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Frenchmans and Thozets Creek Local Catchment Study

Baseline Flooding and Hazard Assessment - Volume 1

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Baseline Flooding and Hazard Assessment - Volume 1

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Glossary / Abbreviations

1D	One-Dimensional
2D	Two-Dimensional
AECOM	AECOM Australia Pty Ltd
AEP	Annual Exceedance Probability (refer to Notes on Flood Frequency in Section 1.5)
AHD	Australian Height Datum
ARI	Average Recurrence Interval
AR&R	Australian Rainfall and Runoff
BoM	Bureau of Meteorology
DEM	Digital Elevation Model
DFE	Defined Flood Event
DNRM	Queensland Department of Natural Resources and Mines
ESTRY	1D component of TUFLOW
EY	Exceedances per Year
GIS	Geographical Information Systems
GSDM	Generalised Short Duration Method
IFD	Intensity Frequency Duration
LiDAR	Light Detecting and Ranging
Max:Max	Maximum flood levels across a range of storm durations within the model extent
MHWS	Mean High Water Springs
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PWSE	Peak Water Surface Elevation
RCP	Reinforced Concrete Pipe
RCBC	Reinforced Concrete Box Culvert
RRC	Rockhampton Regional Council
TUFLOW	1D / 2D hydraulic modelling software

Executive Summary

Background

In December 2016, Rockhampton Regional Council (RRC) engaged AECOM Australia Pty Ltd (AECOM) to undertake the Floodplain Management Services (FMS) program for the 2017 calendar year. The FMS program entails the completion of a number of individual floodplain management projects including the Frenchmans and Thozets Creek Catchment Study, which is the subject of this report.

Flooding in North Rockhampton can occur as a result of three different flood mechanisms:

- Riverine flooding due to rainfall over the Fitzroy River catchment.
- Overland flooding due to rainfall over the local urban catchment.
- Creek flooding due to rainfall over the local creek catchment.

This study focuses on overland and creek flooding due to rainfall over the local catchment.

The key objectives of this study are:

- The development of a detailed hydraulic model based on current best practice procedures, capable of adequately simulating the flood characteristics and behaviour of the local catchment using the latest available data.
- The assessment of existing flood risk within the study area. It is expected that these results will be used to inform long term infrastructure planning, future emergency planning and floodplain management.
- The development of clear and easy to understand flood mapping products for use in future community education and awareness campaigns.
- Determination of key hydraulic controls within the study area which will later be used to inform mitigation options analysis.

Catchment Characteristics

The Frenchmans and Thozets Creek catchments cover a combined area of approximately 18.5 km^2 starting within the reaches of Mount Archer National Park. Frenchmans Creek is an ephemeral meandering system consisting of low flow paths and riffle pools within the mid and lower portions of the catchment. The natural creek bed material varies from exposed medium-sized cobbles / rocks to silty / sandy soils. Riparian vegetation along the creek varies from very dense grasses, shrubs and trees – to very limited vegetation in higher velocity sections of the reach.

Thozets Creek is also an ephemeral meandering system with low flow paths within the lower portions of the catchment. Two thirds of the reach length is contained within dense bushland, therefore the channel and overbanks are populated by trees and shrubs. Some areas of exposed medium sized rock occur in the lower reaches, along with some sections of very dense channel vegetation.

Urbanisation has increased the proportion of impervious areas such as roads, concrete and building structures. Urban overland flow paths within the Frenchmans and Thozets Creek catchment generally follow defined natural or constructed channels and road corridors.

Hydrologic / Hydraulic Analysis

The Frenchmans and Thozets Creek Phase 1 Baseline Flood Study included the development of a TUFLOW model for the urbanised portions of the Frenchmans and Thozets Creek local catchments. This model utilises a combination of runoff-routing and direct rainfall approaches in order to determine the overland flow paths and establish baseline flood extents and depths within the study area.

Anecdotal and recorded data was obtained and used to calibrate the model to a local flood event caused by TC Marcia in February 2015. Further model validations were undertaken for two other local flood events, namely Ex-TC Debbie in March 2017 and Ex-TC Oswald in January 2013.

The model calibrated very well to the 2015 event. The validation to the 2017 event resulted in a reasonable comparison between modelled and recorded levels, with most points above tolerance. Discrepancies identified between the modelled and recorded levels are largely due to the vegetation density at the time of the flood event and variation in the spatial distribution of rainfall across the rural and urban components of the catchment.

The validation to the 2013 event revealed the majority of anecdotal records matched simulated levels within tolerance. Locations at which discrepancies exceeded allowable tolerances were expected to be a result of changes to the channel geometry due to ongoing geomorphological processes.

Ongoing changes to channel geometry results in additional uncertainty when validating the model to historic events using the latest 2016 terrain data. Despite this, the model calibrates and validates well with modelled behaviours anticipated to appropriately predict flood patterns at the time of this study.

On completion of the calibration / validation process, various design flood events and durations were simulated and results extracted. The critical duration for the catchment was determined to be the 90 minute event.

The modelling has confirmed that there are a number of key hydraulic controls within the catchment – particularly the various culverts / bridges which cross Frenchmans and Thozets Creek. Sensitivity analyses have been undertaken to highlight the uncertainties in the model results and support the selection and application of an appropriate freeboard provision when using the model outputs for planning purposes.

Baseline Flood Hazard and Vulnerability Assessment

Following completion of baseline model development, design event modelling and sensitivity analyses; a flood hazard and vulnerability assessment was completed for the Frenchmans and Thozets Creek catchments. This included:

- Flood hazard analysis.
- Vulnerability assessment of key infrastructure.
- Evacuation route analysis.
- Building inundation and impact assessment.
- Flood Damages Assessment (FDA).

Each of these aspects has been discussed in further detail below.

Flood Hazard

Flood hazard categorisation provides a better understanding of the variation of flood behaviour and hazard across the floodplain and between different events. The degree of hazard varies across a floodplain in response to the following factors:

- Flow depth.
- Flow velocity.
- Rate of flood level rise (including warning times).
- Duration of inundation.

Identifying hazards associated with flood water depth and velocity help focus management efforts on minimizing the risk to life and property. As such, a series of Flood Hazard Zones have been developed according to ARR 2016, in alignment with recommendations made in the ARR, Data Management and Policy Review (AECOM, 2017).

Figure E1 shows the adopted hazard categories along with a general description of the risk associated with each category.

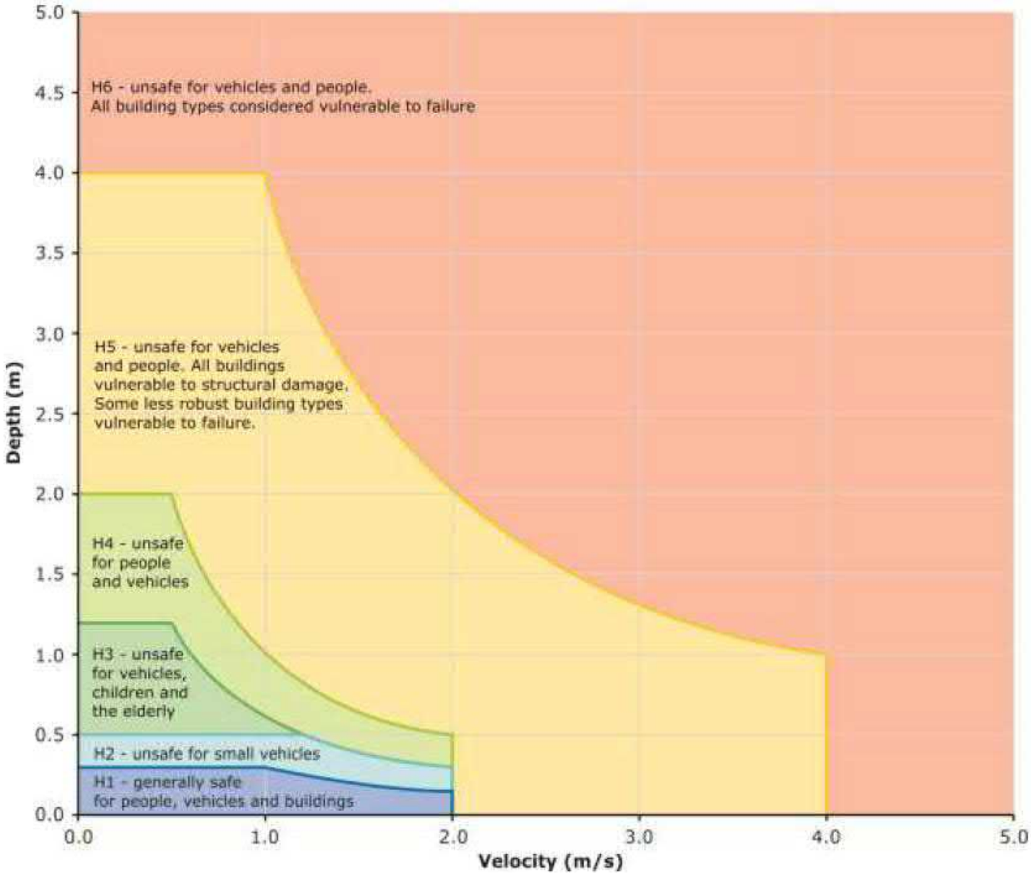

Figure E1 Hazard Vulnerability Classifications (Graphical)

Analysis of the 1% AEP baseline flood hazard within the Frenchmans and Thozets Creek catchments generally shows:

- Low to medium hazard (H1 and H2) across the majority of urbanised areas within the catchment.
- High hazard (H3 and H4) within a majority of natural and man-made channels, as well as open areas such as local parks.
- High to extreme hazard (H4 and H5) within some natural and man-made open channels, aswell as some open areas such as Alan Bray Park, Bill Crane Park, Rigarlsford Park, Ollie Smith Park and Duthie Park.
- High to extreme hazard (H4 and H5) in the vicinity of:
  - the Frenchville State School on Frenchville Road,
  - across the Kerrigan Street crossing of Frenchmans Creek,
  - across Elphinstone Street at Rigarlsford Park,
  - in Honour Street near the Mt Archer Scout Hall.
- Extreme hazard (H5 or H6) within the Frenchmans and Thozets Creek channel and adjacent overbank areas.

Vulnerability Assessment

A baseline vulnerability assessment has been undertaken to identify critical infrastructure and community assets which are at risk of flooding. The following categories have been included in this assessment:

- Water and sewerage infrastructure.
- Emergency services facilities including ambulance, police, fire and hospitals.

- Community infrastructure including schools, day-care centres, nursing homes, retirement villages and community facilities.
- Key road and rail assets.

The following provides a summary of key findings of the vulnerability assessment:

- The Blue Gum Terrace SPS (Ref: 463743), Water Street SPS (Ref: 463740), Frenchville Road SPS (Ref: 463736), Kerrigan Street SPS (Ref: 463748), Wehmeier Street WPS (Ref: 463723) and Pilbeam Drive 1 WPS (Ref: 463707) are predicted to have less than 0.2% AEP flood immunity. It is recommended this information be passed onto FRW as the asset owner.
- Low depth flooding is predicted at Frenchville State School, Mountain View Village, Elfin House Childcare and Skippy's Early Learning Centre in the 0.2% AEP, however the depth and velocity of flooding results in a low risk.
- The Yeppoon Branch Rail Line is predicted to have high level flood immunity to Top of Ballast, with inundation only predicted during the PMF event.
- A number of road segments are predicted to experience inundation in the 1EY event and larger. Approximate TOS values ranges from 1.0 hour to approximately 4 hours.

Evacuation Routes

Generally local catchment flooding within the Frenchmans and Thozets Creek catchment is due to short duration, high intensity rainfall events. The relatively steep upper catchment and urbanisation throughout much of the middle and lower catchment can result in inundation of residential and commercial buildings. In addition, inadequate stormwater infrastructure in some locations results in nuisance flooding within the urbanised catchment due to overland runoff.

Due to the short critical duration of the Frenchmans and Thozets Creek catchment, the warning time between the commencement of the rain event and subsequent flood inundation can be short. This limits the opportunity for evacuation, and generally the action taken by the community is to '*shelter in place*' until the flooding has passed.

An assessment of evacuation routes has therefore focussed on areas that become isolated during flooding, as well as high hazard areas that may require flood free evacuation access.

The following areas have been assessed as being isolated and/or lack adequate evacuation routes during the PMF event:

- Subdivisions off Frenchville Road à loses evacuation via Frenchville Road (includes Cascade Close, Rainbow Court, Lange Street, Frenchmans Lane, Beaumont Drive, Candlebark Court, Rogar Avenue, Seifert Drive, Jard Street, Davey Avenue and side streets).
- Ironbark Terrace, Archerview Terrace, Blue Gum Terrace, Jordan Close à loses evacuation via Ironbark Terrace to Frenchville Road.
- Boyd Street, Moyle Street, Murphy Street à loses evacuation via Beasley Street to Frenchville Road and/or via Murphy Street to Thozet Road.
- Limpus Street, Vallis Street, Coome Street à loses evacuation via Dean Street to Vallis Street.
- Water Street, Bremner Street, Mason Street à loses evacuation via Mason Street to Dean Street and/or via Water Street to Elphinstone Street.

Building Impact Assessment

Council provided a building database containing ~28,000 digitised buildings focussed on Creek flooding extents in North Rockhampton and Fitzroy River flood extents in South Rockhampton. Of these, ~5,900 buildings contained surveyed data.

In order to complete a Building Impact Assessment and FDA, a complete building database with floor levels, classifications and ground levels is needed within the modelled area. To achieve this, the following tasks were completed:

- Review of the digitised buildings, to remove erroneous data such as *footpaths*, *building demolished*, *no building* etc.
- Estimation of ~6,600 floor levels and ground levels within the Frenchmans and Thozets Creek modelled area, for buildings outside Council's surveyed database.
- Classification of ~8,740 buildings within the Frenchmans and Thozets Creek modelled area, in accordance with ANUFLOOD requirements.

The ground level at each building was estimated from aerial survey (LiDAR) provided for the project. Ground levels were assigned to the building footprints based on the average LiDAR elevation within the building extents.

Buildings lacking data regarding number of storeys were assumed to be one storey. Buildings on slabs were assumed to have a minimum habitable floor level of 100mm above ground level. Low set buildings were assumed to have a minimum habitable floor level of 600mm above ground level and high set buildings were assumed to have a minimum habitable floor level of 1,800mm above ground level. Buildings lacking data regarding what type of floor they have were assumed to be on slabs.

Table E2 provides a summary of the number of residential and commercial buildings anticipated to be inundated for various flood events within the Frenchmans and Thozets Creek catchment. These results are also shown graphically in Figure E2. Existing buildings which experience flood levels above ground level are noted and buildings inundated above floor level are shown in brackets beside.

Note that the indicated number of buildings is for entire buildings. Residential multi-unit buildings may contain multiple dwellings per building. Also, large commercial/industrial buildings may include multiple businesses.

Table E2 № of Buildings Impacted

AEP (%)	№ Residential Buildings	№ Commercial Buildings
	Flood level above property ground level (building inundated above floor level)	Flood level above property ground level (building inundated above floor level)
1EY	34 (9)	6 (4)
39	76 (14)	17 (10)
18	169 (52)	30 (19)
10	248 (77)	46 (34)
5	373 (142)	60 (45)
2	482 (198)	72 (53)
1	710 (315)	89 (68)
0.2	974 (435)	123 (102)
0.05	1319 (626)	152 (126)
PMF	2605 (1559)	233 (213)

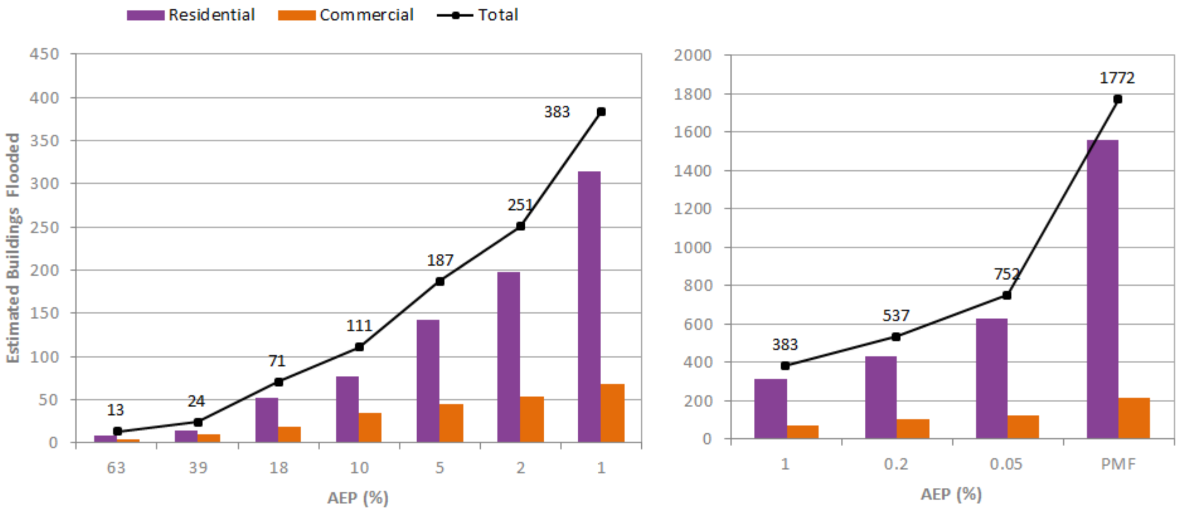

Figure E2 Estimated Buildings with Above Floor Flooding (Number of Buildings)

Figure E3 provides a breakdown of the number of buildings inundated in 'creek' and 'overland flow' areas. The graph confirms that the majority of buildings within the catchment (68%) are not inundated up to and including the PMF event. Of the 32% of buildings predicted to experience inundation, approximately 40% are impacted by overland flow and the other 60% are impacted by creek inundation.

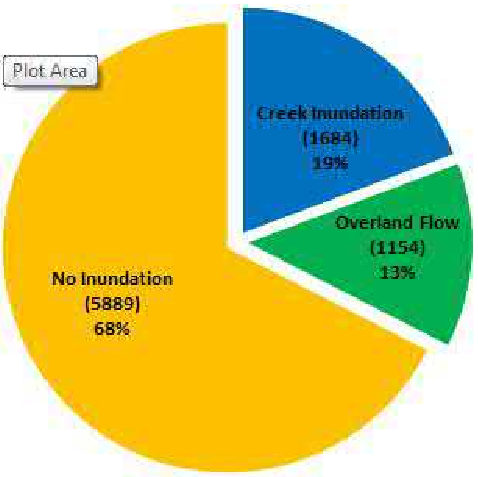

Figure E3 Inundation within Creek and Overland Flow Areas (Number of Buildings)

As shown in Figure E4 (below), median flood depths are generally less than 0.2 metre for each flood event. This indicates that reductions in flood depths of 0.2 metre could significantly reduce overall damage. The figure also shows that a significant number of buildings experience flood depths of 0.2 metre or less during frequent events such as the 1EY flood event, generally corresponding to higher flood damages.

It is noted that where surveyed floor levels were not available, slab on ground buildings were assumed to have a floor level 0.1m above the existing ground level. This is consistent with other studies undertaken in the Rockhampton area, however may result in a higher estimate of inundated buildings and consequential flood damages due to the increased incidence of above floor flooding.

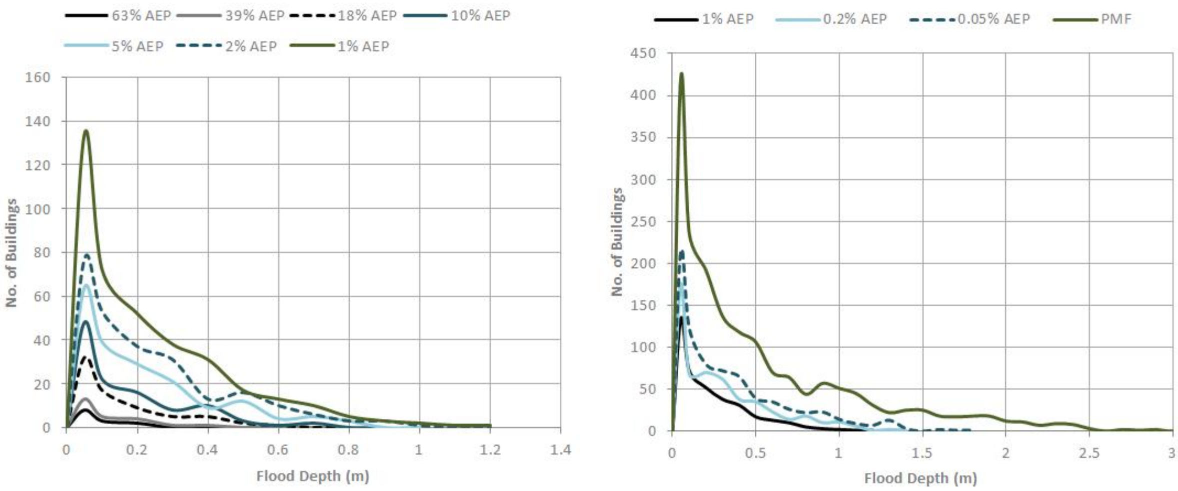

Figure E4 Estimated Flood Depths Above Floor Level by % AEP (Number of Buildings)

Flood Damages Assessment

Flood damages, or the anticipated cost to residents, businesses and infrastructure due to flooding, have been estimated using a standardised approach adopted throughout Australia. The approach estimates the tangible impacts flooding has on people, property, and infrastructure, such as flooding of a building and/or contents, the lost opportunity value associated with wages and revenue and flooding of transport and utility networks. These tangible impacts are estimated based on the depth, likelihood of flooding and type of building. Intangible impacts, such as emotional stress and inconvenience, were not quantified due to their non-tangible nature.

Figure E5 summarises the estimated total flood damages for various flood events according to their AEP. As shown, total damages range from $509,000 (1EY flood event) to $242M (PMF flood event). Figure E2 shows that 13 buildings are expected to be inundated above floor in the 1EY event, whilst 1,772 buildings are anticipated to be inundated above floor in the PMF event

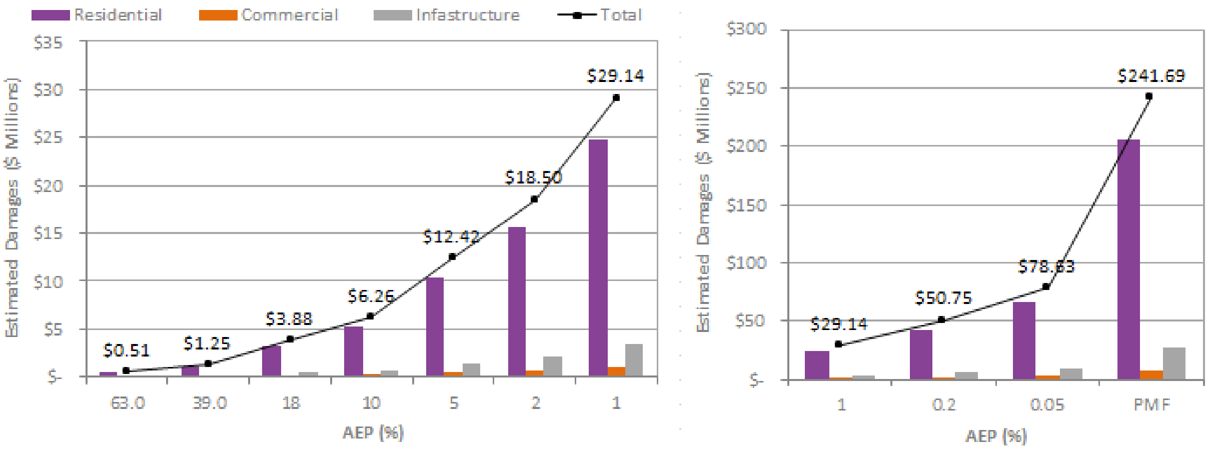

Figure E5 Estimated Flood Damages – O2 Environmental Damage Curves ($ Million)

These figures also demonstrate that Residential buildings make up the large majority of impacted buildings, and consequently estimated flood damages, within the Frenchmans and Thozets Creek catchment across the full range of design events assessed.

While the above provides an estimate of potential damages during specific flood events, understanding what damages may be expected on an annual basis is often an easier way to relate risk to residents and businesses. As such, the above damages were converted to Average Annual Damages (AAD) based on the likelihood of the flood event and the total estimated damage during that event.

The calculated AAD for the Frenchmans and Thozets Creek catchment *is estimated to range from approximately $2,428,000 to $2,832,000 per annum.*

Figure E6 provides a breakdown of the AAD and building impact assessment. The area in blue corresponds to individual building AAD (residential and non-residential combined) in brackets of $100 per annum. The orange line corresponds to the cumulative AAD for residential and non-residential buildings combined. Note that this does not include infrastructure damages.

As shown, 75% of all buildings exhibit less than $500 damage per annum, excluding infrastructure damage.

65% of damages are associated with less than 5% of all buildings. Again, this demonstrates that a minority of buildings produce the majority of damages.

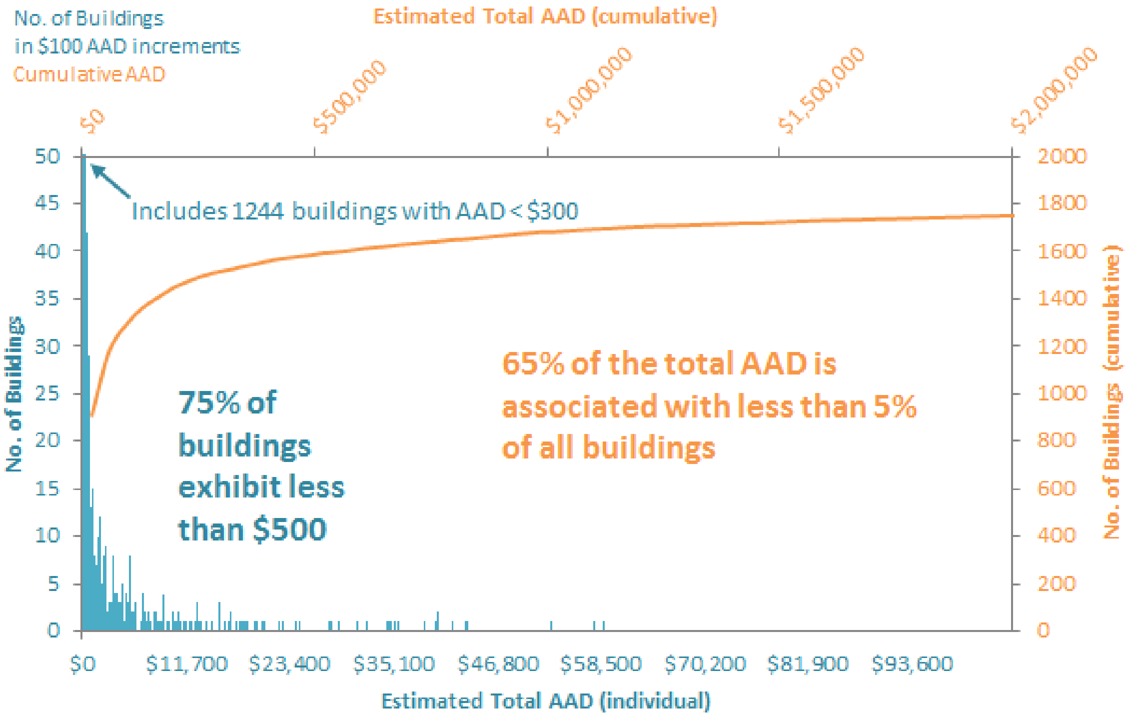

Figure E6 Individual Building vs. Cumulative Total Average Annual Damages

Rainfall Gauge, Maximum Flood Height Gauge and Flood Warning Network

A desktop review of the existing rainfall gauge, maximum flood height gauge and flood warning network yielded the following recommendations/findings for the Frenchmans and Thozets Creek catchment:

- Additional Council rain gauges could be installed at North Rockhampton Sewerage Treatment Plant (NRSTP) and South Rockhampton Sewerage Treatment Plant (SRSTP). These locations are ideal as they are already administered by Council (through Fitzroy River Water) and have access to telemetry.
- In addition to the seven existing maximum flood height gauges within the Frenchmans and Thozets Creek catchment, it is recommended that gauges be install in the following locations:
  - Along Frenchville Road, opposite the Rogar Avenue intersection area.
  - Along Frenchville Road, opposite the Lange Street intersection area.
- There is no current flood warning system within the Frenchmans and Thozets Creek catchment.

Recommendations

A number of recommendations have been made in relation to this study:

- Baseline flood mapping (i.e. peak depths, velocities and water surface elevations) provided in this study should be used to update Council's current Planning Scheme layers, at the next available opportunity.
  - Final post-processing of the GIS flood layers is recommended in accordance with the procedures outlined in the ARR, Data Management and Policy Review (AECOM, 2017).
  - Appropriate freeboard provisions should be included, based on the findings of the sensitivity analyses outlined in this study.
- This report and associated outputs should be communicated to the community and relevant stakeholders when appropriate.
- Hydrologic and hydraulic modelling undertaken for this study has been based on methods and data outlined in Australian Rainfall and Runoff 1987. The 1987 revision has been adopted as per Council's request. It is recommended that future updates to this study incorporate the new 2016 updates.
- It is recommended that Council continue to undertake building floor level survey within the Frenchmans / Thozets Creek catchment to supplement the existing building database. An updated FDA should be undertaken when additional building survey data has been obtained.
- It is recommended that Council continue to record rainfall and flood heights associated with future Frenchmans / Thozets Creek catchment flood events. This data will support ongoing model calibration / validation works that should be undertaken in future updates to this study. The implementation of additional gauges identified in this study is also recommended.
- Updated creek cross sectional survey should be undertaken after major flood events, and prior to undertaking future updates to this study. It is recommended that cross sections be surveyed at the same locations undertaken in this study to assess longer term geomorphic changes, and potential implications to flood behaviour.
- The baseline vulnerability and flood hazard assessment outputs from this report should be used to support Phase 3 of the Study (Flood Mitigation Options Development and Assessment). Potential mitigation options should be focussed on both creek and overland flooding.

1.0 Introduction

1.1 Project Background

In December 2016, Rockhampton Regional Council (RRC) engaged AECOM Australia Pty Ltd (AECOM) to undertake the Floodplain Management Services (FMS) program for the 2017 calendar year. The FMS program entails the completion of a number of individual floodplain management projects including the Frenchmans and Thozets Creek Local Catchment Study, which is the subject of this report.

Flooding in North Rockhampton can occur as a result of three different flood mechanisms:

- Riverine flooding due to rainfall over the Fitzroy River catchment.
- Overland flooding due to rainfall over the local urban catchment.
- Creek flooding due to rainfall over the local creek catchment.

There are six creek catchments located within North Rockhampton which discharge to the Fitzroy River. These are (northernmost first):

- Ramsay Creek;
- Limestone Creek;
- Splitters Creek;
- Moores Creek;
- Frenchmans Creek; and
- Thozets Creek.

This study focuses on flooding due to rainfall over the Frenchmans and Thozets Creek and contributing urban catchments.

Despite the inclusion of a coincident local catchment and riverine flood in the sensitivity analysis, flood hazard and associated risks posed by riverine flooding have been investigated and reported separately in previous studies and does not form a component of this report.

1.2 Phased Approach

The Frenchmans and Thozets Creek Local Catchment Study has been split into three distinct phases, as outlined below.

Phases 1 and 2 involved the development of calibrated numerical models to simulate baseline flood behaviour associated with a range of local rainfall design events and assessing associated hazards and risks. Phase 3 involves the assessment of a range of structural and non-structural flood mitigation options to reduce the hazard and risk posed by future local catchment flood events.

This report covers the technical investigations and results from Phase 1 and 2 of the study. It is intended that this report informs and should be read in conjunction with the Frenchmans and Thozets Creek Local Catchment Study – Mitigation Options Analysis report, which constitutes Phase 3 of this study.

1.3 Phase 1 and 2 Study Objectives

The key objectives of this study are:

- The development of a detailed hydraulic model based on current best practice procedures, capable of adequately simulating the flood characteristics and behaviour of the local catchment using the latest available data.
- The assessment of existing flood risk within the study area. It is expected that these results will be used to inform long term infrastructure planning, future emergency planning and floodplain management.
- The development of clear and easy to understand flood mapping products for use in future community education and awareness campaigns.
- Determination of key hydraulic controls within the study area which will later be used to inform mitigation options analysis.

The minimisation of flood damages through more informed and reliable planning, appropriate mitigation, education, and disaster response is the key to developing more resilient communities which will ultimately result in future growth and prosperity. The overall objective of this study is to minimise loss, disruption and social anxiety; for both existing and future floodplain occupants.

1.4 Report Structure

The Frenchmans and Thozets Creek Local Catchment Study – Baseline Flooding and Hazard Assessment Report has been separated into 2 volumes:

- *Volume 1 à Study methodology, results, findings and recommendations (this report).*
- *Volume 2 à A3 GIS mapping associated with the Volume 1 report.*

The structure of this Volume 1 report is as follows:

- Section 2.0 describes the characteristics of the local catchment, including rainfall distributions, historic events and impacts associated with riverine flood events.
- Section 3.0 outlines the data available for the development and calibration of the hydraulic model.
- Section 4.0 outlines the hydrologic inputs.
- Section 5.0 details the development of the Baseline hydrologic model.
- Section 6.0 details the development of the Baseline hydraulic model.
- Section 7.0 presents the results of the calibration and validation events.
- Section 8.0 presents the Baseline design flood depths, levels, velocities and extents for the study area.
- Section 9.0 presents results of the sensitivity analyses.
- Section 10.0 presents the flood hazard and risk assessment carried out within Phase 2.
- Sections 11.0 and 12.0 summarise the conclusions and outline recommendations.
- Section 13.0 presents the references used during the study.

1.5 Notes on Flood Frequency

The frequency of flood events is generally referred to in terms of their Annual Exceedance Probability (AEP) or Average Recurrence Interval (ARI). For example, for a flood magnitude having 5% AEP, there is a 5% probability that there will be floods of equal or greater magnitude each year. As another example, for a flood having 5 year ARI, there will be floods of equal or greater magnitude once in 5 years on average. Events more frequent than 50% AEP should be expressed as X Exceedances per Year (EY). The correspondence between the two systems is presented in the ensuing table.

Annual Exceedance Probability (AEP) %	Average Recurrence Interval (ARI) Years
63 (1EY)	1
39	2
18	5
10	10
5	20
2	50
1	100
0.5	200
0.2	500

In this report, the AEP terminology has been adopted to describe the frequency of flooding.

1.6 Limitations and Exclusions

The following limitations apply to this study:

- With the exception of the 1% AEP design flood event, all design flood events were assessed for a single critical duration, based on an analysis of multiple storm durations for the 1% AEP event.
  - GIS mapping for the 1% AEP design flood event was prepared using a 'Max:Max' analysis of multiple storm durations, whereas all other design flood events were mapped for only the critical storm.
- Aerial survey data (in the form of LiDAR) used to develop the topography for the hydraulic model has a vertical accuracy of ± 0.15 m on clear, hard surfaces and a horizontal accuracy of ± 0.45 m.
- Where information gaps existed in the underground drainage network, assumptions were made to fill these gaps using desktop assessment methods.
- Assessment of the probability of coincident local rainfall and Fitzroy River flood events has not been undertaken.
- The hydraulic model has been calibrated to a single historical event, being the local flood event which occurred as a result of TC Marcia in February 2015. The model has been validated to two other local flood events, namely Ex-TC Debbie in March 2017 and Ex-TC Oswald in January 2013.
- The approach adopted assumes each catchment is independent of the adjacent catchments. It does not allow for jointly occurring design events. The cross connections between catchments occur in the less frequent events, given this low likelihood of an event actually occurring, this approach was deemed acceptable for this study.
- Hydrologic and hydraulic modelling is based on methods and data outlined in Australian Rainfall and Runoff (AR&R) 1987. The 1987 revision has been adopted as per Council's request. Refer to the ARR, Data Management and Policy Review (AECOM, 2017) for details surrounding changes recommended in the 2016 revision.
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AR&R Revision Project 15 outlines several fundamental themes which are also particularly relevant:

- All models are coarse simplifications of very complex processes. No model can therefore be perfect, and no model can represent all of the important processes accurately.
- Model accuracy and reliability will always be limited by the accuracy of the terrain and other input data.
- Model accuracy and reliability will always be limited by the reliability / uncertainty of the inflow data.
- A poorly constructed model can usually be calibrated to the observed data but will perform poorly in events both larger and smaller than the calibration data set.
- No model is ‘correct’ therefore the results require interpretation.
- A model developed for a specific purpose is probably unsuitable for another purpose without modification, adjustment, and recalibration. The responsibility must always remain with the modeller to determine whether the model is suitable for a given problem.

2.0 Study Area Characteristics

2.1 General Description

The Frenchmans and Thozets Creek catchments cover a combined area of approximately 18.5 km^2 starting within the reaches of Mount Archer National Park. Frenchmans Creek is contained within the residential suburb of Frenchville and serves as a border between Berserker and Koongal. The urban areas of Thozets Creek are situated within the residential suburb of Koongal.

The Frenchmans Creek catchment varies in elevation from over 600 mAHD near the peak of Mount Archer to 2 mAHD at its outlet, covering an area of approximately 14.0 km^2. The land use in the upper catchment is predominantly dense bushland with minimal urbanisation. Overland runoff from the catchment quickly accumulates within the upper reach of Frenchmans Creek due to the steep natural topography and is conveyed by the creek channel towards the urban areas of North Rockhampton.

Plate 1 Frenchmans Creek Channel at Beasley Street

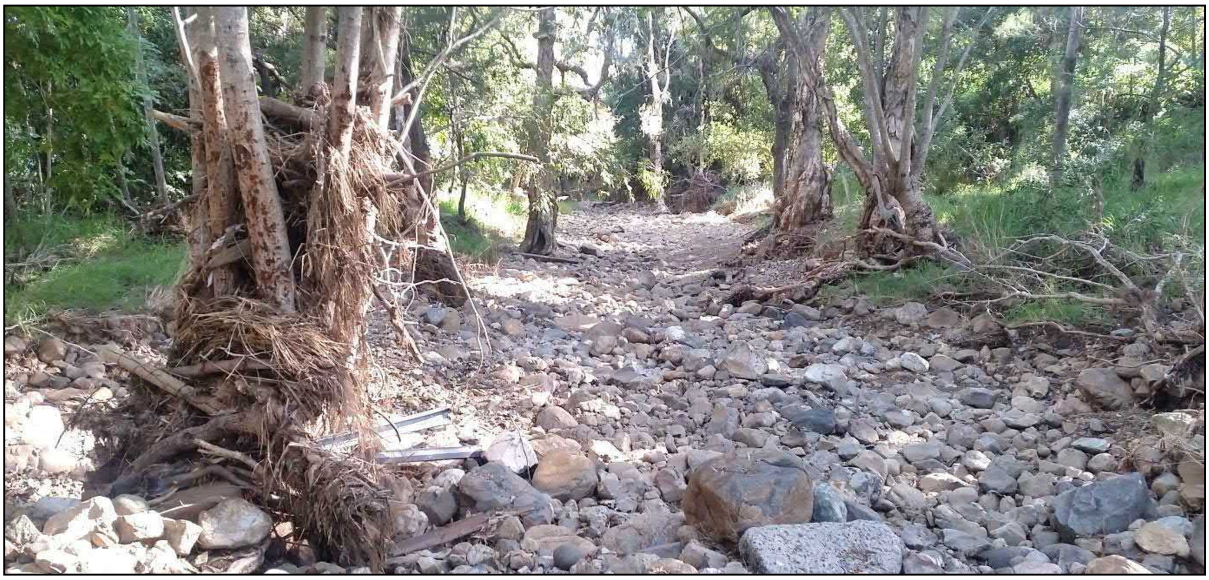
The land use in the mid and lower catchment is predominantly medium density urban, with several recreational parks (i.e. Birdwood Park and Ollie Smith Park) which are situated mostly adjacent to the Creek. Other land uses include educational precincts (i.e. Frenchville State School) and some industrial allotments. The proportions of land uses within the Frenchmans Creek Catchment are outlined in Table 1.

The Thozets Creek Catchment varies in elevation from 420 mAHD to 2 mAHD, covering an area of approximately 4.5 km^2. In the upper/middle section of the catchment, the land use is predominantly dense bushland with steep natural terrain. In the lower catchment, land use is largely medium density urban, again with several recreational parks (i.e. Enid O'toole Park and Alan Bray Park) situated alongside the Creek. Some small industrial allotments also exist within the Thozets Creek Catchment. The land uses proportions within the Thozets Creek Catchment are outlined in Table 1.

Table 1 Frenchmans and Thozets Creek Catchment Land Uses

Frenchmans Creek		Thozets Creek	
Land Use	Proportion	Land Use	Proportion
Rural / Mountainous	42%	Rural / Mountainous	64%
Urban	58%	Urban	36%
· Industrial / Commercial	(7%)	· Industrial / Commercial	(8%)
· Residential	(93%)	· Residential	(92%)

Frenchmans Creek is an ephemeral meandering system consisting of low flow paths and riffle pools within the mid and lower portions of the catchment. The natural creek bed material varies from exposed medium-sized cobbles / rocks to silty / sandy soils. Riparian vegetation along the creek can also vary from very dense grasses, shrubs and trees – to very limited vegetation in higher velocity sections of the reach. Images captured during the site inspection are provided in Plate 2.



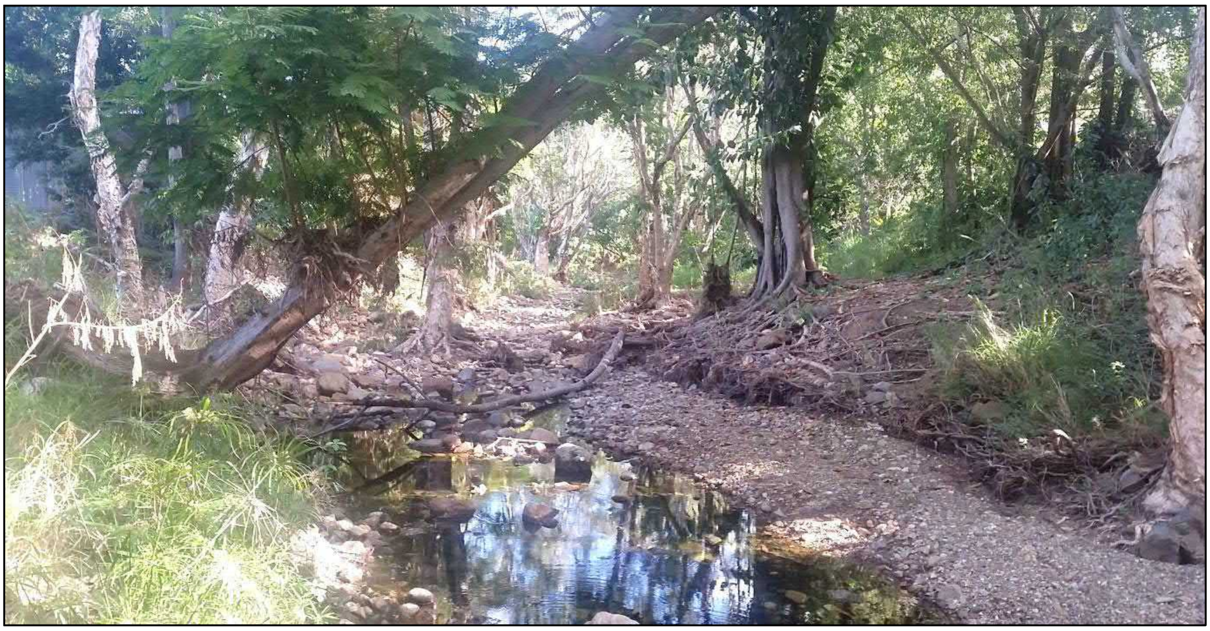


Plate 2 Frenchmans Creek Channel Characteristics Exposed Rock (top) and Riffle Pools (bottom)

The moderate to steep channel grades and smooth rock-laden sections of the channel can allow significant conveyance of upstream runoff and can result in high velocities, flood hazard and limited response times for crossings prone to flash flooding. Evidence of the floodwater velocity is observed in the lack of fine-grained soils throughout the creek bed in the upper and mid catchment, as well as evidence of scouring at hydraulic obstructions.

Thozets Creek is also an ephemeral meandering system with low flow paths within the lower portions of the catchment. Two thirds of the reach length is contained within dense bushland, therefore the channel and overbanks are populated by trees and shrubs. Some areas of exposed medium sized rock occur in the lower reaches, along with some sections of very dense channel vegetation.

Plate 3 Thozets Creek Channel Downstream of Rockonia Road

2.2 Urban Sub-Catchments

Urbanisation has increased the proportion of impervious areas such as roads, concrete and building structures. Urban overland flow paths within the Frenchmans and Thozets Creek catchment generally follow defined natural or constructed channels and road corridors.

Key sub-catchment flow paths within the upper Frenchmans Creek urban catchment are visible along the following reserves:

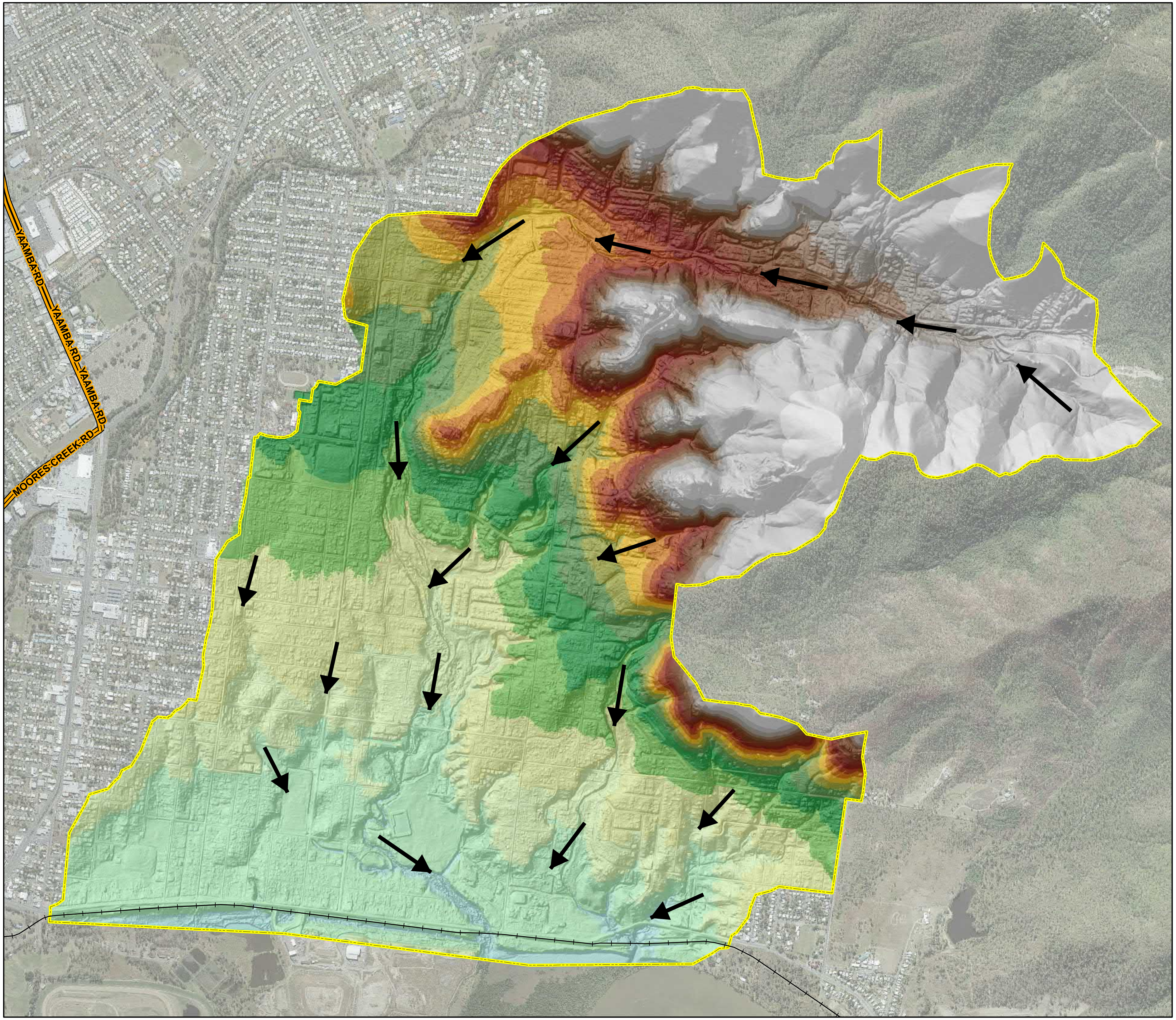
- Shields Avenue and Duthie Park;
- Bloxsom Street and O’Shanesy Street; and
- Rod Gower Park.

Surface runoff originating from urban areas surrounding Woodland Drive and Forbes Avenue, cumulate between the roads and continue south east towards Frenchmans Creek flowing down Shields Avenue, through culverts at Thozets Road and into Duthie Park. After which, the flow path crosses Wigginton Street and through Ollie Smith Park before joining Frenchmans Creek.

Another major urban sub-catchment within the Frenchmans catchment is the runoff that combines at the corner of Elphinstone Street and Berserker Street and flows south west towards McLeod Park. A combination of table drains and low flow stormwater network exists within McLeod Park, connecting to a table drain between Dean Street and Water Street, at which point the flow passes into Frenchmans Creek.

Within the Thozets Creek catchment, a key sub catchment begins in the steep forested areas where runoff makes its way towards Hinds Street. At this point the flow continues south east crossing/passing beneath Paterson Avenue, Rhodes Street, Pilkington Street and Stack Street; before entering Rod Gower Park and joining with Thozets Creek after flowing underneath Lakes Creek Road.

Further discussion surrounding the existing flood behaviours during local catchment events are given in Sections 7.0 and 8.0. Figure 1 provides a visual representation of key flow patterns within the study area during local catchment events.



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Metres

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LEGEND

- Natural FLow Lines
- Highways
- Railway Lines
- Hydraulic Model Extent

Topography (mAHD)

- < 5
- 5 - 10
- 10 - 15
- 15 - 20
- 20 - 25
- 25 - 30
- 30 - 35
- 35 - 40
- 40 - 45
- 45 - 50
- 50 - 55
- 55 - 60
- 60 - 65
- 65 - 70
- 70 - 75
- 75 - 80
- 80 - 90
- 90 - 100
- 100 - 200
- > 200

Data Sources:

DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Frenchmans Creek & Thozets Creek Model

Sub-catchment Delineation and Natural Flow Paths

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	20/06/2017
VERSION:	1

Figure 1

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\Figure 1 Sub Catchment Delineation.mxd

2.3 Climate Characteristics

The combined Frenchmans and Thozets Creek local catchment are situated at latitude 23 º 21’ 32.4” south, about 10km north of the Tropic of Capricorn. The catchment centroid is about 25km west of the Pacific Ocean at Thompson Point. As a result, the catchments experience a tropical maritime climate.

The climate is dominated by summer rainfalls with heavy falls likely from severe thunderstorms and occasionally from tropical cyclones. Heavy rainfall is most likely to occur between the months of December to March.

2.4 Rainfall Characteristics

Rockhampton has a mean annual rainfall of approximately 800 mm. The highest mean monthly rainfall of 145 mm generally occurs in February. The highest and lowest annual rainfall recorded at the Rockhampton Airport is 1631 mm (in 1973) and 360 mm (in 2002) which shows a significant variation in annual rainfall, year on year.

The highest monthly rainfall of 660 mm was recorded in January 1974. The highest daily rainfall of 348 mm was recorded on the 25th of January 2013. The following graph shows the distribution of the mean monthly rainfall depth throughout the year at the Rockhampton Airport.

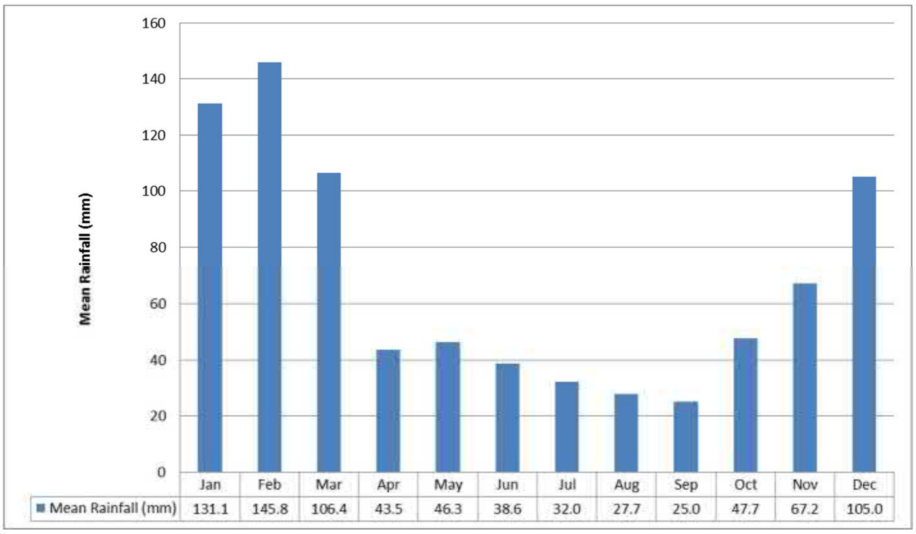

Figure 2 Mean Monthly Rainfall at the Rockhampton Airport Rainfall Station

Analysis of historical rainfall records at key gauges across the City confirmed that the spatial variability of rainfall can significantly vary between North Rockhampton and South Rockhampton. With this in mind, the compilation of historical rainfall records within the catchment was important to accurately verifying the validity of the hydrodynamic model.

It is noted that pluviographic data obtainable through the BoM website (www.bom.gov.au) is available for the Rockhampton Airport (Rockhampton Aero – Site Number 039083). RRC also maintains minute-by-minute (SCADA) rainfall gauges at the following locations:

- Agnes Street Reservoir.
- Glenmore Water Treatment Plant (WTP).
- Rogar Avenue Reservoir.
- West Rockhampton Sewage Treatment Plant (STP).
- Yaamba Road Reservoir.
- Lucas Street Reservoir.

In addition to the above, Council have in the past also obtained 30 minute rainfall data from a private residence at Serocold Street, Frenchville. The rainfall stations are represented spatially in Figure 3.

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Metres

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LEGEND

- Rainfall Gauge Locations
- Highways
- Railway Lines
- Cadastre
- Hydraulic Model Extent

Data Sources:

DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Frenchmans Creek & Thozets Creek Model

Rainfall Gauge Locations

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	19/06/2017
VERSION:	1

Figure 3

Of the abovementioned gauges, Rogar Avenue Reservoir gauge is located within the upper segment of the catchment and is therefore likely to represent the best-estimate of historic rainfall events for the Frenchmans and Thozets Creek Local Catchment model. It should be noted that the Rogar Avenue Reservoir gauge is also situated within the Frenchmans catchment and the Serocold Street gauge is within close proximity to the urban Frenchmans Creek catchment area. Both gauges are also expected to sufficiently represent rainfall contributing to Frenchmans and Thozets Creek.

2.5 Historic Local Catchment Events

Significant local rainfall events leading to overland flooding of the Frenchmans and Thozets Creek urban catchment often originate from tropical cyclonic activity, rapidly intensifying troughs and depressions. Notable incidents of such meteorological events occurring in recent times include the 2013, 2015 and 2017 events.

Other significant events including the 1991 and 2008 events are noted to have caused flooding in Frenchmans and Thozets Creek, although have not been assessed within this study. This is due to the lack of available data for the 1991 and 2008 events and the model topography being more representative of 2013, 2015 and 2017 topographic conditions.

