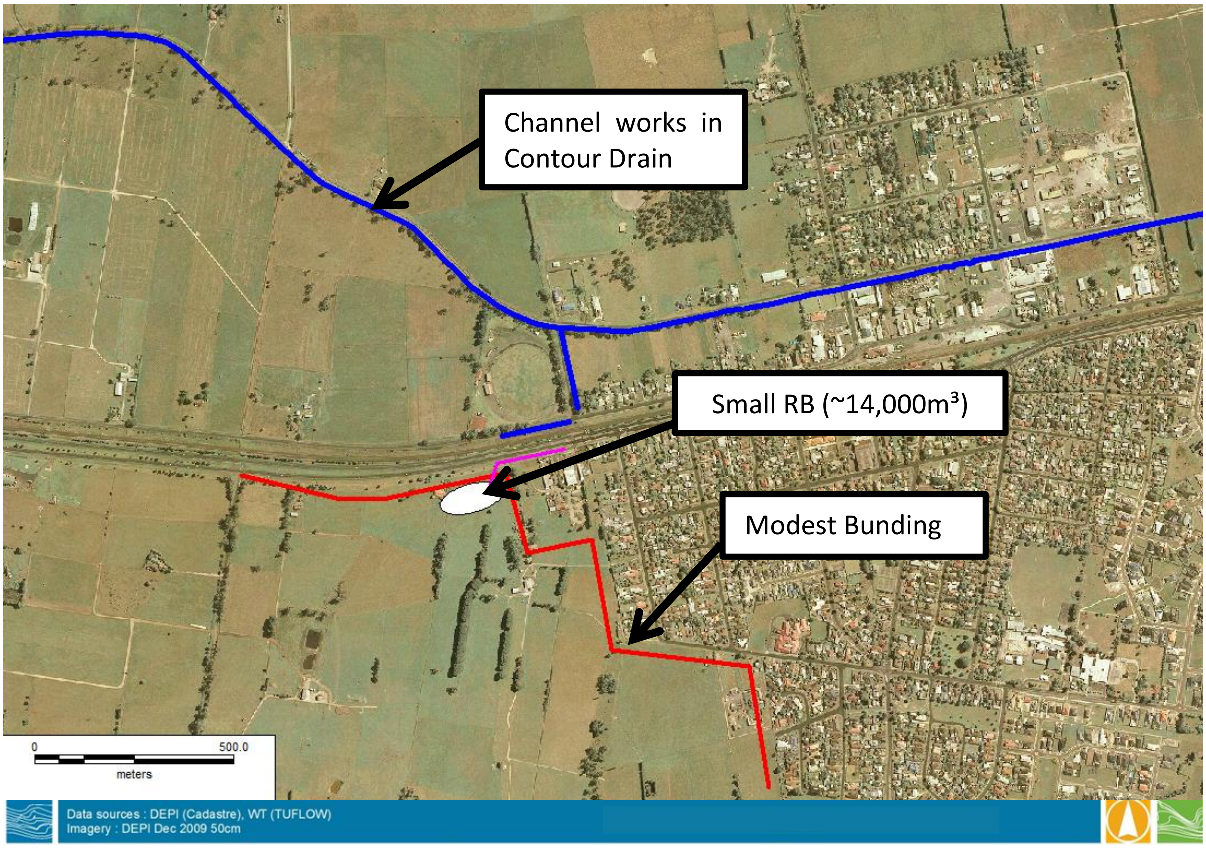


Figure 11-1 Practical option – concept design

11.3.1 Practical Mitigated Condition – 20 year ARI results

Flood modelling results showed that if the small basin was constructed alongside the "common works", flooding behind the highway from Dodemaids Road, through to Seven Mile Road would be practically removed with only a small number of residential parcels inundated. Flood depths throughout the area were reduced by up to 250 mm in the 20 year ARI event. This was largely as result of the Reserve Road crossing and Contour Drain functioning more effectively.

Figure 11-2 and Figure 11-3 show the flood depth results and the ultimate difference in flood depths resulting from these works. It should be noted that the drainage system results for events greater than 20 year ARI would likely be closer to existing conditions as the basin volume was only designed to manage 20 year ARI flows.

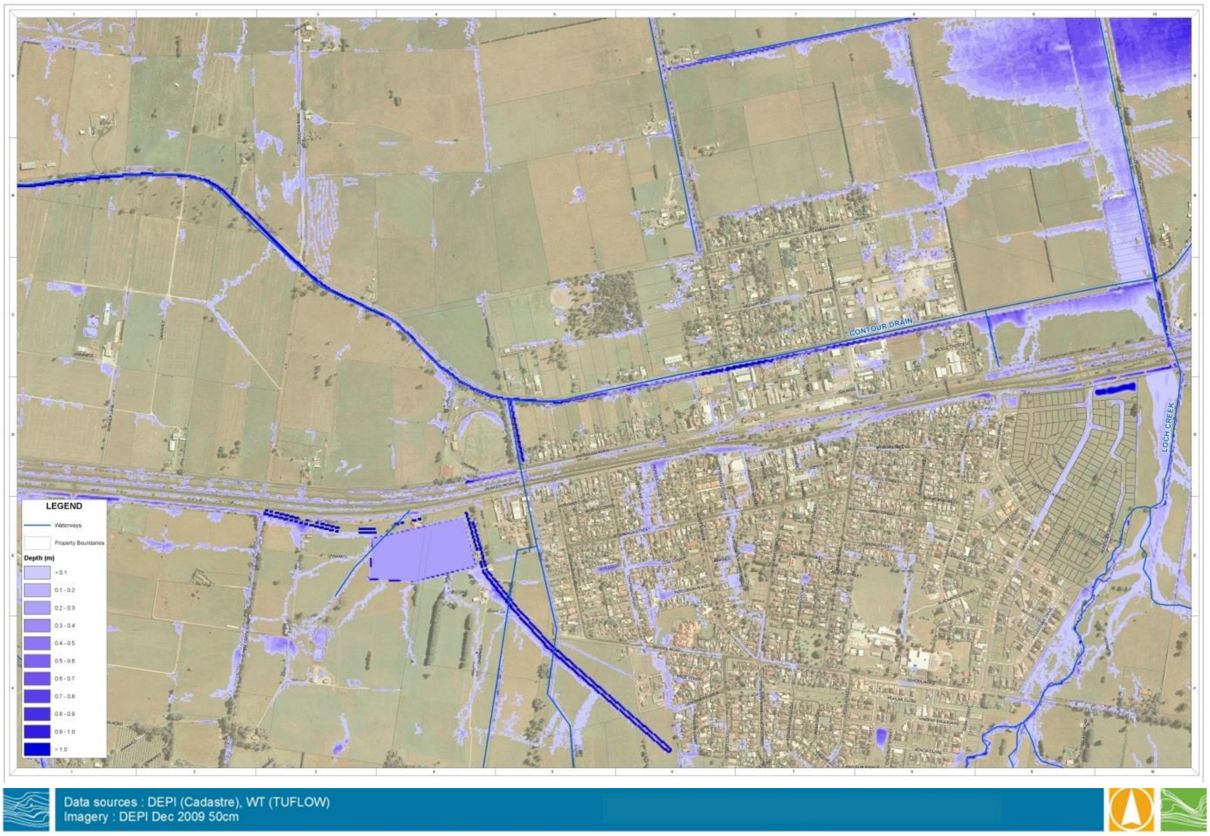


Figure 11-2 Practical mitigation option – 20 year ARI depth plot

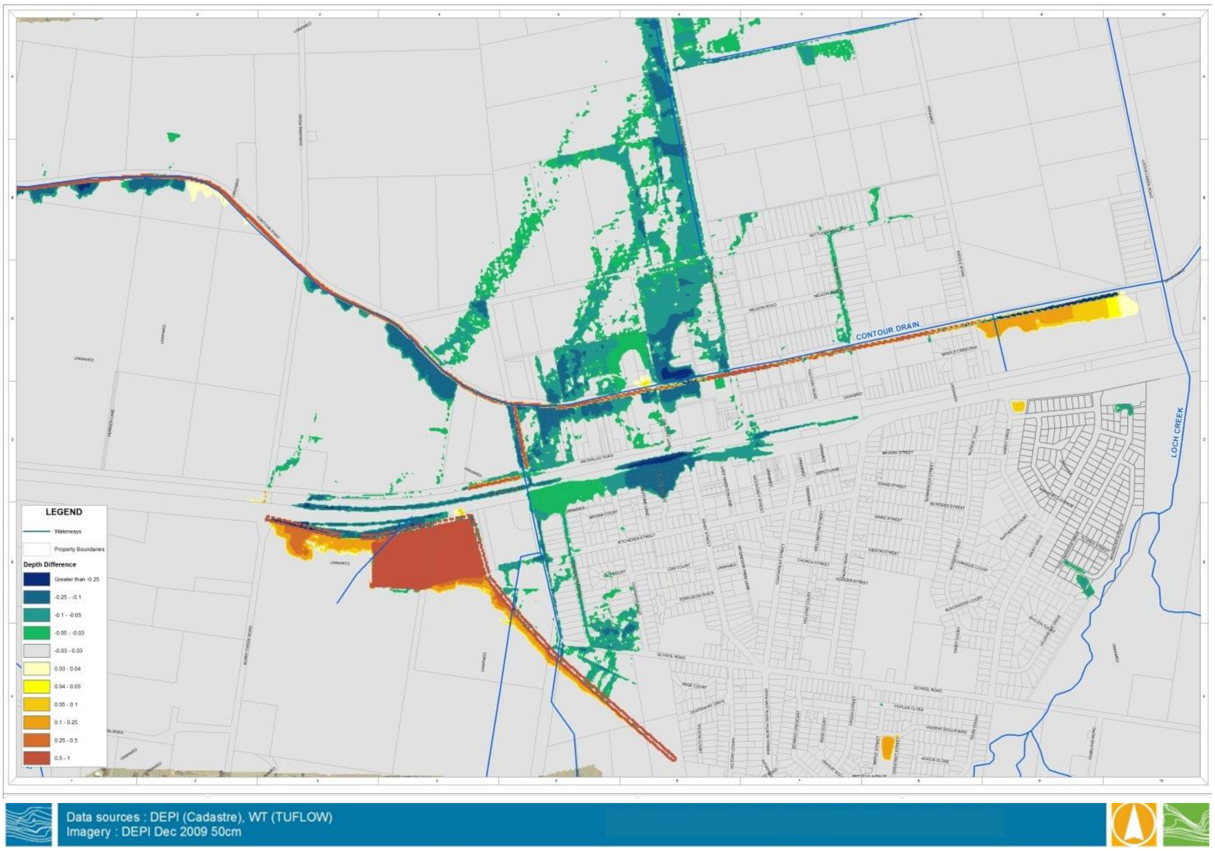


Figure 11-3 Practical mitigation option – 20 year ARI Depth Difference Plot (Existing – Mitigated Scenario) showing reductions in flood depth

11.4 Additional Modelling requested by BBSC - Mitigation Modelling Results

11.4.1 Overview

Flood modelling by Water Technology showed that due to the nature of the terrain, it would not be practical to provide 100 year flood protection to all parts of Trafalgar, so proposed Practical Mitigation option.

Council was however interested in exploring other options which may reduce the extent of inundation further, so two additional modelling runs were carried out. The adopted options were then further refined in a workshop held with BBSC on the 17th of October 2014.

The modelling was completed on the assumption that development of land east of Sunny Creek recently rezoned RZ1 will be designed such that it's not inundated by runoff from the south (e.g. lot levels to be raised and roads to be designed to carry major runoff out of the development). Please note that the modelling for this option by Water Technology did not allow for the raised lot levels within proposed development, consequently the proposed development is shown as inundated.

BBSC Option 1

The objective of option 1 was to ensure that runoff from the Strzelecki ranges (to the south) did not contribute to inundation of the land recently rezoned RZ1 (east of Sunny Creek). It was hoped that with the removal of the significant external flow, drainage features (particularly at Reserve road) would then be able to effectively move the urban stormwater into the Contour drain system.

Option 1 involved construction of a retarding basin (1,000 m^3) on the south side of the Princes highway, as well as a drainage channel to direct runoff to the Contour Drain and eventually the Moe River. Figure 11-4 shows the location of proposed retarding basin and drain. It is noted that the drainage channel location in the model had to be downstream of the hydraulic model's inflow polygons (shown in Figure 11-4) to capture overland flow. If this option was to be further investigated it is recommended that the drain moved slightly south aligning with the 80 m AHD contour. This alignment optimises natural grades and protects additional land. The capacity of this drain should be approximately 0.6 m^3/s.

Water Technology also assessed the proposal to construct a number of retardation basins located on the south side of the proposed drain to determine if the depth of inundation could be reduced further, however the retardation basins did not provide significant reduction in observed flooding.

BBSC Option 2

The objective of option 2 was to provide a comprehensive mitigation solution to the western portion of the Trafalgar Township. Broadly the concept involved moving as much of the townships surface water as practically possible away from the Reserve road crossing and into a large drainage reserve on the north side of the Princes Highway. It was hoped that hazardous flooding along the Princes highway could be significantly reduced, with homes which are currently likely inundated in a 100yr ARI event effectively flood proofed.

