A safer, stronger, more resilient region

Financially, socially and environmentally sustainable

TOOWOOMBA REGION

Rich traditions. Bold ambitions.

Goombungee Flood Studies Information Sheet

WHY UNDERTAKE FLOOD STUDIES?

Following extensive flooding across the Toowoomba region, we commissioned a number of flood studies to better understand how flooding can impact our communities. These studies are now complete and available on our website.

The flood studies found that flood behaviour can be complex and vary between locations, depending on landscape, infrastructure and rainfall pattern.

SOME BASIC FLOOD TERMS

1. **Overland flow** – short duration flooding of backyards, drainage paths, streets and rural properties caused by stormwater as it makes its way into the creek/river system;

2. **Creek flooding** – short to medium duration flooding caused by creeks rising and breaking their banks, which can then flood nearby homes, businesses and rural properties;

3. **River flooding** – longer duration flooding caused by significant rises in a river which can break its banks in the same way as smaller creeks.

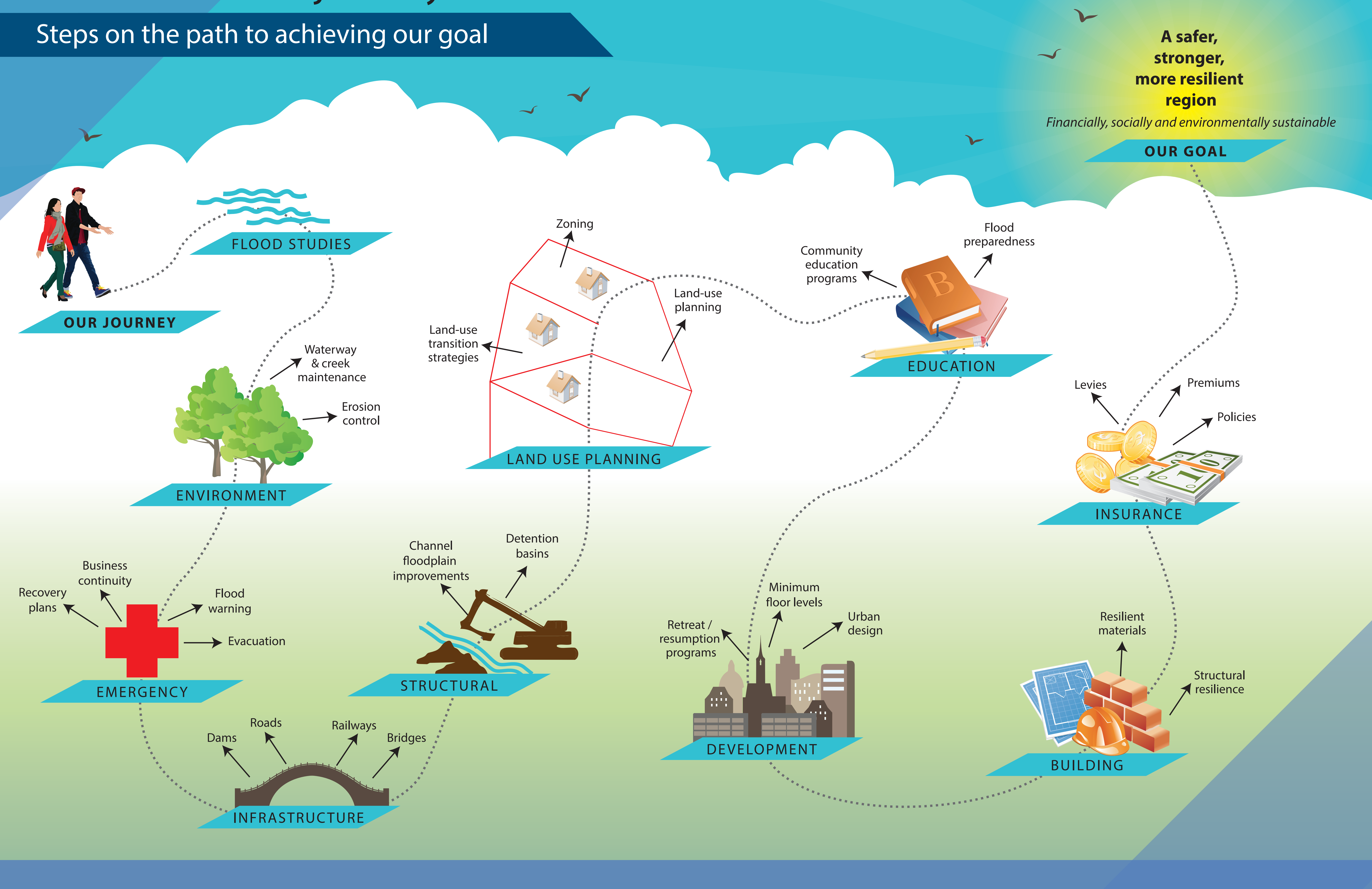
Most of the studies undertaken or commissioned by Council relate to the first two types of flooding – overland flow and creek flooding. It's important to note that these types of flooding can occur separately or together.

KEY MESSAGES

1. Council has a legislative requirement to undertake flood management and the whole community needs to be involved.
2. Flood studies are a foundation and an essential step towards our goal of a safer, stronger, more resilient region.
3. Flood studies have been undertaken by specialist engineers and incorporate the latest data, modelling techniques and community input.
4. Community consultation enables two-way information sharing about the project to increase community awareness, enhance decision making and help achieve our goal of a safer, stronger, more resilient region.

Flood + us - our journey

Steps on the path to achieving our goal



Goombungee Flood Studies Information Sheet

WHAT'S GOOMBUNGEE'S FLOOD STORY?

The flood study and maps for Goombungee were updated using flood information received from the community during consultation held in early 2015. These updated versions are now available to residents. The main source of flooding for the town is overland flow flooding.

The flood study has helped validate flood behaviour observed during the December 2010 and January 2011 floods. The study confirms that some road crossings, such as Kingsthorpe-Haden Road and Pechey-Maclagan Road west-bound, were impacted by flood waters during the 2011 flood event.

A number of properties in the town were directly affected by flood waters during the same event, which mainly impacted those on the western side of Kingsthorpe-Haden Road, as well as some rural properties on the southern side of Pechey-Maclagan Road.

Anecdotal evidence of flood levels supplied by a long-term resident supported the analysis that the modelled January 2011 event generally correlated to a 1% Annual Exceedance Probability event – meaning there is a 1% chance in any year to see this size flood event or larger.

Annual Exceedance Probability (AEP) means the chance of a flood of a given size or larger size occurring in any one year, usually expressed as a percentage.

COMMUNITY INVOLVEMENT

Improving the way we prepare for and respond to flooding as a community is very important to us. Many residents in our region contributed information to build and validate our flood knowledge during the region-wide consultation sessions and other flood studies engagement opportunities.

Community involvement with this project continues to help our region become safer, stronger and more resilient. We encourage you to access the flood study information online and stay up to date with the project by visiting the web address below.

GET INFORMED

You can access our region's current flood studies and maps by heading to
http://yoursay.toowoombarc.qld.gov.au/flood-resilience
For more information, please contact the project team by phone, email or post.

Phone: 131 872

Email: info@tr.qld.gov.au

Post: Strategic Planning & Economic Development,
Toowoomba Regional Council, PO Box 3021, Toowoomba Q 4350.

TOOWOOMBA REGION

Flood Studies

TOOWOOMBA REGION
Rich traditions. Bold ambitions.

Overland Flow Path Studies for Goombungee, Pittsworth and Southbrook

November 2015 • *Endorsed on 15 December 2015*

GENERAL NOTE

These reports/documents are a base source of information that will be continually refined over time.

DISCLAIMER

DOCUMENT STATUS

Version	Doc type	Reviewed by	Approved by	Distributed To	Date issued
v01	Final Report	AMD	AMD	GHD/TRC	19/02/2014
v02	Final Report	AMD	AMD	GHD/TRC	20/03/2014
v03	Final Report	AJT	SQC	GHD/TRC	21/08/2015
v04	Final Report	AJT	AMD	GHD/TRC	17/11/2015

PROJECT DETAILS

Project Name	SP051 Flood Studies – Work Package 11
Client	Toowoomba Regional Council
Client Project Manager	Alister Daly
Water Technology Project Manager	Andrew Thompson
Report Authors	Peter Crichton/Blair Filer
Job Number	J2810-04
Report Number	R03_V04
Document Name	Final Report

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EXECUTIVE SUMMARY

Significant rainfall associated with one of the strongest La Nina events on record occurred across a large portion of Queensland from late November 2010 through to January 2011, forcing the evacuation of thousands of people from towns and cities in the southeast corner of QLD and bordering NSW areas.

Subsequent to these unprecedented flooding events and the conditional approval of the Toowoomba Regional Planning Scheme (TRPS) by the State Government, Toowoomba Regional Council (TRC) appointed a number of organisations under Council contract number SP051 in order to revise and update flood mapping across the greater TRC administrative area. TRC commissioned Water Technology Pty Ltd to undertake the assessment of overland flow paths for the towns included in Work Package 11 (WP11) of the overall SP051 project, namely Goombungee, Pittsworth and Southbrook. This study aims to define and map overland flow path corridors in the current and future development areas within the aforementioned towns.

In order to assess the behaviour of overland flow path flooding within the study areas, catchment discharge estimates were required. The Rational Method was used to estimate catchment discharges contributing to the study areas for three design events pre-determined by TRC, namely the 5, 20 and 100 year Average Recurrence Interval (ARI) events. In order to validate the flow estimates for the larger catchments in the Goombungee and Pittsworth study areas, comparison of Rational Method discharge estimates was undertaken with the Australian Regional Flood Frequency Model (ARFF) (IEAust, 2012). Good correlation was shown between the Rational Method and ARFF peak discharge estimates for the 100 year ARI event, with the Rational Method estimates found to be marginally higher than the ARFF estimates, but in general agreement.

Hydraulic modelling of the three study areas has been undertaken utilising DHI Software's MIKE FLOOD and BMT WBM's TUFLOW modelling packages. The use of MIKE FLOOD was a specific requirement of the project as specified by TRC, with analysis undertaken for all design rainfall events, namely the 5, 20 and 100 year ARI events. Additional analysis was also undertaken for model validation and sensitivity analysis purposes. Given that some flowpaths are ill-defined within the Goombungee Township, a "Direct Rainfall" TUFLOW model was developed, in addition to the MIKE FLOOD model, to more accurately ascertain the extent of flooding due to overland flow in the Goombungee Township.

Validation of the MIKE FLOOD models to historical flood data was undertaken to ensure model predictions were accurately representing real-world flood behaviour in the study areas. For each of the models prepared under this work package, the historical flood level data sourced for the purposes of the model validation comprised a mixture of data sources, including highest known flood level information that was nonspecific in respect to the date of occurrence, as well as observed flood level data supplied by TRC that corresponded to the January 2011 flood event.

Validation of the TUFLOW "Direct Rainfall" model was undertaken by comparing flows extracted from the model with those calculated using the Rational Method. The comparison indicates that flows in the TUFLOW model are within 30% of those estimated using the Rational Method. Additional photographs provided by residents following a severe rainfall event in March 2014 also assisted in validating the results determined using the TUFLOW model.

Model estimates of the design rainfall 100 year ARI flood event within each of the respective study areas were shown to generally correspond well to flood levels collected from residents during field inspections and TRC supplied observed flood levels for the January 2011 event. The observed flood levels provided by TRC for the January 2011 event were shown to generally agree with 100 year ARI design flood event estimates in Pittsworth and Southbrook. Analysis of rainfall records for these areas suggest the rainfall burst that occurred around the 10th to 11th January 2011 was approximately of a

50 year ARI equivalency. This, combined with the significant antecedent rainfall and primed catchment conditions, resulted in a flood magnitude of approximately a 100 year ARI in these areas.

The 100 year ARI design event in Goombungee was predicted to be slightly higher than the January 2011 event TRC observed flood levels, and generally matched well to anecdotal historic flood levels provided by residents (which were based on numerous previous historical events). Analysis of rainfall records from rain gauges near the study area suggest the rainfall burst that occurred on the 10th to 11th January 2011 was equivalent to approximately a 5 year ARI event for the catchment. Again, significant antecedent rainfall and primed catchment conditions resulted in a higher flood magnitude for this area which matched well to the 100 year ARI design flood event magnitude when compared to the TRC observed flood levels for the January 2011 event. For shorter duration events associated with local flooding in the town, the rainfall intensity was determined to be in the order of a 2 year ARI.

Given the good correlation between model predictions of flood behaviour and anecdotal and observed flood information and the subsequent approval of the TUFLOW and MIKE FLOOD models by the TRC appointed peer reviewer, analysis of the three pre-determined design rainfall events (5, 20 and 100 year ARI) was undertaken, with results presented in Appendix C, D and E for the Goombungee, Pittsworth and Southbrook study areas respectively.

It is recommended that the model results developed from this study be adopted by Council and used for inclusion in Council's updated planning scheme and for the purposes of addressing the conditional approval of the scheme, as issued by the State Government on the 17th February 2012.

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ABBREVIATIONS

AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
BoM	Bureau of Meteorology
DNRM	Department of Natural Resources and Mines
DFE	Defined Flood Event
DTM	Digital Terrain Model
DTMR	Department of Transport and Main Roads
GIS	Geographic Information System
LIDAR	Laser Detection and Ranging
NFRAG	National Flood Risk Advisory Group
NHMA	Natural Hazard Management Areas
QR	Queensland Rail
QRA	Queensland Reconstruction Authority
QFCI	Queensland Flood Commission of Inquiry
SPP 1/03	State Planning Policy 1/03
TRC	Toowoomba Regional Council
TRPS	Toowoomba Regional Planning Scheme

GLOSSARY (Note 1)
Annual Exceedance Probability (AEP) means the chance of a flood of a given or large size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (1 in 20 chance) of a 500 m^3/s or larger event occurring in any one year (see ARI).
Australian Bureau of Meteorology (the Bureau) is Australia's national weather, climate and water agency.
Australian Height Datum (AHD) means a common national surface level datum approximately corresponding to mean sea level.
Average Recurrence Interval (ARI) means the long term average number of years between the occurrence of a flood as big as, or larger than, the selected event. For example, floods with a discharge as great as, or greater than, the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event (see AEP).
Catchment is the land area drained by a waterway and its tributaries.
Climate change a change in the state of the global climate induced by anthropogenic change to the atmospheric content of greenhouse gases and that persists for an extended period, typically decades or longer (Note 2)
Culvert is a short passageway under a road, railway or embankment designed to allow stormwater to allow from one side to the other without being dammed.
Defined flood event (DFE) is the flood event adopted by a local government for the management of development in a particular locality.
Defined flood level (DFL) is the level of a flood that would occur during a defined flood event (DFE).
Discharge is the rate of flow of water measured in terms of volume per unit of time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving.
Essential services encompass electrical power, the provision of drinking water, sewerage, stormwater drainage, telecommunications and roads and rail.
Flood relatively high water levels caused by excessive rainfall, storm surge, dam break or a tsunami that overtop the natural or artificial banks of a stream, creek, river, estuary, lake or dam (Note 4)
Flood damage the tangible (direct and indirect) and intangible costs (financial, opportunity cost, clean-up) of flooding. Tangible costs are qualified in monetary terms (e.g. damage to goods and possessions, loss of income or services in the flood aftermath). Intangible damages are difficult to quantify in monetary terms and include the increased levels of physical, emotional and psychological health problems suffered by flood-affected people and attributed to a flooding episode (Note 4)

Flood hazard potential loss of life, injury and economic loss caused by future floods events. The degree of hazard varies with the severity of flooding and is affected by flood behaviour (extent, depth, velocity, duration and rate of rise of floodwaters), topography, population at risk and emergency management (Note 4)
Flood hazard area, for the purposes of Queensland Development Code, proposed new part 3.5: 'Construction of buildings in flood hazard areas', 21 November 2011, means an area, whether or not mapped, designated by a local government as a natural hazard management area (flood) under section 13 of the *Building Regulation 2006.*
Flood map is a map which depicts the extent of a particular flood or floods, for example the 1% AEP flood or a historical flood.
Flood overlay map is a map used in land planning to depict the land constrained by planning controls imposed by a council because of the flood risk associated with the land.
Floodplain is an area of land adjacent to a creek, river, estuary, lake, dam or artificial channel, which is subject to inundation by floodwater.
Flood risk is a term that usually embodies both likelihood of flooding and the consequences of flood.
Flow velocity means the speed and direction of flow, measured in metres per second (m/s). (Note 6)
Hydrodynamic (hydraulic) model uses data about the flow in streams and the terrain of a particular area to estimate flood heights, velocities and flow over rime. In order to do this the hydrodynamic model solves the equations for the conservation of mass and momentum/energy.
Hydrograph a graph that shows for a particular location, the variation with time of discharge (discharge hydrograph) or water level (stage hydrograph) during the course of a flood (Note 4)
Hydrologic model (runoff routing model) uses rainfall data and estimates of the proportion of the rainfall which turns into runoff and the rime which the runoff from each part of the catchment rakes to flow into the stream to estimate flow in the stream over rime.
Hydrology is the term given to the study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
Major flooding is a term used by the Bureau of Meteorology to depict extensive flooding of rural areas and/or urban areas. Properties and towns are likely to be isolated and major traffic routes likely to be closed. Evacuation of people from flood affected areas may be required.
Major Overland Flow Path an overland flow path that drains water from more than one property, has no suitable flow bypass, and has a water depth in excess of 75mm during the major design storms, or is an overland flow path recognized as "significant" by the local government (Note 3).
Major Road a road whose primary function is to serve through traffic. These roads include Collector Roads, Sub-Arterial and Arterial Roads. Refer to Department of Main Roads or AustRoads for further definition (Note 3)

Minor flooding is a term used by the Bureau of Meteorology to depict flooding that occurs in low-lying areas next to watercourses where inundation may require the removal of stock and equipment. Minor roads may be closed and low-level bridges submerged.
Planning scheme is a local planning instrument for regulating development in Queensland. Planning schemes regulate what development must be assessed before it can be undertaken, the type of assessment required and the criteria used in an assessment in each council region. They also contain codes with which self-assessable development must comply.
Probable maximum flood is an estimate of the largest possible flood that could occur at a particular location, under the most severe meteorological and hydrological conditions.
Q100 is a probability-based design flood event discharge, aimed to reflect typical combinations of flood producing and flood modifying factors which act together to produce a flood event at a specific location of interest that has a I in 100 chance of being equalled or exceeded in any one year (1% annual exceedance probability - AEP): it is described as having an average recurrence interval (ARI) of 100 years. It is a theoretical flood model used to inform planning and policy (see AEP and ARI).
Stormwater is the rain water that has not yet entered a river system or soaked into the ground.
Stormwater flooding inundation by local runoff caused by heavier than usual rainfall. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing urban stormwater drainage systems to overflow (Note 4).
Stream /river gauging station (gauge) a manual or automated gauge that measures the height of the water in a river at a particular location.
Watercourse as defined in the Sustainable Planning Regulation 2009 (Note 2): (1) Generally, watercourse means a watercourse as defined under the *Water Act 2000,* schedule 4. (2) Watercourse, for schedule 3, part 1, table 4, item 5(b)(iv), means a river, creek or stream in which water flows permanently or intermittently – (a) in a natural channel, whether artificially improved or not; or (b) in an artificial channel that has changed the course of the watercourse (3) Watercourse, for schedule 24, part 1, section 1(2) – (a) Means a river, creek or stream in which water flows permanently or intermittently – i) in a natural channel, whether artificially improved or note; or ii) in an artificial channel that has changed the course of the watercourse; and iii) Includes the bed and banks and any other element of a river, creek or stream confining or containing water.
Waterway as defined under the *Environmental Protection Act 1994* means any of the following (Note 5): • a creek, river, stream or watercourse • an inlet of the sea into which a creek, river, stream or watercourse flows • a dam or weir

Notes

1. Unless otherwise noted, definitions have been taken from the QFCI Final Report.
2. Definitions taken from SPP1/03.
3. Definitions taken from the Queensland Urban Drainage Manual.

4. Definitions taken from Floodplain Management in Australia, Best Practice Principles and Guidelines.
5. Definitions taken from SPP4/10.
6. Definitions prepared for this study.

1. INTRODUCTION

1.1 Background

The approval of the Toowoomba Regional Planning Scheme (TRPS) by the State Government on the 17 February 2012 was conditional on providing revised and updated flood information for a number of towns within the Toowoomba Regional Council (TRC) Local Government Area (LGA) with no current flood information available. This was in response to the Queensland Floods Commission of Inquiry (QFCI) as well as the State Planning Policy 1/03 "Mitigating the Adverse Impacts of Flood, Bushfire and Landslide" (SPP 1/03). Following the conditional approval, TRC has since completed a "Scoping Plan for Flood Risk Studies" (Scoping Plan Study) in September 2012. Key aspects of this study included:

- The identification of areas with no flood information;
- Prioritising these areas for future upgrades to meet the statutory requirements of the TRPS;
- Defining work packages and general methodologies to inform the future flood studies; and
- Providing budget costs and timelines for completion.

This scoping study formed the basis from which TRC has since appointed a number of organisations under Council contract number SP051 to undertake a range of technical works in order to revise and update flood mapping across the greater TRC LGA. TRC has subsequently commissioned Water Technology Pty Ltd (WT) to undertake the assessment of overland flow paths for the towns included in Work Package 11 (WP11) of the overall SP051 project, namely Goombungee, Pittsworth and Southbrook. This study aims to define and map overland flow path corridors in the current and future development areas within the aforementioned towns.

This study is the first step in the development of Flood Risk Management Plans for the towns, and generally seeks to support land use and infrastructure planning, as well as providing information for emergency planning purposes.

This report details the works, methodologies and assumptions that have gone into the development of the computer based models of the study areas associated with Work Package 11.

1.2 Study Objectives

The main objectives of the study are summarised as follows:

- Development of computer based hydraulic models of the identified areas;
- Determination and documentation of overland flow paths;
- Identification of critical infrastructure and emergency facilities for which safe operation may be disrupted by flood events;
- Preparation of detailed maps and GIS layers for inclusion in Council's databases;
- Detailed reporting of all elements of the Work Package and outcomes; and
- Provide emergency planning information to input into Councils Emergency and development planning information databases to assist Council in its emergency management, planning, preparedness and response.

2. DATA

Data utilised to determine flooding behaviour within the study areas have been obtained from a variety of sources during the course of the assessment process. The following sections summarise the data used for this study and provides detail on the sources and accuracy levels of the data sets as applicable.

2.1 Topographic Survey

Two topographic datasets have been used in this study, namely:

- LiDAR Survey supplied by TRC - This dataset was collected in 2010 and has a 1 m resolution. This dataset has been used as the basis for the hydraulic models, as well as being the dominant dataset for catchment delineation (where available). Any recent localised changes to topographic variation by developments or other works within the study areas may not be represented in this dataset.

  A collection report was provided to accompany the 2010 LiDAR Capture Project dataset as prepared by Schlenker Mapping Pty Ltd. The data was collected from the 29th June to the 16th July 2010. The report states that the accuracy achieved was 94% of points within +/- 150 mm accuracy of ground controls. This is considered appropriate for adoption and was well within the accuracy specifications of the LiDAR Capture Project. The LiDAR data was used to developed 1m resolution Digital Elevation Models (DEMs) of the study areas for this project.

- TRC supplied 25 m DEM – This dataset was supplied by TRC and covers the TRC LGA. The dataset was supplied in the Latitude/Longitude (GDA94) horizontal projection. The source of the data (although not stated by TRC) is likely the Department of Natural Resources and Mines (DNRM), who states the accuracy of the data as follows:

  "The accuracy of this DEM depends on the accuracy of the source data and the error of ANUDEM`s interpolation. The average accuracy of AUSLIG's 1:100000 source data is + or - 25 metres in the horizontal position of well-defined detail and + or - 5 metres in elevation for most map sheets"

2.2 Aerial Imagery

High resolution aerial imagery has been supplied by TRC for use in this study. Each of the study areas has either a 12.5 cm or 25.0 cm resolution imagery available. Where coverage of the finer resolution imagery was not available, 50.0 cm resolution imagery also supplied by TRC has been used.

Imagery has been used to identify specific hydraulic structures, confirm land uses and associated impervious values and to delineate floodplain roughness in conjunction with site observations, oblique photographic records and other imagery (i.e. Google Earth).

2.3 Land Use

Council have supplied a Digital Cadastral Database (DCDB) for use in this study in a Geographic Information System (GIS) format. This has been used to accurately determine catchment imperviousness based on an ultimate development scenario. Additionally, Council have also provided a GIS layer detailing the broadhectare mapping for future urban areas over a time horizon exceeding 10 years. The broadhectare mapping was used to supplement the DCDB land use for ultimate catchment development.

In some cases the provided datasets did not cover areas in the upper catchment areas of the larger external contributing catchments, and hence a review of aerial photography, surrounding land uses and the TRC Planning Scheme was undertaken to develop land uses for these areas. Typically these were areas of rural or natural land use.

2.4 Rainfall Data

2.4.1 Design Rainfall

Design rainfall Intensity Frequency Duration (IFD) data was obtained from the Bureau of Meteorology website for the analysis of overland flow path flooding. This online service automates the Australian Rainfall and Runoff (IEAust, 1998) datasets for each of the study areas.

The IFD data was obtained for a point representing the centroid of each overall contributing catchment to the respective study areas.

2.4.2 Historical Rainfall

Historical rainfall data for a number of rainfall gauges within or near the Work Package 11 study areas have been sourced from the various organisations including the Bureau of Meteorology (BoM), the Department of Natural Resources and Mines (DNRM) as well as Toowoomba Regional Council (TRC).

Historical rainfall data comprised both daily total rainfall data as well as 6 minute interval pluviograph rainfall data and was sourced generally for the period December 2010 to January 2011. Of specific interest was the period extending from the 9^{th} to 12^{th} January 2011 which resulted in some of the largest flooding to occur across the study areas. Historical rainfall data was sourced to assess historical rainfall frequencies to aid in model validation tasks. Historical rainfall frequency is discussed separately in Section 5.4.

2.5 Hydraulic Structures

Council provided information on sub-surface stormwater drainage structures in a GIS format. This data only included the Pittsworth study area within Work Package 11. There is limited existing stormwater infrastructure in either the Southbrook or Goombungee township areas and these were generally located outside of the flowpath areas to be assessed.

Data for all other hydraulic structures in the study area including culverts, bridges as well as isolated stormwater drainage were identified and measured during the course of the site inspection works. This included the location, size, cover, material as well as any other relevant details from which a GIS hydraulic structure database was prepared to aid in the development of the hydraulic models. Oblique photographic records were also taken for each of the structures of interest during the site inspection works. The photographic record for all structures and model areas will be provided at the completion of the study as part of the digital data sets prepared for Council. Further details on hydraulic structure data for the respective model areas are discussed in Section 5.

2.6 General GIS Datasets

Base GIS information for the study areas were supplied by TRC to aid in the completion of the overland flowpath assessments. This information has been utilised for this study and specifically for catchment hydrology, hydraulic analysis and mapping tasks. Other freely available GIS information has also been sourced to assist in the study such as physical road and rail centreline datasets.

2.7 Historic Flood Level Information

2.7.1 Data Limitations

Historical flood data has been collected for the study from a variety of sources. This includes data received from TRC being observed flood levels that were visible and accessible at the time of recording after the January 2011 floods, accounts of witnesses, flood information collected through community consultation as well as estimated flood levels recorded during the time of field inspections. The flood data used in the Study is based on the information that was available to TRC and WT at the time which may not be accurate or complete.

2.7.2 Historical Data

Water Technology undertook a consultation program which was primarily completed at the same time as the field inspection works. The consultation activities were documented in a consultation strategy, which was approved by TRC prior to embarking on the various consultation tasks. Part of this consultation strategy included contacting a range of organisations as well as a number of long-term residents to assist in collecting historic flood information for each of the towns. Relevant organisations including local State Emergency Services (SES) representatives, business owners as well as residents with information on flooding were initially contacted and later interviewed at site where appropriate. Not all people contacted or met from the various organisations, business owners and residents were able to provide historical flood information for use in this study. Where historic flood data was identified, this was collected and recorded throughout the specific areas of interest to aid in model validation tasks under this study. Part of this consultation program included ad-hoc discussions and selective door-knocking with various local residents undertaken during the course of the field inspection works.

All historical flood information that was able to be sourced and collected as part of the consultation program has been recorded and has been used to assist in the completion of the flood study works. Specifically, this information has been used to aid in the model validation tasks. In general, the historical data that was collected is summarised as follows: -

- Historical data which related specifically to the January 2011 flood event. This ranged from indicative flood depth estimates for the event through to observed flood level information
- Anecdotal information from residents obtained by TRC relating to a rainfall event that occurred in March, 2014. This information included photographs taken by residents during the event; and
- Other historical data sets relating to the highest known flooding which occurred historically. This historical data was not related to any specific historical event rather was simply anecdotal information for the largest known flooding which may have occurred at the specific area. Some of this type of data represented anecdotal accounts passed down through the generations of long-term residents in the areas.

While the January 2011 event was one of the largest flood events on record for many of the areas under investigation, significant flooding occurred at discrete times throughout the entire period from December 2010 to the end of January 2011. No specific data was sourced as part of the consultation program for other significant flood events that may have occurred throughout this period other than for the largest event.

A more detailed summary of all data collected from the consultation program and the historical flood level data associated with Work Package 5 is presented in Section 5.4.

TRC also provided flood level information collected after the January 2011 flood event. This was supplied in shapefile format *'sde_DCC_TRC_Regional_Flood_Levels_1.shp'.*

3. DESCRIPTION OF DECEMBER 2010 TO JANUARY 2011 EVENT

3.1 Introduction

Significant rainfall associated with one of the strongest La Nina events on record occurred across a large portion of Queensland from late November 2010 through to January 2011. This caused widespread flooding throughout much of Queensland, with the most destructive flooding occurring during the second week of January 2011, forcing the evacuation of thousands of people from towns and cities in the southeast corner of QLD and bordering NSW areas. Three-quarters of the state of Queensland was declared a disaster zone. Thirty-eight people in Queensland died in the 2010/2011 floods. (1)

On the 17th January 2011 a Commission of Inquiry into the Queensland Floods of 2010/2011 was established (termed the Queensland Flood Commission on Inquiry (QFCI)). The QFCI released its final report On 16 March 2012. The report made 177 recommendations across a broad range of issues including floodplain management, land use planning, building regulations, insurance, mines, emergency management and dam management. The QFCI was one of the catalysts to this current project.

3.2 Local Rainfall

Toowoomba sits on the watershed of the Great Dividing Range and is situated approximately 700 meters above sea level. Significant rainfall over the greater Toowoomba region commenced in December 2010 continued throughout January 2011. Table 3.1 shows selected rainfall totals for December 2010 and January 2011 across the greater Toowoomba region and also includes a summary of maximum daily totals. The location of the selected rainfall gauges is shown in

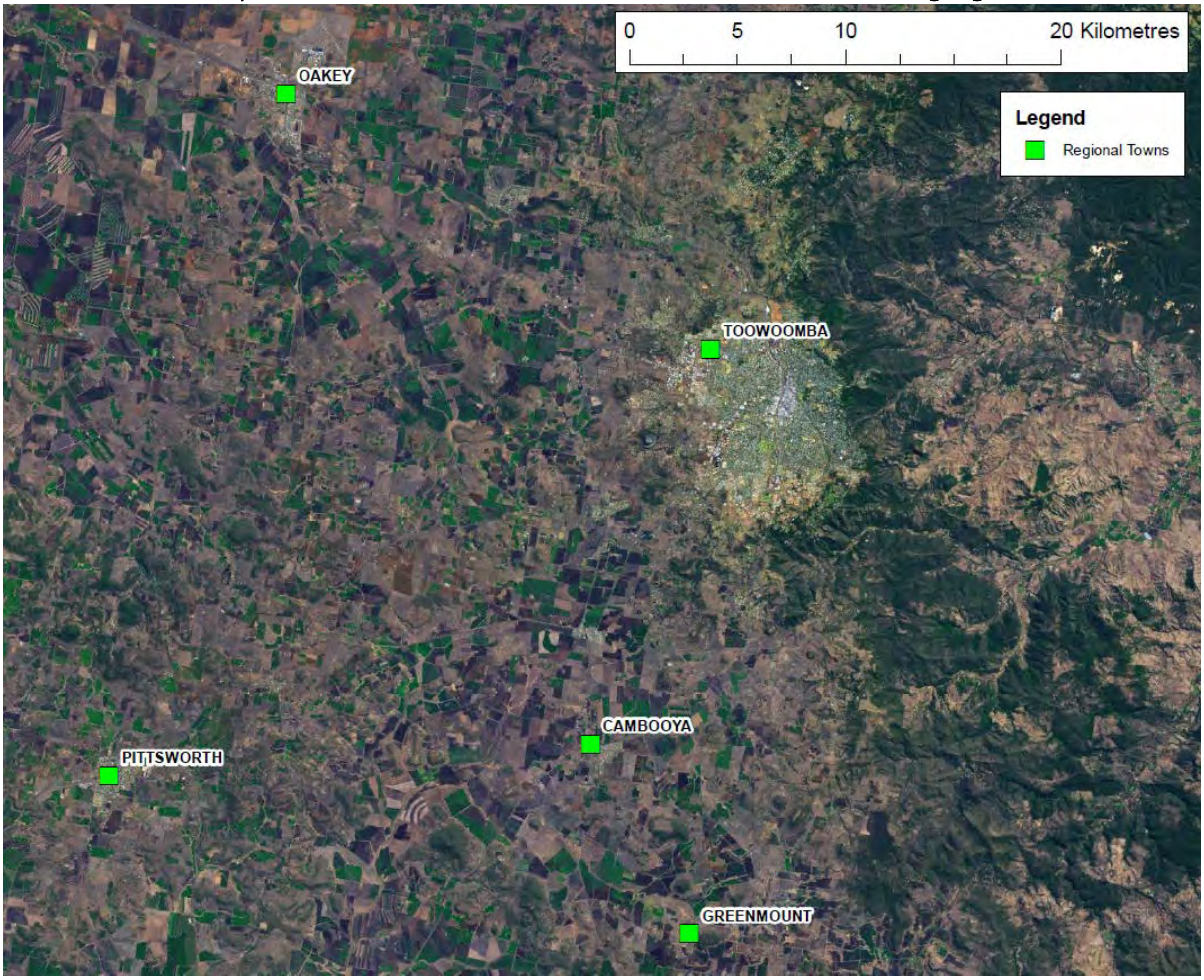


Figure 3.1 Figure 3.1.

Table 3.1 Local Rainfall Totals at Selected Locations for December 2010 and January 2011

Rainfall Gauge (BOM Gauge #)	December 2010		January 2011	
	Total Rainfall (mm)	Maximum Daily Total (mm)	Total Rainfall (mm)	Maximum Daily Total (mm)
Oakey (#041359)	304.2	67.6	265.4	78.8
Pittsworth (#041082)	413	114	149.4	49
Cambooya (#041011)	65.4	25.8	56.4	27.6
Greenmount (#041040)	159.6	48.2	179.2	89.2
Toowoomba (041529)	399.2	64.6	413	123.4

(1) - "Death toll from Queensland Floods" from the Queensland Police Service, 24 January 2011.

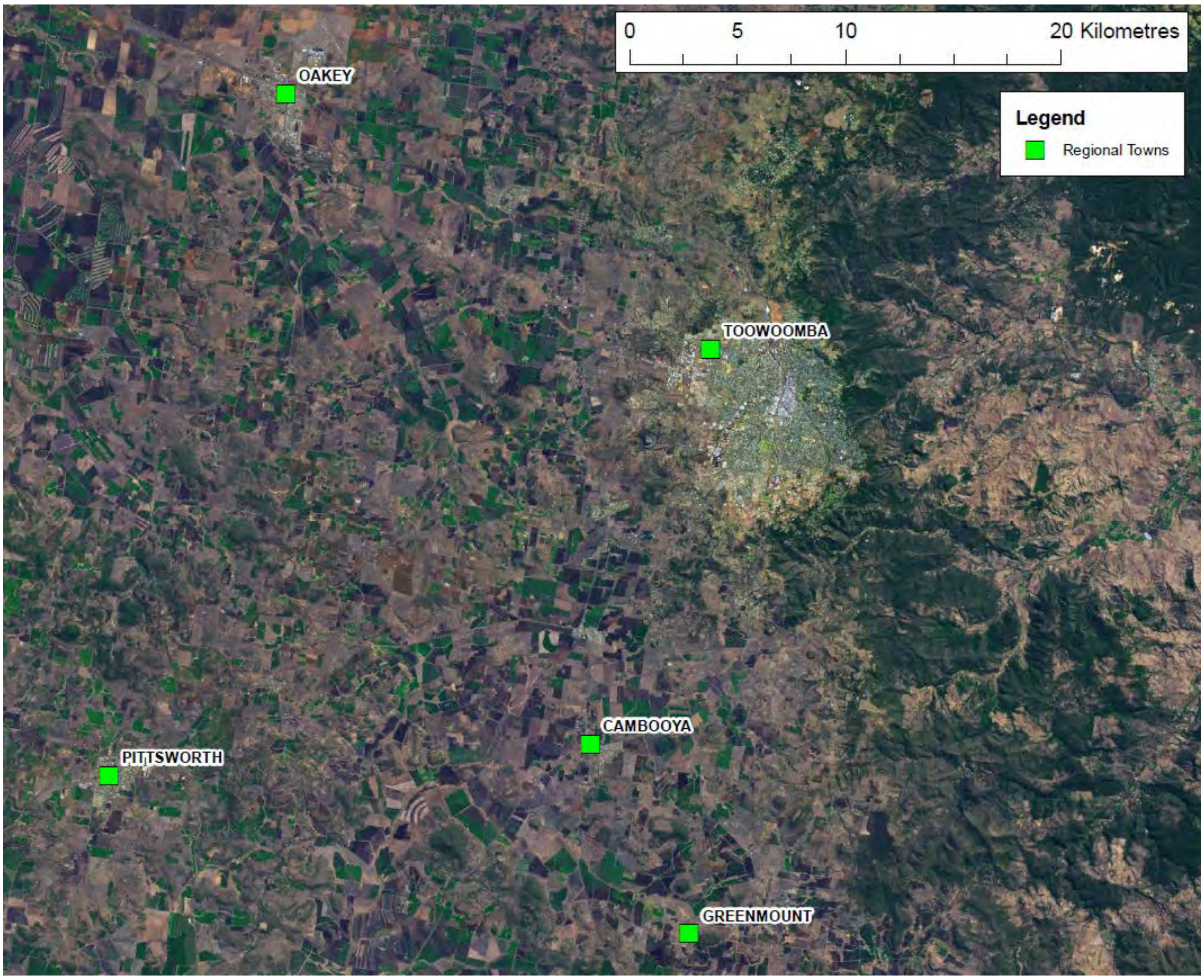


Figure 3.1 Selected Local Rainfall Total Locations for December 2010 and January 2011

Total rainfall depths which fell through December 2010 were significant and in the most part exceeded the monthly rainfall totals that fell in January 2011. Maximum daily total rainfall records show that the heaviest daily rainfall total was for the 24 hour period to 9am on the 11th January 2011. Figure 3.2 shows the cumulative rainfall totals that fell during the months of December 2010 and January 2011.

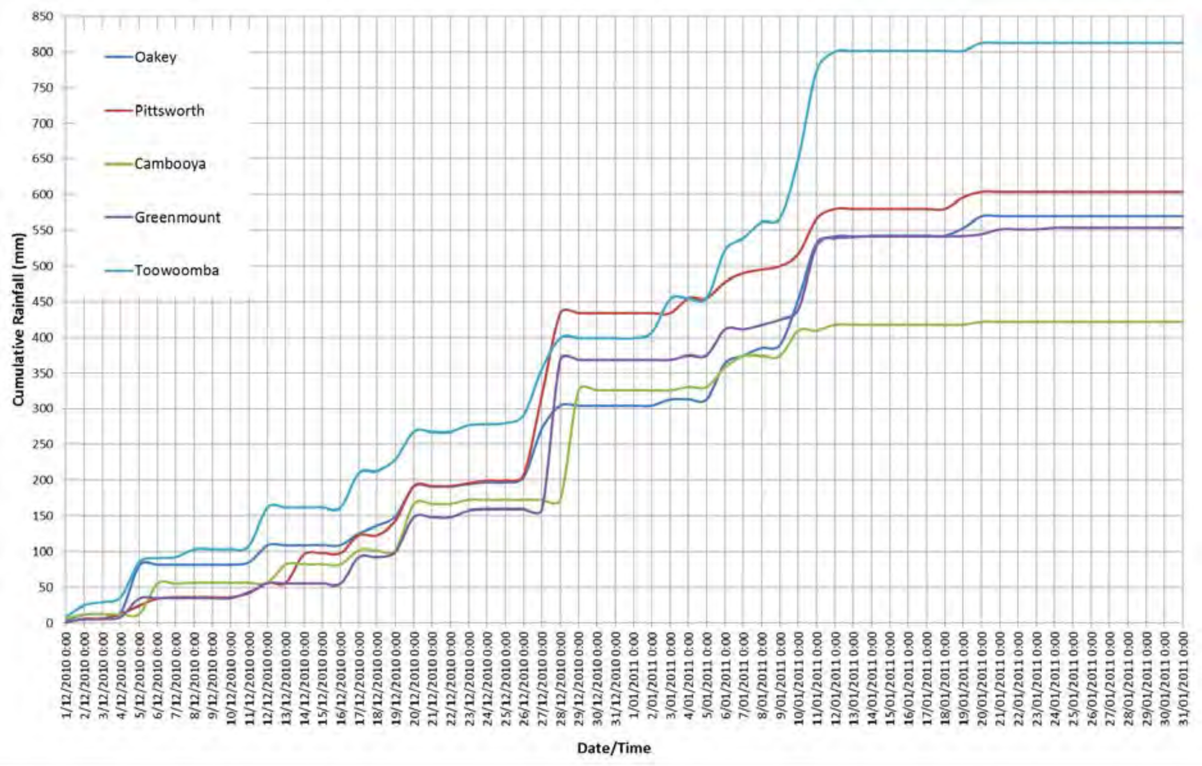


Figure 3.2 Cumulative Rainfall at Selected Locations for December 2010 to January 2011

The following comments are provided in relation to the cumulative rainfall totals at the various gauges presented in Figure 3.2: -

- Rainfall fell from the start of December 2010 through to approximately Christmas Day on the 25th December 2010. Rainfall totals for this period were approximately up to 200 mm across the various gauges.
- Significant rainfall totals were experienced over a 5 day period from the 25th December 2010 to the 29th December 2010. The rainfall totals for this period alone exceeded 200 mm and were larger than the total rainfall occurring for the preceding 24 day period in December 2010.
- Rainfall steadily fell through the early part of January 2011 with significant rainfall occurring over a 5 day period from the 5th to 11th January 2011. Rainfall totals for this period were up to approximately 150 mm.
- While the 5th to 11th January 2011 rainfall burst had a lower total rainfall in comparison to the 25th to 29th December 2010 totals, higher maximum daily rainfall was recorded for this period (refer Table 3.1).

3.3 Historical Flood Reports

The December 2010 rainfall totals were significant, especially over the Christmas period of 2010. This rainfall resulted in flooding occurring to some degree throughout the greater TRC area. Reports from locals and information gathered as part of this study generally confirms and supports that flooding was experienced over this period. The severity of flooding was however more pronounced on about the 10th to 11th January 2011 with many accounts of more significant flooding compared to December 2010 occurring at this time.

Much of the anecdotal information collected and sourced from local residents for this study confirms flooding that occurred as a result of the heavy rainfall that fell over the 24 hour period to 9am on the 11th January 2011 and was more severe in comparison to the December 2010 event. Much of the historical flood level information collected was associated with the January 2011 event. Indeed, it was this event which resulted in significant flooding in the City of Toowoomba itself and specifically East and West Creeks.

While the flooding that occurred throughout the region over December 2010 and January 2011 generally reflects the rainfall which occurred, flooding associated with the January 2011 event was more severe, hinting at AEP non-neutrality in regards to catchment discharges resulting from the rain that fell over this period.

4. CATCHMENT HYDROLOGY

In order to assess the behaviour of overland flowpath flooding within the study areas, catchment discharge estimates were required. The following sections detail the methodology and assumptions made during the derivation of these catchment discharge estimates.

4.1 Catchment and Flowpath Definition

Water Technology undertook the identification of the flowpaths in the vicinity of the towns under Work Package 11. The identification process included a CatchSIM analysis to define the various stream order tributary lines from which a set of flowpaths to be included in this study were identified for mapping. These included both local tributaries as well as larger creek and waterway systems. These nominated flow paths were subsequently approved by TRC for assessment.

4.2 Methodology

The Rational Method was used to estimate the 5, 20 and 100 year Average Recurrence Interval (ARI) design discharges for the contributing catchments to the respective study areas. These 3 design events were selected and pre-determined by TRC for use in this study.

Figure 4.1 to Figure 4.3 show the catchment boundaries and study area locations for each of the study areas. Catchment boundaries were established using the topographic data sets outlined in Section 2.1 and included a CatchSIM analysis with manual intervention as part of the review process and in order to accurately represent contributing sub-catchments to each of the identified flowpath lines.

For the purposes of analysing overland flow within the Goombungee Township, a “direct rainfall” hydraulic modelling approach was adopted. Given that some flowpaths are ill-defined within the Goombungee Township, the use of direct rainfall modelling assists in areas where traditional runoff routing models may prove to be inadequate in determining catchment runoff.

4.3 Catchment Descriptions

All of the overall catchments contributing to the three study areas are similar in nature, with typically rural or natural land uses in the larger external contributing catchments as well as discrete areas of urban development within the townships. Figure 4.1 to Figure 4.3 illustrates the catchment extents and topographic variability for the Goombungee, Pittsworth and Southbrook study areas respectively.

4.4 Design Rainfall

Design rainfall intensities for the centroids of each of the respective study areas were determined via the Bureau of Meteorology website for this analysis. This online service automates the standard procedures in Australian Rainfall and Runoff (IEAust, 1998).