This study included the simulation of 2013, 2015 and 2017 local catchment events, with the 2015 event serving as the calibration event. The 2017 and 2013 events have been used to verify the model performance.

2.6 Riverine Flooding Influence

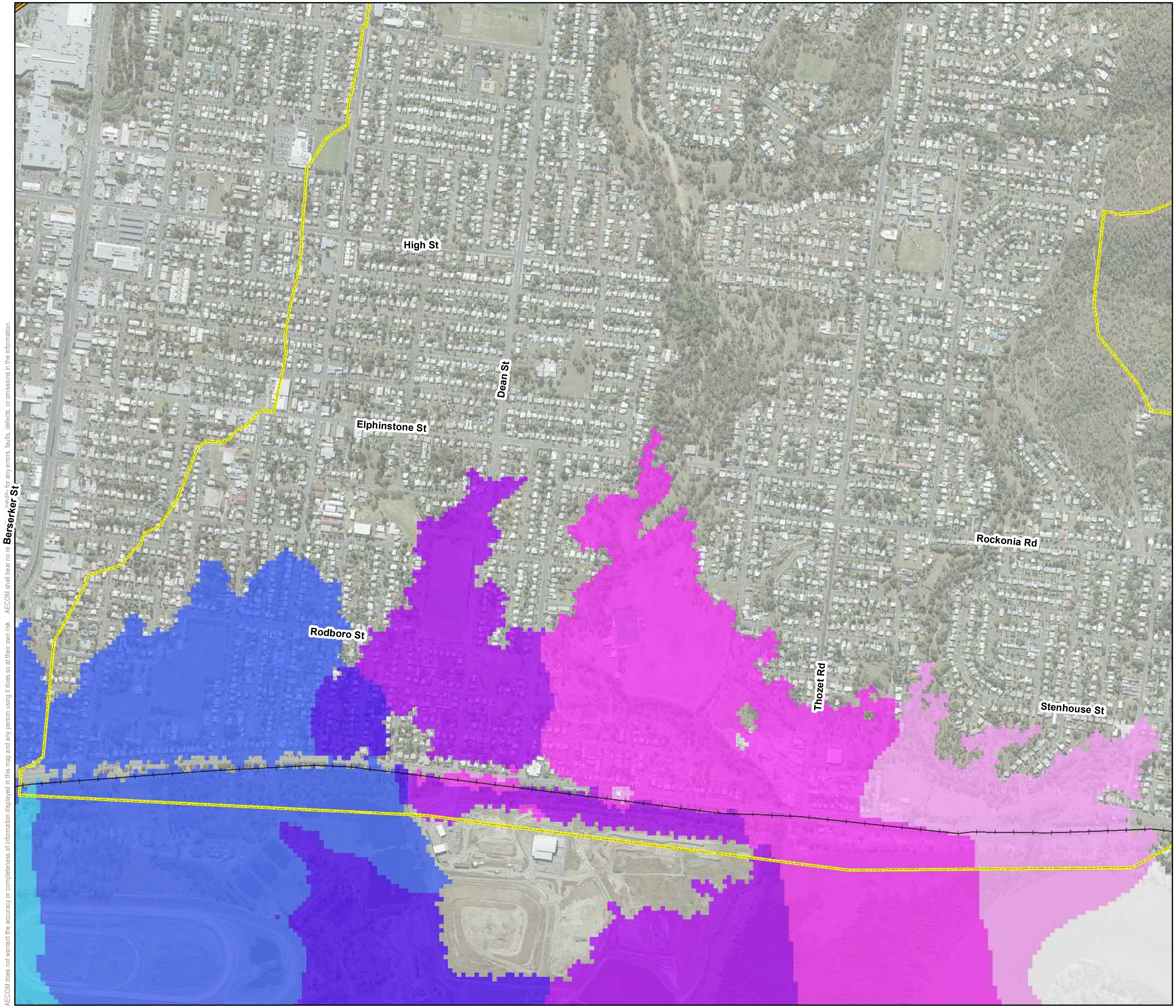
Riverine floods in Rockhampton can result from extended periods of rainfall within the 142,000 km^2 Fitzroy River basin. As peak discharge increases along the Fitzroy River, a key breakout occurs upstream of Rockhampton at the Pink Lily meander, which can result in the inundation of large areas of South Rockhampton. In addition, backwaters effects impact low-lying areas adjacent to creeks on the Northside and Southside of Rockhampton, including Frenchmans and Thozets Creek which is the subject of this report.

Figure 4 outlines the riverine flood heights for a 1% AEP flood event. It is evident that portions of the lower Frenchmans and Thozets Creek catchments become inundated by riverine flood waters in a flood event of this magnitude. Fitzroy River floodwaters extend along Frenchmans Creek just beyond the cross-drainage structures beneath Elphinstone Street. Low-lying parcels and recreational areas surrounding Rodboro Street are predicted to be inundated. Floodwater extents reach approximately half way between Lakes Creek Road and Rockonia Road along Thozets Creek as well as low-lying areas south of Stenhouse Street.

The effect of riverine backwater levels on local catchment flood behaviour have been modelled as part of the sensitivity analysis which simulates the coincidence of a 1% AEP local catchment event with an 18% AEP riverine event. The results form a component of the discussion made in Section 0.

2.7 Flood Warning System

It is noted that a flood warning and classification system is not presently operated by BoM or RRC for the Frenchmans and Thozets Creek catchments during local rainfall events.



Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

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Metres

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(when printed at A3)

AECOM
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LEGEND

- Highways
- Railway Lines
- Hydraulic Model Extent

Peak Riverine Flood Height (mAHD)

- <7.5
- 7.51 - 7.6
- 7.61 - 7.7
- 7.71 - 7.8
- 7.81 - 7.9
- 7.91 - 8
- 8.01 - 8.1
- 8.11 - 8.2
- 8.21 - 8.3
- 8.31 - 8.4
- 8.41 - 8.5
- 8.51 - 8.6
- 8.61 - 8.7
- 8.71 - 8.8
- 8.81 - 8.9
- > 8.91

DRAFT

Flood results are based on riverine catchment events

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Frenchmans Creek & Thozets Creek Model
Peak Fitzroy River Flood Heights

1% AEP Riverine Flood Event

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	19/06/2017
VERSION:	1

Figure 4

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\Figure 4 Riverine Flood Extent.mxd

3.0 Available Data

3.1 General

Available data for the development of baseline flood modelling for the catchment consisted of:

- Previous studies (AECOM 2017, Aurecon 2014, BMT WBM 2014, AECOM 2014).
- Tidal data (MSQ).
- Topographical data in the form of LiDAR (AAM Pty Ltd).
- Aerial photography (RRC).
- Stormwater infrastructure network database (RRC).
- Details of hydraulic structures within the study area (RRC).
- Historical rainfall data for the 2013, 2015 and 2017 flood events (BoM, RRC).
- Historical flood records for the 2013, 2015 and 2017 flood events (RRC).

Each of these is described in more detail in the subsequent sections.

3.2 Previous Studies

3.2.1 ARR, Data Management and Policy Review (AECOM, 2017)

Completed by AECOM in March 2017 as part of the 2017 FMS project, the ARR, Data Management and Policy Review report sought to identify the implications of applying the latest hydrological methodology presented in AR&R 2016, review Council's existing floodplain management policies and propose appropriate flood mapping guidance based on current industry mapping styles.

The recommendations of the report were to move to the AR&R 2016 hydrologic methodology. Council have consequently resolved to maintain the use of AR&R 1987 hydrologic methodologies whilst developing an implementation plan for the adoption of the AR&R 2016 methodology. AR&R implementation needs to be finalised over a two year period. A further recommendation of the review was to adopt current industry mapping standards as per DNRM 2016 Guidelines, which Council have agreed to adopt where applicable within the Floodplain Management Services Program.

3.2.2 Frenchmans Creek Hydrologic and Hydraulic Modelling Report (Aurecon, 2014)

In May 2014 Aurecon delivered Revision 2 of the *Rockhampton Local Catchments Flood Study - Frenchmans Creek Hydrologic and Hydraulic Modelling Reports* (Aurecon, May 2014). The Frenchmans Creek report formed part of a wider local catchments study whereby the following creeks were assessed:

- Ramsay Creek.
- Limestone Creek.
- Splitters Creek.
- Moores Creek.
- Frenchmans Creek (the focus of this report).
- Thozets Creek (the focus of this report).
- Creeks in the Gracemere area including Washpool Creek, Middle Creek, Gracemere Creek and a Local Catchment.

The study applied XP-Rafts hydrologic model hydrographs as lumped catchment inflows to TUFLOW hydraulic models. The XP-Rafts hydrographs were applied directly within the creek channel, to represent the runoff from upstream sub-catchments.

The modelling undertaken did not simulate overland flows within the upstream sub-catchments, as no direct rainfall was applied within the TUFLOW model.

The TUFLOW two-dimensional hydraulic model was calibrated to recorded levels from the January 2013 local catchment rain event. It was reported that the modelled flood levels had an absolute average difference of 0.35 m when compared to the recorded levels.

Design events were modelled for the 39% AEP, 18% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF local catchment flood events. Climate change scenarios were modelled for 20% and 30% increases in rainfall intensity, for the 1% AEP, 0.5% AEP and 0.2% AEP events.

3.2.3 Thozets Creek Hydrologic and Hydraulic Modelling Report (Aurecon, 2014)

As mentioned above in section 3.2.2, Aurecon delivered Revision 2 of the *Rockhampton Local Catchments Flood Study – Thozets Creek Hydrologic and Hydraulic Modelling Report* in May 2014.

The TUFLOW two-dimensional hydraulic model was calibrated to recorded levels from the January 2013 local catchment rain event. It was reported that the modelled flood levels had an absolute average difference of 0.35 m when compared to the recorded levels.

Again the design events modelled for the 39% AEP, 18% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and PMF local catchment flood events. Climate change scenarios were modelled for 20% and 30% increases in rainfall intensity, for the 1% AEP, 0.5% AEP and 0.2% AEP events.

3.2.4 Independent Review of Rockhampton Local Catchments Flood Study - Numerical Models (BMT WBM, 2014)

In June 2013 BMT WBM Pty Ltd (BMT WBM) were commissioned by RRC to carry out an independent review of the Rockhampton Local Catchments Flood Study, prepared by Aurecon (refer Section 3.2.2 and 3.2.3). At that time the reports were in Draft format, to allow for updates and finalisation following completion of the peer review.

BMT WBM presented their initial Hydrological Review on 23 July 2013, concluding that:

- The Frenchmans Creek XP-Rafts model appeared to be overestimating design flows, by up to double in the 1% AEP event, in comparison to a rational method and Watershed Bounded Network Model (WBNM).
- The Limestone Creek XP-Rafts model was representing peak flows reasonably well in comparison to the rational method and WBNM checks completed.

BMT WBM presented their interim Hydraulic Model Review on 31 July 2013, concluding that:

- The 5m grid resolution may not be representing the creek channel adequately, in areas where the channel is less than 10m wide. This is more prevalent in more frequent events, where flow widths are reduced.
- The location of some local inflows may need to be reviewed, to ensure the reporting of flood extents is ‘not ambiguous’.
- Downstream model boundaries are based on 18% AEP Fitzroy River flood levels. Consideration of Mean High Water Springs (MHWS) and Highest Astronomical Tide (HAT) may be more appropriate. Sensitivity analysis for the 39% AEP Frenchmans Creek event showed reduced flood levels of 100mm to 200mm across the lower floodplain area.
- Generally hydraulic structures were represented adequately, however there were some key structures not included in the TUFLOW model.
- Hydraulic roughness was represented through a spatially varying roughness layer. Generally Manning’s roughness values were within accepted industry ranges, however the riparian corridor (floodplain extent) and creek channel roughness values were found to be unusually high. Sensitivity analysis for the Frenchmans Creek model showed reductions in flood levels of between 100mm and 200mm for the 39% AEP event and between 200mm and 500mm for the 1% AEP event.

- Model stability in both the one-dimensional and two-dimensional domains was found to be acceptable.

RRC, Aurecon and BMT WBM undertook two technical workshops as follows:

- August 2013 à Discussion and review of model recalibration and design event modelling, following initial peer review findings provided by BMT WBM.
- December 2013 à Final meeting to discuss final recalibration results.

Following the workshops and consequence model updates completed by Aurecon, BMT WBM presented their final Hydrological Review on 4 February 2014. This concluded that the XP-Rafts hydrologic models were now considered acceptable by BMT WBM and therefore appropriate for use in the Local Catchments study.

3.2.5 SRFL Hydraulic Model Development (AECOM, 2014)

The South Rockhampton Flood Levee (SRFL) planning and detailed design project was completed by AECOM throughout 2014, and included assessment of Fitzroy River and interior drainage flooding impacts as a result of the proposed SRFL scheme. The hydraulic component of the project involved development of two separate hydraulic models; the first being in relation to riverine flooding and the second to local catchment events.

The Fitzroy River model results have been used to inform tailwater levels during coincident events. Reference should be made to the SRFL Hydraulic Model Development and Comparison report (AECOM, 2014) for further details.

3.3 Tidal Data

Historic tidal data used in the January 2013 and February 2015 validation events was obtained from open data made available by Maritime Safety Queensland. Historical records are available for the inclusive period of 1996-2016 at Port Alma. Adjustments to the timing and levels were made in order to estimate corresponding levels in the Fitzroy River at Rockhampton.

It is noted that tidal data for the 2017 event was not yet available from Maritime Safety Queensland and hence predicted tidal levels for the event were applied.

For design events and sensitivities with no Fitzroy River flooding, tailwater levels used during this investigation were based on the MHWS level at Rockhampton (2.66m AHD). The MHWS level was sourced from the 2014 QLD Tide Tables book (MSQ, 2014).

3.4 Topographic Data

The topographical information used for the Frenchmans and Thozets Creek Local Catchment model was provided by RRC in the form of LiDAR survey, which was undertaken between 30 September 2015 and 23 January 2016 by AAM Pty Ltd. The LiDAR points were used to generate a base Digital Elevation Model (DEM) with a grid spacing of 1m.

It is stated in the report provided by AAM Pty Ltd that the Horizontal Spatial Accuracy is estimated to be ±0.40m and the Vertical Spatial Accuracy is estimated to be ±0.15m, on clear open ground. Council undertook elevation checks and commented that the accuracy of the LiDAR is within the ±0.15m vertical tolerance on hard surfaces.

Creek channel cross-section survey was also included where the LiDAR was expected to misrepresent the terrain. Comparisons between creek cross sections using the 2009 and 2016 topographic datasets were made to provide an indication of where the creek channel had changed. This comparison was used in conjunction with the latest imagery in order to pinpoint areas which showed both differences in bed level and dense vegetation. These areas were subsequently inspected by AECOM staff to confirm the need for survey.

Final areas were nominated for surveyed cross-sections which revealed more than 1m vertical discrepancies in some instances (in comparison to the LiDAR). Detailed comparison of the LiDAR and surveyed cross-sections are included in Appendix B.

Due to the dynamic geomorphic behaviour of Frenchmans and Thozets Creek, large differences in channel elevations are evident between topographic datasets of different time periods. As such, ideal circumstances would call for topographic data preceding significant events in an attempt to best represent the creek conveyance at the time of the event.

With this in mind, the 2016 LiDAR 1m DEM (with inclusion of ground survey) is expected to provide good representation of the creek channel for the March 2017 event. The latest DEM is also expected to be suitable for the 2015 event, although less relevant for the 2013 event.

3.5 Aerial Photography

Aerial photography of Rockhampton City and surrounding region was supplied by RRC. The dataset was supplied as a single mosaic image which covers the extents of the study area. The imagery was captured in September 2016 at a resolution of 10cm intervals.

3.6 Stormwater Infrastructure Network Database

Drainage asset information was supplied by RRC in the form of GIS layers containing location, size and invert data for most culvert, pit and pipe assets. A gap analysis of the database revealed significant proportions of pipe inverts and pit inlet dimensions were missing. RRC undertook an extensive desktop and field investigation to further improve the quality of the stormwater database, however some data gaps remained. Where stormwater infrastructure data was absent, details were estimated using the following assumptions:

- All upstream invert levels are at a higher elevation than downstream invert levels.
- Congruent pipe slopes between known inverts.
- No fall across pit structures.
- Minimum depth of cover of 600mm, where practicable.
- Upstream pipe diameter matched downstream pipe diameter

Given the lack of pit inlet dimensions, nominal dimensions of 900x600mm were assigned to all pits digitised within the hydraulic model. Sensitivity analysis involving increasing the dimensions of all pits to 2000x2000mm resulted in minimal change in flood levels or extents. This was expected as the existing pipe capacity is commonly the limiting component of the stormwater network.

It is noted stormwater network upgrades have been undertaken recently by RRC within the Frenchmans Creek catchment. Upgrades to the network associated with Stage 1 of the McLeod Park Drainage Scheme were already included within the Stormwater Network Database provided by Council. The 2016 LiDAR also captured upgrades to open channel downstream of the park in Stage 1 of the scheme.

Stage 2 of the scheme involved the construction of a new underground stormwater pipe from Simpson Street down through Pine Street and into Moores Creek. Design drawings were provided by Council for these works and have been included in the model.

3.7 Hydraulic Structures

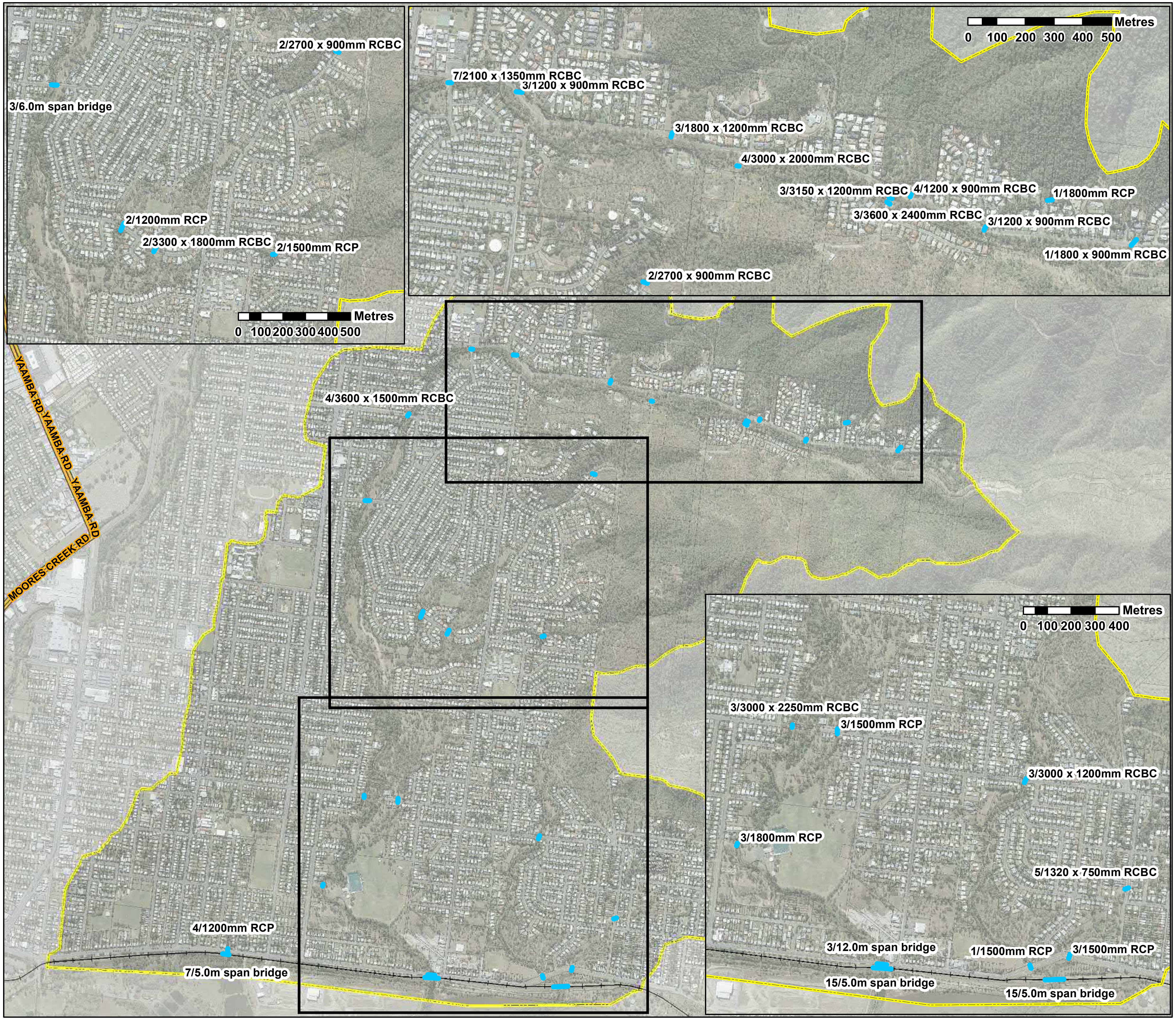
Identification of hydraulic structures associated with the major road / rail crossings within the study area was completed using a combination of Council's stormwater infrastructure network database and site visits.

Approximately 60 culverts and 5 bridge structures were identified along Frenchmans and Thozets Creeks. Minor structures which were not expected to convey significant flows or connect key flow paths were not incorporated in the hydraulic model.

Table 2 presents a list of major structures within the study area which were incorporated into the hydraulic model; these are shown spatially in Figure 5. Most culvert structures are represented in a 1-dimensional scheme, with bridges and some key culvert crossings represented within the 2-dimensional domain as layered flow constrictions.

Table 2 Key Hydraulic Structures Incorporated to the Model

Drainage Structure	Configuration	Model Representation
Bridges		
Honour Street	3/6.0m span bridge	2D
Lakes Creek Road	3/12.0m span bridge	2D
Yeppoon Branch Railway (West of Frenchmans Creek)	7/5.0m span bridge	2D
Yeppoon Branch Railway (Frenchmans Creek)	15/5.0m span bridge	2D
Yeppoon Branch Railway (Thozets Creek)	15/5.0m span bridge	2D
Major Culverts		
Access off Bloxsom Street	2/1500mm RCP	1D
Access off Frenchville Road	4/3000x2000mm RCBC	1D
Access off Lange Street	1/1800mm RCP	1D
Access off Water Street	3/1800mm RCP	1D
Beasley Street	7/2100x1350mm RCBC	2D
Elphinstone Street	3/3000x2250mm RCBC	1D
Elphinstone Street	3/1500mm RCP	1D
Frenchville Road	3/1800x1200mm RCBC	1D
Frenchville Road	1/1800x900mm RCBC	1D
Frenchville Road	4/1200x900mm RCBC	1D
Frenchville Road	3/1200 x 900mm RCBC	1D
Frenchville Road	3/1200 x 900mm RCBC	1D
Ironbark Terrace	3/3600x2400mm RCBC	1D
Ironbark Terrace	3/3150x1200mm RCBC	1D
Kerrigan Street	4/3600x1500mm RCBC	2D
Lakes Creek Road	1/1500mm RCP	1D
Lakes Creek Road	3/1500mm RCP	1D
Lakes Creek Road	4/1200mm RCP	1D
Pilbeam Drive	Arch Culvert	1D
Rockonia Road	3/3000x1200mm RCBC	1D
Stack Street	5/1320x750mm RCBC	1D
Wigginton Street	2/3300x1800mm RCBC	1D
Wigginton Street	2/1200mm RCP	1D
Woodland Drive	2/2700x900mm RCBC	1D



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LEGEND

- Key Hydraulic Structures
- Highways
- Railway Lines
- Cadastre
- Hydraulic Model Extent

DRAFT

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Results Filtering:
75mm Min. Depth
100m² Min. Area

Frenchmans Creek & Thozets Creek Model

Location of Key Hydraulic Structures

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	20/06/2017
VERSION:	1

Figure 5

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\Figure 5 Location of Key Hydraulic Structures.mxd

3.8 Site Inspection

A site inspection was carried out by AECOM staff in May 2017 and was used to capture and check structure details, hydraulic roughness parameters and catchment details for input to the modelling.

3.9 Historical Rainfall Data

Historical rainfall records for 2013, 2015 and 2017 events were acquired from BoM and provided by Council in the form of 1-minute intervals (SCADA) for the range of rainfall stations shown in Figure 3. A list of rainfall gauging stations, their locations, type of data and applicable events is provided in Table 3, where:

- ✓ à reliable data;
- ⊘ à unreliable data; and
- ✗ à no available data.

Table 3 Summary of Rainfall Data used in the Study

Station Number	Site Name	Data Type	Operating Authority	2013 Flood Event	2015 Flood Event	2017 Flood Event
039083	Rockhampton Aero	1-Minute Intervals	BoM	✓	✓	✓
79	Agnes Street Reservoir	1-Minute Intervals	RRC	✗	⊘	✓
02	Glenmore WTP	1-Minute Intervals	RRC	✗	⊘	✓
25	Rogar Avenue Reservoir	1-Minute Intervals	RRC	✗	⊘	✓
42	West Rockhampton STP	1-Minute Intervals	RRC	✗	⊘	✓
14	Yaamba Road Reservoir	1-Minute Intervals	RRC	✗	⊘	✓
-	Lucas Street Reservoir	1-Minute Intervals	RRC	✗	✗	✓
-	Serocold Street	30-Minute Intervals	Private	✓	✓	✗

3.10 Historical Flood Records

3.10.1 Anecdotal Data

Anecdotal flood level data has been collected by RRC following the January 2013 and March 2015 rain events. Generally observed flood levels and extents were recorded from debris marks, water stains and/or resident observations. It is understood that the 2013 and 2015 events anecdotal data was collected by RRC using a Real Time Kinematic (RTK) satellite navigation device.

The anecdotal data locations are shown in Figure 6 for 2015 and Figure 7 for 2013, with the collated data presented in Table 4 for 2015 and Table 5 for 2013.

As can be seen from Table 4 and Table 5, many of the heights relate to debris marks, with some indicating the height of remaining debris post flood event. The use of debris presents limitations surrounding the accuracy of the data, noting that the height and extent of debris marks are highly variable depending on the type of debris, flow depth and other external factors such as surface turbulence and man-made waves. As such, each event's dataset has been reviewed in terms of logical locations and recorded levels in an attempt to ensure erroneous and/or unusable records do not skew the assessment and ultimately impact chosen model parameters.

Table 4 2015 Anecdotal Data

2015 Event				
Point ID	Easting (m)	Northing (m)	Peak Flood Level (mAHD)	Comments
15FRE-1	249492.8	7416266.1	52.05	Debris on ground
15FRE-2	249061.8	7416402.9	43.85	Owner observation
15FRE-3	248790.1	7416247.2	39.51	Mark on shed
15FRE-4	248770.3	7416205.0	38.36	Mark on shed
15FRE-5	248552.3	7415853.4	32.31	Resident observation
15FRE-6	248603.1	7415874.2	32.79	Debris mark
15FRE-7	248504.1	7415901.8	34.11	Overland observation owner
15FRE-8	248540.0	7416015.7	35.30	Mark on fence
15FRE-9	248555.8	7416018.9	35.45	Mark on blind wooden wall
15FRE-10	248586.5	7416042.5	35.59	Mark on blind wooden wall
15FRE-11	248628.0	7416099.2	36.42	Owner observation
15FRE-12	248418.4	7415474.3	27.69	Debris on ground
15FRE-13	248391.8	7415666.8	29.91	Level on top of debris verified
15FRE-14	249029.1	7416368.6	43.16	Level on top of debris verified
15FRE-15	249016.2	7416394.3	43.22	Mark on ground advised
15FRE-16	249141.5	7416422.2	44.60	Mark on ground advised
15FRE-18	249160.7	7416373.9	46.39	Mark on ground advised
15FRE-19	248308.2	7413450.2	7.27	Mark on wall
15FRE-20	248320.5	7413392.7	6.73	Mark on wall
15THO-1	249147.4	7413266.0	8.34	Mark on wooden fence
15THO-2	249104.0	7413472.1	10.15	Level advised
15THO-3	249206.9	7413338.6	9.06	Mark on ground
15THO-4	249245.1	7413506.7	10.82	Debris on ground
15THO-5	249285.7	7413592.5	11.73	Debris on ground
15THO-6	249422.6	7412952.6	5.78	Debris on ground
15THO-7	249409.2	7413970.4	18.43	Debris on ground
15THO-8	249420.7	7413827.1	15.92	Top of debris
15THO-9	249435.9	7414212.9	23.03	Top of debris on ground
15THO-10	249529.7	7414319.0	26.22	Top of debris on ground

Given the relative consistency of anecdotal evidence, a blanket ±0.30m allowance has been adopted for comparison between anecdotal and modelled flood levels.

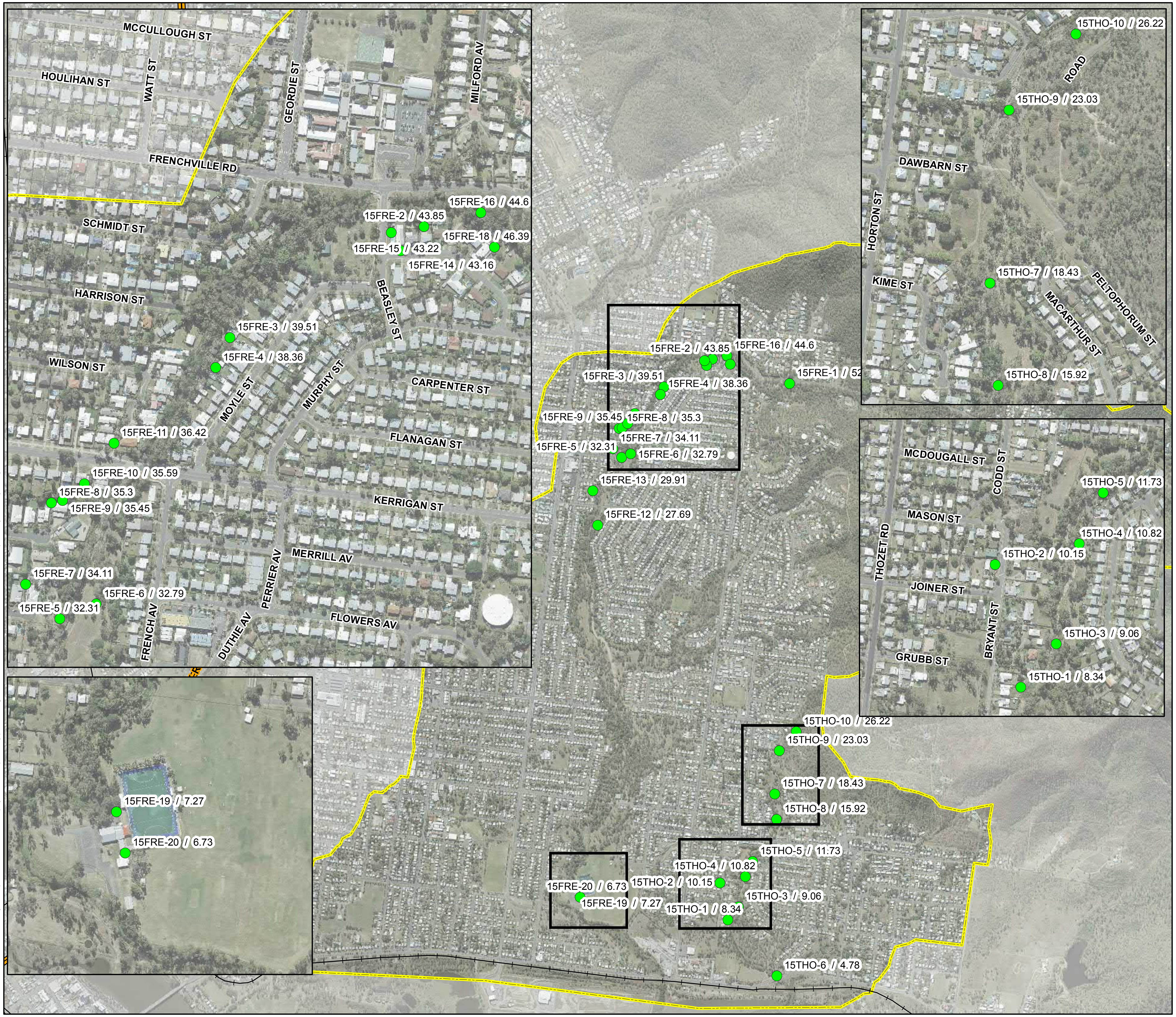
Table 5 2013 Anecdotal Data

2013 Event				
Point ID	Easting (m)	Northing (m)	Peak Flood Level (mAHD)	Comments
13THO-1	249401.8	7413741.3	-	Debris Edge
13THO-2	249302.9	7413726.9	-	Water extent explained by Res
13THO-3	249376.7	7413725.0	-	Debris Edge
13THO-4	249363.8	7413679.5	13.53	Debris Edge
13THO-5	249404.8	7413719.5	-	Debris Edge
13THO-6	249330.0	7413707.4	-	Water height explained by Res
13FRE-4	248895.2	7416287.4	40.85	Water extent based on photo
13FRE-5	248866.3	7416287.6	-	Water height shown by Resident
13FRE-6	248684.7	7416116.0	-	Debris Edge
13FRE-7	248668.8	7416102.1	-	Debris Edge
13FRE-8	248685.1	7416083.5	-	Debris Edge
13FRE-9	248581.3	7416057.7	35.06	Water height shown by Resident
13FRE-10	248552.0	7416033.5	34.79	Water Mark on Shed
13FRE-11	248554.6	7416021.6	34.94	Water Mark 1 on Fence
13FRE-13	248569.6	7416021.0	34.98	Water Mark on Fence
13FRE-14	248567.8	7416013.4	34.53	Water Mark on Structure
13FRE-15	248617.3	7415989.3	34.15	Debris Top Centre
13FRE-16	248623.6	7415979.9	-	Debris Top Centre
13FRE-17	248622.9	7415979.4	-	Debris Top Centre
13FRE-18	248590.0	7415939.8	32.77	Debris mark on tree
13FRE-19	248440.2	7415606.2	-	Debris Top Centre
13FRE-20	248427.8	7415547.0	-	Debris Edge
13FRE-22	248299.5	7415342.3	-	Resident description of extent
13FRE-23	248309.6	7415335.3	24.65	Water Mark on Structure
13FRE-24	248468.0	7414781.5	-	Debris Edge
13FRE-25	248449.5	7414769.1	-	Debris Edge
13FRE-26	248508.2	7414768.0	-	Debris Edge
13FRE-27	248518.6	7414747.7	-	Debris Edge
13FRE-29	248546.3	7414718.2	-	Debris Edge
13FRE-30	248565.3	7414688.7	-	Debris Edge
13FRE-31	248571.3	7414688.3	-	Debris Edge
13FRE-32	248551.8	7414609.4	-	Debris Edge
13FRE-38	248413.9	7413927.1	-	Debris Edge
13FRE-39	248588.0	7413924.0	-	Debris Edge

2013 Event				
Point ID	Easting (m)	Northing (m)	Peak Flood Level (mAHD)	Comments
13FRE-40	248596.0	7413923.6	-	Debris Edge
13FRE-42	248563.8	7413802.0	-	Debris Top Centre
13FRE-43	248559.5	7413798.7	-	Debris Top Centre
13FRE-44	248547.2	7413753.7	-	Debris Top Centre

Anecdotal records for the January 2013 event were obtained in May 2013 based on images, indicative extents from residents and remaining debris. Due to the inconsistency of anecdotal evidence, a review of the data was undertaken in which Debris Top Centre points (aside from those indicating extents) were excluded from the assessment. As such, a blanket ±0.50m range has been adopted for comparison between anecdotal and modelled flood levels.

Debris Edge points indicating peak flood extents have been maintained in order to assess the model performance based on peak modelled extent. The allowable tolerance for the flood extent has been adopted as 3m which is the size of a single cell within the model’s Cartesian grid.



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LEGEND

Anecdotal Data Locations
(Label - mAHD)

- 2015
- Highways
- Railway Lines
- Hydraulic Model Extent

Data Sources:

DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Frenchmans Creek & Thozets Creek Model

Anecdotal Record Locations (2015)

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	20/06/2017
VERSION:	2

Figure 6

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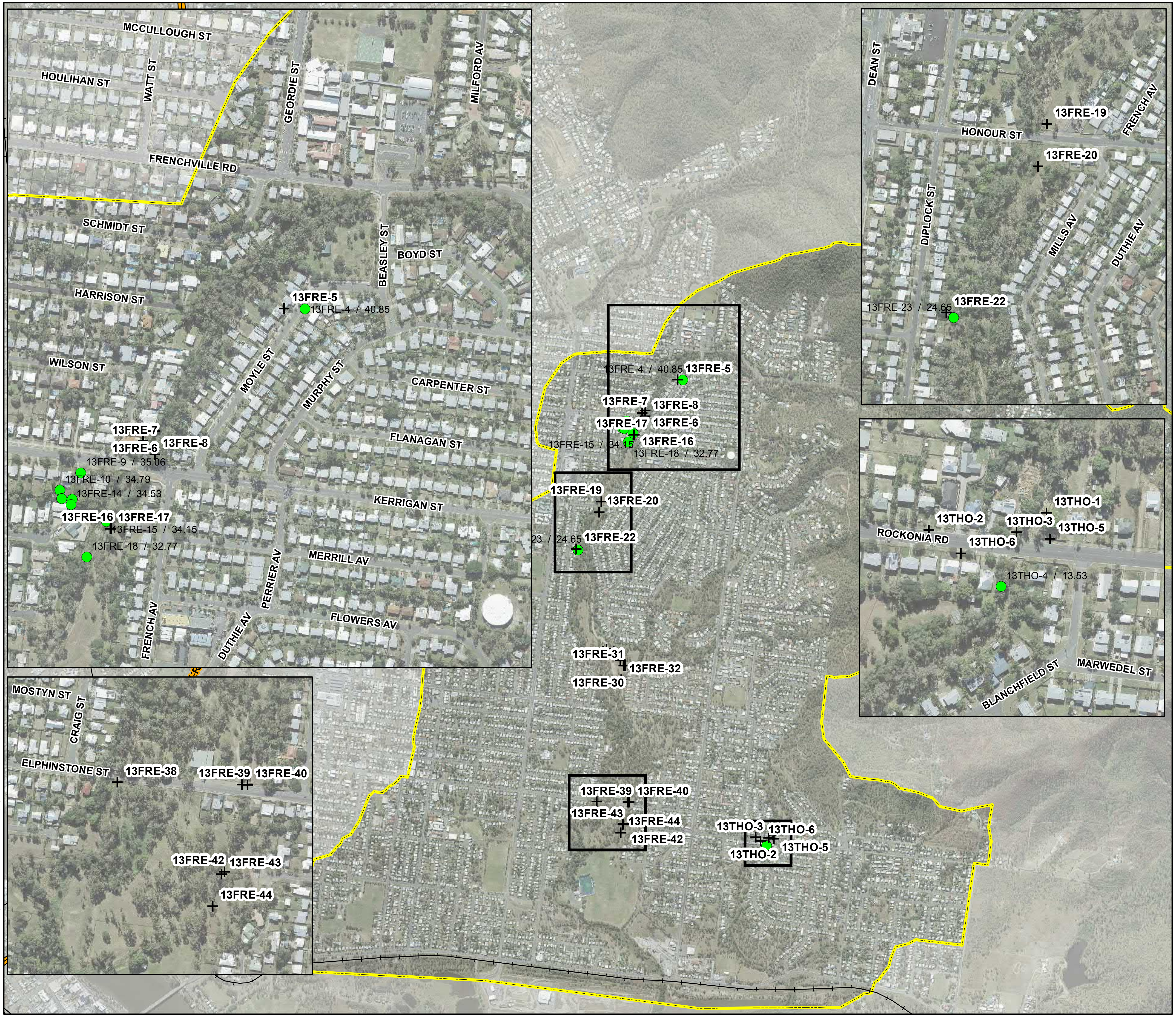

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LEGEND

- Anecdotal Data Extents
- Anecdotal Data Levels
- Highways
- Railway Lines
- Hydraulic Model Extent

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Frenchmans Creek & Thozets Creek Model

Anecdotal Record Locations (2013)

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	21/07/2017
VERSION:	2

Figure 7

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\Figure 7 2013 Anecdotal Data Locations.mxd

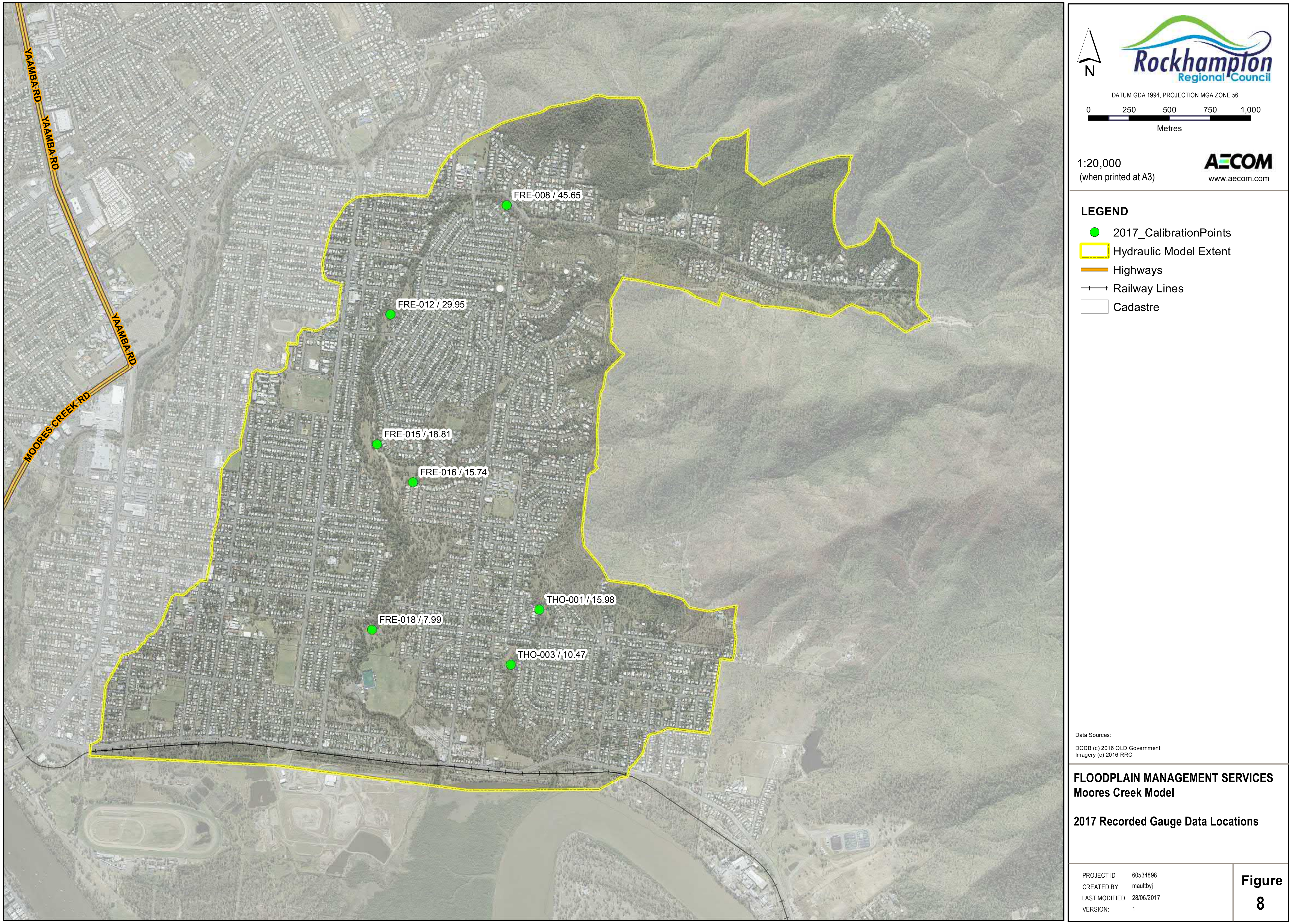
3.10.2 Recorded Data

Recorded data at key locations along Frenchmans and Thozets Creeks were provided by Council for the 2017 event. The data included the locations and maximum readings of gauges shown in Figure 8.

Table 6 presents the spatial locations and peak heights of Council's gauges within the Frenchmans and Thozets Creeks Local Catchment model for the 2017 event. Adopted validation tolerances in the 2017 event were ±0.15m.

Table 6 Recorded Gauge Data

Gauge Label	Point ID	Easting (m)	Northing (m)	Zero Gauge Level (mAHD)	Peak Gauge Depth (m)
Macarthur Street	THO-001	249410.9	7413887.2	15.94	0.04
Blanchfield Street	THO-003	249233.4	7413547.0	10.09	0.38
Frenchville Road	FRE-008	249208.3	7416378.6	45.58	0.07
Honour Street	FRE-012	248493.3	7415706.6	29.43	0.52
Halford Street	FRE-015	248409.6	7414905.4	18.76	0.05
Kavanagh Cr	FRE-016	248631.0	7414672.1	15.23	0.51
Tooker St	FRE-018	248379.3	7413763.2	6.58	1.41



FLOODPLAIN MANAGEMENT SERVICES
Moores Creek Model

2017 Recorded Gauge Data Locations

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	28/06/2017
VERSION:	1

Figure 8

4.0 Hydrologic Inputs

4.1 Runoff-Routing Approach

4.1.1 Overview

An XP-RAFTS runoff-routing hydrologic model has previously been developed for a northern portion of both Frenchmans and Thozets Creek catchments (Aurecon, 2014) and was provided by RRC. The models compute the design discharge hydrographs from this catchment by modelling catchment flows using Laurenson’s non-linear routing methods. XP-RAFTS has been widely used throughout Queensland and is an accepted model to quantify flood flows. The models predict flows for urban and rural catchments and are well suited to modelling this catchment.

Use of the existing XP-RAFTS model was necessary as the hydraulic model did not cover the entire catchment, as can be seen by Figure 9 and therefore the direct rainfall approach could not estimate runoff from the portion of the catchment that was outside the hydraulic model extent.

4.1.2 Model Configuration

The upper sections of both Frenchmans and Thozets Creek catchments were delineated using a GIS interface based on the available topographic data. The portion of the total catchment that was external to the hydraulic model extents was subdivided into 15 sub-catchments according to tributary network, catchment topography, land use and location where the hydrograph would be applied as a boundary condition to the hydraulic model.

Each sub-catchment (as specified by Aurecon, 2014) was described in the XP-RAFTS model by specifying:

- Sub-catchment areas (in hectares).
- Average equal area sub-catchment slope (in %).
- Sub-catchment roughness.
- Fraction Impervious.

The roughness and fraction impervious factors were reviewed and no changes were made to those adopted from the existing Frenchmans and Thozets Creeks Hydrologic Models (Aurecon, 2014).

4.2 Direct Rainfall Approach

4.2.1 Overview

In traditional flood modelling, separate hydrological and hydraulic models are constructed. The hydrological model converts the rainfall within a sub-catchment into a peak flow hydrograph. This flow hydrograph is then applied to the hydraulic model, which estimates flood behaviour across the study area.

In the direct rainfall approach, the hydrological model is either partially or completely removed from the process. The hydrological routing is undertaken in the two dimensional hydraulic model domain, rather than in a lumped hydrological package.

The direct rainfall method involves the application of rainfall directly to the two dimensional model domain. The rainfall depth in a particular timestep is applied to each individual hydraulic model grid cell, and the two dimensional model calculates the runoff from this particular cell.

AR&R Revision Project 15 notes the following advantages of direct rainfall modelling:

- Use of the direct rainfall approach can negate the need to develop and calibrate a separate hydrological model, thus reducing overall model setup time.
- Assumptions on catchment outlet locations are not required. When a traditional hydrological model is utilised, an assumption is required on where the application of catchment outflows are made to the hydraulic model.

- Assumptions on catchment delineation are not required. Flow movement is determined by 2D model topography and hydraulic principles, rather than on the sub catchment discretisation, which is sometimes based on best judgement and can be difficult to define in flat terrains.
- Cross catchment flow is facilitated in the model. In flat catchments, flow can cross a catchment boundary during higher rainfall events. This can be difficult to represent in a traditional hydrological model.
- Overland flow is incorporated directly. Overland flow models in traditional hydrological packages require a significant number of small sub-catchments, to provide sufficient flow information to be applied to a hydraulic model.

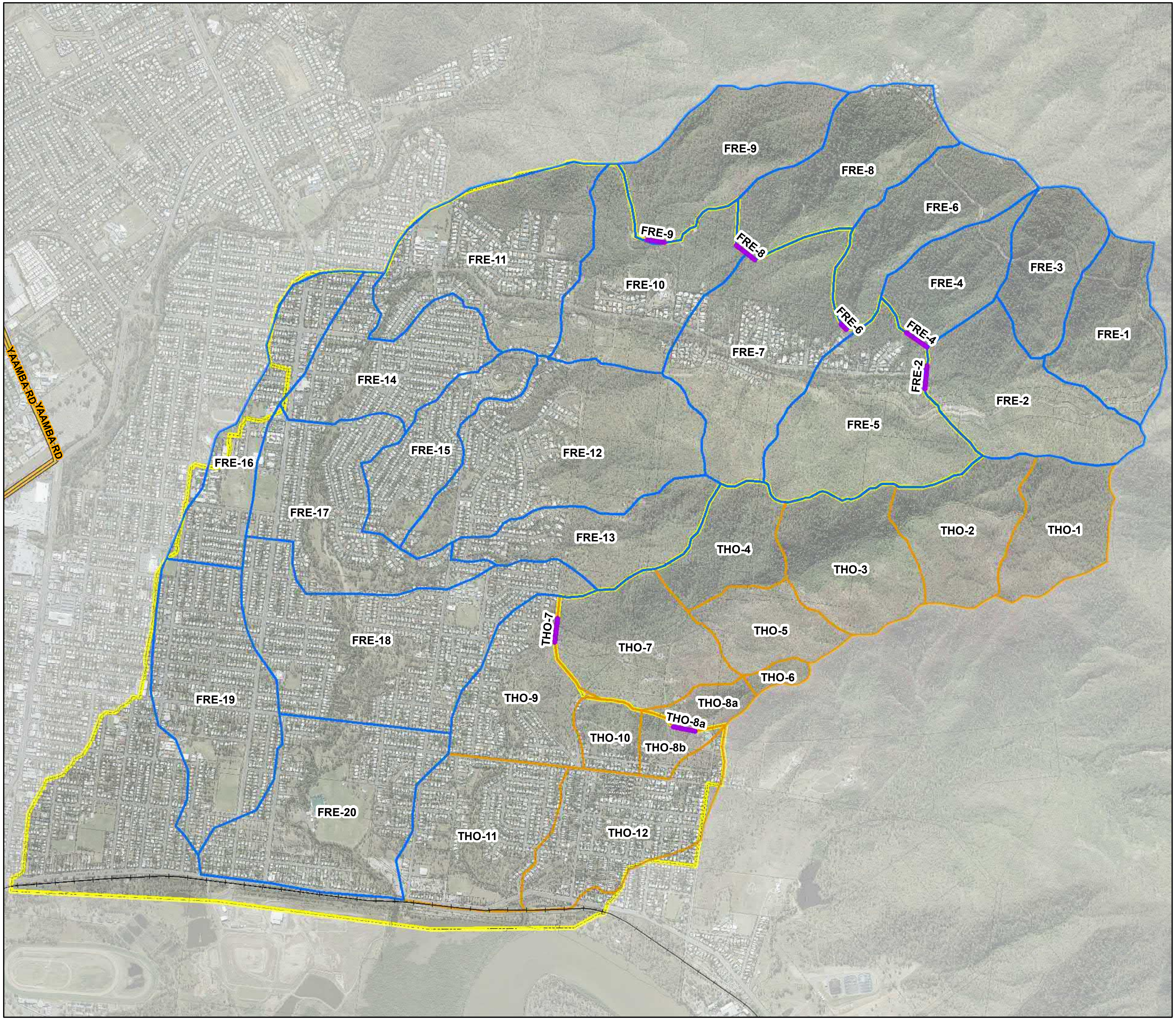
There are also several disadvantages associated with the use of the direct rainfall approach:

- Direct rainfall is a new technique, with limited calibration or verification to gauged data.
- The rain-on-grid approach can potentially increase hydraulic model run times.
- Requires digital terrain information. Depending on the accuracy of the results required, there may be a need for extensive survey data, such as aerial survey data.
- Insufficient resolution of smaller flow paths may impact upon timing. Routing of the rainfall applied over the 2D model domain occurs according to the representation of the flow paths by the 2D model.
- The shallow flows generated in the direct rainfall approach may be outside the typical range where Manning’s ‘n’ roughness parameters are utilised.

4.2.2 Approach

Two dimensional rainfall time series for each design storm event were created to represent the local precipitation for the study area. The rainfall excess was calculated by applying initial and continuing losses to the design rainfall to represent infiltration and storage of runoff in surface depressions. Losses chosen for this project are discussed in Section 4.4.5.

The time series of rainfall were developed for a range of design events by applying a temporal pattern in accordance with AR&R 1987 for magnitudes of 1EY up to the PMP event (total of ten events).



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LEGEND

- Highways
- Railway Lines
- Inflow Boundary
- Thozets Creek Hydrologic Model Subcatchments
- Frenchmans Creek Hydrologic Model Subcatchments
- Cadastre
- Hydraulic Model Extent

Flood results are based on local catchment events

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Results Filtering:
75mm Min. Depth
100m² Min. Area

Frenchmans & Thozets Creeks Model

Hydrologic and Hydraulic Model Layout

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	21/07/2017
VERSION:	1

Figure 9

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\Figure 9 Hydrologic and Hydraulic Model Extents.mxd

4.3 Historic Rainfall Data

Historic rainfall records for the 2013, 2015 and 2017 events were obtained for the Rockhampton Aero pluviograph station located approximately 6km southwest of the study area. Records at Council-managed gauges were available for the 2015 and 2017 events, although the incremental 2015 data was noted as erroneous due to a suspected power failure. Records from the privately-owned gauge at Serocold Street were obtained by Council for the 2013 and 2015 events. Data was not available from the Serocold Street gauge for the 2017 event. Simulated rainfall plots of the abovementioned events are included in subsequent sections.

4.3.1 2013 Event – Ex-TC Oswald

Tropical Cyclone Oswald passed over parts of Queensland and New South Wales towards the end of January 2013, reducing in intensity to a tropical low system before reaching Rockhampton. Ex-TC Oswald resulted in significant precipitation over a number of days across Rockhampton, resulting in local catchment flooding followed by a Fitzroy River flood peak of 8.61m as a result of rainfall in the Fitzroy River catchment. The timeseries of rainfall data from the Serocold Street rainfall gauge is shown in Figure 10.