Option 2 comprised of 16 deep culverts under the highway, railway line and Waterloo Road (1.8 m wide by 0.9 m high – with a capacity ~16m^3/s). This crossing purpose was to reduce the extent of inundation south of the highway. Council's land north of the Highway, bounded by Reserve Road, Contour Road and the Highway was used to provide retardation, noting that proposed playing fields (and equestrian site) could not be used for storage and may need be raised to ensure they are flood proofed. The storage volume provided was approximately 200,000 m^3. It is anticipated that the retarding basin feature, would be coupled with Water Sensitive Urban Design features (such as wetlands) and water re-use systems to achieve an integrated solution for the township. The retarding basin was modelled with a nominal low flow outlet. The storage volume could be reduced depending on the size of the outlet adopted.

An excavation adjacent the contour drain to just above the invert level including bunding (~0.6m high) has been included in concept to provide additional storage. This option also included the construction of major underground drainage features (sizes range from 0.9 m wide by 0.3 m deep to 1.5 m wide by 0.9 m deep) within the existing residential development along School Road. These works inside the existing residential area were included to remove some of the overland flow away from the Reserve Road crossing (refer to Figure 11-5).

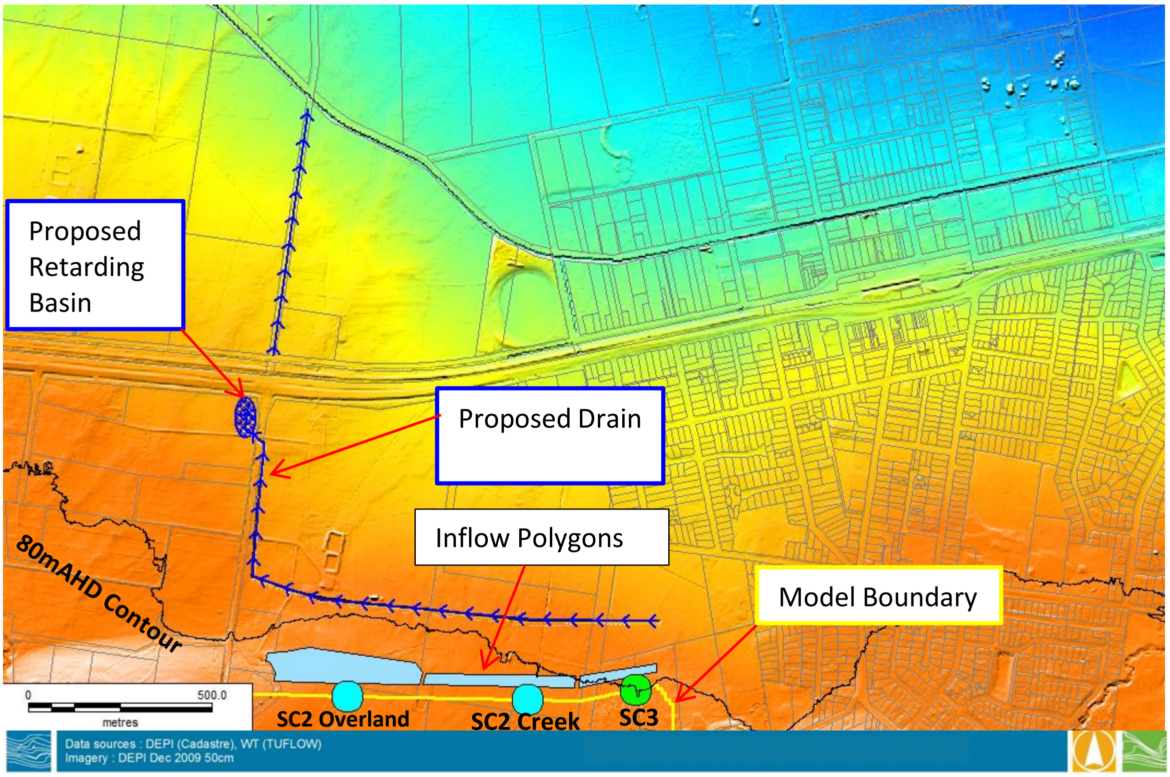


Figure 11-4 Mitigation Option 1

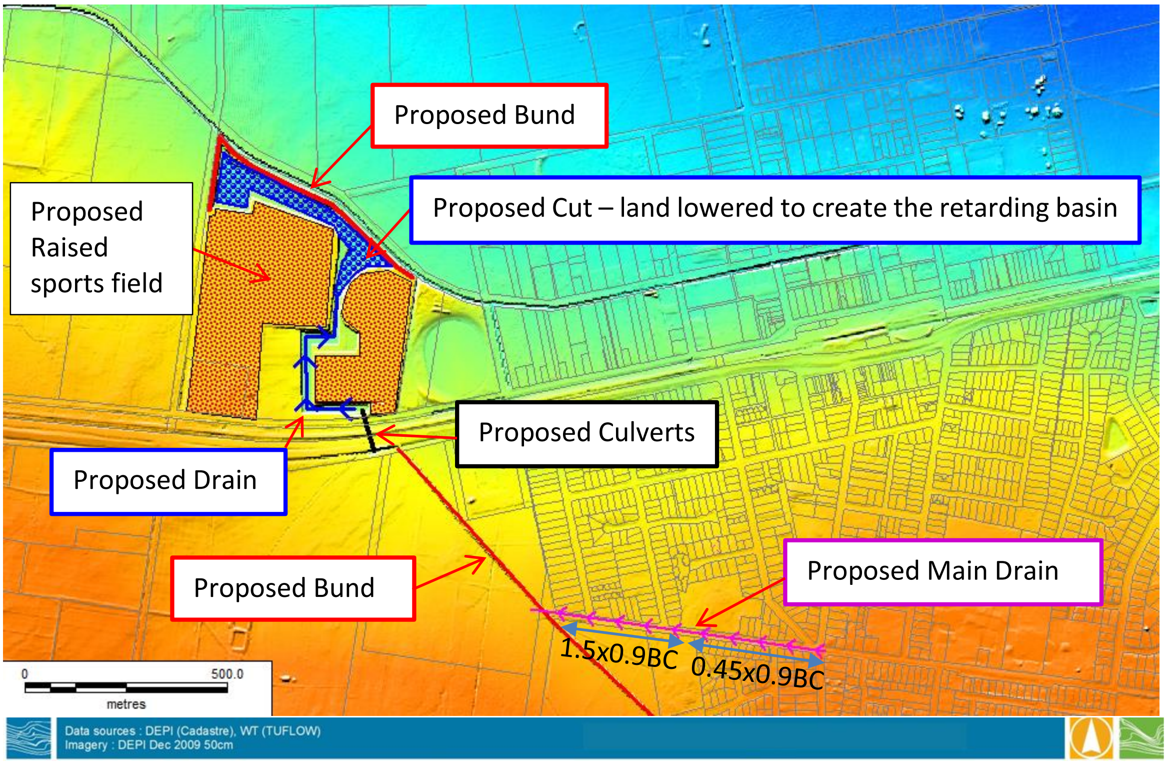


Figure 11-5 Mitigation Option 2

11.4.2 Option 1 Mitigation Results

Flood modelling results showed that if the drainage channel and the small basin were constructed, flooding of the land east of Sunny Creek (recently zoned RZ1) will be reduced. This was largely as a result of the reduction of inflow runoff from the south. The modelling did not however reduce 100 year ARI flooding back to a low hazard level south of the highway, around the Reserve road crossing.

Figure 11-6 and Figure 11-7 show the flood depth results and the ultimate difference in flood depths resulting from these works.

It is noted that the location of the proposed drainage features were not set to their optimal locations, this was a result of the hydraulic model schematisation. The goal the mitigation option modelling (option 1) was to prove the concept and determine the required feature capacities. It is anticipated this would need to be refined if the mitigation option was to be further progressed. Available land and consequent negotiations with appropriate land owners would need to be undertaken to determine the ultimate alignment and resulting feature sizing.

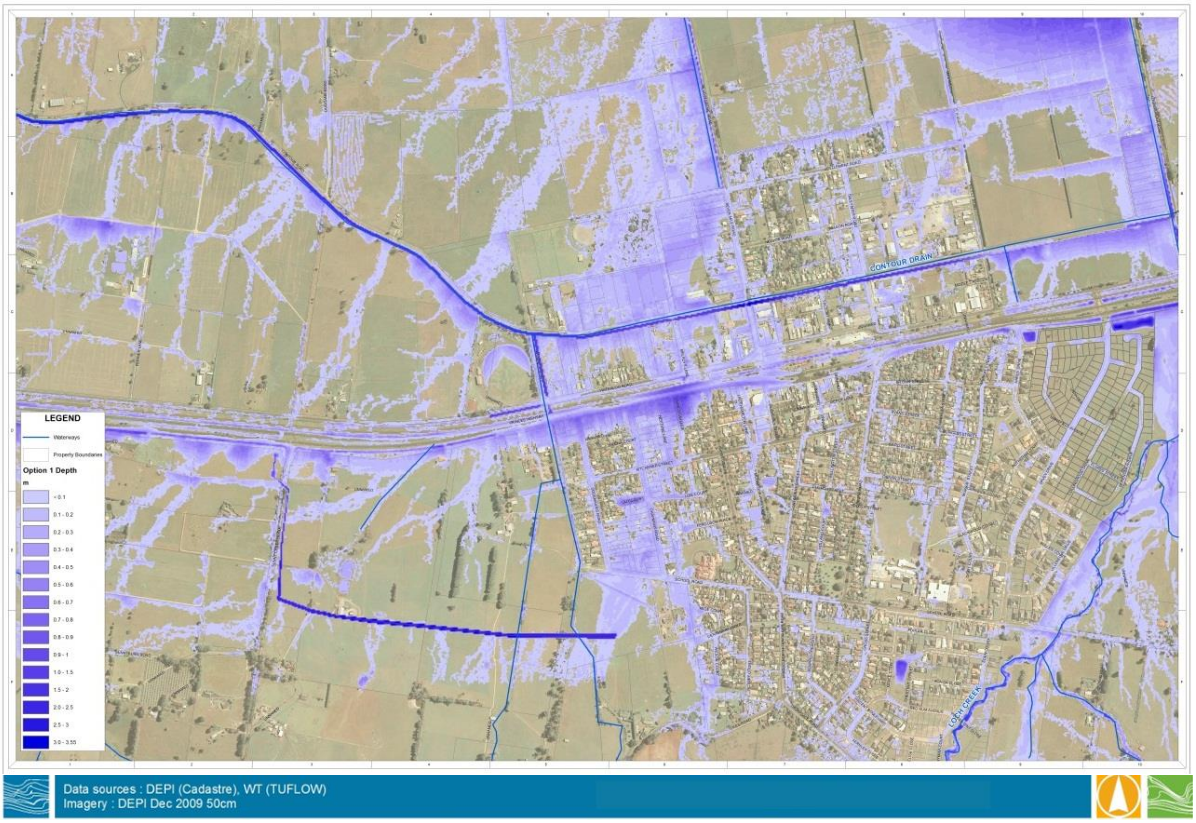


Figure 11-6 Mitigation Option 1 Depth Plot (100yr ARI flows)

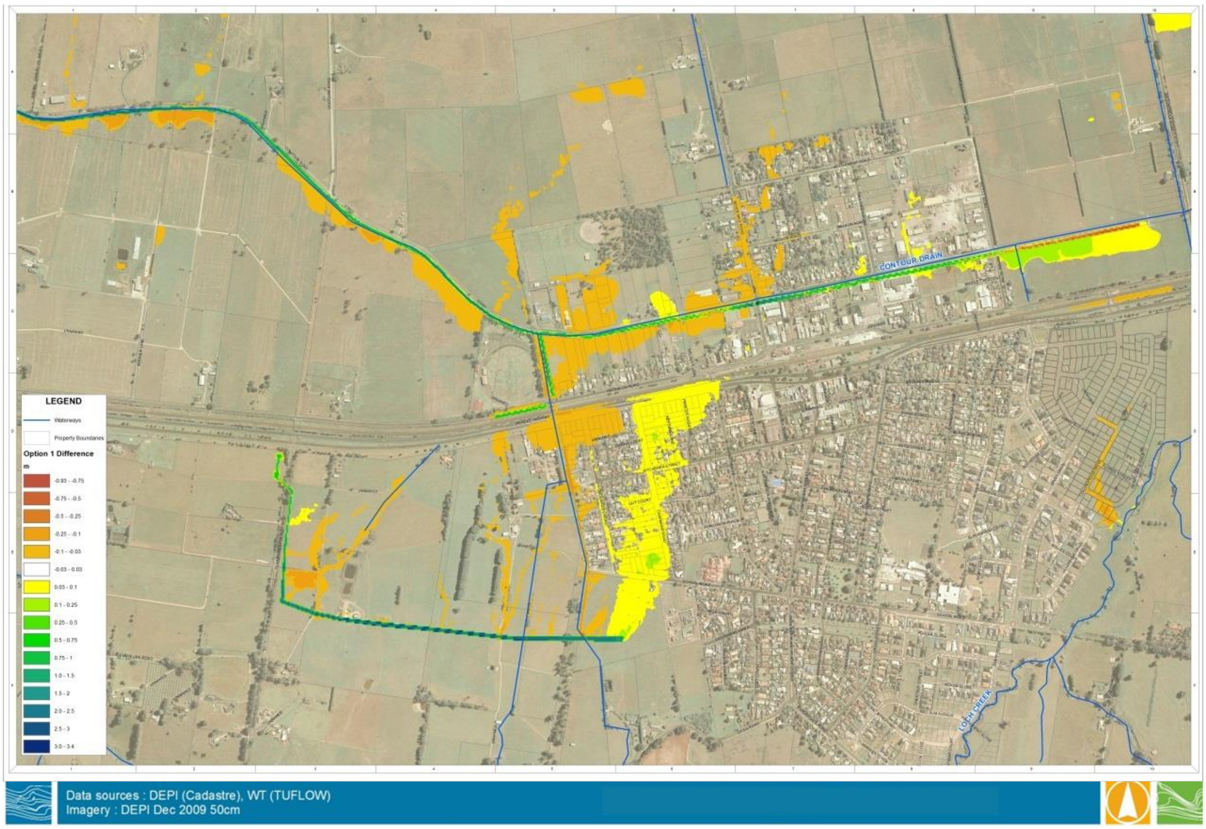


Figure 11-7 Mitigation Option 1 Depth Difference Plot, 100 year ARI

11.4.3 Option 2 Mitigation Results – 100 Year ARI

Flood modelling results showed that if the major road drainage in School Road was constructed, along with creating a new large crossing (under the highway, railway line and Waterloo Road) and providing a bund around the Council's reserve, significant reduction in the flooding of the existing and future residential developments can be achieved, up to reductions in depth of 0.9m.