The IFD data was obtained for a point representing the centroid of each overall contributing catchment to the respective study areas.

4.5 Ultimate Catchment Land Use

Table 4.1 presents the adopted fraction impervious values adopted for use in this study against each land use category defined in Council’s GIS information for each town. The values have been determined generally in accordance with QUDM (NRW, 2007) and QUDM (EWS, 2013) provisions, noting the very specific land use types being represented within the TRC supplied data. The ultimate fraction impervious values for each of the sub-catchment areas has been determined based on a weighted average for the different land use types within the respective catchment areas.

Table 4.1 Adopted Fraction Impervious Values

Land Use Description	Fraction Impervious
Abattoir	0.7
Animals Special	0.2
Body Corporate in any strata titled scheme	0.85
Building Format Plan Primary Use Only	0.7
Car Parks	0.7
Caravan Parks	0.7
Cattle grazing	0
Cattle Grazing Breeding	0
Cattle Grazing Breeding and Fattening	0
Cattle Grazing Fattening	0
Cemeteries (Include Crematoria)	0.2
Child Care excluding Kindergarten	0.5
Church/Facilities	0.5
Combined Dwelling & Shops	0.9
Community Protection Centre	0.2
Community Purposes	0.2-0.5(1)
Creek	0.2
Dairy Cattle Milk	0.2
Educational include Kindergarten	0.5
Extractive Quarry / Industry	0.5
General Industry or Medium Industry	0.7
Grains	0
Heavy Industry	0.9
Horses	0.2
Hospitals, Convalescent Homes (Medical Care) (Priv)	0.7
Hotel/Tavern	0.7
Large Home Site Dwelling	0.15

Land Use Description	Fraction Impervious
Large Home Site Vacant	0.5
Library/Museum	0.9
Light Industry A	0.7
Light Industry B	0.9
Low density Residential	0.5
Motel	0.7
Multi Dwellings or Flats	0.85
Nurseries (Plants)	0.2
Open space	0
Other Clubs Non Business	0.2
Outbuildings	0.2
Outdoor Storage Area/Contractors Yard	0.7
Parks, Gardens	0
Pigs	0.2
Poultry	0.2
Professional Offices	0.7
Reservoir, Dam, Bores	1
Residential Choice	0.6
Residential Living	0.6
Restaurant/Function Centre	0.7
Retail Warehouse	0.7
Roads	0.7
Rural	0
Rural Vacant Land	0
Sales Area Outdoors (Dealers, Boats, Cars etc)	0.7
Section 49 Valuation Vacant Urban Land	0.6
Service Station	0.7
Shop Single	0.7
Shopping Group (2-6 Shops)	0.7
Show Ground, Race Course, Airfield	0.2
Single Unit Dwelling	0.7
Small Crops and Fodder Irrigation	0
Special Tourist Attraction	0.2

Land Use Description	Fraction Impervious
Sports Clubs/Dance Facilities	0.2
Township	0.2-0.6 (1)
Transformers	0.7
Transport Terminal	0.7
Urban Residential	0.7
Vacant Urban Land	0.6
Warehouse and Bulk Stores	0.9

Notes
1. Depends on relative density of the specific areas of interest

4.6 Time of Concentration

4.6.1 Rural Catchments

A combination of the Friend's Equation and the Stream Velocity Method were used to determine the time of concentration for each of the rural catchments in the study area. This is the recommended methodology for rural catchments of less than 25 km^2 in area, as outlined in Section 4.06.11 of the Queensland Urban Drainage Manual (QUDM) (NRM, 2007).

Stream Velocities

The Manning's equation for open channel flow was used to estimate average channel velocities within the various flow paths of the study areas.

Channel velocity estimates were derived iteratively with the Rational Method discharge calculations. That is, the Rational Method requires a channel velocity as input (estimated from the Manning's Equation) and the Manning's Equation requires a discharge as input (estimated from the Rational Method).

Estimates were undertaken for representative sections of a number of different streams within each study area and these representative values were then adopted. Estimates of stream velocity in the main creek branches typically ranged from 1.6 m/s in the flatter catchments to up to 2.5 m/s in the steeper catchment areas using this methodology.

4.6.2 Urban Catchments

In order to develop accurate time of concentration estimations for the local urban catchments within each study area, a combination of a Standard Inlet Time and Stream Velocity Method was adopted as recommended in Section 4.06.03 of QUDM (NRM, 2007).

Standard inlet times were based on the catchment slope at the top of the respective catchment, with the associated inlet time determined from Table 4.06.1 of QUDM (NRM, 2007). Typically, adopted inlet times were in the order of 13 – 15 minutes due to the flat nature of the catchments.

Stream velocities were estimated for these urban areas using the Manning's equation using a typical table drain cross section. Estimates were undertaken for various longitudinal slopes at a number of different locations with these representative values then being adopted.

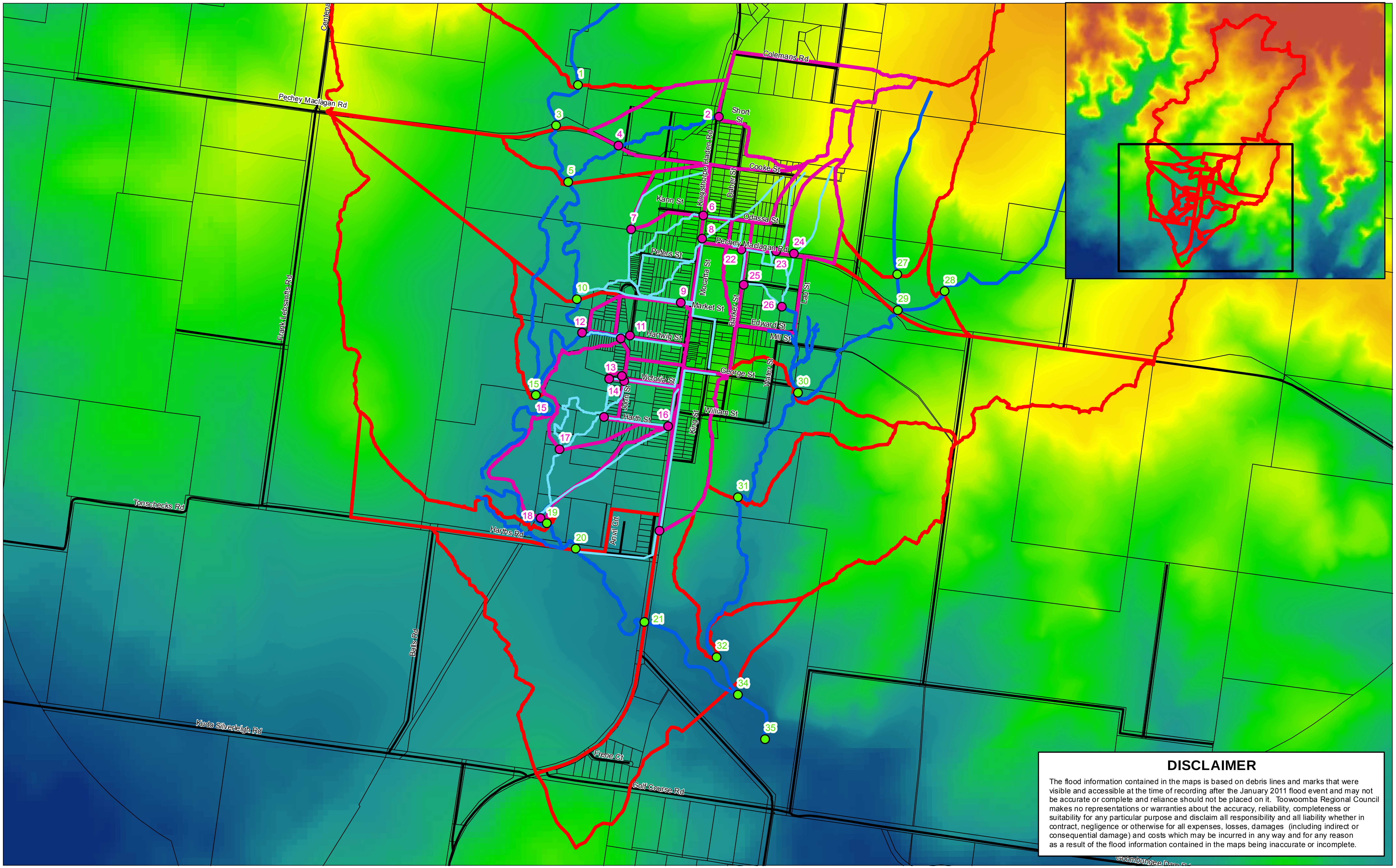
4.7 Coefficient of Discharge

The estimate of a coefficient of discharge (C) is required for the rational method to adequately represent factors influencing peak catchment discharge such as infiltration and other losses.

The C_{10} values as outlined in Table 4.05.3 (a) and 4.05.3 (b) of QUDM (NRM, 2007) were adopted for use in this assessment based on the associated fraction impervious values as determined from the assessment of ultimate catchment land use. A zero percent fraction impervious C_{10} value of 0.49 has been adopted for all catchments in this study.

4.8 Catchment Discharge Estimate Results

Table 4.2 to Table 4.4 summarise the Rational Method design discharge estimates at various points of interest for Goombungee, Pittsworth and Southbrook respectively for the 5, 20 and 100 year ARI design storms. A copy of the Rational Method flow calculation summaries for each of the towns is included in Appendix B.



DISCLAIMER

The flood information contained in the maps is based on debris lines and marks that were visible and accessible at the time of recording after the January 2011 flood event and may not be accurate or complete and reliance should not be placed on it. Toowoomba Regional Council makes no representations or warranties about the accuracy, reliability, completeness or suitability for any particular purpose and disclaim all responsibility and all liability whether in contract, negligence or otherwise for all expenses, losses, damages (including indirect or consequential damage) and costs which may be incurred in any way and for any reason as a result of the flood information contained in the maps being inaccurate or incomplete.

TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550
Meters

GDA 1994 MGA Zone 56

N

Legend

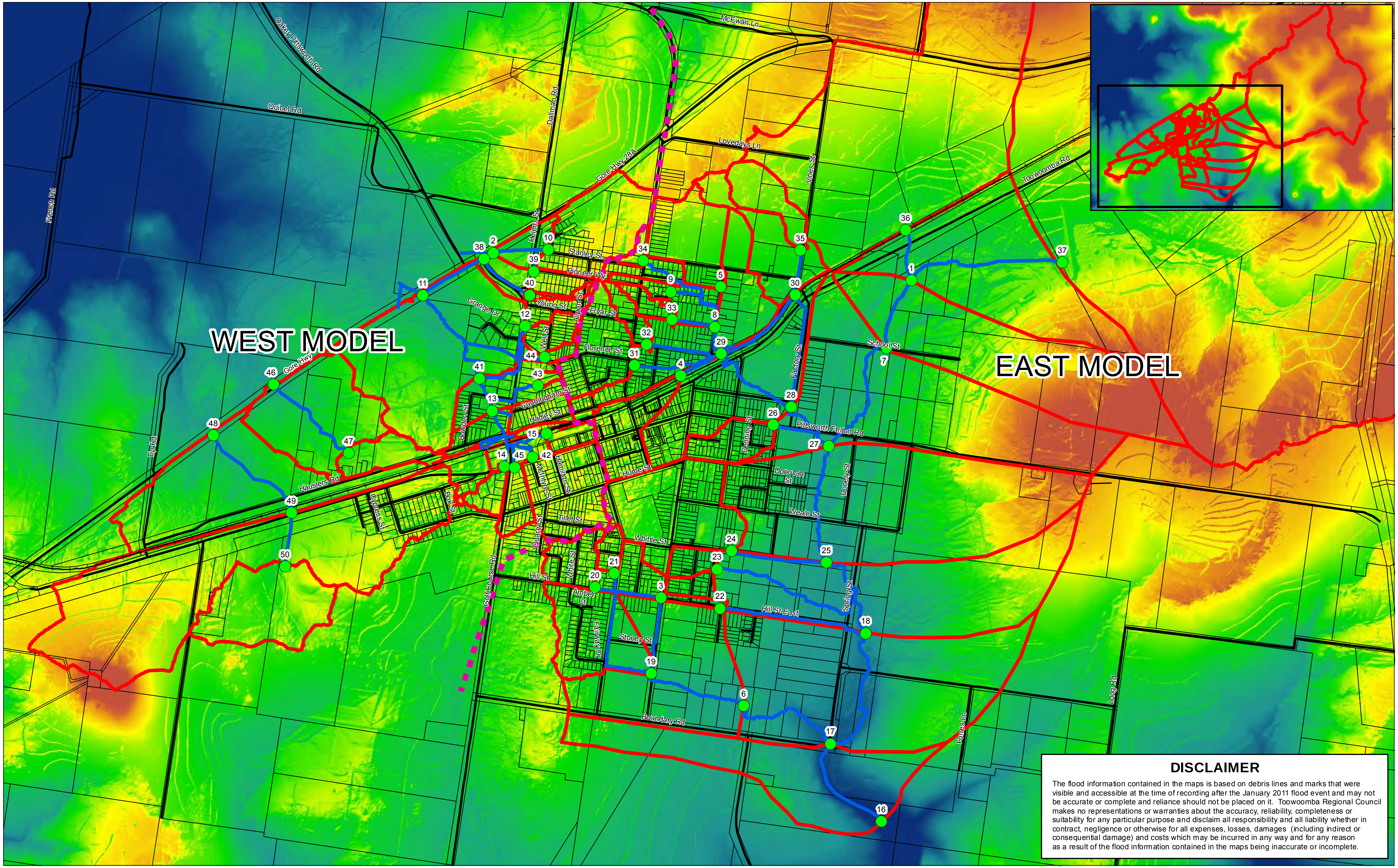
- Overland Catchment Outlets
- Overland Flow Paths
- Overland Catchments
- Riverine Catchment Outlets
- Riverine Flow Paths
- Riverine Catchments
- Cadastre
- Major Road

Topography (mAHD)

Value
High : 600
Low : 450

SP051 Flood Studies - Work Package 11
Goombungee Catchment Plan
Figure 4-1

J2810-04-Goombungee_Catchment.mxd
Author/Date: blairfiler 03/11/2015



DISCLAIMER

The flood information contained in the maps is based on debris lines and marks that were visible and accessible at the time of recording after the January 2011 flood event and may not be accurate or complete and reliance should not be placed on it. Toowoomba Regional Council makes no representations or warranties about the accuracy, reliability, completeness or suitability for any particular purpose and disclaim all responsibility and all liability whether in contract, negligence or otherwise for all expenses, losses, damages (including indirect or consequential damage) and costs which may be incurred in any way and for any reason as a result of the flood information contained in the maps being inaccurate or incomplete.

TOOWOOMBA REGIONAL COUNCIL

1:18,000 (at A3)

0 137.5 275 550
Meters

GDA 1994 MGA Zone 56

N

Legend

- East / West Pittsworth Model Boundary
- Catchment Outlet ID
- Catchment Flowpaths
- QLD Rail Network
- Catchment Boundaries
- Major Road
- Cadastre

Topography

Value (mAHD)

High : 580

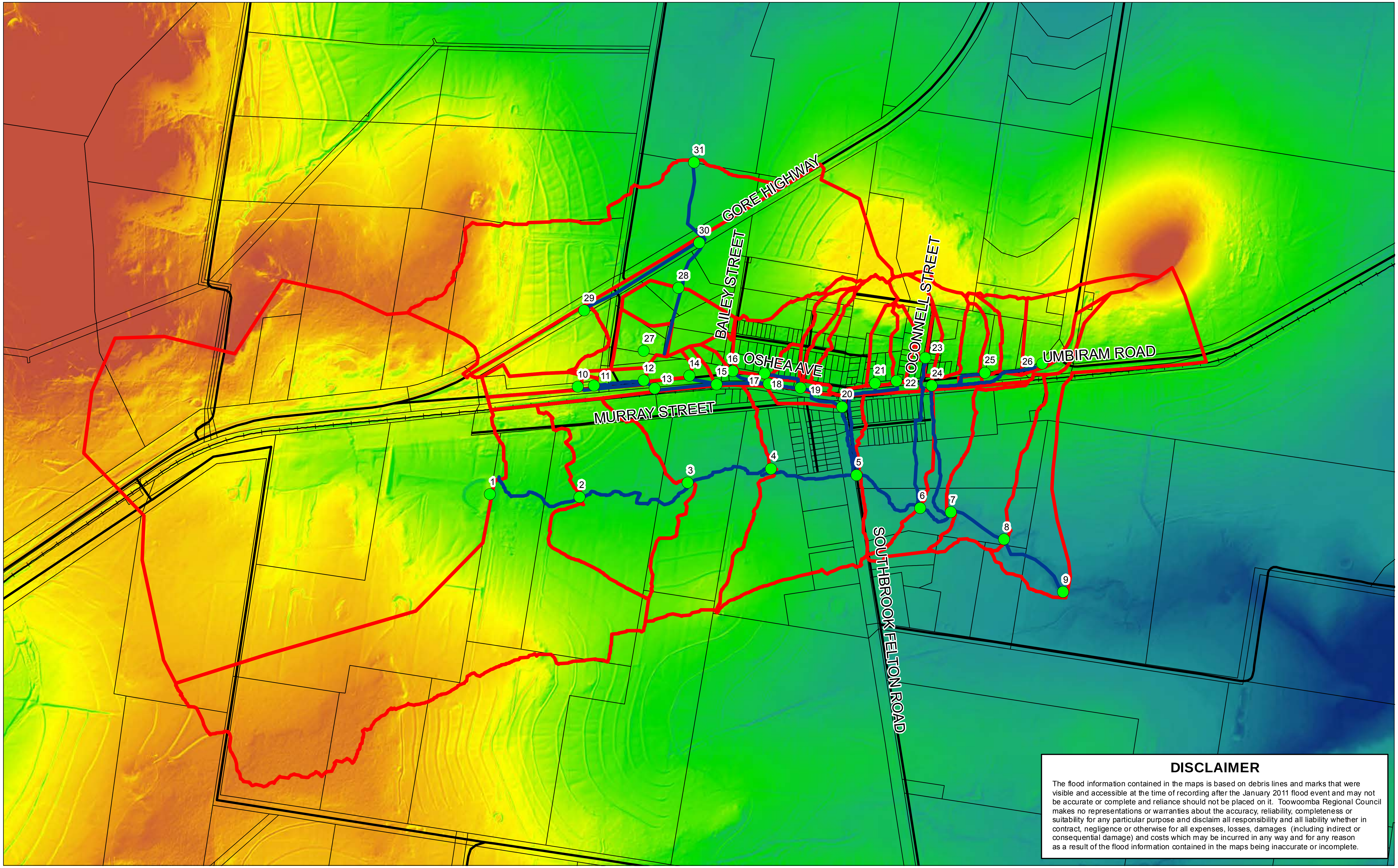
Low : 480

SP051 Flood Studies - Work Package 11

Pittsworth Catchment Plan

Figure 4-2

J2810-04-Pittsworth_catchment.mxd
Author/Date: luke.mcavoy 18/03/2014



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TOOWOOMBA REGIONAL COUNCIL

1:12,000 (at A3)

0 90 180 360

Meters

GDA 1994 MGA Zone 56

N

Legend

- Catchment Outlet ID
- Catchment Flowpaths
- Catchment Boundaries
- QLD Rail Network
- Major Road
- Cadastre

Topography (mAHD)

Value

High : 630

Low : 510

SP051 Flood Studies - Work Package 11

Southbrook Catchment Plan

Figure 4-3

J2810-04-Southbrook_catchment.mxd
Author/Date: luke.mcavoy 18/03/2014

Table 4.2 Rational Method Peak Discharge Estimates for Goombungee

Catchment ID (Note 1)	Total Contributing Catchment Area to Catchment ID (hectares)	Rational Method Peak Discharge Estimates (m^3/s)		
		100 Year ARI	20 Year ARI	5 Year ARI
1	1594.8	126.9	85.4	60.9
2	34.3	6.2	4.2	2.9
3	1687.7	130.5	87.8	62.6
4	59.1	9.3	6.3	4.4
5	1762.0	132.1	88.9	63.4
6	11.2	2.0	1.3	0.9
7	8.7	1.8	1.2	0.8
8	2.1	0.8	0.5	0.4
9	13.4	3.8	2.5	1.8
10	1883.2	133.4	89.8	64.1
15	1915.8	138.7	93.4	66.6
16	0.5	0.2	0.1	0.1
17	29.2	4.6	3.1	2.2
19	2102.3	140.7	94.8	67.6
20	2145.6	146.8	98.9	70.5
21	2250.2	151.1	101.7	72.6
22	1.6	0.6	0.4	0.3
23	9.1	2.7	1.8	1.2
24	10.9	1.7	1.1	0.8
25	4.9	1.4	0.9	0.7
26	37.4	6.6	4.4	3.2
27	53.6	9.2	6.1	4.3
28	277.3	39.4	26.4	18.8
29	343.2	48.8	32.7	23.2
30	470.8	63.0	42.2	30.0
31	508.1	63.9	42.9	30.5
32	598.4	71.3	47.9	34.0
34 – Note 2	2911.2	198.9	133.9	95.6
36	16.6	5.3	3.5	2.5
38	3.6	1.4	0.9	0.7
39	3.3	1.3	0.9	0.6
40	3.9	1.5	1.0	0.7
41	6.4	2.3	1.5	1.1

Notes

(1) Refer Figure 4.1 for flow reporting locations
(2) Catchment outlet node.

Table 4.3 Rational Method Peak Discharge Estimates for Pittsworth

Catchment ID (Note 1)	Total Contributing Catchment Area to Catchment ID (hectares)	Rational Method Peak Discharge Estimates (m^3/s)		
		100 Year ARI	20 Year ARI	5 Year ARI
1	1601.4	117.7	80.0	57.7
2	25.6	7.0	4.7	3.4
3	16.5	5.2	3.5	2.5
4	12.4	3.6	2.4	1.7
5	15.9	4.7	3.2	2.2
6	63.0	14.0	9.4	6.7
7	1664.6	118.6	80.6	58.2
8	31.5	9.3	6.3	4.5
9	2.1	0.7	0.5	0.3
10	20.8	6.0	4.0	2.9
11	158.9	34.0	23.0	16.5
12	3.6	1.2	0.8	0.6
13	48.3	13.4	9.0	6.4
14	25.6	7.0	4.7	3.4
15	3.0	0.8	0.5	0.4
16 – Note 2	2314.1	139.2	94.6	68.2
17	2266.9	140.5	95.4	68.8
18	2117.6	136.2	92.6	66.7
19	19.6	5.4	3.6	2.6
20	7.2	2.4	1.6	1.2
21	2.6	1.0	0.6	0.5
22	1.4	0.5	0.3	0.2
23	6.3	2.3	1.5	1.1
24	29.0	7.8	5.3	3.8
25	2026.7	135.0	91.8	66.2
26	7.8	2.6	1.7	1.2
27	1904	130.4	88.6	63.9
28	151.3	37.0	25.0	17.9
29	77.9	22.1	14.9	10.6
30	24.1	5.6	3.8	2.7
31	14	4.5	3.0	2.2
32	3.7	1.2	0.8	0.6
33	2.8	0.9	0.6	0.4
34	1.5	0.4	0.3	0.2
35	8.9	1.9	1.3	0.9

Catchment ID (Note 1)	Total Contributing Catchment Area to Catchment ID (hectares)	Rational Method Peak Discharge Estimates (m^3/s)		
		100 Year ARI	20 Year ARI	5 Year ARI
36	132.1	20.7	14.0	10.1
37	1410.8	109.4	74.3	53.6
38	34.3	10.2	6.8	4.9
39	3.5	1.2	0.8	0.6
40	1.2	0.4	0.3	0.2
41	59.7	14.3	9.7	6.9
42	17.8	5.9	4.0	2.8
43	0.8	0.3	0.2	0.1
44	1.5	0.5	0.3	0.2
45	4.8	1.6	1.1	0.8
46	36.6	6.2	4.2	3.0
47	7.4	1.4	0.9	0.7
48	164.5	24.8	16.8	12.1
49	117.1	21.9	14.8	10.6
50	24.6	4.6	3.1	2.2

Notes

(1) Refer Figure 4.2 for flow reporting locations
(2) Catchment outlet node.

Table 4.4 Rational Method Peak Discharge Estimates for Southbrook

Catchment ID (Note 1)	Total Contributing Catchment Area to Catchment ID (hectares)	Rational Method Peak Discharge Estimates (m^3/s)		
		100 Year ARI	20 Year ARI	5 Year ARI
1	141.7	21.1	14.2	10.1
2	211.7	30.0	20.2	14.3
3	232.8	31.5	21.1	15.1
4	258.8	33.0	22.2	15.8
5	318.2	40.5	27.2	19.4
6	330.9	40.9	27.5	19.6
7	356.2	43.1	29.0	20.7
8	368.6	44.0	29.6	21.2
9 – Note 2	390.6	45.5	30.7	21.9
10	2.5	0.6	0.4	0.3
11	2.7	0.7	0.5	0.3
12	3.9	1.0	0.7	0.5
13	6.1	1.7	1.1	0.8
14	1.2	0.4	0.3	0.2
15	8.7	2.7	1.8	1.3
16	0.8	0.2	0.2	0.1
17	11.0	3.4	2.2	1.6
18	5.3	1.7	1.2	0.8
19	19.0	8.7	5.7	3.9
20	27.7	12.3	8.0	5.5
21	2.7	0.7	0.5	0.3
22	1.6	0.6	0.4	0.3
23	2.3	0.5	0.4	0.3
24	8.3	2.5	1.7	1.2
25	1.6	0.4	0.3	0.2
26	5.7	1.3	0.8	0.6
27	3.0	0.6	0.4	0.3
28	8.5	1.6	1.1	0.7
29	5.6	1.4	0.9	0.6
30	41.1	8.3	5.5	3.9
31	76.2	22.6	14.9	10.3

Notes

(1) Refer Figure 4.3 for flow reporting locations

(2) Catchment outlet node.

4.9 Flow Estimate Validation for Larger Catchments

In order to validate the flow estimates for the larger catchments in the Goombungee and Pittsworth study areas, comparison of Rational Method discharge estimates was undertaken with the Australian Regional Flood Frequency Model (ARFF) (IEAust, 2012).

4.9.1 Comment on Suitability of the Rational Method and ARFF Check

The Rational Method

It is recommended that the application of the Rational Method be limited to rural catchments with a catchment areas less than 25 km^2 and for urban catchments less than 5 km^2 in area (QUDM [NRM, 2007]). The large external catchment areas contributing to both the main flow path to the west of Goombungee (22.5 km^2 - catchment ID 21 in Table 4.2) and to the main flow path to the east of Pittsworth (23.1 km^2– catchment ID 16 in Table 4.3) are at the upper limit of this recommendation. The overall Goombungee catchment at the study area outlet (a combination of both eastern and western flow paths) only just exceeds this recommended limit (29.1 km^2 –catchment ID 34 in Table 4.2). Notwithstanding the one catchment that exceeded the recommended size limitation, the Rational Method has been adopted in this study for all catchments for the following reasons: -

- The Rational Method does not allow for flow attenuation/catchment storage; the estimates are therefore likely to be conservative and appropriate for a planning scheme study.
- The Rational Method gives some guidance on the discharge magnitude. The only alternative to using the Rational Method would be to have an un-calibrated rainfall-runoff model. It is considered this would have considerably greater uncertainty than the use of the Rational Method.

The Australian Regional Flood Frequency Model (ARFF)

The Australian Regional Flood Frequency Model (ARFF) (IEAust, 2012) has been considered as part of this study. The ARFF was used to check the flood magnitude estimates for the larger contributing catchments in the Goombungee, Pittsworth and Southbrook study areas. Although the ARFF estimates are based on natural catchment conditions, it was considered that the small difference in urbanisation between the existing and ultimate development land uses in the study areas given the catchment sizes was likely to be negligible and consequently the ARFF estimates could be used to provide further validation of the catchment flows. Table 4.5 shows the comparison of ARFF and Rational Method discharge estimates for the three study areas. Good correlation was shown between the Rational Method and ARFF peak discharge estimates for the 100 year ARI event, with the Rational Method estimates shown to be between 7% (Goombungee) and 15% (Pittsworth) greater than the ARFF estimates. In all cases, the Rational Method 100 year ARI estimates were found to be slightly higher than the ARFF estimates, but in general agreement.

The discrepancy between the Rational Method and the ARFF Model discharge estimates for the lower ARI events is considered of lesser importance than the 100 year ARI; as it is this flood magnitude upon which the planning scheme is based. Estimate comparisons for other studies undertaken by Water Technology have shown similar discrepancies for these lower order magnitude events between the ARFF and other discharge estimation methods.

Table 4.5 Discharge Estimates for Rational Method and ARFF Model

	Goombungee - Western Flowpath (Area = 22.5 km^2) (Note 1)		Pittsworth East (Area = 23.1 km^2) (Note 2)		Southbrook (Area = 3.9 km^2) (Note 3)	
ARI Years	Rational Method Peak Discharge (m^3/s)	ARFF Peak Discharge (m^3/s)	Rational Method Peak Discharge (m^3/s)	ARFF Peak Discharge (m^3/s)	Rational Method Peak Discharge (m^3/s)	ARFF Peak Discharge (m^3/s)
5	72.6	30.9	68.2	27.4	21.9	9.10
20	101.7	72.7	94.6	64.6	30.7	21.4
100	151.1	136.2	139.2	121.0	45.5	40.2

Notes

(1) Refer catchment ID 21 in Table 4.2;
(2) Refer catchment ID 16 in Table 4.3;
(3) Refer catchment ID 9 in Table 4.4.

5. HYDRAULIC MODELLING

5.1 Model Description

Hydraulic modelling of the three study areas has been undertaken utilising DHI Software's MIKE FLOOD modelling system. The use of MIKE FLOOD was a specific requirement of the project as specified by TRC.

MIKE FLOOD combines via dynamic coupling the one-dimensional MIKE 11 river model and MIKE 21 fully two-dimensional model systems. Through coupling of these two systems it is possible to accurately represent in and over-bank floodplain flood behaviour as well as sub-surface drainage flow behaviour through the application of a comprehensive range of hydraulic structures (including culverts, bridges, weirs, control gates etc.).

In addition to the MIKE FLOOD hydraulic modelling, overland flow in the Goombungee township was analysed using the TUFLOW "Direct Rainfall" method. This approach involves applying a rainfall pattern over a polygon covering the township of Goombungee and allows the model to determine the direction of the overland flow. This approach allows a more accurate representation of the flood levels in the township of Goombungee.

5.2 Modelled Events

This report summarises the hydraulic model results for all design rainfall events analysed in this study, namely the 5, 20 and 100 year ARI events.

5.3 Model Details

5.3.1 Model Area and Extents

The model areas and extents for the various MIKE FLOOD models developed for this study are presented in Figure 5.1 to Figure 5.3. The model areas and extents for the Goombungee TUFLOW model are presented in Figure 5.4.

5.3.2 Model Resolution

The MIKE FLOOD and TUFLOW models developed for this assessment have utilised a 2 m cell resolution. This was considered appropriate to accurately represent flood behaviour in the local flowpaths within the township areas, as well as maintaining realistic model simulation times.

It is noted that the Pittsworth study area was divided into two separate model areas due to the spatial variability of the different flow paths nominated to be modelled. This allowed for a 2 m model resolution to be maintained across the greater Pittsworth study area. Amalgamation of the two models into one overall model domain would result in excessively long simulation times, limiting the usefulness of the model for future assessment or mitigation works by Council. Additionally, a coarser model resolution to reduce simulation times would not have allowed for accurate representation of local flowpath flood behaviour.

5.3.3 Model Alignment and Orientation

All models developed for this analysis have been aligned in a traditional North/South orientation (0 degrees).

5.3.4 Hydraulic Structures

In a full 2D modelling environment it is often not possible to accurately describe the hydraulic behaviour of structures such as culverts and bridges. This is due to the fact that grid cell sizes often exceed the dimensions of various structures in addition to the grid cells only representing bottom friction and consequently no roof friction or specific hydraulic structure losses. As a result, hydraulic structures are often more accurately modelled in a 1D modelling environment within the 2D domain, thus allowing prescriptive modelling of the exact characteristics of the various structures. Hydraulic structures within the study areas have therefore been incorporated within the MIKE 11 modelling domain.

As no survey information was available for the hydraulic structures, structure size and location details have been derived from the provided GIS database for Pittsworth, field notes, the structure database prepared for this study as well as the oblique photographic records as described in Section 2.5. Invert levels for the structures were estimated from an assessment of the structure height/diameter and ground cover to the road crown as well as other topographic considerations based on the topographic information. This was then assessed in a GIS environment to determine the likely invert level of each structure from the DEM. A nominal 100mm cross fall between the upstream and downstream invert levels of the structures was adopted in the most part for all hydraulic structures due to lack of any better available information.

Appendix A provides a summary of the hydraulic structures collected during the site visits. Most of these structures have been incorporated within the various MIKE FLOOD and TUFLOW models prepared for each of the towns under this work package. Pipes with a diameter less than 0.3 m were not included in the hydraulic models. Appendix A additionally includes a map illustrating the locations of each of the hydraulic structures. It should be noted that the number of structures in the Goombungee Township differs between the MIKE FLOOD and TUFLOW models. Hydraulic structures located in riverine areas were not included in the overland flow path model (TUFLOW). Similarly, structures located within the overland flow path model area were not included in the riverine model (MIKE FLOOD).

5.3.5 Model Boundaries

Downstream Boundaries

Downstream boundaries for all models were located a sufficient distance downstream from the furthest limit of mapping as to not impact on flood behaviour predictions within the areas of interest.

Iterative assessments of the peak water surface level and local topography longitudinal grade were undertaken until a suitable tailwater level was determined for each model boundary. A summary of the downstream boundary conditions is presented in Table 5.1.

Table 5.1 Adopted Downstream Boundary Conditions

Model Name	Boundary Location Description	Adopted Tailwater Level (m AHD)
Goombungee	Approximately 1000 m downstream of Kingsthorpe Haden Road	465.2
Pittsworth West	Approximately 1300 m downstream of the Gore Highway	483.0
Pittsworth East	Approximately 700 m downstream of the intersection of Boundary Road and Spring Street	478.0
Southbrook	Approximately 400 m downstream of the Gore Highway. (North)	535.0 (North)
	Approximately 1100 m downstream of the Southbrook Felton Road. (South)	522.0 (South)

Inflow Boundaries

The peak catchment discharge estimates for each model inflow location from the Rational Method analysis were applied to the MIKE FLOOD 2D model domains by way of direct application of the representative peak catchment discharge at the respective locations throughout the model domain. These inflows included source and sink inflows applied both throughout the model domain as well as discrete inflows at primary inflow points to the 2D domain.

To preserve flow balances in the hydraulic model to specifically match with the Rational Method flows at all reporting locations throughout the model domain, we have included sink points typically at tributary confluence locations. The sink points are used to reduce excess cumulative flows from the model domain and to ensure that the overall flow balance is preserved in accordance with the Rational Method peak discharge estimates for each location in the study area. The sink points are located within the main channels and where necessary and depending on the magnitude of the sink, have been allocated over a number of sink locations to otherwise prevent unrepresentative model results.

Pittsworth East

It is noted that the Pittsworth East model was simulated in two separate scenarios. The first simulation was undertaken for the major flow path along the eastern fringes of the town, while the second simulation was undertaken for the local overland flow paths within the town itself. This was undertaken to assist in flow balancing along the main creek flow path during the steady state analysis. Results have been merged to create a total flood envelope for the two simulations for presentation in GIS maps.

Goombungee Overland

The Goombungee overland TUFLOW model uses a direct rainfall based on the IFD extracted for the Goombungee area. The initial and continuing loss model parameters were set at 15mm and 1.5mm/hr respectively. There is limited model calibration or validation data associated with overland flooding in the town. The rainfall losses applied are consistent with QUDM and Australian Rainfall and Runoff guidelines.

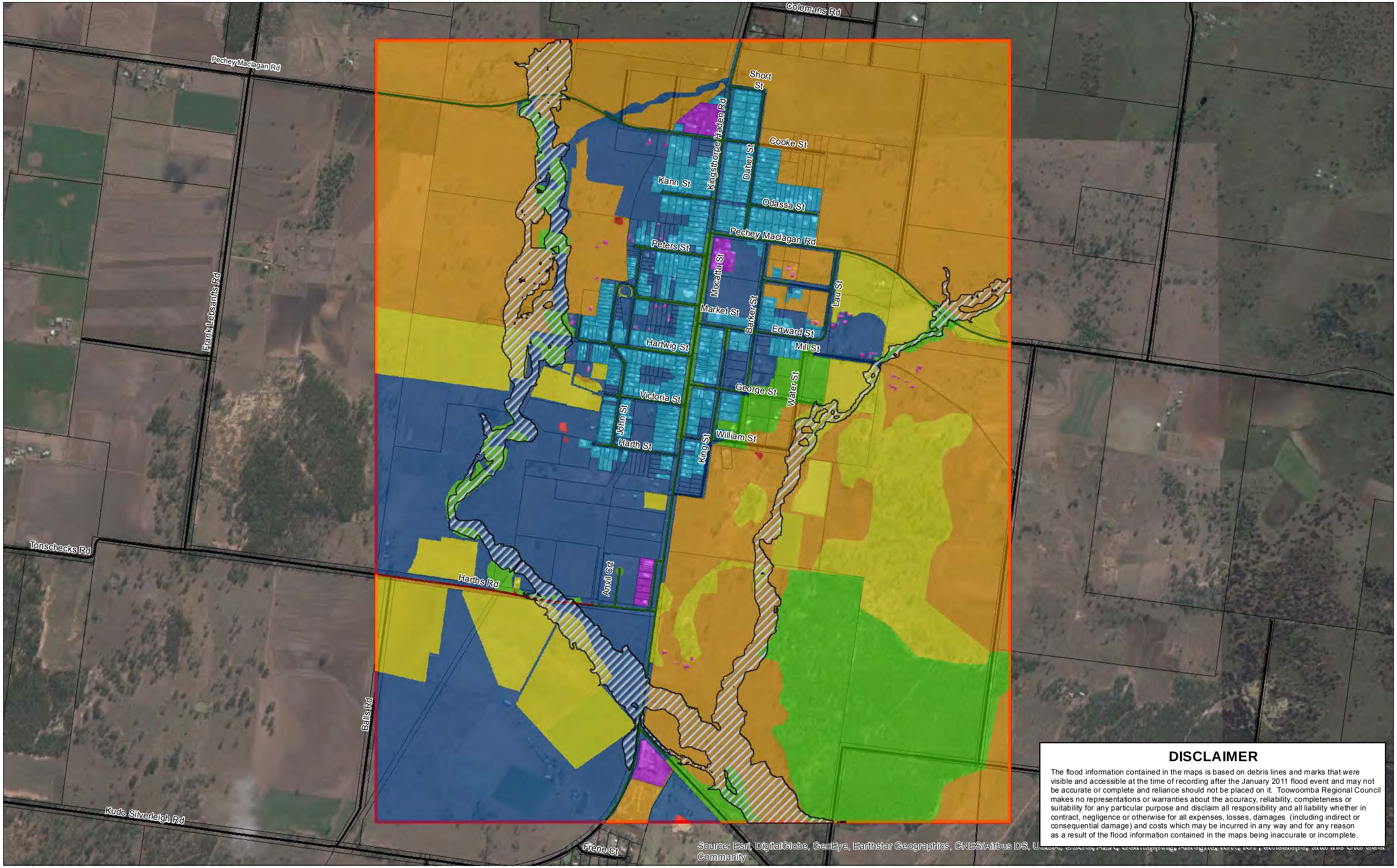
5.3.6 Floodplain Roughness

Floodplain roughness values were derived based on a review of aerial photography, site notes and oblique photographic record as well as recommendations outlined in Table 10-1 of Project 15 of the AR&R review, namely 'Two Dimensional Modelling in Urban and Rural Floodplains'. A summary of the roughness values to be adopted for the hydraulic models was prepared and provided to TRC for approval during the course of the project. A summary of the adopted roughness values is presented in Table 5.2 and these have been applied consistently to each of the respective hydraulic models for each of the town areas. Given the input required for the more detailed TUFLOW model, the floodplain roughness for the analysis of overland flow in the Goombungee Township was amended to show more detail.

Table 5.2 Adopted Floodplain Roughness Values

Floodplain Description	Manning's 'n' Value
Culverts - Concrete	0.014
Concrete Lined Channels	0.017
Roads/Paved Areas/Carparks/Driveways	0.020
Gravel Road	0.025
Lakes/Dams/Water Bodies	0.025
Culverts - Corrugated	0.025
Railway	0.030
Waterways/Channels - Minimal Vegetation	0.040
Open Pervious Areas - Grassed	0.045
Wetlands/Marsh Areas	0.060
Open Pervious Areas - Shrubs	0.060
Waterways/Channels - General Vegetation	0.070
Open Pervious Areas - Treed	0.080
Cropping/Broadhectare	0.080
Waterways/Channels - Thick Vegetation	0.100
Residential - Low Density	0.150
Residential - High Density	0.300
Industrial/Commercial	0.300
Buildings - Permeable	0.500
Residential/Commercial Yards	0.065

Figure 5.1 to Figure 5.4 show the spatial variability of roughness values adopted across the study areas.



TOOWOOMBA REGIONAL COUNCIL

1:15,000 (at A3)

0 115 230 460

Meters

GDA 1994 MGA Zone 56

N

Legend

- 100 year ARI Flood Extent
- Major Road
- MIKE Flood Model Domain
- Cadastre

Manning's 'n' Roughness

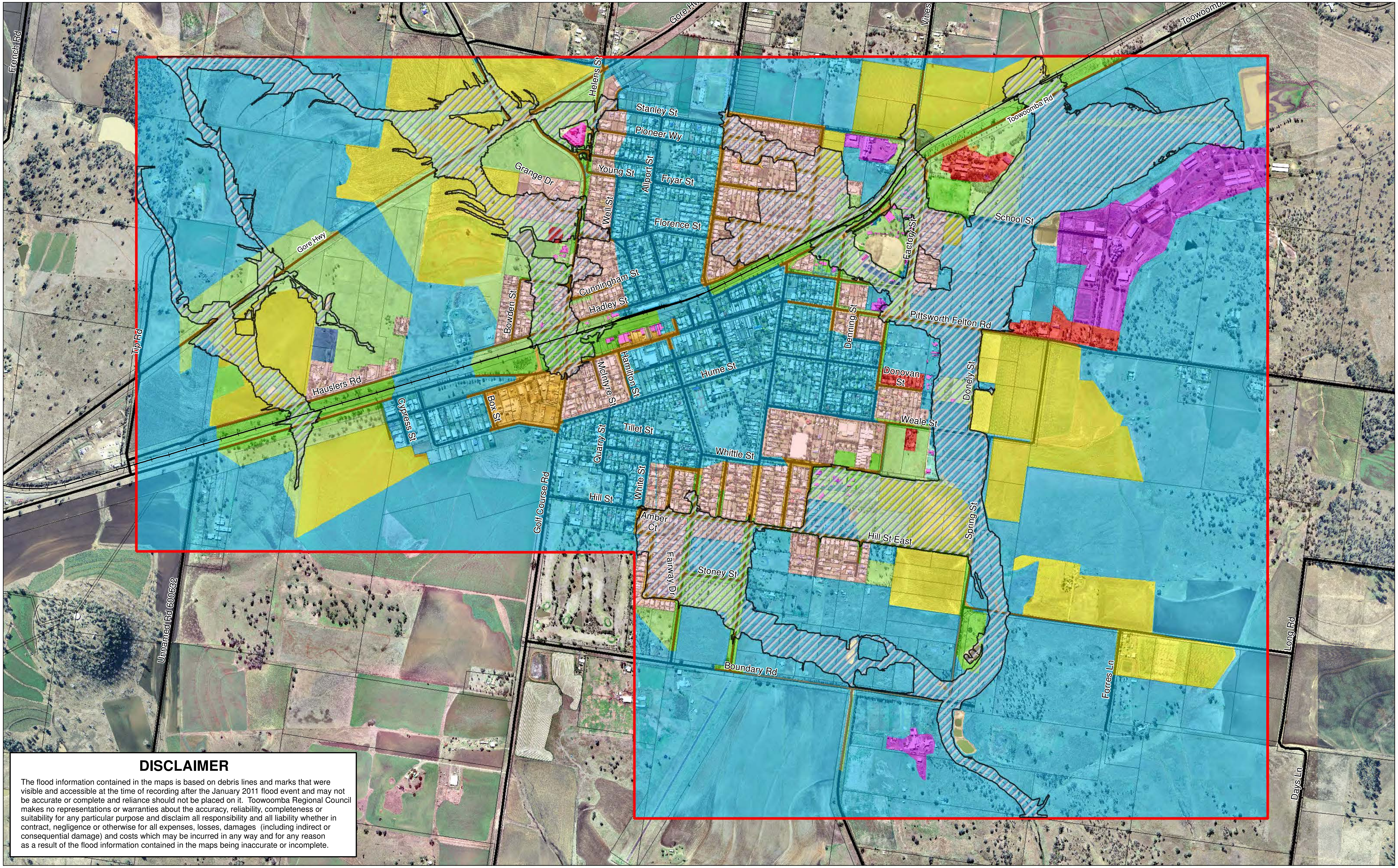
0.5	0.1	0.045
0.3	0.08	0.025
0.15	0.06	0.02

SP051 Flood Studies - Work Package 11

Goombungee Riverine Floodplain Roughness Definition

Figure 5-1

J2810-04-Goombungee_Roughness.mxd
Author/Date: blair.filer 20/08/2015



DISCLAIMER

The flood information contained in the maps is based on debris lines and marks that were visible and accessible at the time of recording after the January 2011 flood event and may not be accurate or complete and reliance should not be placed on it. Toowoomba Regional Council makes no representations or warranties about the accuracy, reliability, completeness or suitability for any particular purpose and disclaim all responsibility and all liability whether in contract, negligence or otherwise for all expenses, losses, damages (including indirect or consequential damage) and costs which may be incurred in any way and for any reason as a result of the flood information contained in the maps being inaccurate or incomplete.