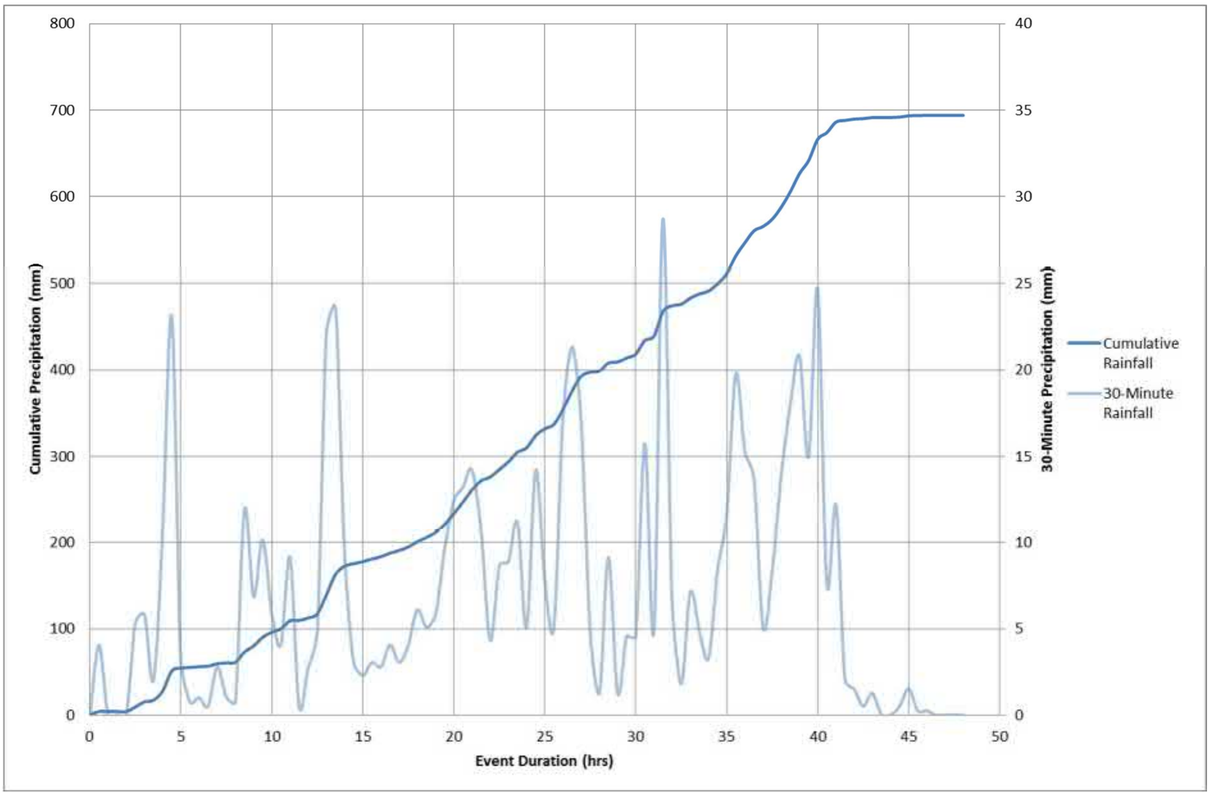


Figure 10 2013 Event Rainfall (Serocold Street)

Records from Serocold Street revealed 693.9mm of rain fell within a 46 hour period. It is noted that the rainfall distribution varied between active gauges during the 2013 event, as detailed below in Table 7. Given that the Serocold Street gauge is situated just outside the Frenchmans and Thozets Creeks catchment, the 30-minute rainfall data will be used for the 2013 validation event. It is noted that the Serocold Street gauge data was also used in the previous study.

Table 7 Summary of 2013 Event Rainfall Data

Total Rainfall (mm)		Difference (mm)	Difference	Adopted Rainfall
Rockhampton Aero	Serocold Street			
488.2	700.5	212.3	43%	Serocold Street

4.3.2 2015 Event – TC Marcia

Tropical Cyclone Marcia crossed the east coast of Queensland as a category 5 system on the 20th of February, 2015. The system weakened to a category 3 cyclone before delivering a total rainfall depth of 245.0mm within the North Rockhampton catchment, with the peak 22 hour period totalling 225.0mm.

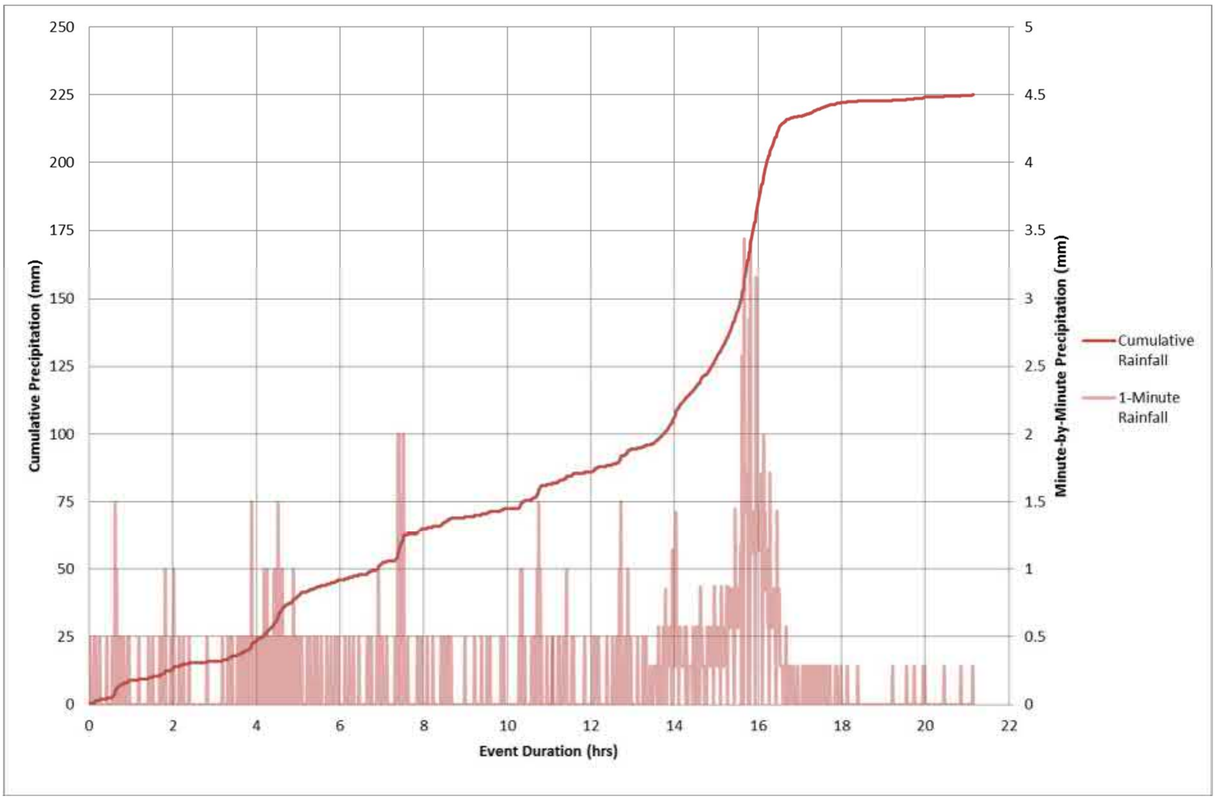


Figure 11 2015 Event Rainfall (Serocold Street)

Rainfall depths recorded at Serocold Street totalled 245mm, approximately 19% more than that of the Rockhampton Aero. The timeseries of rainfall data at Serocold Street for the 2015 event is shown in Figure 11. A summary of the available rainfall data is included below in Table 8.

Table 8 Summary of 2015 Event Rainfall Data

Rainfall Gauge	Total Rainfall (mm)	Difference to Rockhampton Aero (mm)	Difference to Rockhampton Aero (%)
Rockhampton Aero	206.2	-	-
Serocold Street	245.0	38.8	19%
West Rockhampton STP	329.0	122.8	60%
Agnes Street Reservoir	325.0	118.4	57%
Rogar Avenue Reservoir	309.0	102.4	50%
Glenmore WTP	167.7	-38.9	-19%
Yaamba Road Reservoir	245.0	38.8	19%

It was noted that West Rockhampton STP, Agnes Street Reservoir, Rogar Avenue Reservoir, Glenmore WTP and Yaamba Road Reservoir datasets were potentially erratic due to power failure. With this in mind, the Serocold Street rainfall data was used for the 2015 calibration event.

4.3.3 2017 Event – Ex-TC Debbie

Ex-TC Debbie moved across the Fitzroy Catchment and Rockhampton in late March, 2017. Significant rainfall triggered a major Fitzroy River flood peak of 8.90m at Rockhampton, preceded by a local catchment flood event as a result of the 308.0mm of rain across North Rockhampton.

Detailed 1-minute interval records were available for the Rogar Avenue Reservoir gauge. The location of the gauge is within the Frenchmans Creek catchment and is the closest available source of rainfall data for the Frenchmans and Thozets Creek catchments. As such, the Rogar Avenue Reservoir rainfall data was adopted. The time series of rainfall data at Rogar Avenue Reservoir for the 2017 event is shown in Figure 12.

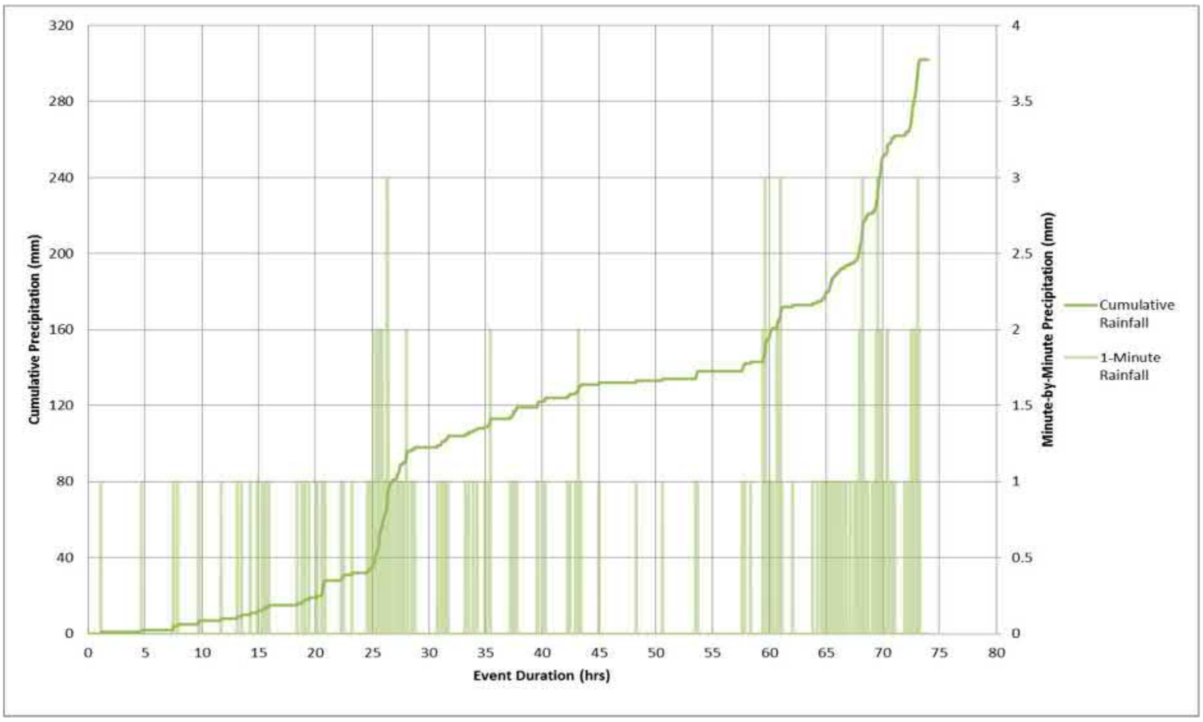


Figure 12 2017 Event Rainfall (Rogar Avenue Reservoir)

Total rainfall depths between the gauges in North Rockhampton showed recorded rainfall depths at Rogar Avenue were significantly higher than those situated further north and west of the catchment.

Table 9 Summary of 2017 Event Rainfall Data

Rainfall Gauge	Total Rainfall (mm)	Difference to Rockhampton Aero (mm)	Difference to Rockhampton Aero (%)
Rockhampton Aero	186.6	-	-
West Rockhampton STP	203.0	16.4	9%
Agnes Street Reservoir	204.5	17.9	10%
Rogar Avenue Reservoir	308.0	121.4	65%
Glenmore WTP	199.7	13.1	7%
Yaamba Road Reservoir	211.0	24.4	13%
Lucas Street Reservoir	200.0	13.4	7%

As the Rogar Avenue Reservoir, is situated within the Frenchmans and Thozets Creeks model area, this rainfall data was adopted for the 2017 validation event.

4.4 Design Rainfall Data

4.4.1 IFD Parameters

Design rainfall data was sourced from the Bureau of Meteorology (BoM) online IFD tool (bom.gov.au/water/designRainfalls/ifd-arr87/index.shtml). IFD parameters required to determine rainfalls for events not previously modelled were sourced using a single set of parameters, derived at the location (150.500 E, 23.300 S). The IFD input data set obtained is shown in Table 10.

Table 10 Adopted IFD Input Parameters

Parameter	Value
1 hour, 2 year intensity (mm/hr)	44.3
12 hour, 2 year intensity (mm/hr)	9.1
72 hour, 2 year intensity (mm/hr)	2.7
1 hour, 50 year intensity (mm/hr)	90.9
12 hour, 50 year intensity (mm/hr)	19.6
72 hour, 50 year intensity (mm/hr)	6.9
Average Regional Skewness	0.21
Geographic Factor, F2	4.22
Geographic Factor, F50	17.72

Standard techniques from AR&R 87 were used to determine rainfall intensities up to the 12 hour duration for the 1EY (exceedance per year), and 39%, 18%, 10%, 5%, 2% and 1% AEP events. The calculated IFD data is shown in Table 11.

Table 11 Intensity Frequency Duration Data for Rockhampton

Duration (hr)	Intensity (mm/hr)						
	1EY	39% AEP	18% AEP	10% AEP	5% AEP	2% AEP	1% AEP
1	34.2	44.3	57.3	65.4	76.2	90.9	103.0
1.5	26.8	34.8	45.0	51.3	59.8	71.4	80.6
2	22.4	29.1	37.6	43.0	50.1	59.8	67.5
3	17.3	22.4	29.1	33.2	38.8	46.4	52.3
6	11.0	14.3	18.6	21.3	25.0	29.9	33.8
12	7.0	9.1	12.0	13.9	16.3	19.6	22.3

4.4.2 Temporal Pattern

Temporal patterns for Zone 3 were adopted for events up to the 0.2% AEP using the standard methodology outlined in AR&R (1987).

Temporal pattern for the Probable Maximum Precipitation (PMP) event were sourced from data provided with the Generalised Short Duration Method (GSDM) guidebook (refer Section 4.4.4).

4.4.3 Areal Reduction Factors

The IFD rainfall values derived in Section 4.4.1 are applicable strictly only to one point; however AR&R state that they may be taken to represent IFD values over a small area. No reduction of the IFD rainfall was undertaken due to the relatively small catchment areas associated with this investigation.

4.4.4 Probable Maximum Precipitation Event

The PMP has been defined by the World Meteorological Organisation (2009) as '*the greatest depth of precipitation for a given duration, meteorologically possible for a given size storm area at a particular location at a particular time of year*'.

The PMP event results in a Probable Maximum Flood (PMF) event. This is a theoretical event which is very unlikely to ever occur within any given catchment. The PMF event is typically used in design of hydraulic structures, such as dams. Its most common use is in design of dam spillways to minimise the risk of overtopping of a dam and minimise the likelihood of dam failure. Other than this practical use, it is used to provide an indication of the largest flood extents expected within any given catchment and also forms the upper bound within flood damages assessments.

PMF behaviours can be used by emergency management agencies in their understanding of and planning for flood events.

The Generalised Short-Duration Method (GSDM), as revised in 2003, was applied to derive estimates of PMP for short duration storms. The GSDM applies to catchments up to 1,000 km^2 in area and durations up to 6 hours, which makes the method applicable to the Frenchmans and Thozets Creek Local Catchment Study which has a catchment area of approximately 18.5 km^2 and a critical duration of 90 minutes (refer Section 8.2).

Using the methodology set out in the GSDM Guidebook (BoM, 2003), the following data for the PMP was determined:

- The coastal GSDM Method is applicable as the catchment lies on the Queensland coast.
- The Roughness (R), Elevation Adjustment Factor (EAF) and Moisture Adjustment Factor (MAF) were calculated as 1.0, 1.0 and 0.90 respectively.
- PMP parameters were calculated as shown in Table 12.

Table 12 Adopted PMP Parameters

Duration (hrs)	Rainfall Total (mm)	Rainfall Intensity (mm/hr)
1	400	400
1.5	510	340
2	600	300
3	720	240

The AEP of the PMP event was calculated as recommended in AR&R (Pilgrim, et al, 1987). For a combined catchment area of 18.5 km^2, the PMP event is approximately a 1 in 10,000,000 AEP event.

4.4.5 Design Event Rainfall Loss Parameters

The adopted losses vary from a maximum of 15 mm initial loss and 1.0 mm continuing loss for very pervious surfaces to a minimum of 0 mm for both the initial and continuing losses on impermeable materials, depending upon the material. They are presented in Table 45 in Appendix A.

Aurecon's previous study (2014) adopted variable losses depending on the event, whereas in this study the design losses adopted have been maintained across all events, excluding the PMF.

During the PMF design event it was assumed the catchment had been saturated by the pre-burst rainfall, in order to simulate this, the initial loss applied was reduced to 0 mm. This is a conservative approach; noting that the continuing loss remained for the current study.

Table 13 Adopted Losses Comparison

Event (AEP)	Previous Study		This Study	
	Initial Loss (mm)	Continuing Loss (mm/h)	Initial Loss (mm)	Continuing Loss (mm/h)
18% and smaller	15.0	2.5	15.0	1.0
10%	10.0	2.5	15.0	1.0
5%	5.0	2.5	15.0	1.0
2% and larger	0.0	2.5	15.0	1.0
PMF	0.0	0.0	0.0	1.0

5.0 Hydrologic Inflows

5.1 Overview

This section of the report discusses the further development of the existing XP-RAFTS hydrologic models previously used to inform the Frenchmans and Thozets Creek inflows as a part both the Frenchmans and Thozets Creek Hydrologic and Hydraulic Modelling Reports (Aurecon, 2014). The hydrologic models have been used to estimate inflows at various upstream boundaries of the Frenchmans and Thozets Creek hydraulic models.

The XP-RAFTS hydrologic models were revised and updated during this investigation to ensure consistent rainfall and loss parameters were applied between the hydrologic and hydraulic models. An initial loss of 15mm and continuing loss of 1.0mm were applied, with rainfall being introduced using timeseries .csv files.

XP-RAFTS build version 2013 was used for this assessment. An overview of the hydrologic models development can be reviewed in the Frenchmans and Thozets Creek Hydrologic and Hydraulic Modelling Reports (Aurecon, 2014).

5.2 Hydrologic Inflow Comparison

An overview of the inflows applied to the previous (Aurecon, 2014) and updated model (AECOM, 2017) is provided in Table 14.

Table 14 Hydrologic Model Setup Overview

Event (AEP)	Previous Study Peak Inflows (m^3/s)		This Study Peak Inflows (m^3/s)		Difference (FRE-2)	Difference (THO-7)
	Node FRE-2*	Node THO-7*	Node FRE-2*	Node THO-7*		
1EY	-	-	6.6	10.1	-	-
39%	10.0	15.5	10.5	16.2	5.0%	4.5%
18%	-	-	16.3	25.1	-	-
10%	21.5	32.6	20.2	30.8	-6.0%	-5.5%
5%	28.7	43.7	25.6	38.7	-10.8%	-11.4%
2%	35.8	55.4	31.7	48.5	-11.5%	-12.5%
1%	41.4	64.4	37.5	57.3	-9.4%	-11.0%
0.2%	67.9	104.8	57.7	89.2	-15.0%	-14.9%
0.05%	-	-	76.1	117.6	-	-
PMF	180.2	242.6	173.9	283.7	-3.5%	16.9%
January 2013	14.2	29.2	16.2	26.4	14.1%	-9.6%
February 2015	-	-	28.0	45.0	-	-
March 2017	-	-	13.8	20.6	-	-

* Note: Sub-catchment node reference as per Figure 9.

As outlined in Section 4.4.5, variation in the adopted rainfall losses results in some discrepancies in the hydrologic inflows between the previous and current studies.

A lower total rainfall loss was applied for events smaller than a 10% AEP event, which is resembled in the 39% AEP inflows being 5% higher. In contrast, a higher total loss was applied to events larger than 18% AEP, resulting in lesser flows being applied to the model boundary, especially for events for 5% AEP and larger.

6.0 Hydraulic Model Development

6.1 Overview

This section of the report discusses the further development of the existing hydraulic model previously used to assess creek flooding in the Frenchmans and Thozets Creek Local Catchment. The updated model has been used to assess key local catchment flood behaviours and deficiencies in the existing stormwater network leading to increased flood risk. These assessments will assist in the development of mitigation options in Phase 3.

In order to improve the representation of key hydraulic features, the model resolution was improved from a 5m to 3m numerical Cartesian grid. A timestep of 1.0 second was adopted (2.0 second previously), giving an effective runtime of approximately 4.7 real-time hours to 1 simulation hour.

TUFLOW build version 2016-03-AE was used for this assessment.

6.2 Hydraulic Model Parameters

Detailed updates made to the existing TUFLOW model are located within Appendix A.

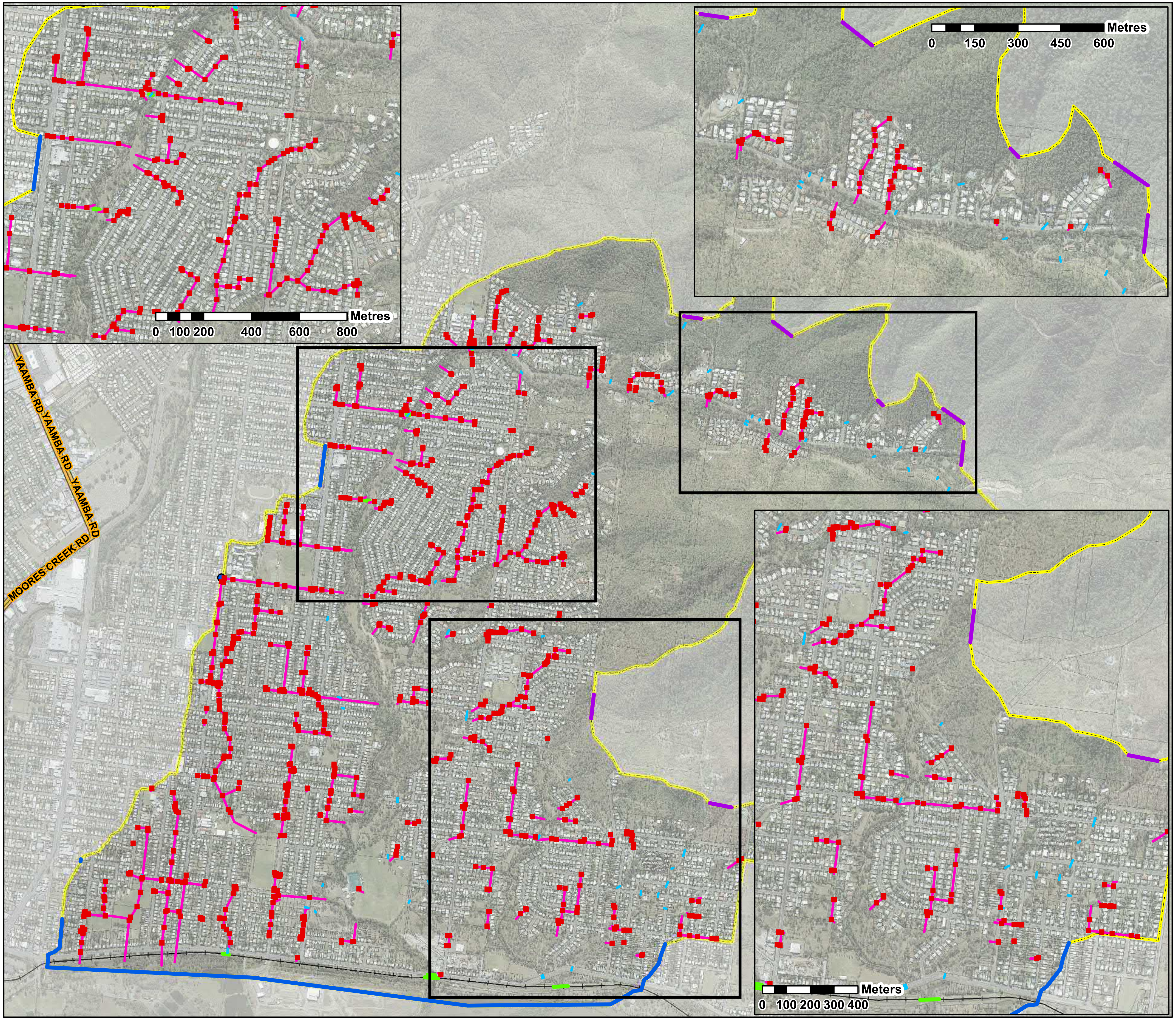
An overview of the model setup and key parameters for the model is provided in Table 15.

Table 15 Hydraulic Model Setup Overview

Parameter	Frenchmans & Thozets Creek Local Catchment Model
Completion Date	June 2017
AEP's Assessed	1EY, 39%, 18%, 10%, 5%, 2%, 1%, 0.2%, 0.05% AEP and PMF
Hydrologic Modelling	XP-RAFTS Inflow and Direct Rainfall Approach
IFD Input Parameters	Refer to Section 4.4.1
Hydraulic Model Software	TUFLOW version 2016-03-AE-w64-iDP
Grid Size	3m
DEM (year flown)	2016
Roughness	Spatially varying and depth varying standard values – consistent with South Rockhampton Model and Frenchmans and Thozets Creek Hydrologic and Hydraulic Modelling Report (Aurecon, 2014).
Eddy Viscosity	Smagorinsky
Model Calibration	Calibrated to 2015 event, verified to 2013 and 2017 events.
Downstream Model Boundary	7 inflow boundary along the steep bushland boundaries, 2 rating curve boundary conditions along the western boundary, 1 tidal boundary on the south boundary.
Timesteps	1 second (3m 2D) and 0.5 second (1D)
Wetting and Drying Depths	Cell centre 0.0002 m
Sensitivity Testing	Stormwater Infrastructure Blockage, ±15% Hydraulic Roughness, Riverine and Local Catchment Coincident Event, Inlet Structure Dimensions and Climate Change

6.3 Model Setup

A visual representation of the model setup including the code, boundaries, 1D network and hydraulic roughness delineation are included as Figure 13 and Figure 14 to supplement the detailed updates outlined in Appendix A.



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Rockhampton Regional Council

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LEGEND

- Pit Inlet
- 1D Outflow Boundary Condition
- Culverts
- Pipe
- Inflow Boundary Conditions
- Outflow Boundary Conditions
- Layered Flow Constrictions
- Highways
- Railway Lines
- Cadastre
- Hydraulic Model Extent

Data Sources:

DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

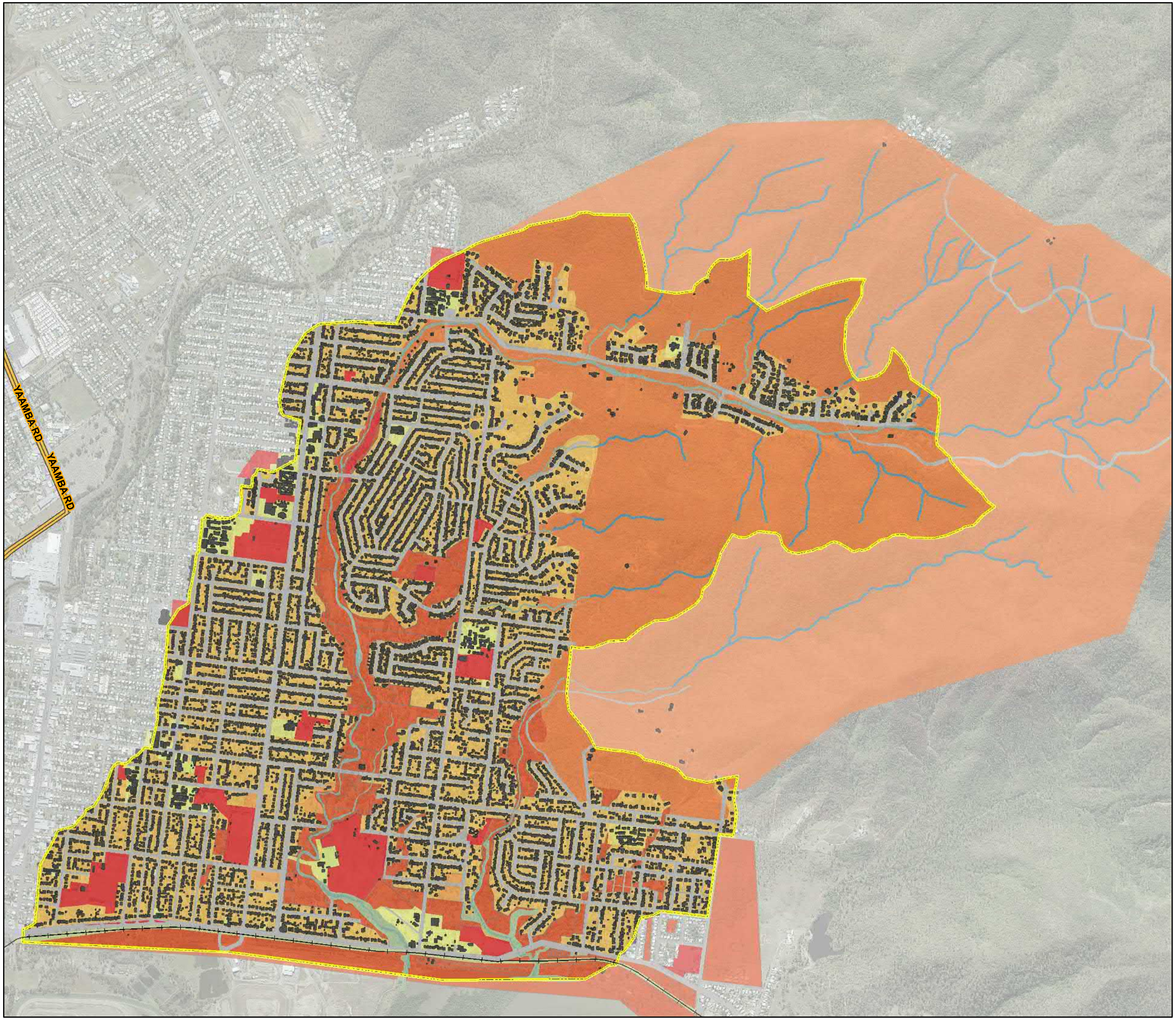
Frenchmans Creek & Thozets Creek Model

Model Setup and 1D Network Map

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	20/06/2017
VERSION:	1

Figure
13

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\Figure 12 Model Setup and 1D Network Map.mxd



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LEGEND

- Highways
- Railway Lines
- Hydraulic Model Extent
- Building Footprints
- Road Corridor
- Gullies
- Fitzroy River Bed
- Creek Channel
- Riparian Corridor
- Railway
- Commercial Industrial block
- High Density Residential
- Medium Density Residential
- Low Density Residential
- Medium Vegetation
- Low Vegetation
- Maintained Grass

Data Sources:

DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Frenchmans Creek & Thozets Creek Model

Hydraulic Roughness Delineation

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	20/06/2017
VERSION:	1

Figure 14

7.0 Calibration and Validation

7.1 Adopted Methodology

Calibration and validation of the TUFLOW model was undertaken by simulating historical flood events and comparing the results to recorded / anecdotal data provided by Council. The model was calibrated to the 2015 flood event, during which time the 2017 event occurred. The model parameters have been varied to match anecdotal data by varying roughness, initial losses, continuing losses and stormwater infrastructure assumptions (roughness and blockage). The model has been further verified to the 2017 and 2013 events. Exclusion of the pre-burst rainfall was adopted in order to make model runtimes more manageable.

Varying tidal levels were applied to the 2013 and 2015 based on historic records, with the 2017 event utilising predicted tidal levels. Surveyed peak flood levels are generally based upon flood debris marks or reported flood marks and are of varying levels of accuracy; therefore they are less reliable than recorded gauge levels. Adopted calibration tolerances for anecdotal records have been adopted as ±0.30m.

7.2 Calibration to the 2015 Event

The 2015 rainfall gauge data at the Serocold Street gauge was applied to the TUFLOW model. The maximum water surface elevations were extracted from the hydraulic model and compared to anecdotal peak flood levels provided by RRC.

The following model configurations have been simulated for the 2015 event:

Table 16 February 2015 Event Calibration Model Iterations Summary

Model Iteration No.	Initial Loss (mm)	Continuing Loss (mm)	Other Changes
E001	0	1.0	-
E401	0	1.0	Inclusion of full 1D network, verification of bridge losses to detailed 1D HEC-RAS models and modified topography across densely vegetated areas based on surveyed cross-sections.
E601	0	1.0	Implemented depth-varying channel hydraulic roughness, amended channel topography in further detail based on site visits and surveyed cross-sections

Peak flood levels were recorded at 19 locations within the Frenchmans Creek corridor and 10 locations within the Thozets Creek corridor. The peak heights predicted within the above simulations were compared to the heights at the recorded locations. Results are presented in Table 17.

Table 17 February 2015 Calibration Events Results Comparison

Point ID	Recorded Level (mAHD)	Peak Flood Height (mAHD)		
		E001	E401	E601
15FRE-1	52.05	52.21	52.07	52.07
15FRE-2	43.85	43.71	43.77	43.66
15FRE-3	39.51	39.38	39.43	39.39
15FRE-4	38.36	38.53	38.63	38.42
15FRE-5	32.31	32.71	32.72	32.51
15FRE-6	32.79	33.05	33.12	33.05
15FRE-7	34.11	34.13	34.12	34.11
15FRE-8	35.30	35.36	35.24	35.14

Point ID	Recorded Level (mAHD)	Peak Flood Height (mAHD)		
		E001	E401	E601
15FRE-9	35.45	35.39	35.28	35.18
15FRE-10	35.59	35.48	35.39	35.31
15FRE-11	36.42	36.20	36.26	36.17
15FRE-12	27.69	27.48	27.55	27.51
15FRE-13	29.91	29.91	30.03	30.00
15FRE-14	43.16	43.38	43.39	43.37
15FRE-15	43.22	43.16	43.16	43.16
15FRE-16	44.60	45.06	45.12	44.92
15FRE-18	46.39	46.12	46.15	46.11
15FRE-19	7.27	7.49	7.49	7.51
15FRE-20	6.73	6.93	6.83	6.79
15THO-1	8.34	8.29	8.29	8.26
15THO-2	10.15	10.28	10.27	10.23
15THO-3	9.06	9.09	9.09	9.00
15THO-4	10.82	11.13	11.13	11.09
15THO-5	11.73	12.38	12.38	12.30
15THO-6	5.78	5.90	5.88	5.88
15THO-7	18.43	18.47	18.45	18.38
15THO-8	15.92	16.20	16.20	16.13
15THO-9	23.03	23.60	23.60	23.51
15THO-10	26.22	26.48	26.48	26.35

Results from the final **E601** simulation are presented in Table 18.

Table 18 February 2015 Calibration Event Results

Point ID	Recorded Level (mAHD)	Peak Flood Height (mAHD)			Difference (m)	Tolerance
		E601	Lower Tolerance	Upper Tolerance		
15FRE-1	52.05	52.07	51.75	52.35	0.02	In tolerance
15FRE-2	43.85	43.66	43.55	44.15	-0.19	In tolerance
15FRE-3	39.51	39.39	39.21	39.81	-0.12	In tolerance
15FRE-4	38.36	38.42	38.06	38.66	0.06	In tolerance
15FRE-5	32.31	32.51	32.01	32.61	0.20	In tolerance, high
15FRE-6	32.79	33.05	32.49	33.09	0.26	In tolerance, high
15FRE-7	34.11	34.11	33.81	34.41	0.00	In tolerance
15FRE-8	35.30	35.14	35.00	35.60	-0.16	In tolerance low
15FRE-9	35.45	35.18	35.15	35.75	-0.26	In tolerance

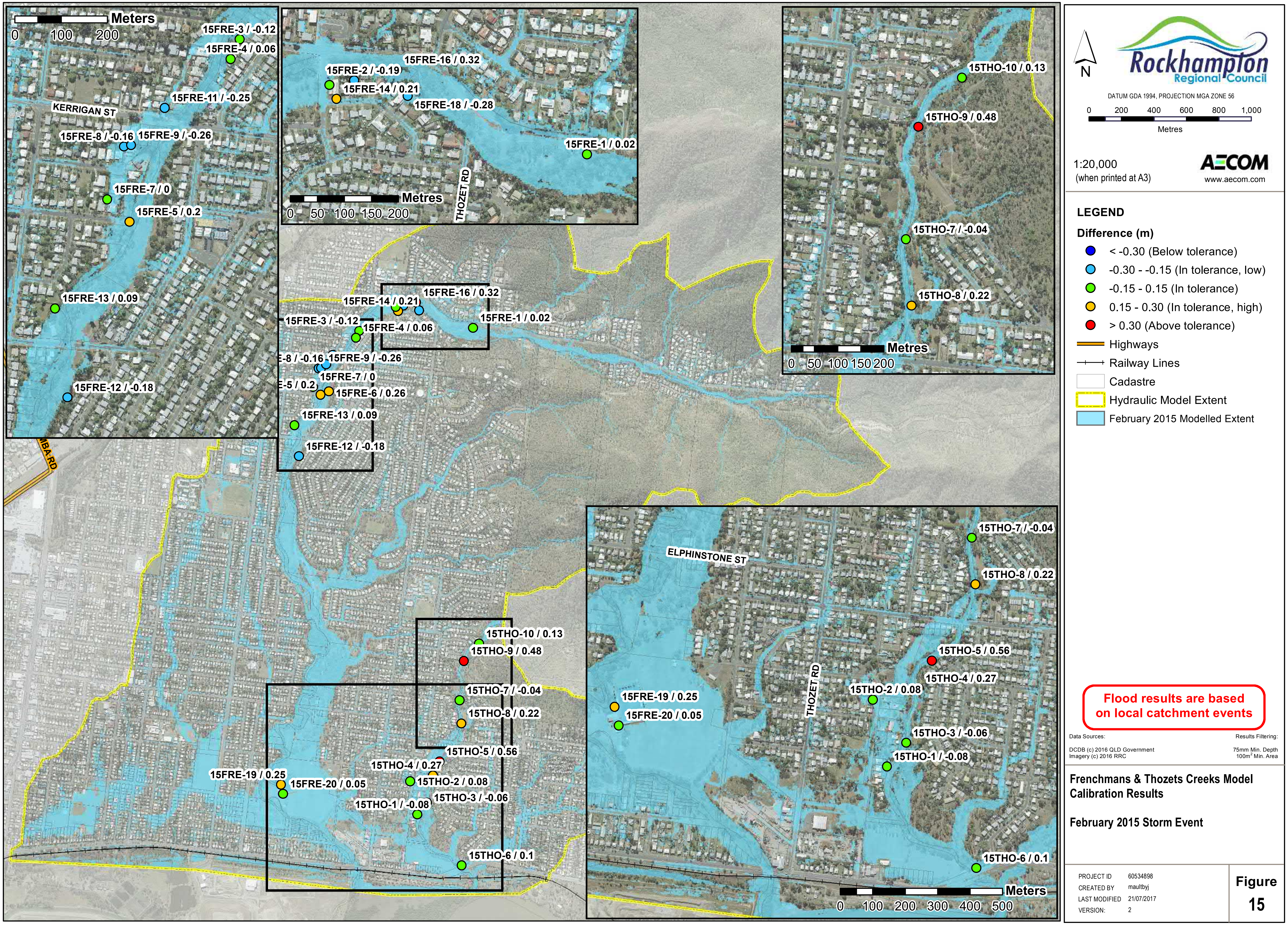
Point ID	Recorded Level (mAHD)	Peak Flood Height (mAHD)			Difference (m)	Tolerance
		E601	Lower Tolerance	Upper Tolerance		
						low
15FRE-10	35.59	35.31	35.29	35.89	-0.28	In tolerance low
15FRE-11	36.42	36.17	36.12	36.72	-0.25	In tolerance low
15FRE-12	27.69	27.51	27.39	27.99	-0.18	In tolerance low
15FRE-13	29.91	30.00	29.61	30.21	0.09	In tolerance
15FRE-14	43.16	43.37	42.86	43.46	0.21	In tolerance, high
15FRE-15	43.22	43.16	42.92	43.52	-0.06	In tolerance
15FRE-16	44.60	44.92	44.30	44.90	0.32	Above tolerance
15FRE-18	46.39	46.11	46.09	46.69	-0.28	In tolerance low
15FRE-19	7.27	7.51	6.97	7.57	0.25	In tolerance, high
15FRE-20	6.73	6.79	6.43	7.03	0.05	In tolerance
15THO-1	8.34	8.26	8.04	8.64	-0.08	In tolerance
15THO-2	10.15	10.23	9.85	10.45	0.08	In tolerance
15THO-3	9.06	9.00	8.76	9.36	-0.06	In tolerance
15THO-4	10.82	11.09	10.52	11.12	0.27	In tolerance, high
15THO-5	11.73	12.30	11.43	12.03	0.56	Above tolerance
15THO-6	5.78	5.88	5.48	6.08	0.10	In tolerance
15THO-7	18.43	18.38	18.13	18.73	-0.04	In tolerance
15THO-8	15.92	16.13	15.62	16.22	0.22	In tolerance, high
15THO-9	23.03	23.51	22.73	23.33	0.48	Above tolerance
15THO-10	26.22	26.35	25.92	26.52	0.13	In tolerance

Key outcomes from the initial calibration are:

- Of the 29 recorded points, 26 were within the corresponding tolerances with 3 above tolerance.
- The average difference between modelled and recorded levels was calculated to be 0.05 m with standard deviation of 0.22 m.
- The modelled extents appear to match well with the spatial distribution of the recorded flood heights.

The adopted calibration settings are geographically presented in Figure 15 and relate to scenario E601 outlined and discussed above.

Calibration results are also represented through long section profiles in Appendix C. The results from the 2015 calibration are shown in sketches SK-11 to SK-13 (Frenchmans Creek) and SK-18 (Thozets Creek). The water surface profiles shows reasonably consistent hydraulic gradients with minor hydraulic jumps associated with topographic features and key road crossings. The sketches reflect the calibration results shown in Table 18, as the water surface profile passes within the tolerance ranges of most calibration points.



Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\Figure 15 February 2015 Event Calibration Results Map.mxd

7.3 Validation to the 2017 Event

During calibration of the model to the 2015 event, Ex-TC Debbie occurred resulting in a moderate rainfall event in Rockhampton during late March 2017. Council supplied recorded gauge data at three points within the model which have been compared to the peak flood heights predicted during the simulation. The Rogar Avenue Reservoir rainfall profile has been applied to the model as the gauge is within the mountainous portion of the catchment.

Peak flood levels were gauged at 7 locations within the Frenchmans and Thozets Creek corridors. The peak heights predicted within the simulation were compared to the heights at the recorded locations and are presented below in Table 19.

Table 19 March 2017 Validation Results Analysis

Point ID	Anecdotal Level (mAHD)	Peak Height (mAHD)			Difference (m)	Tolerance
		E601	Lower Tolerance	Upper Tolerance		
THO-001	15.98	16.51	15.83	16.13	0.52	Above tolerance
THO-003	10.47	10.93	10.32	10.62	0.46	Above tolerance
FRE-008	45.65	45.79	45.50	45.80	0.14	In tolerance, high
FRE-012	29.95	30.28	29.80	30.10	0.33	Above tolerance
FRE-015	18.81	19.24	18.66	18.96	0.43	Above tolerance
FRE-016	15.74	16.03	15.59	15.89	0.30	Above tolerance
FRE-018	7.99	7.99	7.84	8.14	0.00	In tolerance

Analysis of the validation results reveals the following:

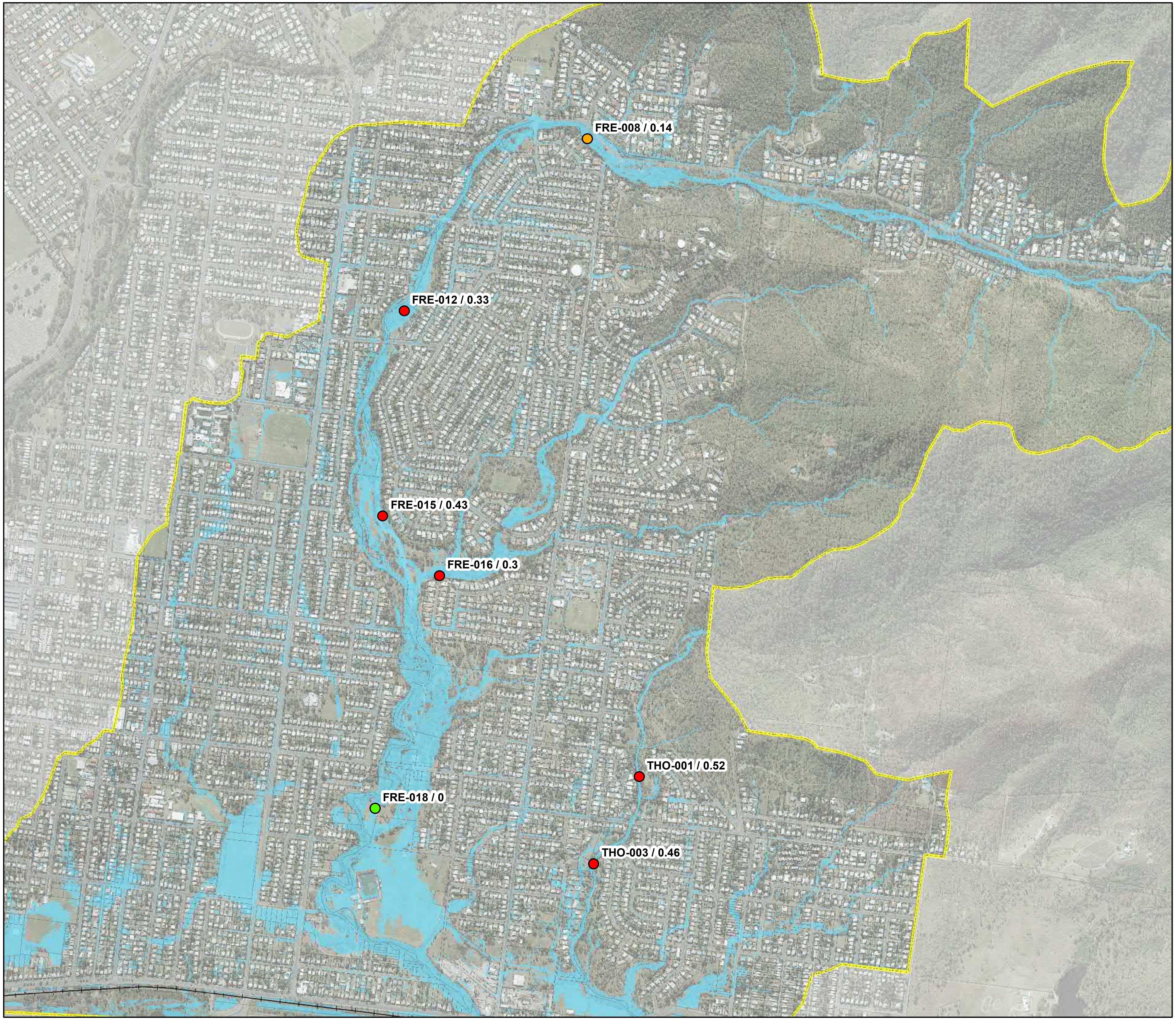
- Of the 7 recorded points, 2 were within the corresponding tolerances with 5 above the tolerance of ±0.15 m.
- The average difference between modelled and recorded levels was calculated to be 0.31 m with standard deviation of 0.17 m.

Discrepancies identified between the modelled and recorded levels are assumed to be a result of three key factors, these being:

- Vegetation density at the time of the flood event;
- Variation in the spatial distribution of rainfall across the rural and urban components of the catchment; and
- Changes in channel cross-section between the LiDAR date of capture and date of the event.

Considering the stringent tolerances, significant variation in rainfall between the urban and mountainous catchment across North Rockhampton during the event and effect of vegetation on events of smaller magnitude, the 2017 model simulation serves as a suitable validation for the calibrated model.

Calibration results are also represented through long section profiles in Appendix C. The results from the 2017 calibration are shown in sketches SK-14 to SK-16 (Frenchmans Creek) and SK-19 (Thozets Creek). The proximity of the water surface profile to the calibration point tolerances shown on the sketches reflect the validation results summarised in Table 19.



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Difference (m)

- < -0.15 (Below tolerance)
- -0.15 - -0.10 (In tolerance, low)
- -0.10 - 0.10 (In tolerance)
- 0.10 - 0.15 (In tolerance, high)
- > 0.15 (Above tolerance)
- Highways
- Railway Lines
- Cadastre
- Hydraulic Model Extent
- March 2017 Modelled Extent

Flood results are based on local catchment events

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Results Filtering:
75mm Min. Depth
$100m^2$ Min. Area

Frenchmans & Thozets Creeks Model Validation Results

March 2017 Storm Event

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	21/07/2017
VERSION:	2

Figure 16

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\Figure 16 March 2017 Gauge Record Comparison.mxd

7.4 Validation to the 2013 Event

In order to verify the model to the rainfall data for Ex-TC Oswald in January 2013 was obtained from the Serocold Street site. Council obtained anecdotal peak water elevations from residents in known hotspots, the limitations of this data have been discussed previously in Section 3.10.1, and these heights have been compared to the peak flood heights predicted during the simulation. Additionally, anecdotal points marking the peak flood extent have been compared to the peak modelled extent with the lateral difference being used as a measure of model performance.

In order to undertake the validation the **E601** model from the February 2015 calibration was taken forward. Peak flood levels were recorded at 10 locations and peak flood extents at 31 locations within the Frenchmans and Thozets Creek corridors. The peak heights predicted within the simulation were compared to the heights at the recorded locations and are presented below in Table 20.

Table 20 January 2013 Validation Results Analysis

Point ID	Anecdotal Level (mAHD)	Peak Height (mAHD)			Peak Height Difference (m)	Peak Extent Horizontal Difference* (m)	Tolerance
		E601	Lower Tolerance	Upper Tolerance			
13THO-1	-	-	-	-	-	0.2	In tolerance
13THO-2	-	-	-	-	-	-2.1	In tolerance low
13THO-3	-	-	-	-	-	-1.9	In tolerance low
13THO-4	13.53	13.37	13.03	14.03	-0.16	-0.7	In tolerance
13THO-5	-	-	-	-	-	-6.2	Below tolerance
13THO-6	-	-	-	-	-	-1.4	In tolerance
13FRE-4	40.85	40.74	40.35	41.35	-0.11	-0.7	In tolerance
13FRE-5	-	-	-	-	-	0.2	In tolerance
13FRE-6	-	-	-	-	-	0.8	In tolerance
13FRE-7	-	-	-	-	-	0.3	In tolerance
13FRE-8	-	-	-	-	-	0.9	In tolerance
13FRE-9	35.06	35.08	34.56	35.56	0.02	0.7	In tolerance
13FRE-10	34.79	34.83	34.29	35.29	0.03	-	In tolerance
13FRE-11	34.94	34.83	34.44	35.44	-0.12	-	In tolerance
13FRE-13	34.98	34.83	34.48	35.48	-0.16	-	In tolerance
13FRE-14	34.53	34.83	34.03	35.03	0.30	-	In tolerance, high
13FRE-15	34.15	34.14	33.65	34.65	0.00	-	In tolerance
13FRE-16	-	-	-	-	-	-1.6	In tolerance low
13FRE-17	-	-	-	-	-	-0.8	In tolerance
13FRE-18	32.77	33.01	32.27	33.27	0.24	-	In tolerance
13FRE-19	-	-	-	-	-	-0.3	In tolerance
13FRE-20	-	-	-	-	-	-0.8	In tolerance
13FRE-22	-	-	-	-	-	-1.5	In tolerance
13FRE-23	24.65	24.70	24.15	25.15	0.05	-	In tolerance

Point ID	Anecdotal Level (mAHD)	Peak Height (mAHD)			Peak Height Difference (m)	Peak Extent Horizontal Difference* (m)	Tolerance
		E601	Lower Tolerance	Upper Tolerance			
13FRE-24	-	-	-	-	-	0.5	In tolerance
13FRE-25	-	-	-	-	-	-0.9	In tolerance
13FRE-26	-	-	-	-	-	-1.4	In tolerance
13FRE-27	-	-	-	-	-	-1.6	In tolerance low
13FRE-29	-	-	-	-	-	-3.3	Below tolerance
13FRE-30	-	-	-	-	-	0.3	In tolerance
13FRE-31	-	-	-	-	-	-0.3	In tolerance
13FRE-32	-	-	-	-	-	-0.1	In tolerance
13FRE-38	-	-	-	-	-	-0.4	In tolerance
13FRE-39	-	-	-	-	-	4.2	Above tolerance
13FRE-40	-	-	-	-	-	0.5	In tolerance
13FRE-42	-	-	-	-	-	-0.6	In tolerance
13FRE-43	-	-	-	-	-	0.7	In tolerance
13FRE-44	-	-	-	-	-	1.3	In tolerance

*Note: A negative value indicates modelled extent did not reach recorded flood extent.

Analysis of the validation results reveals the following:

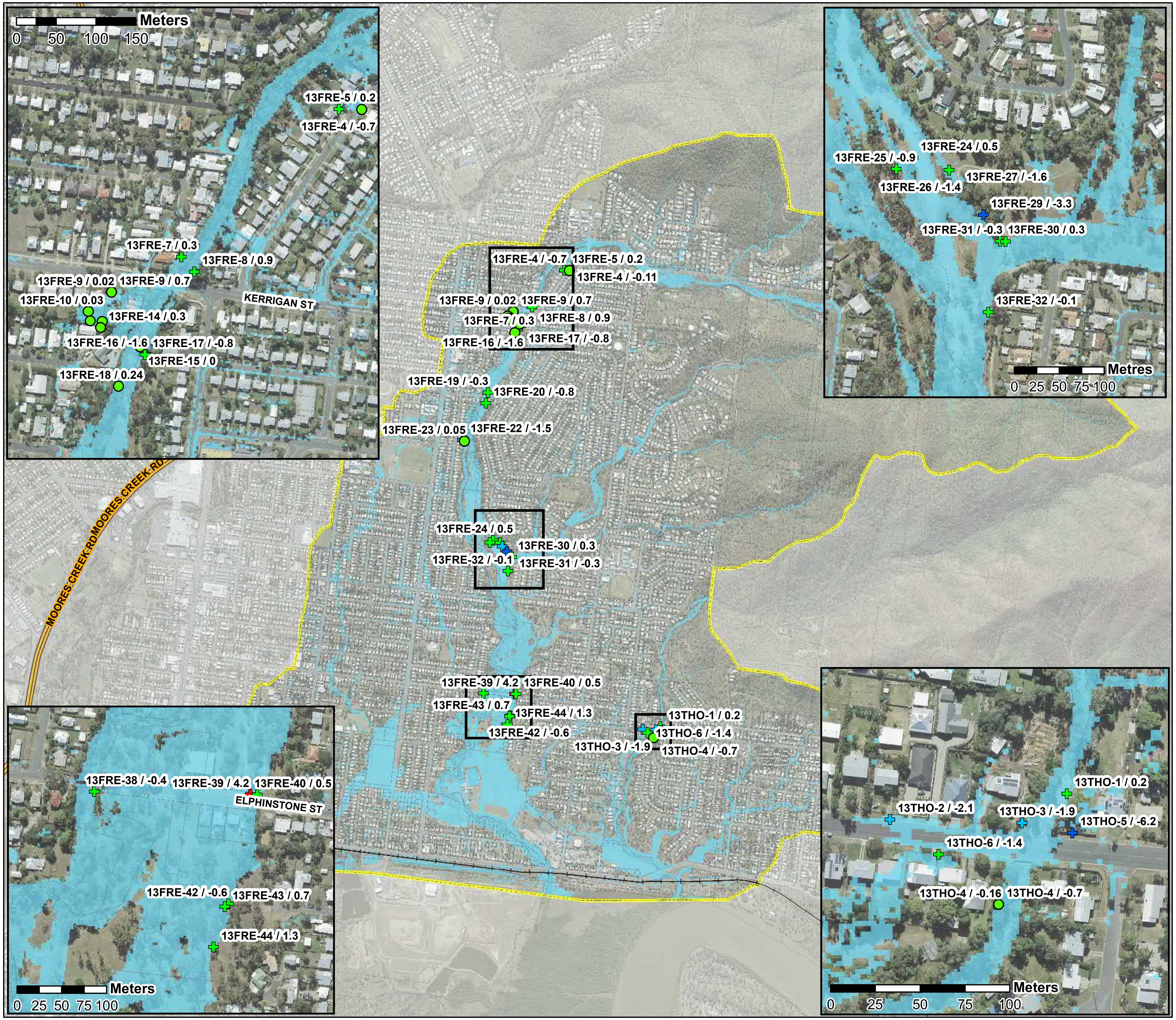
- Of the 10 recorded levels, all were within the corresponding tolerances with an average difference calculated to be 0.01 m and standard deviation of 0.15 m.
- Of the 31 recorded extents, 28 were within the corresponding tolerances with 2 falling below and 1 exceeding the allowable tolerance. The average difference in extent was calculated to be 0.5 m with a standard deviation of 1.67 m.