Figure 11-8 and Figure 11-9 show the flood depth results and the ultimate difference in flood depths resulting from these works.

It is noted that depending on the outcomes of more detailed assessments the playing fields and equestrian site within Council reserve may need to be raised to ensure they do not become inundated during a flood event. Water Technologies flood modelling assumed these facilities needed to be protected from a 100 year ARI event. With further design that considers the Contour Drains capacity and outflow from the bunded retarding basin, basin volumes and foot prints could likely be reduced. The current results (using a nominal low flow outlet) show the peak water surface elevations inside the retarding basin (100 year ARI event) to be approximately 70 m AHD. If it is acceptable to inundate sports fields, the alignment of the storage area could be reviewed at the detailed design stage. The bund should also provide sufficient freeboard to the top water level.

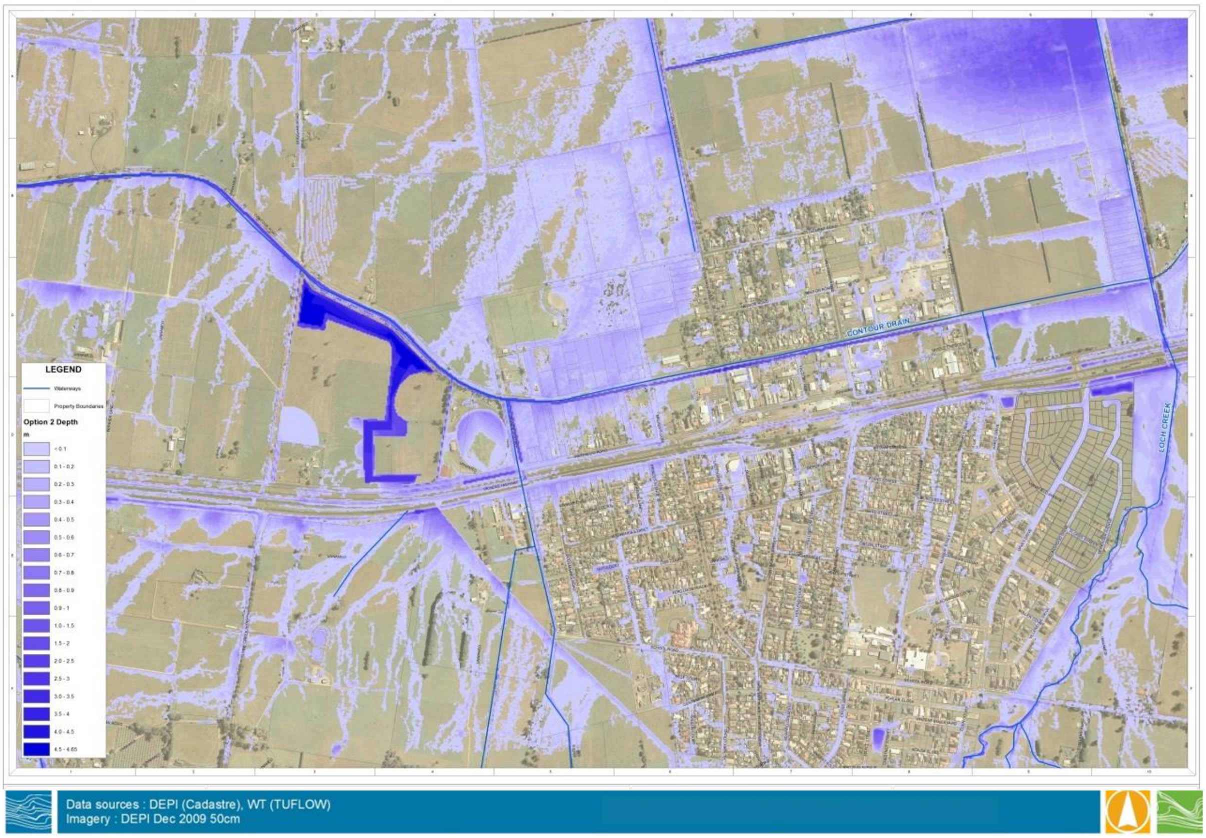


Figure 11-8 Mitigation Option 2 Depth Plot (100 year ARI)

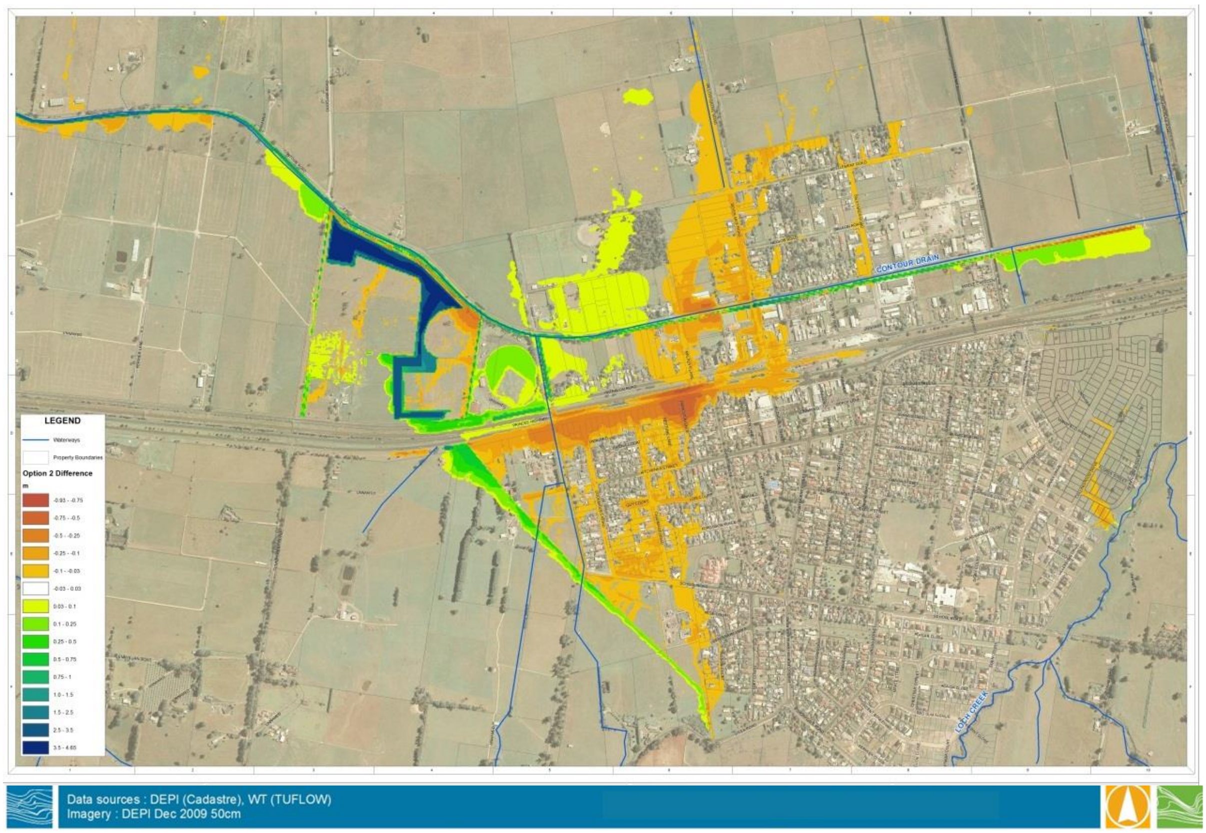


Figure 11-9 Mitigation Option 2 Depth Difference Plot (100 year ARI)

11.5 Costing and Recommendations

Preliminary "order of magnitude" cost estimates has been undertaken for the three mitigation options presented in Section 11.4. Table 11-2 shows the preliminary project estimates. Further detail of this analysis is provided in Appendix B.

Table 11-2 Preliminary Cost Estimates

Mitigation Option	Sub-total	Contingency (20%)	GST	Total
Practical Option	\$1.5M	\$300K	\$150K	\$2M
Option 1	\$1M	\$200K	\$100K	\$1.3M
Option 2	\$18M	\$3.6M	\$1.8M	\$23.4

The following assumptions are applicable to the cost estimates above.

1. Melbourne Water 2012 rates were used for the estimates where available and indexed appropriately;
2. No land acquisition is taken into consideration;
3. It is assumed that spoil excavated on site is unsuitable for reuse on site and will be disposed of offsite, it is assumed that the spoil is not contaminated;
4. It is assumed that fill will be able to be imported to site;
5. There is no hard digging accounted for in the estimates;
6. Topsoil is to be stockpiled and reused;
7. Rock pitching is to be used at bends in channels and at outlets for energy dissipation;

8. No re-use of road pavement is allowed for;
9. A bulking factor of 1.2 has been used;
10. A contingency of 20% has been included in the estimates;
11. Service allowances are estimates only and further detailed analysis of the existing services is required to accurately estimate the value of location, protection and potentially diversion/reinstatement of services. It should be noted that this can significantly impact the estimated cost.

12. RECOMMENDATIONS ON THE LSIO AND FO AND EMERGENCY RESPONSE

12.1 Overview

A component of the Trafalgar Flood study project was the task of recommending an extent of a future Land Subject to Inundation Overlay (LSIO) and consider implications for flood emergency response.

Anecdotal evidence and preliminary hydrological analysis of the Trafalgar catchment suggested that flooding which impacted the highly populated areas came from two unique mechanisms, flash flooding (or stormwater) resulting from intense rainfall falling on the highly impervious area within the urban growth boundary, and riverine flooding from the Strzelecki Ranges resulting from rain in the upper catchments moving through the catchment and inundating low lying developed areas around Trafalgar. Flooding exclusively from the Latrobe River was considered less significant on the main township but was noted to play a significant role in broader flooding problems for the town.

Due to the moderately steep nature and relatively small size of the upstream catchments (Loch and Sunny Creeks and their adjacent catchments) the system could be considered a flashy catchment (i.e. flooding is caused by flash flood), suggesting the travel times between a significant rain event in the upper catchment and the flooding which impacts Trafalgar township is minimal.

While mapping the LSIO conditions throughout the study area was a relatively simple task involving interpretation of the hydraulic modelling results and well documented guidelines, development of suitable emergency response data was more of a challenging task as emergency management response varies between townships and flood event magnitudes and durations. Considering the unique flood emergency response challenges that were identified and were beyond the scope of this project, outputs were restricted to additional mapping and GIS analysis processes to assist in better understanding the flood risks within Trafalgar.

12.2 Flood Overlays

The delineation of flood overlays is set out in accordance with the WGCMA – "*Guidelines for development in flood prone areas"* adopted by the WGCMA in 2013. The WGCMA guidelines are influenced by all relevant guidelines including the Department of Infrastructure -2000 "*Applying the flood provisions in planning schemes"* and the most recent flood safety research in the Australian Rainfall and Runoff Revision (Project 10), which investigates appropriate safety criteria for people. This project has redefined acceptable flood hazard criteria, reducing flood depths that are considered hazardous.

The WGCMA uses four main planning overlays to manage flooding within their region. They are defined in the guidelines as follows:

Urban Floodway Zone (Clause 37.03 of the Planning Scheme)

The UFZ applies to riverine flooding in urban areas. Unlike the overlays, the UFZ controls land use as well as development, with land use being restricted to low intensity uses such as recreation and agriculture. Development is generally not encouraged in the UFZ.

Floodway Overlay (Clause 44.03 of the Planning Scheme)

The FO applies to riverine flooding in both rural and urban areas where there is a flood risk and there is less need to control land use. Particular types of development are not encouraged but buildings and works associated with low intensity uses such as agriculture may be permitted. Key considerations are whether the development will obstruct flood flows or increase flood risk.

Land Subject to Inundation (Clause 44.04 of the Planning Scheme)

The LSIO applies to riverine flooding in both rural and urban areas. Areas covered by the LSIO can have a similar flood risk to the UFZ or FO areas but the extent of this risk may not as yet have been mapped precisely.

Special Building Overlay (Clause 44.05 of the Planning Scheme)

The SBO applies to overland or flash flooding in urban areas. The purpose of the SBO is to ensure that flood waters are not obstructed or diverted by development. The SBO is only used in limited areas in Gippsland due to a lack of mapping of overland flow paths.

12.2.1 Post Processing of the 100 year ARI results to define the LSIO

The model results were filtered and edited according to the following criteria, the method is consistent with that applied in other flood studies by BBSC:

1. The raw modelling results are filtered twice once using;
   - Maximum(V*D) >= 0.008 m^2/s or Maximum(d) >= 0.05m
   - In addition islands < 400m^2 are removed.