TOOWOOMBA REGIONAL COUNCIL

1:15,000 (at A3)

0 115 230 460
Meters

GDA 1994 MGA Zone 56

N

Legend

- QLD Rail Network
- 100 Year ARI Flood Extent
- MIKE Flood Model Domain
- Major Road
- Cadastre

Manning's 'n' Roughness

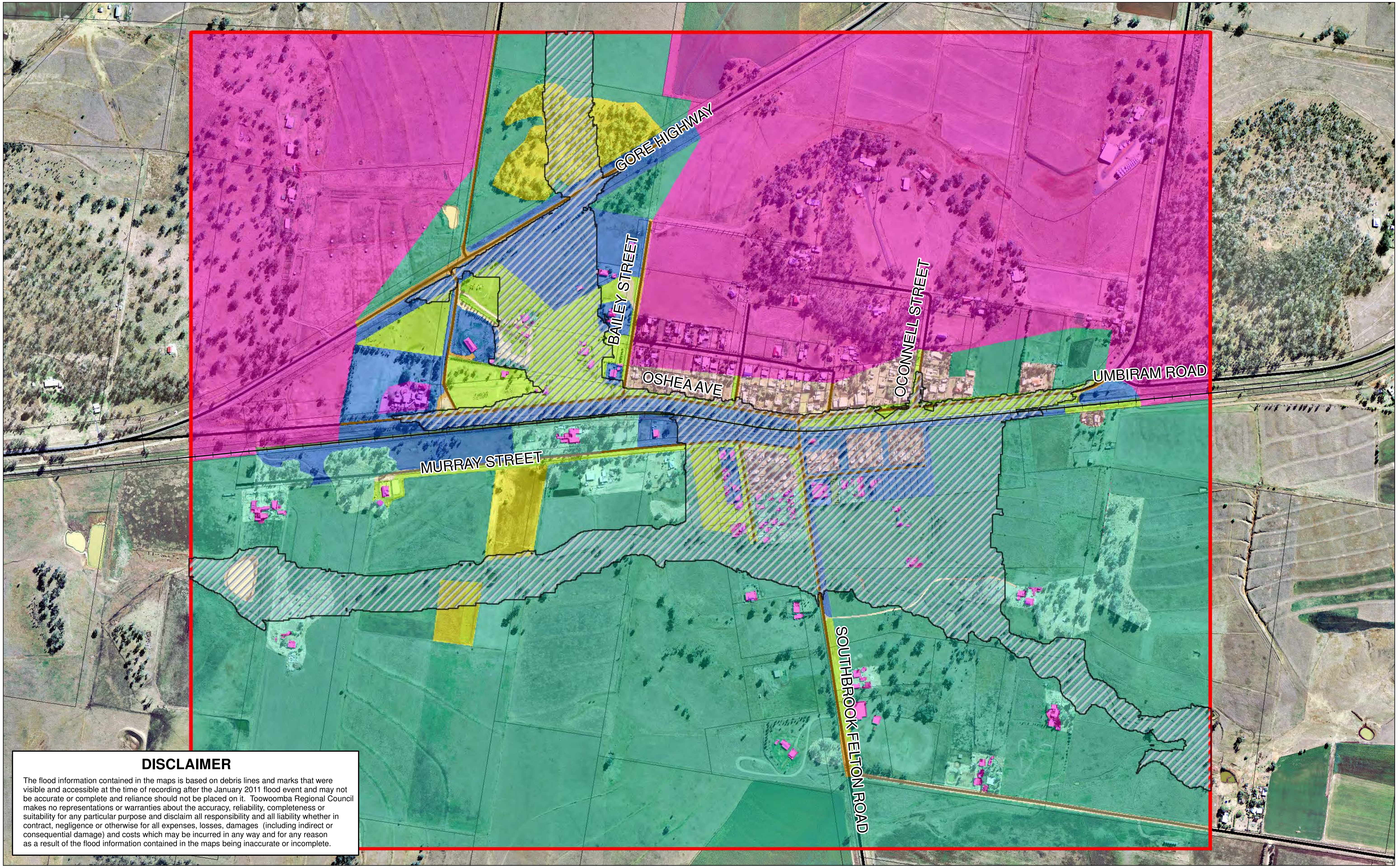
0.5	0.1	0.06	0.04	0.02
0.3	0.08	0.05	0.03	
0.15	0.07	0.045	0.025	

SP051 Flood Studies - Work Package 11

Pittsworth Floodplain Roughness Definition

Figure 5-2

J2810-04-Pittsworth_West_rough.mxd
Author/Date: Ryan.dermek 18/03/2014



DISCLAIMER

The flood information contained in the maps is based on debris lines and marks that were visible and accessible at the time of recording after the January 2011 flood event and may not be accurate or complete and reliance should not be placed on it. Toowoomba Regional Council makes no representations or warranties about the accuracy, reliability, completeness or suitability for any particular purpose and disclaim all responsibility and all liability whether in contract, negligence or otherwise for all expenses, losses, damages (including indirect or consequential damage) and costs which may be incurred in any way and for any reason as a result of the flood information contained in the maps being inaccurate or incomplete.

TOOWOOMBA REGIONAL COUNCIL

1:8,000 (at A3)

0 60 120 240

Meters

GDA 1994 MGA Zone 56

N

Legend

- QLD Rail Network
- 100 year ARI Flood Extent
- MIKE Flood Model Domain
- Major Road
- Cadastre

Manning's 'n' Roughness

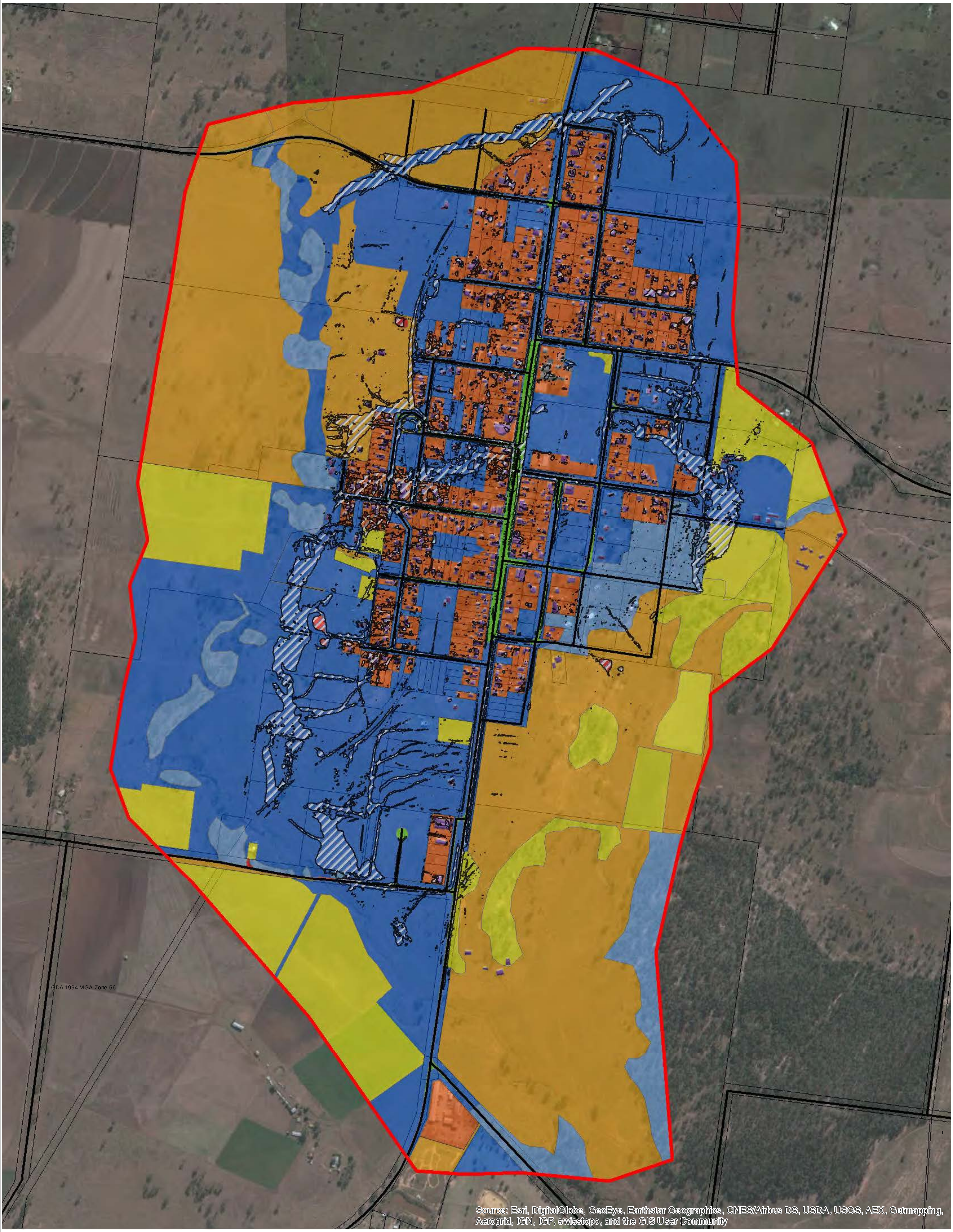
0.5	0.08	0.045	0.025
0.3	0.07	0.04	0.02
0.15	0.06	0.03	

SP051 Flood Studies - Work Package 11

Southbrook Floodplain Roughness Definition

Figure 5-3

J2810-04-Southbrook_Rough.mxd
Author/Date: Ryan.dermek 18/03/2014



TOOWOOMBA REGIONAL COUNCIL

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

GDA 1994 MGA Zone 56

Legend

100 year ARI Flood Extent

Cadastre

TUFLOW Flood Model Domain

Major Road

0 75 150 300 450 Metres

1:10,000 (at A3)

Manning's 'n' Roughness

0.02, 0.025, 0.04, 0.045, 0.05, 0.06, 0.065, 0.08, 0.3, 0.5

N

SP051 Flood Studies
Work Package 11

Goombungee Overland
Floodplain Roughness Definition
Figure 5-4

5.3.7 Topographic Changes

Minor topographic changes have been made in all models to assist in accurate representation of flow behaviour and model stability around model boundaries.

Changes were typically limited to areas around MIKE 11 structures to aid in accurate representation of structure inverts and flow transference between the 1D and 2D model domains. Additionally, filling of road embankments at these locations was often required due to the LiDAR data having filtered out the road embankment at the creek crossings.

Minor changes to topography around model boundaries have been undertaken to assist in model stability during the simulations. These changes have no effect on flood behaviour estimations in the areas of interest in these assessments.

5.4 Model Validation

5.4.1 Model Validation Philosophy

The project briefing requirements for model validation for Work Package 11 specified a methodology which was to be determined by the consultant and having regard to the available historical flood information. Accordingly, we have applied a model validation approach which is consistent with the project briefing requirements. The approach has included the analysis of the 100 year ARI flood event for each of the Goombungee, Pittsworth and Southbrook overland flow path studies for model validation.

One of the better techniques available for model validation is to undertake formal calibration involving rainfall runoff modelling using historical rainfall and matching historical flood levels. Hydraulic model predictions can then be assessed and model parameters adjusted within appropriate tolerances to achieve the best fit to historic flood levels and timing of flood peaks. This approach can be undertaken for a range of historical flood events, culminating in a set of appropriate model parameters that best matches the catchment response and hydraulic properties of the waterway. This approach typically requires extensive data sets including catchment specific historical rainfall (both daily and sub-daily rainfalls) in addition with accurate peak flood level information. As these studies have adopted steady-state style analyses, this methodology was not applicable.

An alternative to the above approach, and in the absence of rainfall-runoff modelling, is to match hydraulic model results to anecdotal peak historical flood levels using a range of inflow values. The magnitude of the inflows adopted in the hydraulic model that result in modelled flood heights matching anecdotal historic flood levels is then rationalised by comparison with historical stream gauge records and/or flood frequency analyses. Where these are not available, other methods including the use of regional relationships such as the Australian Regional Flood Frequency Model (ARFF) may also be used. The primary purpose in these approaches is to ensure that the inflow estimates adopted in the hydraulic model are reasonable and appropriate in the context of any historical and anecdotal information that may be available.

The validation approach applied for all overland flow path studies for Work Package 11 towns is based on a comparison of historical flood level information to the 100 year ARI design rainfall event. This approach has been adopted for model validation given the absence of detailed catchment calibration information, no available stream flow records within the catchments and in consideration of the lower regional ARFF flow estimates for each of the towns.

For each of the Goombungee, Pittsworth and Southbrook models prepared under this work package, the historical data sourced for the purposes of the model validation comprised a mixture of data sources which included a combination of highest known flood level information that was nonspecific in respect to the date of occurrence, as well as historical flood level data that corresponded to the January 2011 event.

The January 2011 flood level data was generally limited in spatial coverage and when considered in isolation, was generally not sufficient to provide any meaningful model validation outcomes. To improve the coverage of historical flood level information, both sets of data were considered together as a set of historical validation points on which to compare the performance of the flood model. This approach is appropriate for model validation and for the purposes of testing overall model performance and in the absence of undertaking model calibration.

5.4.2 Limitations of Anecdotal Historic Flood Level Data

All historical flood information sourced and collected as part of the consultation program has been has been used to aid in the model validation tasks. In general, the historical data collected included the following: -

- Observed flood level data provided by TRC which related specifically to the January 2011 flood event. This ranged from indicative flood depth estimates for the event through to observed flood level information; and
- Other historical data sets relating to the highest known flooding which occurred historically. This historical data was not related to any specific historical event rather was simply anecdotal information for the largest known flooding which may have occurred at the specific area. Some of this type of data represented anecdotal accounts passed down through the generations of long-term residents in the areas.

While the January 2011 event was one of the largest flood events on record for many of the areas under investigation, significant flooding occurred at discrete times throughout the entire period from December 2010 to the end of January 2011. No specific data was sourced as part of the consultation program for other significant flood events that may have occurred throughout this period other than for the largest event.

We note that the use of anecdotal historic flood level information has inherent inaccuracies that may impact on the accuracy of the historic flood levels provided. Recollections of historic floods can be sometimes vague, (e.g. “I don’t think I’ve seen it overtop the road”), as well as respondents recalling different historic rainfall events of different magnitude for different areas. Additionally, it may not be possible to determine whether the observed flood height represented the flood peak, or whether the flood was rising or receding at the time of observation.

As a result, the historic flood level information sourced as part of the consultation program and in the most part supplied by local residents should be viewed as a validation tool only, and in no way represents a formal calibration of either catchment discharge estimates or hydraulic model results.

5.4.3 Goombungee Model Validation Results

Historic Flood Levels

Historic flood levels for the Goombungee study area were supplied by a long-term local resident. Table 5.3 summarises the supplied historic flood data for Goombungee validation for both the riverine and overland flow in the MIKE FLOOD model. Where depths or levels have been provided, these have been converted to an approximate representative flood level by inspection of the DEM at the point of interest and comparison with consultation notes. The points represented by the Flood Level ID as well as the 100 year ARI peak flood depths can be seen in Appendix C.

Table 5.3 Goombungee Historic Flood Level Details

Flood Level ID	Description	Anecdotal Flood Record Level (m AHD) (approx.)	Modelled 100 Year ARI Peak Flood Level (m AHD)
GM_FL1	Debris observed on fence downstream of crossing during inspection. Height of debris approx. 1-1.2m above causeway.	472.8 – 473.0	473.5
GM_FL2	Long-term resident reported that railway bridge has never been overtopped. Highest water level estimated to be 6 foot below bridge. Railway embankment was washed out in the 1938 event - occurred in an area to the North East of the bridge along the railway embankment.	474.8	475.4
GM_FL3	Long-term resident reported that water has previously gone into the M&S Steel property in the 2010/2011 event, although he believes this was from the local catchment to the south.	470.3	469.8
GM_FL4	Long-term resident reported that water has previously gone over the crossing. About 2 foot in 2010/2011 event. Thought that 1m depth would be absolute extreme for flooding.	470.8 – 471.2	470.9
GM_FL5	Long-term resident reported the maximum water level to reach the 2nd tier of the landform at this location (on RHS bank downstream of road crossing of creek).	472.3	472.5
GM_FL6	Long-term resident reported that the house located on Harths Road adjacent to the railway bridge has never been flooded to above floor level. Floor level estimated approx. 500mm above ground level.	<476.4	Not Flooded
GM_FL7	Long-term resident reported flooding well over causeway on Harts Road. Estimated to be well over 1m deep.	>472.8	473.4
GM_FL8	Long-term resident reported that the creek came up to the rear of the property. Approximately 200m from rear property boundary fence.	481.1	481.1
GM_FL9	Long-term resident reported that creek flooding has never worried properties at the bottom of Victoria Street.	-	Local sheet flooding only
GM_FL10	Long-term resident reported that the shed on the creek bank has never been flooded.	<482.5	Local sheet flooding only
GM_FL11	Long-term resident reported that properties on Lebsanft Street have never been known to flood.	-	Local sheet flooding only

Flood Level ID	Description	Anecdotal Flood Record Level (m AHD) (approx.)	Modelled 100 Year ARI Peak Flood Level (m AHD)
GM_FL12	Long-term resident reported that there was talk of the 1938 flood event reaching Nicholas Street at this location. Seemed to think that this is very unlikely though.	-	Local sheet flooding only
GM_FL13	Long-term resident reported that Lilly Street is not known to have been cut by floodwaters.	<499.3	499.6
GM_FL14	Long-term resident reports flooding over crossing to 1m deep. Crossing was cut in 2010/2011 event. Was regularly cut in the old days - Has been upgrades to crossing since those times.	494.7	494.7
GM_FL15	Long-term resident reports no real flooding issues with this crossing. Not known to go over the road.	<494.2	493.6
333	TRC supplied observed flood level 2011 event.	485.5	485.6
334	TRC supplied observed flood level 2011 event.	470.7	470.9
335	TRC supplied observed flood level 2011 event.	470.4	470.9
336	TRC supplied observed flood level 2011 event.	494.2	494.5
337	TRC supplied observed flood level 2011 event.	494.1	494.1

Model Result Validation to Historic Flood Levels

It can be seen from results presented in Table 5.3 that the MIKE FLOOD model developed for Goombungee is accurately representing flood behaviour for a major flood event (100 year ARI) based on anecdotal information.

Flood behaviour predictions by the model at all major road crossing locations (such as Kingsthorpe-Haden Road, west-bound Pechey-Maclagen Road) were shown to be accurate in their depiction of reported historic flood levels at these locations. Only the eastern crossing of Pechey-Maclagen Road was shown to be slightly different to historic predictions, with model results suggesting minor overtopping (approximately 300 mm) occurring during the 100 year ARI event. Historic recollections by long-term residents at this location indicated that he hadn't believed the road had been overtopped. The minor level of overtopping predicted by the MIKE FLOOD model in this steady state analysis suggest that a hydrodynamic assessment may result in a lower level or even elimination of overtopping at this location due to storage effects behind the large road embankment. The likely 'peaky' nature of the hydrograph at this location due to the steep feeder catchments would also support this assumption. It is also noted that given the likely rapid rise and fall of flood levels at his location and due to the nature of the upstream catchment area, it is possible the flood peak (and minor overtopping) could pass rapidly through this area, meaning overtopping of the road embankment may not necessarily be observed.

Minor differences in modelled and observed flood levels were also noted in two other areas - at the abandoned rail line crossing (GM_FL2) and at the rear of the property at the end of Harth Street (GM_FL8). Long-term residents suggested the rail bridge had never been overtopped and had not come within 6 feet (approx. 1.8 m) of overtopping the bridge. Model results however suggest that floodwaters come within approximately 1.2 m of overtopping the bridge, and predicted that overtopping of the rail line occurred to the north-east of the bridge due to the lower topography at that location. This is supported by long-term resident's comments on the washout of this area during the 1938 event. Given the location of the bridge away from any easy observation point during times of flooding (besides the house located adjacent to the bridge) and the consistent nature of the predictions with the location of the railway embankment washout in the 1938 event, it is considered that the model is accurately representing flooding through this feature.

Long-term resident also noted flooding at the back of the property at the end of Harth Street (GM_FL8) had reached approximately 200m from the back fence. Analysis of GIS data at this location shows that 200m from the back fence of the property is in fact almost in the creek invert (left-hand over-bank flood level adopted in (Table 5.3). Review of the DEM shows a rise in the local topography approximately 90m from the back fence of this property, where the predicted 100 year ARI flood extent is located. It is likely that this is in fact where the long-term resident reports relate to and suggesting flooding had reached this area and is shown to be a major break out flow path from the main creek alignment. To allow the model to accurately predict in-bank flooding only as described by long-term resident accounts would suggest, flow estimates in the model would need to be significantly reduced, resulting in poor correlation between modelled and historic levels at other locations upstream and downstream of this site that are currently shown to produce very good correlation.

Observed flood levels from the January 2011 event supplied by TRC showed generally good correlation with the modelled 100 year ARI results at most locations. Typically, model results were approximately 200 mm higher than the TRC observed flood levels (collected after the January 2011 event). The only slightly larger discrepancy in predicted and observed levels occurred at location 335 which showed a 500 mm difference between modelled versus observed levels. Given that the observed levels at points 334 and 335 are both located immediately upstream of Kingsthorpe-Haden Road and the observed levels at these points are shown to have some 300 mm difference in elevation, it may be possible that this TRC observed flood level is erroneous or inaccurate. It is not clear if this in particular is due to debris receding with flood waters and consequently a lower observed level.

As a general note in relation to the TRC observed flood data, there is limited information on the levels in terms of the actual date of observation, whether these represent peak levels, descriptions on what has been observed (i.e. peak water levels, debris marks, estimated edge of extents, etc) as well as general comments on observations. With this in mind, we believe that the modelled results matched quite well to the observed levels and further aids in the model validation process.

It is noted that due to the rapid nature of local overland flow path flooding within the town resulting from the small feeder catchments, no definitive assessment of historic levels for these locations within the town was able to be undertaken. Long-term residents could not recollect any serious local stormwater flooding issues in the town.

TUFLOW "Direct Rainfall" Model Result Validation

In addition to the MIKE FLOOD validation, the TUFLOW "Direct Rainfall" model was, as far as possible, validated to the anecdotal observations of flooding and photos supplied by the long-term residents following a severe rainfall event on the 30th March, 2014. The levels and location shown in Table 5.3 typically refer to riverine flooding which was not analysed using TUFLOW. However, inundation by overland flow (local sheet flooding) at Locations GM_FL9, GM_FL10, GM_FL11 and GM_FL12 is reflected in the TUFLOW "Direct Rainfall" modelling results. It has been observed and reported that the Rural Fire Brigade and the SES locations encountered overland flooding which is reflected in the overland model results in Appendix D. Inundation was also observed at the intersections of John Street and Nicholas Street, and John Street and Hartwig Street. The TUFLOW modelling result show inundation at these locations. Photographs taken by residents and supplied to WT by TRC had incorrectly georeferenced metadata which placed the photograph locations well outside the area of interest. As such, it was not possible to accurately ascertain exactly where the photographs were taken unless specific landmarks were visible. Figure 5.5 shows inundation of Kingsthorpe-Haden Road during the March 2014 event. The TUFLOW model results exhibit inundation consistent with these locations. A selection of photographs at two unknown locations within the Goombungee Township are shown in Figure 5.6 and Figure 5.7.

Figure 5.5 Photograph showing inundation of Kingsthorpe – Haden Road, March 2014 (Source: Shane Maxwell)

Figure 5.6 Photograph showing inundation of roads in Goombungee, March 2014 (Source: Shane Maxwell)

Figure 5.7 Photograph showing overland flooding in Goombungee, March 2014 (Source: Shane Maxwell)

An additional validation of the TUFLOW model results was undertaken to confirm the accuracy of the model output. Peak flows at selected locations were extracted from the model results and compared to the flows estimated using the Rational Method calculation, as presented in Table 4.2. A comparison of the extracted and estimated flows for the Q100 design event is presented in Table 5.4. The comparison indicates that the peak flow extracted from the TUFLOW model is within 30% of that estimated using the Rational Method.

Table 5.4 Comparison of TUFLOW and Rational Method Peak Flows

Location	TUFLOW Peak Flow	Rational Method Flows	Difference
	(m^3/s)	(m^3/s)	(%)
7	1.4	1.8	20.9
8	0.9	0.8	25.5
9	4.9	3.8	28.6
24	1.5	1.7	7.3
25	1.3	1.4	9.2
26	7.4	6.6	11.4

5.4.4 Pittsworth Model Validation Results

Historic Flood Levels

Historic flood levels for the Pittsworth study area were supplied by a number of people with relevant history in the study area. Table 5.5 summarises the supplied historic flood data for Pittsworth. Where depths or levels have been provided, these have been converted to an approximate representative flood level by inspection of the DEM at the point of interest and comparison with consultation notes. The points represented by the Flood Level ID as well as the 100 year ARI peak flood depths can be seen in Appendix C.

Table 5.5 Pittsworth Historic Flood Level Details

Flood Level ID (Note 1)	Model Area	Description	Anecdotal Flood Record Level (m AHD) (approx.)	Modelled 100 Year ARI Peak Flood Level (m AHD)
PW_FL1	East Model	Flood depth marker board at this location.	n/a	n/a
PW_FL2	East Model	Long-term resident reported that the flood level got to the property at 318 Pittsworth-Felton Road (approx. location) in 2010/2011 event. Also estimated that depth of water over crossing was approx. 1 metre.	504.5	504
PW_FL3	East Model	Long-term resident reported that flood waters on road behind school will stop people/traffic crossing the road. Depth maybe 200 to 400mm. Comes up and down quite quickly.	512.3 – 512.5	512.3
PW_FL4	East Model	Long-term resident reported that flood waters flow across/though showgrounds downstream of this location.	n/a	n/a
PW_FL5	East Model	Long-term resident reported that shallow flood waters flow across road at this location - probably 100m wide.	510.8 (2)	510.9
PW_FL6	East Model	Long-term resident reported that he has seen floodwaters near this property at this location.	n/a	n/a
PW_FL7	East Model	Alexia Street - long-term resident reported drainage issues at this location at the end of the court bowl - constriction point here. Properties downstream of court have flooding issues as no overland flow path here.	n/a	n/a
PW_FL11	East Model	Long-term resident reports some issues here and reports that water has cut the road in this location. However, not really a problem at this location but more-so further to the south on the Clifton-Pittsworth Road.	n/a	n/a
PW_FL12	East Model	Council representative reports that drainage is an issue in the Short Street area. Issue is overland flows through properties and extends downstream to Cooper Street. 3rd houses along from corner of Florence St/Short St always an issue also. Big issue in 1996	n/a	n/a
PW_FL13	East Model	Council representative reports that drainage is an issue in the Briggs Street and Collins Street areas. Issue is flat topography and ponding of water in general area. Also overland flows through properties. Various local drainage works have been implemented.	n/a	n/a

Flood Level ID (Note 1)	Model Area	Description	Anecdotal Flood Record Level (m AHD) (approx.)	Modelled 100 Year ARI Peak Flood Level (m AHD)
PW_FL14	East Model	Council representative reports flooding over Felton Road (Duckhams Gully) - in 1996 event the water came up to the bonnet of cars (approximately 1 metre deep).	504.5	504.0
PW_FL16	East Model	Council representative reports a lot of water flows through the showground area but not on the main ring.	n/a	n/a
PW_FL17	East Model	Council representative reports flooding issues on Forrest Street. This is a trapped sag at the end of Forrest Street and water overlands through several properties downstream - impacts to 4/6 Forrest Street properties.	n/a	n/a
PW_FL18	East Model	Council representative reported that flooding was well over Felton Road. Unknown depth. Known drainage/flooding issue at this location.	n/a	504
PW_FL20	East Model	Council representative reports that areas around the Golf Course get closed due to road flooding. Occurs on Clifton-Pittsworth Road.	n/a	n/a
PW_FL22	East Model	Council representative reports some drainage issues locally.	n/a	509.3
PW_FL23	East Model	Council representative reports flooding issues associated with the showground area. Development proposal by Show Society was not approved as a result of known flooding locally.	n/a	n/a
PW_FL8	West Model	Council representative reports water likely to go over the road at this location but not much of an issue. Not a lot of water in this catchment.	511.3 (1)	511.3
PW_FL9	West Model	Gore Highway crossing – long-term resident has not seen water over the Gore Hwy crossing at this location.	n/a	501.6
PW_FL10	West Model	Industrial area and road to tip - long-term resident has seen water over this road. Probably 200-300mm in depth over a width of 50-60m. Can still drive through though.	511.1 (1)	511.1
PW_FL15	West Model	Gore Highway crossing – Council representative has not seen this crossing flooded.	n/a	501.6

Flood Level ID (Note 1)	Model Area	Description	Anecdotal Flood Record Level (m AHD) (approx.)	Modelled 100 Year ARI Peak Flood Level (m AHD)
PW_FL19	West Model	Gore Highway crossing – Council representative reports crossing not known to be flooded.	n/a	501.63
PW_FL21	West Model	Council representative reports flooding over road to industrial area/tip - gets flooded but still trafficable.	511.1 (1)	511.1

Notes

1. No actual flood level was noted based on anecdotal records. However, an anecdotal level can be inferred from the anecdotal account of the likely depth of flooding over the road. We have assumed a flood depth of 300 mm over the road being the limit for road trafficability and have determined the flood level using the LiDAR topography levels.
2. Estimated flood level based on anecdotal records assuming 150 mm water depth over crest of road based on topographic information.

Model Result Validation to Historic Flood Levels

The Pittsworth hydraulic model was established as two separate MIKE FLOOD models covering the east and western areas as illustrated in Figure 4.2 previously. The model validation results are therefore presented below in respect to each of the separate model areas.

Pittsworth East Model

The following summary is provided in relation to modelled flood levels for the Pittsworth east model:
-

- On Toowoomba Road to the north of the school (point PW_FL3), the road is overtopped with flood depths up to approximately 200 mm. The estimated flood levels at this location are consistent with the anecdotal records.
- Flooding is predicted to occur in the residential street areas associated with Alexia Street at point PW_FL7 and the flood behaviour at this location matches with anecdotal records. Considerable flooding of properties downstream of the court is predicted to occur and this outcome also matches well with the historical account of the flooding problem area. Sheet flow and overland flooding of properties in areas upstream from this location are also estimated to occur. Maximum depths of overland flooding are up to 250 mm but are typically 100 mm to 200 mm in these areas.
- At point PW_FL6, anecdotal flooding was reported to occur to the property at this location. The estimated flooding based on the model confirms flooding throughout this general area. Flooding in this area is typically overland sheet flow type flooding to a large area.
- At points PW_FL12 and PW_FL17, anecdotal records indicate flooding to residential properties. We understand that this was a significant issue in 1996 but the drainage has since been upgraded and lessened the degree of flooding which occurred in the 2010/2011 event. Although these locations are outside of the mapping flowpath limits in Pittsworth, given the estimated flooding in other adjacent and similar style residential areas, by inference it is likely that flooding would also occur in these areas.
- On Railway Street just north of the showgrounds (point PW_FL5), long-term resident accounts reported that shallow flood waters flow across road at this location (probably 100 m wide). The model results show that water overtops the road crest at this location with depths of less

than 150 mm and a flood width of approximately 150 m. The model results are consistent with anecdotal records at this location.

- Flooding in and around the showground area was reported to occur by Council representatives (point PW_FL23, PW_FL16 and PW_FL4). A further account of flooding of the showground area was also made by other Council representatives who reported a lot of water through the showground area generally but not on the main arena. The model results provide a very accurate comparison of historical flooding as no inundation is predicted to occur to the main arena for the 100 year ARI event modelled. Flood depths in the main drainage path running adjacent to the showground itself are approximately 300 mm to 500 mm and increase up to 750 mm in depth towards Factory Street.
- Flooding at Pittsworth-Felton Road (points PW_FL2, PW_FL14 and PW_FL18) is well known to occur over the road at these locations. Anecdotal records indicate a depth of flooding over the road of up to 1 metre and includes for the 1996 flood event. Model results show flooding to above the road over a width of some 270 metres and a maximum depth of 600 mm. The width of flooding estimated matches well with the account provided by long-term residents but the predicted water depths are some 400 mm less than the anecdotal records at these locations. For water depths greater than generally 300 mm (being at the limit of trafficability), it is generally difficult to estimate water depths accurately. The estimated depths of 600 mm are very similar to the anecdotal records and are considered to be an appropriate match to the historical information at this location especially as the width of flooding matches well with the account of flooding in the 2010/2011 event.
- At points PW_FL11 and PW_FL20, anecdotal records indicate flooding has occurred across the road. These areas are outside of the mapping flowpath limits in Pittsworth and consequently road flooding is unable to be confirmed using the model results.
- At PW_FL13, Council representatives report that drainage is an issue in the Briggs Street and Collins Street areas. Although the modelling extents do not extend upstream to Collins Street, significant overland flooding was predicted to occur along Briggs Street and this extended into residential properties. Flooding in this area was typified by sheet flows over large flow widths and in areas where the natural low point was located through private property. Flood depths in these areas were up to 200 mm in isolated areas but were typically less than 100 mm. The estimated flooding in this area is consistent with the anecdotal records in this area.
- Local drainage issues were reported to occur on Murray Street downstream from the cemetery (point PW_FL22). Flood depths over the road were estimated to be approximately 150 mm extending over a width of some 170 m. There is a defined drainage channel immediately downstream from this location with flood depths of up to 600 mm occurring within the channel. The immediate upstream catchment areas all confluence at this location and result in local flooding over the road which contributes to the drainage issues reported and for which are confirmed from the model.

On the basis of the model results and discussions as outlined above, it can be seen that the MIKE FLOOD model developed for Pittsworth east is representing the flood behaviour for a major flood event (100 year ARI) based on the anecdotal information and historical accounts.

Pittsworth West Model

The following summary is provided in relation to modelled flood levels for the Pittsworth west model:

- Flood levels at Yandilla Street and on the road to the industrial area at point PW_FL21 were found to be up to 300 mm above the road crest. The flood levels matched with the anecdotal account at this location assuming a maximum flood depth of up to 300 mm for road trafficability standards given the anecdotal record.
- At Krinke Street at point PW_FL8, anecdotal records identified water likely to overtop the road but no real issues given not a lot of water in the catchment and the likely short duration of

the flood event. Modelled results did show that water flows over the road and to a depth of less than 300 mm. The modelled depths are therefore very similar to the anecdotal record at this location and matches very well by inference. We note that although the anecdotal record infers not much of a flood issue at this location, the model inundation extents do impact on several properties in the local area and further assessment as to floor level inundation status of these properties may be required.

- At the Gore Highway point PW_FL19, anecdotal records suggested that the highway has not been cut by flood waters. The model results did however predict flooding over the highway and this resulted in the highway being cut in two separate locations at PW_FL19 as well as some 170 m further to the west in the low point on the highway. The maximum depth over the road was found to be less than 150 mm however and would therefore remain trafficable. The period of inundation over the road is also expected to be short given the short duration catchment upstream. The modelled results are based on the 100 year ARI event under ultimate catchment development and it is possible that a large historical event similar in magnitude to the 100 year ARI may not have occurred in this catchment which would explain the difference observed. In any case, the modelled results are similar to the anecdotal record in that the difference is only 150 mm.

Other general comments in relation to the modelled results in areas without anecdotal flood information include the following: -

- Flooding was estimated to occur in areas of Yandilla Street just south of the Pittsworth CBD. Flooding spread out over a wide area and was generally sheet flow in nature. Flood depths were limited to less than 75 mm.
- Flood depths over Hadley Street were predicted to be up to 150 mm.
- The railway upstream of Hadley Street was overtopped with a maximum depth of up to 100 mm.
- A number of properties in and around Helens Street as well as downstream of Hadley Street were identified as being subject to flooding from sheet flows.
- Overtopping of the Gore Highway was estimated to occur downstream of Yandilla Street associated with the local catchment area to the industrial area and to the west of the town. Flood depths over the highway were up to 350 mm for the 100 year ARI event and occurred over a width of some 300 m.

On the basis of the model results and discussions as outlined above, it can be seen that the MIKE FLOOD model developed for Pittsworth west is representing the flood behaviour for a major flood event (100 year ARI) based on the anecdotal information and historical accounts.

5.4.5 Southbrook Model Validation Results

Historic Flood Levels

Historic flood levels for the Southbrook study area were supplied by a number of people with relevant history in the study area. Table 5.6 summarises the supplied historic flood data for Southbrook. Where depth or levels have been provided, these have been converted to an approximate representative flood level by inspection of the DEM at the point of interest and comparison with consultation notes. The points represented by the Flood Level ID as well as the 100 year ARI peak flood depth can be seen in Appendix C.

Table 5.6 Southbrook Historic Flood Level Details

Flood Level ID	Description	Anecdotal Flood Record Level (m AHD) (approx.)	Modelled 100 Year ARI Peak Flood Level (m AHD)
SB_FL1	Local resident reports that floodwaters have reached this driveway in events prior to 2010.	534.6	534.9
SB_FL2	Local resident reports that floodwaters have reached this property previously. Property not flooded to above floor but water under house. Property may be raised up to 8 foot or so.	534.7	534.8
SB_FL3	Debris observed on fence to rear of property during inspection. Possible overland flows to property immediately to south. Understood to be a drainage complaint area based on TRC records.	543.6	543.6
SB_FL4	Local business owners reports having seen water up to 1.2m deep over crossing. Also reports stormwater flooding has been observed through the adjacent concrete yard (associated with an upstream local catchment area).	534.1	533.6

Model Result Validation to Historic Flood Levels

Flood behaviour predictions by the model at Southbrook-Felton Road were found to be less than the peak levels estimated by local residents. In this case, modelled flood levels over the road were found to be up to 625 mm over the road while the maximum anecdotal records suggested depths of up to 1.2 m. We note from our discussions with other local residents in the general area that there has been a previous report of flooding over the road at this location which reportedly occurred as a result of a failure of an upstream dam located on a rural property. This apparently occurred during the 2010/2011 event and in combination with significant rainfall. If this report is accurate, it is possible that a dam failure flooding mechanism combined with significant rain at the time would likely result in higher flood levels over Southbrook-Felton Road owing to the propagation of the flood wave in comparison to the 100 year ARI design event alone. It is not clear if the anecdotal account of the peak depths over the road was made during the dam failure event but would likely be the cause of any discrepancy at this location. The modelled results based on the 100 year ARI flows could not achieve levels at the same location nor would a model analysis based on ARFF flow estimates given that these are lower than the 100 year ARI event. To achieve a depth of some 1.2 m above the road crest, a discharge equivalent to some 10 times the 100 year ARI flow would be required based on a broad crested weir equation. While it is possible that a previous historical event may have occurred to well in-excess of the 100 year ARI event, it is considered unlikely that flood levels over the road have reached 1.2 m in depth.

The modelled results match well to anecdotal records that water levels reached properties at flood level points SB_FL1 and SB_FL2. For the 100 year ARI event analysed, water depths were approximately 200 mm to 400 mm in the vicinity of these properties and this accords well with the statements that there was water flowing underneath the raised buildings at this location. We note that flood depths at these properties would be significantly greater (likely to be an additional 600 mm or so with a total depth of up to 1 m) when considering a water depth of 1.2 m over Southbrook-Felton Road. The reported levels at these locations would also tend to suggest that flood depths over Southbrook-Felton Road may not have been as high as the 1.2 m reported.

At location SB_FL3, debris was observed on the rear fence to the property at this location during the inspection. The modelled results correspond well at this location and shows flood waters flowing in and around these areas. Flood depths were limited to approximately 100 mm. However, flooding in this general area occurs as sheet flows generally of low depth but over a significant area. The sheet flows also extend downstream across Sterling Street and then enter the creek further to the south. Anecdotal reports provided by local residents have identified flooding through the concrete yard itself from the upstream local catchment and this is also confirmed from the modelling that has been prepared.

On the northern side of the town, the Gore Highway is predicted to be overtopped by flooding at the existing crossing location to the east of Linthorpe Valley Road. Flood depths over the road at this location were limited to approximately 100 mm. No historical levels were available to confirm overtopping of the Gore Highway but given the small depths and short duration catchment response, it is likely that any flooding would be very short in duration. The road is likely to remain trafficable under this event in any case.

Other comments of note based on the flood model results also include the following: -

- For the flowpath traversing to the north of the town, flood waters in the upper reaches of the flowpath towards the school were also observed to divert to the south in areas around Bailey Street and O'Shea Avenue. These flows ultimately flow to the existing creek to the south rather than in a northerly direction. The flow splits and diversions that occur in this area are as a result of the local topography conditions where a series of channel works and levee banks exist to complicate flow patterns locally.
- For the main town area of Southbrook, extensive inundation was observed to occur however this is primarily sheet type flows of limited depth. A combination of the road formation of O'Shea Avenue as well as the railway formation, with the series of isolated culvert crossings, leads to flows overtopping the embankments and wide sheet flows down local streets and through a large number of residential properties.

On the basis of the model results and discussions as outlined above, it can be seen that the MIKE FLOOD model developed for Southbrook is representing the flood behaviour for a major flood event (100 year ARI) based on the anecdotal information and historical accounts.

5.4.6 Model Validation to Historic Rainfall and AEP Estimation

As described previously in this report, the validation approach applied for all overland flow path studies for Work Package 11 towns is based on a comparison of historical flood level information to the 100 year ARI design rainfall event. This approach has been adopted for model validation given the absence of detailed catchment calibration information (i.e. no available stream gauge records within the catchments).

As a further check and comparison of the model validation results and in order to estimate the recurrence interval of the validation events, we have considered historical rainfalls for the January 2011 event in comparison to the design rainfall approaches documented in Australian Rainfall and Runoff (IEAust, 1998).

While this approach has been used as a further validation check, the approach is not a strictly correct measure of catchment discharge and/or flood magnitude, as rainfall intensity of a given magnitude (measured as ARI or AEP) often does not correlate to an equivalent flood magnitude (also measured as ARI or AEP) due to a number of other influential factors. These factors can include but are not limited to antecedent rainfall (of which there was a significant amount before the January 2011 event) and rainfall distribution across the catchment. Therefore, the ARI of the January 2011 rainfall event across the catchment areas will not directly correlate to the same ARI flood discharge. This is also known as ARI (or AEP) non neutrality. Within this context and at the request of Council's peer reviewer, rainfall has been considered for each of the work package towns and is discussed separately below.

Rainfall data in the form of 6 minute pluviograph data is required to undertake a historical rainfall frequency assessment especially for short duration events which typically dominate the overland flow paths assessed in this study. The closest available pluviograph stations to each respective study area have been used for this assessment.

Goombungee Historic Rainfall

While the closest rainfall pluviograph gauge to the Goombungee township is located at Cooby Dam, this gauge was not considered representative of January 2011 rainfall for Goombungee based on the storm direction. Rather, the Crows Nest (gauge ID 540161), some 20 km to the east was selected as being more representative of the January 2011 rainfall. Historical data recorded at the Crowns Nest gauge for the period 9th to the 12th January 2011 has been sourced and used to undertake a rainfall frequency analysis which has subsequently been adopted as being representative for the Goombungee Township. Figure 5.8 shows the rainfall data intensity for the event against the Intensity-Frequency-Duration (IFD) data in accordance with Australian Rainfall and Runoff (IEAust, 1998). For shorter duration events up to approximately 5 hours, the event rainfall intensities varied between a 2 and 5 year ARI equivalency. It is noted that the ARI of the historical rainfall was generally equal to a 10 year ARI for durations exceeding 5 hours. The historical rainfall was also found to be up to a 50 year ARI for the longer 48 hour duration event. A similar result was also found to occur based on the same analysis using historical rainfall records for the same event at the Oakey gauge (ID 041359), located 20km to the south of Goombungee.

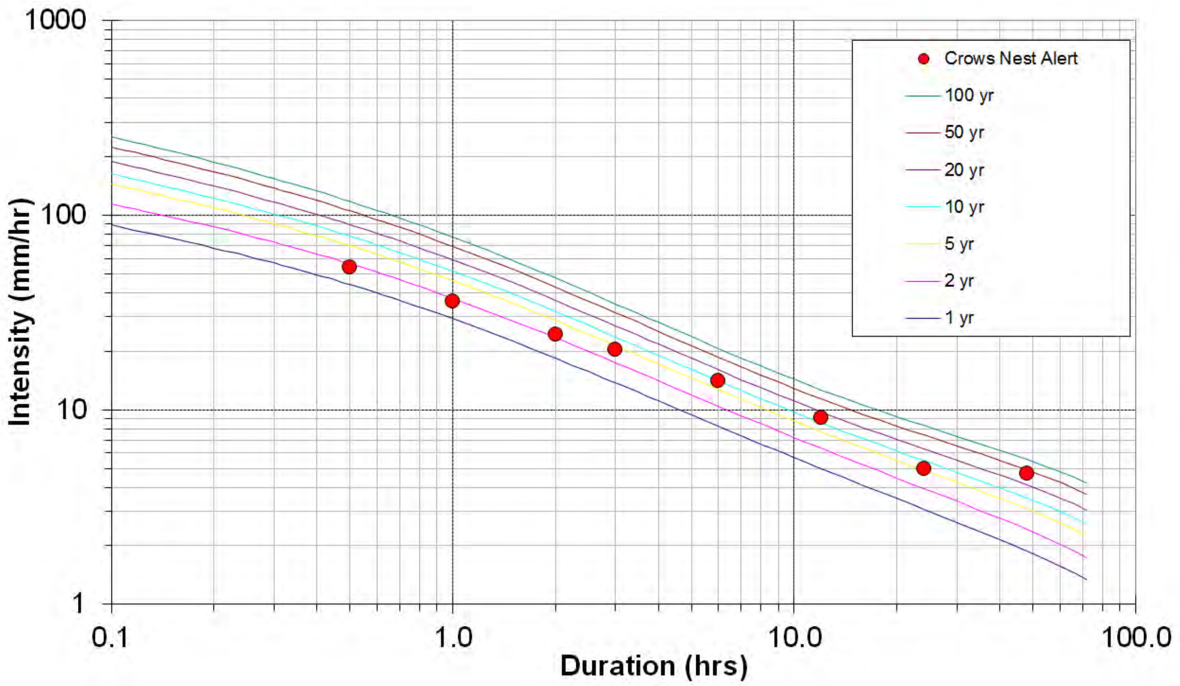


Figure 5.8 **Intensity Frequency Duration Curves for Goombungee together with historic rainfall intensities from the Crows Nest gauge for the period 9th to 12th January 2011**

The results from the hydraulic model validation undertaken for the Goombungee study area found that the observed January 2011 flood levels were on average around 200 mm below the predicted 100 year ARI design event flood levels.