Discrepancies identified between the modelled and recorded levels are assumed to be a result of three key factors, these being:

- Vegetation density at the time of the flood event;
- Variation in the spatial distribution of rainfall across the rural and urban components of the catchment; and
- Changes in channel cross-section between the LiDAR date of capture and date of the event.

Considering the consistency of the anecdotal data, lack of rainfall data within the catchment for the event and significant changes in channel conveyances as a result of flooding, the 2013 model simulation serves as a good validation of the calibrated model.

Calibration results are also represented through long section profiles in Appendix C. The results from the 2013 calibration are shown in sketches SK-08 to SK-10 (Frenchmans Creek) and SK-17 (Thozets Creek). As can be seen from the long section plots, the modelled water surface profiles pass within the tolerances of anecdotal points. The hydraulic gradient is reasonably consistent and reflects reasonable changes in energy gradient at locations where sudden changes in topography would incur a change to flow regime.



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Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 200 400 600 800 1,000 Metres

1:20,000 (when printed at A3)

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LEGEND

Difference in Height (m)

- < -0.5 (Below tolerance)
- -0.50 - -0.30 (In tolerance, low)
- -0.30 - 0.30 (In tolerance)
- 0.30 - 0.50 (In tolerance, high)
- > 0.50 (Above tolerance)

Difference in Extent (m)

- < -3.0 (Below tolerance)
- -3.0 - -1.5 (In tolerance, low)
- -1.5 - 1.5 (In tolerance)
- 1.5 - 3.0 (In tolerance, high)
- > 3.0 (Above tolerance)
- Highways
- Railway Lines
- Cadastre
- Hydraulic Model Extent
- January 2013 Modelled Extent

Flood results are based on local catchment events

Data Sources: DCDB (c) 2016 QLD Government; Imagery (c) 2016 RRC

Results Filtering: 75mm Min. Depth; 100m² Min. Area

Frenchmans & Thozets Creeks Model Validation Results

January 2013 Storm Event

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	21/07/2017
VERSION:	2

Figure 17

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\Figure 17 January 2013 Event Validation Results Map.mxd

7.5 Key Outcomes

Summarised below are the key calibration / validation parameters for the Frenchmans and Thozets Creek Local Catchment model.

7.5.1 Final Design Losses and Roughness

The final design losses adopted following the calibration and validation process is outlined in Table 13. Pervious areas were modelled with an initial loss of 15 mm and continuing loss of 1 mm.

The adopted roughness values for each of the different land uses are outlined in Table 44 in Appendix A. Following the calibration and validation process the adopted roughness within the channel was delineated in more detail with increased roughness across heavily vegetated areas for shallow flows.

7.5.2 Adopted Blockage

The adopted blockage for the final baseline design across major bridge structures follows best-estimates of piers and abutments within the bridge cross-section.

Site inspections revealed limited blockage within major culvert structures and as such, additional blockage was not incorporated.

8.0 Baseline Hydraulic Modelling

8.1 Overview

The Frenchmans and Thozets Creek Local Catchment model was used to simulate the 1EY, 39%, 18%, 10%, 5%, 2%, 1%, 0.2%, 0.05% AEP and PMF events.

8.2 Critical Duration Assessment

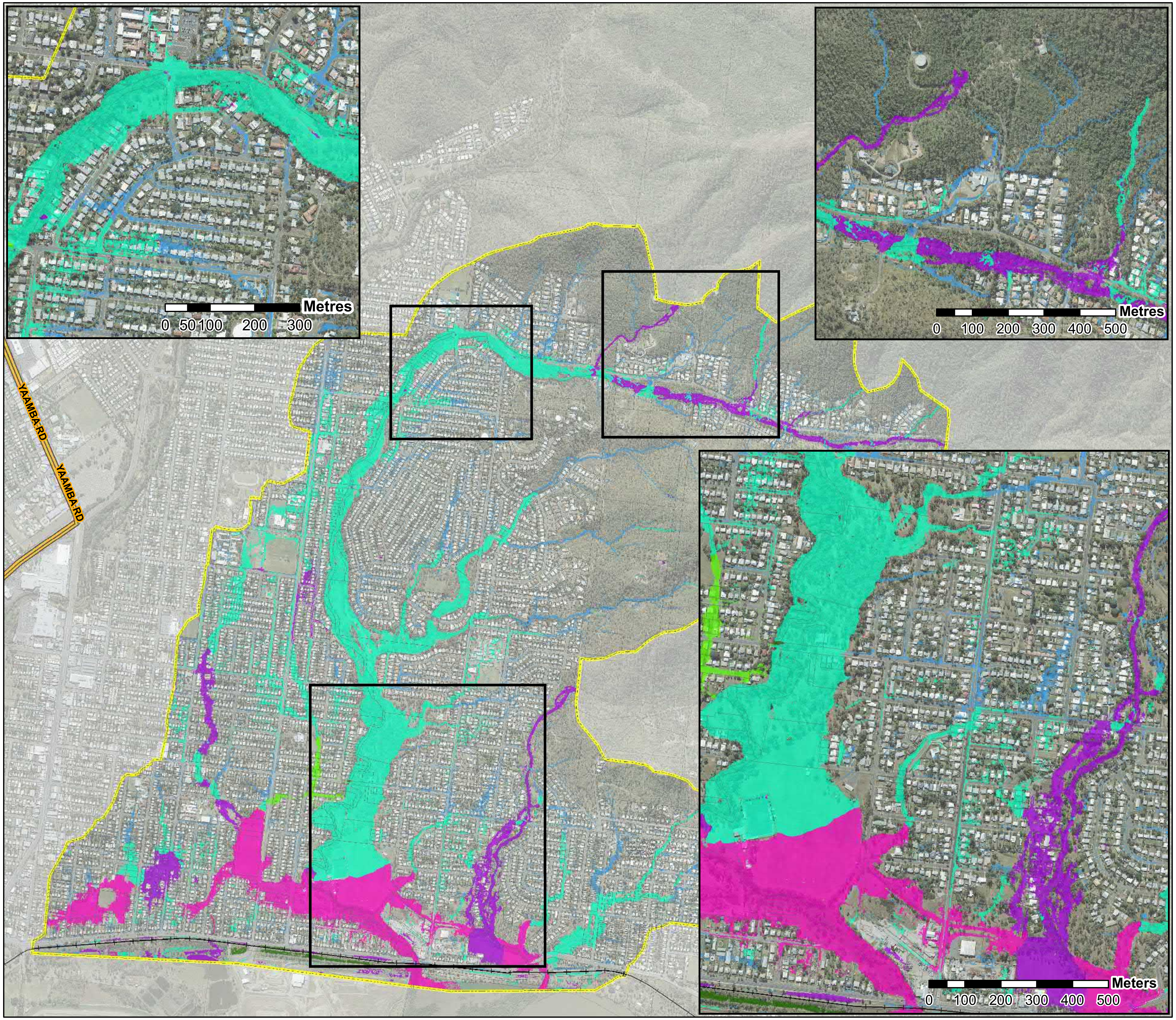
The critical storm duration for the Frenchmans and Thozets Creek Local Catchment area was assessed by simulating the 30min, 60min, 90min, 120min, 180min and 270min durations for the 1% AEP event.

Figure 18 shows that for a 1% AEP event, Frenchmans Creek shares has a critical duration of 90min upstream of Seifert Drive, 60min for the middle section of the creek until Birdwood Park and 120min for the downstream section. For Thozets Creek a large portion of the reach up to Bryant Street has a critical duration of 90min, after which the critical duration becomes 120min.

In order to select the critical duration, an analysis of differences between the 90min and 60min storm event revealed that for much of Frenchmans and Thozets Creeks the maximum flood height results were within ± 20 mm, as can be seen in Figure 19. The area of lower Frenchmans Creek experiences increases of up to 75 mm in the 120min storm event in comparison to the 90min. Similarly, comparisons between the 90min and 120min durations showed predicted peak flood heights were within ± 75 mm.

With the exception of the 1% AEP event, the 90 minute critical duration was applied to all design flood events mentioned in Section 8.1. For the 1% AEP a 'Max:Max' analysis was undertaken, whereby results from the 30min, 60min, 90min, 120min, 180min and 270min storm durations were compared and the maximum flood levels extracted at each cell within the model domain.

This ensures that the maximum flood level for the 1% AEP design flood event which is used for planning purposes for the Rockhampton Region is shown to be independent of the critical storm duration variance across the model extent.



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Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

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Metres

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LEGEND

- Highways
- Railway Lines
- Cadastre
- Hydraulic Model Extent

Storm Duration

- 030min
- 060min
- 090min
- 120min
- 180min
- 270min

Flood results are based on local catchment events

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Results Filtering:
75mm Min. Depth
$100m^2$ Min. Area

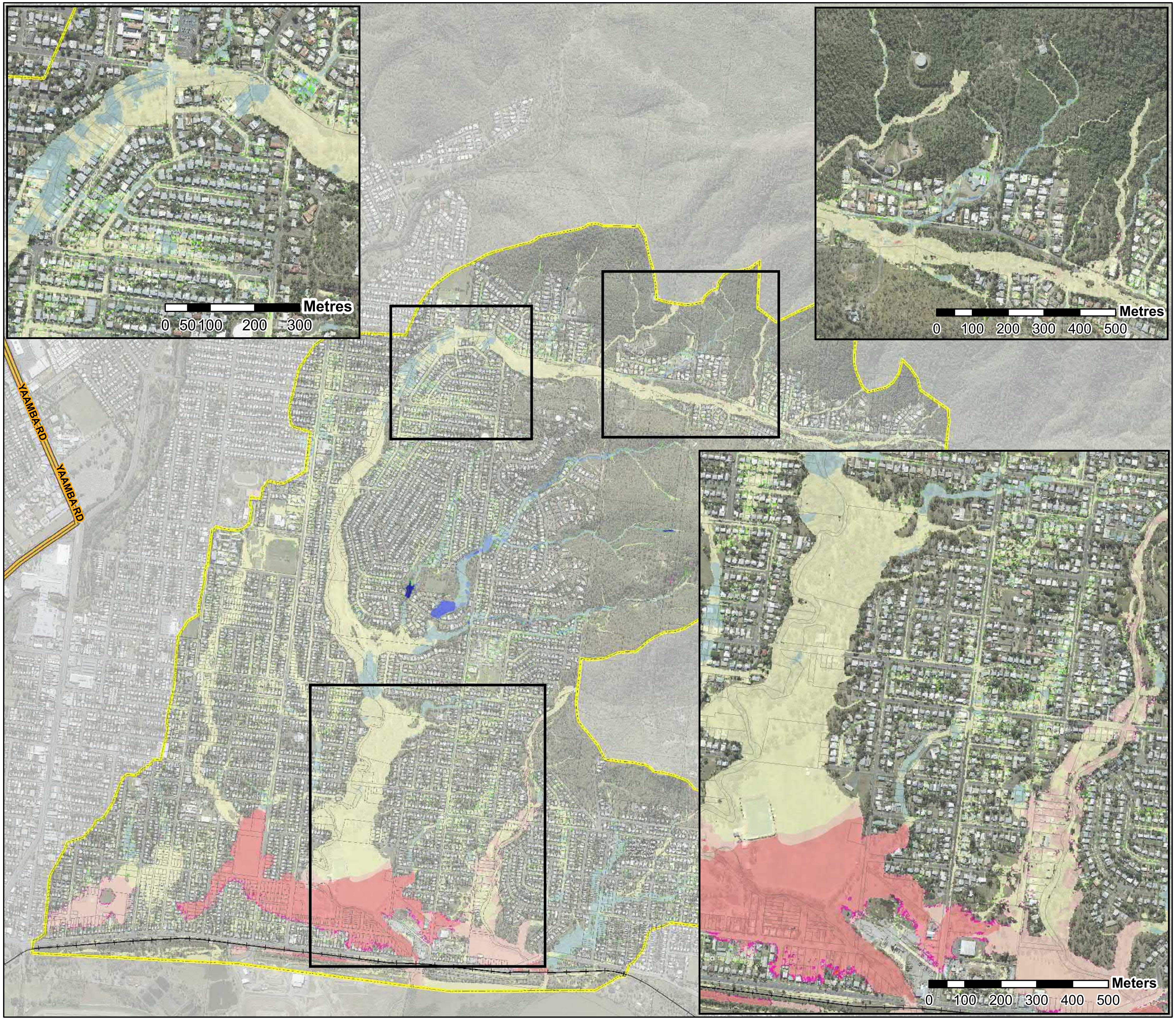
Frenchmans Creek & Thozets Creek Model
Critical Storm Duration Assessment

1% AEP Event

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	25/07/2017
VERSION:	1

Figure 18

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\Figure 18 Critical Duration.mxd



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Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 200 400 600 800 1,000
Metres

1:20,000
(when printed at A3)

AECOM
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LEGEND

- Highways
- Railway Lines
- Cadastre
- Hydraulic Model Extent

Difference in PWSE (m)

- < -0.3
- -0.3 to -0.225
- -0.225 to -0.15
- -0.15 to -0.075
- -0.075 to -0.02
- -0.02 to 0.02
- 0.02 to 0.075
- 0.075 to 0.15
- 0.15 to 0.225
- 0.225 to 0.3
- > 0.3
- Was Dry Now Wet
- Was Wet Now Dry

Flood results are based on local catchment events

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Results Filtering:
75mm Min. Depth
$100m^2$ Min. Area

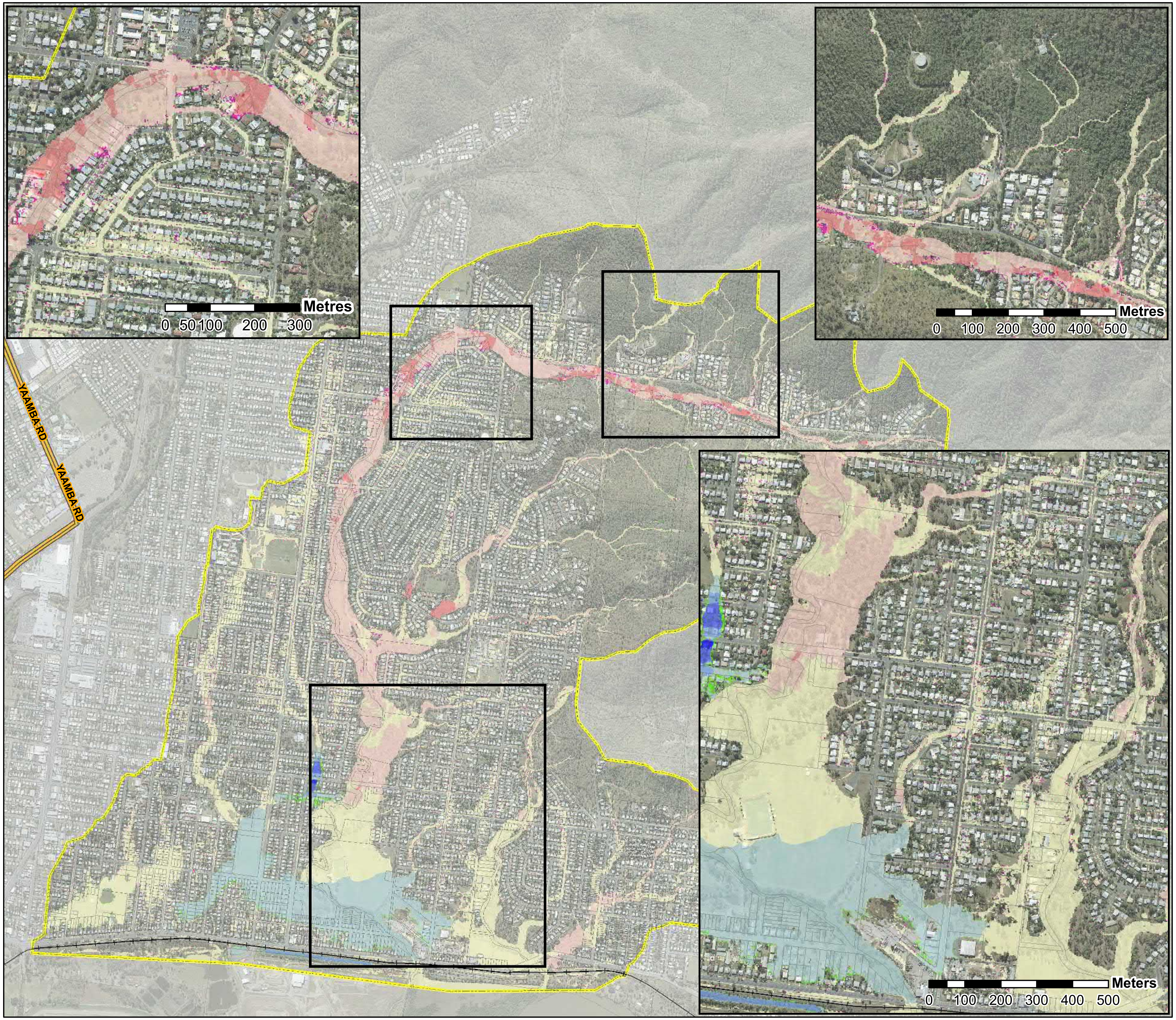
Frenchmans Creek & Thozets Creek Model
Difference in Peak Flood Heights
90min Storm minus 60min Storm

1% AEP Event

PROJECT ID	60534898
CREATED BY	maultby|
LAST MODIFIED	19/06/2017
VERSION:	1

Figure 19

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\Figure 19 - 90min minus 60 min.mxd



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Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 200 400 600 800 1,000

Metres

1:20,000
(when printed at A3)

AECOM
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LEGEND

- Highways
- Railway Lines
- Cadastre
- Hydraulic Model Extent

Difference in PWSE (m)

- < -0.3
- -0.3 to -0.225
- -0.225 to -0.15
- -0.15 to -0.075
- -0.075 to -0.02
- -0.02 to 0.02
- 0.02 to 0.075
- 0.075 to 0.15
- 0.15 to 0.225
- 0.225 to 0.3
- > 0.3
- Was Dry Now Wet
- Was Wet Now Dry

Flood results are based on local catchment events

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Results Filtering:
75mm Min. Depth
$100m^2$ Min. Area

Frenchmans Creek & Thozets Creek Model
Difference in Peak Flood Heights
90min Storm minus 120min Storm

1% AEP Event

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	19/06/2017
VERSION:	1

Figure 20

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\Figure 20 - 90min minus120 min.mxd

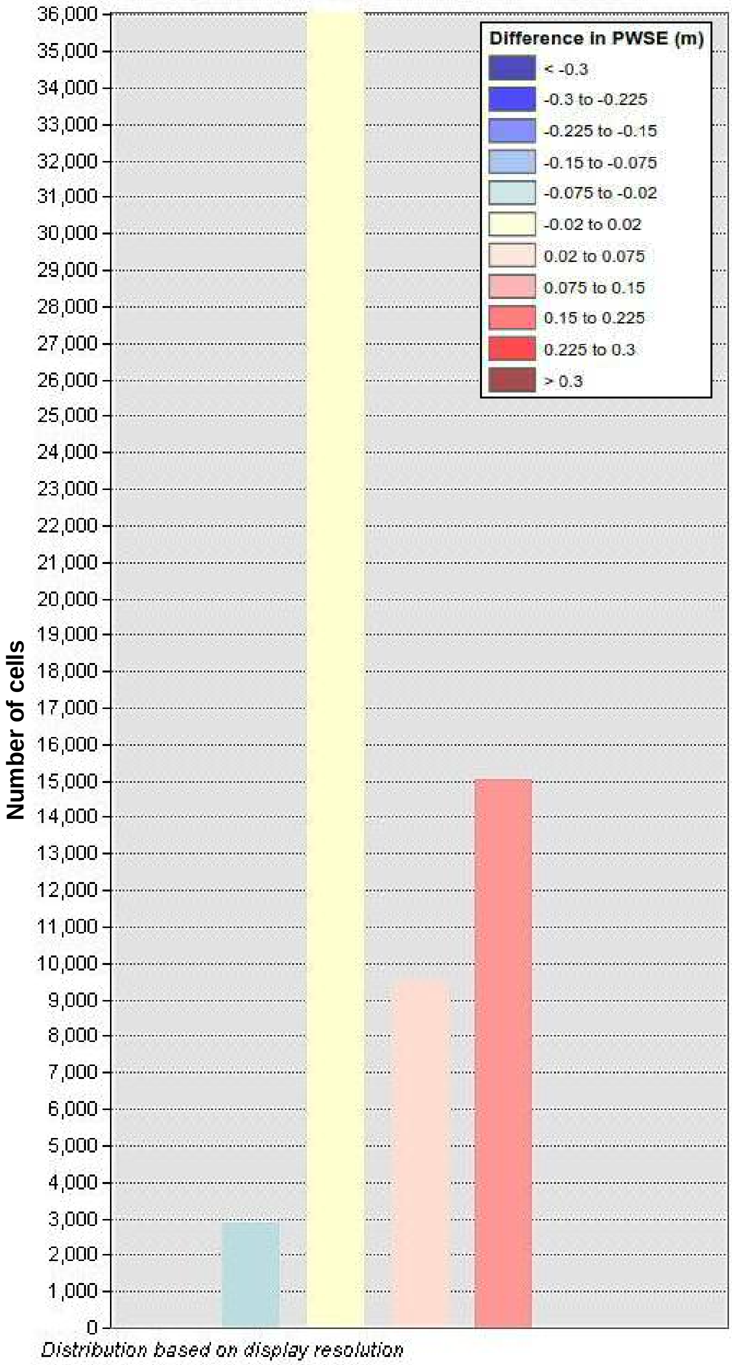


Figure 21 1% AEP – 90min PWSE minus 60min PWSE palette histogram

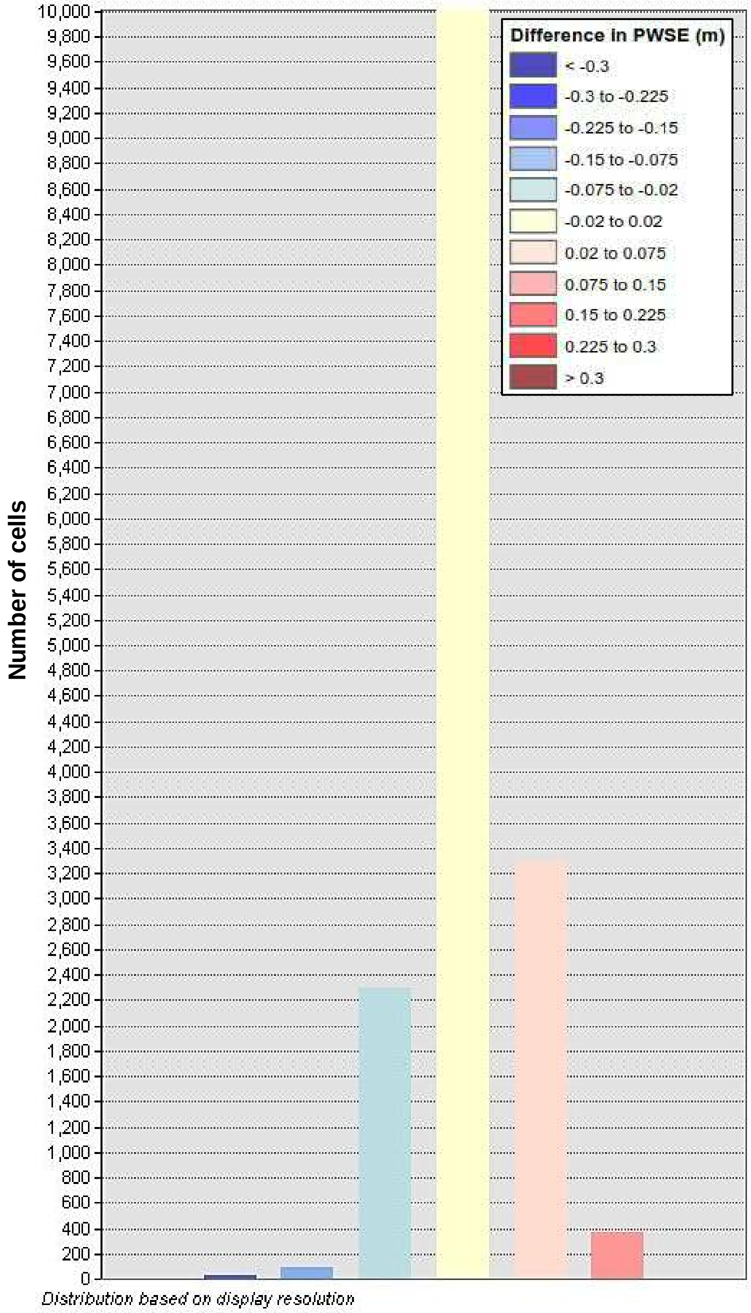


Figure 22 1% AEP – 90min PWSE minus 120min PWSE palette histogram

8.3 Baseline Flood Depths, Extents and Velocities

Rain-on-grid modelling uses a process whereby rainfall is applied to every model cell. Mapping of these results in their raw form would show that the entire model extent was flooded. For this reason, areas where the flow depth is less than 75mm were removed from the mapping. In addition, a filtering process was completed whereby flooded areas of less than 100 m^2 were removed from the mapping. Note that these depths are not excluded in the computational scheme. This process is aligned to guidance from AR&R Project 15 (Engineers Australia, 2012).

Mapping for the catchments in the Volume 2 report has been split into the Upper Catchment (maps denoted with the 'UF' prefix) and the Lower Catchment (maps denoted with the 'FT' prefix). Maps 1 to 30 (Upper Catchment and Lower Catchment) show the baseline design flood depth, heights and velocities for the 1EY, 39%, 18%, 10%, 5%, 2%, 1%, 0.2%, 0.05% AEP and PMF events.

The baseline modelling shows:

- **Maps 1 to 3** – 1EY Baseline

The maximum flood extents during the 1EY event in the Frenchmans and Thozets Catchment are contained mostly within drainage reserves and road corridors. Flood depths near various hydraulic structures increase, with only two significant culverts in the upper catchment overtopping at Beasley Street (near the intersection with Frenchville Road) and the Thozets Road (near Doug Pickering Park). The depths of flow in both these locations are less than 0.3 m.

In the lower Frenchmans and Thozets catchment, the flood extent is manly contained within the drainage reserves, aside from some houses to the south of Elphinstone Street which experience inundation with depths over the road and in the properties up to 0.3 m. Additionally some properties experience depths again up to 0.3 m in the overland flow path running south from High Street across Elphinstone Street and finishing at Bedford Street.

Depths within private properties reach up to 0.3 m at the corner of Rodboro Street and Berserker Street. For much of the length of the Creeks, the depths of flow are up to 1.8 m until the longitudinal grades of the creek flatten and increased overland flows enters the systems. Depths on the outside bends of the creek meanders can reach up to 3.0 m. In the lower ends of the Creeks the flow is contained within the hydraulic structures that allow the water to cross underneath Lakes Creek Road.

In the 1EY event, Mcleod Park is inundated to a depth of up to 0.6 m. Within Birdwood Park the flow is contained mainly within the table drain. At the Elphinstone Street crossing the peak flood height is up to 10 mAHD. At the outlets of Thozets Creek crossing Lakes Creek Road the peak flood height varies between 4 - 5 mAHD.

Velocities in much of Frenchmans Creek exceed 2 m/s, except in the lower reach where the velocities begin to decrease as the Creek begins to meander through the parkland.

- **Maps 4 to 6** – 39% AEP Baseline

In the 39% AEP event the flood extents continue to expand, and many of the smaller drain/overland flow paths become more pronounced within the catchment. In the upper reach of Frenchmans Creek, the Kerrigan Street crossing is overtopped. At Beasley Street the overbank flow begins to travel through Joyce Harding Park and inundate the allotments of private properties. Significant overland flow along Murphy Street is also noted. Breakout flows from Frenchmans Creek are predicted to inundate properties along Diplock Street.

In the lower areas of the catchment, the floodplain areas begin to convey flows into much of the parkland and surrounding areas. Depths within much of Thozets Creek reach up to 1.8 m. Elphinstone Street continues to be overtopped with depths up to 0.9 m. Properties to the south of Elphinstone Street off Tooker Street experience flow though the allotments. Stack Street is overtopped and flow also begins to overtop Water Street near Birdwood Park, with depths less than 0.3 m.

The peak flood height at Elphinstone Street is up to 11 mAHD. The peak flood height at the two Thozets Creek crossings of Lakes Creek Road are up to 6.00 mAHD for both crossings.

The peak depth average velocities through Birdwood Park reach up to 1 m/s. Velocities across Elphinstone Street reach up to 2 m/s. Much of Frenchmans and Thozets Creek have a peak depth average velocity greater than 2 m/s.

- **Maps 7 to 9** – 18% AEP Baseline

Notably within the upper Frenchmans Creek catchment, the flow extends into additional properties near Beasley Street. Much of the lower catchment experiences flood depths exceeding 0.3 m, particularly in floodplain areas currently used for recreational purposes. Private allotments on Mason Street experiencing inundation from Frenchmans Creek. Berserker Street, Rodboro Street and Princess Street are all expected to be inundated, including a number of adjacent properties.

The peak flood heights at both Thozets Creek crossings on Lakes Creek Road are up to 6 mAHD and at Elphinstone Street the peak flood height is up to 10 mAHD. Depth averaged velocities through Birdwood Park reach up to 1.5 m/s and velocities along the Frenchmans and Thozets Creek channels exceed 2.0 m/s.

- **Maps 10 to 12** –10% AEP Baseline

The flood extents continue to expand and overtopping occurs at Thozet Road (near Bloxsom Street). An overland flow path is expected to develop parallel to Marsh Avenue through the rear of allotments. Significant inundation is expected to occur along some roadways adjacent to Frenchmans Creek, notable examples include Kavanagh Crescent and O'Shanesy Street, with depths up to 0.3 m.

The western Lakes Creek Road crossing of Thozets Creek is inundated, with flow depths up to 0.3 m and velocities up to 2 m/s. Stenhouse Street is also inundated, with depths of up to 0.3 m.

Overland flow also overtops local roads from North Rockhampton High School to Elphinstone Street, peak depth averaged velocities in these crossings are increased due to the reduced roughness of the roads.

Depths along full length of both Frenchmans and Thozets Creek are greater than 3 m. Velocities for the entire lengths of both Creeks are greater than 2 m/s.

- **Maps 13 to 15 – 5% AEP Baseline**

Ironbark Terrance overtops with depths less than 0.3 m. Various properties to the north of Frenchville Road are inundated by overland flowpaths. Multiple sections of Frenchville Road are also inundated by a combination of Creek and overland flow paths. Additional properties alongside Frenchmans Creek near Beasley Street become inundated during this event. A number of properties in the area surrounding the intersection of Berserker Street and Rodboro Street, and adjacent to McLeod Park are impacted during the event.

The width of the flow path crossing Lakes Creek Road has expanded in comparison to the 10% AEP event and the connectivity between the Frenchmans and Thozets Creek catchments can be seen in this event. Peak flood heights at Lakes Creek Road reach up to 6 mAHD and 7 mAHD.

- **Maps 16 to 18** – 2% AEP Baseline

Honour Street begins to overtop with depths up to 0.6 m. Various properties along Kerrigan Street are impacted by overland runoff tending towards Frenchmans Creek. The corner of Frenchville Road near the intersection with Davey Avenue becomes inundated with depths up to 0.9 m. The overland flow paths within the catchment continue to expand and deepen. The eastern Thozets Creek crossing of Lakes Creek Road now overtops the road, with a depth up to 0.3 m. Near the outflow of Frenchmans Creek various properties to the north of Peter Street experience inundation.

The peak flood height at Elphinstone Street vary between 10 mAHD and 11 mAHD, with significant areas of the lower Frenchmans catchment experiencing peak flood heights of between 6 mAHD and 7 mAHD.

- **Maps 19 to 21** – 1% AEP Baseline

Peak flood depths upstream of key culverts beneath Pilbeam Drive and Wigginton Street are predicted to increase by up to 0.6m. Flood depths of up to 0.9m is expected to overtop Beasley Street, Kerrigan Street and Elphinstone Street. Honour Street is predicted to be overtopped by up to 0.9m with the majority of the crossings between Diplock Street and Mills Avenue also inundated. Minor overland flow paths across the lower urban catchments are more apparent as the capacity of the subsurface stormwater infrastructure network is exceeded.

Peak flood heights for the lower reaches directly upstream of Lakes Creek Road are predicted to increase, with peak flood heights reaching 7 mAHD adjacent to private properties. Peak flood heights are predicted to exceed 10.5 mAHD at Elphinstone Street, 36 mAHD at Kerrigan Street and 44 mAHD at Beasley Street.

Predicted peak depth averaged velocities within the creek channels and prominent tributaries are expected to exceed 2 m/s. A high proportion of floodplain flows and runoff within road corridors is expected to exceed 1.5 m/s. The connectivity between the two creek systems is more prevalent.

- **Maps 22 to 24** – 0.2% AEP Baseline

Flow overtops Wigginton Street, to the south east, with a depth less than 0.3 m. In this event, there is expected to be significant connectivity between the creek channels and the floodplain areas, resulting in inundation of numerous low lying private properties. Flood extents within the lower reaches of the catchments increase notably, especially near Lakes Creek Road. The peak depth averaged velocity down both creek reaches is predicted to be greater than 2 m/s.

- **Maps 25 to 27** – 0.05% AEP Baseline

In the 0.05% AEP storm event the flood extents impact on a significant number of developed parcels either side of both Frenchmans and Thozets Creeks. The subsurface drainage infrastructure is providing limited benefit, resulting in overland flow paths becoming pronounced. Cross-catchment connectivity continues to increase, with velocities within some road corridors expected to exceed 2 m/s.

- **Maps 28 to 30** – PMF Baseline

The effect of the significant increase in rainfall depths during the PMF event is obvious across both catchments. The depth of flow through both creek channels exceed 3 m. Inundation depths within the adjacent floodplains is predicted to exceed 1.5 m in most instances. A large number of properties west of Frenchmans Creek become inundated during this event, nearly to the extent of the model boundary. The cross-drainage structures beneath Lakes Creek Road are significantly under-capacity for the extreme nature of this event, resulting in the road structures attenuating flows attempting to reach the Fitzroy River. The result is significant storage upstream of Lakes Creek Road which is expected to affect hundreds of properties in the low-lying areas of the catchment.

- **Map 31** – Design Event Extent Comparison

From the various design flood extent maps, the full extent of the PMF event can be seen to be impacting a significantly large proportion of the catchment. During the smaller magnitude events, much of the flow is contained within drainage reserves and road corridors. In the upper catchment it should be noted that there is little difference between the flood extent in the 1EY storm event and the PMF due to the steep terrain and supercritical flow behaviour. There is a significant difference in flood extents within the lower reaches of the creeks.

8.4 Baseline Peak Discharges

Peak discharges across the range of simulated design events were extracted at key locations, including but not limited to:

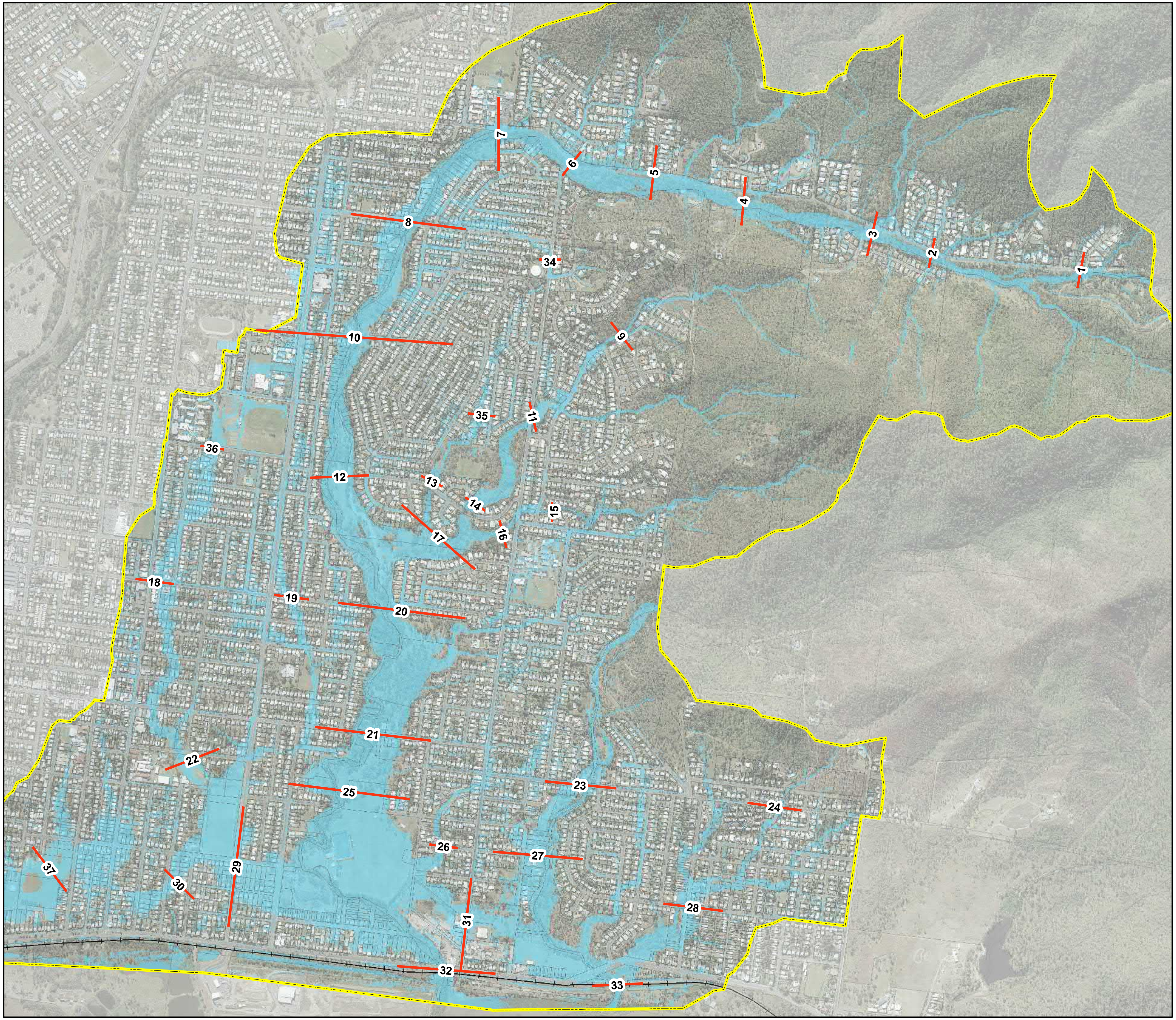
- Frenchmans Creek major crossings;
- Thozets Creek major crossings;
- Thozet Road;
- High Street;
- Rockonia Road; and
- Lakes Creek Road.

The flow from the trunk stormwater system adjacent to Musgrave Street conveying runoff to the Fitzroy River has also been included. Refer to Figure 23 for extraction cross-section locations. Table 21 below presents the results at corresponding locations.

Table 21 Summary of Basecase Peak Discharges

Flow Path Label / ID	ID	Peak Discharge (m^3/s) for Design AEP									
		1EY	39%	18%	10%	5%	2%	1%	0.2%	0.05%	PMF
Frenchmans Creek	1	8.9	14.2	21.7	26.9	34.0	41.8	49.5	76.1	100.4	228.0
	2	18.8	29.4	43.1	52.2	65.0	76.2	91.2	143.6	185.0	400.0
	3	25.0	39.8	59.2	72.5	90.7	106.1	124.4	187.6	243.2	521.4
	4	29.0	47.2	69.3	83.8	103.4	120.7	142.5	212.5	273.1	577.4
	5	33.5	54.2	80.0	96.6	119.6	140.2	164.7	249.4	321.2	687.1
	6	34.6	56.9	83.9	101.6	125.1	146.5	171.8	259.7	332.8	693.6
	7	37.4	61.1	90.1	108.2	132.8	155.7	181.9	275.4	352.9	735.6
	8	39.0	63.1	94.7	112.4	138.2	162.5	190.0	285.0	365.0	786.5
Woodland Drive	9	5.2	8.6	11.7	13.1	15.7	17.4	19.8	28.1	35.5	58.3
Frenchmans Creek	10	43.5	69.1	101.3	118.8	144.7	172.6	203.9	300.9	385.5	848.4
Thozet Road	11	5.8	10.9	16.6	19.7	23.7	26.4	31.2	48.6	63.9	118.0
Frenchmans Creek	12	42.6	69.1	101.1	119.3	145.7	172.5	202.3	302.2	387.6	818.5
Wigginton Street	13	2.9	4.3	5.8	6.7	7.7	8.5	8.9	11.0	18.1	38.3
	14	9.7	15.3	22.3	25.9	30.7	34.5	39.4	58.2	76.8	136.6
Shields Avenue	15	3.9	6.1	8.4	9.8	11.7	12.6	14.1	18.8	22.7	35.5
Thozet Road	16	5.3	8.3	11.7	13.6	17.2	17.8	20.2	27.6	33.9	59.4
Downstream of Wigginton Street	17	16.9	26.9	39.0	45.6	54.1	60.5	68.6	97.8	132.4	244.2
High Street	18	0.3	0.7	2.0	3.1	4.6	6.3	7.9	12.7	16.1	38.8
	19	0.3	0.9	1.8	2.3	2.9	3.6	4.4	7.0	9.2	21.2
Frenchmans Creek	20	58.3	88.1	133.6	157.3	190.8	225.3	262.7	385.8	489.3	1060.0
	21	8.7	39.0	83.5	112.2	156.9	180.7	220.6	353.1	501.0	1171.9
Bedford Street	22	1.3	1.9	3.7	4.7	6.1	7.6	9.8	18.2	25.9	80.1
Rockonia Road	23	0.7	1.0	2.8	6.7	14.1	24.2	33.0	66.1	96.4	294.7
	24	0.4	0.5	1.3	2.3	3.6	4.6	5.9	10.4	14.3	28.1
Frenchmans Creek	25	57.5	91.5	139.1	167.6	225.1	256.2	286.4	419.4	531.9	1177.6
Joiner Street	26	0.2	0.7	1.7	2.4	3.3	4.0	5.0	8.0	10.6	21.4
Thozets Creek	27	12.5	18.9	28.5	34.6	43.4	54.5	64.2	99.1	130.7	334.7
Stenhouse Street	28	8.1	12.0	17.1	20.7	25.0	28.1	32.4	46.7	59.2	104.7

Flow Path Label / ID	ID	Peak Discharge (m^3/s) for Design AEP									
		1EY	39%	18%	10%	5%	2%	1%	0.2%	0.05%	PMF
Dean Street	29	0.3	2.1	4.8	6.3	10.6	13.3	14.5	26.7	33.9	105.9
Bowden Street	30	0.2	0.2	0.4	0.6	0.9	1.0	1.3	9.1	19.6	112.1
Thozet Road	31	0.1	0.2	0.2	0.2	0.6	4.3	8.5	38.0	74.7	328.1
Frenchmans Creek Outlet	32	57.6	88.6	127.9	148.9	188.5	210.4	227.2	282.3	328.0	656.9
Thozets Creek Outlet	33	18.6	26.9	38.6	50.2	61.3	75.7	88.7	150.0	216.9	749.5
Thozet Road	34	0.8	1.3	1.8	2.1	2.5	2.7	3.1	4.6	5.0	7.0
Irving Avenue	35	1.4	2.0	2.6	2.9	3.3	3.5	3.8	5.3	6.5	10.0
Simpson Street	36	0.6	1.2	2.0	2.8	4.4	5.1	6.2	9.7	14.7	35.3
Elizabeth Park	37	0.5	0.9	1.6	2.0	2.5	2.9	3.3	7.4	10.5	70.2



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DATUM GDA 1994, PROJECTION MGA ZONE 56

0 150 300 450 600 750

Metres

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LEGEND

- Discharge Cross-sections
- Hydraulic Model Extent
- Highways
- Railway Lines
- Cadastre
- 1% AEP Flood Extent

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Results Filtering:
75mm Min. Depth
100m² Min. Area

Frenchmans Creek & Thozets Creek Model

Key Flow Path Discharge Locations

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	21/07/2017
VERSION:	2

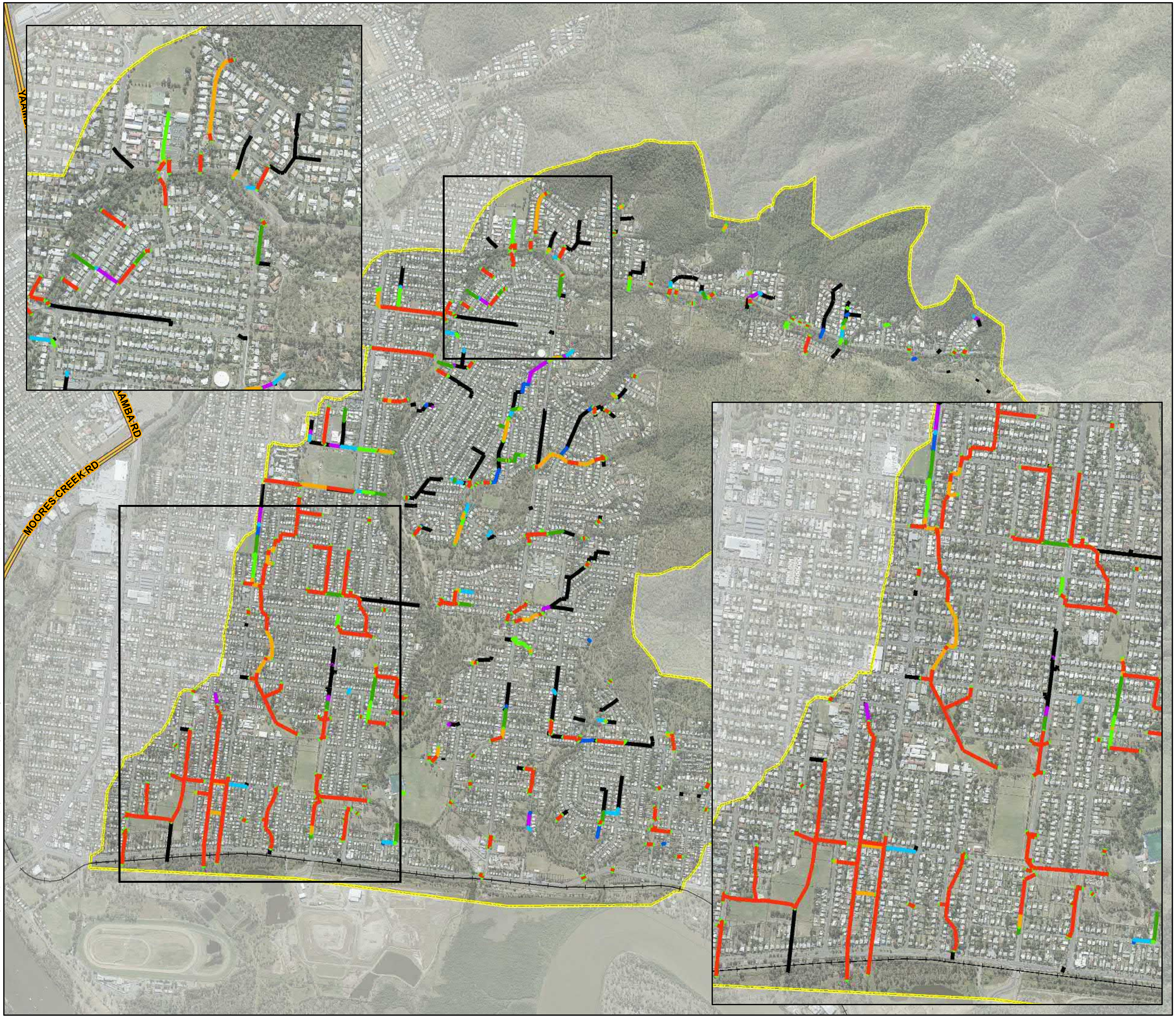
Figure 23

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\Figure 22 Key Flow Output Locations.mxd

8.5 Stormwater Network Capacity

Figure 24 provides a spatial analysis of the existing underground network capacity during the 180 minute critical storm duration. It shows the event at which the capacity of the pipe/culvert is reached. It is noted that culverts were considered to have reached capacity once they exceeded 80% of their full flow capacity.

It can be seen that several segments of the network have less than 1EY immunity – an estimated 44% of the modelled network. Approximately 61% of the network has less than 10% AEP immunity, which includes the majority of pipes to the west of Frenchmans Creek. In a 1% AEP event, approximately 70% of the network is considered as flowing at full capacity.



Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 250 500 750 1,000
Metres

1:20,000
(when printed at A3)

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LEGEND

Pipe Flowing Full in

- 1EY
- 39% AEP
- 18% AEP
- 10% AEP
- 5% AEP
- 2% AEP
- 1% AEP
- > 1% AEP
- Highways
- Levee Alignment
- Railway Lines
- Cadastre
- Hydraulic Model Extent

Data Sources:

DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Frenchmans Creek & Thozets Creek Model

Basecase 1D Network Capacity Analysis

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	21/07/2017
VERSION:	A

Figure 24

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\Figure 23 Basecase 1D Network Capacity Analysis.mxd

8.6 Comparison with Previous Study Results

8.6.1 Recommended Changes from Previous Study Peer Review

Within BMT WBM's Independent Review of Rockhampton Local Catchments Flood Study - Numerical Models (2014), several recommendations were made to improve the flood behaviours predicted by the TUFLOW model. These include:

- Refined grid cell size;
- Depth-varying roughness and more detailed delineation;
- Industry-standard hydrologic losses and MHWS tidal boundary;
- Improved representation of hydraulic structures; and
- Additional validation of the model to recorded events.

8.6.2 Changes Implemented in this Study

The updated model has been upgraded to a rain-on-grid model with a reduced grid size of 3m. The combination of a reduced grid size and rain applied across the urban catchment provides significantly more detail on local catchment flow paths and better informs future planning. Bridge structures have been digitized as layered flow constrictions in the 2D domain and applied a head loss to a single row of cells. This approach ensures a constant head loss is applied across the width of the structure.

The 1D network was updated to match Council's current GIS database. More than 900 pipes and several key culverts were added to the TUFLOW model within the 1D domain. The implementation of the stormwater network indicated that there were instances where the subsurface network conveyed surface runoff not previously included in the hydrologic model to Frenchmans and Thozets Creek.

Channel roughness was inspected onsite and delineated in greater detail using the latest imagery. Hydraulic roughness was also applied with depth-varying roughness to better represent frictional losses of the water profile as depth increases.

Areas suspected to be inaccurately represented by the LiDAR 1m DEM were surveyed and compared to the relevant LiDAR cross-section which revealed thick weed and trees caused the channel conveyance to be underestimated in several locations. To mitigate this, survey was incorporated into the model and matched back to the surrounding LiDAR where dense vegetation was not expected to have impacted the DEM precision.

The rainfall losses applied to both the urban catchment and XP-RAFTS hydrologic model were revised and updated to consistent values across the suite of design events as per standard industry practice.

The February 2015 calibration event was adopted as the calibration event, with the January 2013 and March 2017 serving as validation events to confirm the performance of the hydraulic model over a range of events.

8.6.3 Results Comparison between Previous and Current Study

Figure 25 to Figure 28 show the differences in predicted peak flood heights and depths as a result of the changes listed above. The comparison shows:

- **Figure 25** – 18% AEP Height Difference Map

Many of the overland flow paths in the upper catchments were previously modelled as inflows either directly into Frenchmans or Thozets Creeks or applied at the sub-catchment outlets. These are now represented in the updated modelling due the direct rainfall modelling approach. The overland flow paths coincide with gullies and lower sections of the natural topography, as the runoff is conveyed towards the Creeks.

Along much of the length of Frenchmans Creek the overall flood extents have been reduced, highlighted by the areas that were 'wet and are now dry.' This is especially evident near Moyle Street as many properties which had been modelled to experience flooding are no longer expected to be affected in this event. This reduction in extents is attributed to the channel being more defined due to a smaller model grid size and the culverts at Beasley Street being better represented in the model.

Thozets Creek exhibits a similar pattern, with the flood extents reduced in the latest modelling, especially in areas surrounding the creek. This can be attributed to improved topographic data and improved digitisation of the channel.

Overall the PWSE in the current study is higher than the previous study. This difference in PWSE is largely due to the use of new ground survey (in the form of 2016 LiDAR). It is noted that the 2016 LiDAR is higher than the LiDAR utilised in the previous study. In the 18% AEP event the continuing rainfall losses in this study are less than the previous study, resulting in additional runoff and higher flood heights.

Other localised differences between the models can be attributed to the introduction of the 1d network, slight changes in topography and a more refined model grid size.

- **Figure 26** – 18% AEP Depth Difference Map

Overall the difference in depths on the floodplains of both Frenchmans and Thozets Creek are either lower or slightly higher. In the lower reaches of the creek channels, the depth is greater in this study - again indicating the improved channel representation using surveyed cross sections and a more refined model grid size.