   And again using
   - Maximum(V*D) >= 0.008 m^2/s or Maximum(d) >= 0.05m
   - In addition islands < 600m^2 are removed.
2. Both sets of results are then used to estimate the percentage each parcel inside the study area is flooded;
3. Land Parcels (from both datasets) which have <=5% of the parcel flooded are identified and reviewed with parcels on the “flood fringe” (i.e. outside the main flow paths) manually deleted.
4. The two sets of data (i.e. from the 400m^2 and 600m^2 filtering processes) are compared and amalgamated. In this study, the two set of results were practically the same so the 400m^2 results were adopted.

12.2.2 Recommended Planning layers

Towards the conclusion of the study Water Technology were advised by BBSC that the WGCMA only wished to apply the Land Subject to Inundation Overlay inside Trafalgar. Based on the comprehensive and detailed methodology presented in this study (Section 7) Water Technology recommends the following shape (Figure 12-1) to be considered as LSIO layers within the Trafalgar study area. Currently there is no LSIO over the majority this Land.

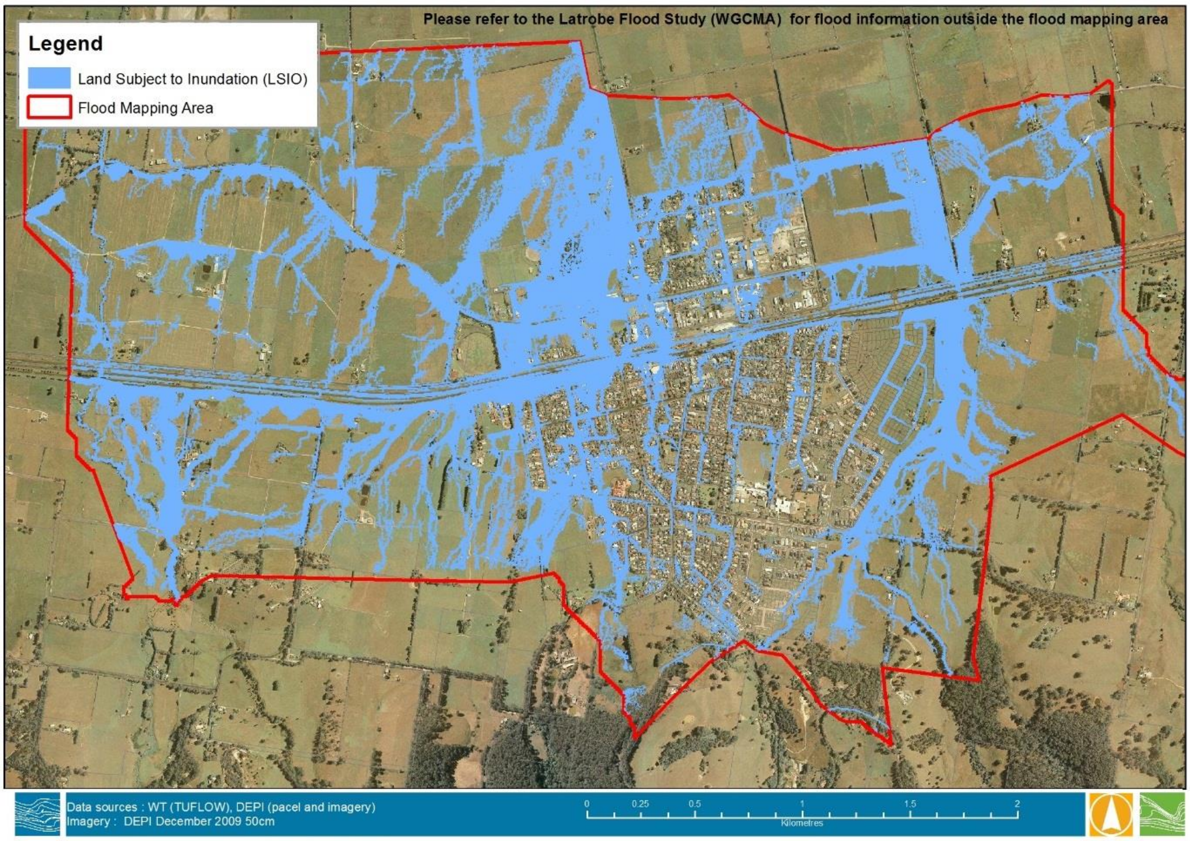


Figure 12-1 Recommended LSIO and FO shape from the Trafalgar Flood study and modelling project

12.3 Development of suitable emergency response data

As discussed earlier, specific flood warning processes or systems were not developed as part of this study, instead a series of maps and tables resulting from post processing flood modelling results were generated.

Details of land parcels inundated are a key parameter for emergency management and planning processes. As no floor level data is available for the Trafalgar area, production of maps of inundation above floor level (a typical output from this type of study) was not possible. In the absence of this data it was proposed to provide a map and table of land parcels which experience inundation greater than 0.1m. This data could then be revisited if and when floor level data is collected in the Trafalgar area. Results of this analysis are shown in Figure 12-2.

Hazard mapping is another key tool which can be used to understand flood risk. Figure 12-3 presents flood risk for all of the Trafalgar flood study.

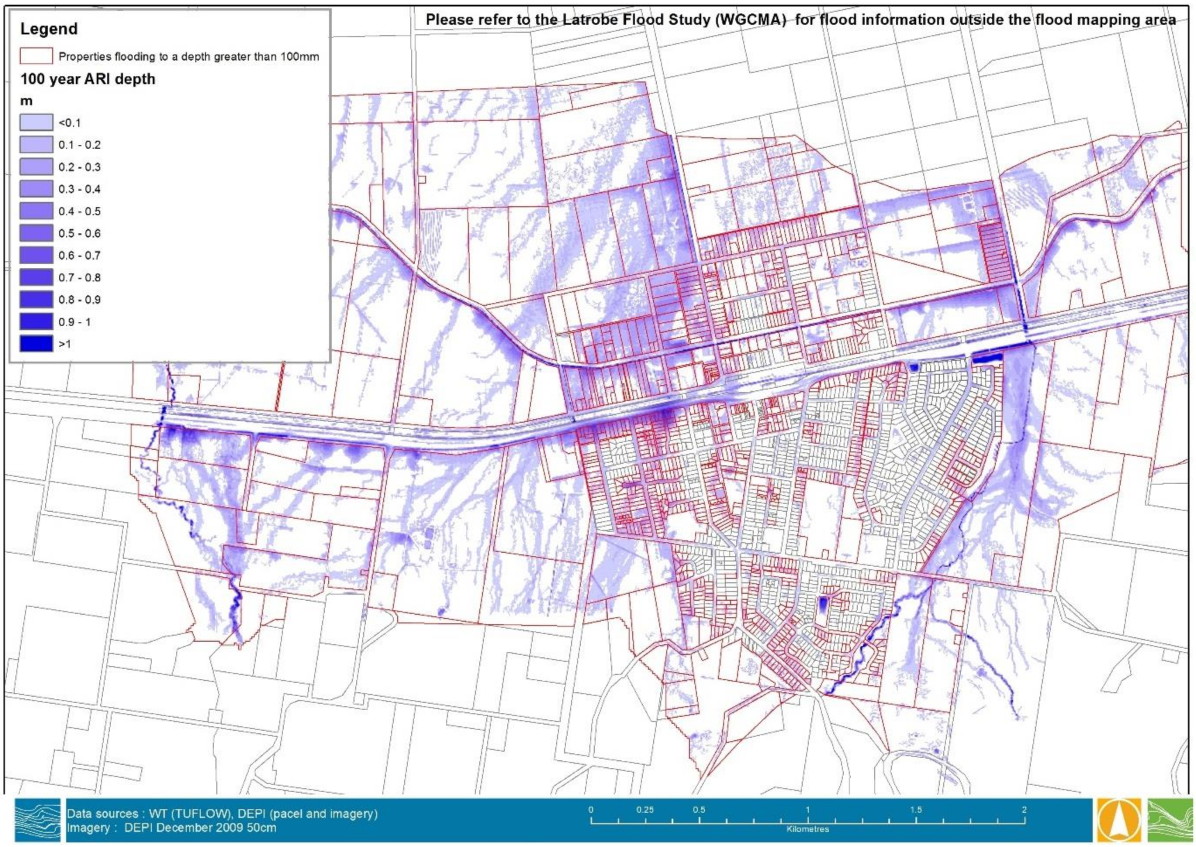


Figure 12-2 Parcels inundated above 0.1m in the Trafalgar study area (highlighted in red)

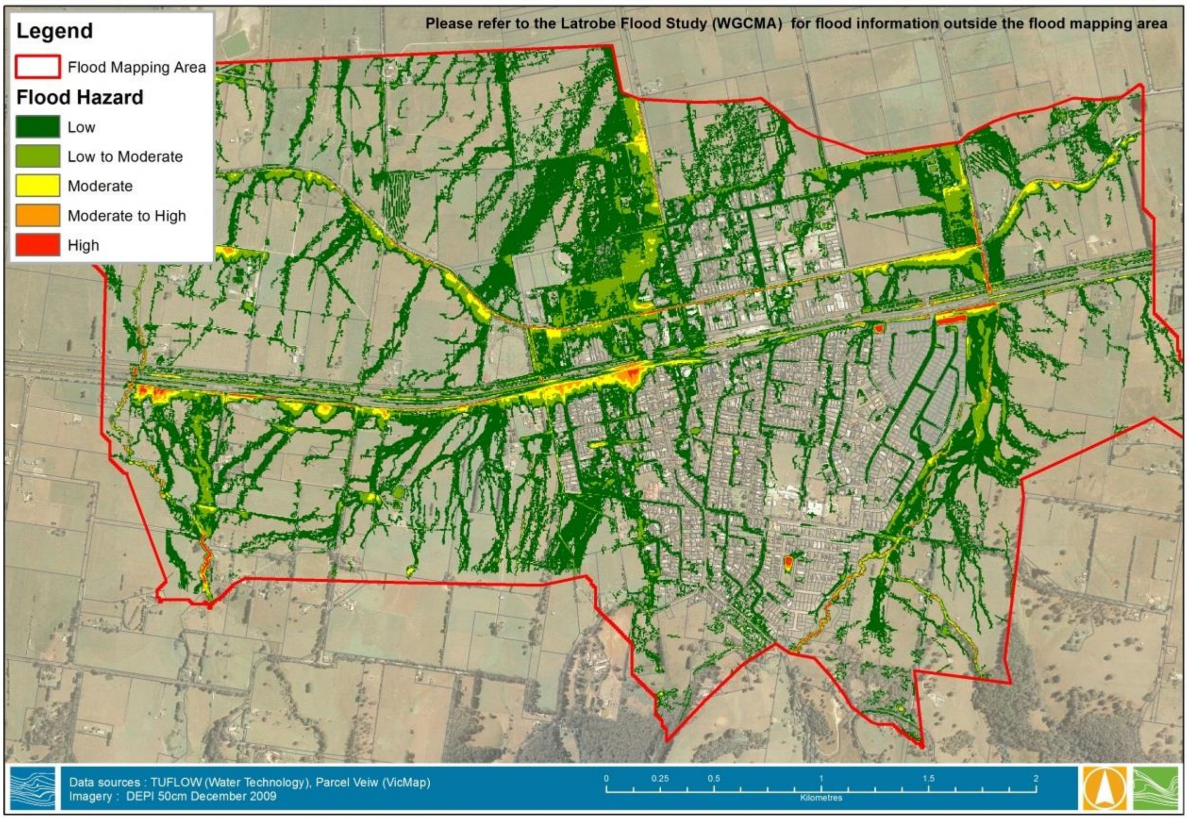


Figure 12-3 100 Year ARI Flood Hazard Risk

13. CONCLUSION

At the conclusion of the project initiation meeting held with BBSC, WGCMA, VicSES and Water Technology, each of the main stakeholders commented on what would constitute a successful study. These key outcomes are listed again below, with a summary of how each has been addressed and met.

WGCMA

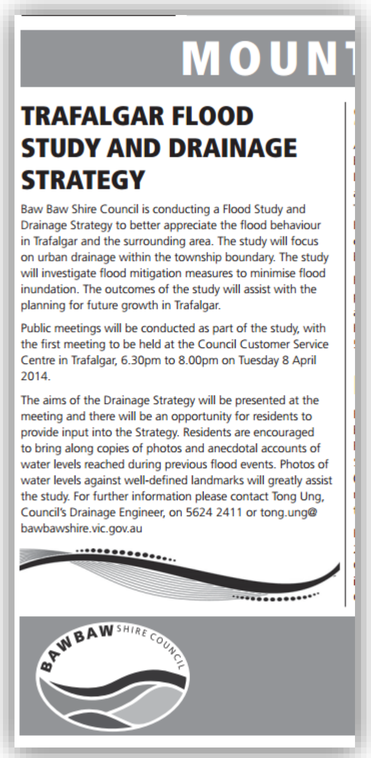
They noted the study will need to address waterway interface issues including:

- Development and flooding concerns associated with the Contour Drain;
    - Flooding throughout Trafalgar, including the Contour Drain has been shown for existing and future developed catchment scenarios.
- Proposed development west of Trafalgar in the Sunny Creek catchment;
    - The future developed conditions modelling undertaken assessed the potential impact of the western development. A study commissioned by the developer was being completed concurrently with this study, with the results of this study likely to influence the requirements for retardation of flows from the development in a range of ARI events and durations back to existing conditions.
- Latrobe (Moe Drain) Flood study showed no impacts on the Trafalgar township, confirming this with the higher resolution study would be a priority for WGCMA;
    - A review of the Latrobe Flood Study was completed with the results through Trafalgar adopted for this study. With the inclusion of higher resolution topographical information, the results of the previous flood study were confirmed.
- Education of the Trafalgar community on the true factors causing flooding in the town (flood concurrence, etc.)
    - The community engagement sessions demonstrated to the community that there are multiple types of potential flooding within Trafalgar. The residents of Trafalgar showed a thorough understanding of these mechanisms and how they may interact with each other, valuable information for input to the study.