Comparison of the rainfall analysis in Figure 5.8 and the corresponding Rational Method time of concentration of the larger external Goombungee catchment area suggest that the rainfall burst on the 10th to 11th January 2011 was approaching a 5 year ARI intensity equivalency.

Historical rainfall totals from December 2010 to January 2011 event (discussed separately in Section 3) show significant amounts of antecedent rainfall fell in the catchment prior to the rainfall burst on the 10th to 11th January 2011, resulting in super-saturated catchment conditions. Given this, a greater portion of rainfall that fell in during this time would therefore be readily converted to runoff given the significantly lower catchment losses. These primed catchment conditions likely resulted in the higher flood magnitude recorded in the town (approximately a 100 year ARI flood magnitude based on design event assessments carried out for this study and comparison to the TRC observed flood levels for the January 2011 event). For shorter duration events associated with local flooding in the town, the rainfall intensity was in the order of a 2 year ARI.

As a result, and considering the catchment conditions at the time of the rainfall burst on the 10th to 11th January 2011, this event was assessed to be approximately a 5 year ARI rainfall event, resulting in approximately a 20 year ARI flood magnitude in the main flowpath within the Goombungee township.

Pittsworth and Southbrook Historic Rainfall

The closest rainfall pluviograph gauge to the Pittsworth and Southbrook Townships is located at Cambooya (gauge ID 42230974A), located some 25 km and 16 km to the east of these towns respectively. Historical data for the period 9th to the 12th January 2011 has been sourced and used to undertake a rainfall frequency analysis which is plotted against design rainfall IFD determined based on a Pittsworth point rainfall location. Figure 5.9 shows the rainfall data intensity for the event against the Intensity-Frequency-Duration (IFD) data for Pittsworth in accordance with Australian Rainfall and Runoff (IEAust, 1998) and is also considered to be applicable for the Southbrook Township. For shorter duration events up to approximately 1 hours, the event rainfall intensities were in the order of a 20 to 50 year ARI equivalency, depending on duration. Historical rainfall was found to be generally equal to a 5 year ARI for longer durations exceeding 1 hours.

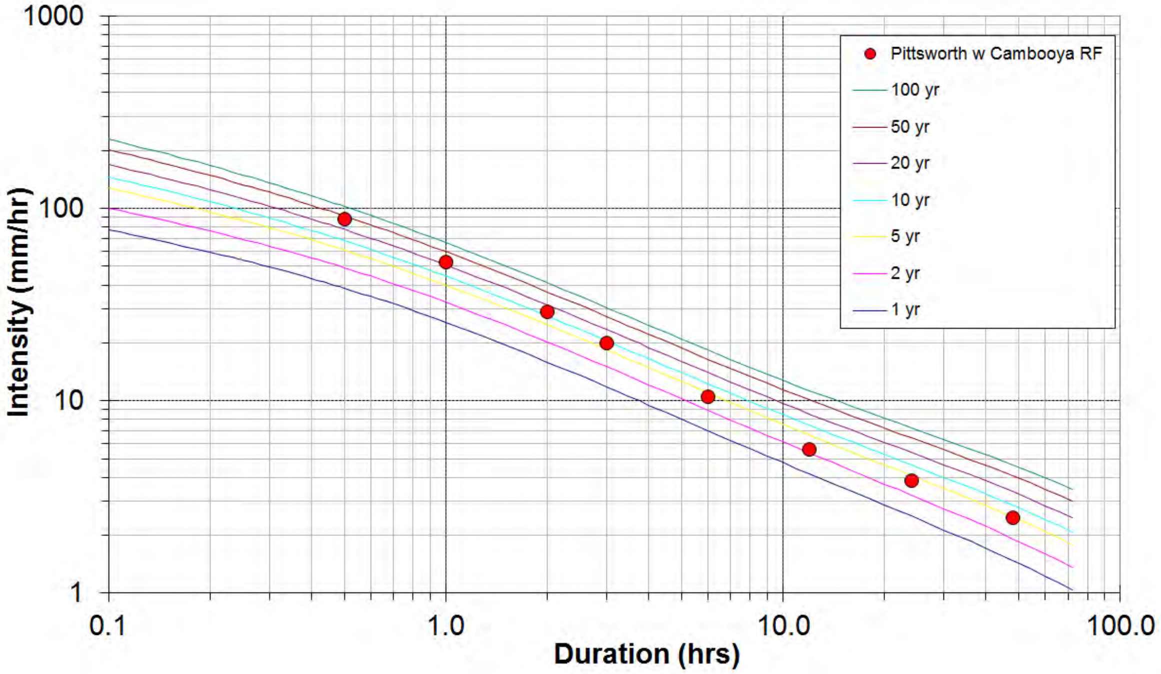


Figure 5.9 Intensity Frequency Duration Curves for Pittsworth together with historic rainfall intensities from the Cambooya gauge for the period 9th to 12th January 2011

The results from the hydraulic model calibration undertaken at both Pittsworth and Southbrook found that the historical flood records (some of which were January 2011 flood levels) were equivalent to approximately a 100 year ARI design flood event.

As was the case for the Goombungee study area, historical rainfall totals from December 2010 to January 2011 event (discussed separately in Section 3) show significant amounts of antecedent rainfall fell in the catchment prior to the rainfall burst on the 10th to 11th January 2011. A greater portion of rainfall that fell in during this time would therefore be readily converted to runoff given the significantly lower catchment losses. These primed catchment conditions likely resulted in the higher flood magnitude recorded in Pittsworth and Southbrook towns (approximately a 100 year ARI flood magnitude).

The analysis undertaken suggests that the rainfall burst around the 10th to 11th January 2011 in these locations was approximately equivalent to a 50 year ARI event, which resulted in a flood magnitude in the order of a 100 year ARI event due to antecedent rainfall and primed catchment conditions.

5.4.7 Conclusions

Model estimates of the design rainfall 100 year ARI flood event within each of the respective study areas have been shown to generally correspond well to historic flood levels collected from residents during field inspections and TRC supplied observed flood levels from the January 2011 event. It is inherently difficult to match all anecdotal flood levels, due to the uncertainty surrounding the corresponding rainfall event and timing of the observation with respect to the flood peak, as well as the validation methodology adopted.

The observed flood levels provided by TRC for the January 2011 event were shown to generally agree with 100 year ARI design flood event estimates in Pittsworth and Southbrook. Analysis of rainfall records for these areas suggest the rainfall burst that occurred around the 10th to 11th January 2011 was approximately a 50 year ARI equivalency. This, combined with the significant antecedent rainfall and primed catchment conditions, resulted in a flood magnitude of approximately a 100 year ARI in these areas.

The model validation results for Goombungee as outlined above have shown a general match in respect to both the 20 year and 100 year ARI design events. This is not strictly correct in respect to both events being considered to provide a suitable match to validation points given the differences in the magnitude of flows that exist between the events. The likely reasons for both the 20 year and 100 year ARI events fitting well with the validation points relates to the hydraulic characteristics of the floodplain. That is, the broad floodplain and sheet flow conditions will likely result in only a modest difference in flood level for a relatively large difference in flow. These modest differences in flood levels are also comparable and within the accuracy tolerances for validation of the hydraulic model. This results in both events, while considerably different in respect to flow magnitude, being considered to provide a suitable match to historical levels.

Notwithstanding the aforementioned limitations, the results presented demonstrate that all of the MIKE FLOOD models developed as part of this work package are adequately representing major flood behaviour in each of the respective model areas based on comparisons with the anecdotal flood information provided by residents and observed flood levels provided by TRC. Assessment of any discrepancies between predicted flood levels and observed or anecdotal historic flood levels has also been noted.

Appendix C shows the model validation 100 year ARI peak flood depth maps for the Goombungee, Pittsworth and Southbrook study areas which have been adopted for the purposes of model validation.

6. DESIGN FLOOD EVENT ANALYSIS

6.1 Introduction

The previous sections of this report have described in detail the MIKE FLOOD and TUFLOW model development and validation assessments that have been undertaken as part of this study. The validated TUFLOW model and MIKE FLOOD models were subject to a peer review process undertaken by Council's appointed peer reviewer. The outcomes from the peer review process provided approval to commence with the design flood event assessments.

6.2 Methodology

The hydraulic models developed for each of the towns and for model validation tasks have been adopted as the basis on which to undertake the design flood event assessments. The validated models have in the most part been adopted without change with the exception of any minor amendments that may have otherwise been requested by Council's peer reviewer. In the most part, no considerable changes to the validated hydraulic models have been necessary.

The validated hydraulic models have been adopted and used for the design event simulations. Inflows to the models have been based on the previously determined Rational Method flows for each of the 5, 20 and 100 year Average Recurrence Interval (ARI) design events. These 3 design events were selected and pre-determined by TRC for use in this study and have been assessed using a design rainfall Intensity Frequency Duration (IFD) data in accordance with the guiding principles outlined in Australian Rainfall and Runoff (IEAust, 1998). The Rational Method flows represent ultimate catchment development in accordance with TRC's strategic plan and include future urbanised planning areas associated with broadhectare mapping prepared by TRC. The adopting of catchment flows based on ultimate catchment conditions is appropriate for the purposes of inclusion into Council's future planning scheme overlays and this approach was also agreed with TRC and Council's appointed Project Manager.

6.3 Model Events and Nomenclature

Design flood events for the 5, 20 and 100 year ARI events have been analysed for each of the Goombungee, Pittsworth and Southbrook models. In addition, model sensitivity assessments have also been undertaken, specifically the assessment of structure blockages, based on the 100 year ARI event (discussed in Section 6.4). The hydraulic modelling naming nomenclature for the various scenarios undertaken for this work package have been prepared based on Council's naming convention and a detailed summary is provided as part of the digital study data provided for this project.

6.4 Sensitivity Assessments

A sensitivity assessment for each of the hydraulic models prepared as part of this study was undertaken based on the 100 year ARI event. The sensitivity assessment includes provision for blockages of cross-drainage culvert and bridge structures and a pre-determined blockage factor of 50% was specified by TRC for the analysis. Technical advice provided from Council's peer reviewer specified that the blockages were to be applied based on a reduction in the flow conveyance areas with the respective inverts maintained at the same level. For box culverts, this involved a reduction in the structure width by 50% while for circular culverts, an effective diameter pipe size was determined and applied based on a 50% reduction in the culvert conveyance area. For bridge structures, the flow opening width was reduced by direct application of a 50% blockage ratio.

6.5 Model Results

6.5.1 Design Events

The model results prepared for the 5, 20 and 100 year ARI design events for each of the towns for Goombungee, Pittsworth and Southbrook and presented by way of a series of GIS maps. The GIS maps are included in Appendix D, E and F respectively for each of the Goombungee, Pittsworth and Southbrook town areas. To provide greater detail, the riverine and overland flow maps for the Goombungee Township have been separated into different maps in Appendix C. This was undertaken by overlaying the two datasets and then trimming the flood extents at overlapping sections, as shown in Figure 6.1. Owing to the “Direct Rainfall” method, flooding is shown to occur even for very shallow depths. For illustration purposes, very shallow depths of flooding have been excluded from the mapping by applying a colour palette that excludes all depths less than 75mm. This is considered to be an appropriate depth cut-off limit for the purposes of the mapping. Although applying this filter results in discontinuity in some flowpaths, it shows areas of inundation without highlighting areas of very shallow inundation (less than 10 mm). Due to this filtering, the colour palette used for the overland flow maps is slightly different to that used in the riverine maps.

A summary of the GIS maps prepared to illustrate the results of the design flood events are presented in Table 6.1. All GIS maps prepared for this study have been undertaken based on the project specific technical requirements which include the mapping requirements and standards outlined in the project brief.

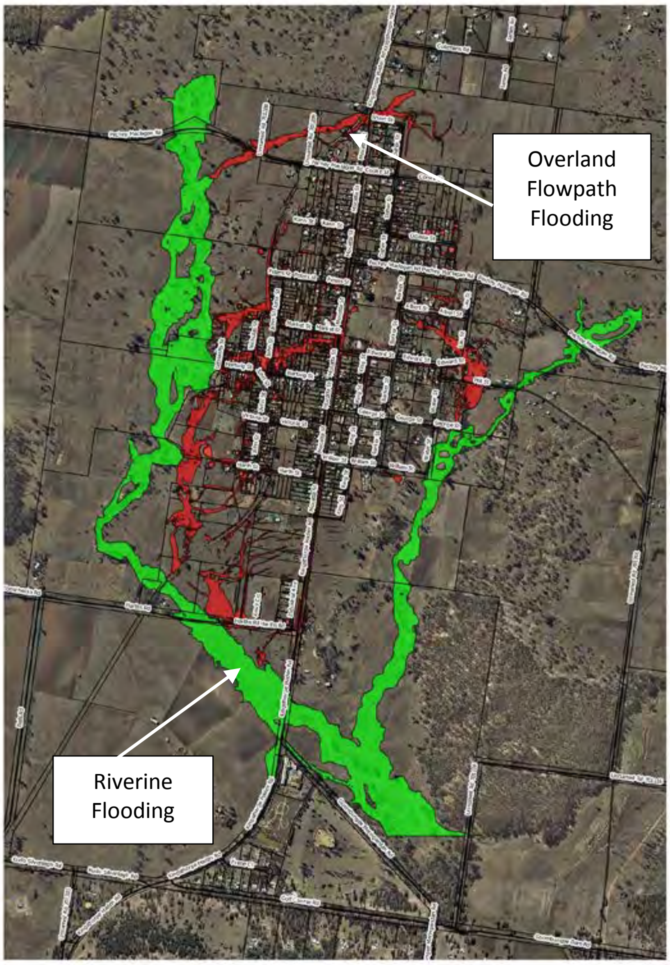


Figure 6.1 Separation of Riverine and Overland Flowpaths, Goombungee

Table 6.1 Summary of GIS Maps for Design Events

Location	Town Area	Design Event	Map Type
Appendix D	Goombungee - Riverine	100 Year ARI	Water Level Map
	Goombungee - Riverine	100 Year ARI	Water Depth Map
	Goombungee - Riverine	100 Year ARI	Flood Hazard Map
	Goombungee - Riverine	20 Year ARI	Water Level Map
	Goombungee - Riverine	20 Year ARI	Water Depth Map
	Goombungee - Riverine	5 Year ARI	Water Level Map
	Goombungee - Riverine	5 Year ARI	Water Depth Map
	Goombungee - Overland	100 Year ARI	Water Depth Map
	Goombungee - Overland	100 Year ARI	Flood Hazard Map
	Goombungee - Overland	20 Year ARI	Water Depth Map
	Goombungee - Overland	5 Year ARI	Water Depth Map
Appendix E	Pittsworth - East	100 Year ARI	Water Level Map
	Pittsworth - East	100 Year ARI	Water Depth Map
	Pittsworth - East	100 Year ARI	Flood Hazard Map
	Pittsworth - East	20 Year ARI	Water Level Map
	Pittsworth - East	20 Year ARI	Water Depth Map
	Pittsworth - East	5 Year ARI	Water Level Map
	Pittsworth - East	5 Year ARI	Water Depth Map
	Pittsworth - West	100 Year ARI	Water Level Map
	Pittsworth - West	100 Year ARI	Water Depth Map
	Pittsworth - West	100 Year ARI	Flood Hazard Map
	Pittsworth - West	20 Year ARI	Water Level Map
	Pittsworth - West	20 Year ARI	Water Depth Map
	Pittsworth - West	5 Year ARI	Water Level Map
	Pittsworth - West	5 Year ARI	Water Depth Map
Appendix F	Southbrook	100 Year ARI	Water Level Map
	Southbrook	100 Year ARI	Water Depth Map
	Southbrook	100 Year ARI	Flood Hazard Map
	Southbrook	20 Year ARI	Water Level Map
	Southbrook	20 Year ARI	Water Depth Map
	Southbrook	5 Year ARI	Water Level Map
	Southbrook	5 Year ARI	Water Depth Map

6.5.2 Sensitivity Cases

The sensitivity assessments undertaken for this study included a 50% blockage factor assumed for all cross-drainage culvert and bridge structures. The model results prepared for Goombungee, Pittsworth and Southbrook based on the 100 year ARI event are presented by way of a series of GIS maps and are included in Appendix F. A summary of the GIS maps prepared to illustrate the results of the sensitivity assessments are presented in Table 6.2.

Table 6.2 Summary of GIS Maps for Sensitivity Assessments

Town	Design Event	Map Type
Goombungee	100 Year ARI (50% blockage)	Water Level Difference (Afflux) Map
Pittsworth - East	100 Year ARI (50% blockage)	Water Level Difference (Afflux) Map
Pittsworth - West	100 Year ARI (50% blockage)	Water Level Difference (Afflux) Map
Southbrook	100 Year ARI (50% blockage)	Water Level Difference (Afflux) Map

6.5.3 Digital Flood Data

All model result files and associated results will be provided to Council in a digital format at the completion of the flood study works and following acceptance of the final report. The digital data sets comprise detailed flood information in respect to flood levels, depths, velocities and flood hazards and will therefore inform the Planning Scheme revisions.

6.5.4 Emergency Management

As part of the assessment of flooding within the Goombungee, Pittsworth and Southbrook townships, consideration has also been given to the likely impact of the predicted flood behaviour for each design event assessed on critical Emergency Management infrastructure. Similarly, impacts on emergency egress (road access) to and from these infrastructure in each of the towns has also been assessed.

Given the steady-state modelling analysis undertaken for these towns, time-based assessments such as periods of inundation of roadways or other infrastructure are not able to be determined. Therefore this assessment provides information regarding the maximum inundation at the peak of the flood for each design event analysed with respect to critical emergency management infrastructure, as well as emergency egress standards of the major access roads to the towns.

Table 6.3 summarises the respective flood immunities and trafficability standards achieved by critical Emergency Management Infrastructure and major access roads within the respective study areas.

Table 6.3 Flood Impacts on Critical Emergency Management Infrastructure and Egress Routes

Town	Critical Infrastructure Item/Route	Flood Standard Achieved
Goombungee	Rural Fire Brigade	100 year ARI immunity
	Police Station	100 year ARI immunity
	SES	100 year ARI immunity
	Kingsthorpe Haden Road	< 5 year ARI trafficability[1]
	Peachey Maclagen Road (East Trib)	20 year ARI trafficability[1]
	Peachey Maclagen Road (Main Creek)	< 5 year ARI trafficability[1]
Pittsworth	Ambulance	100 year ARI immunity
	Evacuation Centre	100 year ARI immunity
	Fire Station	100 year ARI immunity
	Hospital	100 year ARI immunity
	Nursing Home	100 year ARI immunity
	Police Station	100 year ARI immunity
	SES	100 year ARI immunity
	Toowoomba Road	100 year ARI trafficability[1]
	Pittsworth Felton Road	< 5 year ARI trafficability[1]
	Hauslers Road	< 5 year ARI trafficability[1]
	Gap Road	20 year ARI trafficability[1]
	Gore Highway	20 year ARI trafficability[1]
Southbrook	Rural Fire Brigade	100 year ARI immunity
	Gore Highway	100 year ARI trafficability[1]
	Southbrook Felton Road	< 5 year ARI trafficability[1]
	O'Shea Avenue	100 year ARI trafficability[1]
	Oberhardt Road	100 year ARI trafficability[1]

1. N.B Trafficability standards have been assessed in accordance with QUDM (NRM, 2007) Table 7.04.1

6.5.5 Assessment Uncertainties and Limitations

During the course of the assessment, various datasets have been used to assess flood behaviour for a number of design rainfall events.

Given the multiple datasets that have been used in this assessment and their associated limitations and accuracies, there is an inherent limitation in the accuracy of the final model results and hence flood behaviour predictions.

Datasets that will inherently impact on the accuracy of the model results are as follows:

- Design rainfall datasets have been derived from the procedures set out in Australian Rainfall and Runoff (IEAust, 1998). A new IFD dataset (IFD 2013) has been developed by AR&R with an additional 30 years of rainfall data as well as data from an additional 2300 rainfall stations. This dataset is not yet recommended for use by AR&R, however comparison of the 100 year

ARI 120 minute duration event for the Goombungee catchment revealed a predicted 5.4% increase in rainfall intensity. As such, any changes to predicted design rainfall intensities as a result of the new AR&R IFD dataset will not be reflected in the results of this study.

- Baseline topographic data - The MIKE FLOOD models prepared as part of this study are based on the LiDAR dataset as supplied by TRC. The results are therefore inherently subject to the accuracy and detail of the topographic survey (94% of points within +/- 150 mm accuracy of ground controls). Accuracy is reduced for areas under heavy vegetative cover and at derived points (from the DEM). Additionally, if changes have occurred to the topographic variation in the study areas due to development or other construction activities since the LiDAR data was collected, this will not have been accurately assessed in the model results.
- Where changes/upgrades to sub-surface drainage features such as major culverts have been undertaken since the site visit, this will not be accurately represented within the model results.
- No detailed survey data has been collected for this project. Hydraulic structures included in the flood models prepared under this work package are based on site measurements. Invert levels for the culverts have been estimated using the DTM. In heavily vegetated areas, the levels from the DTM may not be accurate and accordingly hydraulic structure representation within the models may not be accurate and this may result in inaccuracies associated with flood level predictions.
- The steady state modelling approach does not allow for the effects of floodplain storage to be assessed within the MIKE FLOOD models. Results could therefore be considered to be conservative.

Nonetheless, given the good replication of recent historic flood levels within the MIKE FLOOD models during the model verification stage, assessment of historic rainfall and model inflows, as well as model parameters being generally consistent with industry standards, the outcomes of this assessment are considered to be appropriate for the purposes of the project objectives.

7. CONCLUSION AND RECOMMENDATIONS

A number of MIKE FLOOD models have been developed to assess flood behaviour within the Goombungee, Pittsworth and Southbrook towns. A separate TUFLOW model, using the "Direct Rainfall" method, was developed to assess overland flow within the Goombungee Township. These towns and associated models represent Work Package 11 of the overall SP051 Flood Studies project, where the assessment of overland flow paths was required.

The purpose of the overland flow path studies is to identify areas at risk of flood inundation, their impact upon current and future development of the towns and to identify flood hazards for the inundation areas for the defined flood event (DFE). In order to accurately achieve this goal, a series of MIKE FLOOD models have been developed and then validated to historic flood levels to ensure model outputs correspond well with historical flood information. Given that some flowpaths are ill-defined within the Goombungee Township, a "Direct Rainfall" TUFLOW model was developed to more accurately ascertain the extent of flooding due to overland flow in the Goombungee Township.

The Rational Method was used to estimate peak catchment runoff contributing to the study areas. A select number of large catchments contributing to the Goombungee and Pittsworth study areas were shown to be at the upper limit of the acceptable range for use of the Rational Method. Comparison was therefore undertaken between Rational Method peak discharge estimates for these large catchments with flow estimates derived using the Australian Regional Flood Frequency (ARFF) procedures. Good correlation was shown to occur between the Rational Method and ARFF peak discharge estimates for the 100 year ARI event, with the Rational Method estimates shown to be between 7% (Goombungee) and 15% (Pittsworth) greater than the ARFF estimates. A comparison of flows extracted from the Goombungee TUFLOW model with those estimated using the Rational Method was undertaken at a select number of locations within the study area. The comparison indicates that the flows extracted from the TUFLOW model correlate well to those estimated using the Rational Method with difference within the range of +/- 30%.

The predictions of flood behaviour by the MIKE FLOOD models and TUFLOW model were validated using available flood level information provided by local residents and TRC within the study areas. This information was established based on a consultation program completed during the course of the works. For the validation assessments, the 100 year ARI was assessed and compared to the anecdotal historic flood records. This was undertaken in the absence of more detailed information such as stream gauge data and local rainfall records which precluded detailed model calibrations. The results demonstrate that all of the MIKE FLOOD models developed for each of the towns of Goombungee, Pittsworth and Southbrook are accurately representing major flood behaviour based on comparisons to historical rainfall and anecdotal flood information and using standard model parameter sets. Similarly, flooding from overland flow paths as observed by residents compares well to the results produced by the TUFLOW "Direct Rainfall" model. Additional photographs provided by residents following a severe rainfall event in March 2014 also assisted in validating the results determined using the TUFLOW model. On this basis, the models for each of the respective study areas were considered by the TRC nominated peer reviewer to be appropriately validated and are representative of flooding behaviour.

Following the approval of the models by Council's nominated peer reviewer, each of the validation models have been adopted with minor change for the assessment of design flood events and sensitivity analyses for this study. Design flood events for each of the Goombungee, Pittsworth and Southbrook models have been assessed using the 5, 20 and 100 year ARI design rainfall catchment discharge estimates, which represented the 3 approved events nominated by Council.

Results from these assessments have been presented in this report by way of extensive GIS mapping which have been prepared in accordance with Council's nominated mapping conventions and standards. Additionally, a range of sensitivity assessments for the 100 year ARI event has also been assessed using a 50% structure blockage applied to all cross-drainage culverts.

The results for the sensitivity assessments have also been presented in this report as a series if GIS maps to depict the change in peak water levels which occurs under the 50% blockage scenario.

It is recommended that the model results be adopted by Council and used for inclusion in Council's updated planning scheme and for the purposes of addressing the conditional approval of the scheme, as issued by the State Government on the 17th February 2012.

8. DISCLAIMER

While every care is taken by the Toowoomba Regional Council (TRC) and Water Technology (WT) to ensure the accuracy of the data used in the study and published in the report, TRC and WT makes no representations or warranties about its accuracy, reliability, completeness or suitability for any particular purpose and disclaim all responsibility and all liability whether in contract, negligence or otherwise for all expenses, losses, damages (including indirect or consequential damage) and costs which may be incurred in any way and for any reason as a result of data being inaccurate or incomplete.

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APPENDIX A HYDRAULIC STRUCTURE DETAILS

Structure ID	Town	Latitude	Longitude	Type	Material	Barrels	Diameter Width (mm)	Height (mm)	Approx. Cover (mm)	Notes
GM_ST1	Goombungee	-27.3019	151.857	Pipe	concrete	2	600		900	Lilley St corner Lau Street
GM_ST2	Goombungee	-27.3047	151.863	Pipe	concrete	4	1800		700	Lilley Street
GM_ST3	Goombungee	-27.3018	151.856	Pipe	concrete	1	375		500	Lilley Street
GM_ST4	Goombungee	-27.3017	151.855	Box	concrete	1	900	450	600	Lilley Street
GM_ST5	Goombungee	-27.3017	151.855	Pipe	concrete	1	375		600	Lilley Street
GM_ST6	Goombungee	-27.3033	151.855	Pipe	concrete	1	450		300	Albert Street
GM_ST7	Goombungee	-27.3193	151.849	Box	concrete	6	2100	1200	700	
GM_ST8	Goombungee	-27.3159	151.846	Pipe	concrete	1	450		700	Debris on fence d/s crossing - approx. 1.2m above causeway
GM_ST9	Goombungee	-27.3145	151.844	Bridge	timber	1				12 span @5.7m each - 500mm diam piers - 650mm super structure. Refer site notes
GM_ST10	Goombungee	-27.3162	151.85	Pipe	concrete	refer notes	refer notes	refer notes	500	refer notes - multiple culverts of different sizes
GM_ST11	Goombungee	-27.3151	151.85	Pipe	concrete	2	600		400	Under main road to Goombungee

Structure ID	Town	Latitude	Longitude	Type	Material	Barrels	Diameter Width (mm)	Height (mm)	Approx. Cover (mm)	Notes
GM_ST12	Goombungee	-27.3078	151.848	Pipe	concrete	1	450		300	
GM_ST13	Goombungee	-27.3078	151.848	Pipe	concrete	1	450			local stormwater outlet
GM_ST14	Goombungee	-27.3058	151.848	Pipe	concrete	1	450		200	refer notes - multiple culverts of different sizes
GM_ST15	Goombungee	-27.3057	151.848	Pipe	concrete	1	450		100	refer notes - multiple culverts of different sizes
GM_ST16	Goombungee	-27.3057	151.848	unknown	concrete	unknown	unknown			refer notes - multiple culverts of different sizes
GM_ST17	Goombungee	-27.3055	151.846	Pipe	concrete	1	600			co-ords at pipe outlet - Hartwig Street
GM_ST18	Goombungee	-27.3054	151.846	Pipe	concrete	1	450		300	under Lebsonft St
GM_ST19	Goombungee	-27.3036	151.848	Box	concrete	2	900	600	700	
GM_ST20	Goombungee	-27.3039	151.849	Box	concrete	2	900	600	200	
GM_ST21	Goombungee	-27.3023	151.852	Box	concrete	1	900	600		local stormwater outlet - from Lintel on street u/s opposite school (27.30231, 151.85250)
GM_ST22	Goombungee	-27.3013	151.853	box	concrete	1	900	300	600	under Lilly Street

Structure ID	Town	Latitude	Longitude	Type	Material	Barrels	Diameter Width (mm)	Height (mm)	Approx. Cover (mm)	Notes
GM_ST23	Goombungee	-27.2959	151.845	Pipe	concrete	4	1800		400	Main creek crossing and main road to Oakey
GM_ST24	Goombungee	-27.2967	151.848	Box	concrete	4	750	600	600	
GM_ST25	Goombungee	-27.2953	151.853	Pipe	concrete	2	1200		700	
DP14694	Goombungee	-	-	Pipe	concrete	1	450		-	Supplied by TRC
DP14693	Goombungee	-	-	Pipe	concrete	1	450		-	Supplied by TRC
DP14692	Goombungee	-	-	Pipe	concrete	1	450		-	Supplied by TRC
DP14691	Goombungee	-	-	Pipe	concrete	1	450		-	Supplied by TRC
DP14689	Goombungee	-	-	Pipe	concrete	1	450		-	Supplied by TRC
SB_ST1	Southbrook	-27.6783	151.715	Pipe	concrete	1	450		400	
SB_ST2	Southbrook	-27.6784	151.714	Pipe	concrete	2	375		700	

Structure ID	Town	Latitude	Longitude	Type	Material	Barrels	Diameter Width (mm)	Height (mm)	Approx. Cover (mm)	Notes
SB_ST3	Southbrook	-27.6788	151.713	Pipe	concrete	1	900		500	railway crossing
SB_ST4	Southbrook	-27.6788	151.713	Pipe	corrugated	2	450		900	railway crossing - 50% blocked on d/s side
SB_ST5	Southbrook	-27.6791	151.713	Pipe	concrete	1	600		400	road crossing
SB_ST6	Southbrook	-27.6797	151.713	Pipe	concrete	1	450		500	Stirling Street
SB_ST7	Southbrook	-27.68	151.713	Pipe	concrete	1	450		300	concrete invert to drain
SB_ST8	Southbrook	-27.6801	151.713	Pipe	concrete	1	450		200	
SB_ST9	Southbrook	-27.6802	151.713	Pipe	concrete	1	600		200	local driveway crossing culvert
SB_ST10	Southbrook	-27.6812	151.713	Box	concrete	1	1200	300	500	Road culvert. Survey mark 144119 on headwall
SB_ST11	Southbrook	-27.6786	151.716	Box	concrete	1	1200	650	600	Railway crossing. Possible overland flows to properties immediately d/s of culvert to the RHS looking d/s. Debris on fence here.
SB_ST12	Southbrook	-27.6785	151.718	Pipe	concrete	2	450		700	Railway crossing

Structure ID	Town	Latitude	Longitude	Type	Material	Barrels	Diameter Width (mm)	Height (mm)	Approx. Cover (mm)	Notes
SB_ST13	Southbrook	-27.6781	151.719	Pipe	concrete	2	375		500	Outside 15 O'Shea Avenue
SB_ST14	Southbrook	-27.6782	151.716	Box	concrete	1	600	300	400	Local driveway crossing culvert
SB_ST15	Southbrook	-27.6782	151.716	Pipe	concrete	2	375		400	Open pit junction here - 1200x1200
SB_ST16	Southbrook	-27.6782	151.716	Pipe	concrete	1	450		500	Cnr. O'Connell Street
SB_ST17	Southbrook	-27.6786	151.712	Pipe	concrete	2	450		500	Railway crossing
SB_ST18	Southbrook	-27.6784	151.711	Pipe	concrete	1	450		300	Cnr. of Queen Street
SB_ST19	Southbrook	-27.6782	151.711	Pipe	concrete	1	375		200	Cnr. of Queen Street
SB_ST20	Southbrook	-27.6782	151.711	Pipe	concrete	1	375		400	Cnr. of Queen Street
SB_ST21	Southbrook	-27.6782	151.711	Pipe	concrete	2	450		300	Road crossing
SB_ST22	Southbrook	-27.6784	151.71	Pipe	concrete	2	450		700	Railway crossing
SB_ST23	Southbrook	-27.678	151.709	Pipe	concrete	1	450		800	Cnr. Bailey Street - skew culvert across road

Structure ID	Town	Latitude	Longitude	Type	Material	Barrels	Diameter Width (mm)	Height (mm)	Approx. Cover (mm)	Notes
SB_ST24	Southbrook	-27.6782	151.707	Pipe	concrete	1	450		500	Skew Culvert across road - opp. Park equip
SB_ST25	Southbrook	-27.6783	151.706	Pipe	concrete	1	450		600	Opp. Fire brigade - skew culvert across road
SB_ST26	Southbrook	-27.6782	151.705	Box	concrete	1	600	200	500	Under road to Pittsworth
SB_ST27	Southbrook	-27.6783	151.704	Pipe	concrete	1	375		500	Opp. Southbrook state school
SB_ST28	Southbrook	-27.6784	151.704	Pipe	concrete	1	375		400	Opp. State school - skew culvert
SB_ST29	Southbrook	-27.6755	151.705	Pipe	concrete	2	600		400	With highway
SB_ST30	Southbrook	-27.6738	151.708	Pipe	concrete	8	600		900	Highway
PW_ST1	Pittsworth	-27.7122	151.638	Pipe	concrete	1	900			S/W outlet from u/s street system
PW_ST2	Pittsworth	-27.7124	151.638	Pipe	concrete	1	750			s/w outlet from u/s street system
PW_ST3	Pittsworth	-27.7134	151.638	Pipe	concrete	1	825			s/w outlet -2 No
PW_ST4	Pittsworth	-27.7131	151.637	Pipe	concrete	2	750		200	Local pedestrian crossing beside railway

Structure ID	Town	Latitude	Longitude	Type	Material	Barrels	Diameter Width (mm)	Height (mm)	Approx. Cover (mm)	Notes
PW_ST5	Pittsworth	-27.7123	151.639	Pipe	concrete	3	900		400	RCP protruded ends under road
PW_ST6	Pittsworth	-27.7125	151.639	Bridge	timber	1				3 span @5m, 6.1m, 5m (Height 0.6m, 1.1m, 0.6m) - 420mm diam piers - 650mm super structure. Refer site notes
PW_ST7	Pittsworth	-27.7127	151.639	Box	concrete	3	1200	600	100	Road Crossing
PW_ST8	Pittsworth	-27.7129	151.639	Box	concrete	3	1200	450	200	Pedestrian Crossing
PW_ST9	Pittsworth	-27.7134	151.64	Box	concrete	1	1200	300		Road Crossing - Surcharge chamber on D/S side. Refer Site notes.
PW_ST10	Pittsworth	-27.715	151.642	Box	concrete	1	1200	450		Pedestrian bridge with handrails (1m high)
PW_ST11	Pittsworth	-27.715	151.642	Box	concrete	5	1200	600	100	Road Crossing with no hand rails.
PW_ST12	Pittsworth	-27.716	151.644	Box	concrete	5	1200	900	300	Road Crossing
PW_ST13	Pittsworth	-27.7162	151.645	Box	concrete	2	1200	400	300	Road Crossing, No hand rails, flood depth board
PW_ST14	Pittsworth	-27.7215	151.638	Pipe	concrete	1				Pipe outlet from u/s stormwater system
PW_ST15	Pittsworth	-27.7217	151.639	Pipe	concrete	2	600		400	Daniel St, Inlet pit arrangement. Refer site notes.

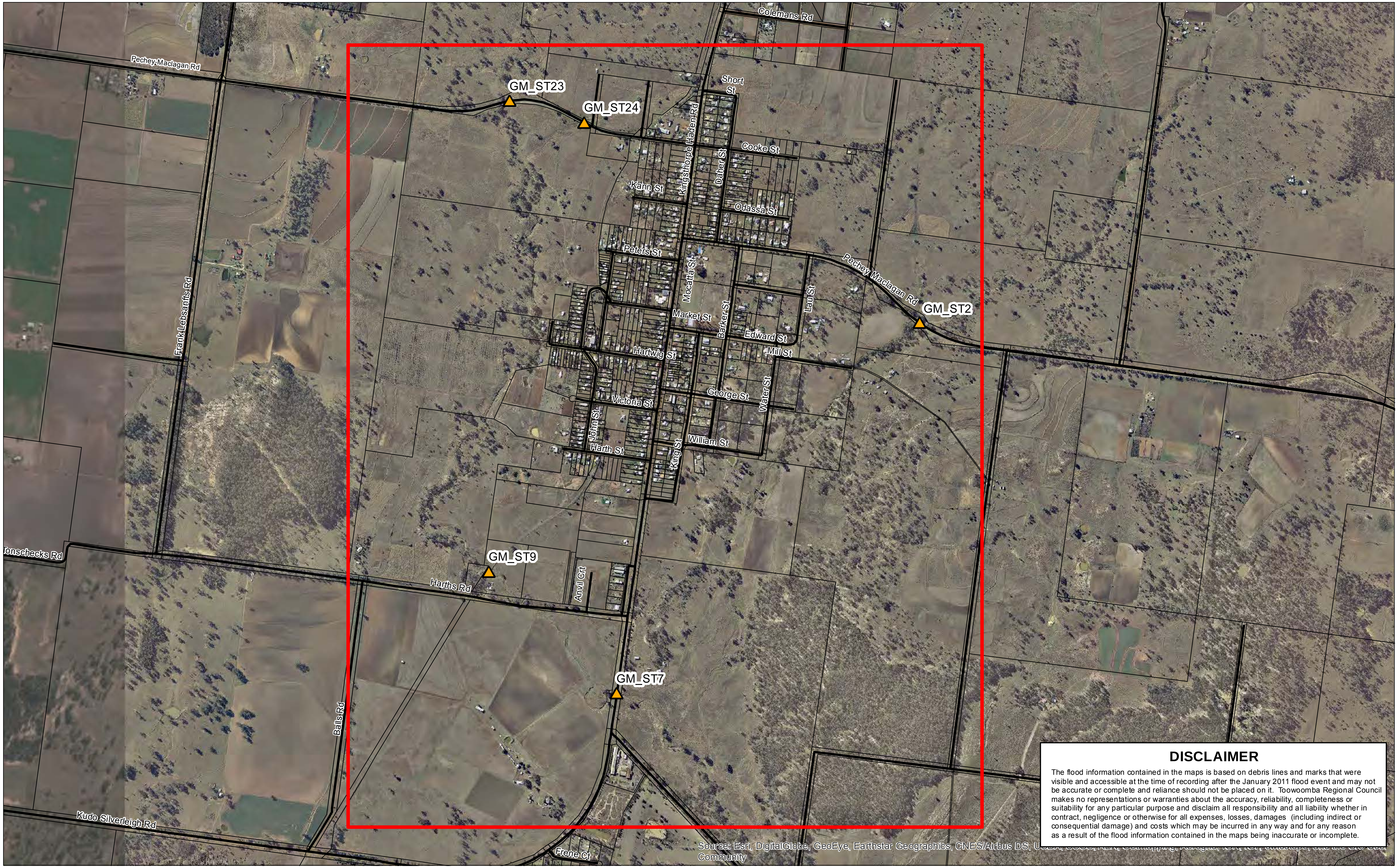
Structure ID	Town	Latitude	Longitude	Type	Material	Barrels	Diameter Width (mm)	Height (mm)	Approx. Cover (mm)	Notes
PW_ST16	Pittsworth	-27.7219	151.64	Box	concrete	2	450	900	250	local driveway crossing culvert
PW_ST17	Pittsworth	-27.722	151.641	Box	concrete	1	1200	450	nil	
PW_ST18	Pittsworth	-27.7218	151.638	Box	concrete	1	450	1200	100	Tyson St/Daniel St. drop inlet on u/s side
PW_ST19	Pittsworth	-27.7277	151.635	Pipe	concrete	2	375		600	Road Crossing opposite cemetery
PW_ST20	Pittsworth	-27.7262	151.635	Pipe	concrete	1	375			
PW_ST21	Pittsworth	-27.7268	151.633	Pipe	concrete	1	600		400	Grate = 20 diam bars @ 100mm spacing. Refer Site notes
PW_ST22	Pittsworth	-27.7271	151.633	Box	concrete	1	750	450		
PW_ST23	Pittsworth	-27.7309	151.644	Pipe	concrete	1	450		400	
PW_ST24	Pittsworth	-27.7286	151.626	Pipe	corrugated	2	300		300	Boundary Rd/Clifton Rd.
PW_ST25	Pittsworth	-27.7089	151.643	Box	concrete	1	600	1200	100	Campbell St crossing
PW_ST26	Pittsworth	-27.7092	151.643	Box	concrete	1	1200	600	300	local driveway crossing culvert
PW_ST27	Pittsworth	-27.7092	151.643	Box	concrete	1	750	300	100	

Structure ID	Town	Latitude	Longitude	Type	Material	Barrels	Diameter Width (mm)	Height (mm)	Approx. Cover (mm)	Notes
PW_ST28	Pittsworth	-27.7097	151.643	Box	concrete	1	900	450	200	
PW_ST29	Pittsworth	-27.7097	151.643	Box	concrete	1	300	600	300	old railway bridge 5m D/S - since fallen down, broken, no capacity
PW_ST30	Pittsworth	-27.71	151.643	Box	concrete	2	1200	300	200	
PW_ST31	Pittsworth	-27.7102	151.643	Box	concrete	2	1200	300	100	
PW_ST32	Pittsworth	-27.7096	151.642	Box	concrete	2	600	300		
PW_ST33	Pittsworth	-27.7073	151.649	Box	concrete	1	1200	300	300	Also - 375 RCP 500 cover. Refer Site Notes.
PW_ST34	Pittsworth	-27.7066	151.649	Bridge	timber	1				Bridge 3 span - 5m/6.1m/5m, deck 700mm, 450 diam. piers. Refer Site notes.
PW_ST35	Pittsworth	-27.7078	151.648	Pipe	concrete	1	375		300	
PW_ST36	Pittsworth	-27.7162	151.628	Pipe	concrete	1	750		1500	
PW_ST37	Pittsworth	-27.7165	151.627	Pipe	corrugated	2	600		1200	R/W Crossing
PW_ST38	Pittsworth	-27.7166	151.627	Pipe	concrete	6	600		500	Rd Crossing

Structure ID	Town	Latitude	Longitude	Type	Material	Barrels	Diameter Width (mm)	Height (mm)	Approx. Cover (mm)	Notes
PW_ST39	Pittsworth	-27.7168	151.627	Pipe	concrete	2	600		600	
PW_ST40	Pittsworth	-27.7169	151.627	Pipe	concrete	2	600		600	
PW_ST41	Pittsworth	-27.7175	151.627	Box	concrete	1	600	300		S/W outlet
PW_ST42	Pittsworth	-27.7173	151.328	Box	concrete	1	1500	375		S/W outlet
PW_ST43	Pittsworth	-27.7172	151.629	Box	concrete	1	1200	250		S/W outlet
PW_ST44	Pittsworth	-27.7171	151.629	Pipe	concrete	1	1200		400	S/W outlet
PW_ST45	Pittsworth	-27.7167	151.629	Pipe	concrete	1	600		500	Old Railway Spur crossing
PW_ST46	Pittsworth	-27.7164	151.628	Pipe	concrete	1	600		1500	local crossing for spur railway
PW_ST47	Pittsworth	-27.7161	151.627	Box	concrete	4	1200	540		
PW_ST48	Pittsworth	-27.7167	151.626	Pipe	concrete	2	450		1000	Refer site notes
PW_ST49	Pittsworth	-27.7167	151.626	Bridge	timber	1				Old Railway bridge single span 4m, refer site notes

Structure ID	Town	Latitude	Longitude	Type	Material	Barrels	Diameter Width (mm)	Height (mm)	Approx. Cover (mm)	Notes
PW_ST50	Pittsworth	-27.7167	151.626	Bridge	timber	1				Old Railway bridge single span 4m, refer site notes
PW_ST51	Pittsworth	-27.7143	151.626	Box	concrete	1	600	300	400	
PW_ST52	Pittsworth	-27.7145	151.628	Pipe	concrete	3	450		500	
PW_ST53	Pittsworth	-27.7151	151.628	Box	concrete	1	1200	300	300	
PW_ST54	Pittsworth	-27.7094	151.623	Pipe	concrete	3	1350		2000	Gore Hwy
PW_ST55	Pittsworth	-27.7138	151.615	Pipe	concrete	2	1200		1000	far limit Gore Hwy
PW_ST56	Pittsworth	-27.71	151.622	Pipe	concrete	2	900		400	Immediately west of 54 adjacent to Hwy signs.
PW_ST57	Pittsworth	-27.7078	151.626	Box	concrete	1	1200	450	800	Intersection Gore Hwy/ Pittsworth Road
PW_ST58	Pittsworth	-27.7074	151.627	Pipe	concrete	3	1200		1000	Protruded
PW_ST59	Pittsworth	-27.7073	151.629	Pipe	concrete	2	1200		700	Houses possibly below road crown level u/s of road embankment. Refer site notes.
PW_ST60	Pittsworth	-27.7082	151.629	Pipe	concrete	1	475		400	Pioneer way

Structure ID	Town	Latitude	Longitude	Type	Material	Barrels	Diameter Width (mm)	Height (mm)	Approx. Cover (mm)	Notes
PW_ST61	Pittsworth	-27.7094	151.629	Pipe	concrete	3	375		400	Williams/Helens St Intersection
PW_ST62	Pittsworth	-27.9032	151.628	Box	concrete	1	1200	300	300	d/s Pittsworth Hotel
PW_ST63	Pittsworth	-27.7113	151.628	Pipe	concrete	2	450		500	Helen St Near Grange Dr
PW_ST64	Pittsworth	-27.7115	151.628	Pipe	concrete	2	450		600	Grange Dr near Helens St
PW_ST65	Pittsworth	-27.7123	151.628	Pipe	concrete	3	450		600	North side of Florence St
PW_ST66	Pittsworth	-27.7126	151.628	Pipe	concrete	2	450		500	south side of Florence St
PW_ST67	Pittsworth	-27.7145	151.628	Pipe	concrete	3	450		500	Opposite Krinke St



DISCLAIMER

The flood information contained in the maps is based on debris lines and marks that were visible and accessible at the time of recording after the January 2011 flood event and may not be accurate or complete and reliance should not be placed on it. Toowoomba Regional Council makes no representations or warranties about the fluid information, accuracy, reliability, completeness or suitability for any particular purpose and disclaim all responsibility and all liability whether in contract, negligence or otherwise for all expenses, losses, damages (including indirect or consequential damage) and costs which may be incurred in any way and for any reason as a result of the flood information contained in the maps being inaccurate or incomplete.