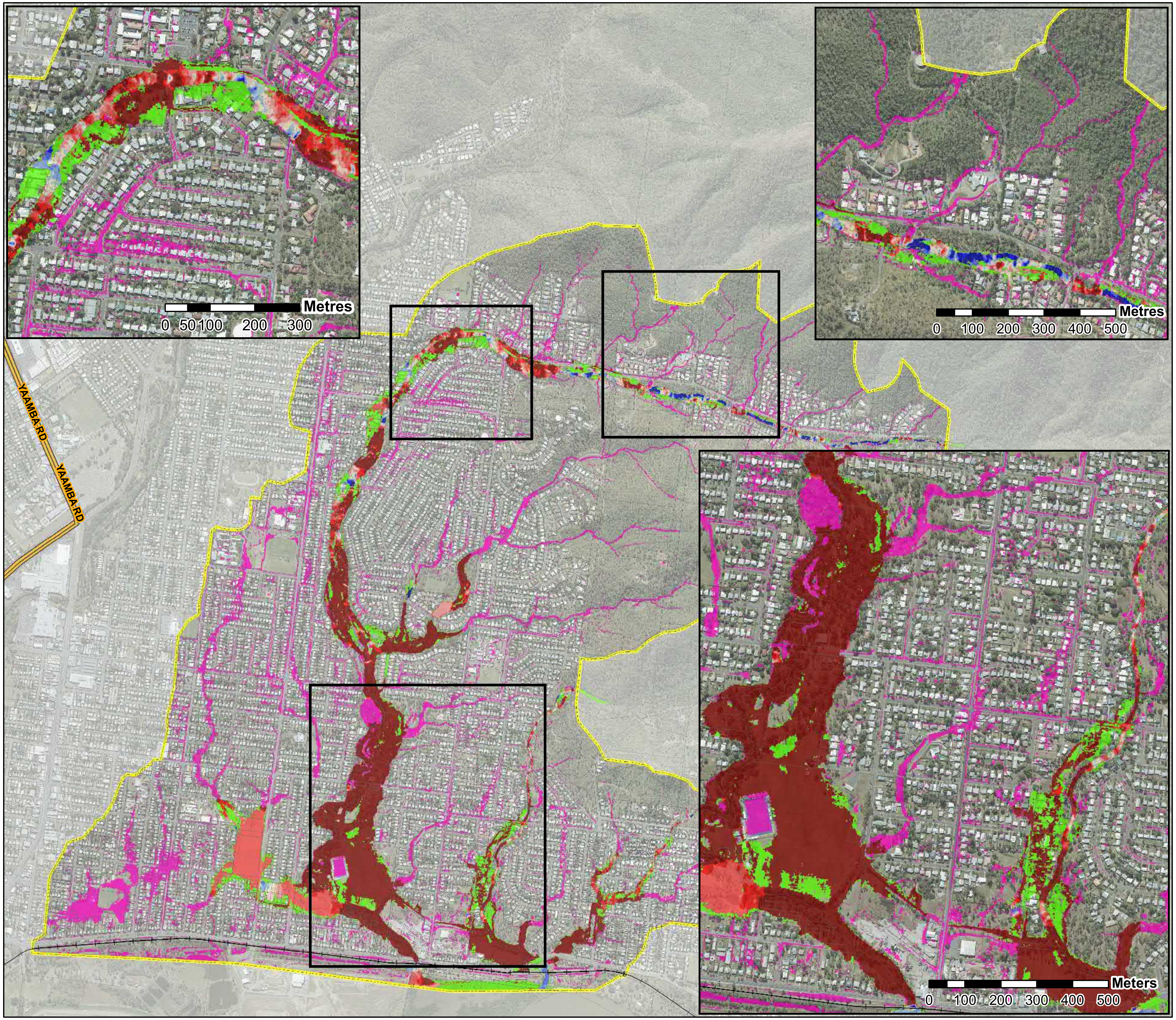
- **Figure 27** – 1% AEP Height Difference Map

As noted above, the overall flood extents are reduced, due to the improved channel digitization and topographic data.

The impacts of the improved digitization of the channel is particularly visible near Beasley Street, south of Wigginton Street and along Thozets Creek where the extents are considerably more restricted despite an overall increase to the PWSE.

- **Figure 28** – 1% AEP Depth Difference Map

In the 1% AEP comparison the floodplains are shown to have reduced depths. Contrastingly, creek channels are shown to increase in depth by more than 0.3m due to increased channel conveyance resulting from better digitization in the current model. The reduction in depths at McLeod Park can be attributed to the improvements made by Council since the development of the previous model (i.e. McLeod Park Drainage Scheme Stage 1 and 2.



Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

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Metres

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(when printed at A3)

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LEGEND

- Highways
- Levee Alignment
- Railway Lines
- Cadastre
- Hydraulic Model Extent

Difference in PWSE (m)

- < -0.3
- -0.3 to -0.225
- -0.225 to -0.15
- -0.15 to -0.075
- -0.075 to -0.02
- -0.02 to 0.02
- 0.02 to 0.075
- 0.075 to 0.15
- 0.15 to 0.225
- 0.225 to 0.3
- > 0.3
- Was Dry Now Wet*
- Was Wet Now Dry

* May be due to previously unmodelled overland flow

Flood results are based on local catchment events

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Results Filtering:
75mm Min. Depth
100m² Min. Area

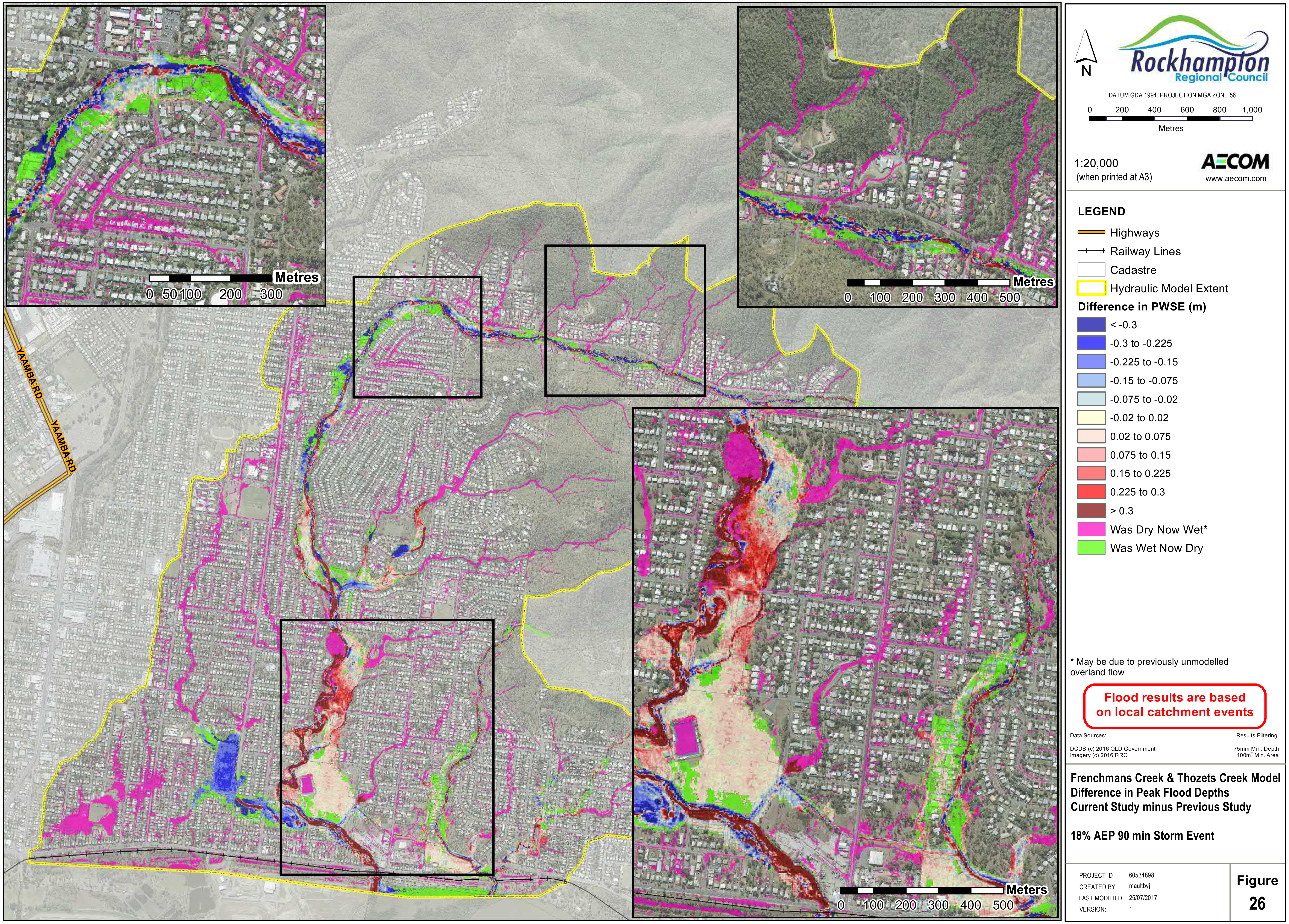
Frenchmans Creek & Thozets Creek Model
Difference in Peak Flood Heights
Current Study minus Previous Study

18% AEP 90min Storm Event

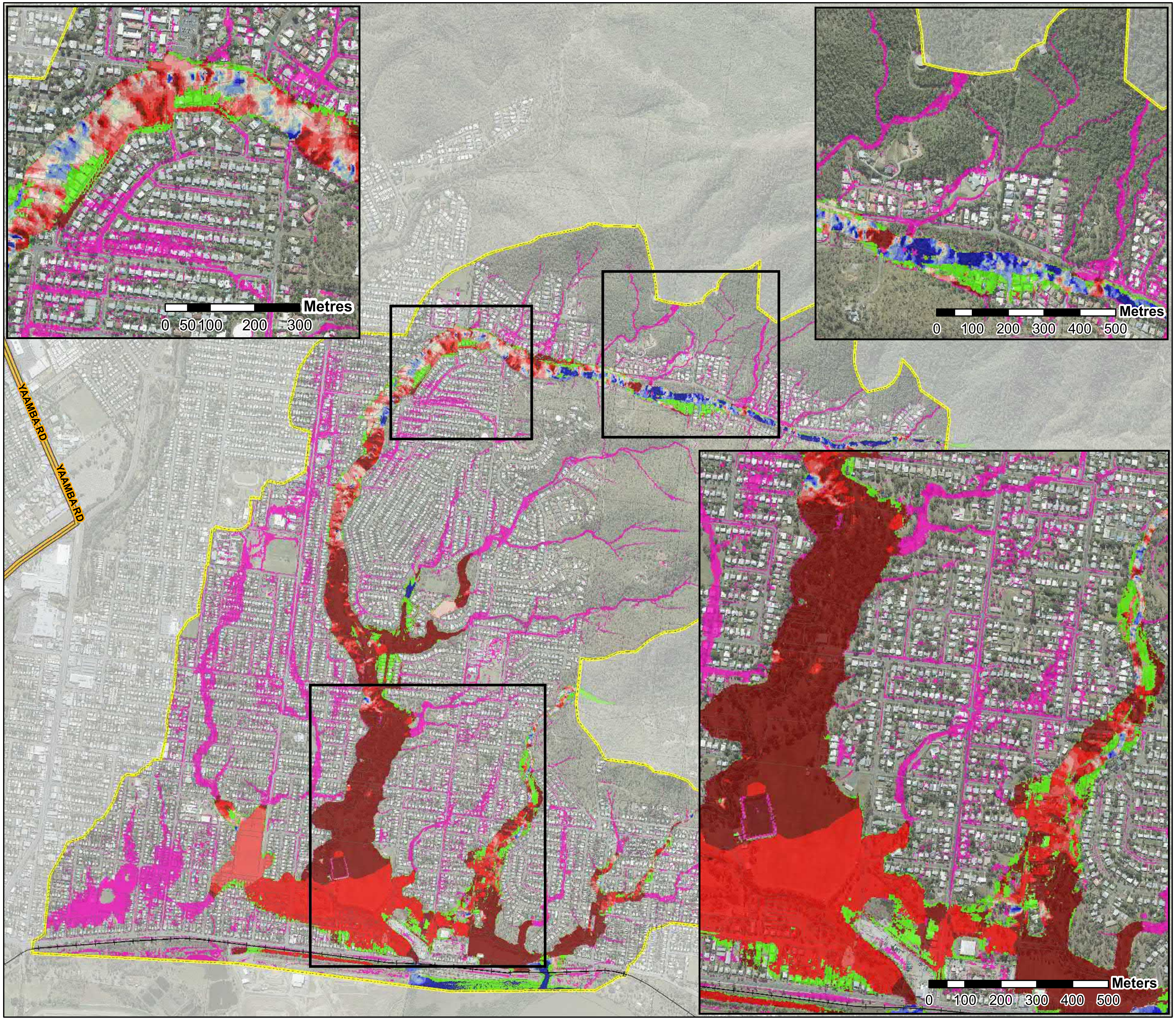
PROJECT ID 60534898
CREATED BY maultbyj
LAST MODIFIED 25/07/2017
VERSION: 1

Figure 25

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\Figure 25 Results Comparison 18% AEP.mxd



Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\Figure 26 Results Comparison 18% AEP_Depth.mxd



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Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

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Metres

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(when printed at A3)

AECOM
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LEGEND

- Highways
- Railway Lines
- Cadastre
- Hydraulic Model Extent

Afflux (m)

Difference in PWSE (m)

- < -0.3
- -0.3 to -0.225
- -0.225 to -0.15
- -0.15 to -0.075
- -0.075 to -0.02
- -0.02 to 0.02
- 0.02 to 0.075
- 0.075 to 0.15
- 0.15 to 0.225
- 0.225 to 0.3
- > 0.3
- Was Dry Now Wet*
- Was Wet Now Dry

* May be due to previously unmodelled overland flow

Flood results are based on local catchment events

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Results Filtering:
75mm Min. Depth
100m² Min. Area

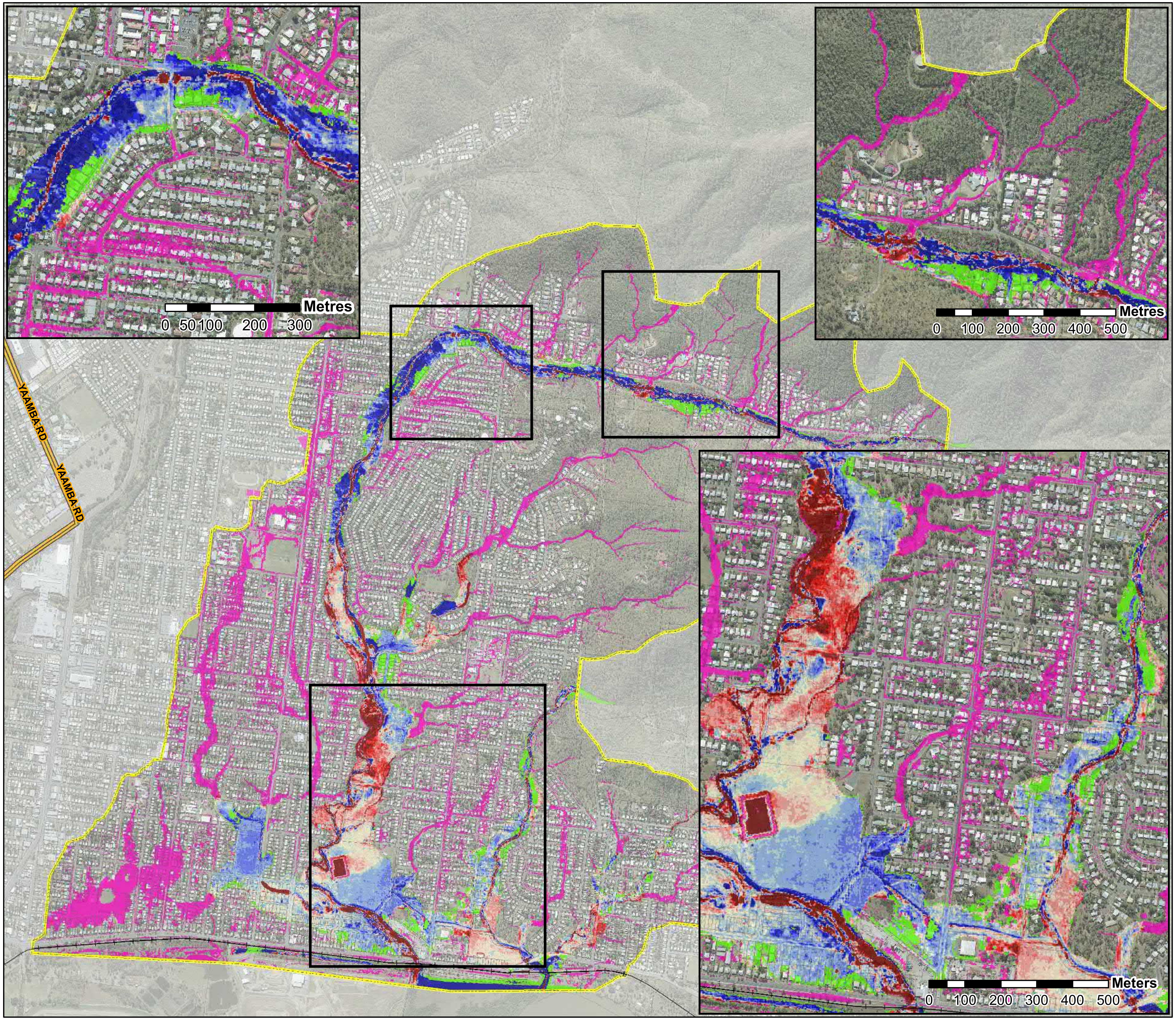
Frenchmans Creek & Thozets Creek Model
Difference in Peak Flood Heights
Current Study minus Previous Study

1% AEP 90min Event

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	25/07/2017
VERSION:	1

Figure 27

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\Figure 27 Results Comparison 1% AEP.mxd



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Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

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Metres

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(when printed at A3)

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LEGEND

- Highways
- Railway Lines
- Cadastre
- Hydraulic Model Extent

Difference in Depth (m)

- < -0.3
- -0.3 to -0.225
- -0.225 to -0.15
- -0.15 to -0.075
- -0.075 to -0.02
- -0.02 to 0.02
- 0.02 to 0.075
- 0.075 to 0.15
- 0.15 to 0.225
- 0.225 to 0.3
- > 0.3
- Was Dry Now Wet*
- Was Wet Now Dry

* May be due to previously unmodelled overland flow

Flood results are based on local catchment events

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Results Filtering:
75mm Min. Depth
100m² Min. Area

Frenchmans Creek & Thozets Creek Model
Difference in Peak Flood Depths
Current Study minus Previous Study

1% AEP 90min Storm Event

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	25/07/2017
VERSION:	1

Figure 28

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\Figure 28 Results Comparison 1% AEP_Depth.mxd

9.0 Sensitivity Analysis

9.1 Overview

A number of sensitivity analyses have been completed as part of the study which included:

- Sensitivity 1 – Increase in manning's roughness values (15%).
- Sensitivity 2 – Decrease in manning's roughness values (15%).
- Sensitivity 3 – Increase in rainfall intensities to replicate potential climate change impacts (30% increase in rainfall intensity).
- Sensitivity 4 – Coincident 18% AEP Fitzroy River Tailwater Level.
- Sensitivity 5 – 20% Underground Stormwater Infrastructure Blockage.
- Sensitivity 6 – 50% Underground Stormwater Infrastructure Blockage.
- Sensitivity 7 – 100% Underground Stormwater Infrastructure Blockage.
- Sensitivity 8 – Increased Inlet Structure Dimensions.
- Sensitivity 9 – Key Cross Drainage Culvert Blockage.

Further discussion on each sensitivity analysis is provided below.

9.2 Hydraulic Roughness

Testing of the model sensitivity to seasonal changes in roughness was undertaken for the 1% AEP event using both an increase and decrease in the Manning Roughness Coefficient by 15% across all material types. The sensitivity was implemented by increasing and decreasing all manning's roughness values listed in the TUFLOW materials file.

The following maps represent the results of the sensitivity testing.

- 15% Increase in Roughness à **Map FT-62**
- 15% Decrease in Roughness à **Map FT-63**

Map FT-62 indicates that with a uniformly increased roughness value across all material types, there is a corresponding overall increase in peak flood heights and overland flood extents. The majority of the urban areas within the catchment experience negligible increases in peak water surface elevations. Residential areas adjacent to Stenhouse Street and Rockonia Road are predicted to have minor increases in peak flood heights (up to 40mm). The most significantly impacted areas within the Frenchmans and Thozets Creek catchments are that of the creek channel and neighbouring floodplain areas, with increases of peak flood heights by up to 0.25m within Frenchmans Creek and up to 0.1m within Thozets Creek.

The result from the sensitivity analysis which applies a 15% decrease in manning's roughness values are shown in **Map FT-63**. The decrease in roughness indicates a corresponding decrease in peak flood heights. The reduction in peak flood heights is negligible throughout most of the catchment area however some residential areas adjacent to Stenhouse Street and Rockonia Road are predicted to experience reductions in peak flood height (average of 40mm). Reductions in peak flood height of up to 0.1m are predicted within the Thozets Creek corridor, with the Frenchmans Creek corridor and adjacent floodplains predicted to be more sensitive to changes in roughness with a predicted reduction of up to 0.3m.

9.3 Climate Change

A suite of climate change literature is available, covering global, national and more localised state based climate change discussion and analysis. Whilst much of the literature states that, for Queensland, total annual rainfall is decreasing and rainfall intensity during rainfall events is increasing, there is comparatively little literature recommending actual values to adopt for these changes.

The DERM, DIP and LGAQ Inland Flooding Study (2010) was specifically aimed at providing a benchmark for climate change impacts on inland flood risk. The study recommends a 'climate change factor' be included into flood studies in the form of a 5% increase in rainfall intensity per degree of global warming.

For the purposes of applying the climate change factor, the study outlines the following temperature increases and planning horizons:

- 2°Celsius by 2050;
- 3°Celsius by 2070; and
- 4°Celsius by 2100.

Other literature such as the Guidelines for Preparing a Climate Change Impact Statement (CCIS) published by the Queensland Office of Climate Change predict that by 2050 there will be a 20-30% increase in cyclonic rainfall intensity.

As a conservative approach, the overall rainfall in the Frenchmans and Thozets Creeks TUFLOW model was increased by 30% to represent the predicted rainfall patterns in 2100. The rainfall in the XP-RAFTS simulation for the inflows was also increased by 30%, for the 1% AEP design event.

Map FT-64 indicates that the 30% increase in applied rainfall significantly increases peak flood heights and extents throughout the catchment, with a notable increase to peak flood extent visible in the lower catchment floodplains south of Elphinstone Street. The peak flood height throughout the majority of the creek channel is predicted to increase between 0.4m and 0.5m. Results indicate that for smaller tributaries of the creek system, peak flood heights will increase by up to 0.3m with the peak flood depths upstream of major crossings traversing Wigginton Street expected to increase by 0.6m to 0.7m. A number of previously unaffected properties in the lower portion of the catchment (directly upstream of Lakes Creek Road) are expected to be impacted due to the increase in peak flood extents.

9.4 Riverine and Local Catchment Coincident Event

In the baseline design events, it was assumed that riverine and local catchment flooding would not coincide. In this sensitivity analysis, the downstream water level in the TUFLOW model was set at the peak flood height corresponding to the 18% AEP Fitzroy River flood event (5.3 mAHD) to coincide with a 1% AEP design storm event in the Frenchmans and Thozets Creeks catchments. The Fitzroy River flood height of 5.3 mAHD has been determined based upon results from RRC's Fitzroy River model (refer to Section 3.2.5).

As can be seen from **Map FT-65** the effect of this tailwater level is confined to the lower catchment area with the major impacts confined to the floodplains downstream of Lakes Creek Road. The results indicate that in the lower catchment area upstream of Lakes Creek Road, the peak flood height increases by up to 0.05m. Peak flood heights within the Fitzroy are predicted to increase by more than 2.5m. The variation in peak water surface elevation and increase to peak flood extents across most residential areas is negligible, however it is predicted that residential properties neighbouring Lakes Creek Road along Frenchmans Creek will experience increases in peak flood height of up to 30mm.

9.5 Stormwater Infrastructure Blockage

Testing of the model sensitivity to the underground stormwater infrastructure being blocked by debris, was undertaken for the 18% AEP event using an increasing percentage blockage on the underground stormwater network. This excluded cross drainage structures which was the subject of a specific sensitivity analysis (refer to Section 9.7).

Sensitivities were undertaken using 20%, 50% and 100% blockage factors. The following maps represent the results of the sensitivity testing.

- 20% Increase in Blockage à **Map FT-66**
- 50% Increase in Roughness à **Map FT-67**
- 100% Increase in Roughness à **Map FT-68**

9.5.1 20% Blockage of Stormwater Infrastructure

A 20% blockage factor was adopted which can be considered as a reasonable representation of standard operating conditions throughout the working life of the stormwater infrastructure.

The results presented in map **FT-66** indicate that across the majority of the catchment, applying a 20% blockage to the stormwater network causes negligible change in peak water surface elevation with most areas being between ± 0.02 m of the baseline peak flood height results. However, specific areas in the vicinity of Edward Street, Rodboro Street and the major flow path north of Elphinstone Street are predicted to have increases in peak flood heights between 0.02m and 0.25m when the stormwater network is 20% blocked. The overland flow path at Tomkys Street is predicted to be the most sensitive to a 20% stormwater network blockage with increases expected to exceed 0.3m.

9.5.2 50% Blockage of Stormwater Infrastructure

A 50% blockage factor is more representative of stormwater infrastructure during extreme events where there is a more significant presence of flood borne debris.

Blockage of the stormwater infrastructure by 50% results in higher peak flood heights in a number of areas and overland flow paths. These include those mentioned in Section 9.5.1 as well as the flow paths upstream of Thozets Road near Wigginton Street with increases in peak flood heights between 0.05m and 0.3m expected. As before, the overland flow path at Tomkys Street is predicted to be the most sensitive to stormwater network blockage with increases of up to 0.6m predicted.

9.5.3 100% Blockage of Stormwater Infrastructure

As a worst case analysis, the model has also been tested with the stormwater network being 100% blocked. The results shown in **FT-68** indicate that several areas experience increases in flood heights.

Areas which are predicted to experience the largest increases are those surrounding Tomkys Street, Rodboro Street and the major flow path north of Elphinstone Street; all of which have notable corresponding increases to peak flood extents which impacts additional developed parcels. Attenuation of overland runoff leads to a minor reduction in peak flood heights of up to 40mm within Frenchmans Creek between Elphinstone Street and Lakes Creek Road.

9.6 Inlet Structure Dimensions

As documented in Appendix A, one of the assumptions made during the development of the 1D component of the TUFLOW model was that all inlet pits were a standard size of 900mm by 600mm. This assumption was made in the absence of survey inlet types and sizes. A sensitivity analysis was undertaken in order to test the potential impact of this assumption. In order to test this sensitivity all pit sizes were increased from 900mm by 600mm to 2000mm by 2000mm.

As indicated in map **FT-69**, the difference in peak flood height is between ± 0.02 m across the majority of the catchment. Floodplain storage areas at Mcloed Park and overland flow paths near Wigginton Street and Thozets Road are expected to see reductions in peak water surface elevations of up to 0.1m in an 18% AEP 90min storm event. With the exception of the flow paths near Rodboro Street, areas where peak flood heights are shown to undergo a reduction are primarily non-residential.

9.7 Key Cross Drainage Culvert Blockage

The following has been sourced from ‘Australian Rainfall & Runoff – Blockage guidelines for culverts and small bridges (Feb, 2015)’ and ‘Australian Rainfall & Runoff: A Guide to Flood Estimation (2016)’.

Blockage can have a severe impact on the capacity of drainage systems and peak flood extents. Determination of likely blockage levels and mechanisms, when simulating design flows, is therefore an important consideration in quantifying the potential impact of blockage of a particular structure on design flood behaviour.

This procedure has been developed to quantify the most likely blockage level and mechanism for a small bridge or culvert when impacted by sediment or debris laden floodwater. This procedure includes consideration of the impact of both floating and non-floating debris as well as non-floating sedimentation blockage within a structure. It is restricted to constant (i.e. not time-varying) structure blockage during throughout design event.

9.7.1 Factors influencing blockage

The factors that most influence the likely blockage of a bridge or culvert structure are:

- Debris Type and Dimensions - whether floating, non-floating or urban debris present in the source area and its size.
- Debris Availability – the volume of debris available in the source area.
- Debris Mobility – the ease with which available debris can be moved into the stream.
- Debris Transportability – the ease with which the mobilised debris is transported once it enters the stream.
- Structure Interaction – the resulting interaction between the transported debris and the bridge or culvert structure.
- Random Chance – an unquantifiable but significant factor.

9.7.2 Common Blockages

All blockages that do occur arise from the arrival and build-up of debris at a structure. There are three different types of debris typically present in debris accumulated upstream of or within a blocked structure. This debris may be classified as floating (e.g. trees), non-floating or depositional (e.g. sediment) and urban (e.g. cars and other urban debris).

9.7.2.1 Floating Debris

Floating debris in rural or forested streams is generally vegetation of various types. Small floating debris, less than 150mm long, can include small tree branches, sticks, leaves and refuse from yards such as litter and lawn clippings and all types of rural vegetation. Medium floating debris, typically between 150mm and 3m long, mainly consists of tree branches of various sizes. Large floating debris, more than 3m long, consists of logs or trees, typically from the same sources as for medium floating debris. Small items of vegetation will usually pass through drainage structures during floods, while larger items may be caught in the structure. Once larger items are caught, this then allows smaller debris to collect on the structure.

9.7.2.2 Non-Floating Debris

Non-floating debris in rural or forested streams is usually sediment of all types. Fine sediments (silt and sand) typically consist of particles ranging from 0.004 to 2mm. The deposition of finer clay-sized particles is normally a concern in tidal areas, with lower flood surface gradients and velocities. Gravels and cobbles consist of rock typically ranging in size from 2 to 63mm and 63 to 200mm respectively. The source of this material may be from gully formation, channel erosion, landslips or land mass failure although landslips and/or land mass failures of any size will likely create hyper concentrated or even debris flows which are not covered by this guideline. Boulders comprise rocks greater than 200mm. The source of boulders is mostly from gully and channel erosion, landslips and the displacement of rocks from channel stabilisation works.

9.7.2.3 Urban Debris

Urbanisation of catchments introduces many different man-made materials that are less common in rural or forested catchments and which can cause structure blockage. These include fence palings, building materials, and mattresses, garbage bins, shopping trolleys, fridges, large industrial containers and vehicles.

9.7.3 Design Blockage Level

The following tables and methodology has been used in the assessment of blockage. Assessment of Inlet Blockage (Floating or Non-Floating) and Barrel Blockage (Non-Floating) has been undertaken for each culvert selected for the sensitivity analyses. A "worst case" result is then adopted for the blockage across all structures assessed. This enables a comparative analysis of the model sensitivity to culvert blockage (as blockage is consistent) and a reasonable prediction of flood behaviours under the assessed event with logically-derived blockage.

9.7.3.1 Debris Availability

Table 22 Debris Availability - in Source Area of a Particular Type/Size of Debris (Table 6.6.1 ARR, 2016)

Classification	Typical Source Area Characteristics (1% AEP Event)
High	· Natural forested areas with thick vegetation and extensive canopy cover, difficult to walk through with considerable fallen limbs, leaves and high levels of floor litter. · Streams with boulder/cobble beds and steep bed slopes and steep banks showing signs of substantial past bed/bank movements. · Arid areas, where loose vegetation and exposed loose soils occur and vegetation is sparse. · Urban areas that are not well maintained and/or where old paling fences, sheds, cars and/or stored loose material etc., are present on the floodplain close to the water course.
Medium	· State forest areas with clear understory, grazing land with stands of trees. · Source areas generally falling between the High and Low categories.
Low	· Well maintained rural lands and paddocks with minimal outbuildings or stored materials in the source area. · Streams with moderate to flat slopes and stable bed and banks. · Arid areas where vegetation is deep rooted and soils are resistant to scour. · Urban areas that are well maintained with limited debris present in the source area.

A **High** classification of debris availability for Frenchmans and Thozets Creeks has been selected as:

- Natural forested areas with thick vegetation and extensive canopy cover, difficult to walk through with considerable fallen limbs, leaves and high levels of floor litter.
- Streams with boulder/cobble beds and steep bed slopes and steep banks showing signs of substantial past bed/bank movements.
- Urban areas that are not well maintained and/or where old paling fences, sheds, cars and/or stored loose material etc., are present on the floodplain close to the water course.

9.7.3.2 Debris Mobility

Table 23 Debris Mobility - Ability of a Particular Type/Size of Debris to be Moved into Streams (Table 6.6.2 ARR, 2016)

Classification	Typical Source Area Characteristics (1% AEP Event)
High	· Steep source areas with fast response times and high annual rainfall and/or storm intensities and/or source areas subject to high rainfall with sparse vegetation cover. · Receiving streams that frequently overtop their banks. · Main debris source areas close to streams.
Medium	· Source areas generally falling between the High and Low mobility categories.
Low	· Low rainfall intensities and large, flat source areas. · Receiving streams infrequently overtops their banks. · Main debris source areas well away from streams.

A **High** classification of debris mobility for Frenchmans and Thozets Creeks has been selected as:

- Steep source areas with fast response times and high annual rainfall and/or storm intensities and/or source areas subject to high rainfall intensities with sparse vegetation cover.
- Receiving streams that frequently overtop their banks.
- Main debris source areas close to streams.

9.7.3.3 Debris Transportability

Table 24 Debris Transportability - Ability to Transport Debris to the Structure (Table 6.6.3 ARR, 2016)

Classification	Typical Transporting Stream Characteristics (1% AEP Event)
High	· Steep bed slopes (> 3%) and/or high stream velocity (V > 2.5 m/s) · Deep stream relative to vertical debris dimension (D > $0.5L_{10}$) · Wide stream relative to horizontal debris dimension.(W > L_{10}) · Stream relatively straight and free of major constrictions or snag points. · High temporal variability in maximum stream flows.
Medium	· Stream generally falling between High and Low categories.
Low	· Flat bed slopes (< 1%) and/or low stream velocity (V < 1m/s). · Shallow depth relative to vertical debris dimension (D < 0.5 L_{10}). · Narrow stream relative to horizontal debris dimension (W < L_{10}). · Stream meanders with frequent constrictions/snag points. · Low temporal variability in maximum stream flows.

In the absence of historical data, the following is recommended:

> *In an urban area the variety of available debris can be considerable with an equal variability in L_{10}. In the absence of a record of past debris accumulated at the structure, an L_{10} of at least 1.5 m should be considered as many urban debris sources produce material of at least this length such as palings, stored timber, sulo bins and shopping trolleys. (Clause 6.4.4.1 ARR, 2016)*

As such, 1.5m has been adopted as the average length of possible debris in the upper 10% quantile (L_{10}).

A **High** classification of debris transportability for Frenchmans and Thozets Creeks has been selected as:

- Steep bed slopes (> 3%) and/or high stream velocity (V > 2.5 m/s)
- Deep stream relative to vertical debris dimension (D > $0.5L_{10}$)
- Wide stream relative to horizontal debris dimension.(W > L_{10})
- High temporal variability in maximum stream flows.

9.7.3.4 Debris Potential

Table 25 1% AEP Debris Potential (Table 6.6.4 ARR, 2016)

Classification	Combinations of the Above (any order)
High	· HHH · HHM
Medium	· MMM · HML · HMM · HLL
Low	· LLL · MML · MLL

A **High** classification of debris potential for Frenchmans and Thozets Creeks has been selected as the combination of individual factors is HHH.

9.7.3.5 AEP Adjusted Debris Potential

Table 26 AEP Adjusted Debris Potential (Table 6.6.5 ARR, 2016)

Event AEP	(1% AEP) Debris Potential at Structure		
	High	Medium	Low
AEP > 5%	Medium	Low	Low
AEP 5% - AEP 0.5%	High	Medium	Low
AEP < 0.5%	High	High	Medium

A **Medium** classification of AEP Adjusted Debris Potential for Frenchmans and Thozets Creeks has been selected as the event AEP assessed is 18%.

9.7.3.6 Design Blockage Level

Subsequent components of the methodology were applied to each culvert individually.

Table 27 Most Likely Inlet Blockage Levels - B_{DES}% (Table 6.6.6 ARR, 2016)

Control Dimension Inlet Clear Width (W) (m)	AEP Adjusted Debris Potential At Structure		
	High	Medium	Low
$W < L_{10}$	100%	50%	25%
$L_{10} \leq W \leq 3^*L_{10}$	20%	10%	0%
$W > 3^*L_{10}$	10%	0%	0%

Inlet Blockage Levels based on the structure clear width was assessed for each culvert individually which can be reviewed in more detail within Table 30.

9.7.3.7 Sediment Deposition

A mean sediment size present of 63 to 200mm has been adopted based on site visits conducted after an event sized similarly to an 18% AEP event.

Table 28 Likelihood of Sediment Being Deposited in Barrel/Waterway (Table 6.6.7 ARR, 2016)

Peak Velocity Through Structure (m/s)	Mean Sediment Size Present				
	Clay/Silt 0.001 to 0.04 mm	Sand 0.04 to 2 mm	Gravel 2 to 63 mm	Cobbles 63 to 200 mm	Boulders >200 mm
>= 3.0	L	L	L	L	M
1.0 to < 3.0	L	L	L	M	M
0.5 to < 1.0	L	L	L	M	H
0.1 to < 0.5	L	L	M	H	H
< 0.1	L	M	H	H	H

This was assessed for each culvert individually which can be reviewed in more detail within Table 30.

Table 29 Most Likely Depositional Blockage Levels – B_{DES}% (Table 6.6.8 ARR, 2016)

Likelihood that Deposition will Occur	AEP Adjusted Non Floating Debris Potential (Sediment) at Structure		
	High	Medium	Low
>= 3.0	100%	60%	25%
1.0 to < 3.0	60%	40%	15%
0.5 to < 1.0	25%	15%	0%

As above, this was assessed for each culvert individually which can be reviewed in Table 30.

Table 30 Frenchmans and Thozets Creeks Culvert Blockage Assessment

Culvert Specification	Control Dimension	AEP Adjusted Debris Potential	Most Likely Inlet Blockage Levels	Peak Velocity (m/s)	Sediment Likelihood	Most Likely Depositional Blockage Levels	Highest Blockage Factor
7/2100x1350mm RCBC	L10 < W < 3*L10	Medium	10%	2.6	M	40%	40%
4/3600x1500mm RCBC	L10 < W < 3*L10	Medium	10%	2.7	M	40%	40%
2/1200mm RCP	W < L10	Medium	50%	3.1	L	15%	50%
2/2700x900mm RCBC	L10 < W < 3*L10	Medium	10%	3.3	L	15%	15%
2/1200mm RCP	W < L10	Medium	50%	2.6	M	40%	50%
2/1200x300mm RCBC	W < L10	Medium	50%	1.7	M	40%	50%
3/1800mm RCP	L10 < W < 3*L10	Medium	10%	2.3	M	40%	40%
1/1050mm RCP	W < L10	Medium	50%	3.1	L	15%	50%
2/750mm RCP	W < L10	Medium	50%	2.5	M	40%	50%
3/3000x1200mm RCBC	L10 < W < 3*L10	Medium	10%	2.3	M	40%	40%
2/900mm RCP	W < L10	Medium	50%	3.2	L	15%	50%
2/900mm RCP	W < L10	Medium	50%	3.0	L	15%	50%
3/600mm RCP	W < L10	Medium	50%	3.1	L	15%	50%
2/450mm RCP	W < L10	Medium	50%	1.9	M	40%	50%
2/1050x225mm RCBC	W < L10	Medium	50%	2.1	M	40%	50%
5/1320x750mm RCBC	W < L10	Medium	50%	1.0	M	40%	50%
3/1500mm RCP	L10 < W < 3*L10	Medium	10%	4.3	L	15%	15%
3/1500mm RCP	L10 < W < 3*L10	Medium	10%	3.1	L	15%	15%
Brick Archway	L10 < W < 3*L10	Medium	10%	3.0	M	40%	40%
3/3600x2400mm	L10 < W <	Medium	10%	1.9	M	40%	40%

Culvert Specification	Control Dimension	AEP Adjusted Debris Potential	Most Likely Inlet Blockage Levels	Peak Velocity (m/s)	Sediment Likelihood	Most Likely Depositional Blockage Levels	Highest Blockage Factor
RCBC	3*L10						
3/3150x1200mm RCBC	L10 < W < 3*L10	Medium	10%	1.4	M	40%	40%
4/3000x2000mm RCBC	L10 < W < 3*L10	Medium	10%	3.0	L	15%	15%
2/3300x1800mm RCBC	L10 < W < 3*L10	Medium	10%	3.1	L	15%	15%
3/3000x2250mm RCBC	L10 < W < 3*L10	Medium	10%	4.8	L	15%	15%
1/1500mm RCP	L10 < W < 3*L10	Medium	10%	2.7	M	40%	40%
4/600mm RCP	W < L10	Medium	50%	2.3	M	40%	50%
1/1500mm RCP	L10 < W < 3*L10	Medium	10%	2.7	M	40%	40%
2/1500mm RCP	L10 < W < 3*L10	Medium	10%	1.6	M	40%	40%

The highest blockage factor between both blockage scenarios is taken forward as the blockage adopted for the key cross-drainage structure sensitivity.

Therefore the adopted blockage factor for Frenchmans and Thozets Creeks is 50%.

9.7.4 Results of Sensitivity Analysis

The results which are presented on **Map FT-70** show that there is are several key culvert crossings which show a high level of sensitivity to blockage, these being the culverts under Beasley Street, Kerrigan Street, Wigginton Street, Rockonia Road and Lakes Creek Road. Noteworthy increases to peak flood extent are present downstream of Beasley Street and Kerrigan Street crossings where floodwaters are redirected to the adjacent floodplains.

The specific areas and the corresponding increase in peak flood heights are:

- Culvert under Ironbark Terrace – up to 0.55m increase in peak flood height.
- Culvert under property access opposite Seifert Drive – up to 0.4m increase in peak flood height.
- Culvert under Woodland Drive – up to 0.32m increase in peak flood height.
- Culvert under Beasley Street – up to 0.4m increase in peak flood height.
- Culvert under Kerrigan Street – up to 0.52m increase in peak flood height.
- Culverts under Wigginton Street – up to 0.9m increase in peak flood height.
- Culvert under property access off Bloxsom Street – up to 0.18m increase in peak flood height.
- Culverts under Elphinstone Street – up to 0.1m increase in peak flood height.
- Culverts under Rockonia Road – up to 0.35m increase in peak flood height.
- Culverts under Lakes Creek Road (Thozets Creek) – up to 0.35m increase in peak flood height.

9.8 Summary of Sensitivity Analysis Results

The results from the sensitivity analyses which were undertaken indicate that the most influential parameters are the manning's roughness values and the applied rainfall. As shown in Table 31, the 15% increase roughness caused an increase of peak flood heights throughout a large portion of the catchment. Similarly, the climate change sensitivity can be seen to have increased the peak flood heights throughout almost the entire catchment, with levels rising between 0.1m and 0.7 as previously discussed in Section 9.3.

The 20%, 50% and 100% blockage analysis indicate that only small portions of the flooded area are impacted. However, the localised areas are located within residential areas and may worsen property impacts and damages. The sensitivity runs have highlighted the critical structures which should be maintained regularly in order to minimise the impacts of long term debris build-up. Phase 3 of the study (Mitigation Options Analysis) should also assess the potential need for debris deflectors at key crossings to minimise the risk of blockage.

The Fitzroy River sensitivity indicates that the lower portion of the catchment is predicted to experience significant increases in flood heights. The areas influenced by the increased tailwater conditions are primarily non-developed.

It is expected that Council will apply an appropriate freeboard allowance to the PWSE's provided from this study, noting that this freeboard allowance should account for modelling uncertainty and the implications of the sensitivity analyses undertaken and discussed above.

Table 31 provides a summary of the percentage of the peak flood extent which is increased or decreased as a result of each sensitivity analysis. The results indicate that, apart from the climate change scenario and the Fitzroy River tailwater scenario, the resulting peak flood heights are generally within ±0.3m of the baseline flood results. It is clear that climate induced changes to rainfall intensities would have the most significant impact to predicted flood heights in the Frenchmans and Thozets Creek catchments.

Table 31 Summary of Sensitivity Analysis Results

Change in Peak Water Surface Elevation (m)	Percentage Area of Peak Flood Extent								
	15% Increased Roughness	15% Decreased Roughness	Climate Change to year 2100	20% Blockage of Stormwater Infrastructure	50% Blockage of Stormwater Infrastructure	100% Blockage of Stormwater Infrastructure	Fitzroy River Tailwater Condition	Increased Pit Dimensions	Blockage of Key Cross Drainage Structures
< -0.300	0%	0%	0%	0%	0%	0%	0%	0%	0%
-0.300 to -0.225	0%	0%	0%	0%	0%	0%	0%	0%	0%
-0.225 to -0.150	0%	0%	0%	0%	0%	0%	0%	0%	0%
-0.150 to -0.075	0%	3%	0%	0%	0%	0%	0%	0%	1%
-0.075 to -0.02	0%	36%	0%	0%	0%	0%	5%	7%	4%
-0.02 to 0.02	61%	61%	19%	85%	96%	93%	79%	93%	89%
0.02 to 0.075	37%	0%	20%	11%	4%	5%	10%	0%	4%
0.075 to 0.150	2%	0%	19%	0%	0%	2%	4%	0%	1%
0.150 to 0.225	0%	0%	15%	0%	0%	0%	2%	0%	0%
0.225 to 0.300	0%	0%	9%	0%	0%	0%	0%	0%	0%
>0.300	0%	0%	18%	3%	0%	0%	0%	0%	1%

10.0 Flood Hazard and Risk Assessment

10.1 Overview

Following completion of baseline model development, design event modelling and sensitivity analyses; a flood hazard and vulnerability assessment was completed for the Frenchmans and Thozets Creek catchment. This included:

- Flood hazard analysis.
- Vulnerability assessment of key infrastructure.
- Evacuation route analysis.
- Building inundation and impact assessment.
- Flood Damages Assessment (FDA), including the calculation of Annual Average Damages (AAD).

Each of these aspects has been discussed in further detail below.

10.2 Baseline Flood Hazard Analysis

Flood hazard categorisation provides a better understanding of the variation of flood behaviour and hazard across the floodplain and between different events. The degree of hazard varies across a floodplain in response to the following factors:

- Flow depth.
- Flow velocity.
- Rate of flood level rise (including warning times).
- Duration of inundation.

Identifying hazards associated with flood water depth and velocity help focus management efforts on minimizing the risk to life and property. As such, a series of Flood Hazard Zones have been developed according to ARR 2016, in alignment with recommendations made in the ARR, Data Management and Policy Review (AECOM, 2017).

The hazard curves and classification names in ARR 2016 are identical to those of which shown in the Guide for Flood Studies and Mapping in Queensland document (DNRM, 2016). However, the ARR guidelines provide additional definition as to the classification levels for the hazard classes. This information is summarised in the Table 32 and Table 33.

Table 32 ARR 2016 Hazard Classification Descriptions

Hazard Vulnerability Classification	Description
H1	Generally safe for vehicles, people and buildings.
H2	Unsafe for small vehicles.
H3	Unsafe for vehicles children and the elderly.
H4	Unsafe for vehicles and people.
H5	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.

Table 33 ARR 2016 Hazard Classification Limits

Hazard Vulnerability Classification	Classification Limit (D and V in combination) (m^2/s)	Limiting Still Water Depth (D) (m)	Limiting Velocity (V) (m/s)
H1	D*V ≤ 0.3	0.3	2.0
H2	D*V ≤ 0.6	0.5	2.0
H3	D*V ≤ 0.6	1.2	2.0
H4	D*V ≤ 1.0	2.0	2.0
H5	D*V ≤ 4.0	4.0	4.0
H6	D*V > 4.0	-	-

The ARR 2016 flood hazard classification limits are also shown graphically in Figure 29.

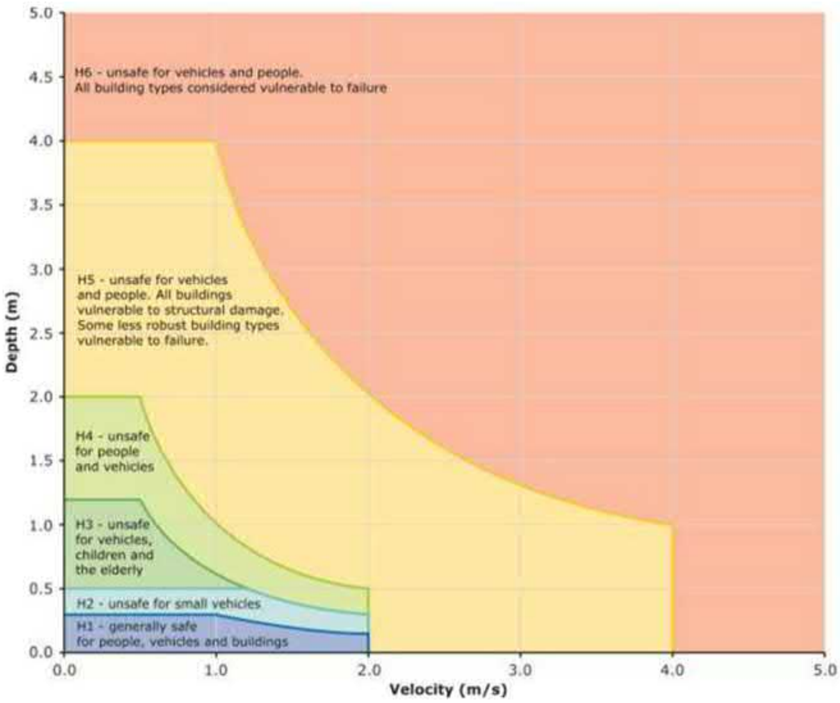


Figure 29 Hazard Vulnerability Classifications (Graphical)

Flood hazard mapping for the 18% and 1% AEP event has been included as maps **FT-71** to **FT-82** in the Volume 2 report. The hazard analysis for the 1% AEP event generally shows:

- Low to medium hazard (H1 and H2) across the majority of urbanised areas within the catchment.
- High hazard (H3 and H4) within a majority of natural and man-made channels, as well as open spaces such as local parks.
- High to extreme hazard (H4 and H5) within some natural and man-made open channels, as well as some open areas such as Alan Bray Park, Bill Crane Park, Rigarlsford Park, Ollie Smith Park and Duthie Park.
- High to extreme hazard (H4 and H5) in the vicinity of the Frenchville State School on Frenchville Road, across the Kerrigan Street crossing of Frenchmans Creek, across Elphinstone Street at Rigarlsford Park and in Honour Street near the Mt Archer Scout Hall.
- Extreme hazard (H5 or H6) within the Frenchmans and Thozets Creek channel and adjacent overbank areas.

10.3 Baseline Sewerage Infrastructure Flood Risk

Maps **FT-83** to **FT-88** show active sewerage infrastructure (gravity mains, rising mains, access chambers and pump stations) overlain on the 18% AEP and 1% AEP Baseline Flood Extents. The intent of these maps is to identify sewerage infrastructure at increased risk of flooding, and therefore potentially stormwater ingress (inflow).

It is recommended these maps are provided to Fitzroy River Water, to inform any future inflow/infiltration (I/I) identification and rectification works.

10.4 Baseline Vulnerability Assessment

A baseline vulnerability assessment has been undertaken to identify critical infrastructure and community assets which are at risk of flooding. The following categories have been included in this assessment:

- Water and sewerage infrastructure.
- Emergency services facilities including ambulance, police, fire and hospitals.
- Community infrastructure including schools, day-care centres, nursing homes, retirement villages and community facilities.
- Key road and rail assets.

Table 34 summarises the criterion used for each category, along with the corresponding reference to the specific table of results and locality figure.

Table 34 Vulnerability Assessment Criterion

Category	Criterion	Table	Figure
Water and Sewerage Infrastructure	Any electrified water or sewerage assets within the Frenchmans and Thozets Creek catchment, experiencing flooding up to the baseline PMF event.	Table 35	Figure 30
Emergency Services	Any emergency services facilities within the Frenchmans and Thozets Creek catchment, experiencing flooding up to the baseline PMF event.	Table 36	Figure 30
Community Infrastructure	Any community and critical infrastructure within the Frenchmans and Thozets Creek catchment, experiencing flooding up to the baseline PMF event.	Table 36	Figure 30
Road Assets	Roads that have inundation depth greater than 0.3m in the 18% AEP event. *There are some exceptions included in the table which have less than 0.3m of inundation in the 18% AEP event, which represent critical road crossings of Frenchmans Creek or Thozets Creek.*	Table 37	Figure 31
Bridge Assets	All bridge crossings of Frenchmans Creek and Thozets Creek were assessed.	Table 38	Figure 31
Rail Assets	Rail segments that have inundation above top of ballast level (segments where rail ballast will be inundated)	Table 39	Figure 31

It is noted that depth values for road, rail and bridge assets were extracted from the centreline of the flooded road / rail / bridge segment.

Relevant information from the road asset vulnerability assessment has been collated and used in the evacuation assessment shown in Section 10.5.

Table 35 Water and sewage infrastructure - inundation depths for all events

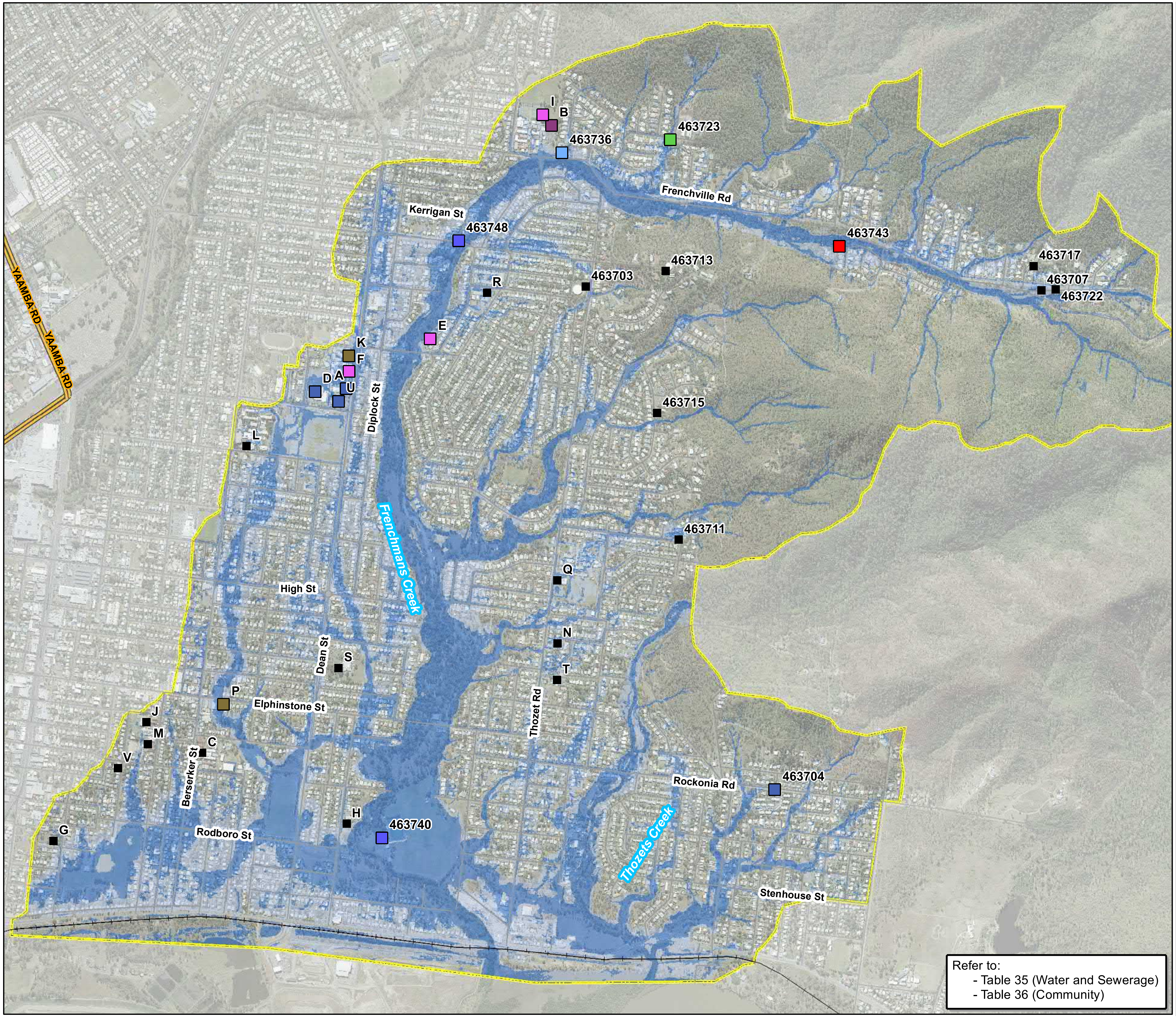
Infrastructure Type (Asset ID)	Suburb	Location	Inundation Depths at Design AEP Events (m) – 180 minute storm										1% AEP Hazard Category *
			1EY	39%	18%	10%	5%	2%	1%	0.2%	0.05%	PMF	
Sewerage Pump Station (463743)	Frenchville	Blue Gum Tce	0.16	0.19	0.24	0.30	0.39	0.47	0.57	0.87	1.07	1.65	H2
Sewerage Pump Station (463740)	Koongal	Water Street	-	-	-	0.07	0.14	0.17	0.19	0.30	0.43	1.44	H1
Sewerage Pump Station (463736)	Frenchville	Frenchville Road	-	-	0.12	0.14	0.15	0.16	0.20	0.23	0.28	0.88	H1
Sewerage Pump Station (463748)	Frenchville	Kerrigan Street	-	-	-	0.13	0.23	0.31	0.41	0.72	0.99	2.12	H2
Water Pump Station (463711)	Frenchville	Bloxsom Street	-	-	-	-	-	-	-	-	-	-	-
Water Pump Station (463715)	Koongal	Rockonia Road	-	-	-	-	-	-	-	-	-	0.12	-
Water Pump Station (463722)	Frenchville	Frenchville Road	-	-	-	-	-	-	-	-	-	-	-
Water Pump Station (463723)	Frenchville	Wehmeier Ave	-	0.58	0.62	0.64	0.67	0.67	0.72	0.74	0.84	0.95	H4
Water Pump Station (463717)	Frenchville	Whiteley Street	-	-	-	-	-	-	-	-	-	-	-
Water Pump Station (463713)	Frenchville	Forbes Ave	-	-	-	-	-	-	-	-	-	-	-
Water Pump Station (463707)	Frenchville	Pilbeam Drive 1	-	-	-	-	-	-	-	0.13	0.31	0.71	-
Water Pump Station (463703)	Frenchville	Thozet Road	-	-	-	-	-	-	-	-	-	-	-
Water Pump Station (463715)	Frenchville	Everingham Ave	-	-	-	-	-	-	-	-	-	-	-

* Where there is no inundation predicted in the 1% AEP event, the 1% AEP Hazard Category is shown as a dash. There may however be some residual hazard in events greater than 1% AEP.