BBSC Planning Dept.

- Education of the community is paramount;
    - The community engagement sessions started the discussion with the community. While the community has a thorough understanding of flooding within their area, this study and the resultant flood modelling results will pave the way for the SES to continue with their FloodSafe and StormSafe programs.
- Help BBSC decide if future development (west of the township) should mirror that to the east or should it be approached differently;
    - The results of the study have shown that the areas upstream of the west and east developments are different. More importantly, the downstream conditions, including development levels, tail water conditions and infrastructure beneath the highway and railway line are different. Any development west of the township will require a tailored and well thought out drainage solution.
- Engaging land owners in the Sunny Creek catchment to understand their local catchment and development drainage pressures;
    - The community engagement process identified some areas within the preliminary mapping where Sunny Creek flooding was not representing what had been observed in the past. Modelling was updated based on the feedback from land owners within this area to better represent what has occurred in the past.
- Establish long term planning controls that are defensible and make sense to the community;
    - The overlays created as part of this study will begin the update of the Planning Scheme for Trafalgar.

- Use the Trafalgar newsletter to engage with the community;
    - Advertisements for the community engagement sessions were advertised through the Traf News.



TRAFALGAR FLOOD STUDY AND DRAINAGE STRATEGY

Baw Baw Shire Council is conducting a Flood Study and Drainage Strategy to better appreciate the flood behaviour in Trafalgar and the surrounding area. The study will focus on urban drainage within the township boundary. The study will investigate flood mitigation measures to minimise flood inundation. The outcomes of the study will assist with the planning for future growth in Trafalgar.

Public meetings will be conducted as part of the study, with the first meeting to be held at the Council Customer Service Centre in Trafalgar, 6.30pm to 8.00pm on Tuesday 8 April 2014.

The aims of the Drainage Strategy will be presented at the meeting and there will be an opportunity for residents to provide input into the Strategy. Residents are encouraged to bring along copies of photos and anecdotal accounts of water levels reached during previous flood events. Photos of water levels against well-defined landmarks will greatly assist the study. For further information please contact Tong Ung, Council's Drainage Engineer, on 5624 2411 or tong.ung@bawbawshire.vic.gov.au

BBSC Engineering Dept.

- Quality mitigation options are a priority;
    - Compared with previous flood studies completed by BBSC, Trafalgar provided some challenges with finding suitable mitigation solutions. The mitigation solutions suggested will reduce the more frequent flood events, and when paired with Planning Controls, will ultimately lead to a reduced flood risk within the township.
- Quality community consultation.
    - The two community engagement sessions were a success. With great representation from all types of residents from around the township, invaluable input to the study was gained. The outcomes of this study would not have been possible without the input from the community.

VicSES

- Flood mapping outputs which help VicSES manage flooding in the township including;
    - Hazard maps;
    - Properties inundated mapping; and,
    - Critical duration mapping (similar to the Warragul FS outputs).

  The above maps have been produced as a part of this flood study. The Critical Duration mapping was not a part of the study but is available to the VicSES upon request.

The above shows that the Trafalgar Flood and Drainage Strategy has met many of the initial goals set by the key stakeholders. The main outputs of the flood study were the flood mapping results for a number of scenarios along with the final recommendations for moving forward in reducing flood risk within Trafalgar.

The flood modelling and mapping results have shown:

- The older parts of the township south of the Princes Highway are largely free from significant flooding in 5 year to 100 year ARI events;
- New development to the east of the township is largely flood proofed by the adopted fill levels and internal drainage arrangements. The exception to this is a small section of the development between Berenger Avenue and Vileneuve Drive where a breakout is observed in events greater than 10 year ARI. This breakout could be managed with a bund approximately 300 mm high (+ freeboard) , sitting above 74.25 m AHD;
- The most significant flooding observed starts behind the Princes Highway and stretches from the centre of the township through to the western edge of town. Flood flows in this area continue north east ultimately ending up ponded behind Seven Mile Road; and
    - Managing this flooding is particularly challenging given the existing development, limited grades and limited space for drainage works;
    - Providing a comprehensive mitigation solution was difficult and expensive. Current development pressure in the immediate area provides both opportunities and constraints on managing flooding in the area;
- Flood modelling has shown Sunny Creek flows breaking out and impacting the western edge of the township.

The following recommendations have been made:

- Maintenance of the existing drainage features is the best place to start to manage flooding in the township. This was evidenced in the mitigation modelling and was a clear message coming from both community consultation sessions; and
- The practical mitigation solution suggested will reduce the more frequent flood events, and when paired with Planning Controls, will ultimately lead to a reduced flood risk within the township.

14. REFERENCES

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Melbourne Water (2010a), MUSIC Guidelines, *Recommended input parameters and modelling approaches for MUSIC users*. Melbourne Water Corporation

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APPENDIX A TRAFALGAR TOWNSHIP URBAN FLOOD MAPPING RESULTS (EXISTING CONDITIONS)