TOOWOOMBA REGIONAL COUNCIL

1:15,000 (at A3)

0 115 230 460

Meters

GDA 1994 MGA Zone 56

N

Legend

- Structures
- Major Road
- MIKE Flood Model Domain
- Cadastre

SP051 Flood Studies - Work Package 11

Goombungee Structure Location - Riverine

J2810-04-Goombungee_structures.mxd
Author/Date: blair.filer 10/11/2015

TOOWOOMBA REGIONAL COUNCIL

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

GDA 1994 MGA Zone 56

Legend

Structures
Major Road
TUFLOW Flood Model Domain
Cadastre

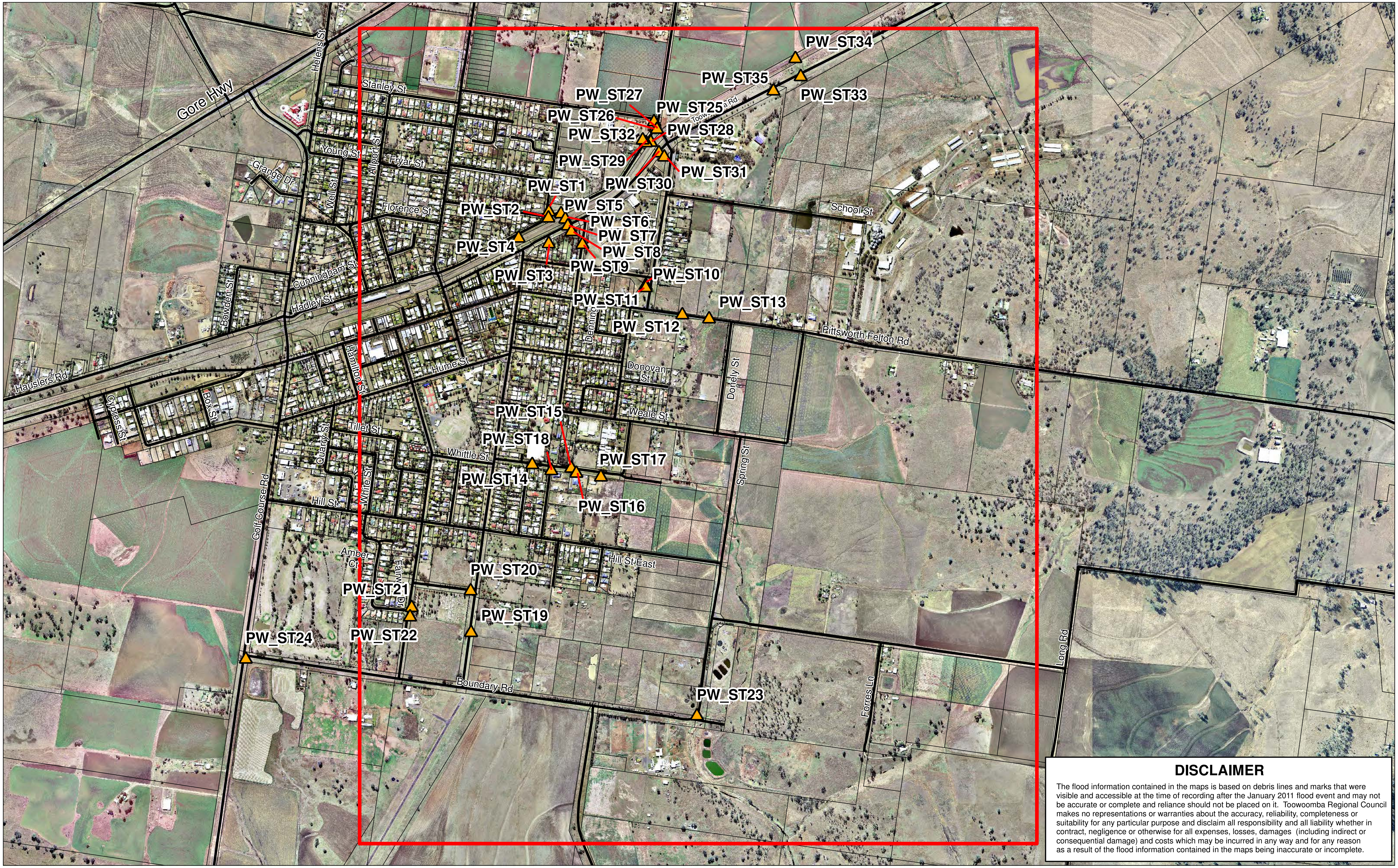
0 45 90 180 270 Metres

1:6,000 (at A3)

N

Gumbungee Flood Study

Goombungee Structure Location
Overland Flow Model



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TOOWOOMBA REGIONAL COUNCIL

1:14,000 (at A3)

0 105 210 420

Meters

GDA 1994 MGA Zone 56

N

Legend

- Structures
- MIKE Flood Model Domain
- Major Road
- Cadastre

SP051 Flood Studies - Work Package 11

Pittsworth East Structure Location

J2810-04-Pittsworth_East_structures.mxd
Author/Date: Ryan.dermek 18/03/2014

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TOOWOOMBA REGIONAL COUNCIL

1:9,000 (at A3)

0 65 130 260
Meters

GDA 1994 MGA Zone 56

N

Legend

- Structures
- QLD Rail Network
- MIKE Flood Model Domain
- Major Road
- Cadastre

SP051 Flood Studies - Work Package 11
Pittsworth West Structure Location

J2810-04-Pittsworth_West_Structures.mxd
Author/Date: Ryan.dermek 18/03/2014

DISCLAIMER

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TOOWOOMBA REGIONAL COUNCIL

1:8,000 (at A3)

0 60 120 240
Meters

GDA 1994 MGA Zone 56

N

Legend

- Structures
- QLD Rail Network
- MIKE Flood Model Domain
- Major Road
- Cadastre

SP051 Flood Studies - Work Package 11

Southbrook Structure Location

J2810-04-Southbrook_Structures.mxd
Author/Date: Ryan.dermek 18/03/2014

APPENDIX B RATIONAL METHOD CALCULATION SUMMARIES

Client Toowoomba Regional Council

Job Goombungee Flood Study

Job No J2810-04

Catchment ID	Area (ha)	Av. Slope (%)	Stream Length (m)	Time of Concentration t_c (min)	5 Yr Rainfall Intensity (mm/hr)	20 Yr Rainfall Intensity (mm/hr)	100 Yr Rainfall Intensity (mm/hr)	C10	Cy_Q5	Cy_Q20	Cy_Q100	Q5 (m^3/s)	Q20 (m^3/s)	Q100 (m^3/s)
1	1594.8	1.2	6789	105.23	29.53	37.47	48.72	0.49	0.47	0.51	0.59	60.9	85.4	126.9
2	34.3	4.5	593	29.95	66.38	84.94	111.31	0.49	0.47	0.51	0.59	2.9	4.2	6.2
3	1687.7	1.2	7200	109.80	28.70	36.40	47.33	0.49	0.47	0.51	0.59	62.6	87.8	130.5
4	59.1	3.0	1163	37.93	58.01	74.04	96.82	0.49	0.47	0.51	0.59	4.4	6.3	9.3
5	1762.0	1.2	7650	114.49	27.84	35.31	45.90	0.49	0.47	0.51	0.59	63.4	88.9	132.1
6	11.2	3.6	631	52.66	47.47	60.44	78.85	0.68	0.64	0.71	0.81	0.9	1.3	2.0
7	8.7	2.8	422	45.41	52.07	66.36	86.65	0.70	0.67	0.74	0.84	0.8	1.2	1.8
8	2.1	3.5	175	18.05	86.13	111.00	146.41	0.74	0.70	0.77	0.88	0.4	0.5	0.8
9	13.4	3.3	350	19.46	83.06	106.91	140.86	0.61	0.57	0.64	0.73	1.8	2.5	3.8
10	1883.2	1.1	8431	123.38	26.32	33.38	43.38	0.49	0.47	0.51	0.59	64.1	89.8	133.4
15	1915.8	1.0	8600	119.63	26.90	34.11	44.33	0.49	0.47	0.51	0.59	66.6	93.4	138.7
16	0.5	3.4	207	15.00	93.88	121.38	160.57	0.75	0.71	0.78	0.89	0.1	0.1	0.2
17	29.2	2.3	1100	71.08	39.10	49.70	64.72	0.73	0.69	0.76	0.87	2.2	3.1	4.6
19	2102.3	0.8	9200	133.02	24.88	31.54	40.99	0.49	0.47	0.51	0.59	67.6	94.8	140.7
20	2145.6	0.8	9450	129.37	25.43	32.24	41.89	0.49	0.47	0.51	0.59	70.5	98.9	146.8
21	2250.2	0.8	9700	132.52	24.96	31.64	41.11	0.49	0.47	0.51	0.59	72.6	101.7	151.1
22	1.6	4.2	122	15.00	93.88	121.38	160.57	0.75	0.71	0.78	0.89	0.3	0.4	0.6
23	9.1	5.0	490	15.00	93.88	121.38	160.57	0.56	0.53	0.58	0.67	1.2	1.8	2.7
24	10.9	5.7	471	40.66	55.70	71.05	92.85	0.49	0.47	0.51	0.59	0.8	1.1	1.7
25	4.9	2.8	218	22.27	77.67	99.76	131.20	0.65	0.61	0.68	0.77	0.7	0.9	1.4
26	37.4	2.9	925	41.95	54.70	69.76	91.15	0.59	0.56	0.61	0.70	3.2	4.4	6.6
27	53.6	4.8	1050	33.28	62.59	79.99	104.71	0.49	0.47	0.51	0.59	4.3	6.1	9.2
28	277.3	2.7	2349	45.03	52.32	66.68	87.07	0.49	0.47	0.51	0.59	18.8	26.4	39.4
29	343.2	2.4	2252	45.08	52.29	66.64	87.02	0.49	0.47	0.51	0.59	23.2	32.7	48.8
30	470.8	1.8	2668	49.64	49.25	62.73	81.86	0.49	0.47	0.51	0.59	30.0	42.2	63.0
31	508.1	1.5	3233	54.49	46.42	59.08	77.06	0.49	0.47	0.51	0.59	30.5	42.9	63.9
32	598.4	1.3	3755	59.21	43.98	55.96	72.94	0.49	0.47	0.51	0.59	34.0	47.9	71.3
34	2911.2	0.6	10628	129.62	25.39	32.19	41.83	0.49	0.47	0.51	0.59	95.6	133.9	198.9
36	16.6	2.3	460	19.79	82.37	106.00	139.62	0.68	0.65	0.71	0.82	2.5	3.5	5.3
38	3.6	3.2	399	15.00	93.88	121.38	160.57	0.75	0.71	0.79	0.90	0.7	0.9	1.4
39	3.3	4.3	278	15.00	93.88	121.38	160.57	0.75	0.71	0.78	0.89	0.6	0.9	1.3
40	3.9	3.7	379	16.00	91.14	117.70	155.54	0.75	0.71	0.78	0.89	0.7	1.0	1.5
41	6.4	3.1	448	18.00	86.23	111.14	146.60	0.74	0.70	0.77	0.88	1.1	1.5	2.3

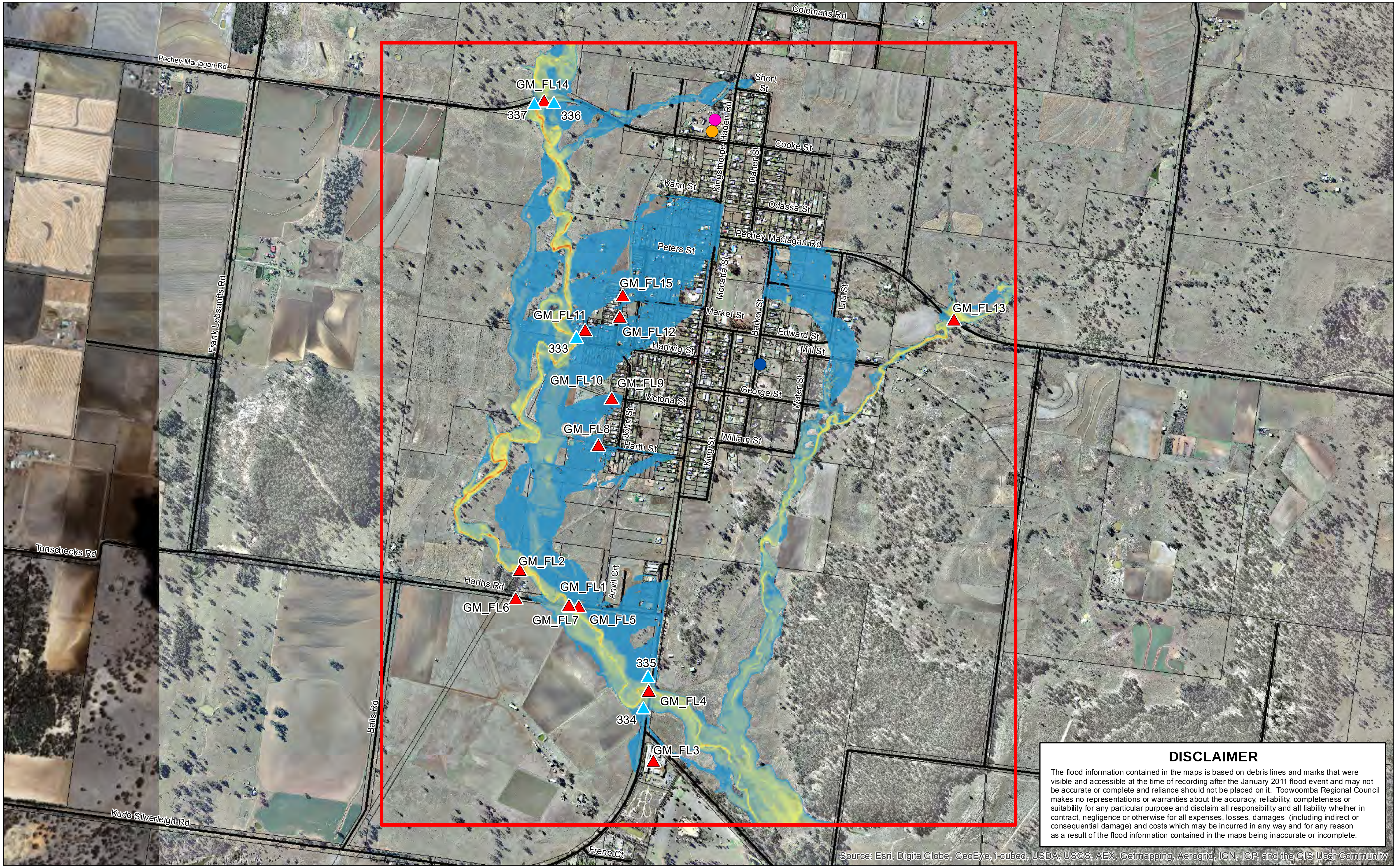
Client: - **Toowoomba Regional Council**
Job: - **Pittsworth Overland Flow Path Study**
Job No: - **J2810-04**

Catchment ID	Model (East / West)	Area (ha)	Av. Slope (%)	Stream Length (m)	Time of Concentration t_c (min)	5 Yr Rainfall Intensity (mm/hr)	20 Yr Rainfall Intensity (mm/hr)	100 Yr Rainfall Intensity (mm/hr)	C10	Cy_Q5	Cy_Q20	Cy_Q100	Q5 (m^3/s)	Q20 (m^3/s)	Q100 (m^3/s)
1	East	1601.4	0.95	7355	114.5	27.87	34.96	45.00	0.49	0.47	0.51	0.59	**57.7**	**80.0**	**117.7**
3	East	16.5	0.40	752	22.0	76.55	97.14	126.48	0.74	0.70	0.78	0.89	**2.5**	**3.5**	**5.2**
4	East	12.4	1.44	758	22.0	76.45	97.01	126.30	0.70	0.66	0.73	0.83	**1.7**	**2.4**	**3.6**
5	East	15.9	2.70	584	20.4	79.46	100.97	131.63	0.68	0.64	0.71	0.81	**2.2**	**3.2**	**4.7**
6	East	63.0	1.52	1314	28.7	66.51	84.04	108.99	0.61	0.58	0.64	0.73	**6.7**	**9.4**	**14.0**
7	East	1664.6	0.87	7751	119.3	27.03	33.90	43.64	0.49	0.47	0.51	0.59	**58.2**	**80.6**	**118.6**
8	East	31.5	1.90	776	22.2	76.16	96.63	125.80	0.71	0.67	0.74	0.85	**4.5**	**6.3**	**9.3**
9	East	2.1	2.20	327	18.0	84.46	107.59	140.56	0.75	0.71	0.78	0.89	**0.3**	**0.5**	**0.7**
16	East	2314.1	0.85	10830	151.6	22.78	28.59	36.82	0.49	0.47	0.51	0.59	**68.2**	**94.6**	**139.2**
17	East	2266.9	0.85	10253	145.6	23.48	29.46	37.94	0.49	0.47	0.51	0.59	**68.8**	**95.4**	**140.5**
18	East	2117.6	0.84	9525	138.1	24.38	30.59	39.38	0.49	0.47	0.51	0.59	**66.7**	**92.6**	**136.2**
19	East	19.6	1.75	787	23.2	74.43	94.37	122.76	0.67	0.64	0.70	0.80	**2.6**	**3.6**	**5.4**
20	East	7.2	0.40	402	18.7	82.93	105.55	137.81	0.74	0.70	0.77	0.88	**1.2**	**1.6**	**2.4**
21	East	2.6	0.40	261	17.4	85.90	109.50	143.16	0.76	0.72	0.79	0.91	**0.5**	**0.6**	**1.0**
22	East	1.4	1.80	290	17.7	85.27	108.66	142.01	0.75	0.71	0.79	0.90	**0.2**	**0.3**	**0.5**
23	East	6.3	1.80	268	17.5	85.75	109.30	142.88	0.75	0.71	0.79	0.90	**1.1**	**1.5**	**2.3**
24	East	29.0	1.59	864	23.0	74.76	94.79	123.32	0.66	0.62	0.69	0.79	**3.8**	**5.3**	**7.8**
25	East	2026.7	0.84	9030	132.9	25.05	31.42	40.46	0.49	0.47	0.52	0.59	**66.2**	**91.8**	**135.0**
26	East	7.8	2.18	555	20.1	79.98	101.66	132.55	0.75	0.71	0.79	0.90	**1.2**	**1.7**	**2.6**
27	East	1904.0	0.82	8397	126.5	25.97	32.58	41.94	0.49	0.47	0.51	0.59	**63.9**	**88.6**	**130.4**
28	East	151.3	1.13	1539	29.3	65.81	83.13	107.78	0.68	0.65	0.71	0.82	**17.9**	**25.0**	**37.0**
29	East	77.9	1.50	1020	24.4	72.44	91.76	119.27	0.72	0.68	0.75	0.86	**10.6**	**14.9**	**22.1**
30	East	24.1	2.30	830	22.7	75.30	95.50	124.28	0.56	0.53	0.59	0.67	**2.7**	**3.8**	**5.6**
31	East	14.0	2.10	549	20.1	80.09	101.80	132.74	0.74	0.70	0.77	0.88	**2.2**	**3.0**	**4.5**
32	East	3.7	2.60	439	19.1	82.18	104.57	136.47	0.73	0.69	0.77	0.88	**0.6**	**0.8**	**1.2**
33	East	2.8	2.10	424	18.9	82.48	104.96	137.01	0.75	0.71	0.78	0.89	**0.4**	**0.6**	**0.9**
34	East	1.5	1.50	388	18.6	83.21	105.93	138.33	0.75	0.71	0.78	0.89	**0.2**	**0.3**	**0.5**
35	East	8.9	2.30	590	20.5	79.35	100.83	131.43	0.49	0.47	0.51	0.59	**0.9**	**1.3**	**1.9**
36	East	132.1	3.50	1662	35.7	58.86	74.17	95.93	0.49	0.47	0.51	0.59	**10.1**	**14.0**	**20.7**
37	East	1410.8	0.94	6515	105.9	29.40	36.87	47.46	0.49	0.47	0.51	0.59	**53.6**	**74.3**	**109.4**
2	West	25.6	2.20	969	24.0	73.17	92.72	120.55	0.68	0.65	0.71	0.82	**3.4**	**4.7**	**7.0**
10	West	20.8	1.80	680	21.3	77.77	98.74	128.63	0.68	0.64	0.71	0.81	**2.9**	**4.0**	**6.0**
11	West	158.9	1.70	1652	32.2	62.41	78.73	101.95	0.63	0.60	0.66	0.76	**16.5**	**23.0**	**34.0**
12	West	3.6	2.00	536	20.0	80.32	102.11	133.16	0.73	0.69	0.77	0.88	**0.6**	**0.8**	**1.2**
13	West	48.3	1.00	907	23.4	74.11	93.94	122.19	0.68	0.65	0.71	0.82	**6.4**	**9.0**	**13.4**
14	West	3.6	2.00	536	20.0	80.32	102.11	133.16	0.73	0.69	0.77	0.88	**0.7**	**0.8**	**0.9**
15	West	3.0	0.60	260	17.4	85.93	109.53	143.20	0.56	0.53	0.58	0.67	**0.4**	**0.5**	**0.8**
38	West	34.3	1.80	680	21.3	77.77	98.74	128.63	0.69	0.66	0.72	0.83	**4.9**	**6.8**	**10.2**
39	West	3.5	3.10	348	17.2	86.36	110.11	143.99	0.75	0.71	0.78	0.89	**0.6**	**0.8**	**1.2**
40	West	3.7	2.60	439	19.1	82.18	104.57	136.47	0.73	0.69	0.77	0.88	**0.7**	**0.8**	**0.9**
41	West	59.7	1.00	1092	26.4	69.59	88.04	114.31	0.63	0.60	0.66	0.76	**6.9**	**9.7**	**14.3**
42	West	17.8	0.80	536	20.0	80.32	102.11	133.16	0.75	0.71	0.78	0.89	**2.8**	**4.0**	**5.9**
43	West	0.8	0.80	138	16.3	88.73	113.27	148.26	0.75	0.71	0.78	0.89	**0.1**	**0.2**	**0.3**
44	West	132.1	3.50	1662	35.7	58.86	74.17	95.93	0.49	0.47	0.51	0.59	**0.5**	**0.5**	**0.6**
45	West	4.8	0.80	369	18.4	83.60	106.45	139.02	0.72	0.68	0.76	0.86	**0.8**	**1.1**	**1.6**
46	West	36.6	2.10	1037	31.2	63.54	80.20	103.90	0.49	0.47	0.51	0.59	**3.0**	**4.2**	**6.2**
47	West	7.4	1.60	485	26.6	69.30	87.67	113.81	0.49	0.47	0.51	0.59	**0.7**	**0.9**	**1.4**
48	West	164.5	1.60	1582	38.0	56.79	71.51	92.43	0.49	0.47	0.51	0.59	**12.1**	**16.8**	**24.8**
49	West	117.1	1.80	982	30.1	64.76	81.78	105.98	0.53	0.50	0.56	0.64	**10.6**	**14.8**	**21.9**
50	West	24.6	2.10	696	26.8	68.95	87.21	113.19	0.49	0.47	0.51	0.59	**2.2**	**3.1**	**4.6**

Client **Toowoomba Regional Council**
Job **Southbrook Flood Study**
Job No **J2810-04**

Catchment ID	Area (ha)	Av. Slope (%)	Stream Length (m)	Time of Concentration t_c (min)	5 Yr Rainfall Intensity (mm/hr)	20 Yr Rainfall Intensity (mm/hr)	100 Yr Rainfall Intensity (mm/hr)	C10	Cy_Q5	Cy_Q20	Cy_Q100	Q5 (m^3/s)	Q20 (m^3/s)	Q100 (m^3/s)
1	141.7	1.5	1450	41.5	50.85	64.65	84.25	0.53	0.50	0.56	0.64	**10.1**	**14.2**	**21.1**
2	211.7	1.5	1450	41.5	50.85	64.65	84.25	0.51	0.48	0.53	0.61	**14.3**	**20.2**	**30.0**
3	232.8	1.5	1780	44.7	48.54	61.66	80.30	0.51	0.48	0.53	0.61	**15.1**	**21.1**	**31.5**
4	258.8	1.4	2180	49.0	45.89	58.25	75.80	0.51	0.48	0.53	0.61	**15.8**	**22.2**	**33.0**
5	318.2	1.4	2490	52.4	44.03	55.84	72.64	0.53	0.50	0.55	0.63	**19.4**	**27.2**	**40.5**
6	330.9	1.3	2780	55.5	42.43	53.80	69.95	0.53	0.50	0.56	0.64	**19.6**	**27.5**	**40.9**
7	356.2	1.3	3050	58.1	41.20	52.21	67.87	0.54	0.51	0.56	0.64	**20.7**	**29.0**	**43.1**
8	368.6	1.3	3175	59.3	40.65	51.51	66.95	0.54	0.51	0.56	0.64	**21.2**	**29.6**	**44.0**
9	390.6	1.3	3400	61.7	39.71	50.31	65.38	0.54	0.51	0.56	0.64	**21.9**	**30.7**	**45.5**
10	2.5	2.9	340	25.8	66.51	85.13	111.61	0.70	0.66	0.73	0.83	**0.3**	**0.4**	**0.6**
11	2.7	2.9	340	25.8	66.51	85.13	111.61	0.70	0.66	0.73	0.83	**0.3**	**0.5**	**0.7**
12	3.9	3.0	390	26.1	66.13	84.63	110.93	0.71	0.67	0.75	0.85	**0.5**	**0.7**	**1.0**
13	6.1	1.8	550	19.6	76.78	98.79	130.16	0.65	0.62	0.68	0.78	**0.8**	**1.1**	**1.7**
14	1.2	1.7	150	16.3	84.11	108.65	143.69	0.71	0.67	0.75	0.85	**0.2**	**0.3**	**0.4**
15	8.7	2.0	200	16.7	83.10	107.29	141.81	0.66	0.62	0.69	0.79	**1.3**	**1.8**	**2.7**
16	0.8	0.8	130	16.1	84.51	109.20	144.44	0.63	0.59	0.66	0.75	**0.1**	**0.2**	**0.2**
16	0.8	4.8	250	14.8	87.82	113.67	150.62	0.74	0.70	0.77	0.88	**0.1**	**0.2**	**0.3**
17	11.0	1.7	175	16.5	83.60	107.97	142.75	0.65	0.62	0.68	0.78	**1.6**	**2.2**	**3.4**
18	5.3	3.8	450	17.8	80.60	103.92	137.18	0.72	0.68	0.75	0.86	**0.8**	**1.2**	**1.7**
19	19.0	1.8	925	7.7	116.73	153.11	205.52	0.67	0.64	0.70	0.80	**3.9**	**5.7**	**8.7**
20	27.7	1.8	960	8.0	114.93	150.67	202.13	0.66	0.63	0.69	0.79	**5.5**	**8.0**	**12.3**
22	1.6	4.5	310	15.6	85.81	110.94	146.85	0.52	0.49	0.55	0.62	**0.2**	**0.3**	**0.4**
22	1.6	5.0	280	14.9	87.59	113.36	150.19	0.67	0.64	0.70	0.80	**0.3**	**0.4**	**0.6**
23	2.3	3.9	305	23.2	70.45	90.36	118.67	0.59	0.56	0.62	0.71	**0.3**	**0.4**	**0.5**
24	8.3	5.5	380	15.3	86.50	111.89	148.16	0.61	0.58	0.64	0.74	**1.2**	**1.7**	**2.5**
26	5.7	5.8	600	22.6	71.44	91.67	120.46	0.56	0.53	0.58	0.67	**0.6**	**0.8**	**1.3**
27	3.0	3.0	230	24.5	68.43	87.67	115.04	0.53	0.50	0.55	0.63	**0.3**	**0.4**	**0.6**
28	8.5	3.0	230	24.5	68.43	87.67	115.04	0.49	0.47	0.51	0.59	**0.7**	**1.1**	**1.6**
29	5.6	3.0	470	27.0	64.87	82.97	108.70	0.67	0.64	0.70	0.80	**0.6**	**0.9**	**1.4**
30	41.1	2.9	380	26.4	65.74	84.11	110.23	0.55	0.52	0.58	0.66	**3.9**	**5.5**	**8.3**
31	76.2	2.4	1344	11.2	99.71	129.85	173.10	0.52	0.49	0.54	0.62	**10.3**	**14.9**	**22.6**

APPENDIX C HISTORIC EVENT VALIDATION MAPS



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TOOWOOMBA REGIONAL COUNCIL

1:15,000 (at A3)

0 115 230 460
Meters

GDA 1994 MGA Zone 56

N

Legend

- Observed Flood Level
- Anecdotal Historic Flood Mark
- MIKE Flood Model Domain
- Major Road
- Cadastre
- Police Station
- Rural Fire Brigade
- SES

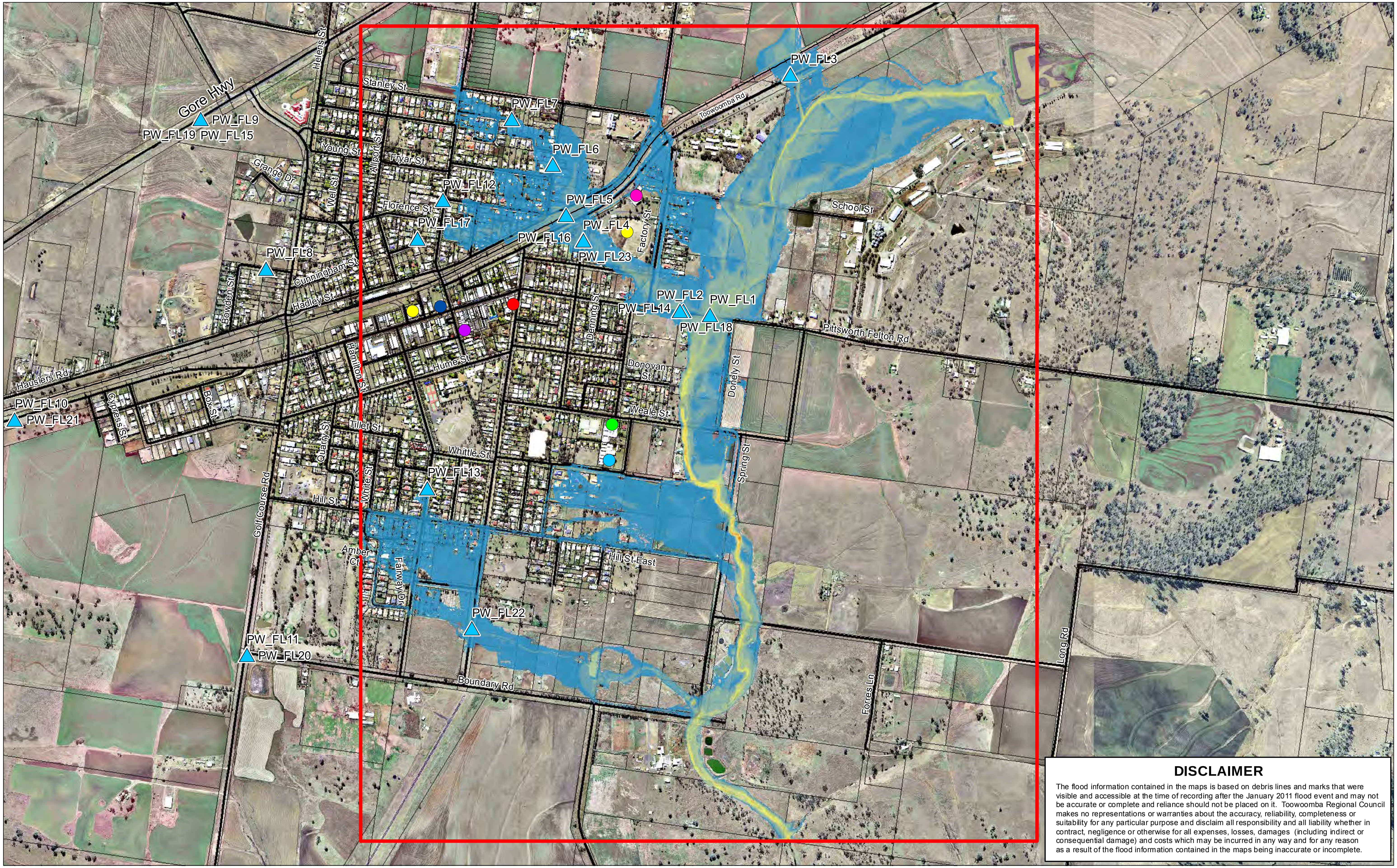
Flood Depth

Depth Band (m)

0.005 to 0.25	0.5 to 1.0	2.0 to 2.5	3.5 to 4.0	>5.0
0.25 to 0.5	1.0 to 1.5	2.5 to 3.0	4.0 to 4.5	
	1.5 to 2.0	3.0 to 3.5	4.5 to 5.0	

SP051 Flood Studies - Work Package 11
Goombungee January 2011 Validation Event
Peak Flood Depth
Approximately Equivalent to a 100 Year ARI Event

J2810-04-Goombungee_Val_Depth.mxd
Author/Date: luke.mcavoy 20/03/2014



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TOOWOOMBA REGIONAL COUNCIL

1:14,000 (at A3)

0 105 210 420
Meters

GDA 1994 MGA Zone 56

N

Legend

- Anecdotal Historic Flood Mark
- Major Road
- MIKE Flood Model Domain
- QLD Rail Network
- Cadastre
- Ambulance
- Evacuation Centre
- Fire Station
- Hospital
- Nursing Homes
- Police Station
- SES

Flood Depth

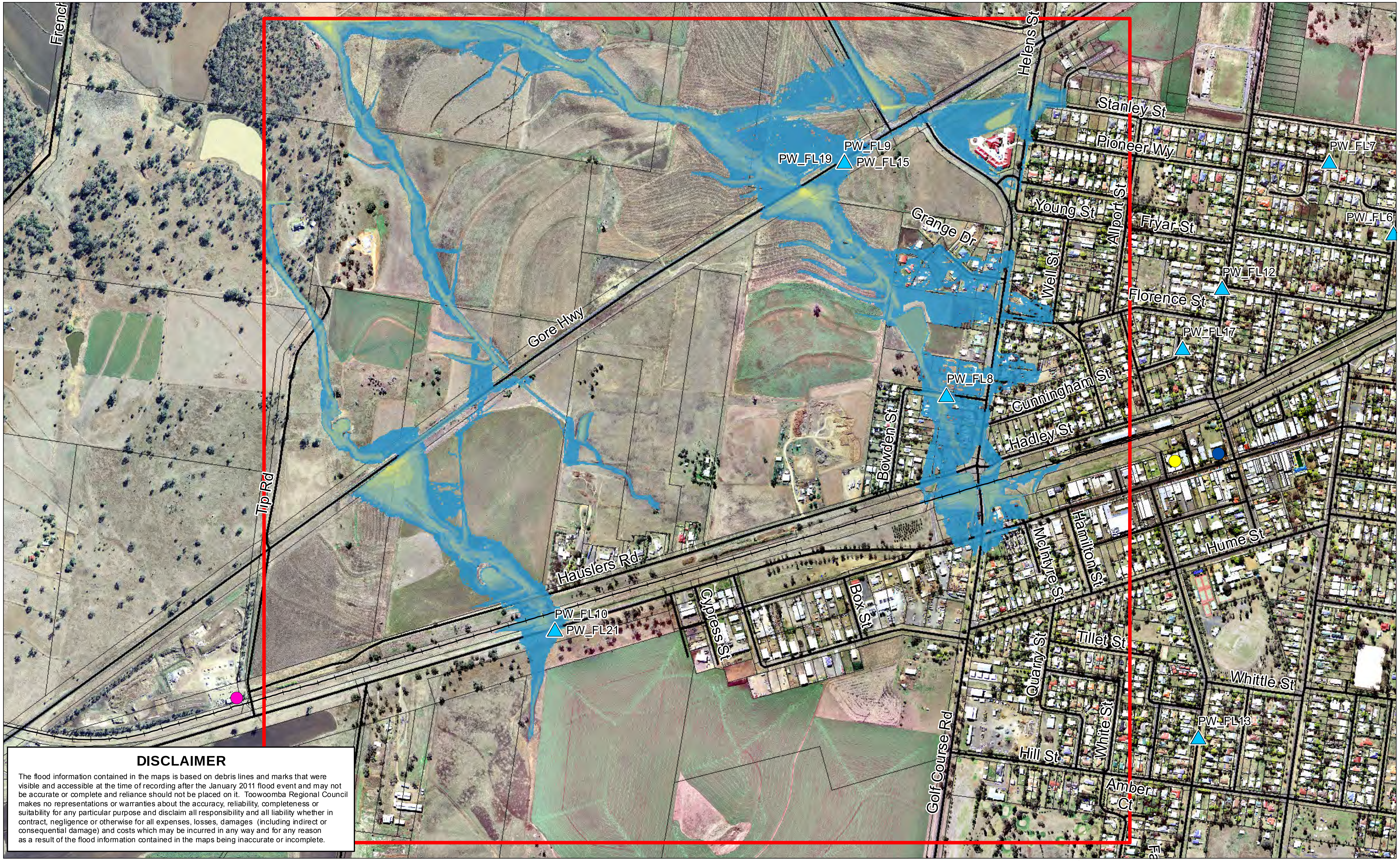
Depth Band (m)

- 0.005 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- 4.5 to 5.0
- >5.0

SP051 Flood Studies - Work Package 11

Pittsworth East January 2011 Validation Event
Peak Flood Depth
Approximately Equivalent to a 100 Year ARI Event

J2810-04-Pittsworth_East_Val_Depth.mxd
Author/Date: luke.mcavoy 20/03/2014



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TOOWOOMBA REGIONAL COUNCIL

1:9,000 (at A3)

0 65 130 260
Meters

GDA 1994 MGA Zone 56

N

Legend

- Anecdotal Historic Flood Mark
- QLD Rail Network
- Major Road
- MIKE Flood Model Domain
- Cadastre
- Evacuation Centre
- Police Station
- Rural Fire Brigade

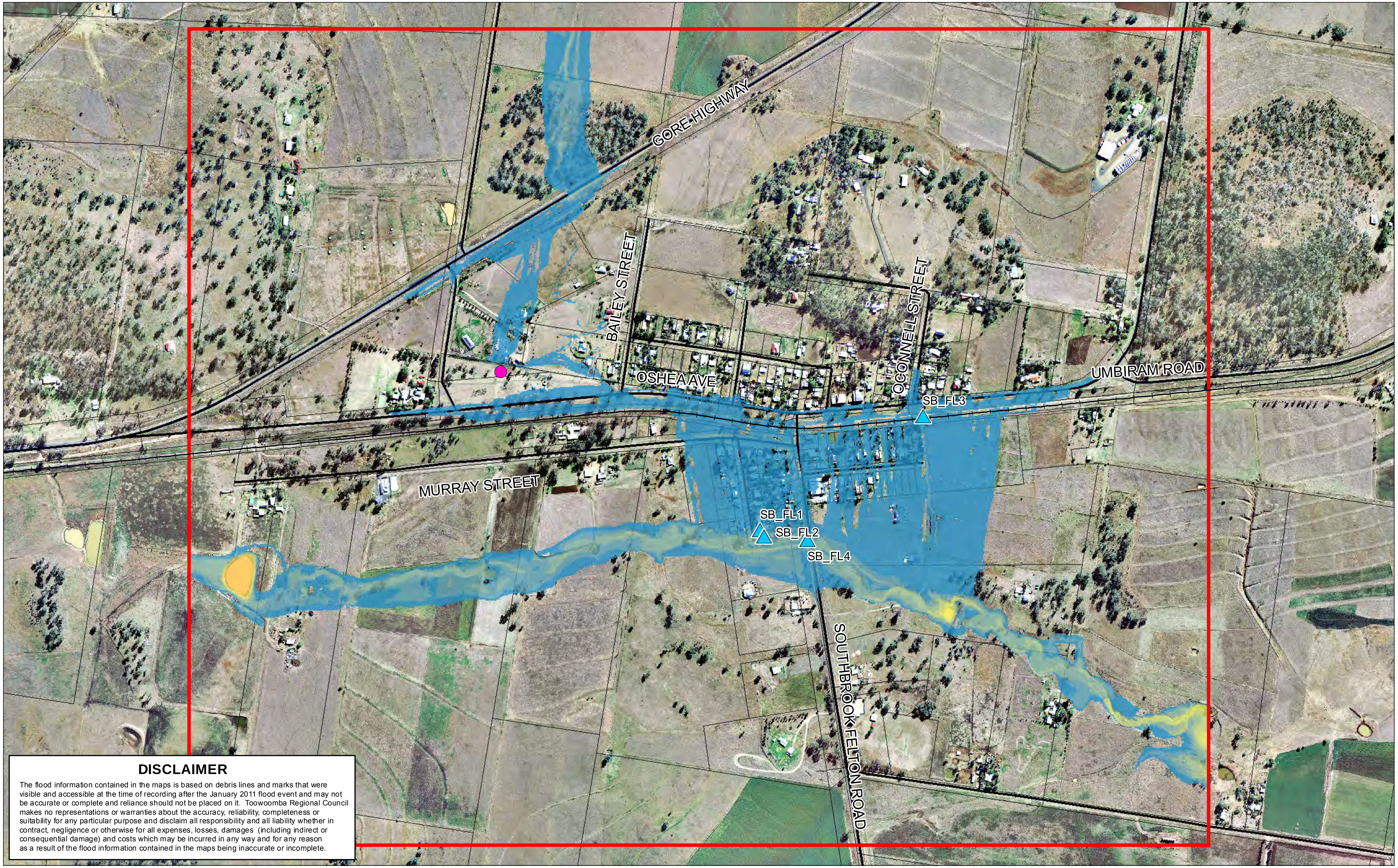
Flood Depth

Depth Band (m)

- 0.005 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- 4.5 to 5.0
- >5.0

SP051 Flood Studies - Work Package 11
Pittsworth West January 2011 Validation Event
Peak Flood Depth
Approximately Equivalent to a 100 Year ARI Event

J2810-04-Pittsworth_West_Val.mxd
Author/Date: luke.mcavoy 20/03/2014



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TOOWOOMBA REGIONAL COUNCIL

1:8,000 (at A3)

0 60 120 240
Meters

GDA 1994 MGA Zone 56

N

Legend

- Anecdotal Historic Flood Mark
- QLD Rail Network
- MIKE Flood Model Domain
- Major Road
- Cadastre
- Rural Fire Brigade

Flood Depth

Depth Band (m)

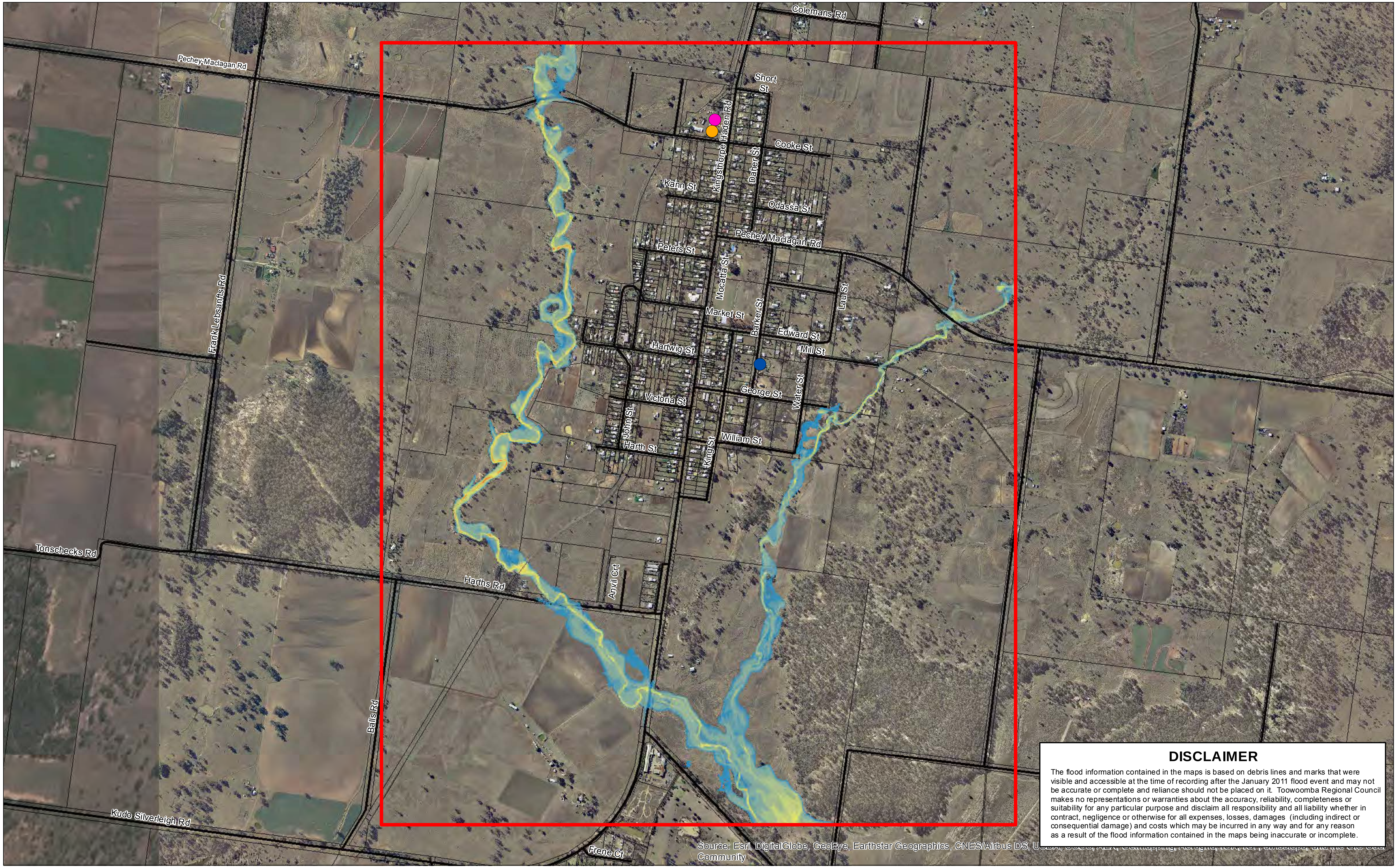
- 0.005 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- 4.5 to 5.0
- >5.0