Table 36 Critical infrastructure, emergency facilities and possible evacuation shelters - Inundation depths for all events

ID	Infrastructure | Facility Name	Suburb	Location	Inundation Depths at Design AEP Events (m) – 180 minute storm										1% AEP Hazard Category *
				1EY	39%	18%	10%	5%	2%	1%	0.2%	0.05%	PMF	
A	Frenchville Childcare	Frenchville	337-339 Dean St	-	-	-	-	-	-	-	-	-	0.14	-
B	Frenchville State School	Frenchville	225-237 Frenchville Rd	-	-	-	-	-	0.08	0.09	0.10	0.13	0.18	H1
C	Berserker State School	Berserker	128-140 Berserker St	-	-	-	-	-	-	-	-	-	-	-
D	Little Zebra Childcare Centre	Frenchville	147-161 Robinson St	-	-	-	-	-	-	-	-	-	0.12	-
E	Bundara Kindergarten	Frenchville	197 Honour St	-	-	-	-	-	-	-	-	0.11	0.36	-
F	Village Life	Frenchville	341-345 Dean St	-	-	-	-	-	-	-	-	0.18	0.48	-
G	Lead Childcare	Berserker	55-57 Edward St	-	-	-	-	-	-	-	-	-	-	-
H	Tarumbal Kindergarten	Berserker	100 Water St	-	-	-	-	-	-	-	-	-	-	-
I	School's Out After School	Frenchville	225-237 Frenchville Rd	-	-	-	-	-	-	-	-	0.09	0.12	-
J	St Mary's Primary School	Berserker	135 Nobbs St	-	-	-	-	-	-	-	-	-	-	-
K	Mountain View Village	Frenchville	347-351 Dean St	-	-	-	-	0.05	0.08	0.12	0.15	0.18	0.51	H1
L	North Rockhampton High	Frenchville	302-328 Berserker St	-	-	-	-	-	-	-	-	-	-	-
M	Nobbs St After School Care	Berserker	135 Nobbs St	-	-	-	-	-	-	-	-	-	-	-
N	Housing Queensland	Koongal	272 Fisher St	-	-	-	-	-	-	-	-	-	-	-
P	Elfin House Childcare	Berserker	132 Elphinstone St	-	-	-	-	-	-	-	0.11	0.24	0.75	-
Q	Mount Archer Primary School	Koongal	242 Thozet Rd	-	-	-	-	-	-	-	-	-	-	-
R	Skippy's Early Learning Centre	Frenchville	385 Duthie Ave	-	-	-	-	0.09	0.11	0.14	0.16	0.18	0.30	H1
S	WIN Television	Berserker	192 Dean St	-	-	-	-	-	-	-	-	-	-	-
T	Little Friends Childcare	Koongal	202 Thozet Rd	-	-	-	-	-	-	-	-	-	-	-
U	North Rockhampton Police	Frenchville	163-171 Robinson St	-	-	-	-	-	-	-	-	-	0.14	-
V	SES Rockhampton	Berserker	90 Charles St	-	-	-	-	-	-	-	-	-	-	-

* Where there is no inundation predicted in the 1% AEP event, the 1% AEP Hazard Category is shown as a dash. There may however be some residual hazard in events greater than 1% AEP.



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Rockhampton Regional Council

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LEGEND

Critical Infrastructure Inundation (Lowest Immunity)

- Outside PMF Event
- 1 EY
- 39%
- 18%
- 10%
- 5%
- 2%
- 1%
- 0.2%
- 0.05%
- PMF
- Highways
- Railway Lines
- Road Centrelines
- Hydraulic Model Extent
- 1% AEP Flood Extents
- PMF Flood Extents

Flood results are based on local catchment events

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Results Filtering:
75mm Min. Depth
$100m^2$ Min. Area

Frenchmans Creek & Thozets Creek Model
Critical Infastructure Inundation

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	29/08/2017
VERSION:	1

Figure 30

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\FT_Figure30_Phase_2_Critical_Infastructure.mxd

Table 37 Roads Assets - Inundation Lengths and TOS for 1% AEP event and Inundation depths for all events

ID	Road | Street Name	Suburb	1% AEP Inundation Length (m)^	1% AEP TOS (hrs)^	Inundation Depths at Design AEP Events (m) – 180 minute storm *										1% AEP Hazard Category
					1EY	39%	18%	10%	5%	2%	1%	0.2%	0.05%	PMF	
1	Beaumont Drive (corner Frenchville Rd)	Frenchville	175	1.6	0.25	0.28	0.33	0.34	0.36	0.37	0.40	0.41	0.44	0.53	H2
2	Jordan Close	Frenchville	95	1.4	0.26	0.30	0.34	0.39	0.49	0.56	0.63	0.84	1.01	1.69	H3
3	Jard Street	Frenchville	45	1	0.25	0.29	0.32	0.33	0.35	0.36	0.41	0.50	0.61	1.39	H2
4	Wehmeier Avenue	Frenchville	50	1.7	0.25	0.28	0.30	0.32	0.33	0.34	0.38	0.38	0.40	0.46	H2
5	Frenchville Road (at Frenchville School)	Frenchville	190	1.2	0.16	0.38	0.58	0.70	0.84	0.95	1.08	1.38	1.57	2.28	H5
6	Frenchville Road (west of Dale Avenue)	Frenchville	280	1.6	0.17	0.20	0.31	0.39	0.52	0.64	0.78	1.09	1.34	2.13	H5
7	High Street (directly west of Berserker St)	Berserker	100	1.7	0.23	0.30	0.44	0.52	0.59	0.65	0.70	0.82	0.91	1.29	H3
8	Elphinstone Street (Rigarlsford Park)	Koongal	255	1.6	0.12	0.49	0.74	0.85	0.97	1.07	1.19	1.46	1.66	2.54	H5
9	Berserker Street (at Rodboro Street)	Berserker	220	3.2	0.37	0.42	0.49	0.54	0.59	0.65	0.69	0.79	0.90	1.88	H3
10	Rodboro Street (at Berserker Street)	Berserker	160	2.5	0.17	0.22	0.30	0.34	0.39	0.45	0.49	0.59	0.70	1.68	H2
11	Princess Street (at Rodboro Street)	Berserker	415	4.3	0.36	0.45	0.53	0.58	0.64	0.69	0.73	0.82	0.94	1.91	H3
12	Shields Avenue	Frenchville	400	4.3	0.48	0.62	0.73	0.79	0.85	0.89	1.02	1.10	1.22	1.57	H6
13	Everingham Avenue (north of Bray Gray Pl)	Frenchville	35	1.2	0.19	0.31	0.38	0.42	0.47	0.48	0.61	0.64	0.75	1.00	H4
14	Thozet Road (north of Zervos Avenue)	Frenchville	60	1.6	0.22	0.31	0.40	0.44	0.48	0.52	0.65	0.75	0.89	1.32	H5
15	Gowdie Avenue	Frenchville	150	4.3	0.55	0.69	0.80	0.86	0.92	0.96	1.10	1.18	1.29	1.65	H6
16	Sheedy Avenue	Frenchville	75	4.3	0.66	0.73	0.80	0.83	0.87	0.89	1.00	1.05	1.12	1.33	H3

ID	Road | Street Name	Suburb	1% AEP Inundation Length (m)^	1% AEP TOS (hrs)^	Inundation Depths at Design AEP Events (m) – 180 minute storm *										1% AEP Hazard Category
					1EY	39%	18%	10%	5%	2%	1%	0.2%	0.05%	PMF	
17	Hansen Street	Frenchville	100	1.6	0.28	0.33	0.37	038	0.40	0.41	0.46	0.46	0.48	0.54	H2
18	Moyle Street	Frenchville	195	1.6	0.26	0.29	0.32	0.34	0.37	0.38	0.42	0.47	0.69	1.93	H3
19	Beasley Street	Frenchville	200	4.3	0.17	0.31	0.44	0.50	0.58	0.64	0.72	0.94	1.10	1.79	H5
20	Kerrigan Street	Frenchville	125	4.3	-	0.12	0.27	0.39	0.54	0.66	0.81	1.13	1.40	2.50	H4
21	Honour Street	Frenchville	180	4.3	0.13	0.15	0.21	0.34	0.53	0.71	0.86	1.23	1.49	2.43	H5
22	Hinton Street	Koongal	80	2	0.34	0.36	0.40	0.41	0.43	0.45	0.52	0.53	0.58	1.37	H3
23	O'Shanesy Street	Koongal	85	1.9	0.39	0.43	0.46	0.48	0.51	0.52	0.60	0.63	0.70	1.64	H3
24	Dempsey Street	Koongal	140	1.6	0.27	0.30	0.33	0.35	0.37	0.38	0.44	0.48	0.55	0.75	H2
25	Rockonia Road (between Horton St & Blanchfield St)	Koongal	120	1.5	-	-	0.21	0.33	0.44	0.54	0.62	0.81	0.97	1.73	H2
26	Pilkington Street	Koongal	80	4.3	0.65	0.71	0.76	0.79	0.82	0.83	0.91	1.00	1.08	1.37	H5
27	Stack Street	Koongal	310	1.5	0.25	0.35	0.45	0.50	0.57	0.61	0.72	0.83	0.94	1.25	H5
28	Dee Street	Koongal	400	1.7	0.21	0.24	0.28	0.31	0.37	0.40	0.46	0.51	0.57	0.81	H5
29	Blanchfield Street	Koongal	40	1.9	0.36	0.41	0.47	0.51	0.56	0.61	0.67	0.73	0.80	1.01	H3

^Note: inundation lengths and TOS values are approximate only, and can vary depending on actual rainfall patterns and antecedent conditions.
* Maximum flood depth at road centreline extracted within the flooded road segment. Flood depths will vary at road shoulders and therefore results are approximate only.

Table 38 Bridge Assets - Inundation depths for all events

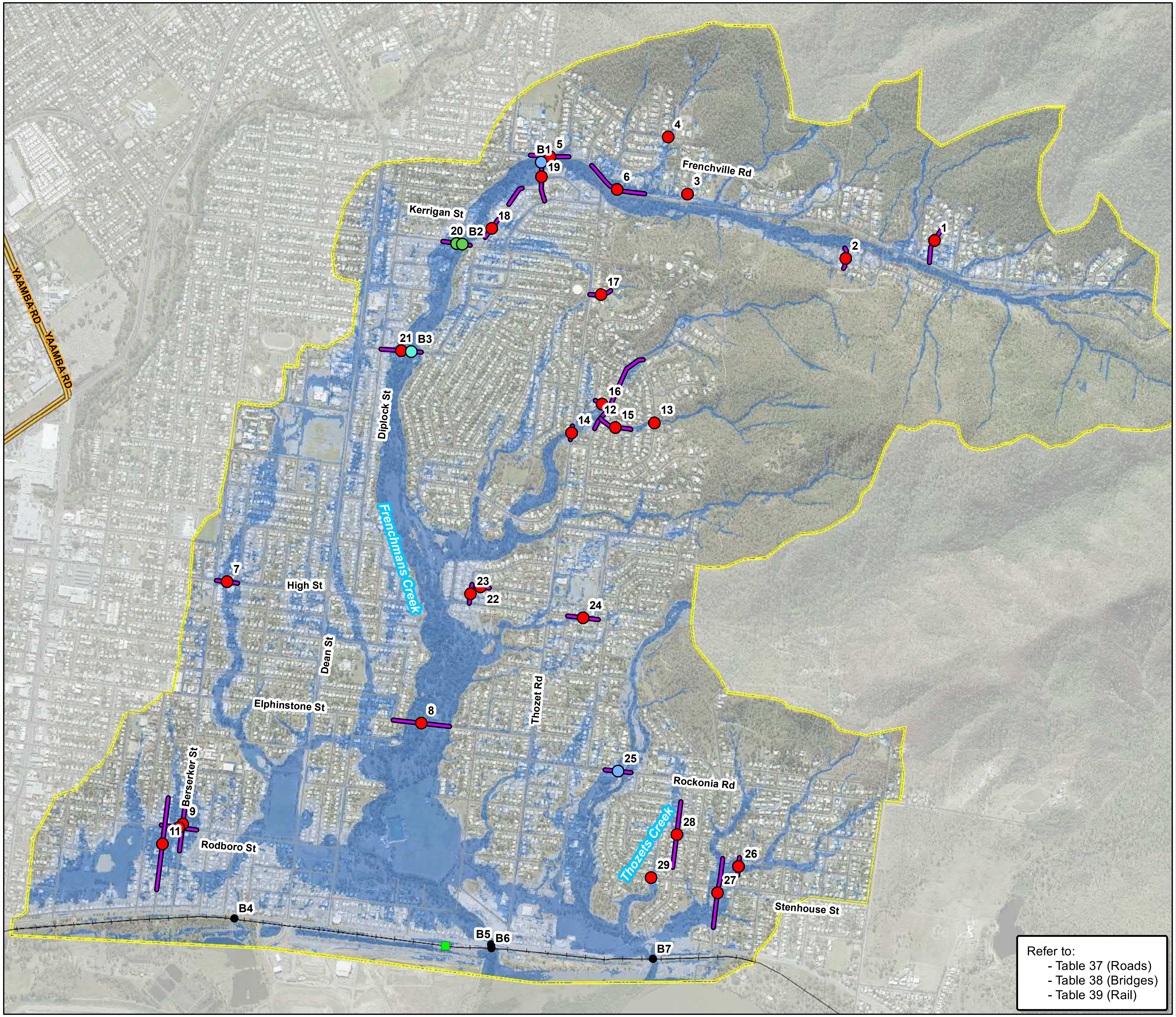
ID	Bridge Name	Deck Height (mAHD) #	Inundation Depths Above Deck at Design AEP Events (m) – 180 minute storm *										1% AEP Hazard Category **
			1EY	39%	18%	10%	5%	2%	1%	0.2%	0.05%	PMF	
B1	Beasley Street (Culverts)	42.70	-	-	0.27	0.35	0.40	0.47	0.58	1.12	1.54	2.55	H5
B2	Kerrigan Street (Culverts)	35.60	-	0.42	0.68	0.84	1.00	1.15	1.29	1.59	1.78	2.72	H5
B3	Honour Street	29.44	-	-	-	-	-	-	0.15	0.38	0.61	1.61	H5
B4	Lakes Creek Road (Rail Bridge at Ellis Street)	7.85	-	-	-	-	-	-	-	-	-	-	-
B5	Lakes Creek Road (Road Bridge at Thozet Road)	7.20	-	-	-	-	-	-	-	-	-	0.70	-
B6	Lakes Creek Road (Rail Bridge at Thozet Road)	7.71	-	-	-	-	-	-	-	-	-	-	-
B7	Lakes Creek Road (Rail Bridge at Dee Street)	7.73	-	-	-	-	-	-	-	-	-	-	-

Bridge deck heights are based on LiDAR levels and are approximate only.
* Maximum flood depth at bridge centreline extracted within the flooded road segment. Flood depths will vary at bridge shoulders and therefore results are approximate only.
** Where there is no inundation predicted in the 1% AEP event, the 1% AEP Hazard Category is shown as a 'dash.' There may however be flood hazard in events greater than the 1% AEP.

Table 39 Rail Assets - Inundation lengths for 1% AEP event and inundation depths for all events

ID	Rail Line	Suburb	1%AEP Inundation Length (m)^	Inundation Depths at Design AEP Events (m) – 180 minute storm *										1% AEP Hazard Category **
				1EY	39%	18%	10%	5%	2%	1%	0.2%	0.05%	PMF	
R1	Yeppoon Branch Rail Line (from Dean Street towards the east)	Park Avenue	1,050	-	-	-	-	-	-	-	-	-	1.11	-

^Note: inundation lengths are approximate only.
* Maximum flood depth at rail centreline extracted within the flooded rail segment. Flood depths will vary across the formation and therefore results are approximate only.
** Where there is no inundation predicted in the 1% AEP event, the 1% AEP Hazard Category is shown as a dash. There may however be flood hazard in events greater than the 1% AEP.



Refer to:
- Table 37 (Roads)
- Table 38 (Bridges)
- Table 39 (Rail)

N

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 200 400 600 800
Metres

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LEGEND

Road, Rail and Bridge Infrastructure (Lowest Immunity)

- Outside PMF Event
- 1 EY
- 39%
- 18%
- 10%
- 5%
- 2%
- 1%
- 0.2%
- 0.05%
- PMF
- Rail Inundation
- 1% AEP Road Inundation Extent (Lengths >75m shown)
- Highways
- Railway Lines
- Road Centrelines
- Hydraulic Model Extent
- 1% AEP Flood Extents
- PMF Flood Extents

Flood results are based on local catchment events

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Results Filtering:
75mm Min. Depth
100m² Min. Area

Frenchmans Creek & Thozets Creek Model Road, Bridges and Rail Inundation

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	29/08/2017
VERSION:	1

Figure 31

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\FT_Figure31_Phase_2_Inundation_Roads.mxd

10.4.1 Vulnerability Assessment Summary

The following provides a summary of key findings of the vulnerability assessment:

- The Blue Gum Terrace SPS (Ref: 463743), Water Street SPS (Ref: 463740), Frenchville Road SPS (Ref: 463736), Kerrigan Street SPS (Ref: 463748), Wehmeier Street WPS (Ref: 463723) and Pilbeam Drive 1 WPS (Ref: 463707) are predicted to have less than 0.2% AEP flood immunity. It is noted however that some of these pump stations are below ground and improvements to flood immunity would be very difficult to achieve. It is recommended this information be passed onto FRW as the asset owner.
- Low depth flooding is predicted at Frenchville State School, Mountain View Village, Elfin House Childcare and Skippy's Early Learning Centre in the 0.2% AEP event.
- The Yeppoon Branch Rail Line is predicted to have high level flood immunity to Top of Ballast, with inundation only predicted during the PMF event.
- A number of road segments are predicted to experience inundation in the 1EY event and larger. Estimated TOS ranges from 1.0 hour to approximately 4 hours.

10.5 Evacuation Routes

Generally local catchment flooding within the Frenchmans and Thozets Creek catchment is due to short duration, high intensity rainfall events. The relatively steep upper catchment and urbanisation throughout much of the middle and lower catchment can result in inundation of residential and commercial buildings. In addition, inadequate stormwater infrastructure in some locations results in nuisance flooding within the urbanised catchment due to overland runoff.

Due to the short critical duration of the Frenchmans and Thozets Creek catchment, the warning time between the commencement of the rain event and subsequent flood inundation can be short (refer Figure 36 to Figure 40). This limits the opportunity for evacuation, and generally the action taken by the community is to '*shelter in place*' until the flooding has passed.

An assessment of evacuation routes has therefore focussed on areas that become isolated during flooding, as well as high hazard areas that may require flood free evacuation access. Table 40 provides a summary of the isolated areas and key evacuation routes, assessed up to the PMF event.

Table 40 Isolated Areas Summary

Isolated Area	Key Evacuation Route/s	Accessed Via	Warning Time Until Evac. Route Cut	Figure Ref.
Subdivisions off Frenchville Rd (Cascade Cl, Rainbow Ct, Lange St, Frenchmans Ln, Beaumont Dr, Candlebark Ct, Rogar Ave, Seifert Dr, Jard St, Davey Ave and side streets)	Frenchville Rd	Direct Access	Up to 0.5 hour	-
Ironbark Terrace, Archerview Terrace, Blue Gum Terrace, Jordan Close	Frenchville Rd	Ironbark Tce	Up to 0.5 hour	Figure 32
Boyd Street, Moyle Street, Murphy Street	Frenchville Rd Thozet Rd	Beasley St Murphy St	Up to 0.5 hour Up to 0.5 hour	Figure 33
Limpus Street, Vallis Street, Coome Street	Dean St	Vallis St	Up to 0.5 hour	Figure 34
Water Street, Bremner Street, Mason Street	Dean St Elphinstone St	Mason St Water St	Up to 0.5 hour Up to 0.5 hour	Figure 35

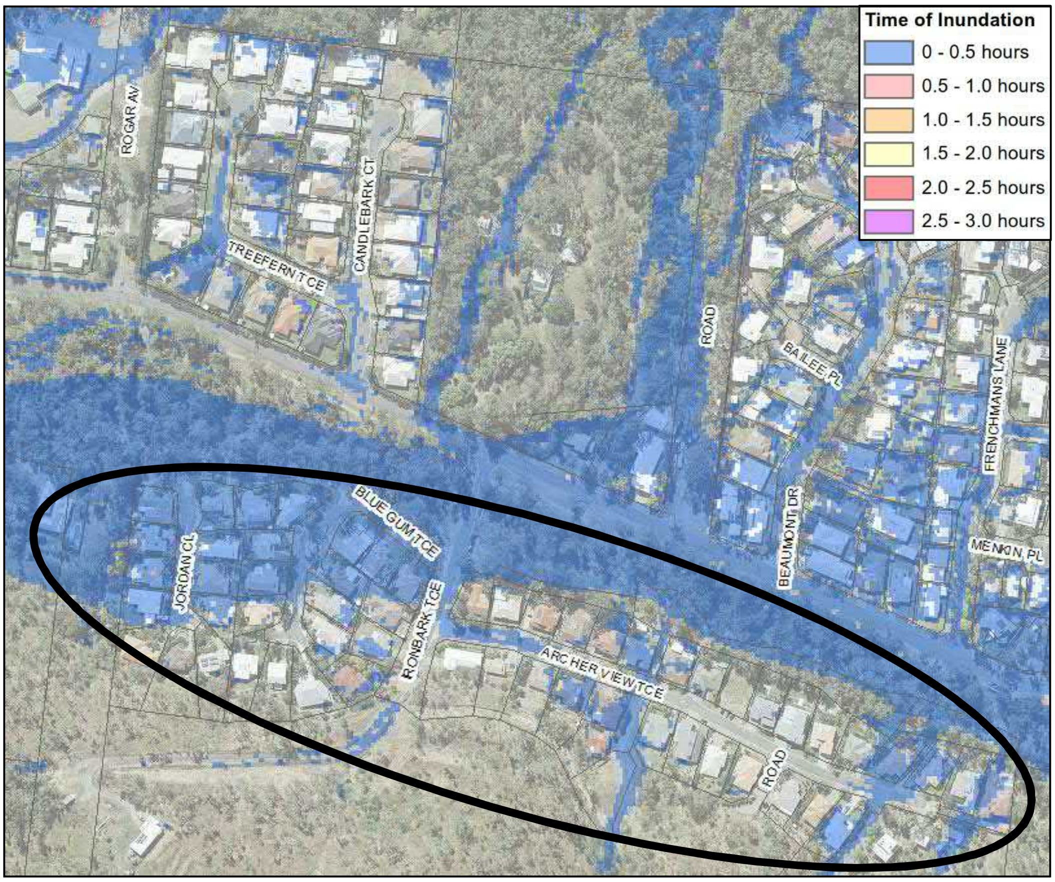


Figure 32 Isolated Area – Ironbark Terrace, Archerview Terrace, Blue Gum Terrace, Jordan Close (Note: PMF flood extents shown)

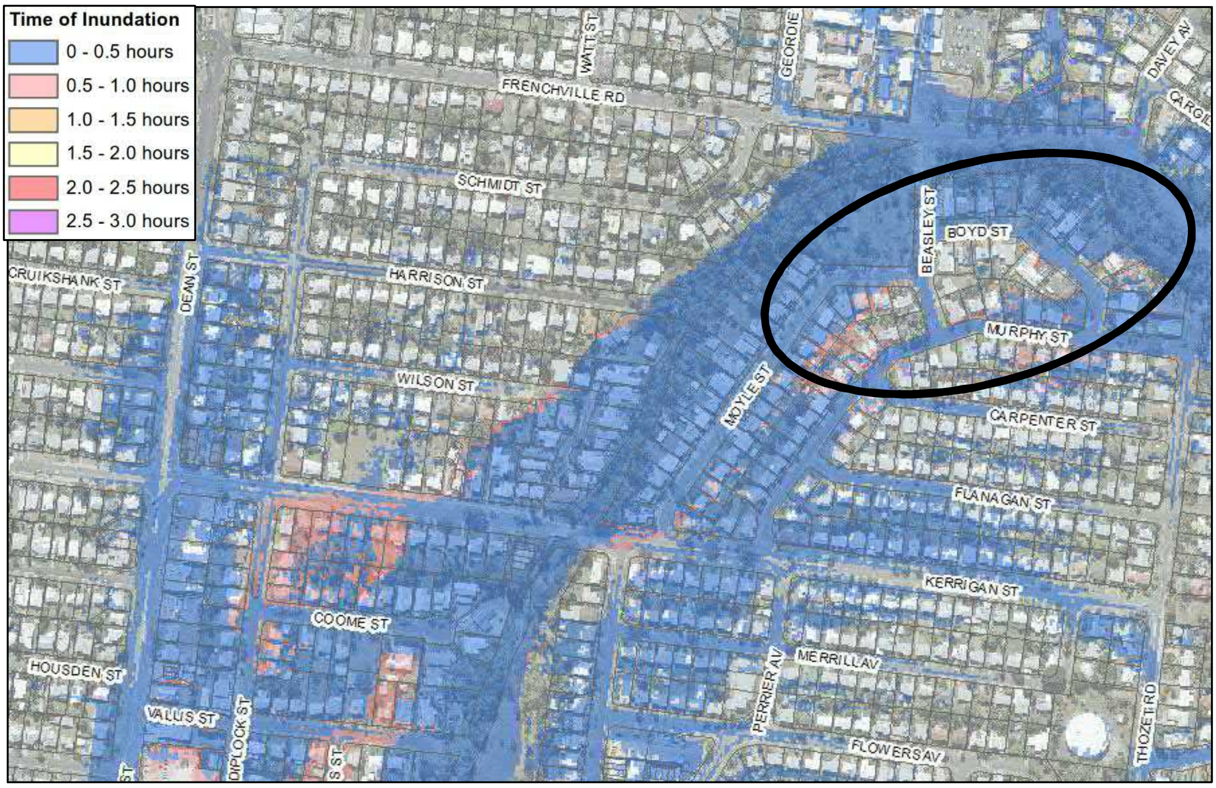
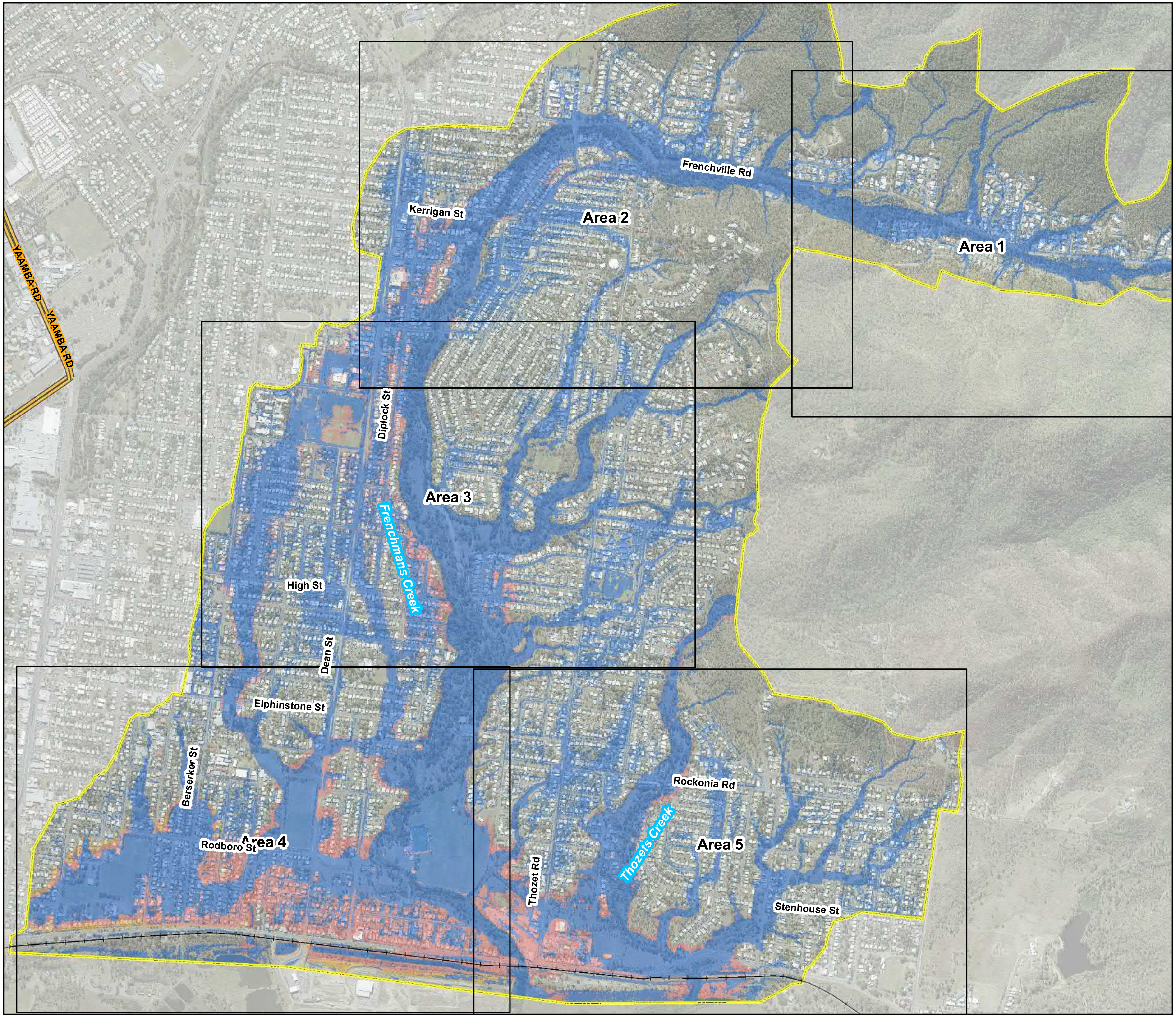


Figure 33 Isolated Area – Boyd Street, Moyle Street, Murphy Street (Note: PMF flood extents shown)

Figure 34 Isolated Area – Limpus Street, Vallis Street, Coome Street (Note: PMF flood extents shown)

Figure 35 Isolated Area – Water Street, Bremner Street, Mason Street (Note: PMF flood extents shown)



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DATUM GDA 1994, PROJECTION MGA ZONE 56

0 150 300 450 600 750

Metres

1:15,000
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LEGEND

- Highways
- Railway Lines
- Cadastre
- Hydraulic Model Extent

Time of Inundation

- 0 - 0.5 hours
- 0.5 - 1.0 hours
- 1.0 - 1.5 hours
- 1.5 - 2.0 hours
- 2.0 - 2.5 hours
- 2.5 - 3.0 hours

Flood results are based on local catchment events

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Results Filtering:
75mm Min. Depth
100m² Min. Area

Frenchmans Creek & Thozets Creek Model
Time of Inundation - Catchment Overview

PMF 90min Storm Event

PROJECT ID	60534898
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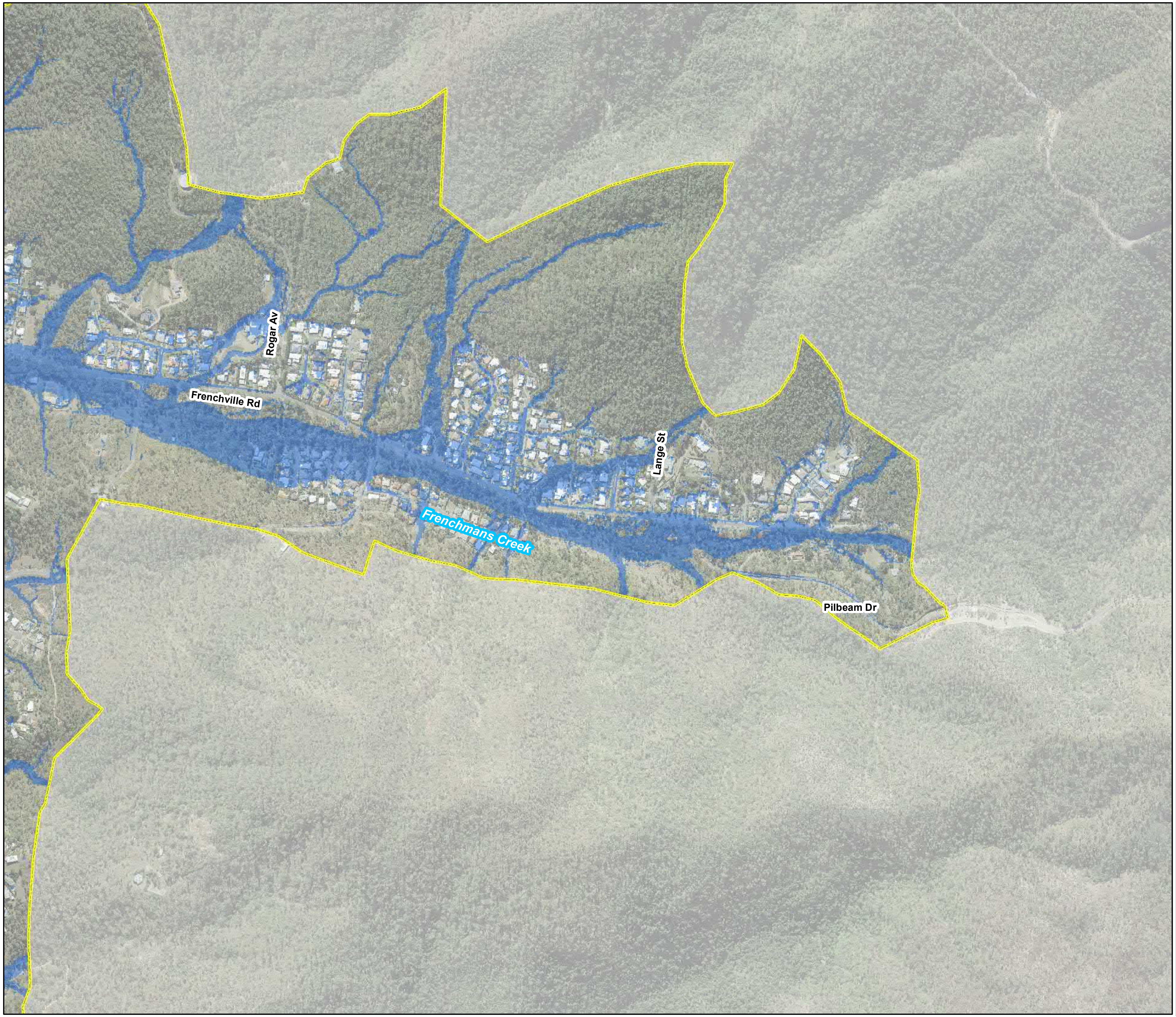
LAST MODIFIED	29/08/2017
VERSION:	1

Figure 36

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\FT_Figure36_Phase_2_Inundation_Time - Catchment Overview.mxd



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0 100 200 300 400
Metres

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LEGEND

Highways
Railway Lines
Cadastre
Hydraulic Model Extent

Time of Inundation

0 - 0.5 hours
0.5 - 1.0 hours
1.0 - 1.5 hours
1.5 - 2.0 hours
2.0 - 2.5 hours
2.5 - 3.0 hours

Flood results are based on local catchment events

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Results Filtering:
75mm Min. Depth
100m² Min. Area

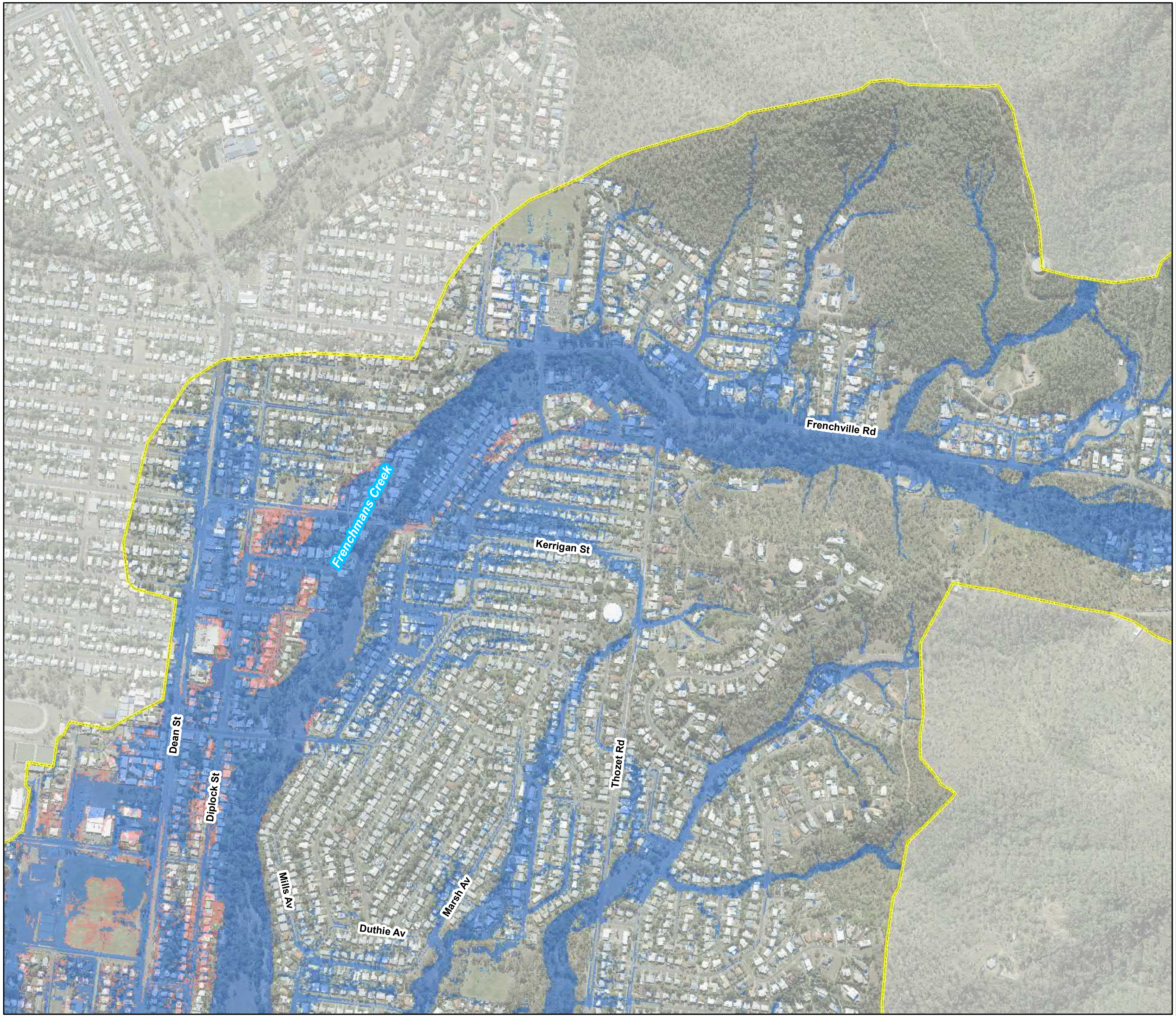
Frenchmans Creek & Thozets Creek Model
Time of Inundation - Area 1

PMF 90min Storm Event

PROJECT ID 60534898
CREATED BY maultbyj
LAST MODIFIED 29/08/2017
VERSION: 1

Figure 37

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\FT_Figure37_Phase_2_Inundation_Time - Area 1_Rev2.mxd



N

Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 100 200 300 400
Metres

1:8,000
(when printed at A3)

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LEGEND

- Highways
- Railway Lines
- Cadastre
- Hydraulic Model Extent

Time of Inundation

- 0 - 0.5 hours
- 0.5 - 1.0 hours
- 1.0 - 1.5 hours
- 1.5 - 2.0 hours
- 2.0 - 2.5 hours
- 2.5 - 3.0 hours

Flood results are based on local catchment events

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Results Filtering:
75mm Min. Depth
$100m^2$ Min. Area

Frenchmans Creek & Thozets Creek Model
Time of Inundation - Area 2

PMF 90min Storm Event

PROJECT ID	60534898
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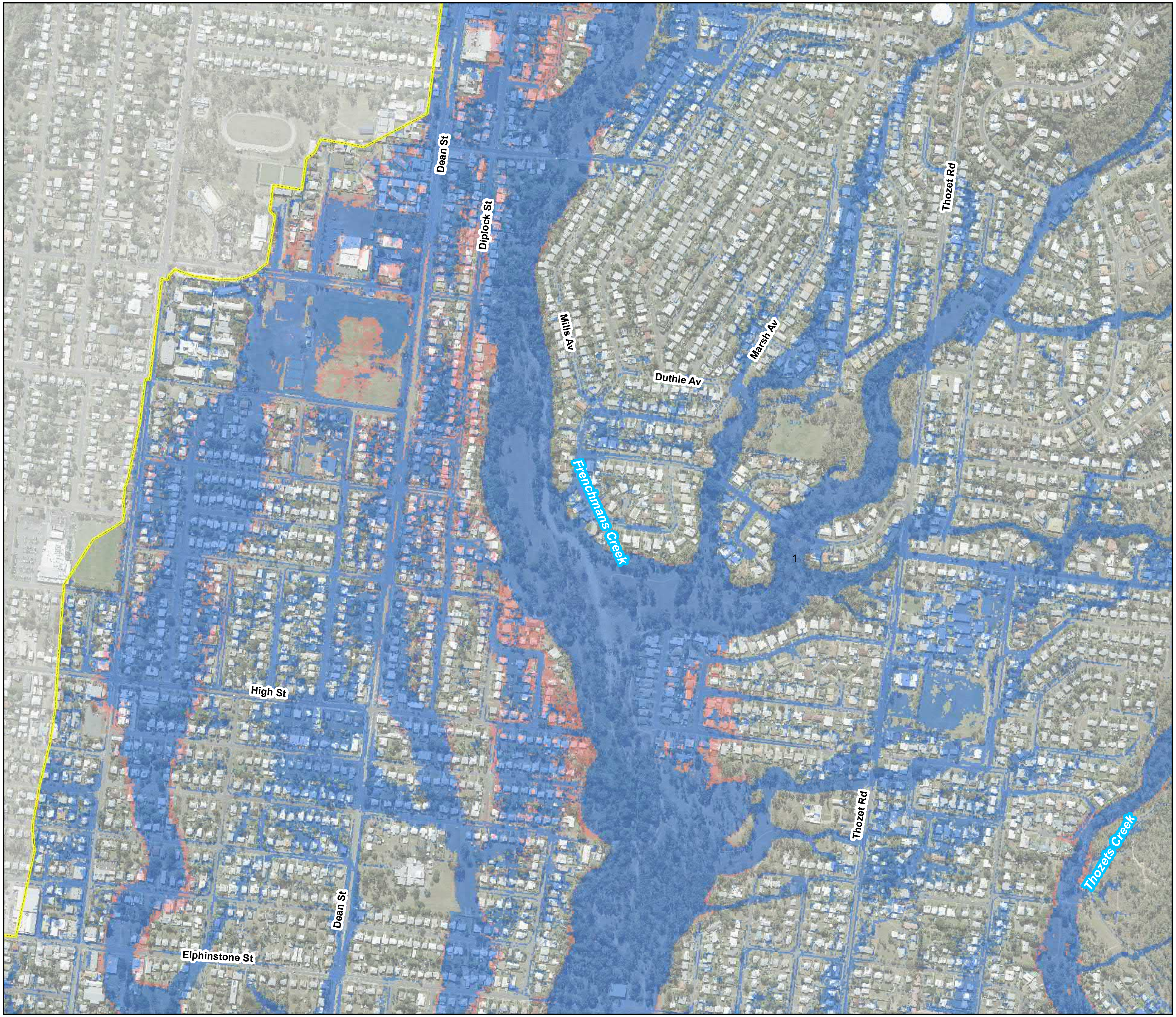
LAST MODIFIED	29/08/2017
VERSION:	1

Figure 37

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\FT_Figure38_Phase_2_Inundation_Time - Area 2.mxd



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Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 100 200 300 400

Metres

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LEGEND

Highways
Railway Lines
Cadastre
Hydraulic Model Extent

Time of Inundation

0 - 0.5 hours
0.5 - 1.0 hours
1.0 - 1.5 hours
1.5 - 2.0 hours
2.0 - 2.5 hours
2.5 - 3.0 hours

Flood results are based on local catchment events

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Results Filtering:
75mm Min. Depth
100m² Min. Area

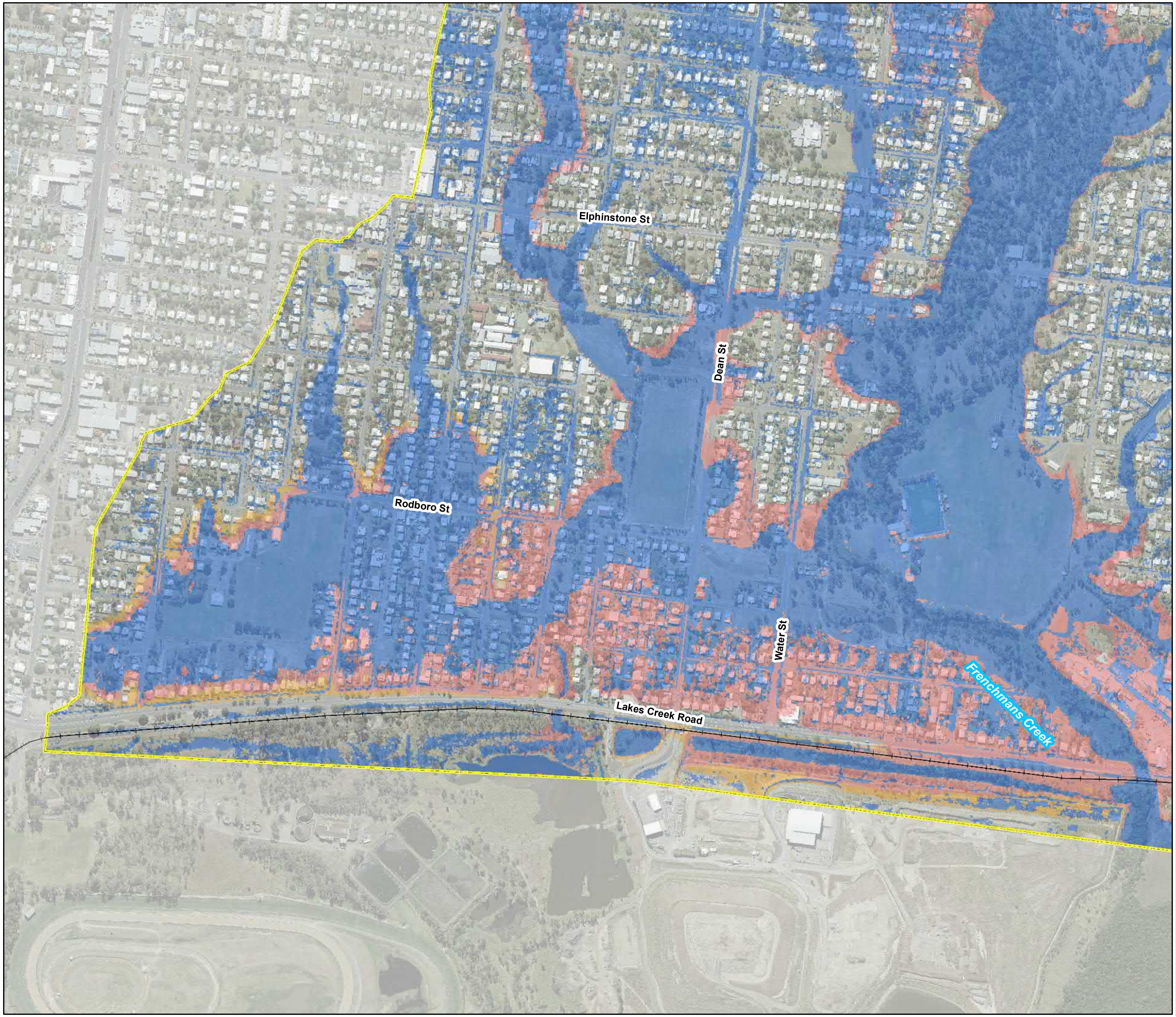
Frenchmans Creek & Thozets Creek Model
Time of Inundation - Area 3

PMF 90min Storm Event

PROJECT ID 60534898
CREATED BY maultbyj
LAST MODIFIED 29/08/2017
VERSION: 1

Figure 39

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\FT_Figure39_Phase_2_Inundation_Time - Area 3.mxd



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Metres

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LEGEND

- Highways
- Railway Lines
- Cadastre
- Hydraulic Model Extent

Time of Inundation

- 0 - 0.5 hours
- 0.5 - 1.0 hours
- 1.0 - 1.5 hours
- 1.5 - 2.0 hours
- 2.0 - 2.5 hours
- 2.5 - 3.0 hours

Flood results are based on local catchment events

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Results Filtering:
75mm Min. Depth
100m² Min. Area

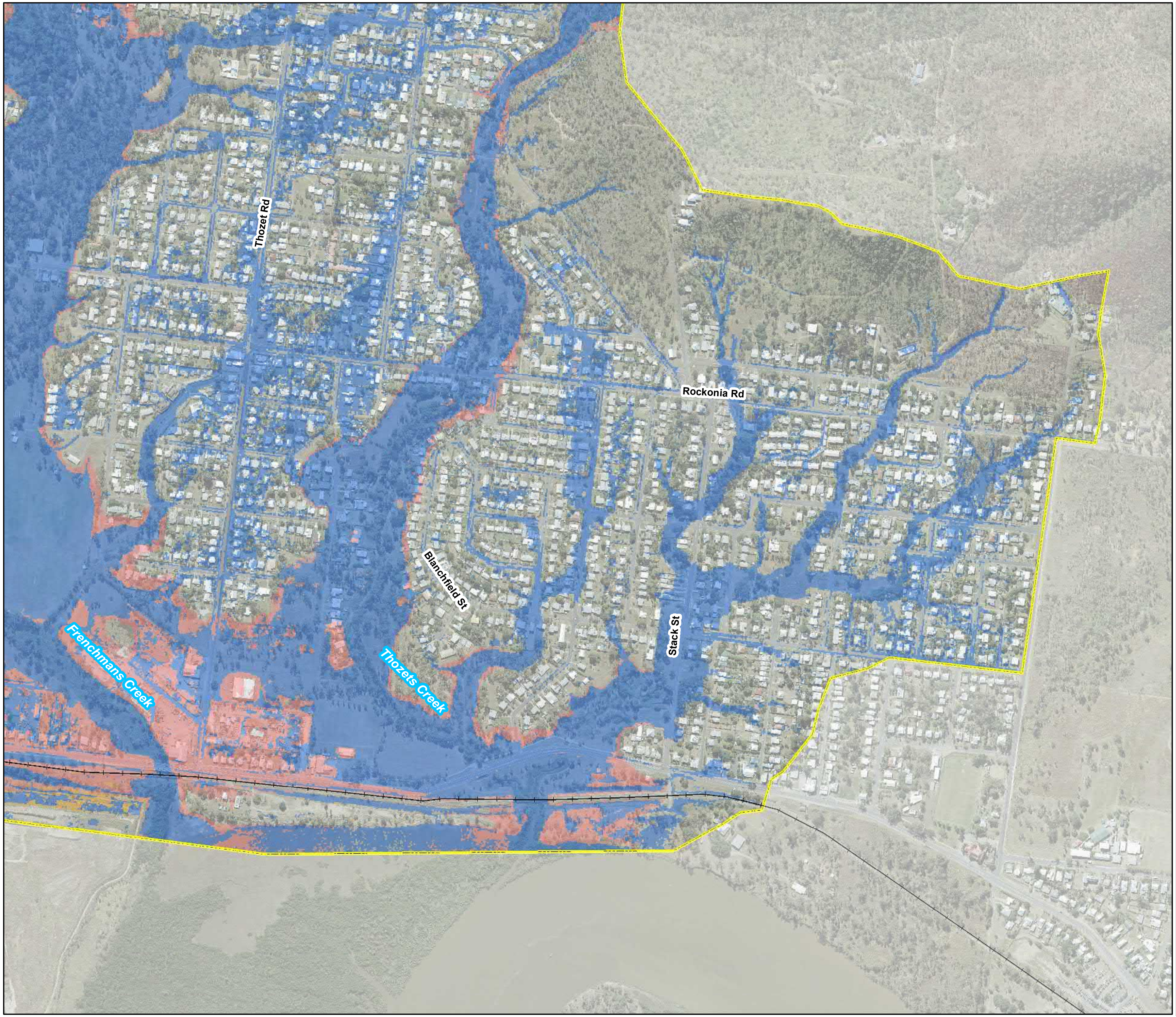
Frenchmans Creek & Thozets Creek Model
Time of Inundation - Area 4

PMF 90min Storm Event

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	29/08/2017
VERSION:	1

Figure 40

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\FT_Figure40_Phase_2_Inundation_Time - Area 4.mxd



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0 100 200 300 400

Metres

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LEGEND

- Highways
- Railway Lines
- Cadastre
- Hydraulic Model Extent

Time of Inundation

- 0 - 0.5 hours
- 0.5 - 1.0 hours
- 1.0 - 1.5 hours
- 1.5 - 2.0 hours
- 2.0 - 2.5 hours
- 2.5 - 3.0 hours

Flood results are based on local catchment events

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Results Filtering:
75mm Min. Depth
100m² Min. Area

Frenchmans Creek & Thozets Creek Model
Time of Inundation - Area 5

PMF 90min Storm Event

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	29/08/2017
VERSION:	1

Figure 41

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\FT_Figure41_Phase_2_Inundation_Time - Area 5.mxd

10.6 Building Impact Assessment and Flood Damages Assessment

The predicted baseline flood levels were used to undertake a building impact assessment and FDA, including calculation of AAD for the catchment.