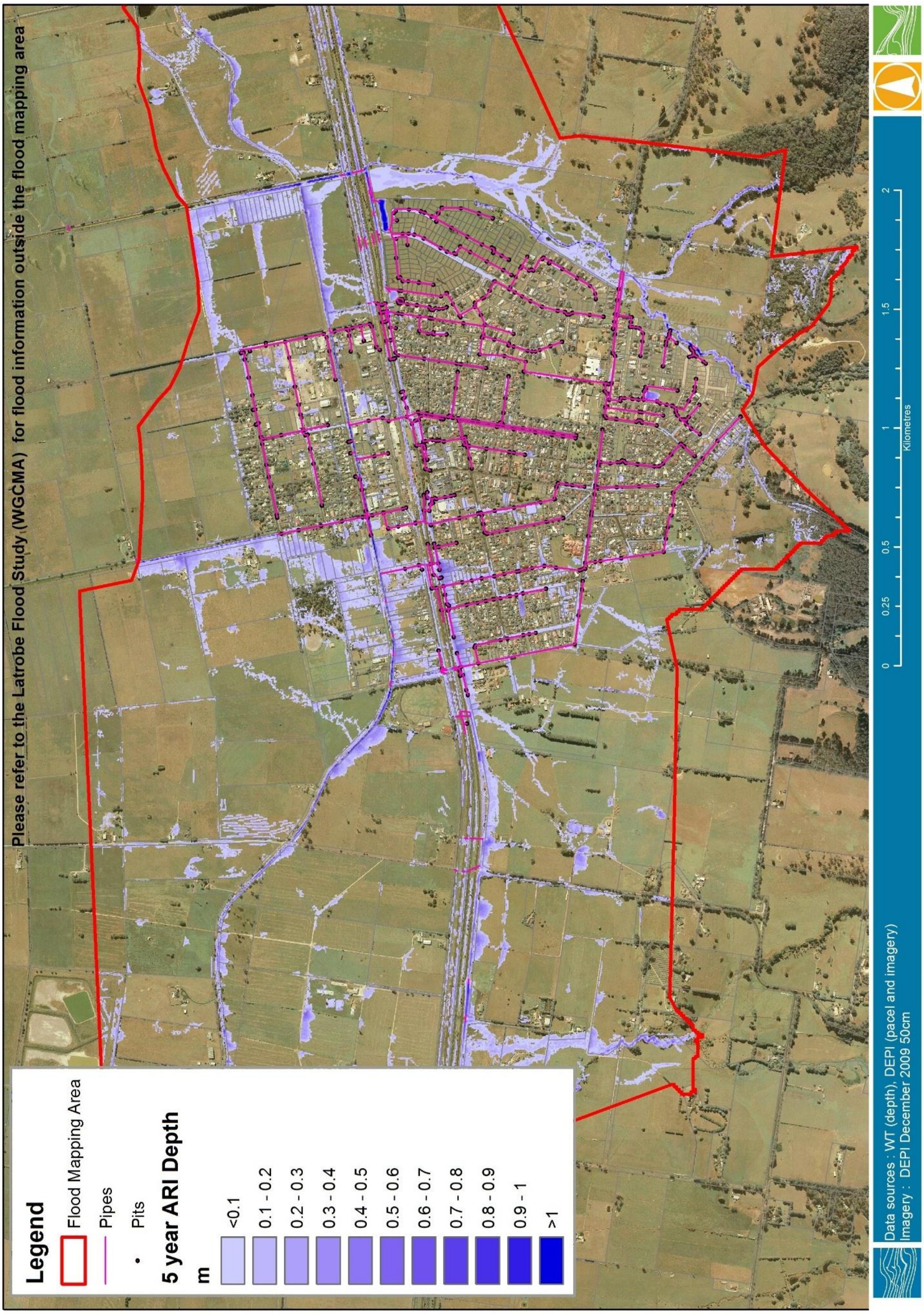

Figure A-14-1 5 Year ARI Flood Maximum Depth Plot – Existing Conditions

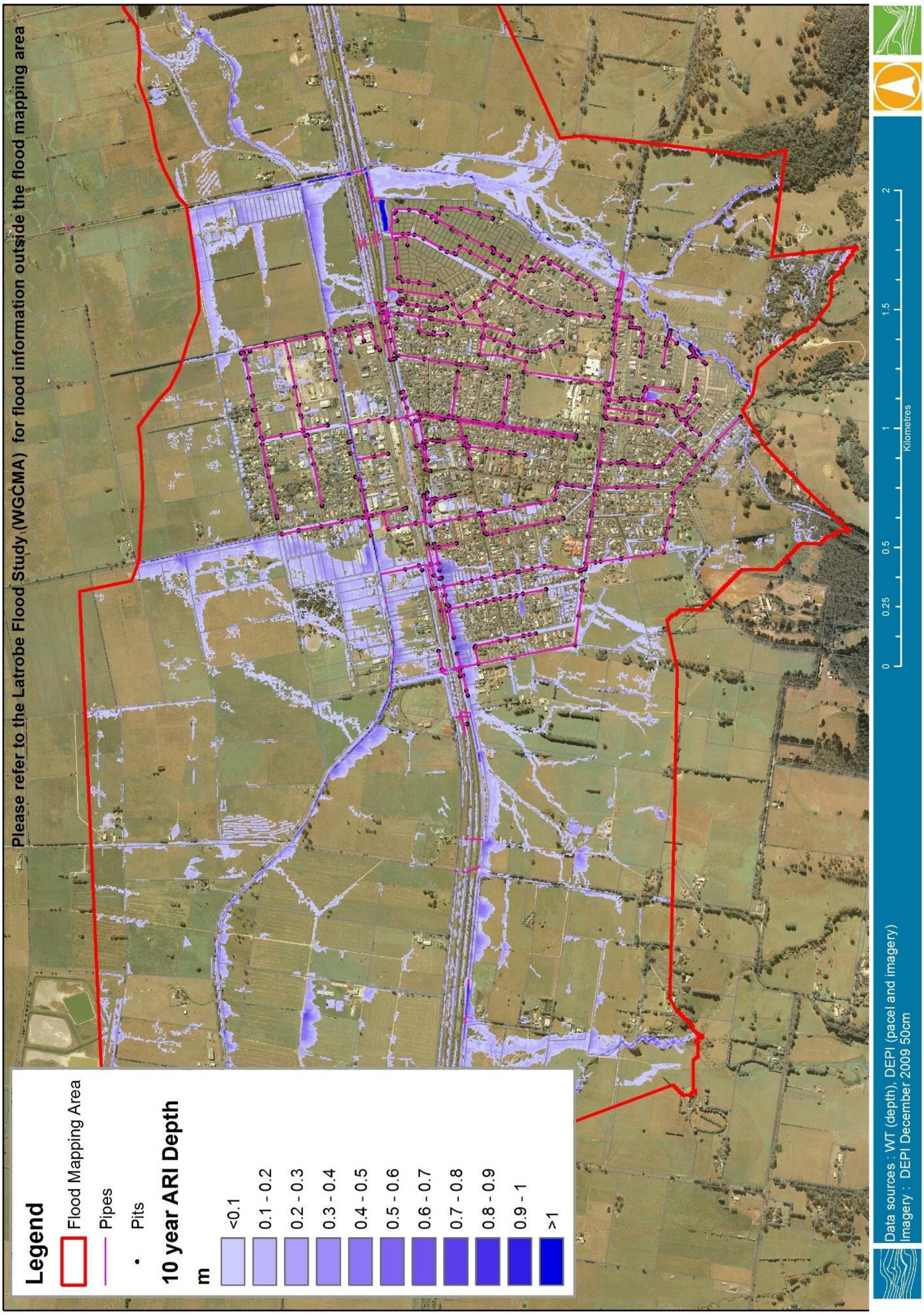

Figure A-14-2 10 Year ARI Flood Maximum Depth Plot – Existing Conditions

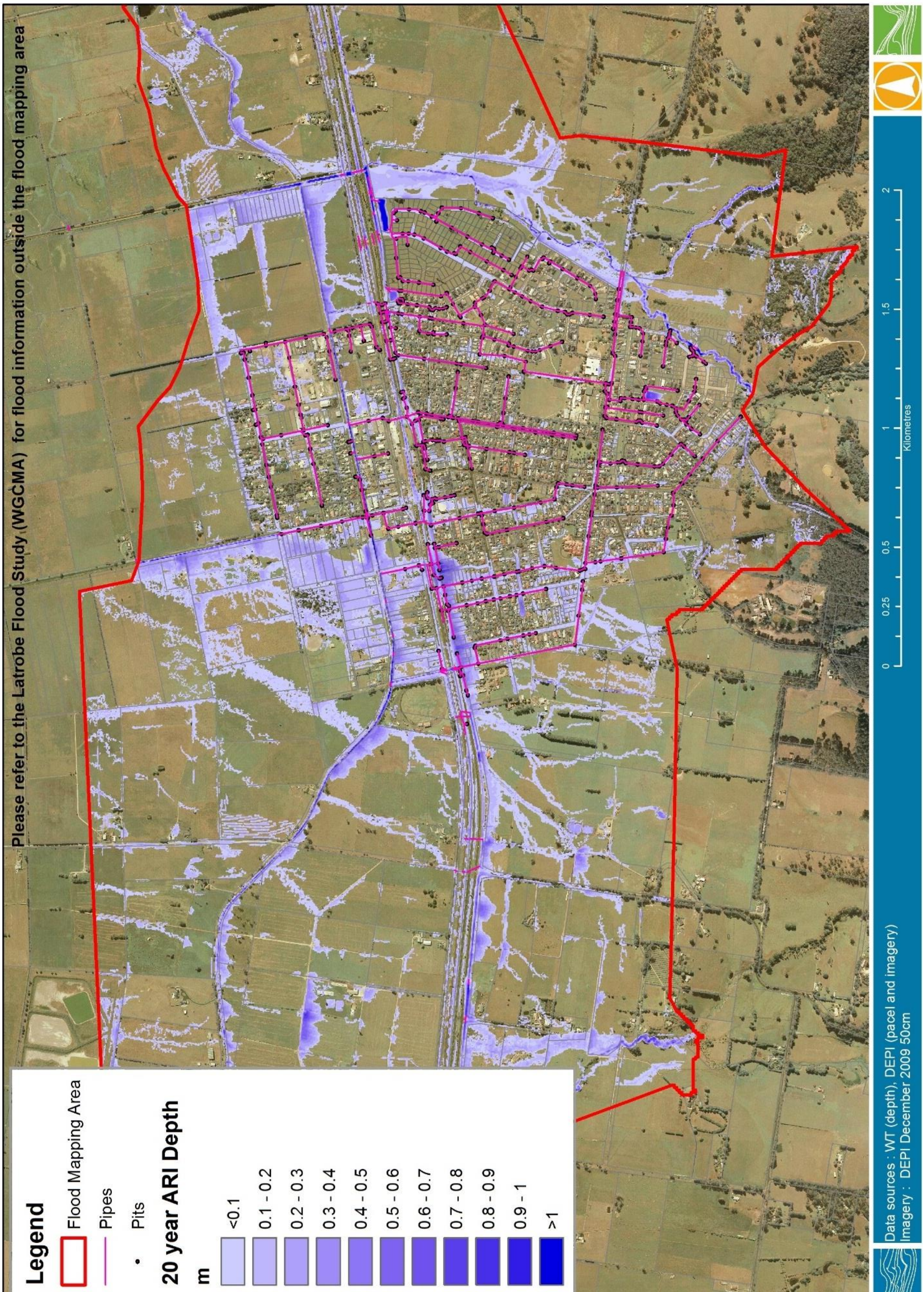

Figure A-14-3 20 Year ARI Flood Maximum Depth Plot – Existing Conditions

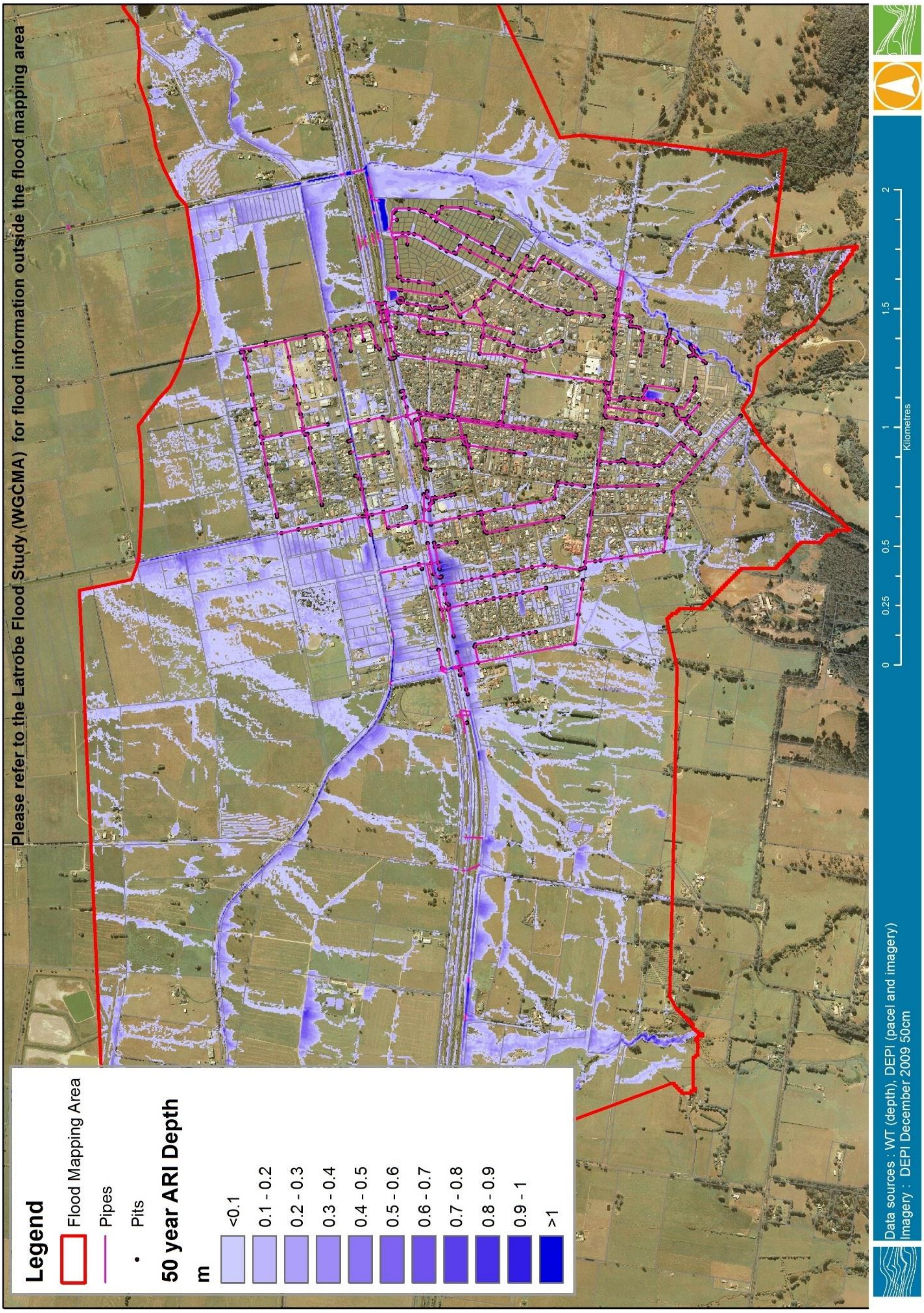

Figure A-14-4 50 Year ARI Flood Maximum Depth Plot – Existing Conditions

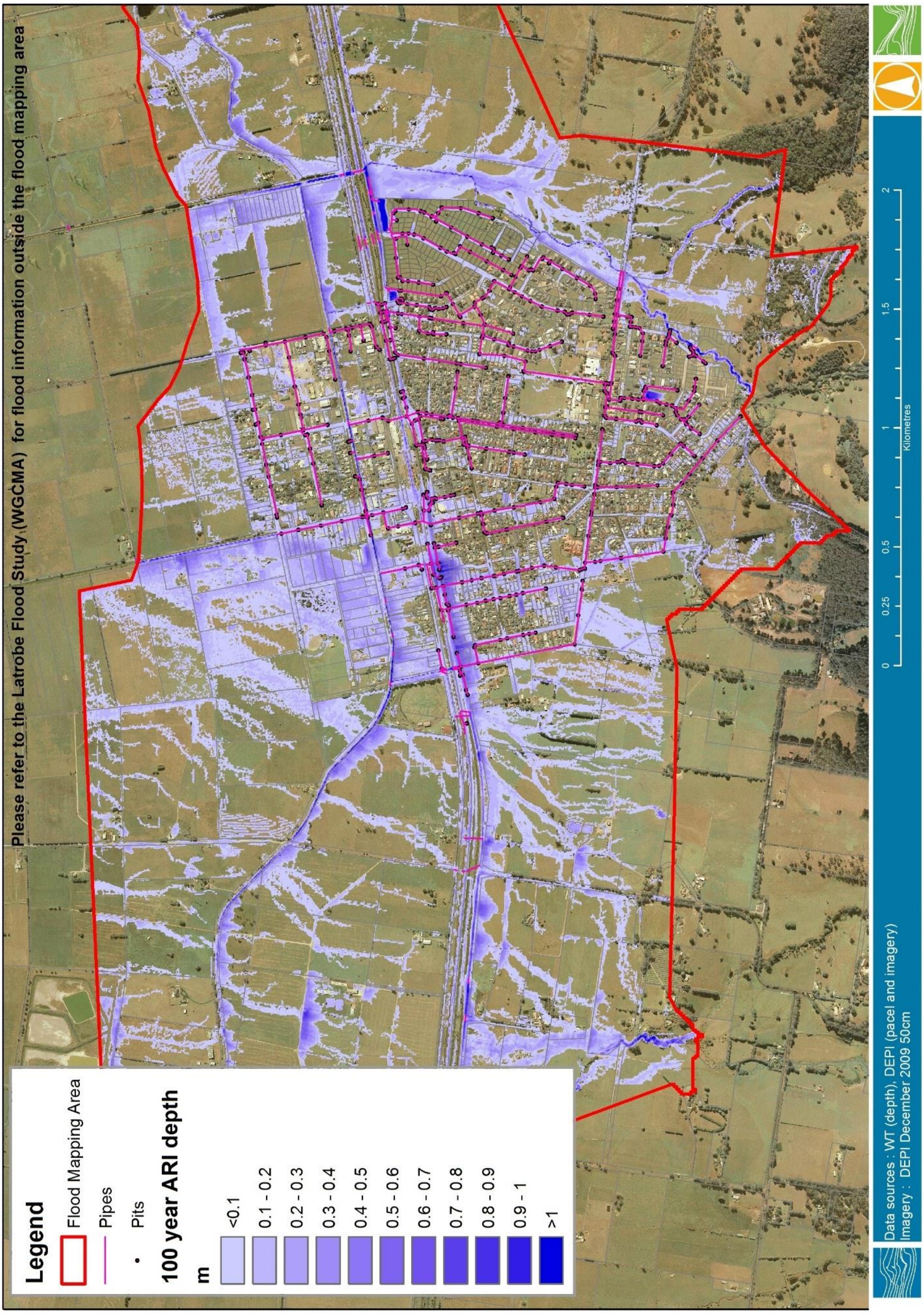

Figure A-14-5 100 Year ARI Flood Maximum Depth Plot – Existing Conditions