SP051 Flood Studies - Work Package 11

Southbrook January 2011 Validation Event
Peak Flood Depth
Approximately Equivalent to a 100 Year ARI Event

J2810-04-Southbrook_Validation_Depth.mxd
Author/Date: luke.mcavoy 20/03/2014

APPENDIX D GOOMBUNGEE DESIGN EVENT MAPS



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TOOWOOMBA REGIONAL COUNCIL

1:15,000 (at A3)

0 115 230 460
Meters

GDA 1994 MGA Zone 56

N

Legend

- MIKE Flood Model Domain
- Major Road
- Cadastre
- Police Station
- Rural Fire Brigade
- SES

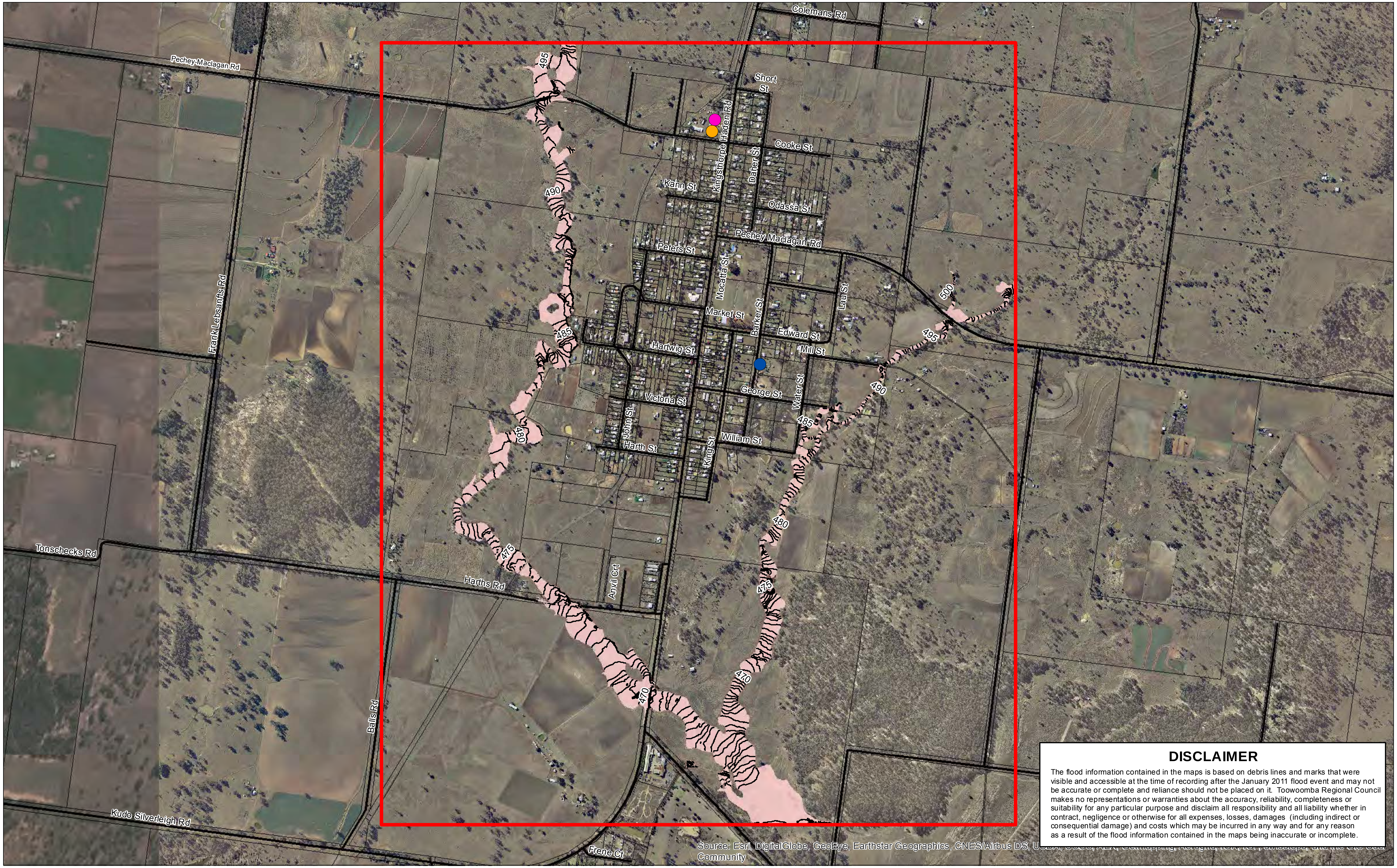
Flood Depth

Depth Band (m)

- 0.005 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- 4.5 to 5.0
- >5.0

SP051 Flood Studies - Work Package 11
Goombungee - Riverine Flow
5 Year ARI Peak Flood Depth

J2810-04-Goombungee_Q5_Depth.mxd
Author/Date: blair.filer 18/08/2015



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TOOWOOMBA REGIONAL COUNCIL

1:15,000 (at A3)

0 115 230 460
Meters

GDA 1994 MGA Zone 56

N

Legend

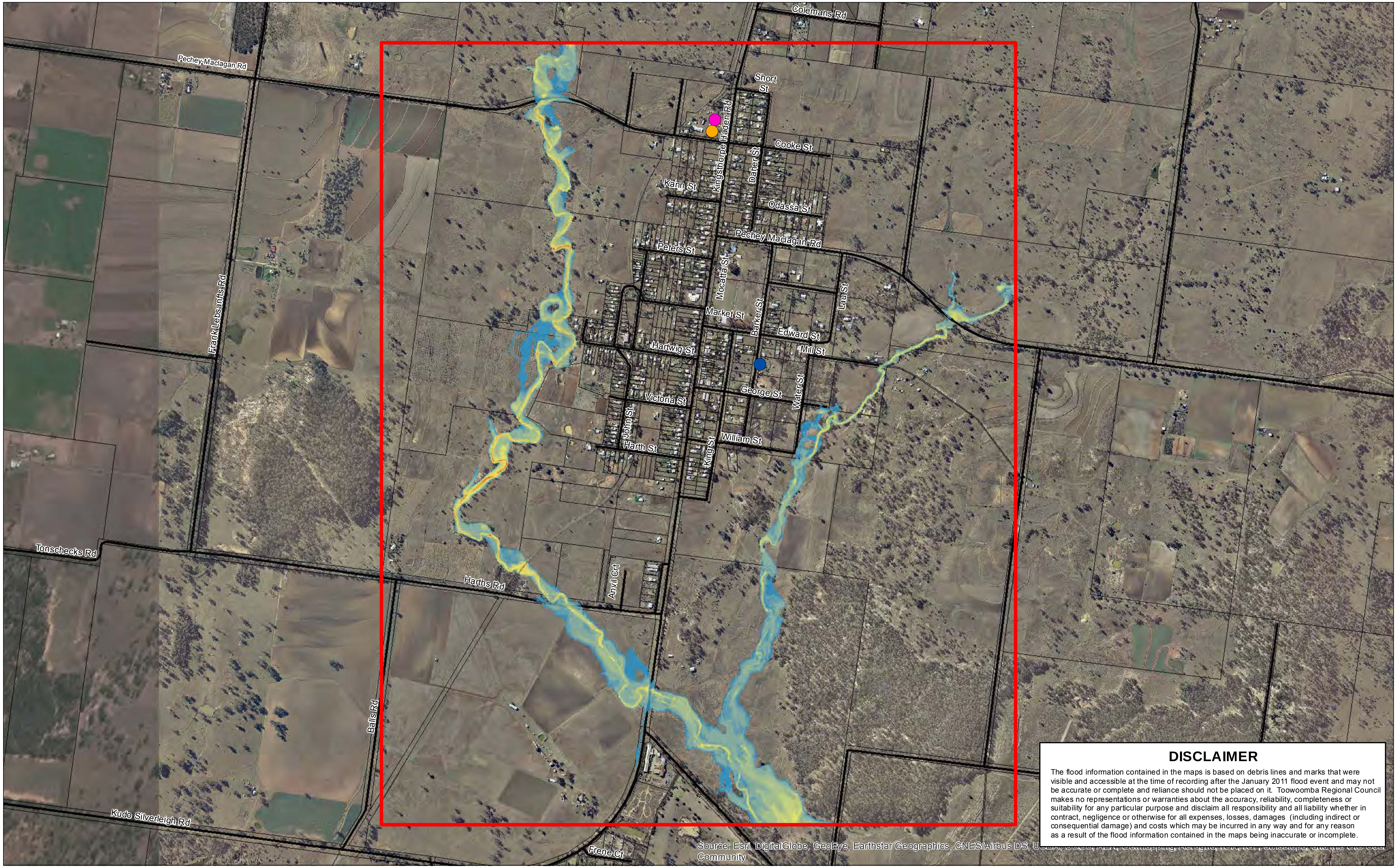
- MIKE Flood Model Domain
- Cadastre
- Major Road
- Police Station
- Rural Fire Brigade
- SES

Flood Extent

- 0.2m contours (mAHD)
- 5yr ARI

SP051 Flood Studies - Work Package 11
Goombungee - Riverine Flow
5 Year ARI Peak Water Surface Level Map

J2810-04-Goombungee_Q5_WL.mxd
Author/Date: blair.filer 18/08/2015



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TOOWOOMBA REGIONAL COUNCIL

1:15,000 (at A3)

0 115 230 460 Meters

GDA 1994 MGA Zone 56

N

Legend

- MIKE Flood Model Domain
- Major Road
- Cadastre
- Police Station
- Rural Fire Brigade
- SES

Flood Depth

Depth Band (m)

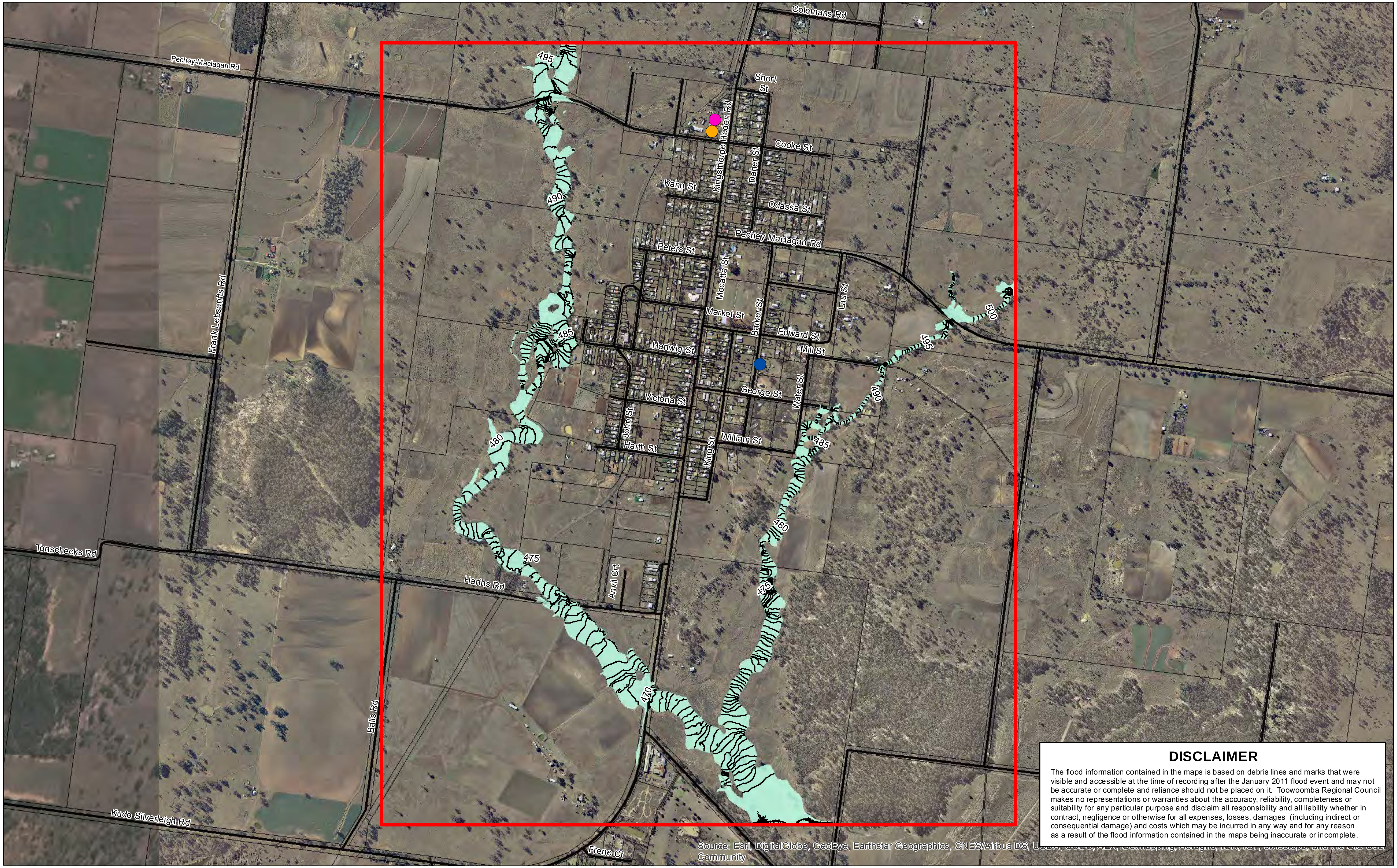
- 0.005 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- 4.5 to 5.0
- >5.0

SP051 Flood Studies - Work Package 11

Goombungee - Riverine Flow

20 Year ARI Peak Flood Depth

J2810-04-Goombungee_Q5_Depth.mxd
Author/Date: blair.filer 18/08/2015



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TOOWOOMBA REGIONAL COUNCIL

1:15,000 (at A3)

0 115 230 460 Meters

GDA 1994 MGA Zone 56

N

Legend

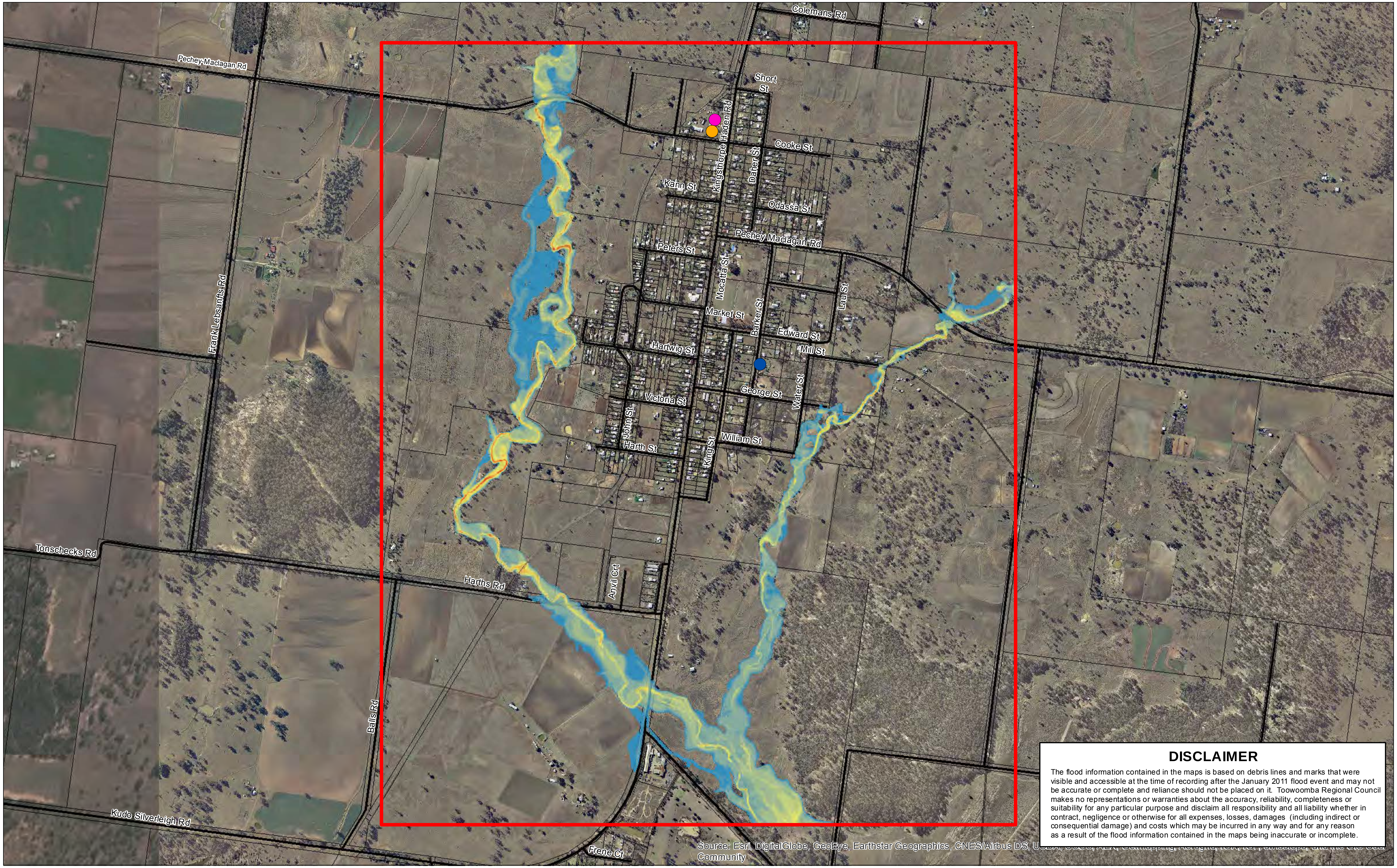
- MIKE Flood Model Domain
- Cadastre
- Major Road
- Police Station
- Rural Fire Brigade
- SES

Flood Extent

- 0.2m contours (mAHD)
- 20yr ARI

SP051 Flood Studies - Work Package 11
Goombungee - Riverine Flow
20 Year ARI Peak Water Surface Level Map

J2810-04-Goombungee_Q5_WL.mxd
Author/Date: blairfiler 18/08/2015



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TOOWOOMBA REGIONAL COUNCIL

1:15,000 (at A3)

0 115 230 460
Meters

GDA 1994 MGA Zone 56

N

Legend

- MIKE Flood Model Domain
- Major Road
- Cadastre
- Police Station
- Rural Fire Brigade
- SES

Flood Depth

Depth Band (m)

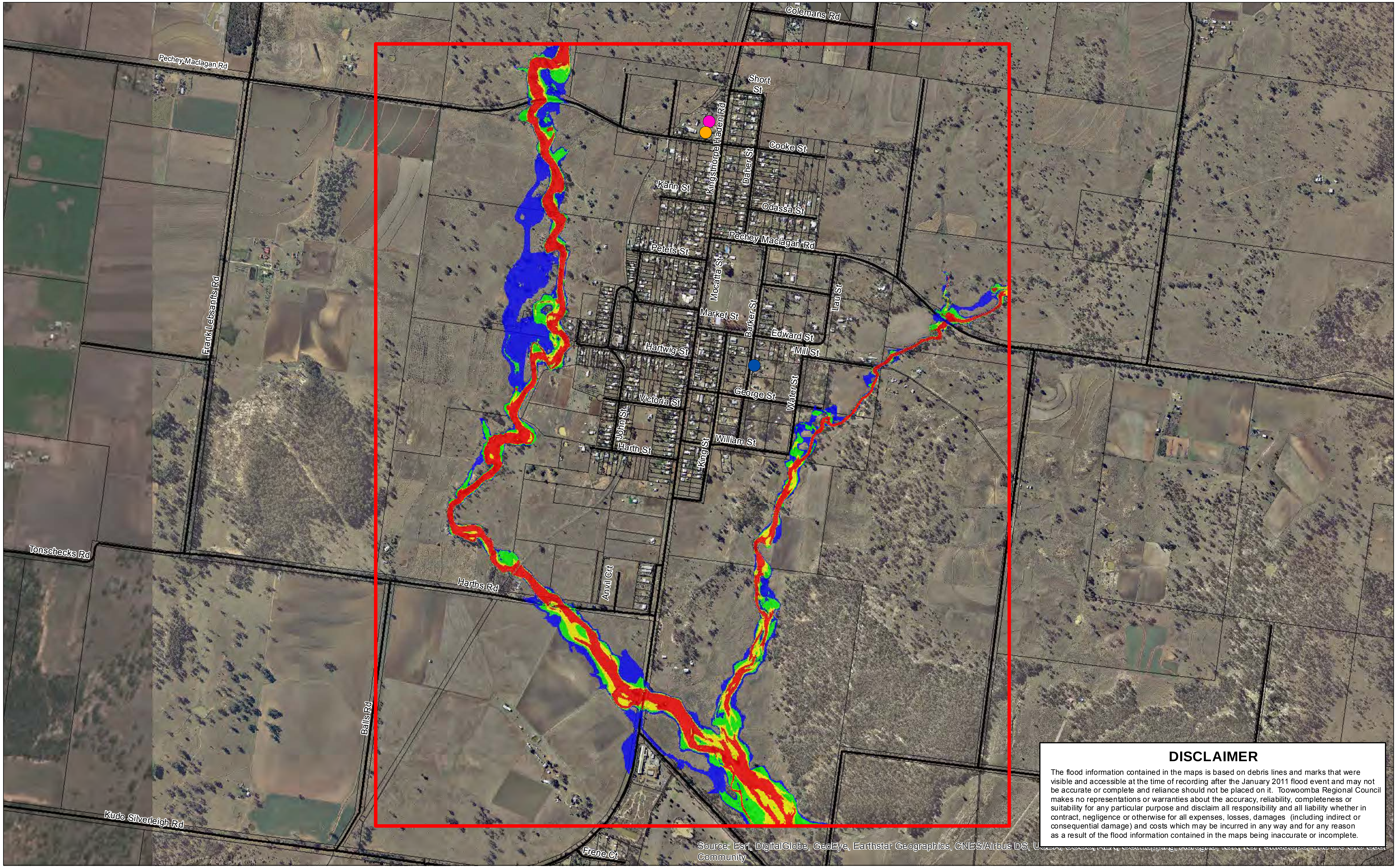
- 0.005 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- 4.5 to 5.0
- >5.0

SP051 Flood Studies - Work Package 11

Goombungee - Riverine Flow

100 Year ARI Peak Flood Depth

J2810-04-Goombungee_Q5_Depth.mxd
Author/Date: blair.filer 18/08/2015



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Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

TOOWOOMBA REGIONAL COUNCIL

1:15,000 (at A3)

0 115 230 460
Meters

GDA 1994 MGA Zone 56

N

Legend

- MIKE Flood Model Domain
- Major Road
- Cadastre
- Police Station
- Rural Fire Brigade
- SES

Hazard Category

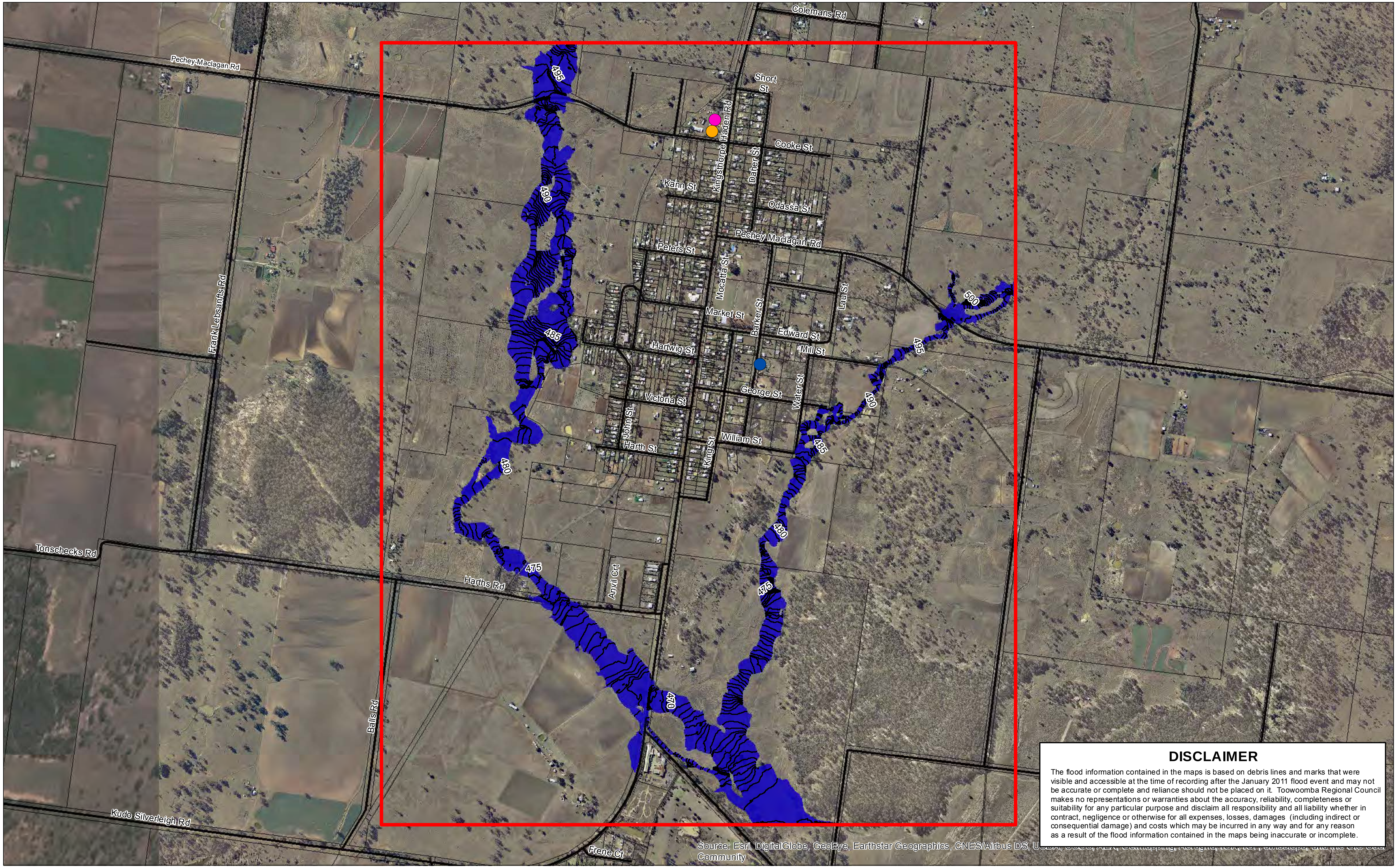
- Low
- Significant
- High
- Extreme

SP051 Flood Studies - Work Package 11

Goombungee - Riverine Flow

100 Year ARI Hazard Map

J2810-04-Goombungee_HAZ.mxd
Author/Date: blair.filer 04/11/2015



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TOOWOOMBA REGIONAL COUNCIL

1:15,000 (at A3)

0 115 230 460
Meters

GDA 1994 MGA Zone 56

N

Legend

- MIKE Flood Model Domain
- Cadastre
- Major Road
- Police Station
- Rural Fire Brigade
- SES

Flood Extent

- 0.2m contours (mAHD)
- 100yr ARI

SP051 Flood Studies - Work Package 11
Goombungee - Riverine Flow
100 Year ARI Peak Water Surface Level Map

J2810-04-Goombungee_Q5_WL.mxd
Author/Date: blair.filer 18/08/2015

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TOOWOOMBA REGIONAL COUNCIL

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

GDA 1994 MGA Zone 56

Legend

- TUFLOW Model Domain
- Major Road
- Cadastre
- Riverine Flow Path
- Police Station
- Rural Fire Brigade
- SES

0 75 150 300 450 Metres

1:10,000 (at A3)

Flood Depth

Depth Band (m)

- 0.075 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- 4.5 to 5.0
- >5.0

N

SP051 Flood Studies
Work Package 11

Goombungee - Overland Flow
5 Year ARI Peak Flood Depth

DISCLAIMER

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TOOWOOMBA REGIONAL COUNCIL

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

GDA 1994 MGA Zone 56

Legend

- TUFLOW Model Domain
- Major Road
- Cadastre
- Riverine Flow Path
- Police Station
- Rural Fire Brigade
- SES

0 75 150 300 450 Metres

1:10,000 (at A3)

Flood Depth

Depth Band (m)

- 0.075 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- 4.5 to 5.0
- >5.0

N

SP051 Flood Studies
Work Package 11

Goombungee - Overland Flow
20 Year ARI Peak Flood Depth

DISCLAIMER

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TOOWOOMBA REGIONAL COUNCIL

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

GDA 1994 MGA Zone 56

Legend

- TUFLOW Model Domain
- Major Road
- Cadastre
- Riverine Flow Path
- Police Station
- Rural Fire Brigade
- SES

0 75 150 300 450 Metres

1:10,000 (at A3)

Flood Depth

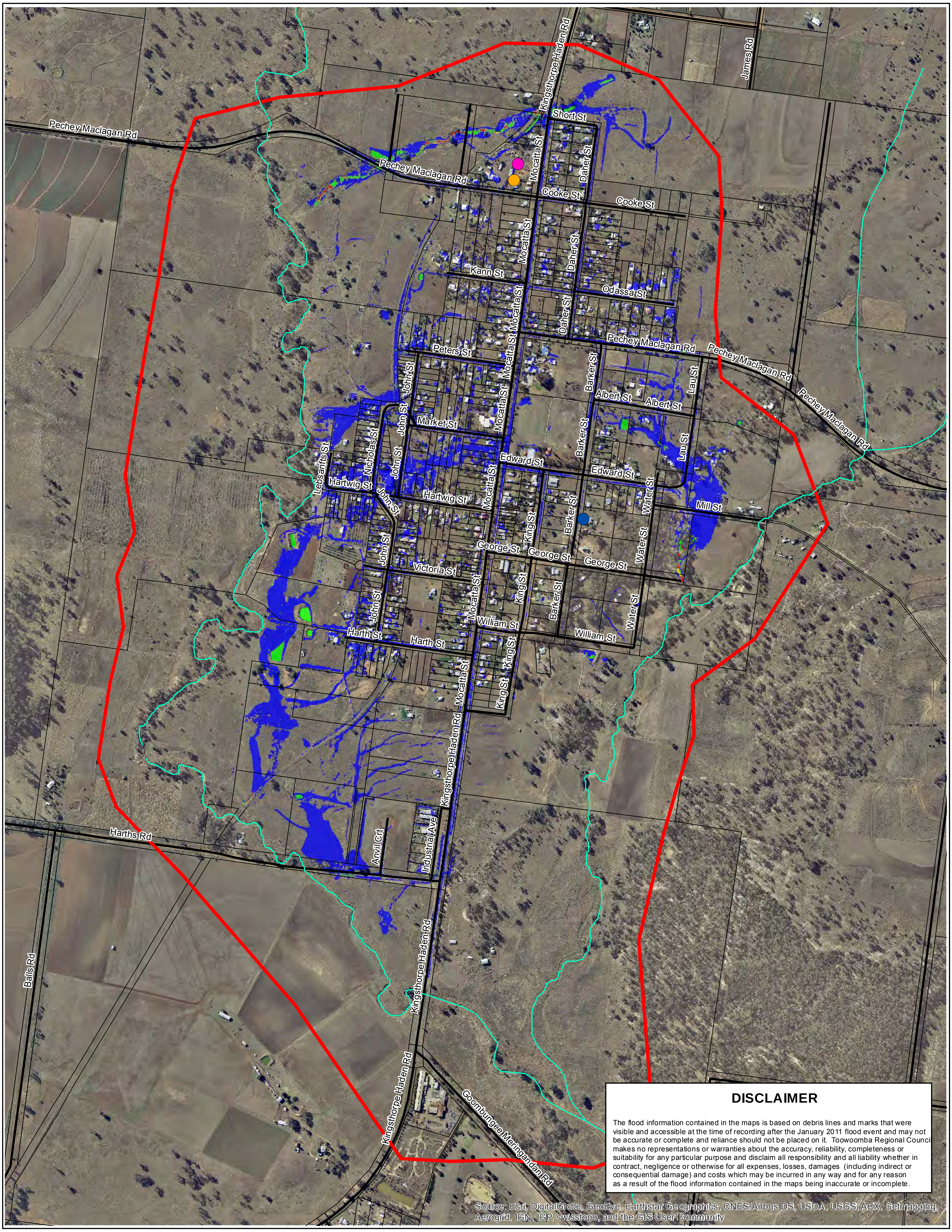
Depth Band (m)

- 0.075 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- 4.5 to 5.0
- >5.0

N

SP051 Flood Studies
Work Package 11

Goombungee - Overland Flow
100 Year ARI Peak Flood Depth



DISCLAIMER

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TOOWOOMBA REGIONAL COUNCIL

WATER TECHNOLOGY
WATER, COASTAL & ENVIRONMENTAL CONSULTANTS

GDA 1994 MGA Zone 56

Legend

- TUFLOW Model Domain
- Major Road
- Cadastre
- Riverine Flow Path
- Police Station
- Rural Fire Brigade
- SES

0 75 150 300 450 Metres

1:10,000 (at A3)

Hazard Category

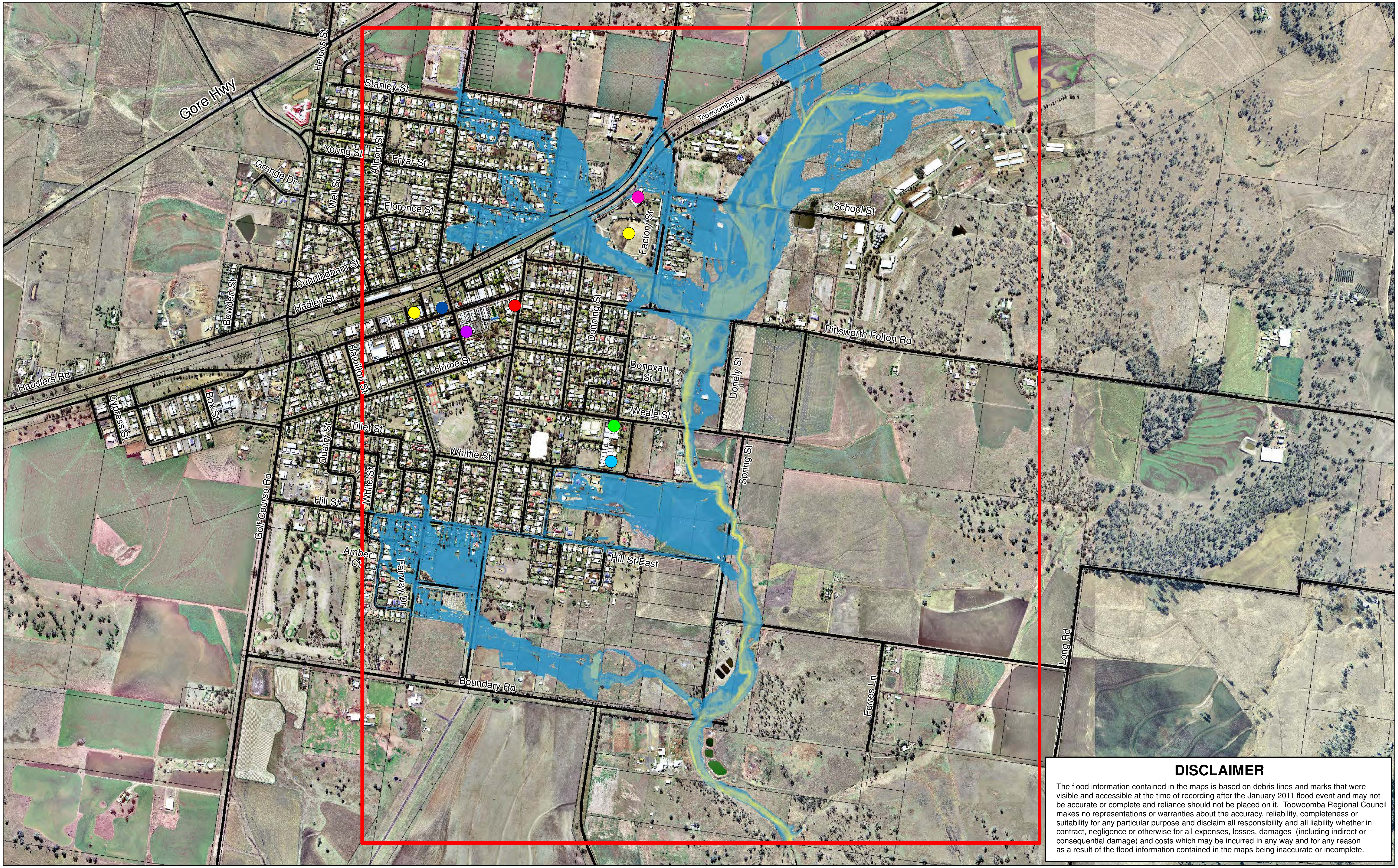
- Low
- Significant
- High
- Extreme

N

SP051 Flood Studies
Work Package 11

Goombungee - Overland Flow
100 Year ARI Hazard Map

APPENDIX E PITTSWORTH DESIGN EVENT MAPS



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TOOWOOMBA REGIONAL COUNCIL

1:14,000 (at A3)

0 105 210 420 Meters

GDA 1994 MGA Zone 56

N

Legend

- MIKE Flood Model Domain
- QLD Rail Network
- Major Road
- Cadastre
- Ambulance
- Evacuation Centre
- Fire Station
- Hospital
- Nursing Homes
- Police Station
- SES

Flood Depth

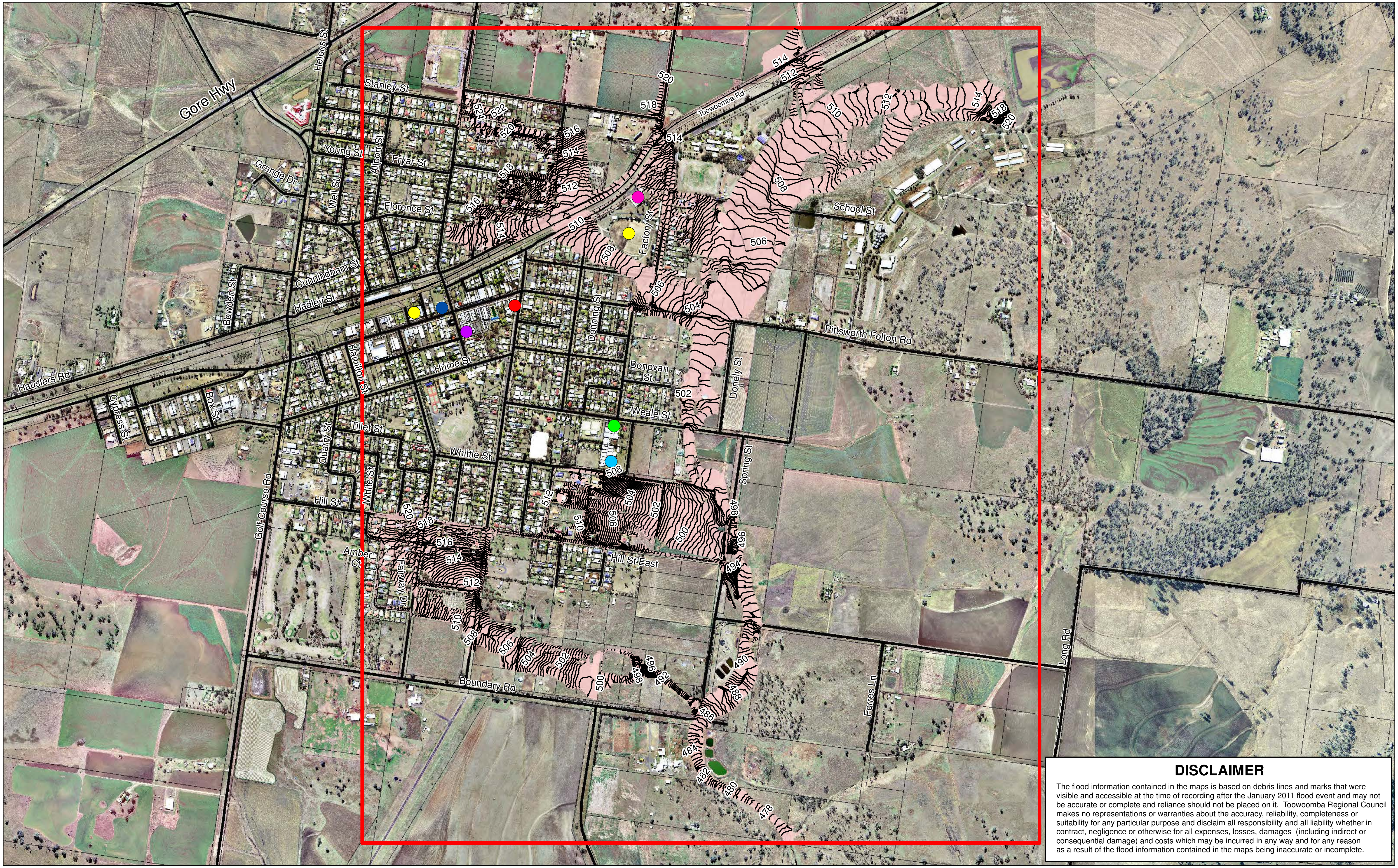
Depth Band (m)

- 0.005 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- 4.5 to 5.0
- >5.0

SP051 Flood Studies - Work Package 11

Pittsworth East 5 Year ARI Peak Flood Depth

J2810-04-Pittsworth_East_Q5_Depth.mxd
Author/Date: Ryan.dermek 18/03/2014



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TOOWOOMBA REGIONAL COUNCIL

1:14,000 (at A3)

0 105 210 420
Meters

GDA 1994 MGA Zone 56

N

Legend

- MIKE Flood Model Domain
- QLD Rail Network
- Major Road
- Cadastre
- Ambulance
- Evacuation Centre
- Fire Station
- Hospital
- Nursing Homes
- Police Station
- SES

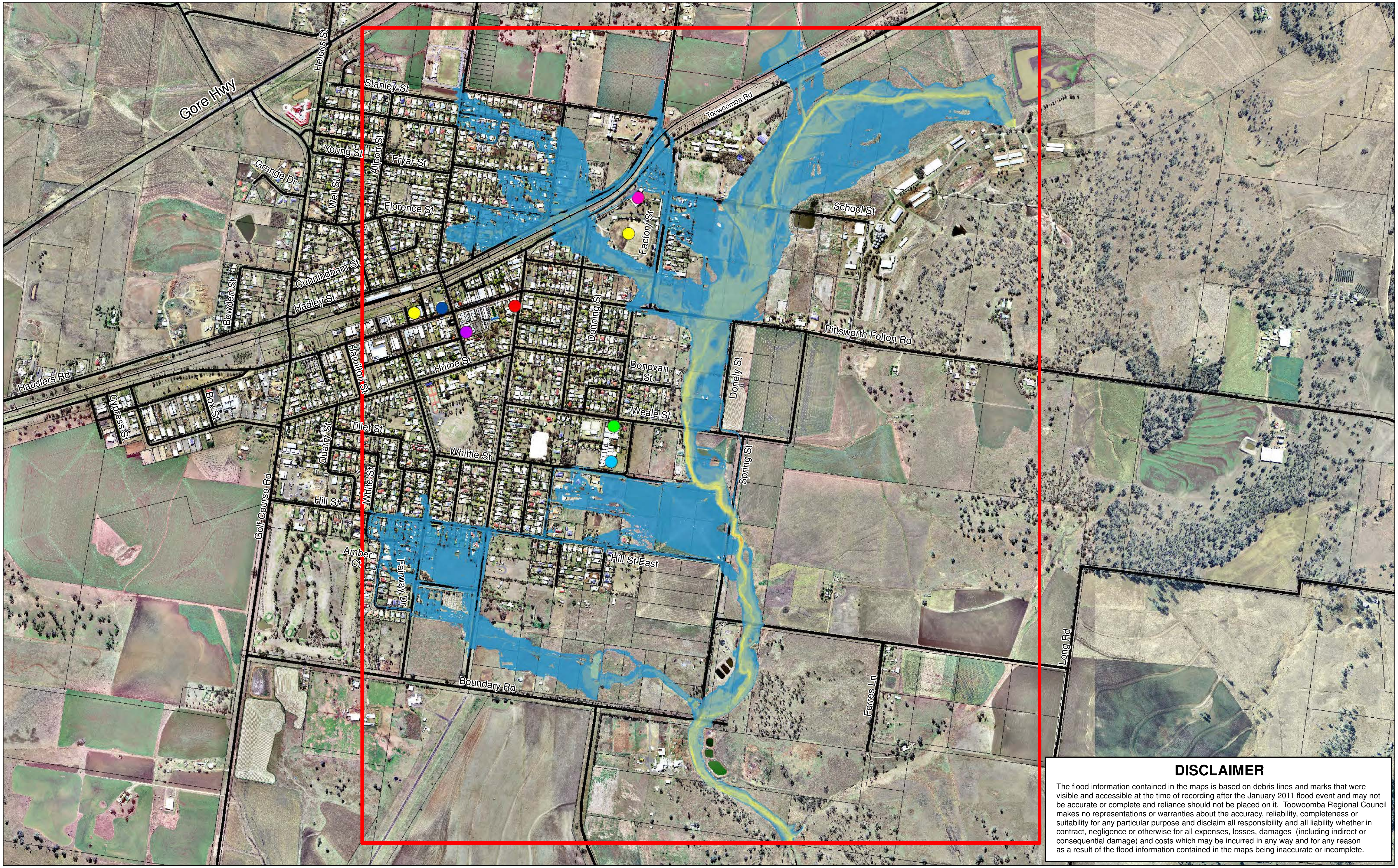
Inundation Extent

- 0.2m Contours (mAHD)
- 5yr ARI

SP051 Flood Studies - Work Package 11

Pittsworth East 5 Year ARI Peak Water Surface Level

J2810-04-Pittsworth_East_Q5_WL.mxd
Author/Date: Ryan.dermek 18/03/2014



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TOOWOOMBA REGIONAL COUNCIL

1:14,000 (at A3)