Flood damages, or the anticipated cost to residents, businesses and infrastructure due to flooding, have been estimated using a standardised approach adopted throughout Australia. The approach estimates the tangible impacts flooding has on people, property, and infrastructure, such as flooding of a building and/or contents, the lost opportunity value associated with wages and revenue and flooding of transport and utility networks. These tangible impacts are estimated based on the depth, likelihood of flooding and type of building. Intangible impacts, such as emotional stress and inconvenience, were not quantified due to their non-tangible nature.

A building's estimated depth of flooding and whether it is a residential single story, multi-story or raised building or a non-residential building, determines the total estimated flood damage for that building. The direct flood damage is determined based on depth-damage curves, which relate building type, building area and flood depth to the damage associated with the structure and content. Indirect damages associated with lost opportunity value, i.e. wages and revenue and the cost of temporary relocation, are then estimated as an additional percentage for residential and non-residential buildings. The combined direct and indirect damages then represent the total damage to the building. Infrastructure damages, i.e. water treatment plants and utility and transport networks, are then estimated as a percentage of the total residential and non-residential damage combined.

Full details of the methodology applied during this study, has been included in Appendix D.

10.6.1 Baseline Building Impact Assessment

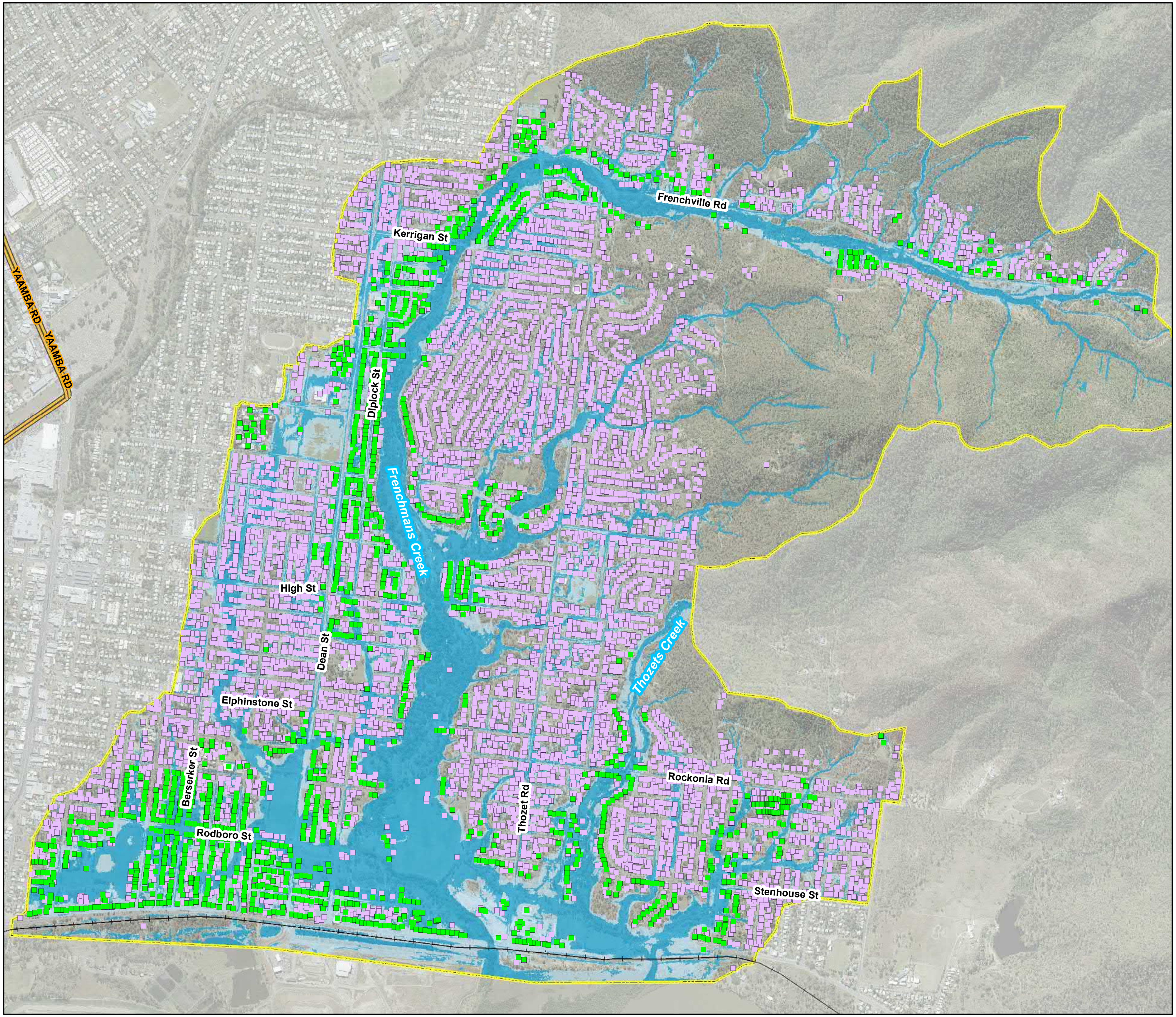
Council provided a building database, containing ~28,000 buildings digitised within the modelled area. Of these, ~5,900 buildings contained surveyed data, focussed on Creek flooding extents in North Rockhampton and Fitzroy River flood extents in South Rockhampton (refer Figure 42).

In order to complete a Building Impact Assessment and FDA, a complete building database with floor levels, classifications and ground levels is needed within the PMF direct rainfall flood extent. To achieve this, the following tasks were completed:

- Review of the digitised buildings, to remove erroneous data such as *footpaths*, *building demolished*, *no building* etc.
- Estimation of floor levels and ground levels for buildings outside Council's surveyed database (~22,100 buildings in total, with ~6,600 within Frenchmans and Thozets Creek catchment).
  - The height above ground level was assumed based on information in the "*Floor_type*" field.
- Classification of buildings within the modelled area, in accordance with ANUFLOOD requirements (~28,000 buildings in total, with ~8,740 within Frenchmans and Thozets Creek catchment):
  - Buildings were divided into residential and commercial based on a combination of fields, depending on what fields contained data for each building.
  - Residential buildings were assigned a class based on the "*Struc_type*" & "*Floor_type*" fields. Detached single storey buildings were also classified by floor area.
  - Commercial buildings were assigned a size class based on floor area – small/medium/large.
  - Commercial building classifications were assigned based on the "*Land_use_d*" field, with a value class of 3 (on a scale from 1 to 5) assigned to buildings lacking data.

The ground level at each building was estimated based on the 1m LiDAR DEM provided for the project. Ground levels were assigned to the building footprints based on the average elevation of the DEM within the building extents.

Buildings lacking data regarding number of storeys were assumed to be one storey. Buildings on slabs were assumed to have a minimum habitable floor level of 100mm above ground level. Low set buildings were assumed to have a minimum habitable floor level of 600mm above ground level and high set buildings were assumed to have a minimum habitable floor level of 1,800mm above ground level. Buildings lacking data regarding what type of floor they have were assumed to be on slabs.



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Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 200 400 600 800
Metres

1:16,000
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LEGEND

- Surveyed Floor Levels
- GIS-Derived Floor Levels
- Highways
- Railway Lines
- Cadastre
- Hydraulic Model Extent
- 1% AEP Extent
- PMF Extent

FLOOR LEVEL SUMMARY

Surveyed Floor Levels = 1,658
GIS-Derived Floor Levels = 6,934

Data Sources:

DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Frenchmans Creek & Thozets Creek Model Building Database Summary

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	29/08/2017
VERSION:	1

Figure 42

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\FT_Figure42_Phase_2_SurveyedNonSurveyed.mxd

Table 41 provides a summary of the number of residential and commercial buildings anticipated to be inundated for various flood events within the Frenchmans and Thozets Creek catchment. These results are also shown graphically in Figure 43.

Existing buildings which experience flood levels above ground level are noted and buildings inundated above floor level are shown in brackets beside.

Note that the indicated number of buildings is for entire buildings. Residential multi-unit buildings may contain multiple dwellings per building. Also, large commercial/industrial buildings may include multiple businesses.

Table 41 № of Buildings Impacted

AEP (%)	№ Residential Buildings	№ Commercial Buildings
	Flood level above property ground level (building inundated above floor level)	Flood level above property ground level (building inundated above floor level)
1EY	34 (9)	6 (4)
39	76 (14)	17 (10)
18	169 (52)	30 (19)
10	248 (77)	46 (34)
5	373 (142)	60 (45)
2	482 (198)	72 (53)
1	710 (315)	89 (68)
0.2	974 (435)	123 (102)
0.05	1319 (626)	152 (126)
PMF	2605 (1559)	233 (213)

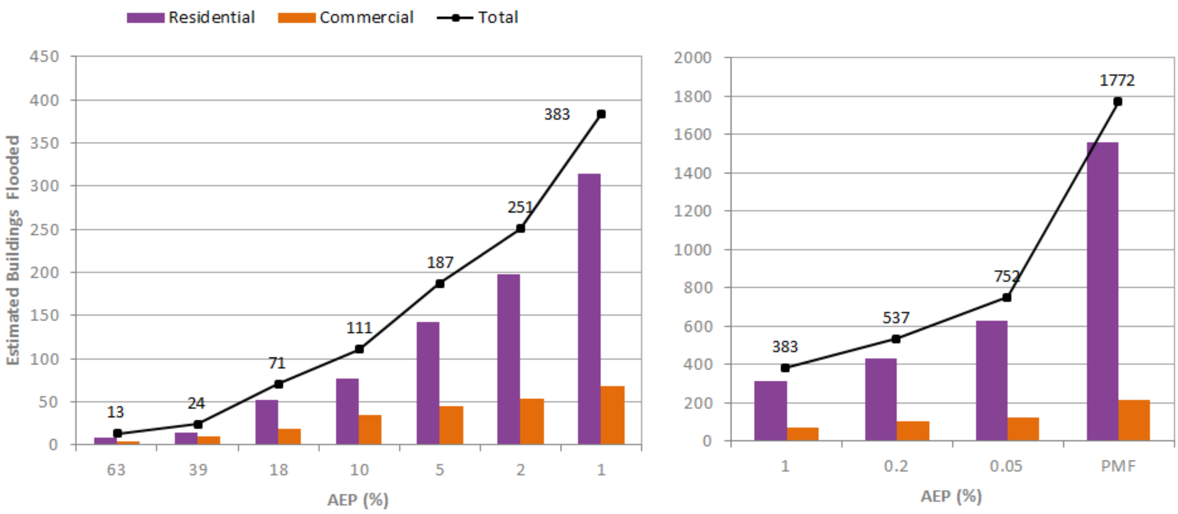


Figure 43 Estimated Buildings with Above Floor Flooding (Number of Buildings)

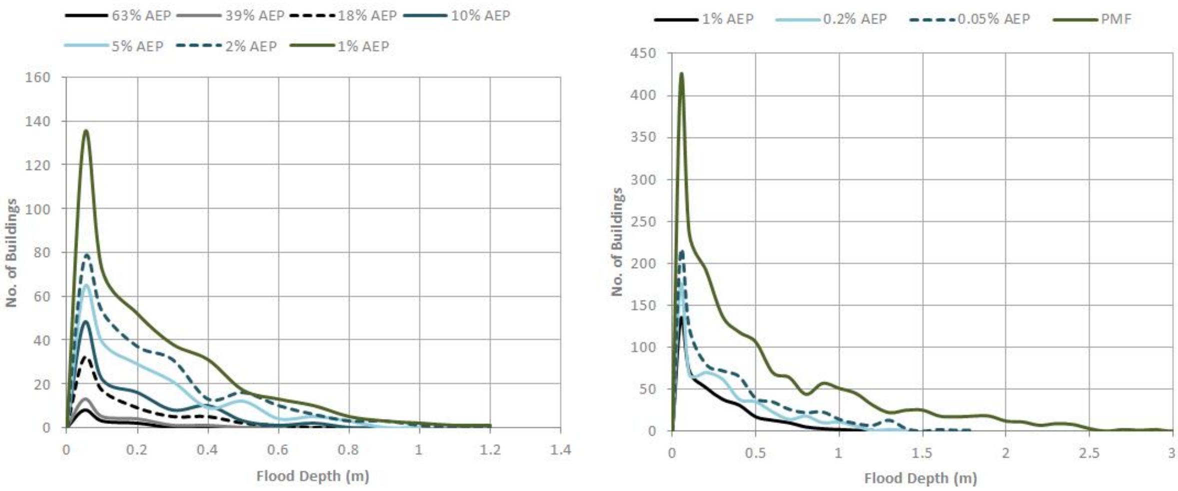


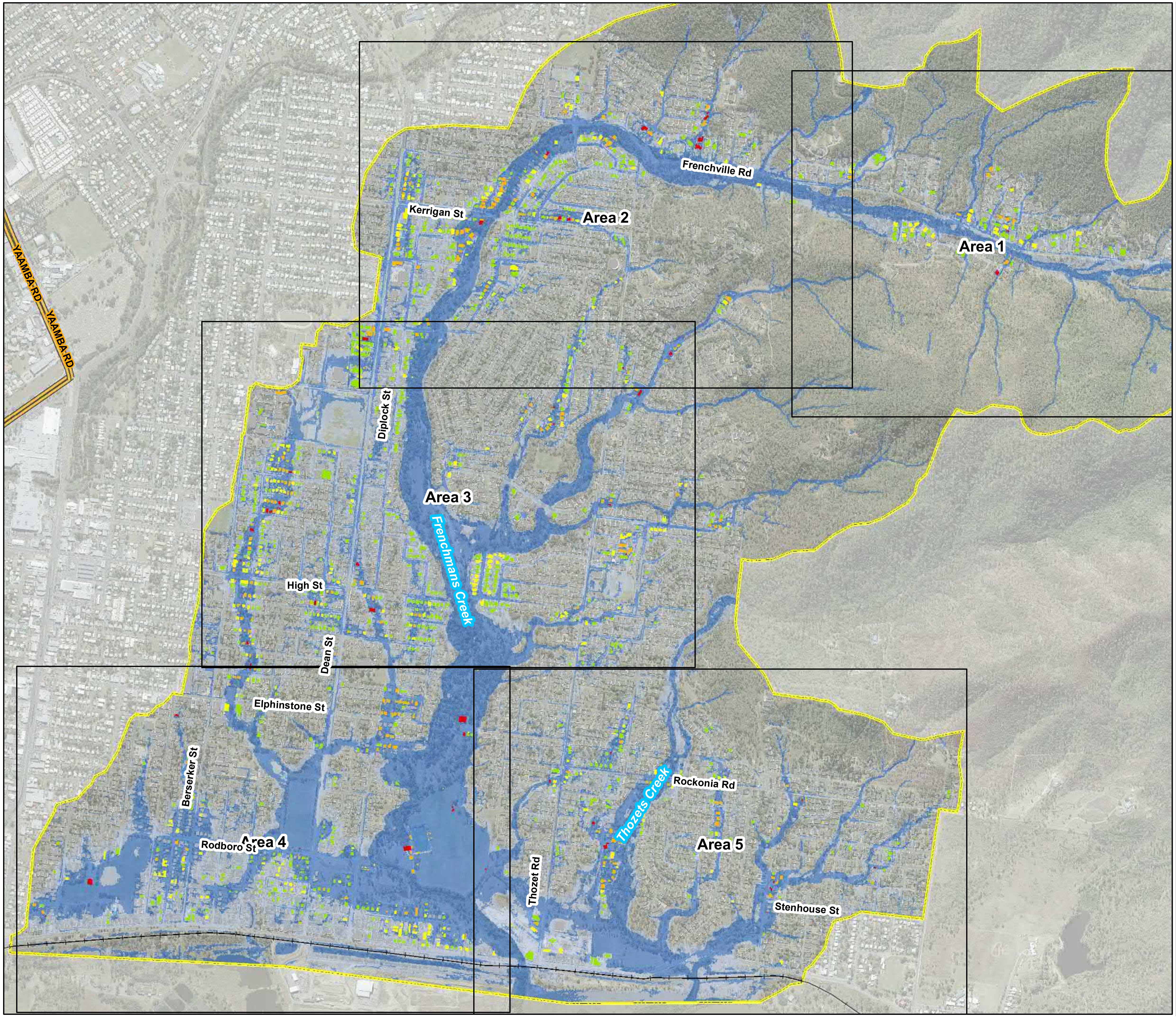
Figure 44 Estimated Flood Depths Above Floor Level by % AEP (Number of Buildings)

As shown in Figure 44, median flood depths are generally less than 0.2 metre for each flood event. This indicates that reductions in flood depths of 0.2 metre could significantly reduce overall damage.

The figure also shows that a significant number of buildings experience flood depths of 0.2 metre or less during frequent events such as the 1EY flood event, generally corresponding to higher flood damages.

It is noted that where surveyed floor levels were not available, slab on ground buildings were assumed to have a floor level 0.1m above the existing ground level. This is consistent with other studies undertaken in the Rockhampton area, however may result in a higher estimate of inundated buildings and consequential flood damages due to the increased incidence of above floor flooding.

Figure 45 to Figure 49 shows the location of buildings predicted to experience above floor flooding, grouped by the earliest AEP upon which they become inundated.



N

Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 150 300 450 600 750

Metres

1:15,000
(when printed at A3)

AECOM
www.aecom.com

LEGEND

- Highways
- Railway Lines
- Cadastre
- Hydraulic Model Extent
- 1% AEP Flood Extents
- PMF Flood Extents

Inundation of Buildings with Above Floor Flooding

- Minor (1EY - 18%AEP)
- Major (10% - 1%AEP)
- Extreme (0.2% - 0.05%AEP)
- PMF
- Outside PMF Extent

Flood results are based on local catchment events

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

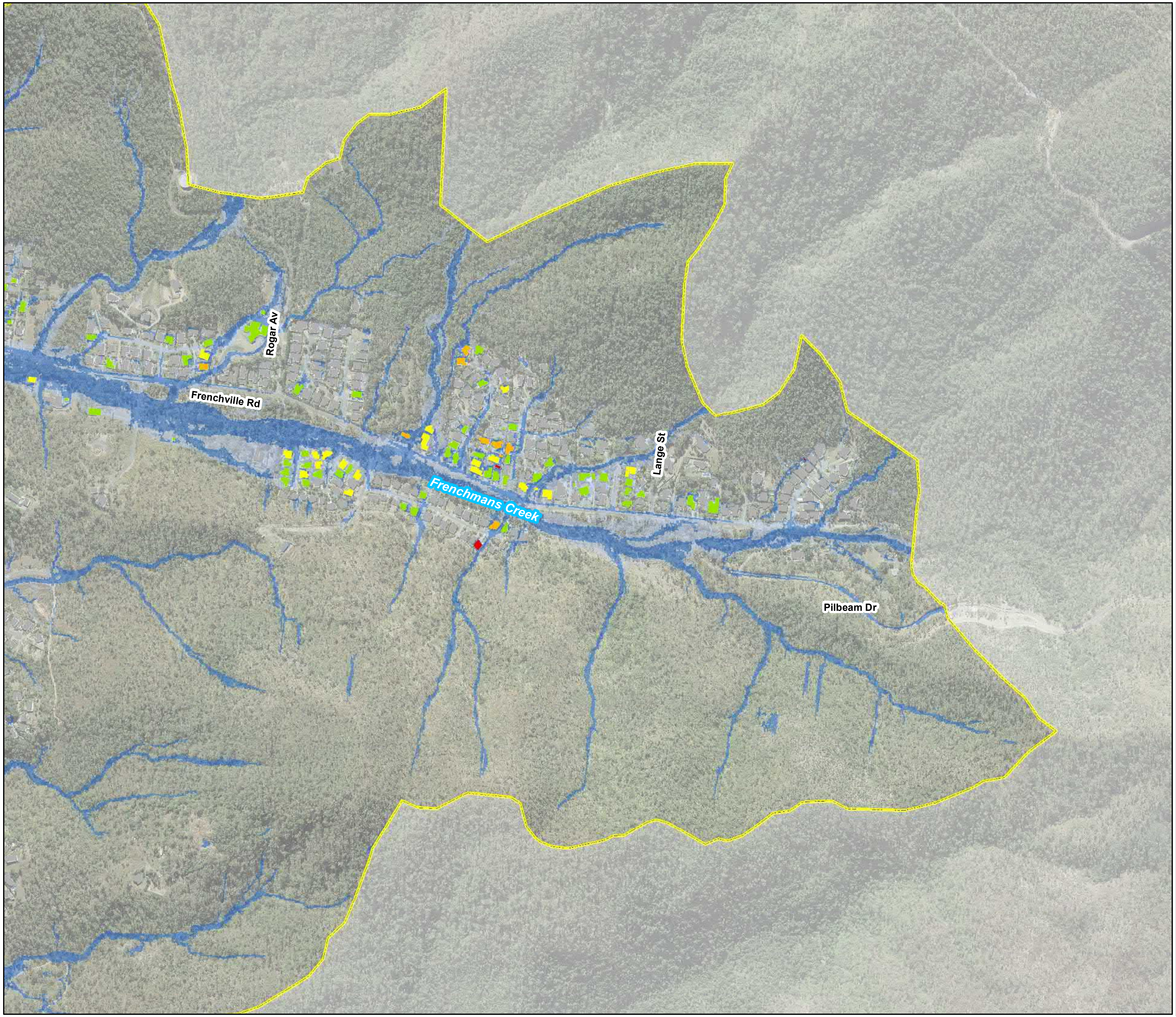
Results Filtering:
75mm Min. Depth
$100m^2$ Min. Area

Frenchmans Creek & Thozets Creek Model Inundation of Buildings with Above Floor Level Flooding - Catchment Overview

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	29/08/2017
VERSION:	1

Figure 45

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\FT_Figure45_Phase_2_Inundated_Buildings - Catchment Overview_Rev2.mxd



N

Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 100 200 300 400
Metres

1:8,000
(when printed at A3)

AECOM
www.aecom.com

LEGEND

- Highways
- Railway Lines
- Cadastre
- Hydraulic Model Extent
- 1% AEP Flood Extents
- PMF Flood Extents

Inundation of Buildings with Above Floor Flooding

- Minor (1EY - 18%AEP)
- Major (10% - 1%AEP)
- Extreme (0.2% - 0.05%AEP)
- PMF
- Outside PMF Extent

Flood results are based on local catchment events

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

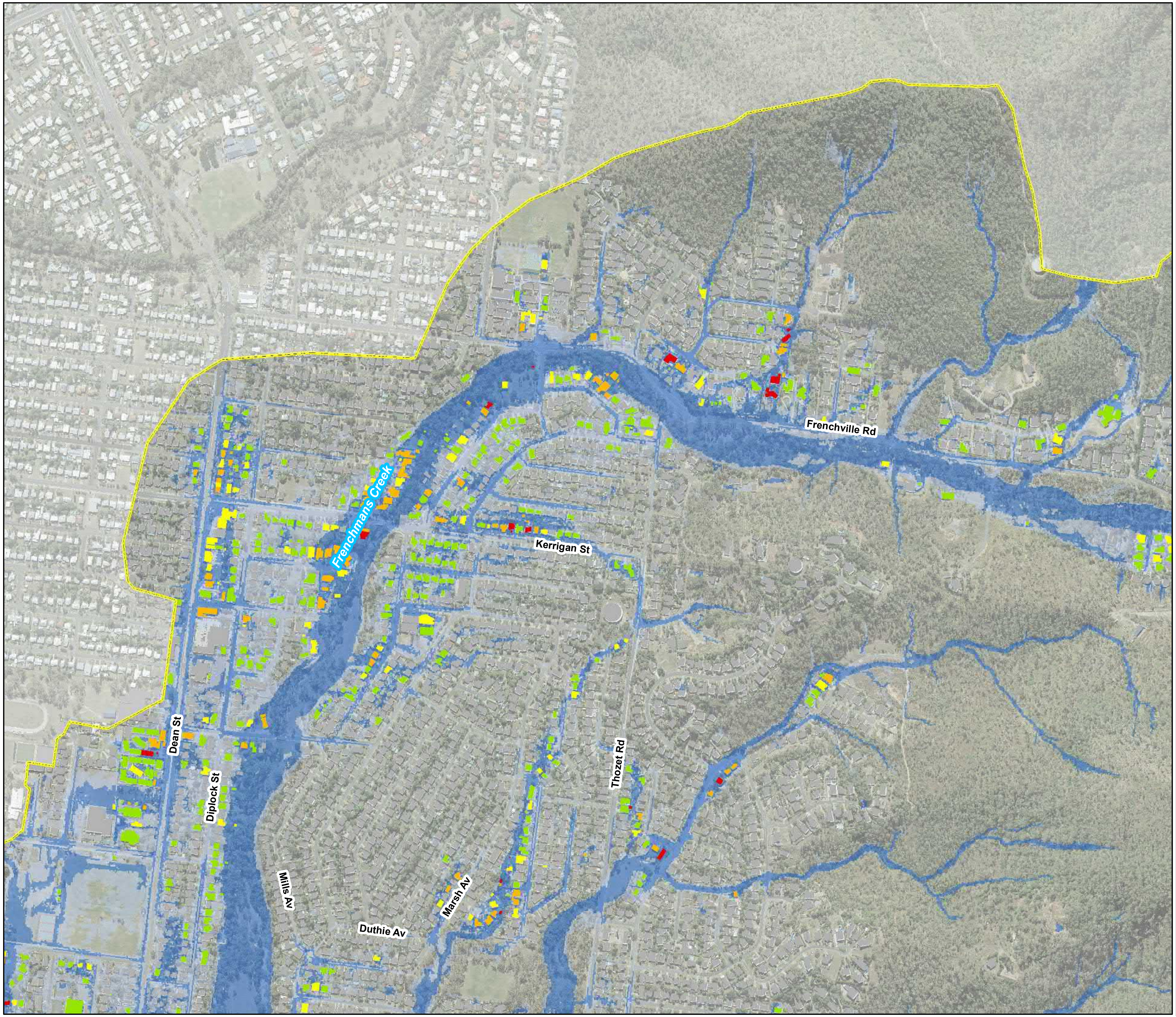
Results Filtering:
75mm Min. Depth
$100m^2$ Min. Area

Frenchmans Creek & Thozets Creek Model Inundation of Buildings with Above Floor Level Flooding - Area 1

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	29/08/2017
VERSION:	1

Figure 46

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\FT_Figure46_Phase_2_Inundated_Buildings - Area 1.mxd



N

Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 100 200 300 400
Metres

1:8,000
(when printed at A3)

AECOM
www.aecom.com

LEGEND

- Highways
- Railway Lines
- Cadastre
- Hydraulic Model Extent
- 1% AEP Flood Extents
- PMF Flood Extents

Inundation of Buildings with Above Floor Flooding

- Minor (1EY - 18%AEP)
- Major (10% - 1%AEP)
- Extreme (0.2% - 0.05%AEP)
- PMF
- Outside PMF Extent

Flood results are based on local catchment events

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

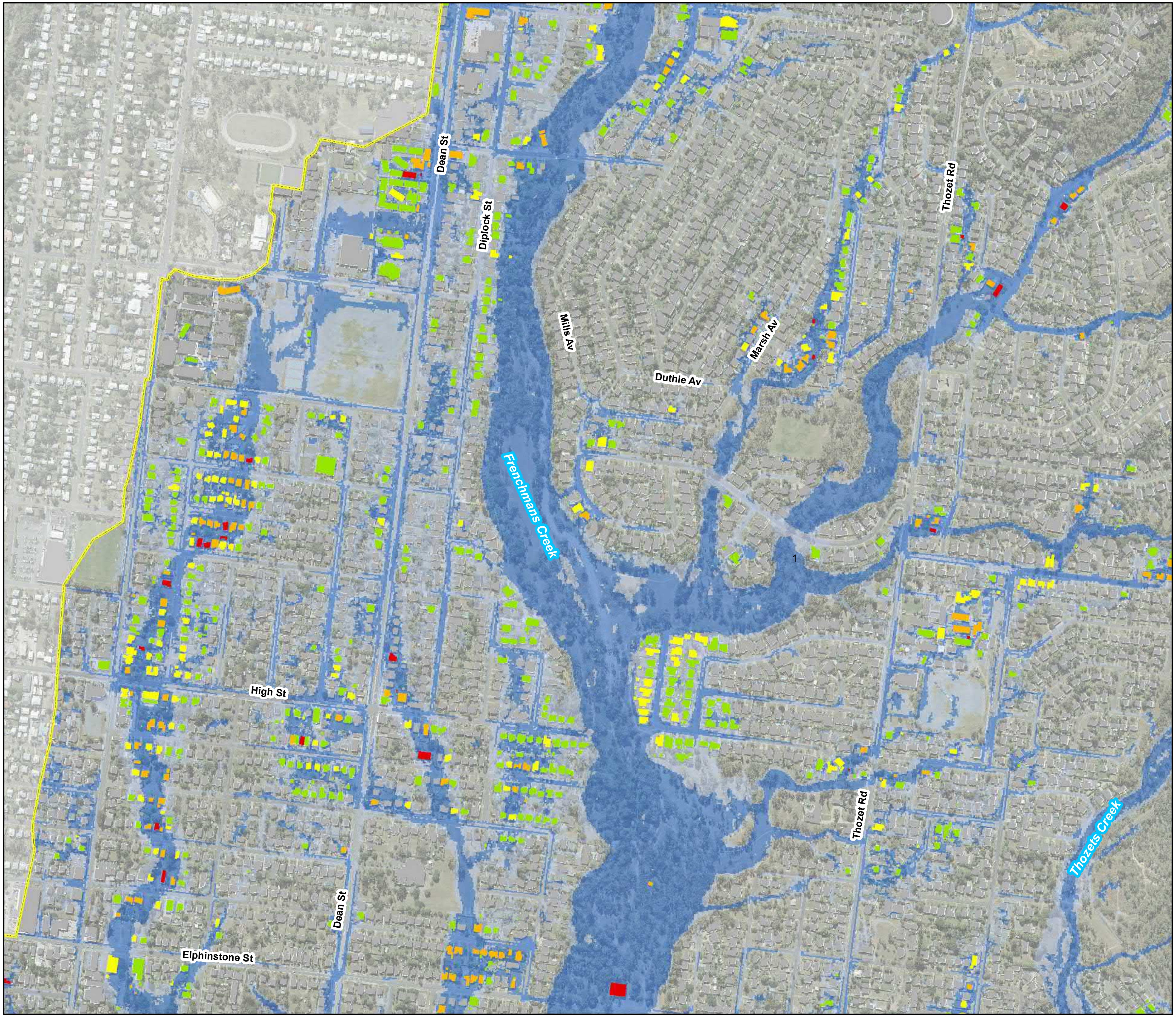
Results Filtering:
75mm Min. Depth
$100m^2$ Min. Area

Frenchmans Creek & Thozets Creek Model Inundation of Buildings with Above Floor Level Flooding - Area 2

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	29/08/2017
VERSION:	1

Figure 47

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\FT_Figure47_Phase_2_Inundated_Buildings - Area 2.mxd



N

Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 100 200 300 400

Metres

1:7,000
(when printed at A3)

AECOM
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LEGEND

- Highways
- Railway Lines
- Cadastre
- Hydraulic Model Extent
- 1% AEP Flood Extents
- PMF Flood Extents

Inundation of Buildings with Above Floor Flooding

- Minor (1EY - 18%AEP)
- Major (10% - 1%AEP)
- Extreme (0.2% - 0.05%AEP)
- PMF
- Outside PMF Extent

Flood results are based on local catchment events

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Results Filtering:
75mm Min. Depth
$100m^2$ Min. Area

Frenchmans Creek & Thozets Creek Model Inundation of Buildings with Above Floor Level Flooding - Area 3

PROJECT ID	60534898
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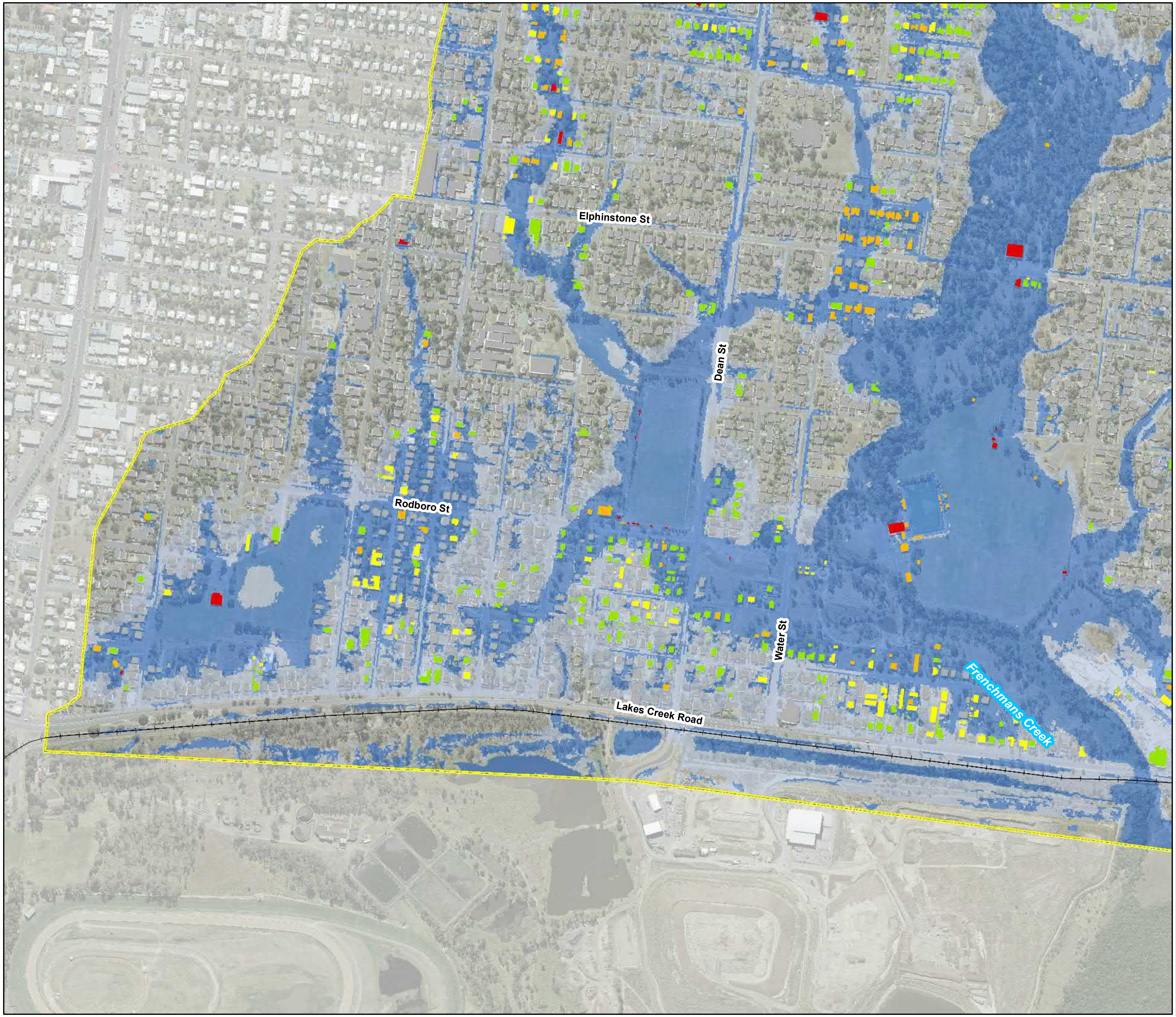
LAST MODIFIED	29/08/2017
VERSION:	1

Figure 48

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\FT_Figure48_Phase_2_Inundated_Buildings - Area 3.mxd



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DATUM GDA 1994, PROJECTION MGA ZONE 56

0 100 200 300 400
Metres

1:7,000
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AECOM
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LEGEND

- Highways
- Railway Lines
- Cadastre
- Hydraulic Model Extent
- 1% AEP Flood Extents
- PMF Flood Extents

Inundation of Buildings with Above Floor Flooding

- Minor (1EY - 18%AEP)
- Major (10% - 1%AEP)
- Extreme (0.2% - 0.05%AEP)
- PMF
- Outside PMF Extent

Flood results are based on local catchment events

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Results Filtering:
75mm Min. Depth
100m² Min. Area

Frenchmans Creek & Thozets Creek Model Inundation of Buildings with Above Floor Level Flooding - Area 4

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CREATED BY	maultbyj
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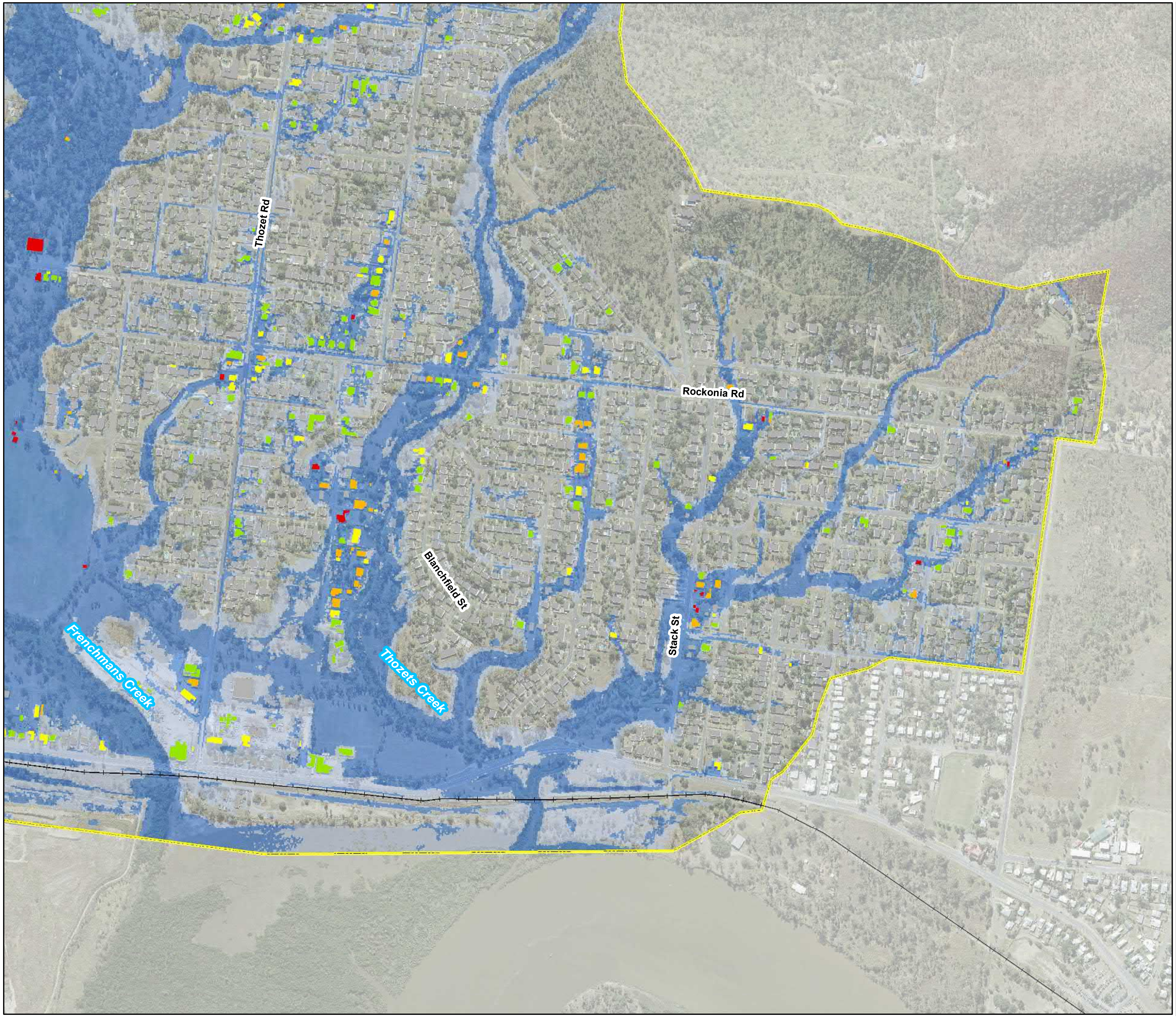
VERSION:	1

Figure 49



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Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 100 200 300 400
Metres

1:7,000
(when printed at A3)

AECOM
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LEGEND

- Highways
- Railway Lines
- Cadastre
- Hydraulic Model Extent
- 1% AEP Flood Extents
- PMF Flood Extents

Inundation of Buildings with Above Floor Flooding

- Minor (1EY - 18%AEP)
- Major (10% - 1%AEP)
- Extreme (0.2% - 0.05%AEP)
- PMF
- Outside PMF Extent

Flood results are based on local catchment events

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Results Filtering:
75mm Min. Depth
100m² Min. Area

Frenchmans Creek & Thozets Creek Model Inundation of Buildings with Above Floor Level Flooding - Area 5

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	29/08/2017
VERSION:	1

Figure 50

10.6.2 Baseline Flood Damages Assessment

Table 42 presents a summary of the estimated tangible flood damages (in March 2017 $) for a range of design flood events, using the WRM (2006) residential stage damage curves and ANUFLOOD commercial stage damage curves. Table 43 presents a summary of the estimated tangible flood damages (in March 2017 $) for a range of design flood events, using the O2 Environmental (2012) residential stage damage curves and ANUFLOOD commercial stage damage curves (Department of Natural Resources and Mines, 2002).

It should be noted that the damage values in the residential and commercial columns of the tables represent the total of direct and indirect damage costs. As can be seen, the impact of changing the source of the damage curves is minimal for smaller events and increases with the magnitude of the flood event. These values should be considered the upper and lower bounds for damages.

Table 42 Summary of flood damages using WRM stage-damage curves

AEP (%)	Flood Damages (,000s of March 2017 $)			
	Residential	Commercial	Infrastructure	Total
63	$458	$18	$62	**$538**
39	$1,005	$62	$137	**$1,204**
18	$2,872	$173	$391	**$3,436**
10	$4,577	$315	$627	**$5,519**
5	$8,776	$573	$1,200	**$10,549**
2	$12,686	$738	$1,726	**$15,150**
1	$20,049	$973	$2,709	**$23,731**
0.2	$32,806	$1,934	$4,466	**$39,206**
0.05	$49,760	$2,890	$6,770	**$59,420**
PMF	$140,959	$8,510	$19,209	**$168,678**

Table 43 Summary of flood damages using O2 Environmental stage-damage curves

AEP (%)	Flood Damages (,000s of March 2017 $)			
	Residential	Commercial	Infrastructure	Total
63	$433	$18	$58	**$509**
39	$1,046	$62	$142	**$1,250**
18	$3,264	$173	$443	**$3,880**
10	$5,234	$315	$713	**$6,263**
5	$10,427	$573	$1,416	**$12,416**
2	$15,654	$738	$2,113	**$18,505**
1	$24,831	$973	$3,333	**$29,137**
0.2	$43,014	$1,934	$5,798	**$50,746**
0.05	$66,756	$2,890	$8,987	**$78,634**
PMF	$205,544	$8,510	$27,634	**$241,687**

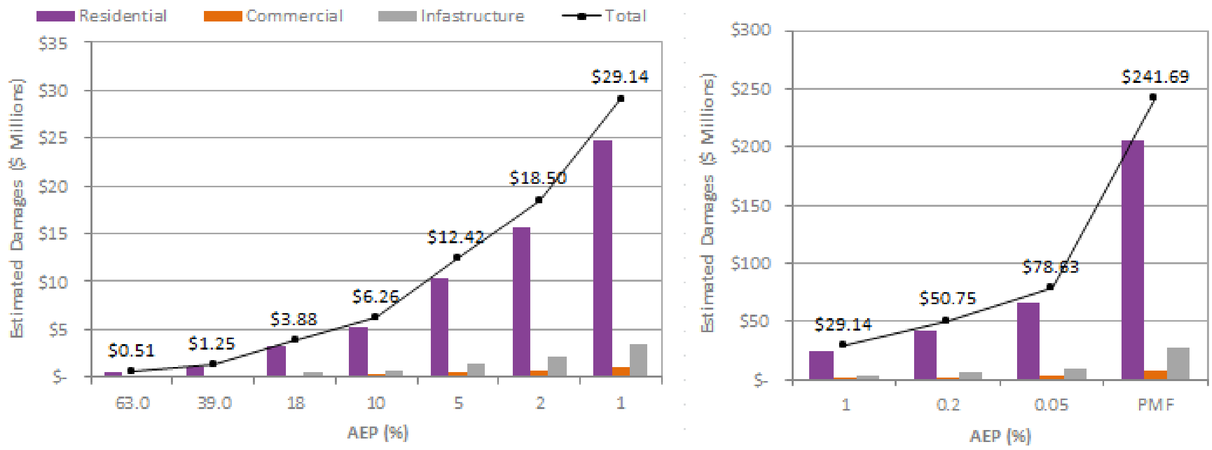


Figure 51 Estimated Flood Damages – O2 Environmental Damage Curves ($ Million)

Figure 51 summarises the estimated total flood damages for various flood events according to their AEP. As shown, total damages range from $509,000 (1EY flood event) to $242M (PMF flood event). Figure 43 shows that 13 buildings are expected to be inundated above floor in the 1EY event, whilst 1,772 buildings are anticipated to be inundated above floor in the PMF event

These figures also demonstrate that Residential buildings make up the large majority of impacted buildings, and consequently estimated flood damages, within the Frenchmans and Thozets Creek catchment across the full range of design events assessed.

10.6.3 Average Annual Damages

While the above provides an estimate of potential damages during specific flood events, understanding what damages may be expected on an annual basis is often an easier way to relate risk to residents and businesses. As such, the above damages were converted to Average Annual Damages (AAD) based on the likelihood of the flood event and the total estimated damage during that event. The AAD is determined by taking the estimated damage for each AEP event and multiplying it by the likelihood of the event. The process is repeated and AAD values are summed for the total AAD. For instance, the AAD for a 10% AEP event is based on the estimated $6.26M damages and 10% or 0.01 likelihood, corresponding to an AAD of $626,000. As a result, low-likelihood events such as the PMF have minor influence due to their low probability of occurrence.

AAD is a measure of the average tangible flood damages experienced each year, and is calculated as the area under the Probability Damages Curve. Therefore, accurate estimates of AAD require consideration of flood events ranging from the smallest flood that causes damage, up to the PMF. For this study, flood events ranging from the 1EY (exceedance per year) event up to the PMF have been considered.

The probability-damage curves used to calculate AAD are displayed in **Appendix D**. Using the WRM damage curves results in an AAD of approximately **$2,428,000** and using those from O2 Environmental gives an AAD of approximately **$2,832,000**. The difference of approximately 16% is largely the result of the increased cost of damages in more extreme events when using the O2 Environmental damage curves, as they extend above a depth of 2m, which is the depth that the WRM curves finish at.

The following graphs and discussions present the O2 Environmental data for analysis.

Figure 52 provides a breakdown of the number of buildings inundated in 'creek' and 'overland flow' areas. The graph confirms that the majority of buildings within the catchment (68%) are not inundated up to and including the PMF event. Of the 32% of buildings predicted to experience inundation, approximately 40% are impacted by overland flow and the other 60% are impacted by creek inundation.

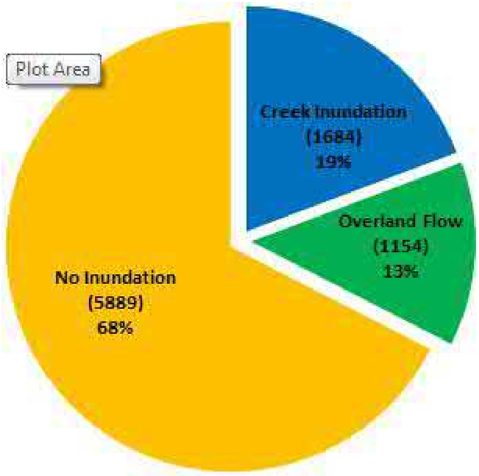


Figure 52 Inundation within Creek and Overland Flow Areas (Number of Buildings)

Figure 53 shows the total AAD split between flooding caused by Frenchmans Creek and Thozets Creek and flooding which occurs due to overland runoff through urbanised areas of the catchment. It can be seen that approximately 35% of AAD within the Frenchmans and Thozets Creek catchment is attributed to overland flooding and 65% of AAD is attributed to creek flooding.

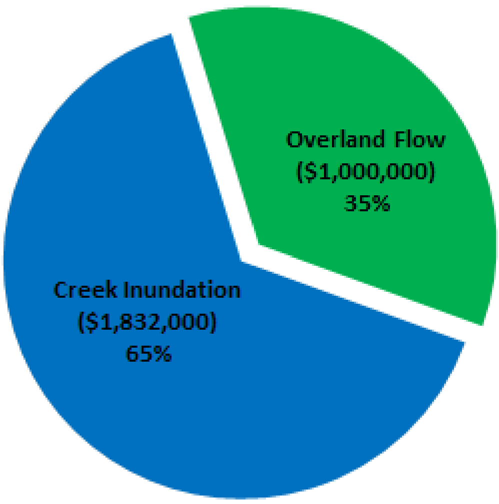


Figure 53 Total AAD within Creek and Overland Flow Areas

Figure 54 shows the breakdown of residential, non-residential and infrastructure AAD over the entire catchment. As shown, a total AAD cost of $2.8M is estimated, with the vast majority (84%) being attributed to residential buildings.

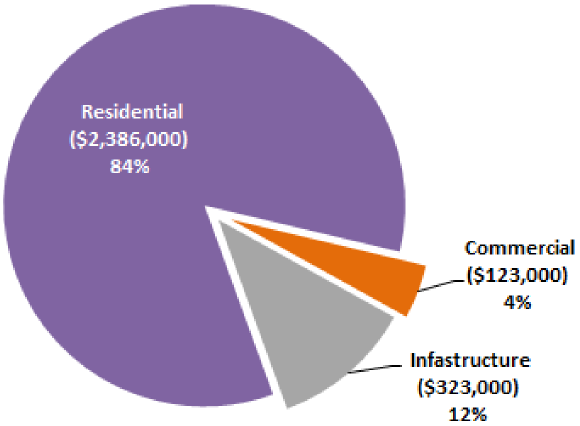


Figure 54 Total AAD by Building Type

Figure 55 and Figure 56 breakdown the AAD for residential and non-residential properties. It can be seen that 75% of residential and 85% of non-residential properties experience a damage cost of less than $500 per annum. As a result, 65% of the total AAD is associated with only 5% of all buildings, demonstrating that a minority of buildings produce the majority of damages within the catchment.

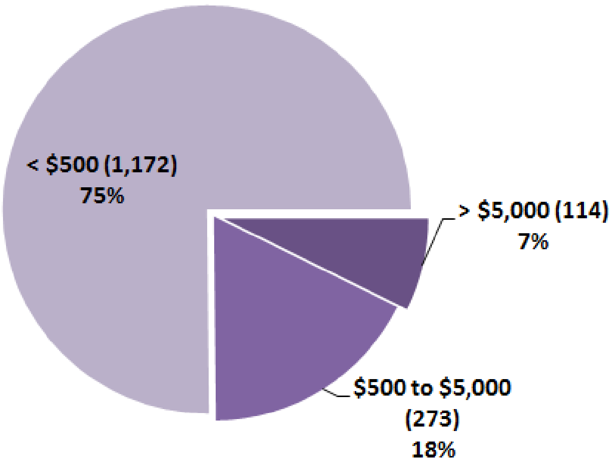


Figure 55 Residential AAD (Number of Buildings)

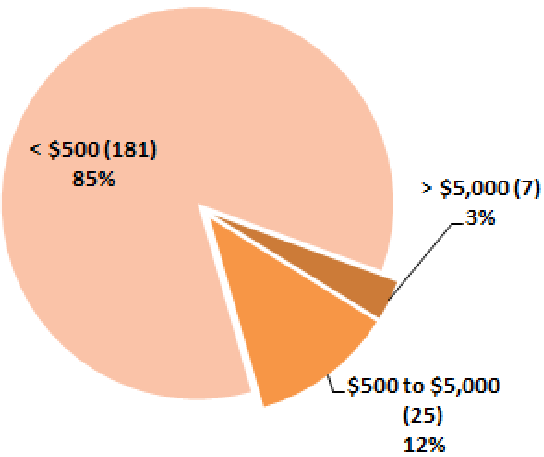


Figure 56 Non-Residential AAD (Number of Buildings)

10.6.4 AAD Summary

Figure 57 summarizes the same information as above in a different manner. The area in blue corresponds to individual building AAD (residential and non-residential combined) in brackets of $100 per annum. The orange line corresponds to the cumulative AAD for residential and non-residential buildings combined. Note that this does not include infrastructure damages.

As shown, 75% of all buildings exhibit less than $500 damage per annum. In addition 65% of damages are associated with less than 5% of all buildings. Again, this demonstrates that a minority of buildings produce the majority of damages.