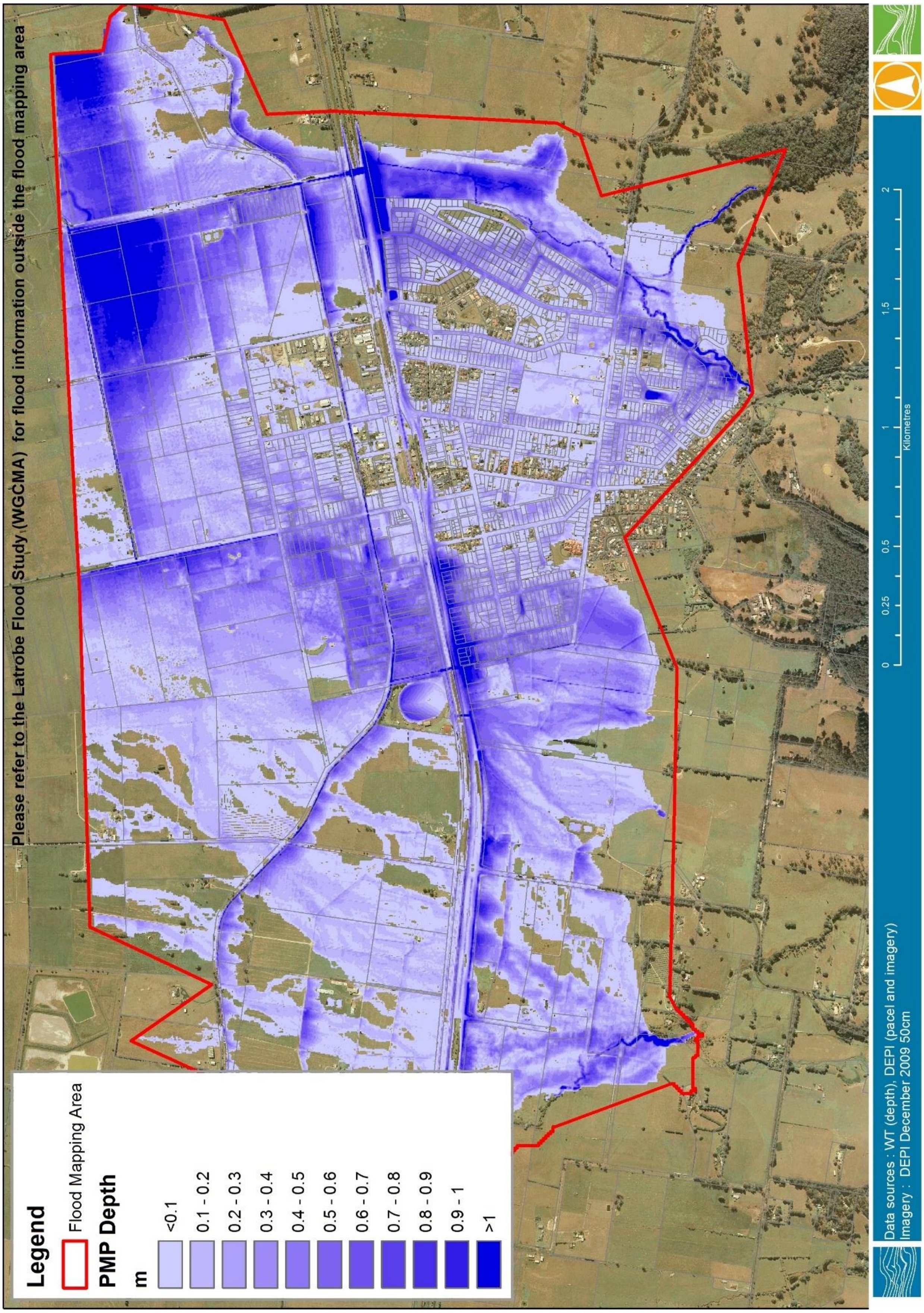

Figure A-14-6 PMP Flood Maximum Depth Plot – Existing Conditions

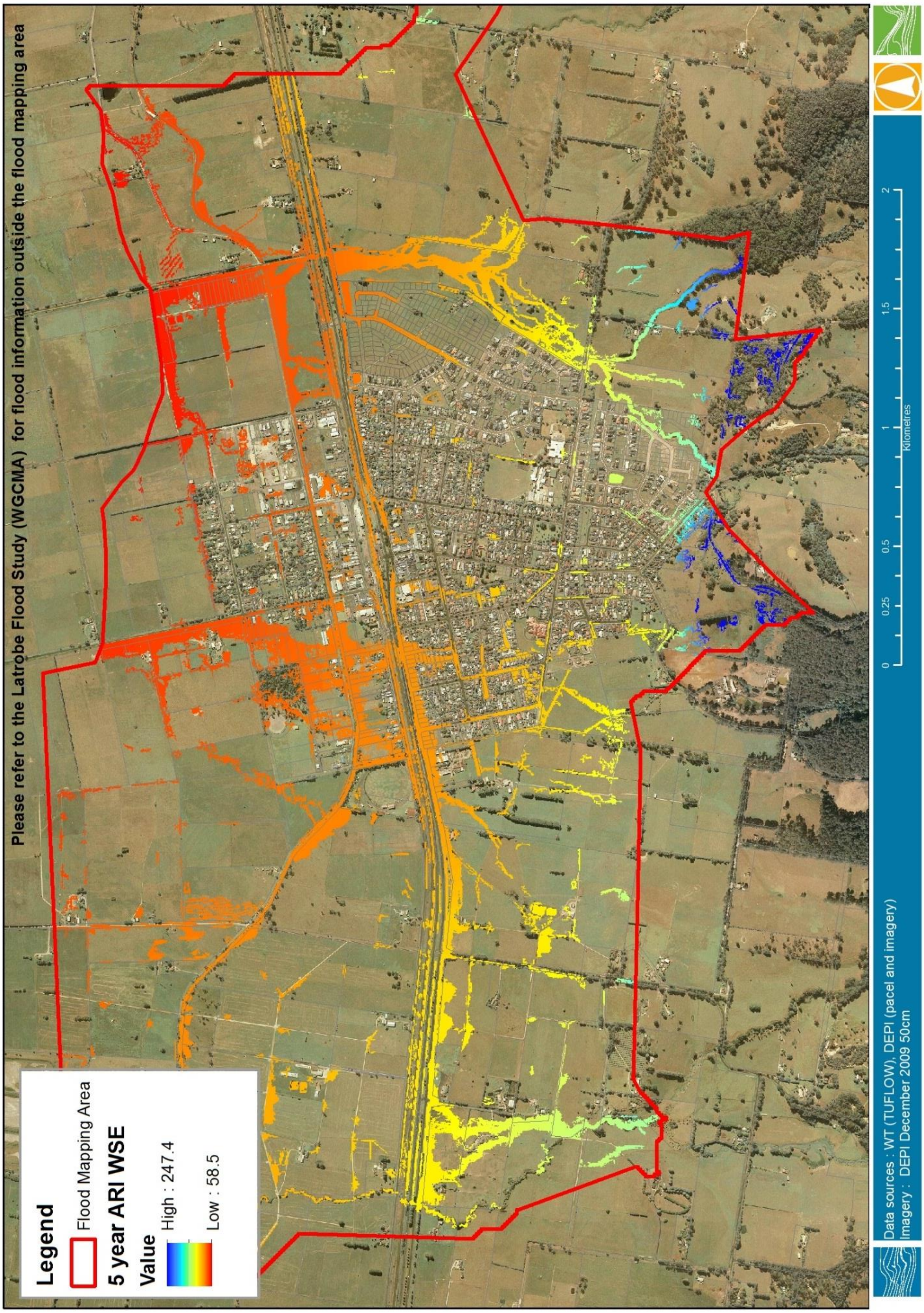

Figure A-14-7 5 Year ARI Flood Maximum Water Surface Elevation Plot – Existing Conditions

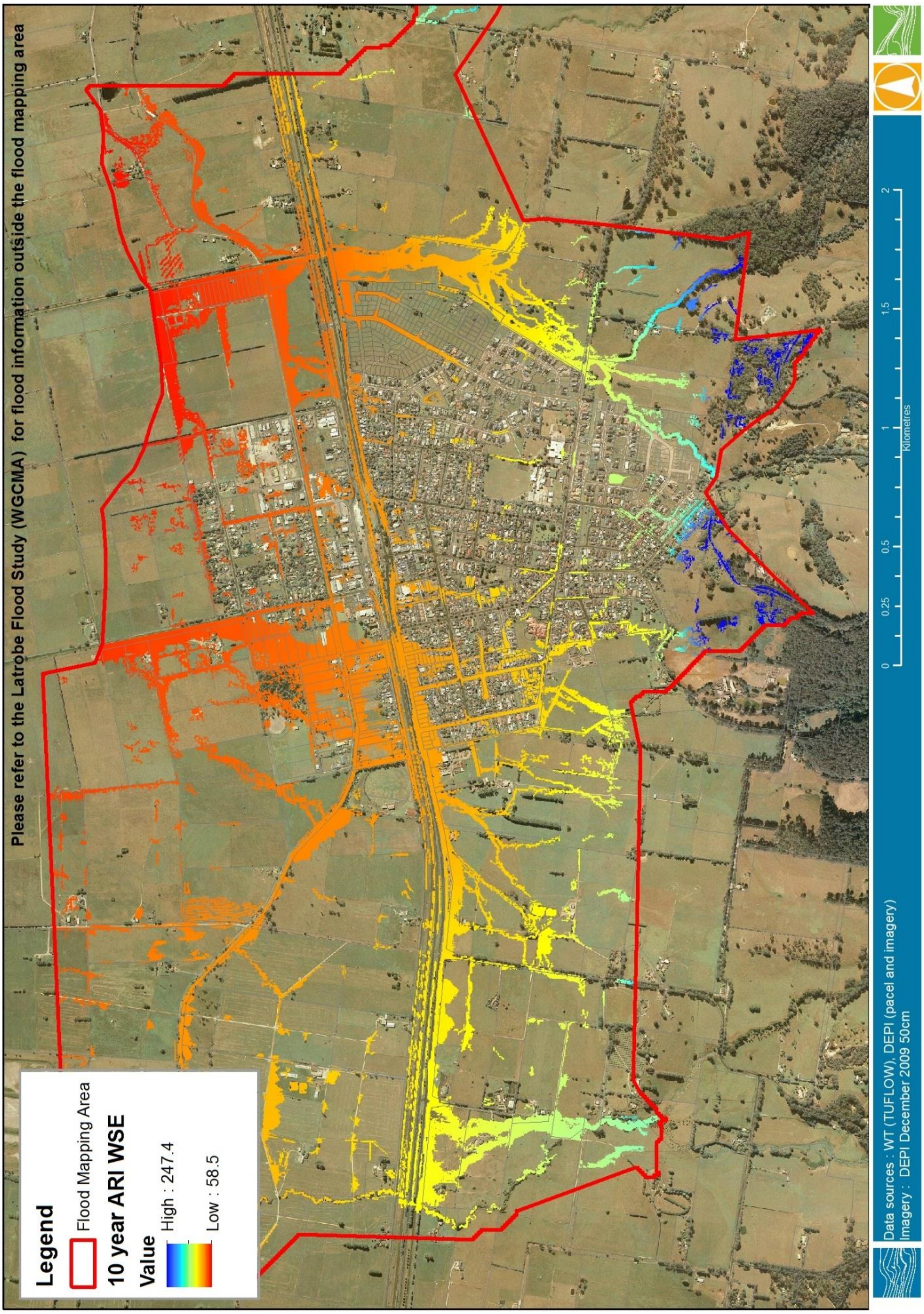

Figure A-14-8 10 Year ARI Flood Maximum Water Surface Elevation Plot – Existing Conditions

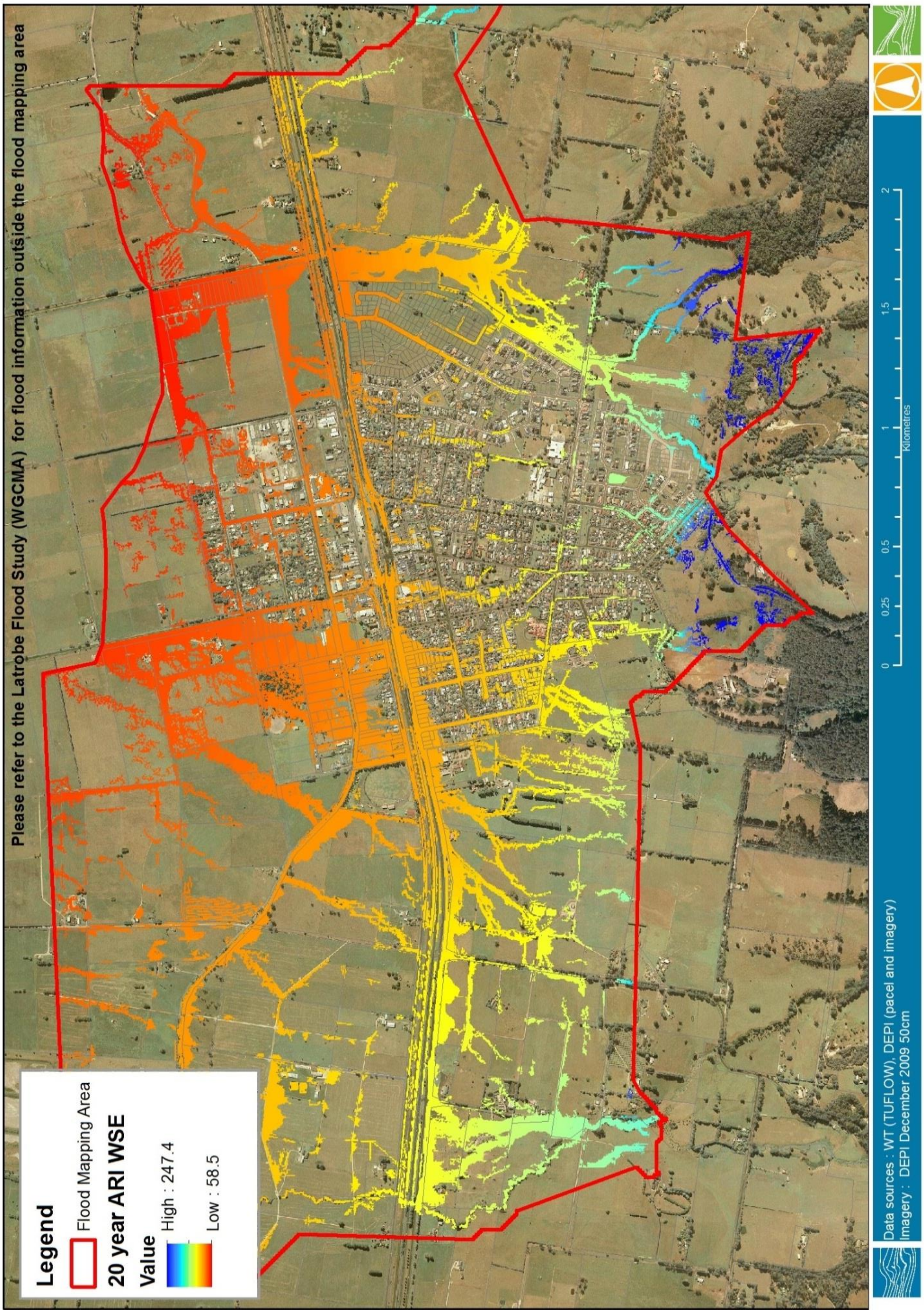

Figure A-14-9 20 Year ARI Flood Maximum Water Surface Elevation Plot – Existing Conditions