0 105 210 420

Meters

GDA 1994 MGA Zone 56

N

Legend

- MIKE Flood Model Domain
- QLD Rail Network
- Cadastre
- Major Road
- Ambulance
- Evacuation Centre
- Fire Station
- Nursing Homes
- Police Station
- Hospital
- SES

Flood Depth

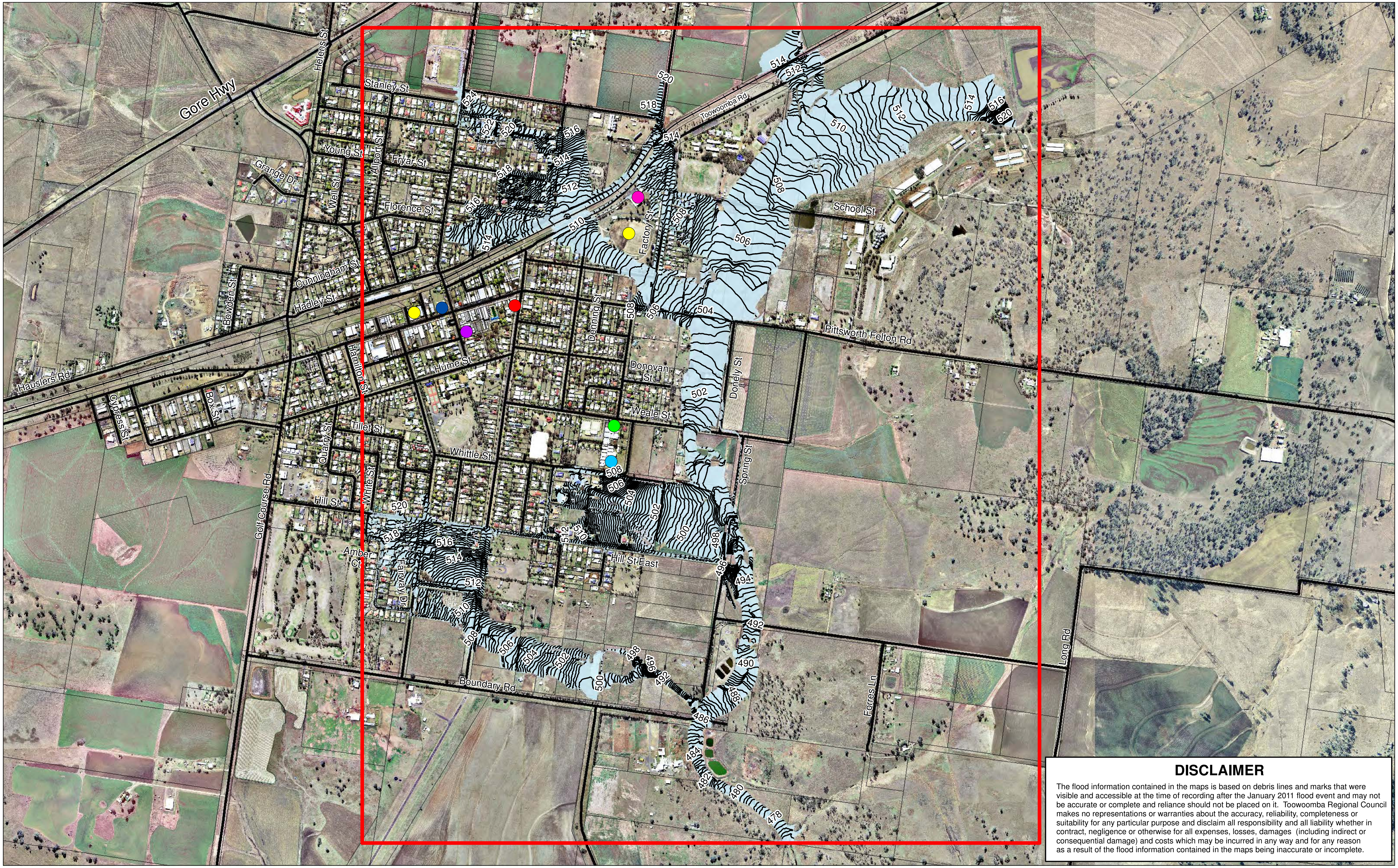
Depth Band (m)

- 0.005 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- 4.5 to 5.0
- >5.0

SP051 Flood Studies - Work Package 11

Pittsworth East 20 Year ARI Peak Flood Depth

J2810-04-Pittsworth_East_Q20_Depth.mxd
Author/Date: Ryan.dermek 18/03/2014



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TOOWOOMBA REGIONAL COUNCIL

1:14,000 (at A3)

0 105 210 420
Meters

GDA 1994 MGA Zone 56

N

Legend

- MIKE Flood Model Domain
- QLD Rail Network
- Major Road
- Cadastre
- Ambulance
- Evacuation Centre
- Fire Station
- Hospital
- Nursing Homes
- Police Station
- SES

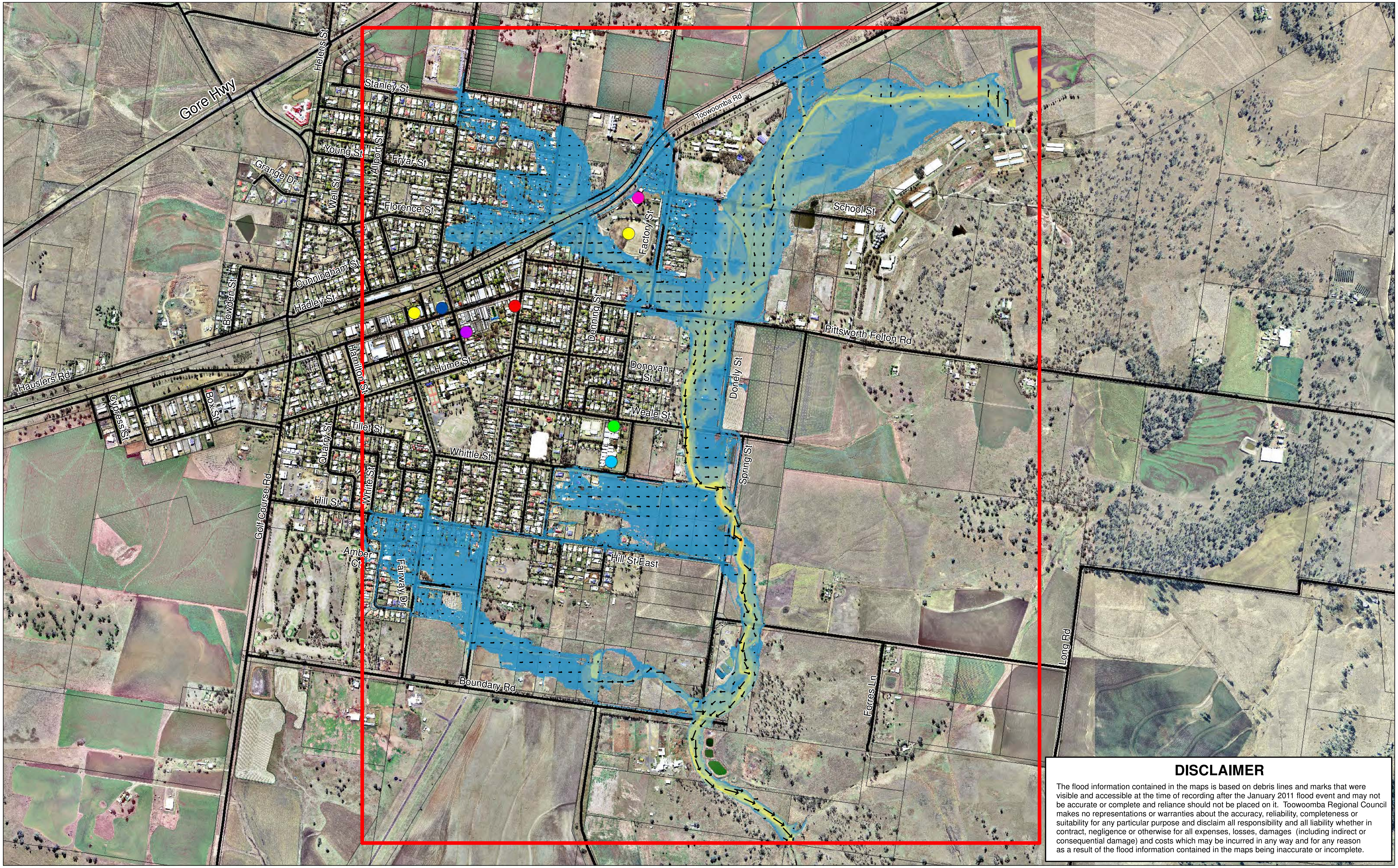
Inundation Extent

- 0.2m Contours (mAHD)
- 20yr ARI

SP051 Flood Studies - Work Package 11

Pittsworth East 20 Year ARI Peak Water Surface Level

J2810-04-Pittsworth_East_Q20_WL.mxd
Author/Date: Ryan.dermek 18/03/2014



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TOOWOOMBA REGIONAL COUNCIL

1:14,000 (at A3)

0 105 210 420
Meters

GDA 1994 MGA Zone 56

N

Legend

- MIKE Flood Model Domain
- QLD Rail Network
- Major Road
- Cadastre
- Ambulance
- Evacuation Centre
- Fire Station
- Hospital
- Nursing Homes
- Police Station
- SES

Flood Depth

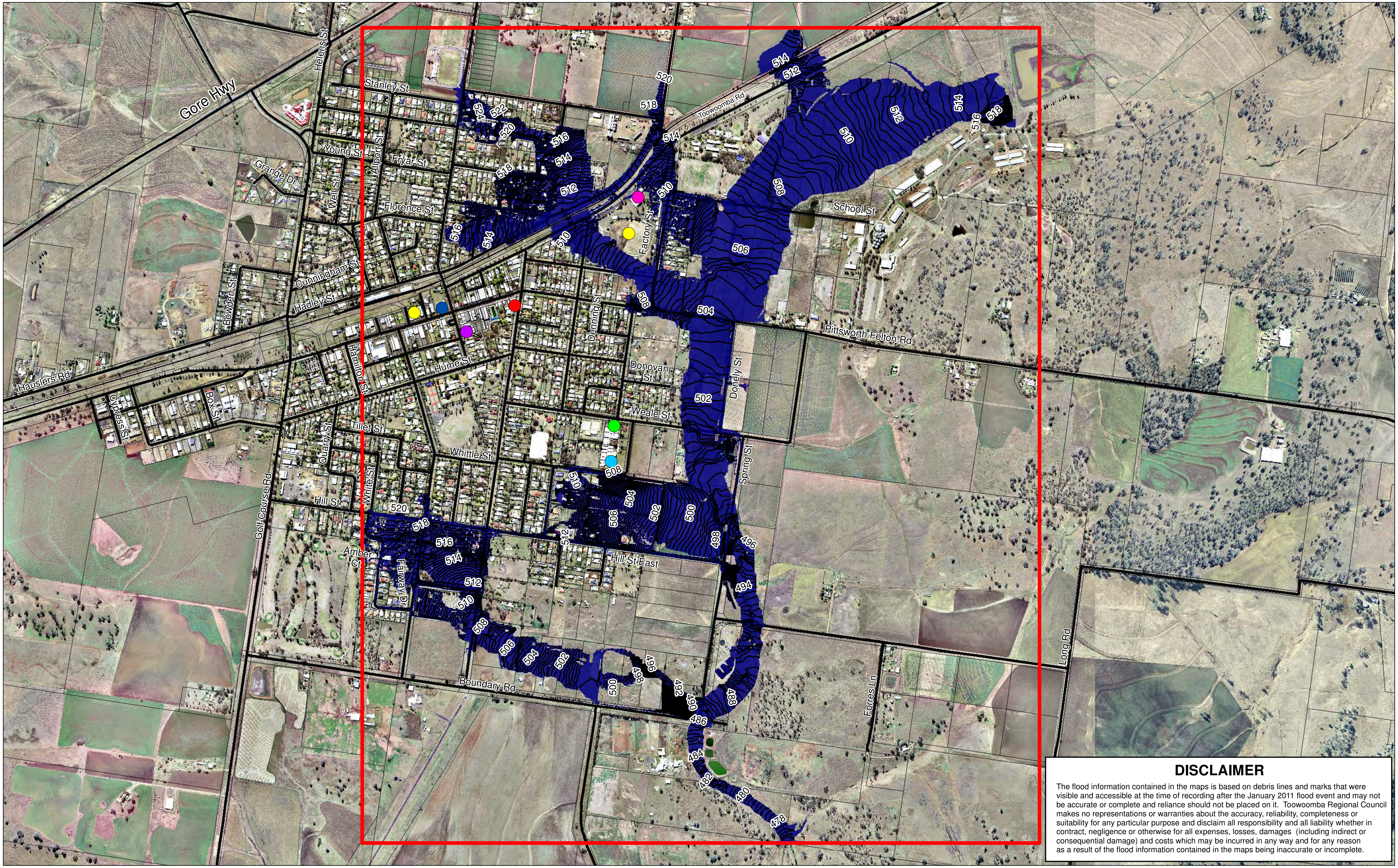
Depth Band (m)

- 0.005 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- 4.5 to 5.0
- >5.0
- Scaled Velocity Vector (1 m/s)

SP051 Flood Studies - Work Package 11

Pittsworth East 100 Year ARI Peak Flood Depth

J2810-04-Pittsworth_East_Q100_Depth.mxd
Author/Date: Ryan.dermek 18/03/2014



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TOOWOOMBA REGIONAL COUNCIL

1:14,000 (at A3)

0 105 210 420
Meters

GDA 1994 MGA Zone 56

N

Legend

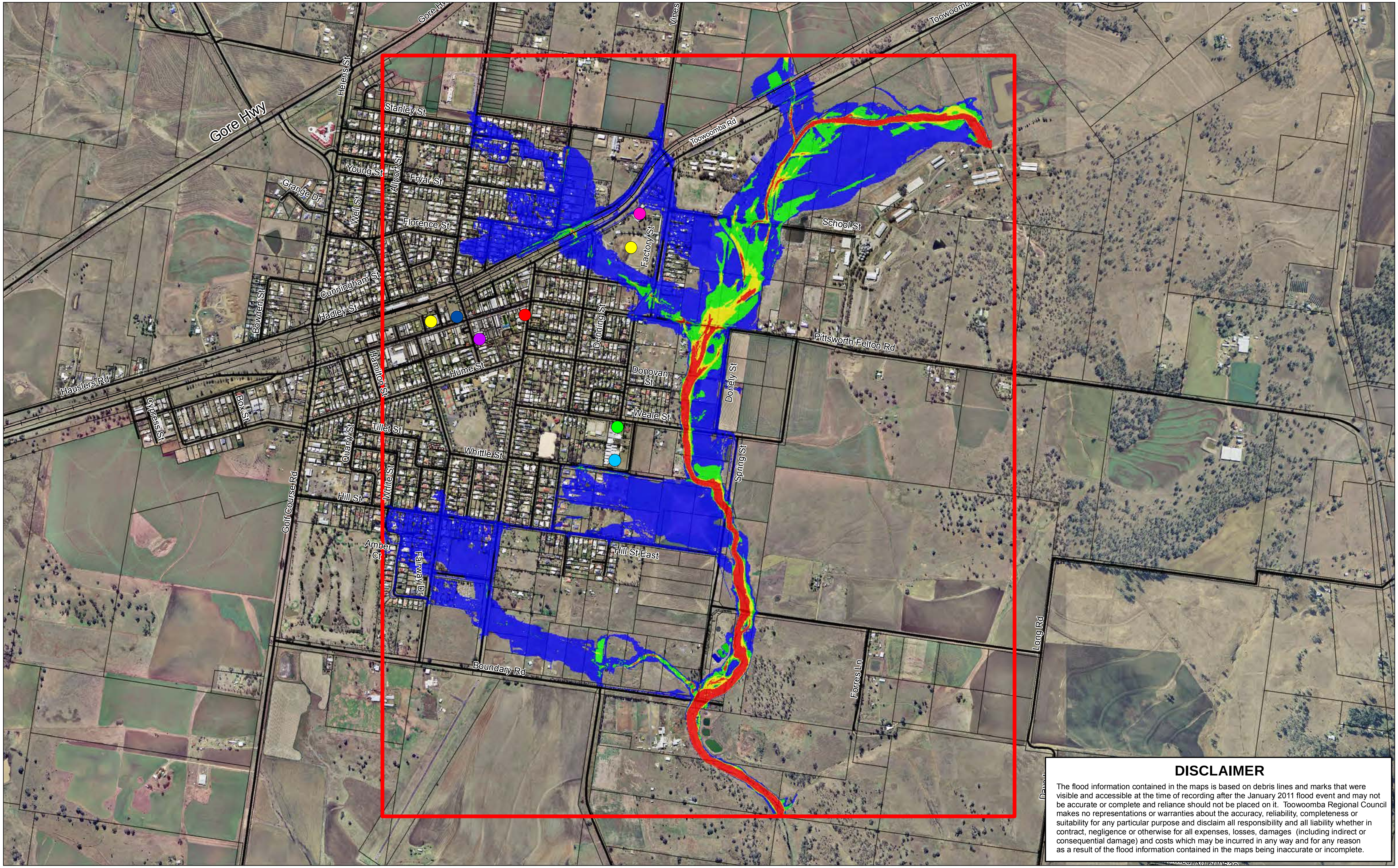
- MIKE Flood Model Domain
- QLD Rail Network
- Major Road
- Cadastre
- Ambulance
- Evacuation Centre
- Fire Station
- Hospital
- Nursing Homes
- Police Station
- SES

Inundation Extent

- 0.2m Contours (mAHD)
- 100yr ARI

SP051 Flood Studies - Work Package 11
Pittsworth East 100 Year ARI Peak Water Surface Level

J2810-04-Pittsworth_East_Q100_WL.mxd
Author/Date: Ryan.dermek 18/03/2014



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TOOWOOMBA REGIONAL COUNCIL

1:15,000 (at A3)

0 115 230 460 Meters

GDA 1994 MGA Zone 56

N

Legend

- MIKE Flood Model Domain
- QLD Rail Network
- Major Road
- Cadastre
- Ambulance
- Evacuation Centre
- Fire Station
- Hospital
- Nursing Homes
- Police Station
- SES

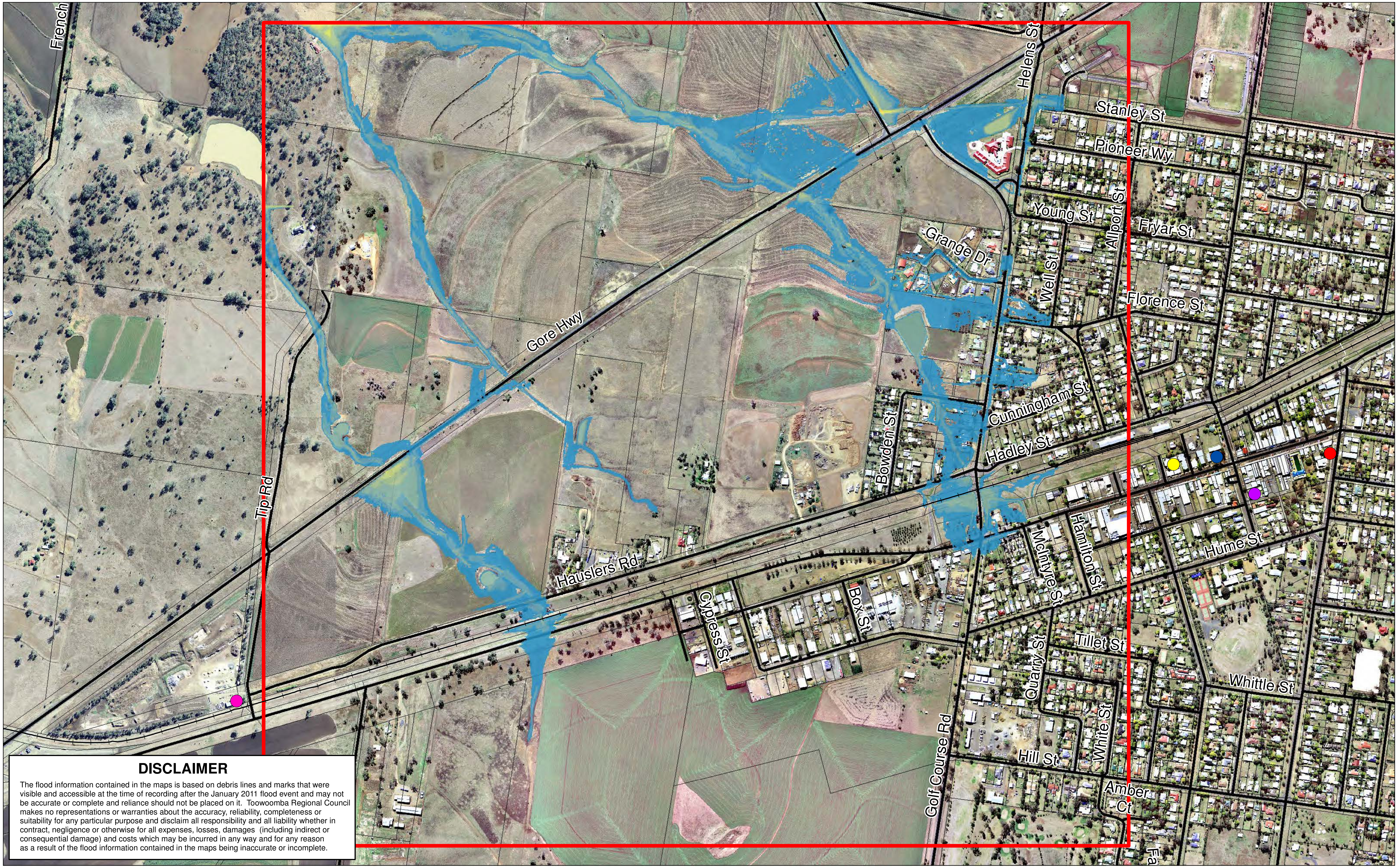
Hazard Category

- Low
- Significant
- High
- Extreme

SP051 Flood Studies - Work Package 11

Pittsworth East 100 Year ARI Flood Hazard

J2810-04-Pittsworth_East_HAZ.mxd
Author/Date: blair.filer 8/09/2014



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TOOWOOMBA REGIONAL COUNCIL

1:9,000 (at A3)

0 65 130 260 Meters

GDA 1994 MGA Zone 56

N

Legend

- QLD Rail Network
- Cadastre
- MIKE Flood Model Domain
- Major Road
- Evacuation Centre
- Police Station
- Rural Fire Brigade
- Fire Station
- Ambulance

Flood Depth

Depth Band (m)

0.005 to 0.25	1.0 to 1.5	3.0 to 3.5	>5.0
0.25 to 0.5	1.5 to 2.0	3.5 to 4.0	
0.5 to 1.0	2.0 to 2.5	4.0 to 4.5	
	2.5 to 3.0	4.5 to 5.0	

SP051 Flood Studies - Work Package 11

Pittsworth West 5 Year ARI Peak Flood Depth

J2810-04-Pittsworth_West_Q5_Depth.mxd
Author/Date: Ryan.dermek 18/03/2014

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TOOWOOMBA REGIONAL COUNCIL

1:9,000 (at A3)

0 65 130 260 Meters

GDA 1994 MGA Zone 56

N

Legend

- MIKE Flood Model Domain
- Cadastre
- QLD Rail Network
- Major Road
- Ambulance
- Evacuation Centre
- Fire Station
- Police Station
- Rural Fire Brigade

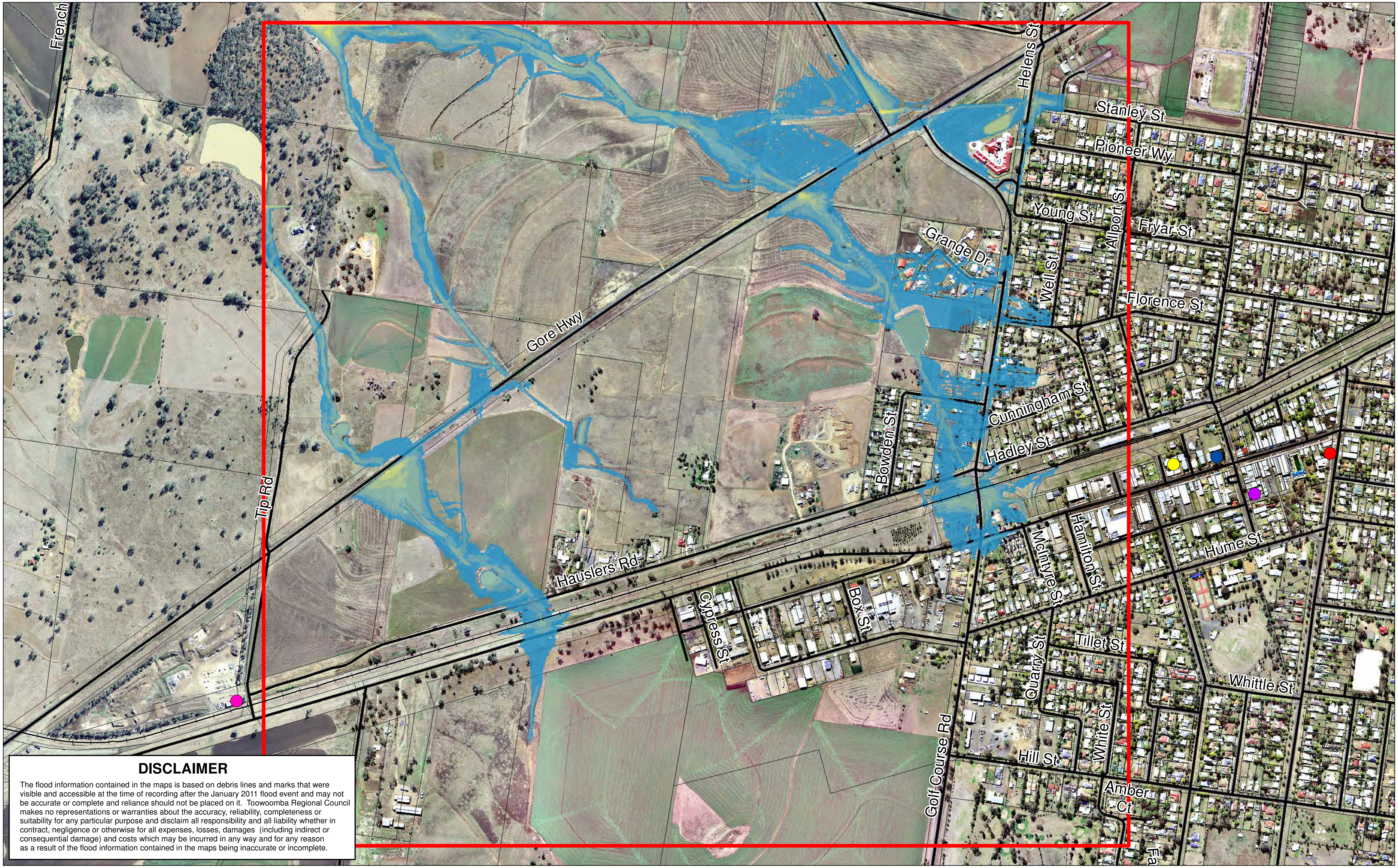
Inundation Extent

- 5yr ARI
- 0.2m contours (mAHD)

SP051 Flood Studies - Work Package 11

Pittsworth West 5 Year ARI Peak Water Surface Level

J2810-04-Pittsworth_West_Q5_WL.mxd
Author/Date: Ryan.dermek 18/03/2014



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TOOWOOMBA REGIONAL COUNCIL

1:9,000 (at A3)

0 65 130 260 Meters

GDA 1994 MGA Zone 56

N

Legend

- QLD Rail Network
- Cadastre
- MIKE Flood Model Domain
- Major Road
- Evacuation Centre
- Police Station
- Rural Fire Brigade
- Fire Station
- Ambulance

Flood Depth

Depth Band (m)

- 0.005 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- 4.5 to 5.0
- >5.0

SP051 Flood Studies - Work Package 11
Pittsworth West 20 Year ARI Peak Flood Depth

J2810-04-Pittsworth_West_Q20_Depth.mxd
Author/Date: Ryan.dermek 18/03/2014

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TOOWOOMBA REGIONAL COUNCIL

1:9,000 (at A3)

0 65 130 260 Meters

GDA 1994 MGA Zone 56

N

Legend

- MIKE Flood Model Domain
- Cadastre
- QLD Rail Network
- Major Road
- Ambulance
- Evacuation Centre
- Fire Station
- Police Station
- Rural Fire Brigade

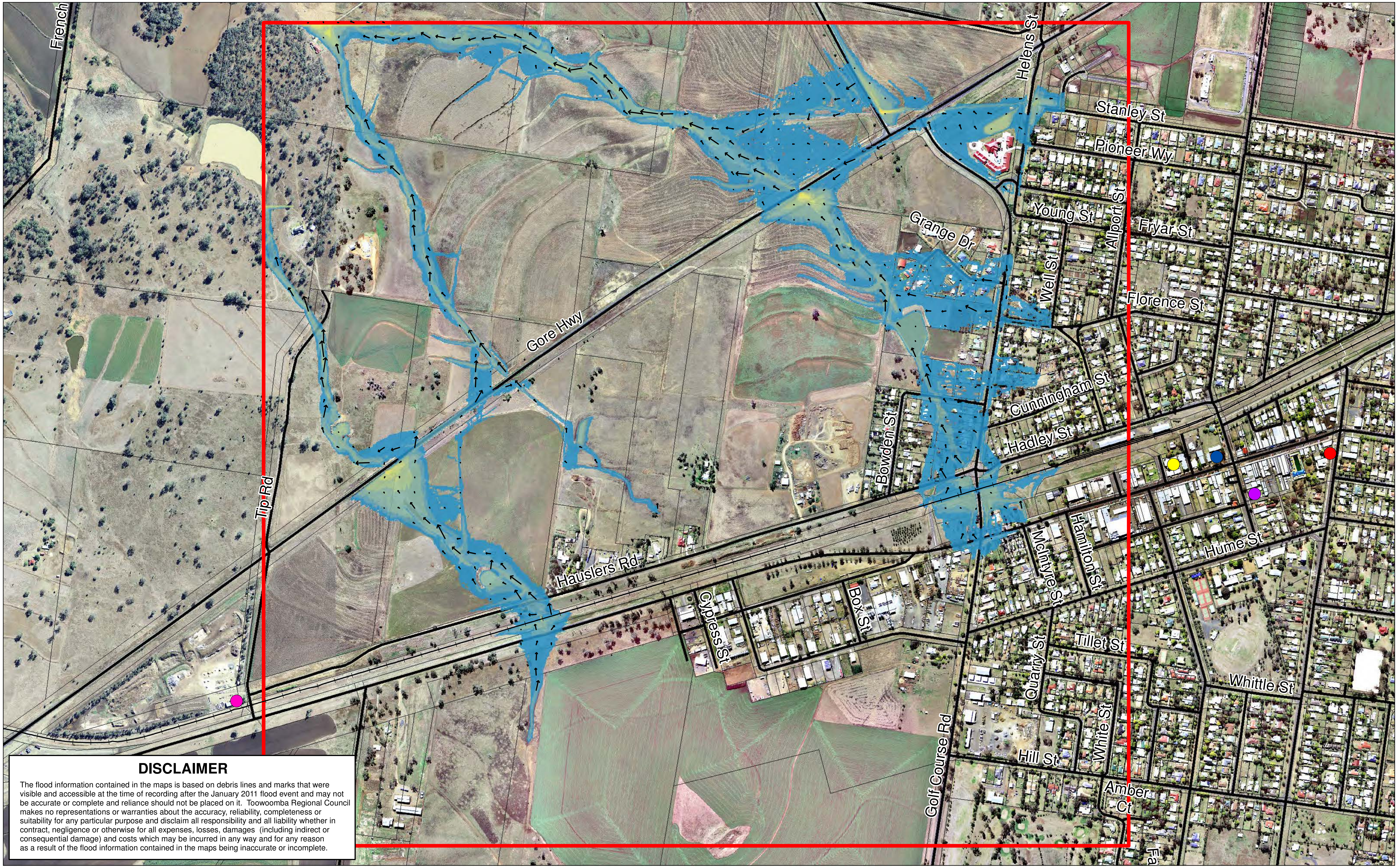
Inundation Extent

- 20yr ARI
- 0.2m contours (mAHD)

SP051 Flood Studies - Work Package 11

Pittsworth West 20 Year ARI Peak Water Surface Level

J2810-04-Pittsworth_West_Q20_WL.mxd
Author/Date: Ryan.dermek 18/03/2014



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TOOWOOMBA REGIONAL COUNCIL

1:9,000 (at A3)

0 65 130 260
Meters

GDA 1994 MGA Zone 56

N

Legend

- QLD Rail Network
- Cadastre
- MIKE Flood Model Domain
- Major Road
- Ambulance
- Evacuation Centre
- Fire Station
- Police Station
- Rural Fire Brigade

Flood Depth

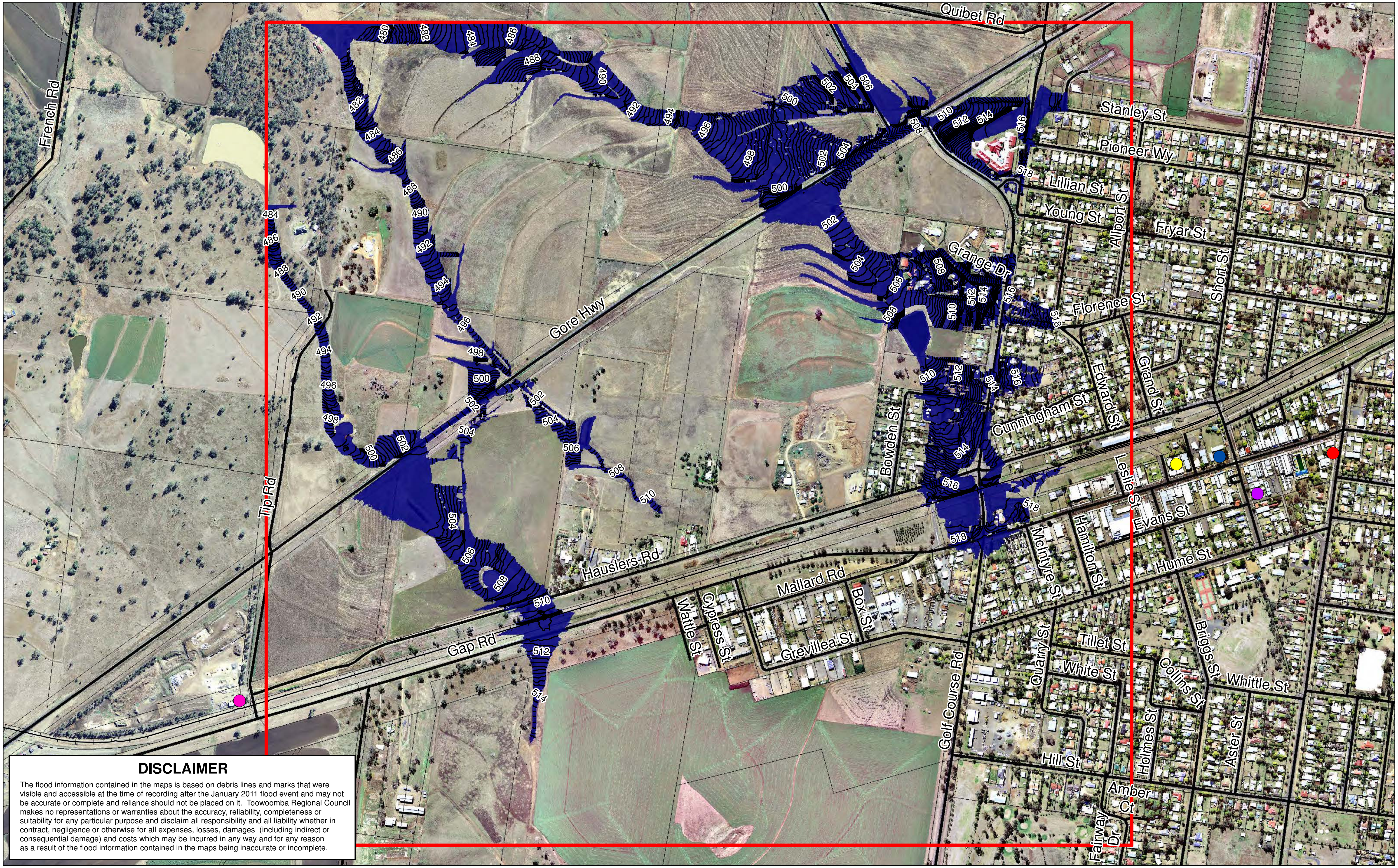
Depth Band (m)

- 0.005 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- 4.5 to 5.0
- >5.0
- → Scaled Velocity Vector (1 m/s)

SP051 Flood Studies - Work Package 11

Pittsworth West 100 Year ARI Peak Flood Depth

J2810-04-Pittsworth_West_Q100_Depth.mxd
Author/Date: Ryan.dermek 18/03/2014



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TOOWOOMBA REGIONAL COUNCIL

1:9,000 (at A3)

0 65 130 260
Meters

GDA 1994 MGA Zone 56

N

Legend

- MIKE Flood Model Domain
- Cadastre
- QLD Rail Network
- Major Road
- Ambulance
- Evacuation Centre
- Fire Station
- Police Station
- Rural Fire Brigade

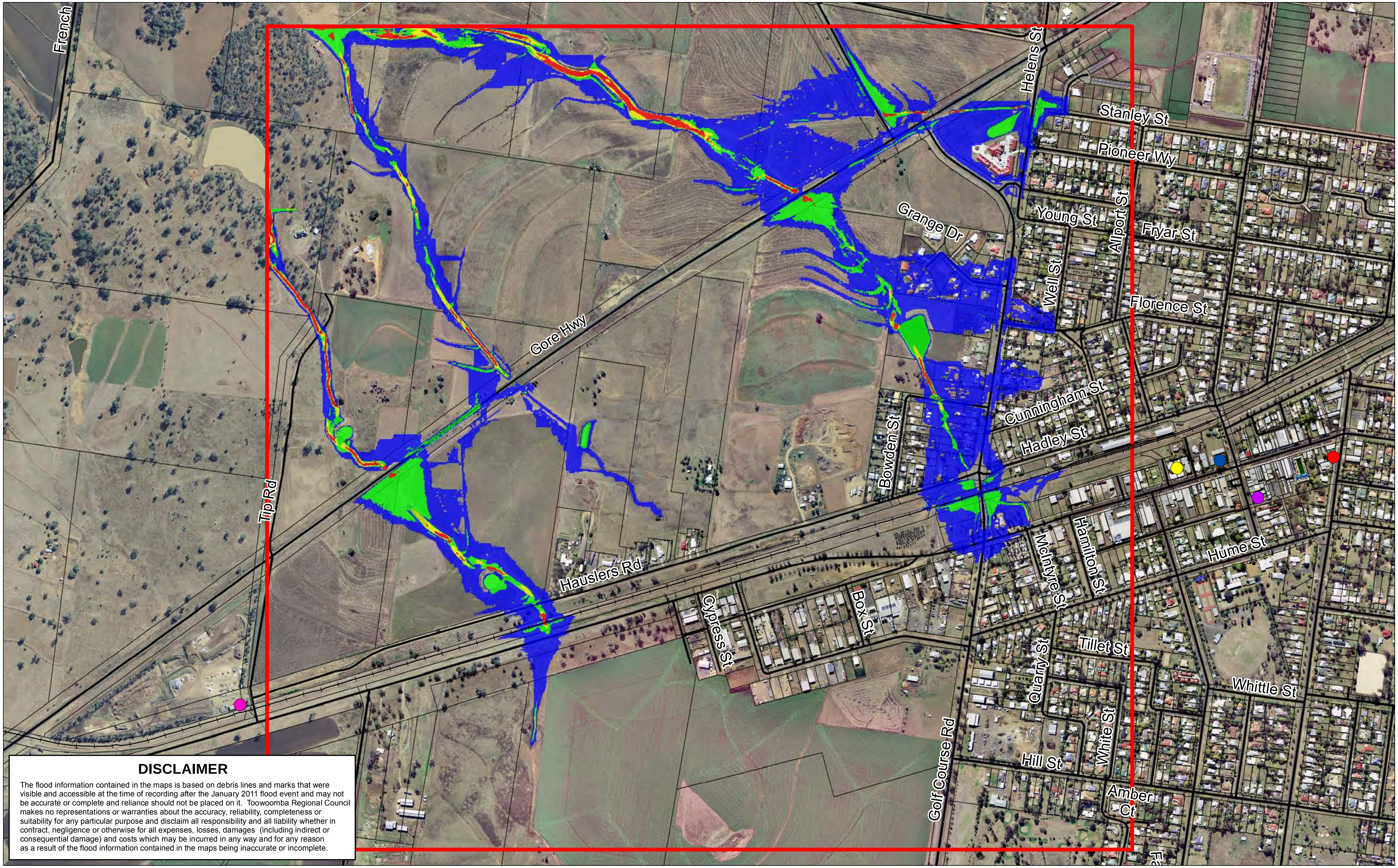
Inundation Extent

- 100yr ARI
- 0.2m contours (mAHD)

SP051 Flood Studies - Work Package 11

Pittsworth West 100 Year ARI Peak Water Surface Level

J2810-04-Pittsworth_West_Q100_WL.mxd
Author/Date: Ryan.dermek 18/03/2014



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TOOWOOMBA REGIONAL COUNCIL

1:9,000 (at A3)

0 65 130 260
Meters

GDA 1994 MGA Zone 56

N

Legend

- QLD Rail Network
- MIKE Flood Model Domain
- Major Road
- Cadastre
- Ambulance
- Evacuation Centre
- Fire Station
- Police Station
- Rural Fire Brigade

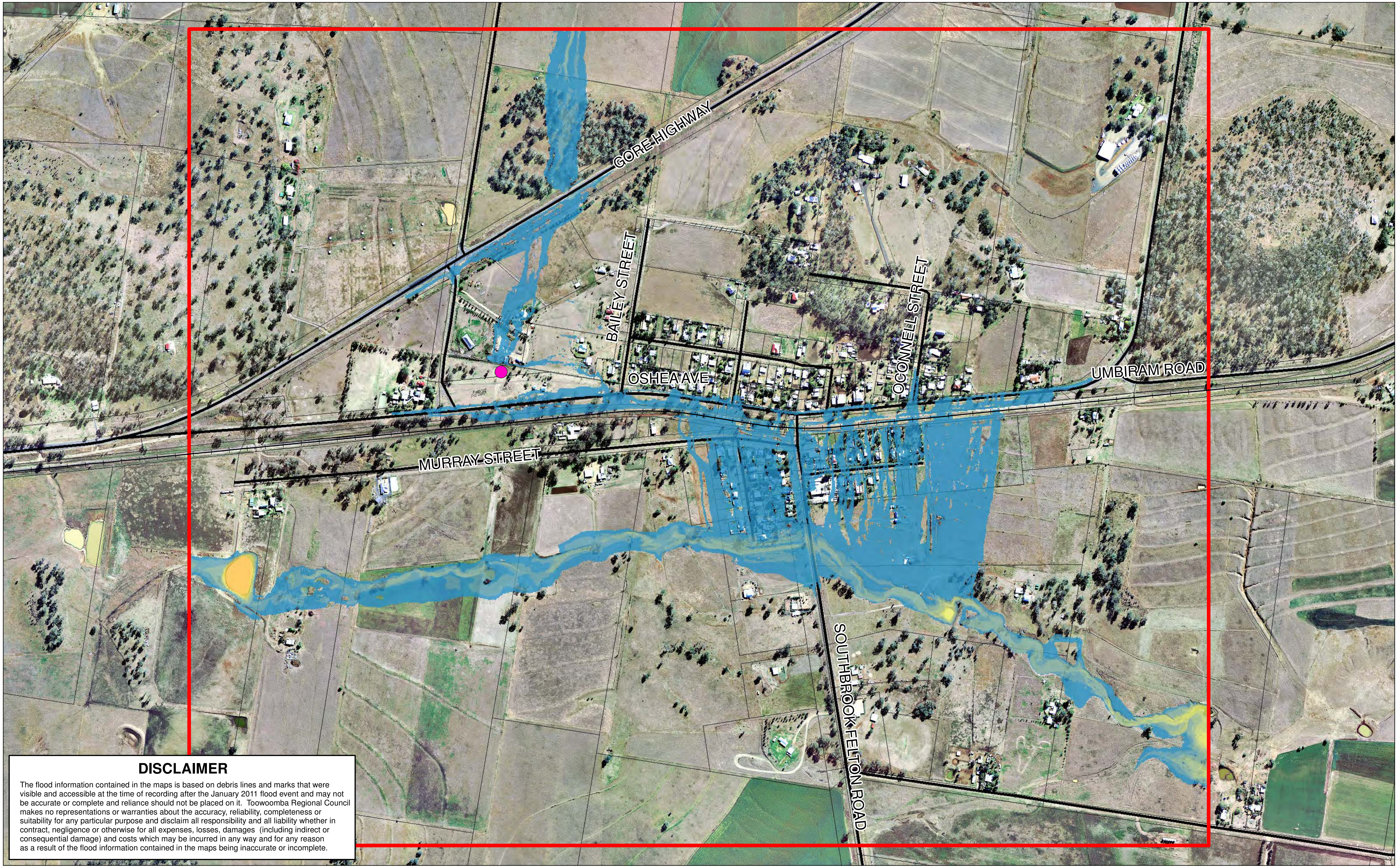
Hazard Category

- Low
- Significant
- High
- Extreme

SP051 Flood Studies - Work Package 11
Pittsworth West 100 Year ARI Flood Hazard

J2810-04-Pittsworth_West_HAZ.mxd
Author/Date: blair.filer 8/09/2014

APPENDIX F SOUTHBROOK DESIGN EVENT MAPS



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TOOWOOMBA REGIONAL COUNCIL

1:8,000 (at A3)

0 60 120 240
Meters

GDA 1994 MGA Zone 56

N

Legend

- QLD Rail Network
- MIKE Flood Model Domain
- Major Road
- Cadastre

Emergency Services

- Rural Fire Brigade

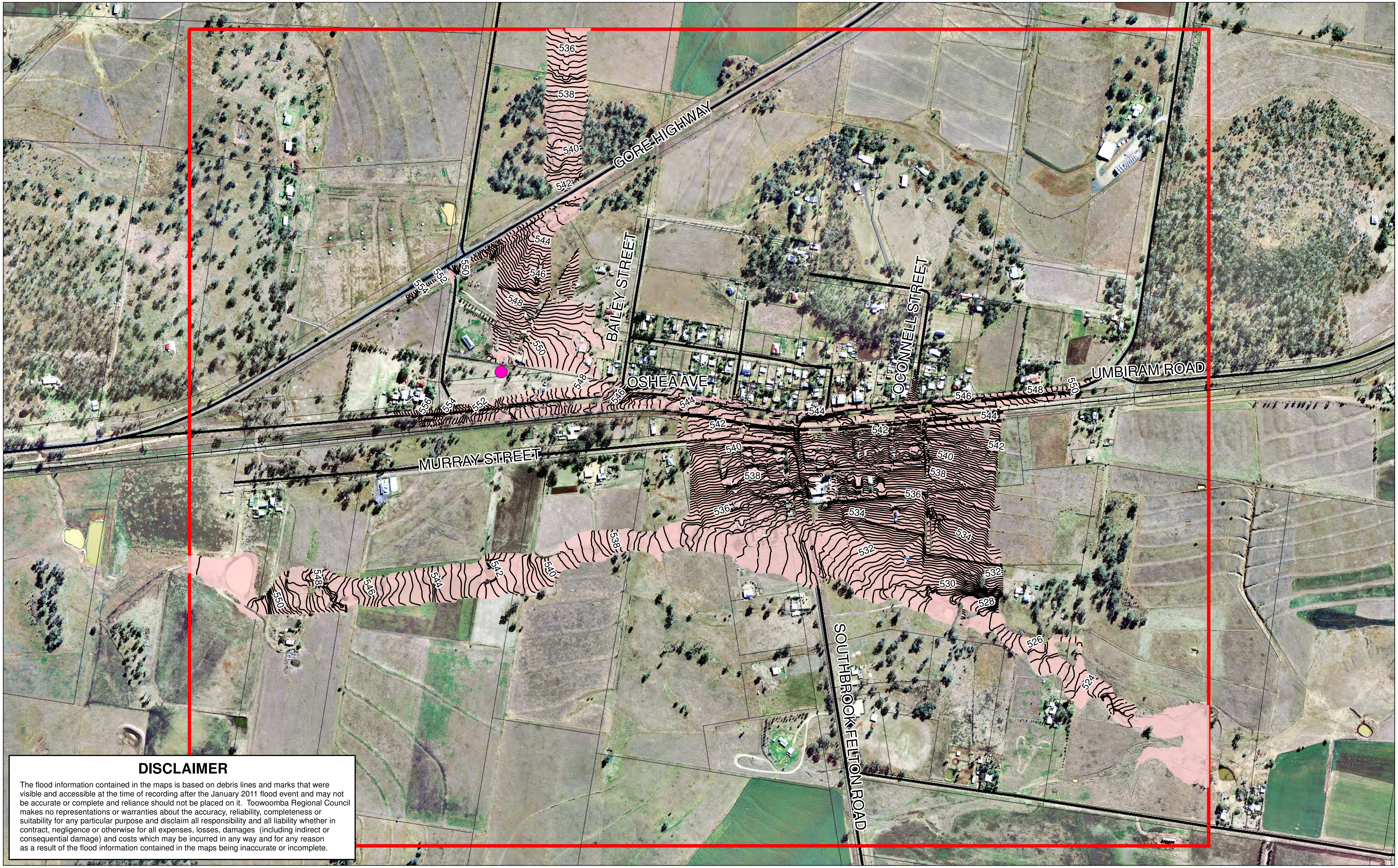
Flood Depth

Depth Band (m)

0.005 to 0.25	0.5 to 1.0	2.0 to 2.5	3.5 to 4.0	>5.0
0.25 to 0.5	1.0 to 1.5	2.5 to 3.0	4.0 to 4.5	
	1.5 to 2.0	3.0 to 3.5	4.5 to 5.0	

SP051 Flood Studies - Work Package 11
Southbrook 5 Year ARI Peak Flood Depth

J2810-04-Southbrook_Q5_Depth.mxd
Author/Date: Ryan.dermek 18/03/2014



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TOOWOOMBA REGIONAL COUNCIL

1:8,000 (at A3)

0 60 120 240
Meters

GDA 1994 MGA Zone 56

N

Legend

- QLD Rail Network
- Cadastre
- MIKE Flood Model Domain
- Major Road

Emergency Services

- Rural Fire Brigade

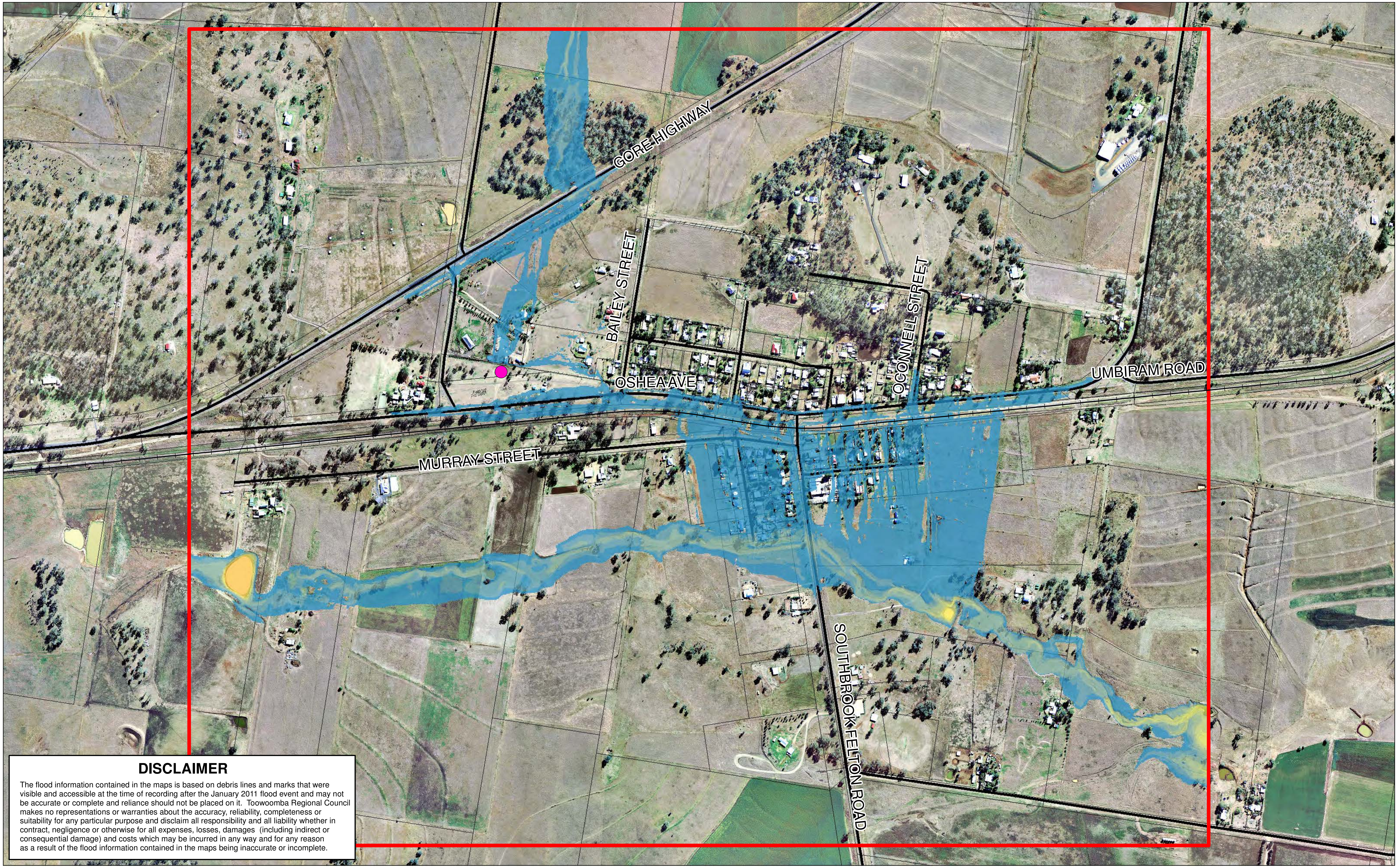
Inundation Extent

- 0.2m contours (mAHD)
- 5yr ARI

SP051 Flood Studies - Work Package 11

Southbrook 5 Year ARI Peak Water Surface Level

J2810-04-Southbrook_Q5_WL.mxd
Author/Date: Ryan.dermek 18/03/2014



DISCLAIMER

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TOOWOOMBA REGIONAL COUNCIL

1:8,000 (at A3)

0 60 120 240
Meters

GDA 1994 MGA Zone 56

N

Legend

- QLD Rail Network
- MIKE Flood Model Domain
- Major Road
- Cadastre

Emergency Services

- Rural Fire Brigade

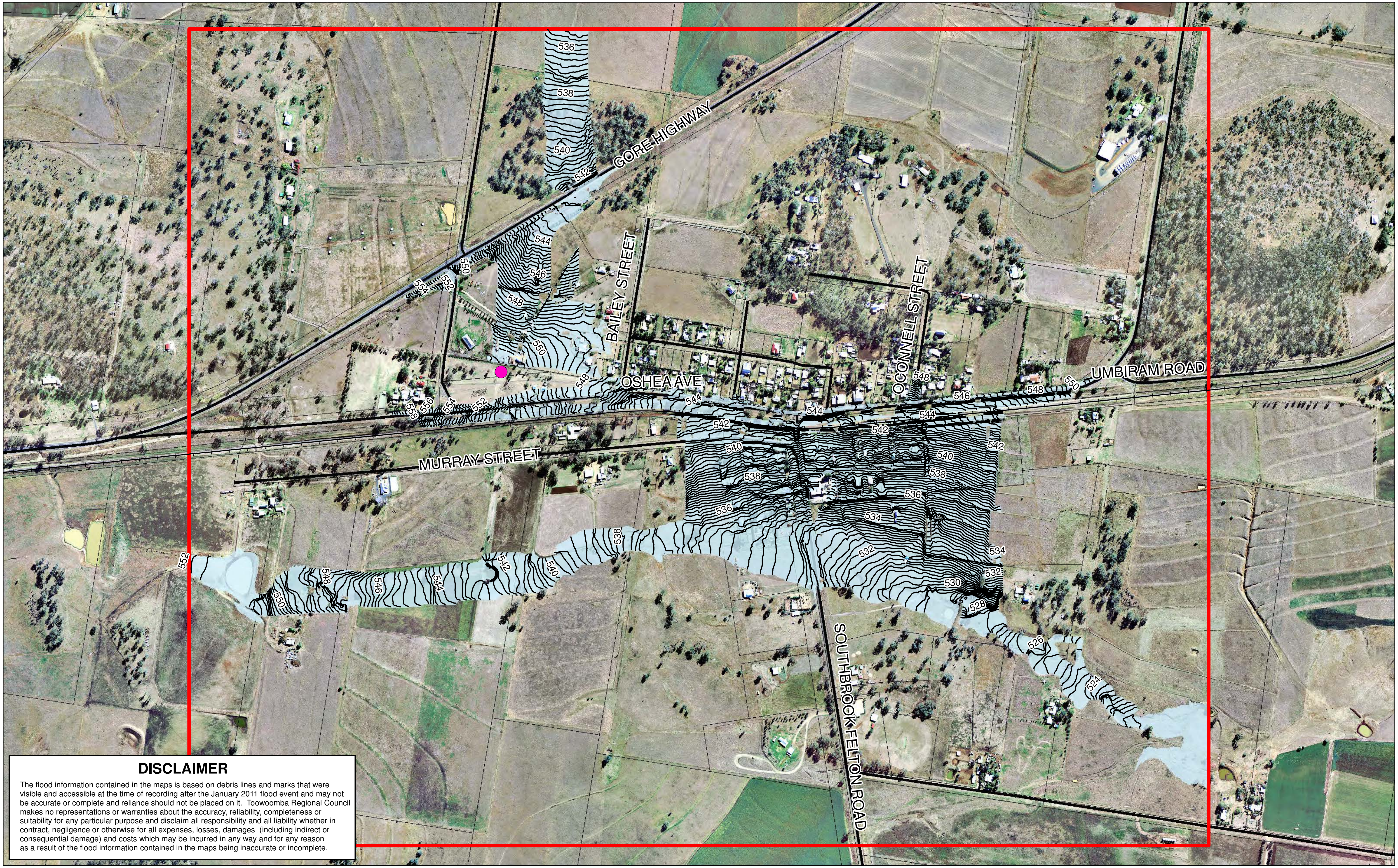
Flood Depth

Depth Band (m)

	0.5 to 1.0	2.0 to 2.5	3.5 to 4.0	>5.0
0.005 to 0.25	1.0 to 1.5	2.5 to 3.0	4.0 to 4.5	
0.25 to 0.5	1.5 to 2.0	3.0 to 3.5	4.5 to 5.0	

SP051 Flood Studies - Work Package 11
Southbrook 20 Year ARI Peak Flood Depth

J2810-04-Southbrook_Q20_Depth.mxd
Author/Date: Ryan.dermek 18/03/2014



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TOOWOOMBA REGIONAL COUNCIL

1:8,000 (at A3)

0 60 120 240
Meters

GDA 1994 MGA Zone 56

N

Legend

- QLD Rail Network
- MIKE Flood Model Domain
- Cadastre
- Major Road

Emergency Services

- Rural Fire Brigade

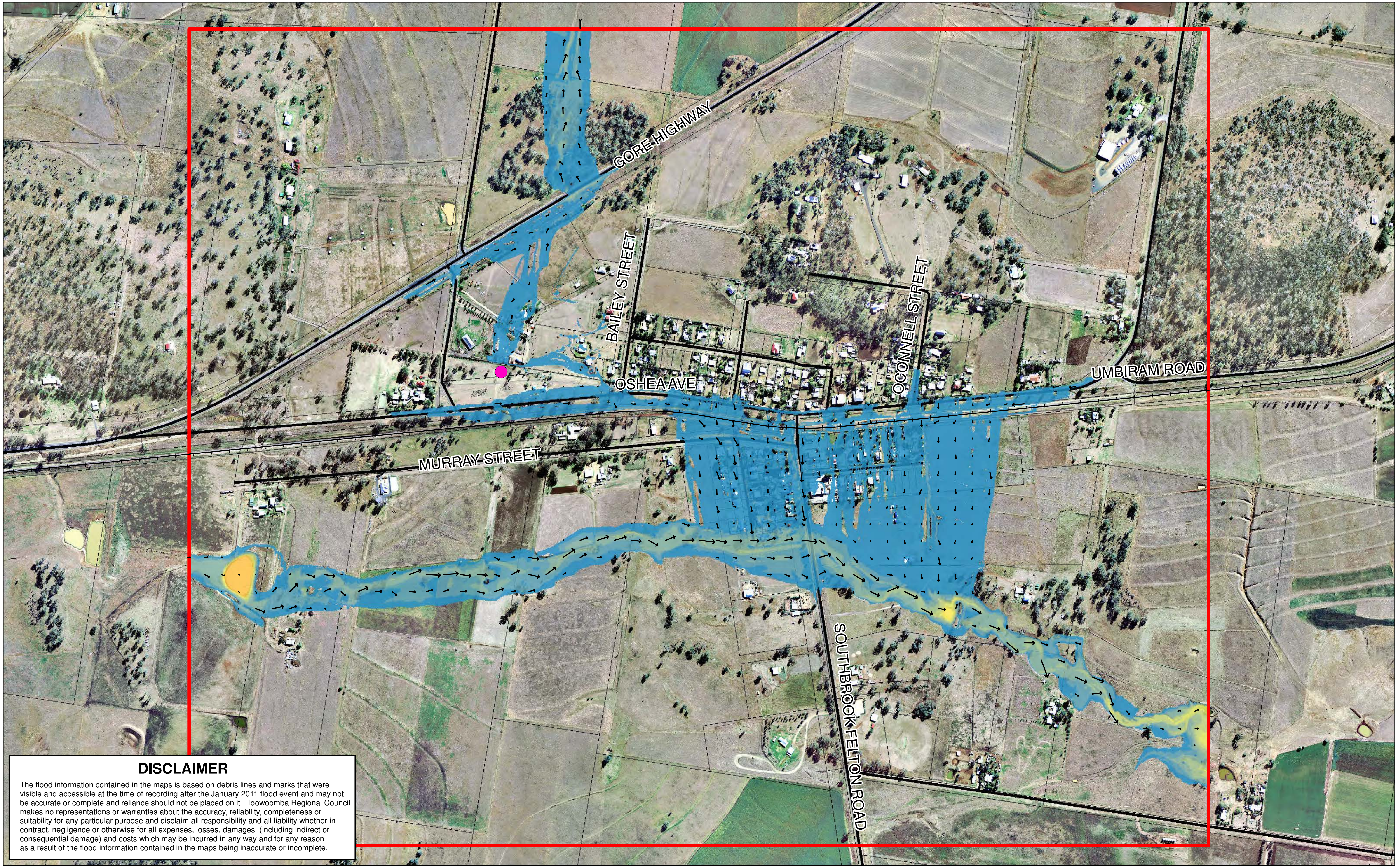
Inundation Extent

- 20yr ARI
- 0.2m contours (mAHD)

SP051 Flood Studies - Work Package 11

Southbrook 20 Year ARI Peak Water Surface Level

J2810-04-Southbrook_Q20_WL.mxd
Author/Date: Ryan.dermek 18/03/2014



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TOOWOOMBA REGIONAL COUNCIL

1:8,000 (at A3)

0 60 120 240
Meters

GDA 1994 MGA Zone 56

N

Legend

- QLD Rail Network
- MIKE Flood Model Domain
- Major Road
- Cadastre

Emergency Services

- Rural Fire Brigade

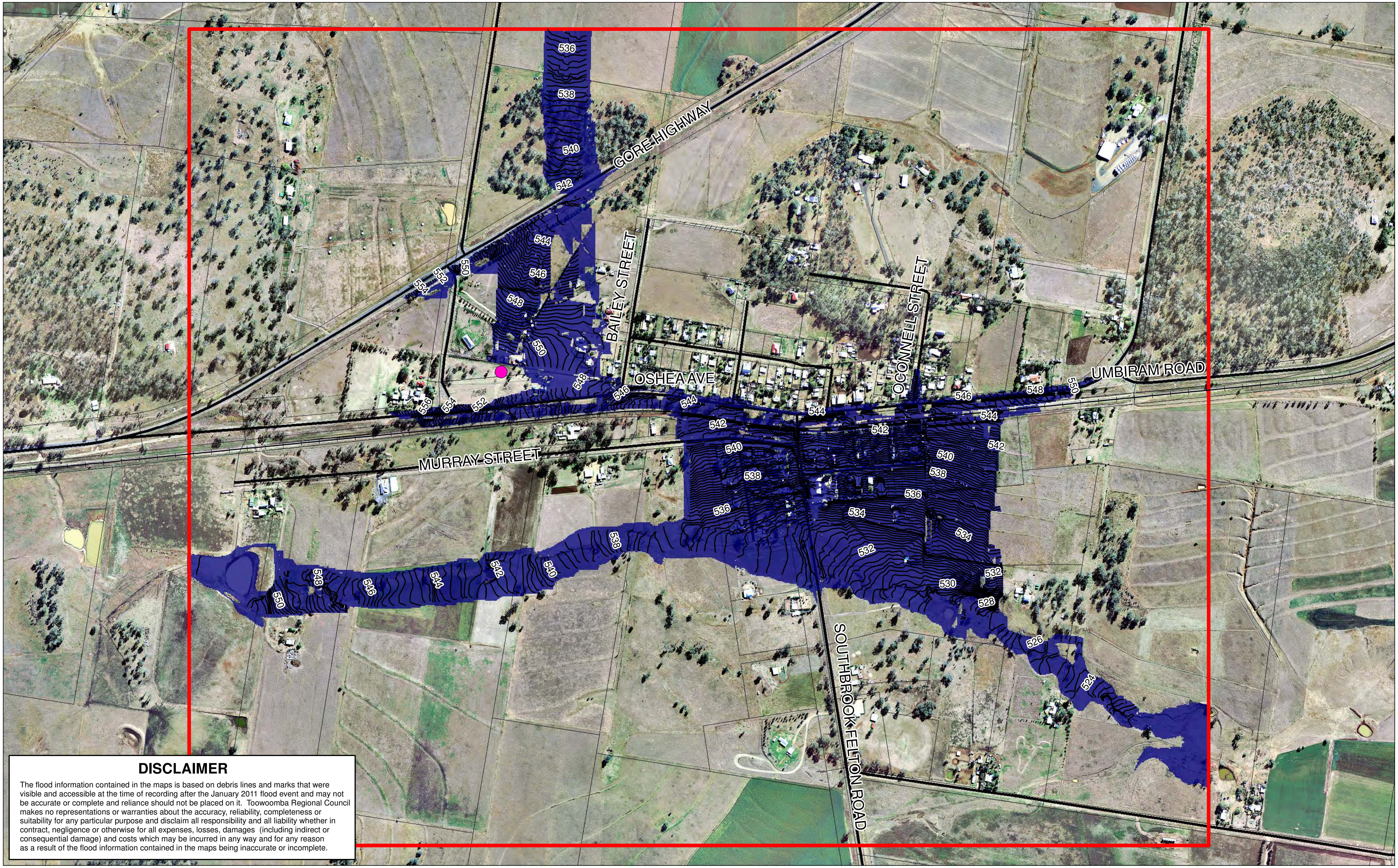
Flood Depth

Depth Band (m)

- 0.005 to 0.25
- 0.25 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- 4.5 to 5.0
- >5.0
- Scaled Velocity Vector (1 m/s)

SP051 Flood Studies - Work Package 11
Southbrook 100 Year ARI Peak Flood Depth

J2810-04-Southbrook_Q100_Depth_Portrait.mxd
Author/Date: Ryan.dermek 18/03/2014



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TOOWOOMBA REGIONAL COUNCIL

1:8,000 (at A3)

0 60 120 240 Meters

GDA 1994 MGA Zone 56

N

Legend

- QLD Rail Network
- MIKE Flood Model Domain
- Cadastre
- Major Road

Emergency Services

- Rural Fire Brigade

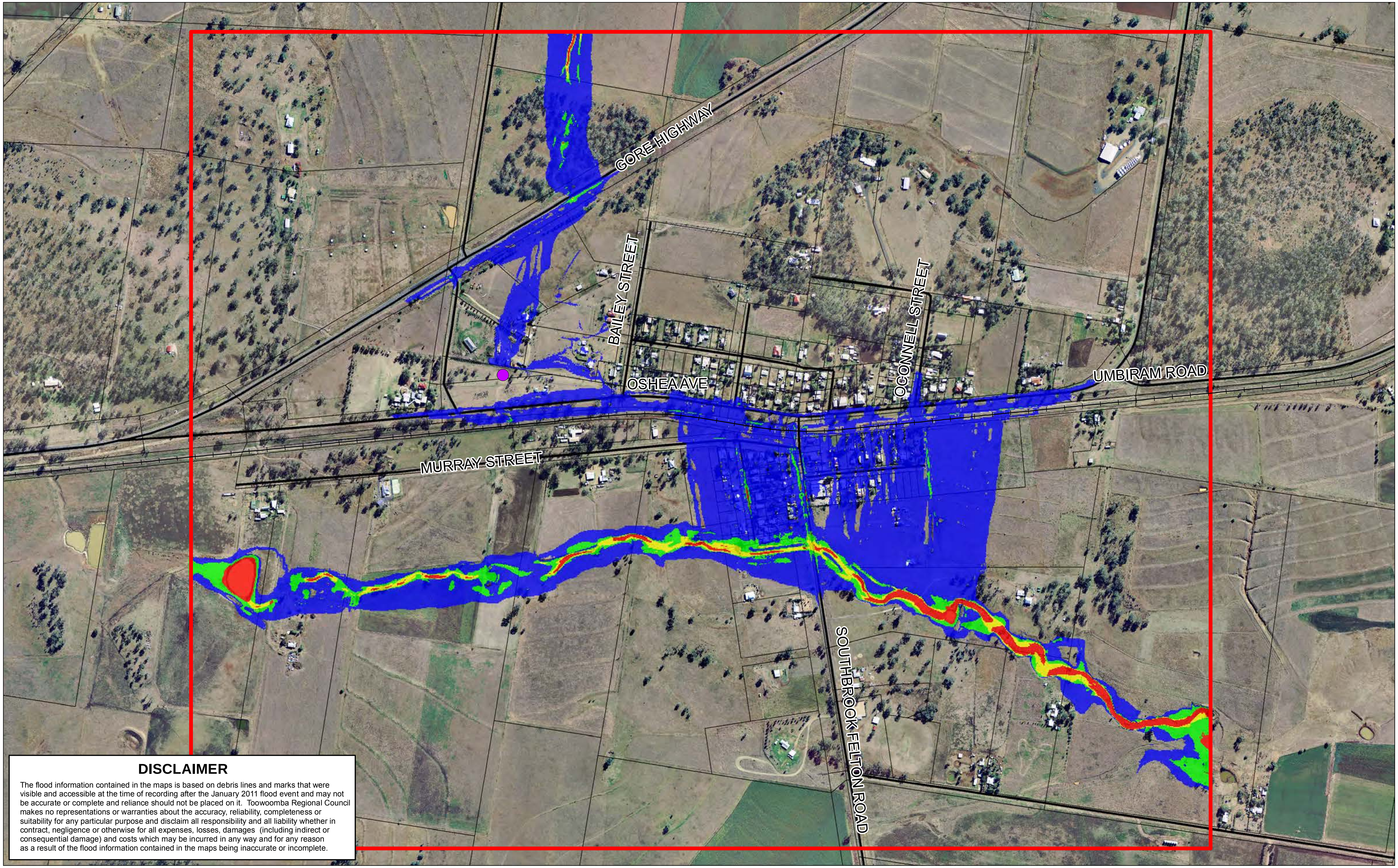
Inundation Extent

- 0.2m contours (mAHD)
- 100yr ARI

SP051 Flood Studies - Work Package 11

Southbrook 100 Year ARI Peak Water Surface Level

J2810-04-Southbrook_Q100_WL.mxd
Author/Date: Ryan.dermek 18/03/2014



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TOOWOOMBA REGIONAL COUNCIL

1:8,000 (at A3)

0 60 120 240
Meters

GDA 1994 MGA Zone 56

N

Legend

- QLD Rail Network
- MIKE Flood Model Domain
- Major Road
- Cadastre
- Rural Fire Brigade

Hazard Category

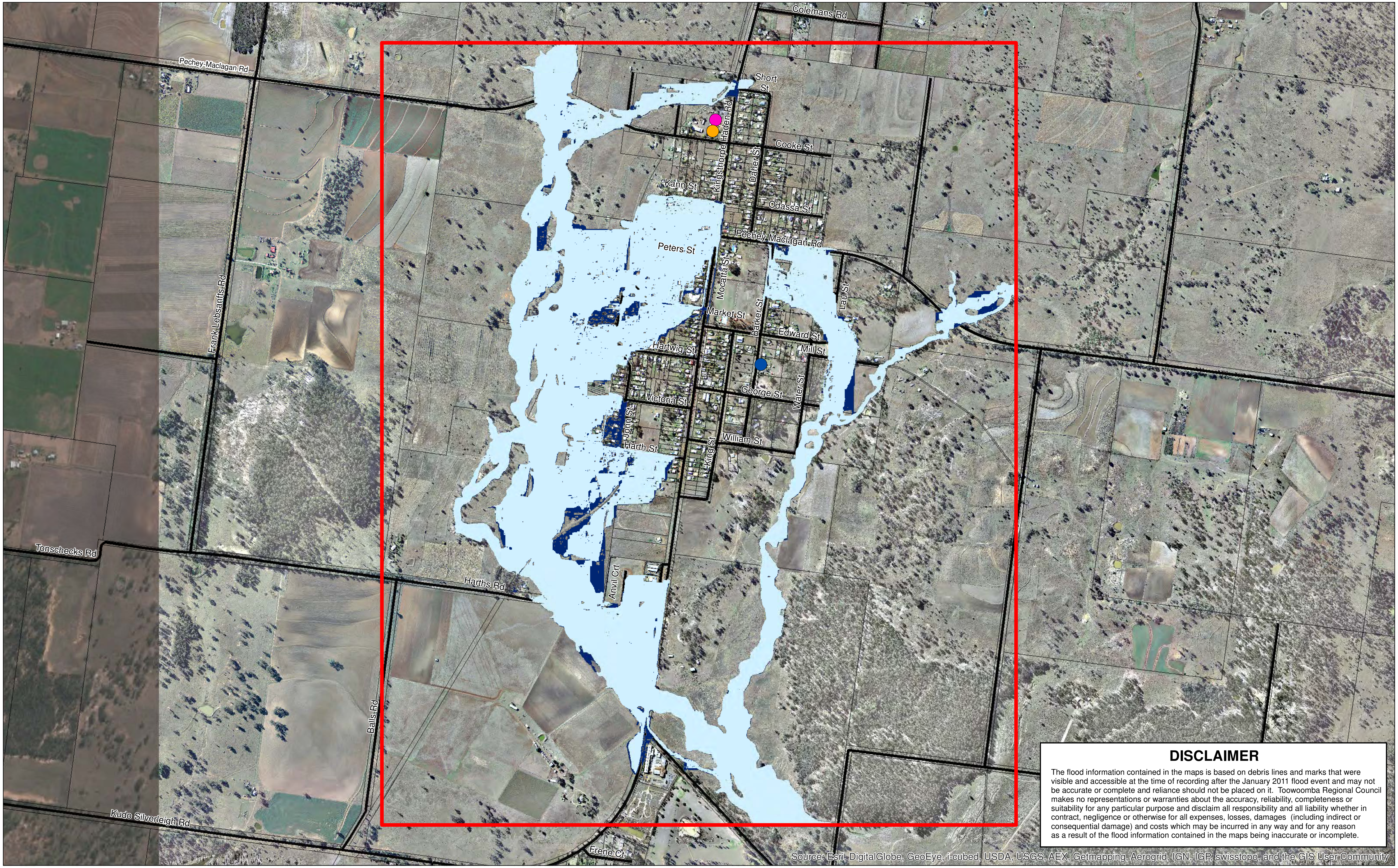
- Low
- Significant
- High
- Extreme

SP051 Flood Studies - Work Package 11

Southbrook 100 Year ARI Flood Hazard

J2810-04-Southbrook_Hazard.mxd
Author/Date: blair.filer 8/09/2014

APPENDIX G SENSITIVITY EVENT MAPS



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TOOWOOMBA REGIONAL COUNCIL

1:15,000 (at A3)

0 115 230 460
Meters

GDA 1994 MGA Zone 56

N

Legend

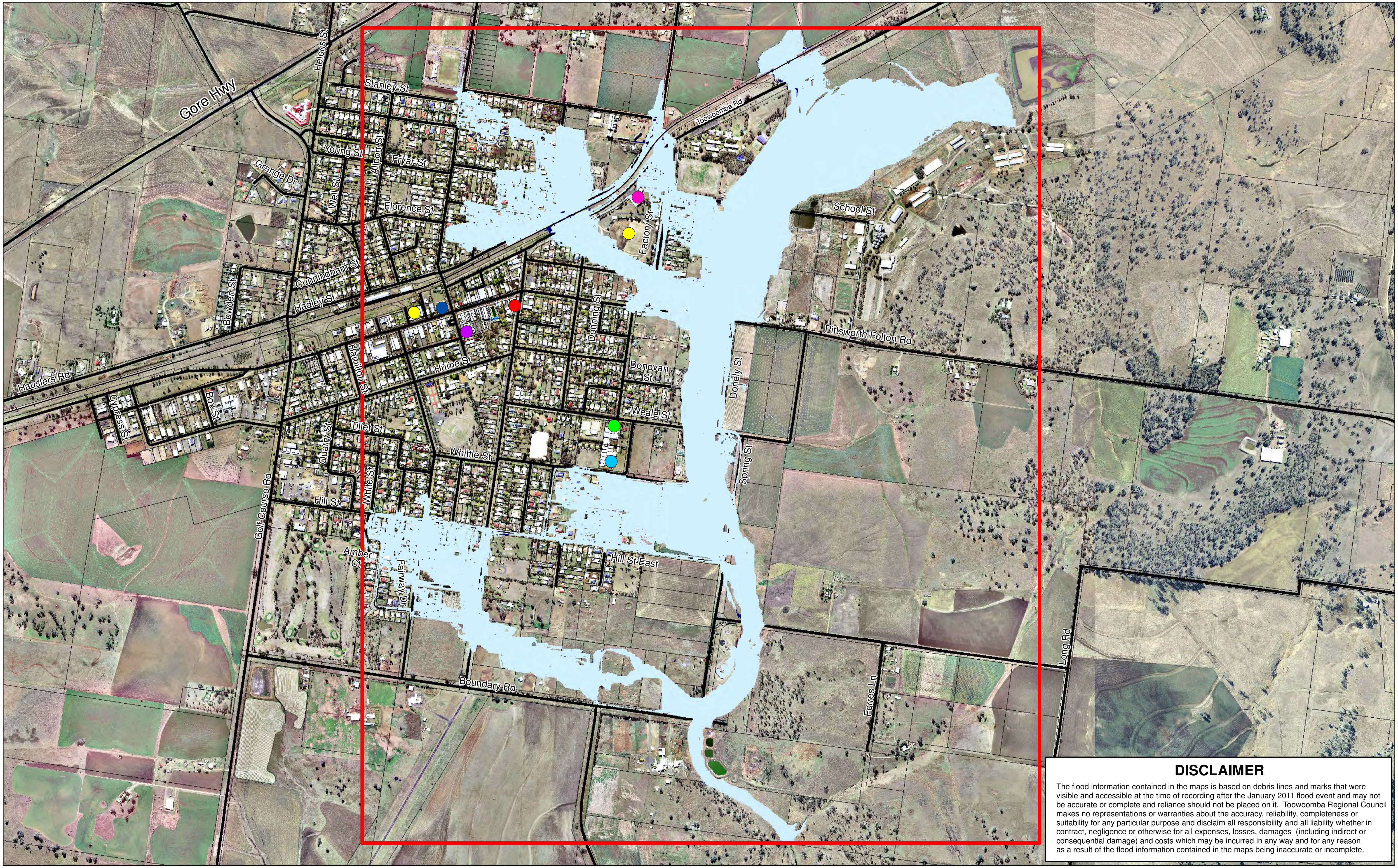
- MIKE Flood Model Domain
- Cadastre
- Major Road
- Police Station
- Rural Fire Brigade
- SES

Inundation Extent

- Baseline Scenario (100yr ARI)
- Blockage Scenario (100yr ARI)

SP051 Flood Studies - Work Package 11
Goombungee 100 Year ARI Sensitivity Assessment
50% Structure Blockage

J2810-04-Goombungee_Blockage.mxd
Author/Date: Ryan.dermek 18/03/2014



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TOOWOOMBA REGIONAL COUNCIL

1:14,000 (at A3)

0 105 210 420
Meters

GDA 1994 MGA Zone 56

N

Legend

- MIKE Flood Model Domain
- QLD Rail Network
- Major Road
- Cadastre
- Ambulance
- Evacuation Centre
- Fire Station
- Hospital
- Nursing Homes
- Police Station
- SES

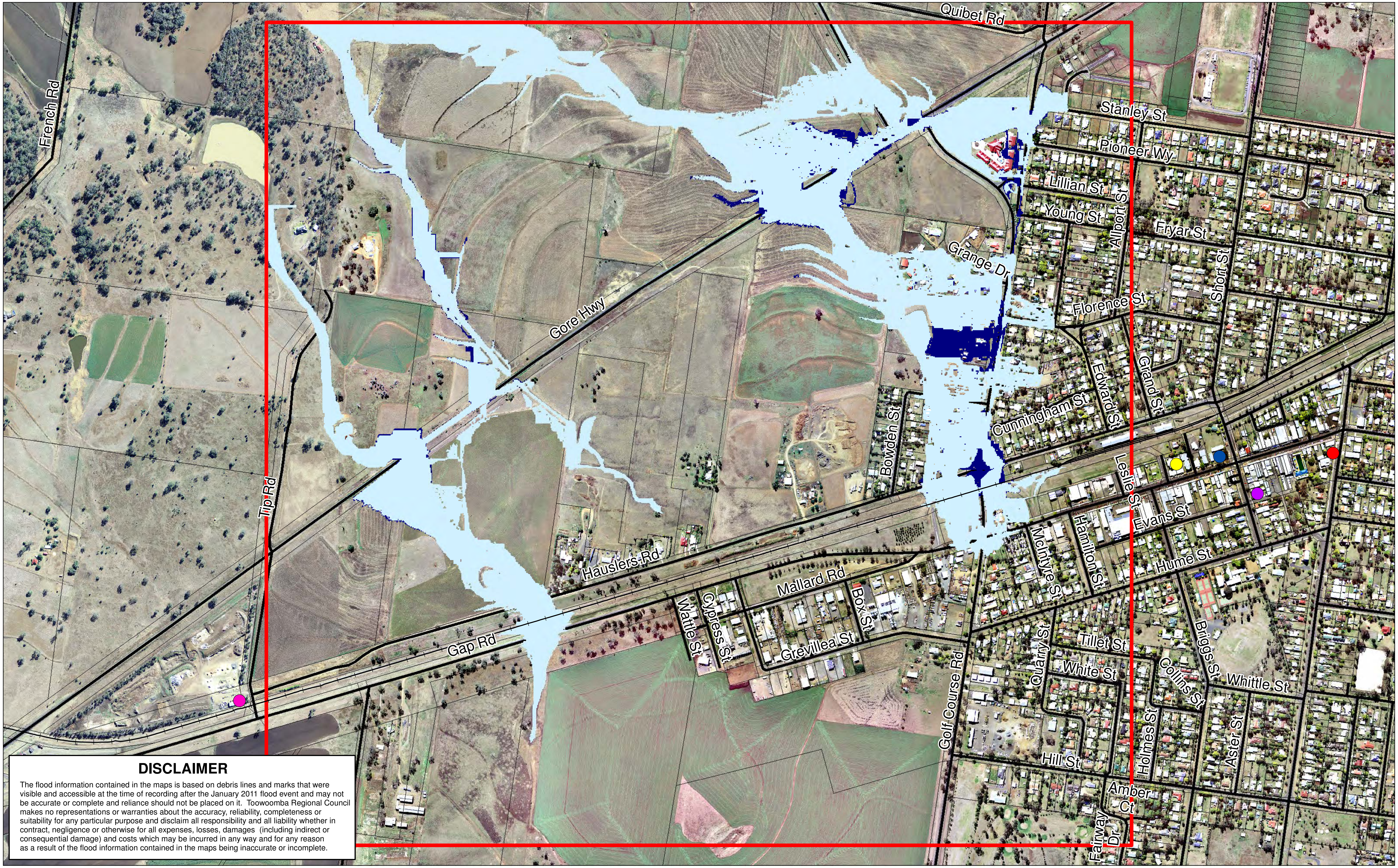
Inundation Extent

- Baseline Scenario (100yr ARI)
- Blockage Scenario (100yr ARI)

SP051 Flood Studies - Work Package 11

Pittsworth East 100 Year ARI Sensitivity Assessment
50% Structure Blockage

J2810-04-Pittsworth_East_Blockage.mxd
Author/Date: Ryan.dermek 18/03/2014



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TOOWOOMBA REGIONAL COUNCIL

1:9,000 (at A3)

0 65 130 260
Meters

GDA 1994 MGA Zone 56

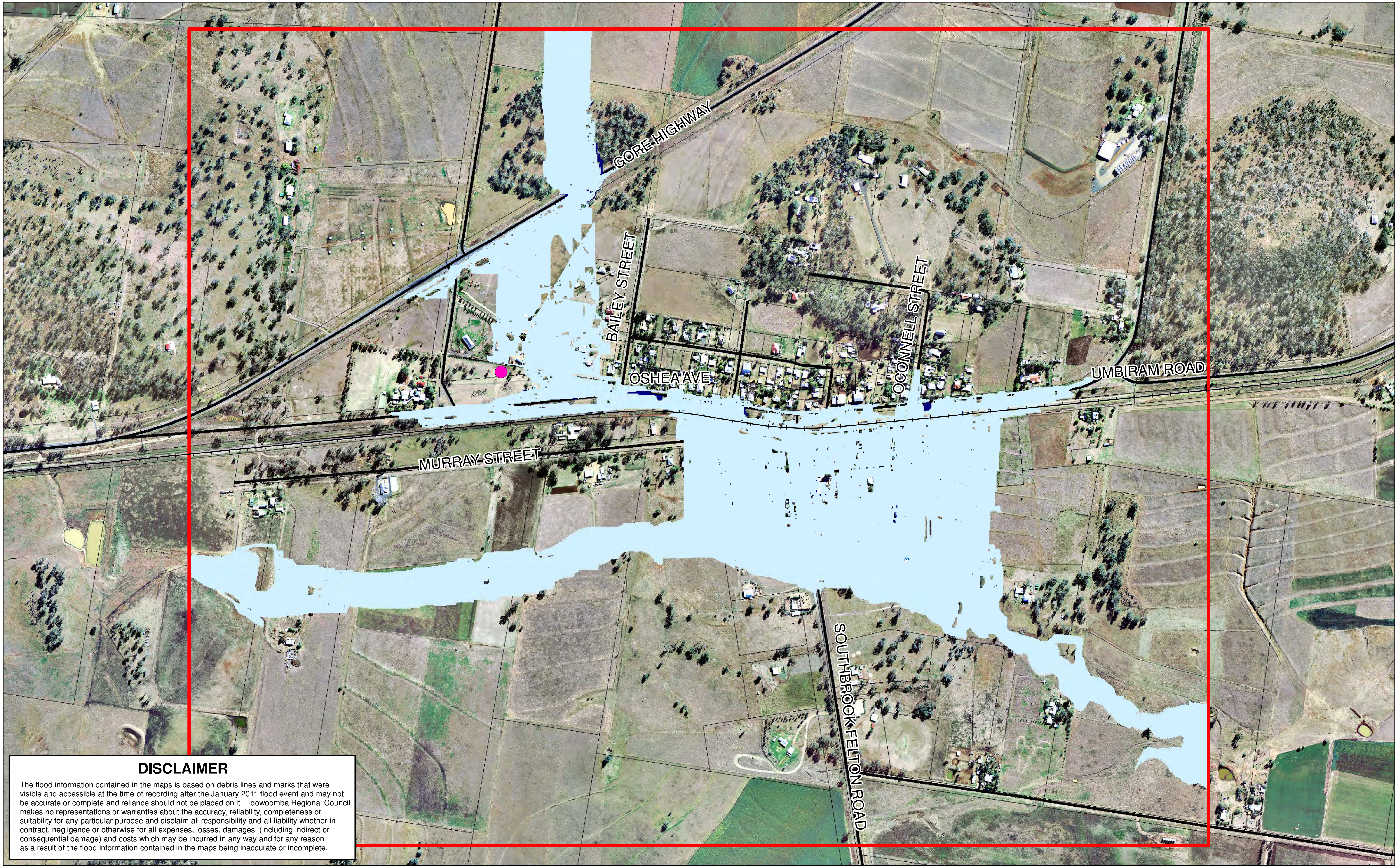
N

Legend
- QLD Rail Network
- MIKE Flood Model Domain
- Cadastre
- Major Road
- Evacuation Centre
- Police Station
- Rural Fire Brigade
- Fire Station
- Ambulance

Inundation Extent
- Baseline Scenario (100yr ARI)
- Blockage Scenario (100yr ARI)

SP051 Flood Studies - Work Package 11
Pittsworth West 100 Year ARI Sensitivity Assessment
50% Structure Blockage Map

J2810-04-Pittsworth_West_Blockage.mxd
Author/Date: Ryan.dermek 18/03/2014



DISCLAIMER

TOOWOOMBA REGIONAL COUNCIL

1:8,000 (at A3)

0 60 120 240
Meters

GDA 1994 MGA Zone 56

N

Legend

- QLD Rail Network
- MIKE Flood Model Domain
- Cadastre
- Major Road

Emergency Services

- Rural Fire Brigade

Inundation Extent

- Baseline Scenario (100yr ARI)
- Blockage Scenario (100yr ARI)

SP051 Flood Studies - Work Package 11
Southbrook 100 Year ARI Sensitivity Assessment
50% Structure Blockage

J2810-04-Southbrook_Blockage.mxd
Author/Date: Ryan.dermek 18/03/2014

TOOWOOMBA REGION

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