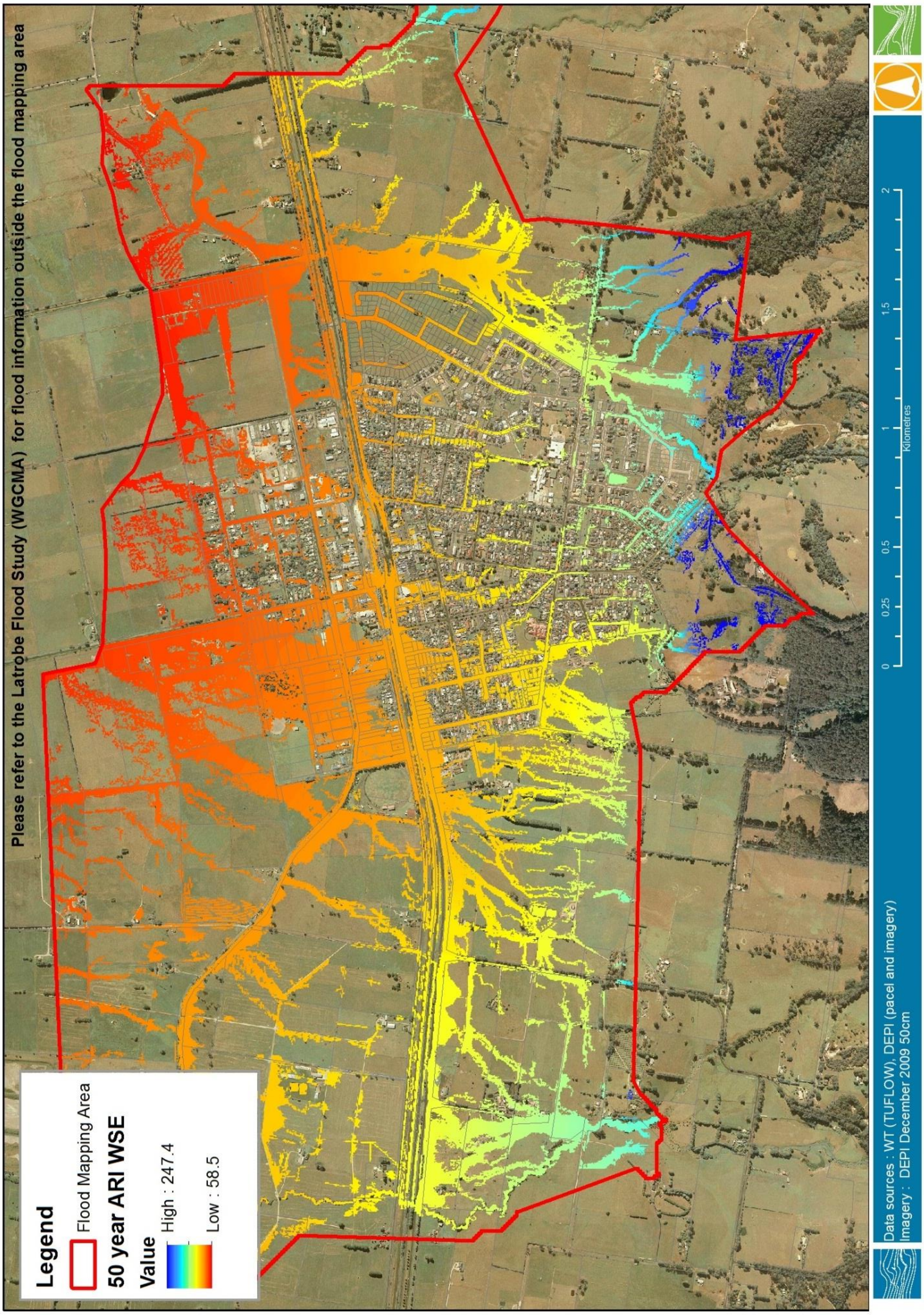

Figure A-14-10 50 Year ARI Flood Maximum Water Surface Elevation Plot – Existing Conditions

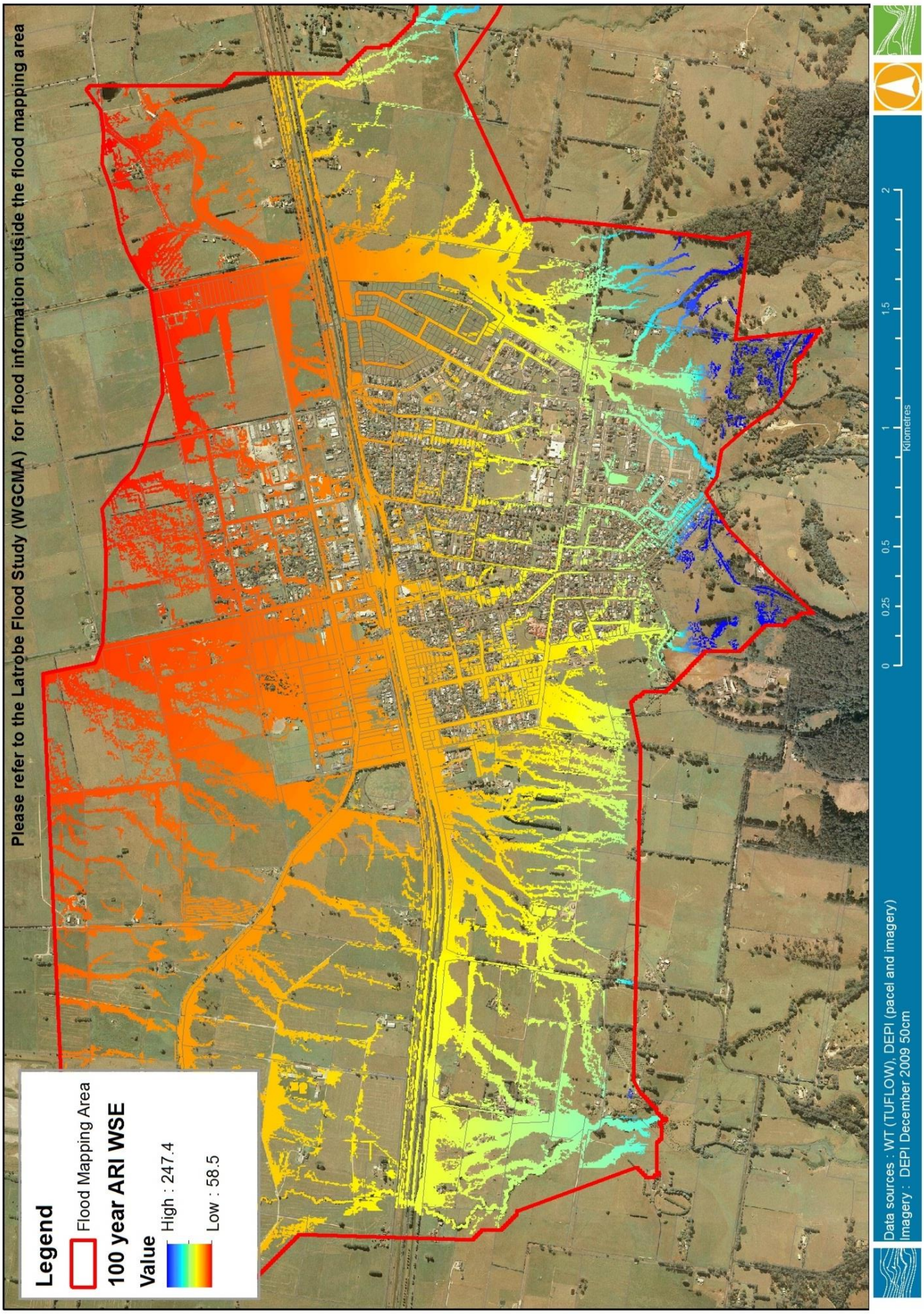

Figure A-14-11 100 Year ARI Flood Maximum Water Surface Elevation Plot – Existing Conditions

APPENDIX B COSTING DETAIL

Mitigation Option	Item	Cost
Option 1 - 100 year	**Channel**	
	Topsoiling	63698
	Excavate channel and dispose of excavated material off site	325308
	Vegetation	276027
	Rockwork at bends and outflow point	8116
	Sub-total Channel	***673149***
	Retarding Basin	
	Topsoiling	6655
	Excavate basin and dispose of excavated material off site	29705
	Grassing	4437
	Sub-total Retarding Basin	***40797***
	Culvert under road	
	Supply 1.8 m span * 0.9 m internal height culvert (assumed based on flow requirements)	40293
	Excavation of spoil and dispose of excavated material off site	6060
	Lay culverts	13297
	Backfill and compact over culverts	2968
	Reinstate pavement and asphalt over culverts	10000
	Supply and install Headwalls	18724
	Rockwork at inflow and outflow points	764
	Traffic Management	5000
	Sub-total Culvert	***97105***
	Pipe outlet	
	Supply and install headwalls	1516
	Supply 0.6 m span * 0.6 m internal height culvert	13678
	Excavation of spoil and dispose of excavated material off site	2094
	Lay culverts	6155
	Backfill and compact over culverts	1185
	Grassing	329
	Rockwork at inflow and outflow points	115
	Sub-total Pipe	***25073***
	Services	
	Locate and protect Telstra cables	20000
	Locate and protect water main	10000
	Locate and protect APA gas main	20000
	Protect overhead power	20000
	Sub-total Services	***70000***
	Sub-total	906123
	Engineering Design	36245
	Engineering Supervision	27184

	Sub-total including engineering	969552
	Contingency	193910
	GST	96955
	Total	**1260417**
Option 2 - 100 year	**Channel & Retarding Basin Cut**	
	Topsoiling	108371
	Excavate channel and dispose of excavated material off site	937437
	Vegetation	469607
	Rockwork at bends and inflow/outflow point	9548
	Sub-total Channel	***1524963***
	Bunds	
	Topsoiling	110650
	Supply and install fill material for bunds	553249
	Grassing	73766
	Sub-total Bunds	***737665***
	Sports fields	
	Topsoiling	426800
	Supply and install fill material for sports fields	2961502
	Hydroseeding	284533
	Sub-total Sports Fields	***3672836***
	Main Pipe Drain	
	Supply and install headwalls	5153
	Supply culverts	
	900 span * 300 internal height	248421
	900 span * 450 internal height	197892
	900 span * 900 internal height	403600
	1200 span * 900 internal height	301244
	1500 span * 900 internal height	881414
	Excavation of spoil and dispose of excavated material off site	189813
	Lay culverts	
	900 span * 300 internal height	111789
	900 span * 450 internal height	89051
	900 span * 900 internal height	181620
	1200 span * 900 internal height	135560
	1500 span * 900 internal height	290867
	Pits	70000
	Supply RCP	
	Diameter 225	1426
	Diameter 450	2766
	Diameter 825	5100
	Connections from existing	1500
	Backfill and compact over culverts	94976

	Grassing	110335
	Rockwork at outlet point	286
	Traffic Management	15000
	Sub-total Main Drain	***3337810***
	Culvert under Hwy and Rail	
	Supply 1.8 m span * 0.9 m internal height culvert (assumed based on flow requirements)	
	Culvert	1192672
	Base slab	1665313
	Lids	1332000
	Excavation of spoil and dispose of excavated material off site	98819
	Lay culverts	2215837
	Backfill and compact over culverts	8585
	Reinstate pavement and asphalt over culverts	30000
	Reinstate train lines	50000
	Supply and install Headwalls	100000
	Rockwork at inflow and outflow points	8250
	Traffic and rail management	500000
	Sub-total Culverts	***7201476***
	Services	
	Locate and protect Telstra cables	100000
	Locate and protect Sewer	20000
	Locate and protect water main	20000
	Protect overhead power	40000
	Locate and protect gas main	20000
	Sub-total Services	***200000***
	Sub-total	16674751
	Engineering Design	666990
	Engineering Supervision	500243
	Sub-total including engineering	17841983
	Contingency	3568397
	GST	1784198
	Total	**23194578**
Practical mitigation option	**Bunds**	
	Topsoiling	30999
	Supply and install fill material for bunds	77499
	Grassing	20666
	Sub-total Bunds	***129165***
	Retarding Basin	
	Topsoiling	192522
	Excavate basin and dispose of excavated material off site	222789

	Grassing	128348
	Sub-total Retarding Basin	***543658***
	Pipe outlet	
	Supply and install headwalls	10000
	Supply 1.2 m span * 0.6 m internal height culvert	89504
	Excavation of spoil and dispose of excavated material off site	5102
	Lay culverts	40277
	Backfill and compact over culverts	1892
	Grassing	663
	Rockwork at inflow and outflow points	917
	Sub-total Pipe	***148355***
	Channel	
	Topsoiling	72725
	Excavate channel and dispose of excavated material off site	132507
	Vegetation	315140
	Sub-total Channel	***520372***
	Services	
	Locate and protect water main	10000
	Locate and protect APA gas main	20000
	Protect overhead power	20000
	Sub-total Services	***50000***
	Sub-total	1391550
	Engineering Design	55662
	Engineering Supervision	41746
	Sub-total including engineering	1488958
	Contingency	297792
	GST	148896
	Total	**1935646**