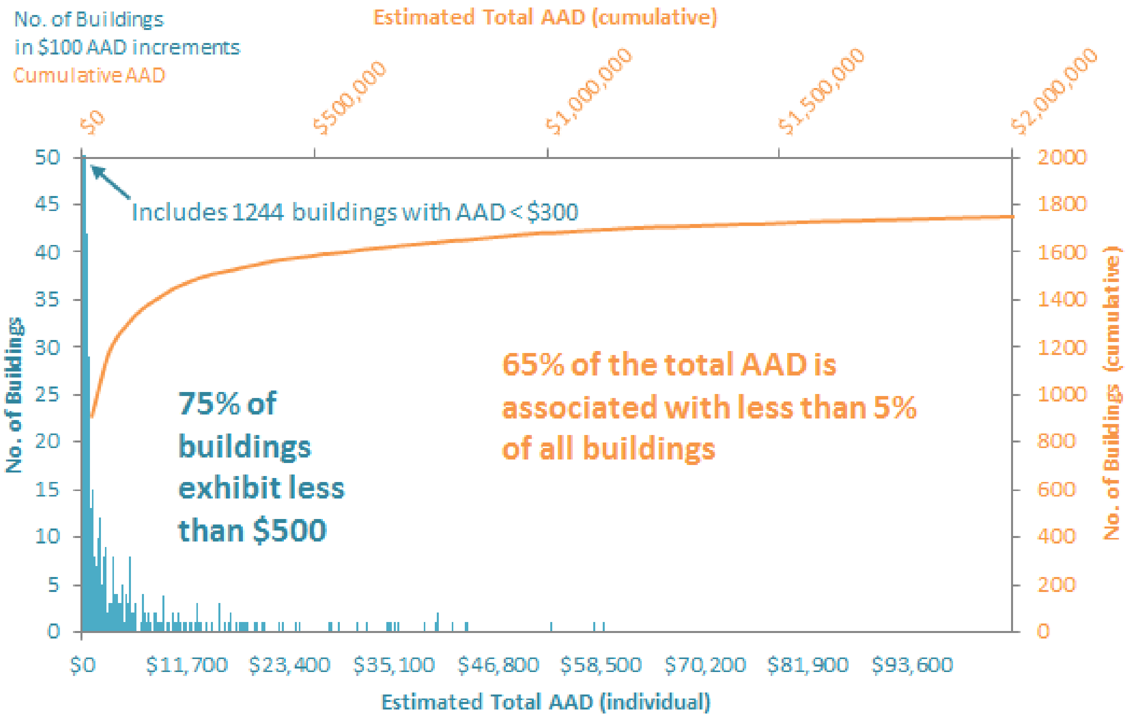


Figure 57 Individual Building vs. Cumulative Total Average Annual Damages

10.7 Rainfall Gauge and Maximum Flood Height Gauge Network Coverage

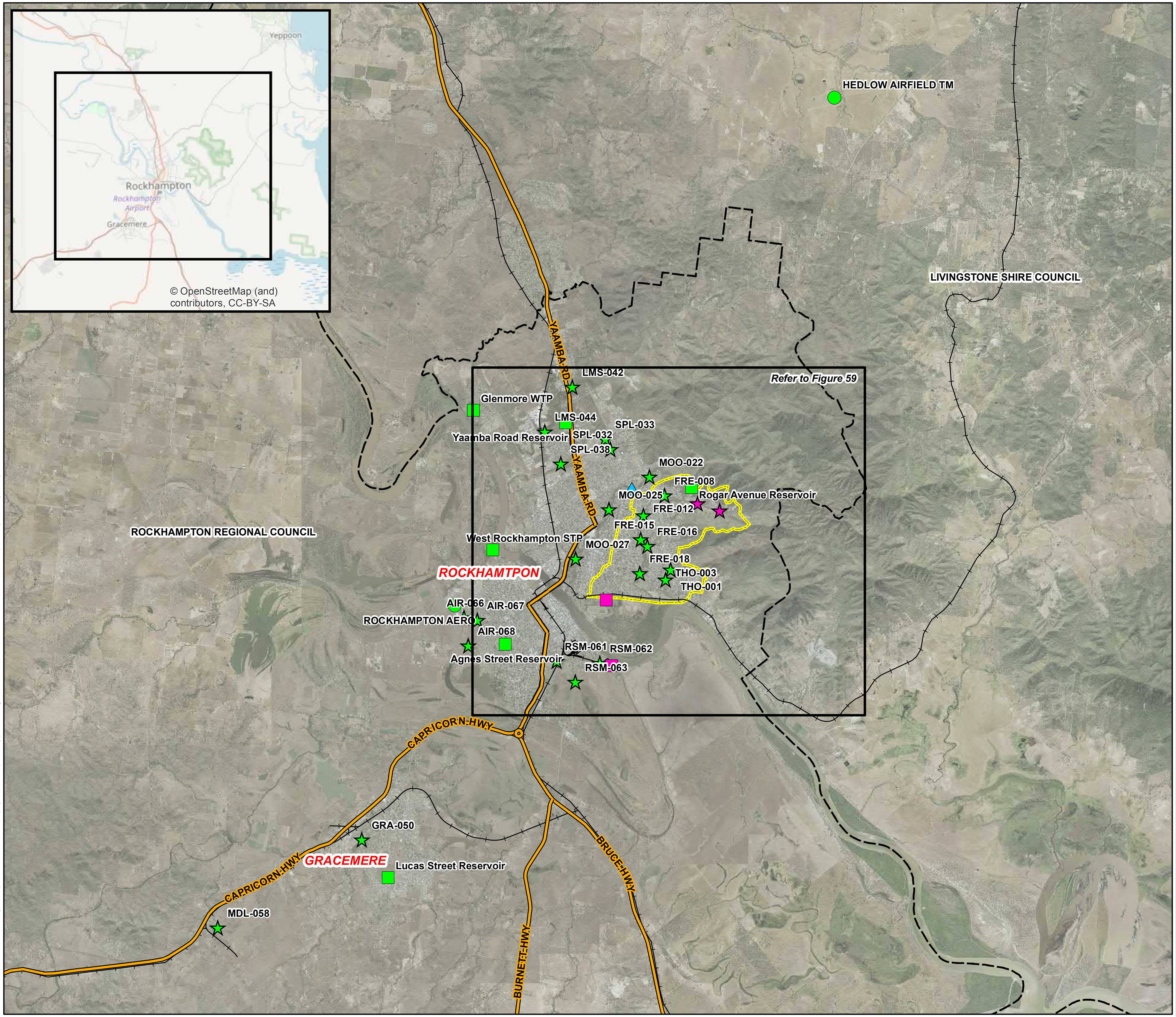
Figure 58 and Figure 59 show the location of existing rainfall gauges within the Rockhampton region, plus Council's maximum flood height gauges.

A high level desktop review of the coverage provided by the existing gauges has been undertaken, with the following recommendations provided for future upgrades to the system:

- Additional Council rain gauges could be installed at North Rockhampton Sewerage Treatment Plant (NRSTP) and South Rockhampton Sewerage Treatment Plant (SRSTP). These locations are ideal as they are already administered by Council (through Fitzroy River Water) and have access to telemetry.
- In addition to the seven existing maximum flood height gauges within the Frenchmans and Thozets Creek catchment, it is recommended that gauges be install in the following locations (as shown on Figure 59):
  - Along Frenchville Road, opposite the Rogar Avenue intersection area.
  - Along Frenchville Road, opposite the Lange Street intersection area.

10.8 Flood Warning Network Coverage

As noted in Section 2.7, there is currently no flood warning network for the Frenchmans and Thozets Creek catchment.



N

Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 1 2 3 4 5 6
Kilometers

1:120,000
(when printed at A3)

AECOM
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LEGEND

Maximum Height Gauges
- RRC

Active Rainfall Gauges
- BOM
- RRC

Inactive Rainfall Gauges
- Private

Proposed Flood Gauges
- RRC

Proposed Rainfall Gauges
- RRC
- Highways
- Railway Lines
- Hydraulic Model Extent Local
- Government Boundaries

Data Sources:

DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

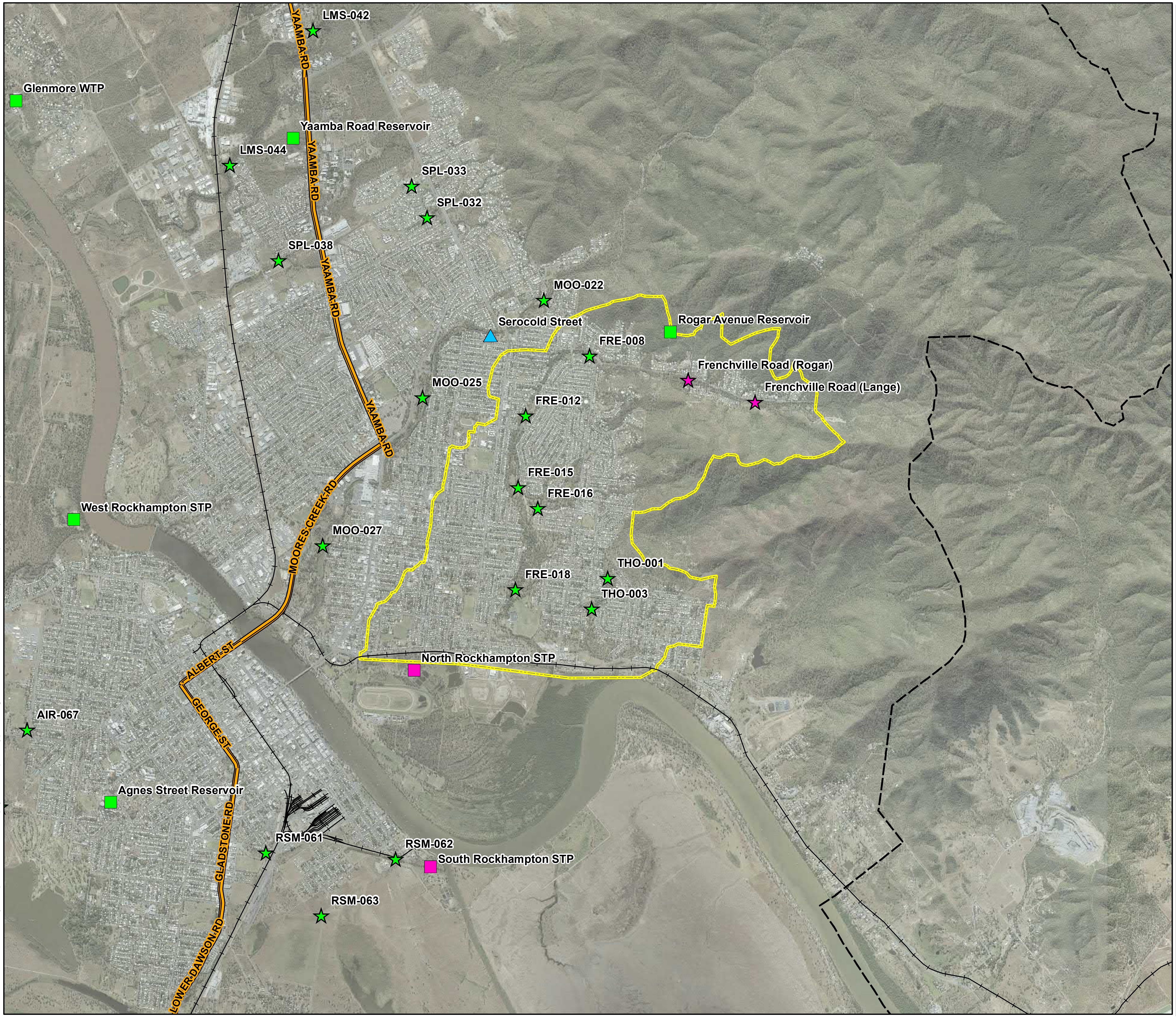
Frenchmans Creek & Thozets Creek Model Rainfall Gauge and Flood Record Network

Overview

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	29/08/2017
VERSION:	2

Figure 58

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\FT_Figure58_Phase_2_Gauges.mxd



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Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 0.5 1 1.5 2
Kilometers

1:40,000
(when printed at A3)

AECOM
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LEGEND

Maximum Height Gauges
- RRC

Active Rainfall Gauges
- BOM
- RRC

Inactive Rainfall Gauges
- Private

Proposed Flood Gauges
- RRC

Proposed Rainfall Gauges
- RRC

- Highways
- Railway Lines
- Hydraulic Model Extent Local
- Government Boundaries

Data Sources:
DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Frenchmans Creek & Thozets Creek Model Rainfall Gauge and Flood Record Network

Figure 58 Inset - Rockhampton

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	29/08/2017
VERSION:	2

Figure 59

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\FT_Figure59_Phase_2_Gauges.mxd

11.0 Conclusion

11.1 Baseline Model Development

The Frenchmans and Thozets Creek Phase 1 Baseline Flood Study included the development of a TUFLOW model for the urbanised portions of the Frenchmans and Thozets Creek local catchments. This model utilises a combination of runoff-routing and direct rainfall approaches in order to determine the overland flow paths and establish baseline flood extents and depths within the study area.

11.1.1 Model Calibration

Anecdotal and recorded data was obtained and used to calibrate the model to a local flood event caused by TC Marcia in February 2015. Further model validations were undertaken for two other local flood events, namely Ex-TC Debbie in March 2017 and Ex-TC Oswald in January 2013.

The model calibrated very well to the 2015 event. The validation to the 2017 event resulted in a reasonable comparison between modelled and recorded levels, with most points above tolerance. Discrepancies identified between the modelled and recorded levels are largely due to the vegetation density at the time of the flood event and variation in the spatial distribution of rainfall across the rural and urban components of the catchment. The validation to the 2013 event revealed the majority of anecdotal records matched simulated levels within tolerance.

Locations at which discrepancies exceeded allowable tolerances were expected to be a result of the ever-changing channel geomorphology, making it difficult to validate historic events using the latest terrain data.

Despite this, the model calibrates and validates well with modelled behaviours anticipated to appropriately predict flood patterns at the time of this study.

11.1.2 Design Event Modelling

On completion of the calibration / validation process, various design flood events and durations were simulated and results extracted. The critical duration for the catchment was determined to be the 90 minute event.

The modelling has confirmed that there are a number of key hydraulic controls within the catchment – particularly the various culverts / bridges which cross Frenchmans and Thozets Creek.

11.1.3 Sensitivity Analysis

Sensitivity analyses have been undertaken to highlight the uncertainties in the model results and support the selection and application of an appropriate freeboard provision when using the model outputs for planning purposes.

11.2 Baseline Flood Hazard and Vulnerability Assessment

The baseline flood hazard and vulnerability assessment undertaken for the Frenchmans and Thozets Creek catchment has identified areas of increased flood risk. The following sections summarise the findings.

11.2.1 Flood Hazard

As can be seen on maps **FT-77** to **FT-82** the 1% AEP baseline flood hazard within the Frenchmans and Thozets Creek catchment generally shows:

- Low to medium hazard (H1 and H2) across the majority of urbanised areas within the catchment.
- High hazard (H3 and H4) within a majority of natural and man-made channels, as well as open areas such as local parks.
- High to extreme hazard (H4 and H5) within some natural and man-made open channels, aswell as some open areas such as Alan Bray Park, Bill Crane Park, Rigarlsford Park, Ollie Smith Park and Duthie Park.

- High to extreme hazard (H4 and H5) in the vicinity of:
  - the Frenchville State School on Frenchville Road,
  - across the Kerrigan Street crossing of Frenchmans Creek,
  - across Elphinstone Street at Rigarlsford Park,
  - in Honour Street near the Mt Archer Scout Hall.
- Extreme hazard (H5 or H6) within the Frenchmans and Thozets Creek channel and adjacent overbank areas.

11.2.2 Vulnerability Assessment

The following provides a summary of key findings of the vulnerability assessment:

- The Blue Gum Terrace SPS (Ref: 463743), Water Street SPS (Ref: 463740), Frenchville Road SPS (Ref: 463736), Kerrigan Street SPS (Ref: 463748), Wehmeier Street WPS (Ref: 463723) and Pilbeam Drive 1 WPS (Ref: 463707) are predicted to have less than 0.2% AEP flood immunity. It is recommended this information be passed onto FRW as the asset owner.
- Low depth flooding is predicted at Frenchville State School, Mountain View Village, Elfin House Childcare and Skippy's Early Learning Centre in the 0.2% AEP, however the depth and velocity of flooding results in a low risk.
- The Yeppoon Branch Rail Line is predicted to have high level flood immunity to Top of Ballast, with inundation only predicted during the PMF event.
- A number of road segments are predicted to experience inundation in the 1EY event and larger. Approximate TOS values ranges from 1.0 hour to approximately 4 hours.

11.2.3 Evacuation Routes

The following areas have been assessed as being isolated and/or lack adequate evacuation routes during the PMF event:

- Subdivisions off Frenchville Road à loses evacuation via Frenchville Road (includes Cascade Close, Rainbow Court, Lange Street, Frenchmans Lane, Beaumont Drive, Candlebark Court, Rogar Avenue, Seifert Drive, Jard Street, Davey Avenue and side streets).
- Ironbark Terrace, Archerview Terrace, Blue Gum Terrace, Jordan Close à loses evacuation via Ironbark Terrace to Frenchville Road.
- Boyd Street, Moyle Street, Murphy Street à loses evacuation via Beasley Street to Frenchville Road and/or via Murphy Street to Thozet Road.
- Limpus Street, Vallis Street, Coome Street à loses evacuation via Dean Street to Vallis Street.
- Water Street, Bremner Street, Mason Street à loses evacuation via Mason Street to Dean Street and/or via Water Street to Elphinstone Street.

11.2.4 Building Impact Assessment

The building impact assessment shows the following:

- 40 buildings (13 with above floor flooding) predicted to be impacted in the 1EY event.
- 199 buildings (71 with above floor flooding) predicted to be impacted in the 18% AEP event.
- 799 buildings (383 with above floor flooding) predicted to be impacted in the 1% AEP event.
- 2,838 buildings (1,772 with above floor flooding) predicted to be impacted in the PMF event.
- Significant number of buildings with less than 0.2m flood depth in frequent events, such as 1EY.
- Of the 32% of the buildings impacted by flooding, 40% is associated with overland flow.

11.2.5 Flood Damages Assessment

The following provides a summary of the Flood Damages Assessment findings:

- WRM and O2 curves used to establish upper and lower bounds for tangible flood damages:
  - $538,000 to $509,000 damages estimated in 1EY event.
  - $3,436,000 to $3,880,000 damages estimated in 18% AEP event.
  - $23,731,000 to $29,137,000 damages estimated in 1% AEP event.
  - $168,678,000 to $241,687,000 damages estimated in PMF event.
- AAD ranging from **$2,428,000 to $2,832,000** for WRM and O2 damage curves respectively.
- 84% of the total AAD is associated with residential buildings.
- 35% of the total AAD is attributed to overland flooding.
- 75% or residential buildings and 85% or commercial buildings exhibit less than $500 damage per annum.
- 65% of the total AAD is attributed to less than 5% of all buildings.

11.2.6 Rainfall Gauge, Maximum Flood Height Gauge and Flood Warning Network

Review of the existing rainfall gauge, maximum flood height gauge and flood warning network yielded the following recommendations/findings for the Frenchmans / Thozets Creek catchment:

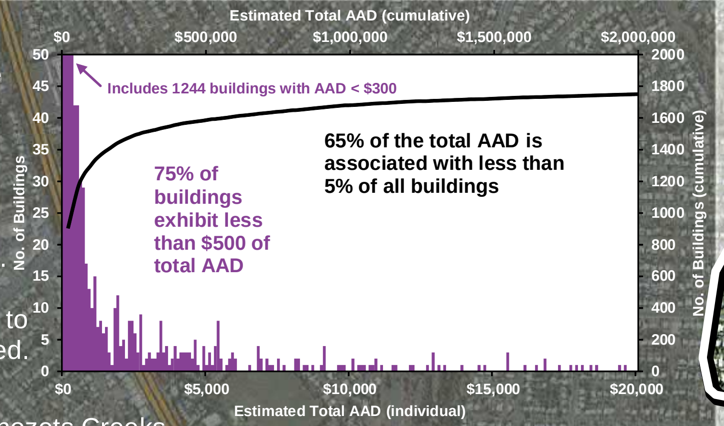
- Additional rain gauges should be installed at NRSTP and SRSTP.
- Additional maximum flood height gauges should be installed:
  - Along Frenchville Road, opposite the Rogar Avenue intersection area.
  - Along Frenchville Road, opposite the Lange Street intersection area.
- There is no current flood warning system within the Frenchmans / Thozets Creek catchment.

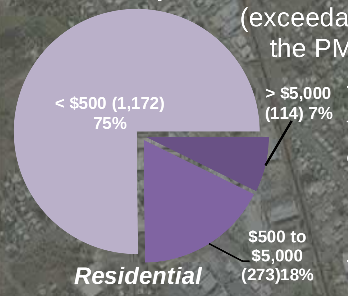
An overview of building impacts and flood damages is provided in Figure 60.

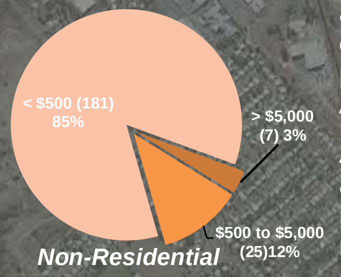
Frenchmans and Thozets Creeks Catchment Overview

Average Annual Damages

Average Annual Damage (AAD) is a measure of the average tangible flood damages experienced each year, and is calculated as the area under the Probability Damages Curve. Therefore, accurate estimates of AAD require consideration of flood events ranging from the smallest flood that causes damage, up to the Probable Maximum Flood (PMF). For this study, flood events ranging from the 1EY (exceedance per year) event up to the PMF have been considered.



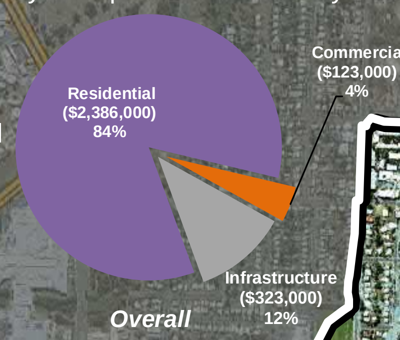




The calculated AAD for the Frenchmans and Thozets Creeks catchment is estimated to range from approximately $2,428,0000 to $2,832,000 per annum. The difference of approximately 16% provides a relatively narrow range for the estimated AAD.

The vast majority (84%) of AAD is attributed to residential buildings. 75% of residential and 85% of non-residential properties experience less than $500 of AAD.

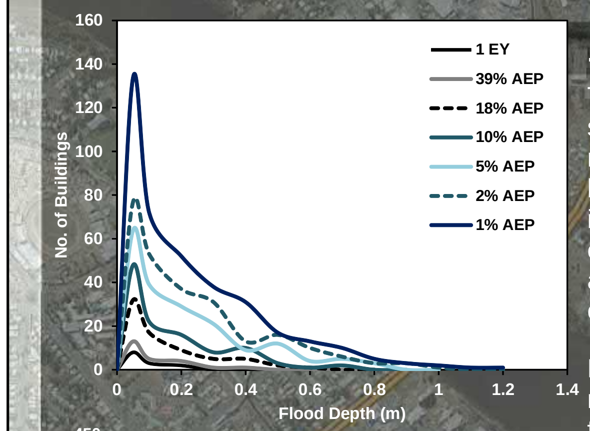
As a result, 65% of the total AAD is associated with only 5% of all buildings, revealing that a minority of buildings are responsible for the majority of damages.

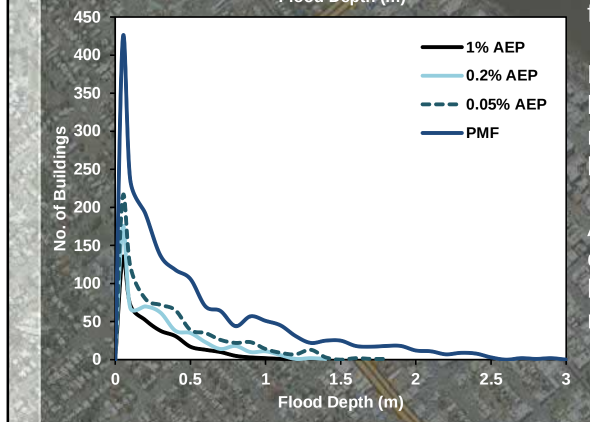


Depth of Inundation

Median flood depths are less than 0.1 m for each flood event. This indicates that reductions in flood depths of 0.1 m could significantly reduce overall damage.

The figures also show that a significant number of buildings experience flood depths of 0.2 m or less during frequent events such as the1 EY flood event, generally corresponding to higher flood damages.





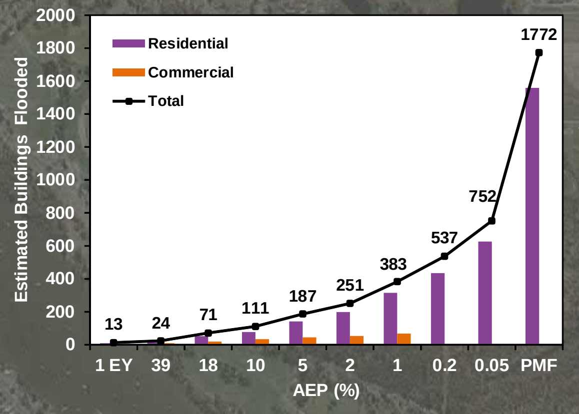
Flood Damages

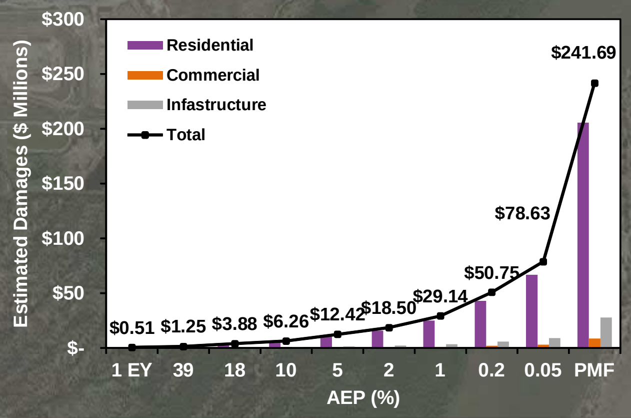
The figure below provides a summary of the number of residential and commercial buildings anticipated to be inundated for various flood events within the Frenchmans and Thozets Creeks catchment.

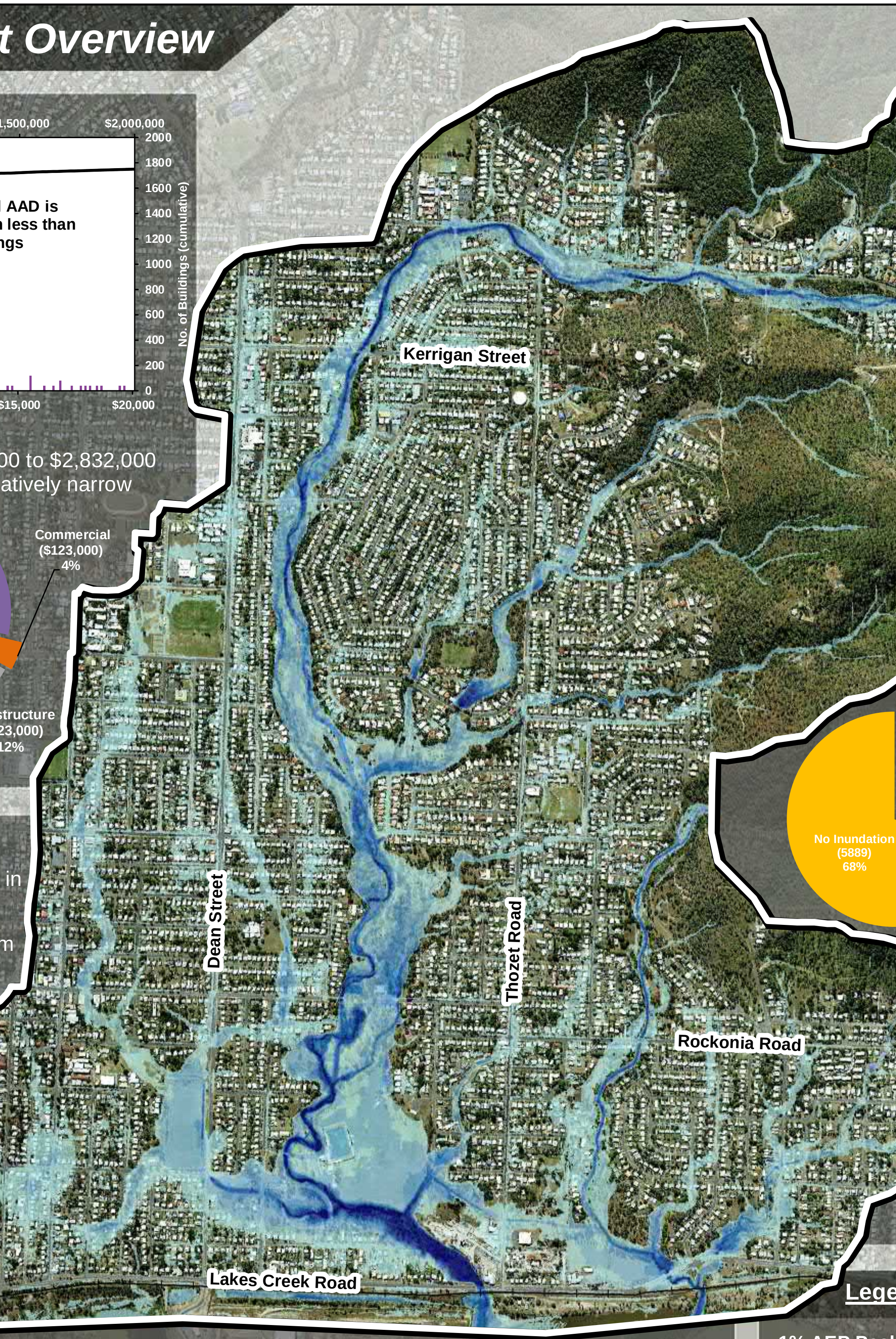
Note that the indicated number of buildings is for entire buildings.

Residential multi-unit buildings may contain multiple dwellings per building.

Also, large commercial/industrial buildings may include multiple businesses.

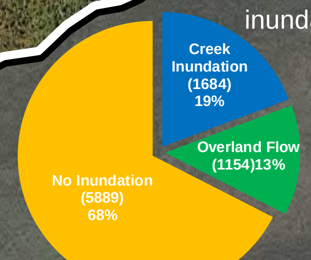






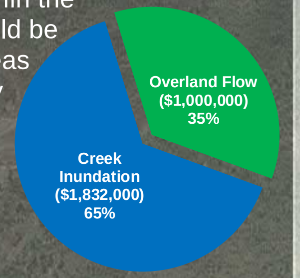
Inundation Breakdown

The graph to the left confirms that the majority of buildings within the catchment are not inundated up to and including the PMF event. Of the 32% of the catchment predicted to experience inundation, more than 40% is associated with overland flow.



It can be seen that approximately 35% of AAD within the Frenchmans and Thozets Creek catchment is attributed to overland flooding.

This indicates that mitigation efforts to reduce AAD within the catchment should be focussed on areas within or directly adjacent to the creek, rather than overland flooding areas.



Flood results are based on local catchment events

Legend

1% AEP Peak Flood Depth (m)

- < 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- 2.0 - 2.5
- 2.5 - 3.0
- > 3.0

Annual Exceedance Probability (AEP) %	Average Recurrence Interval (ARI) Years
63 (1 EY)	1
39	2
18	5
10	10
5	20
2	50
1	100
0.2	500
0.05	2000

0 0.25 0.5 1 km

12.0 Recommendations

A number of recommendations have been made in relation to this study:

- Baseline flood mapping (i.e. peak depths, velocities and water surface elevations) provided in this study should be used to update Council's current Planning Scheme layers, at the next available opportunity.
  - Final post-processing of the GIS flood layers is recommended in accordance with the procedures outlined in the ARR, Data Management and Policy Review (AECOM, 2017).
  - Appropriate freeboard provisions should be included, based on the findings of the sensitivity analyses outlined in this study.
- This report and associated outputs should be communicated to the community and relevant stakeholders when appropriate.
- Hydrologic and hydraulic modelling undertaken for this study has been based on methods and data outlined in Australian Rainfall and Runoff 1987. The 1987 revision has been adopted as per Council's request. It is recommended that future updates to this study incorporate the new 2016 updates.
- It is recommended that Council continue to undertake building floor level survey within the Frenchmans / Thozets Creek catchment to supplement the existing building database. An updated FDA should be undertaken when additional building survey data has been obtained.
- It is recommended that Council continue to record rainfall and flood heights associated with future Frenchmans / Thozets Creek catchment flood events. This data will support ongoing model calibration / validation works that should be undertaken in future updates to this study. The implementation of additional gauges identified in this study is also recommended.
- Updated creek cross sectional survey should be undertaken after major flood events, and prior to undertaking future updates to this study. It is recommended that cross sections be surveyed at the same locations undertaken in this study to assess longer term geomorphic changes, and potential implications to flood behaviour.
- The baseline vulnerability and flood hazard assessment outputs from this report should be used to support Phase 3 of the Study (Flood Mitigation Options Development and Assessment). Potential mitigation options should be focussed on both creek and overland flooding.

13.0 References

Australian Rainfall and Runoff (2012). *Project 15 – Two Dimensional Modelling in Urban and Rural floodplains - Stage 1& 2 Report*. Available at: http://arr.ga.gov.au/, accessed 13 March 2017.

Institution of Engineers Australia (1998), Australian Rainfall and Runoff – A Guide to Flood Estimation, Volumes 1 and 2.

BMT WBM (2016), TUFLOW User manual – Build 2016-03-AA.

Maritime Safety Queensland (2014) QLD Tide Tables book.

Rockhampton Regional Council (2014), South Rockhampton Flood Levee – Hydraulic Model Development and Comparison Report, prepared by AECOM, 2014.

Rockhampton Regional Council (2014), Rockhampton Local Catchments Flood Study: Frenchmans Creek Hydrologic and Hydraulic Modelling Report, prepared by Aurecon, 2014

Rockhampton Regional Council (2014), Rockhampton Local Catchments Flood Study: Thozets Creek Hydrologic and Hydraulic Modelling Report, prepared by Aurecon, 2014

Appendix A

Hydraulic Model Development

Appendix A Hydraulic Model Development

Model Setup Parameters

The time step for the 2D model domain has been set to 1 second. The corresponding 1D time step has been set at 0.5 seconds. These time steps represent an appropriate time step given the grid cell size of 3m.

The wetting and drying depth represents the depth of water on a cell which is the criteria for whether the cell is “wet” or “dry”. Direct rainfall modelling applies rainfall to each cell in small increments, so the wetting and drying values must also be very small or the intermediate calculations will not take place satisfactorily. The wetting and drying depth has been set to the default of 0.0002m for the centre of a cell.

One-Dimensional Network Development

As detailed in Section 3.6, RRC provided a large amount of data related to the existing stormwater drainage network within the study area. Underground pipes were incorporated into the model as 1D elements, which are dynamically linked to the 2D domain via pit and outlet structures. All pits have been represented using assumed dimensions of 900x600mm. Pit inlet elevations have been adopted using surveyed levels where possible and corresponding LiDAR levels where data gaps exist.

All culverts were represented as dynamically linked 1D elements, with major sets of closely situated culverts being digitized using multi-cell links (CN-SX lines). Culvert roughness was set as 0.015 for RCPs and RCBCs.

Bridge Structure Losses

Bridges were digitised as 2D layered flow constrictions. Standard form loss coefficients were calibrated using HEC-RAS models. Losses in the TUFLOW model were increased / decreased based on the velocity head in order to better match the head loss predicted across the bridge structure in the HEC-RAS model.

Model Topography

Base model topography was derived from LiDAR survey flown in 2016 and supplied by RRC. The data was supplied as a 1m resolution Digital Elevation Model (DEM). With reference to Figure 62, a number of surveyed levels have been obtained and incorporated into the model:

- Frenchmans Creek channel cross-sections.
- Thozets Creek channel cross-sections.

Surveyed cross-sections through areas of dense vegetation compared to the LiDAR elevations and incorporated into the model using 2d_zsh layers to lower the vegetated areas (visible in the imagery) by the calculated discrepancies. Cross-sections across areas of combined scour and dense vegetation were digitized within the model through tinning the surveyed cross-section back to LiDAR elevations upstream and downstream of the surveyed cross-section. Examples instances of the ‘before and after’ creek channels are presented below in Figure 61.

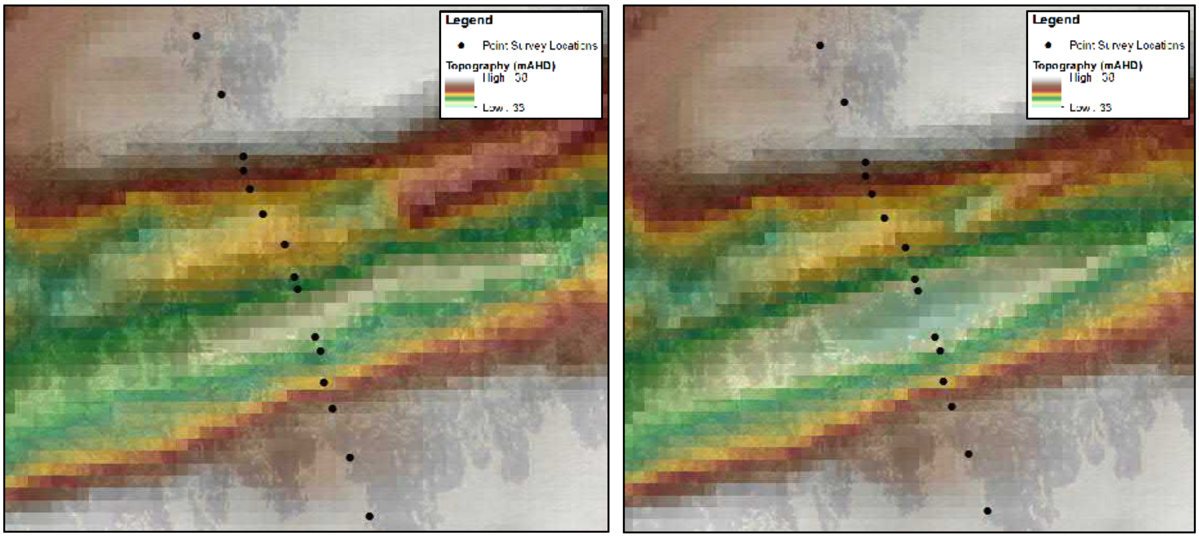
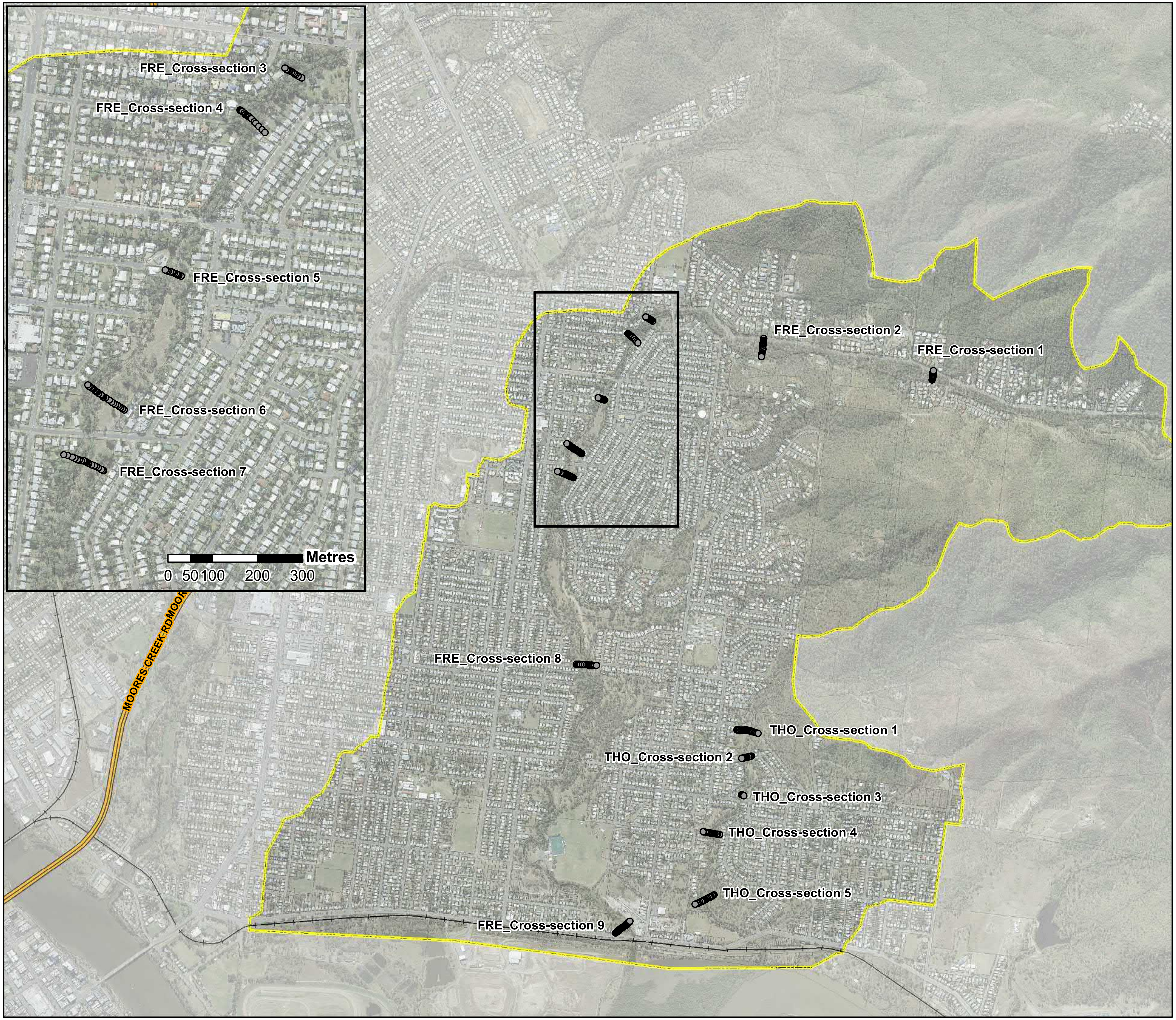


Figure 61 Model Topography using LiDAR (left) versus Model Topography using LiDAR + Survey (right)

Due to limitations surrounding large-scale hydraulic modelling, the adopted grid cell size (3m) may not always adopt the peak crest level of roads. Given the hydraulic significance of road crests within urban catchment flow paths, heights were extracted from the 1m LiDAR DEM at 1.5m intervals (half the grid cell size) using centreline alignments provided by RRC. These point elevations were read into the model after the 1m DEM in order to enforce the road crowns along all surfaces not previously surveyed.



N

Rockhampton Regional Council

DATUM GDA 1994, PROJECTION MGA ZONE 56

0 200 400 600 800 1,000
Metres

1:20,000
(when printed at A3)

AECOM
www.aecom.com

LEGEND

- Cross-section Survey Points
- Highways
- Railway Lines
- Cadastre
- Hydraulic Model Extent

Data Sources:

DCDB (c) 2016 QLD Government
Imagery (c) 2016 RRC

Frenchmans Creek & Thozets Creek Model

Cross Section Survey Point Locations

PROJECT ID	60534898
CREATED BY	maultbyj
LAST MODIFIED	20/06/2017
VERSION:	1

Figure
62

Filename: P:\605x\60534898\4. Tech Work Area\4.99 GIS\3. MXDs\Frenchmans Thozets Creeks Publishing\Figures for Report\Figure 28 Frenchmans_ThozetsCreekSurveyLocations.mxd

Hydraulic Roughness and Losses

The specified hydraulic roughness reflects the different types of development and ground cover that exists within the hydraulic model extent. The roughness categories adopted for this study were developed based on aerial imagery, site visits and land use zoning information. Variable Manning's 'n' values based on depth can be utilised within TUFLOW. Manning's 'n' 1 is applied for all flow depths up to depth 1, between depths 1 and 2 the Manning's 'n' utilised by TUFLOW is interpolated between Manning's 'n' 1 and 2 and for all depths greater than depth 2 Manning's 'n' 2 is applied. In the instance of road reserve a single roughness has been applied.

Specific roughness values for each category as applied in the model are outlined in Table 44.

Table 44 Adopted Roughness Values

Material Description	Manning's 'n'			
	Depth 1 (m)	Manning's 'n' 1	Depth 2 (m)	Manning's 'n' 2
High Density Residential	0.1	0.07	0.3	0.15
Low Density Residential	0.1	0.05	0.3	0.09
Commercial/Industrial	0.1	0.03	0.3	0.06
Dense Vegetation	0.1	0.09	0.3	0.06
Medium Vegetation	0.1	0.075	0.3	0.05
Light Vegetation	0.1	0.06	0.3	0.045
Channel with Rocks and Pools	0.05			
Riparian Corridor	0.07			
Maintained grass	0.035			
Road Reserve	0.025			
Fitzroy River Bed (at DS boundary)	0.022			
Smooth Channel Used for lower reaches	0.035			
Channel: Cobbles with few boulders	0.04			
Medium Density Residential	0.1	0.06	0.3	0.12
Rail Reserve	0.03			
Buildings	0.1	0.018	0.3	0.5
Open space	0.1	0.04	0.3	0.03
Dense rock / trees throughout meandering channels on steep slopes	0.1	0.09	0.5	0.075

Rainfall losses allow TUFLOW to model situations in which water is prevented from reaching the ground or is infiltrated into the soil system before surface ponding and/or runoff occurs. When using a direct rainfall approach initial losses and continuing losses are specified for each material type; this takes into account the pervious nature of the material. Any losses applied remove the loss depth from the rainfall amount **prior** to being applied as a boundary on the 2D cells. Once the initial losses have been satisfied the material is considered saturated and any additional rainfall will become surface water.

During the calibration process if events contained a pre-burst rainfall that was excluded from the simulation the initial losses applied were reduced to 0 mm. This simulates the catchment being saturated by the pre-burst rainfall. Continuing losses remained. This initial loss of 0mm was also applied to the PMF event, as it is conservative to consider the catchment saturated.

The initial losses and continuing losses applied to this model are indicated below in Table 45.

Table 45 Adopted Initial and Continuing Loss Values

Material Description	Initial Loss (mm)	Continuing Loss (mm/h)
High Density Residential	7.5	0.5
Low Density Residential	7.5	0.5
Commercial/Industrial	7.5	0.5
Dense Vegetation	15	1
Medium Vegetation	15	1
Light Vegetation	15	1
Channel with Rocks and Pools	0	0
Riparian Corridor	0	0
Maintained grass	15	1
Road Reserve	0	0
Fitzroy River Bed (at DS boundary)	0	0
Smooth Channel Used for lower reaches	0	0
Channel: Cobbles with few boulders	0	0
Medium Density Residential	7.5	0.5
Rail Reserve	15	1
Buildings	0	0
Open space	15	1
Dense rock / trees throughout meandering channels on steep slopes	15	1

Initial Conditions

Initial water levels were applied to the 1D pipe network and 2D domain. The MHWS water level of 2.66m was specified for the entire model area under design events. This ensured that model boundaries represented the water level of the Fitzroy River were represented at the first time step of the model simulation. During the calibration and validation events the applied initial water level was adjusted to the first height corresponding with the model start time from the tidal boundary hydrograph.

Boundary Conditions

A range of different boundary conditions have been applied within the Frenchmans and Thozets Creek Local Catchment model. The types of boundaries are as follows:

- Direct rainfall.
- Time-varying discharge (QT) inflow boundaries for external catchments.
- Height versus discharge (HQ) outflow boundaries.
- Height versus time (HT) boundaries for the Fitzroy River.

Direct rainfall has been applied to the 2D domain; background to this approach is described in Section 4.1. The QT inflow boundaries apply the predicted inflow over time as generated by the XP-RAFTS hydrologic model for the catchment area external to the 2D domain. HQ type boundaries allow flood waters to discharge from the model relative to the water surface elevation. Using a downstream slope value established using the 1m DEM, TUFLOW automatically generates a height versus discharge curve (rating curve) which is applied to the model boundary. A HT boundary applies a water level to the boundary cells based on a water level versus time curve. MHWS was adopted for design events and historic tidal data during the calibration and validation events was adopted for the Fitzroy River channel.

A summary of the boundary conditions applied to the three models are summarised in Table 46.

Table 46 Summary of Boundary Conditions

Boundary Type	Details
Direct rainfall	Applied across entire 2D domain
QT	Inflows for the external catchment of Mount Archer National Park (northeast)
HT	Fitzroy River outflow boundary (south-western boundary)
HQ	2 outflow boundaries applied along the eastern model boundary

Appendix B

Surveyed Cross-section Comparison

Appendix B Surveyed Cross-section Comparison

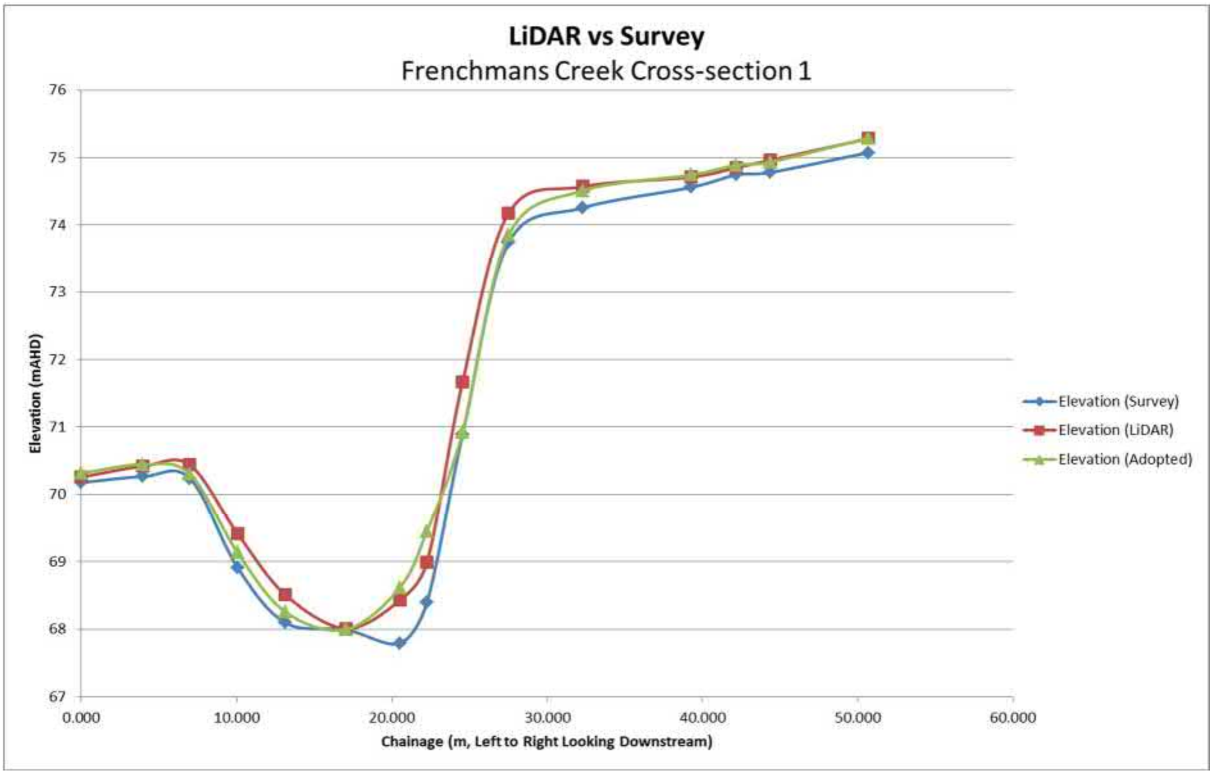


Figure 63 LiDAR verses Survey comparison at FRE_Cross-section 1

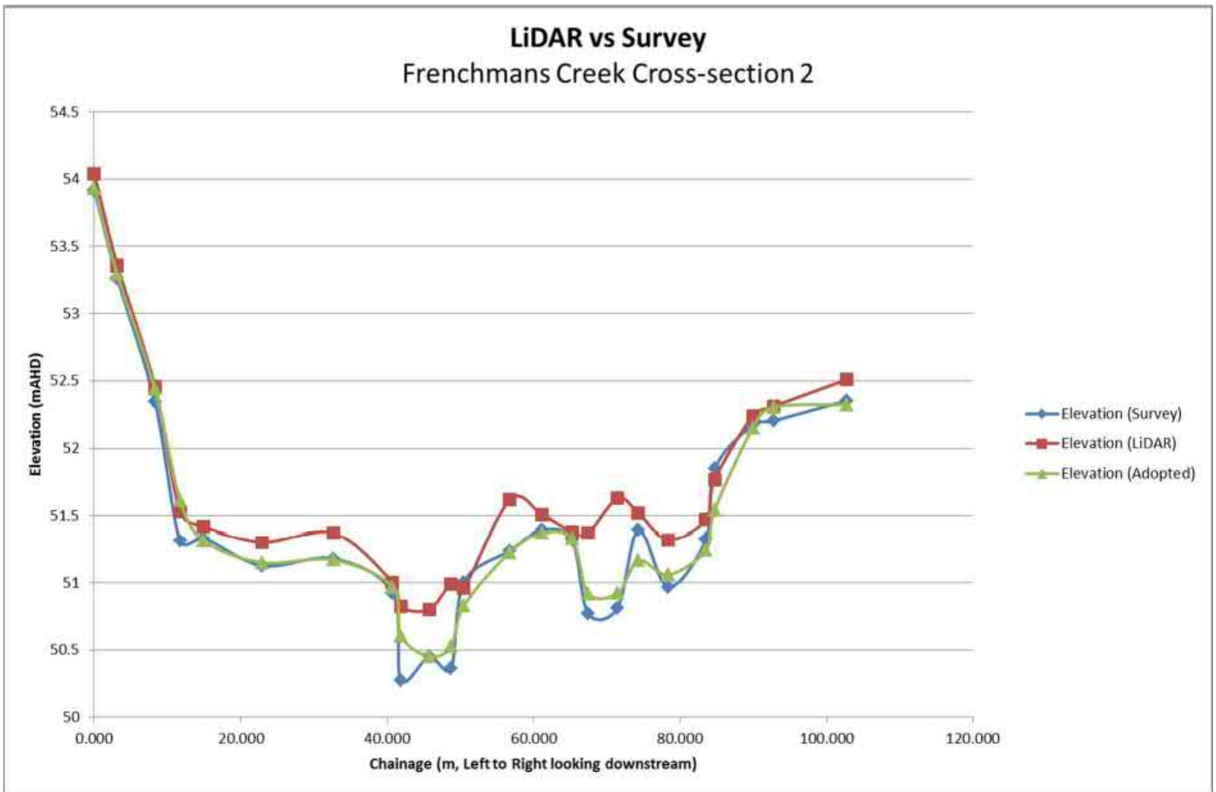


Figure 64 LiDAR verses Survey comparison at FRE_Cross-section 2

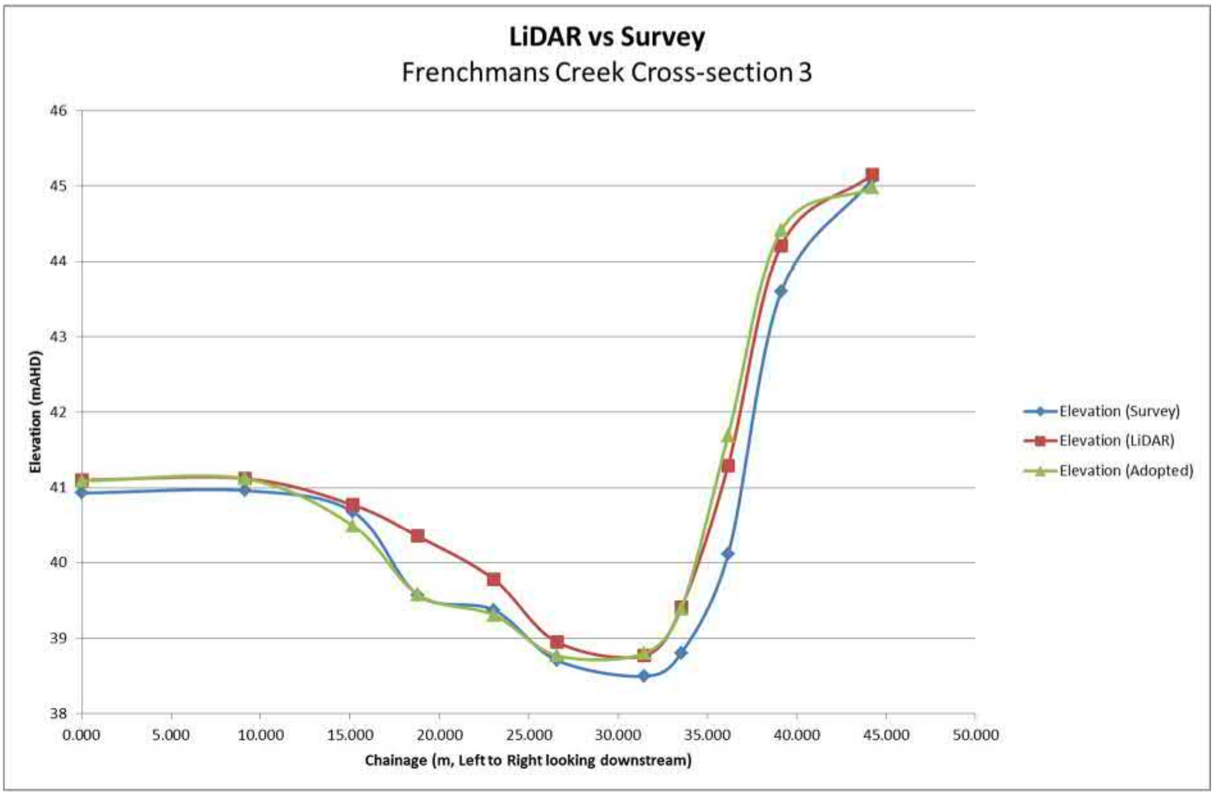


Figure 65 LiDAR verses Survey comparison at FRE_Cross-section 3

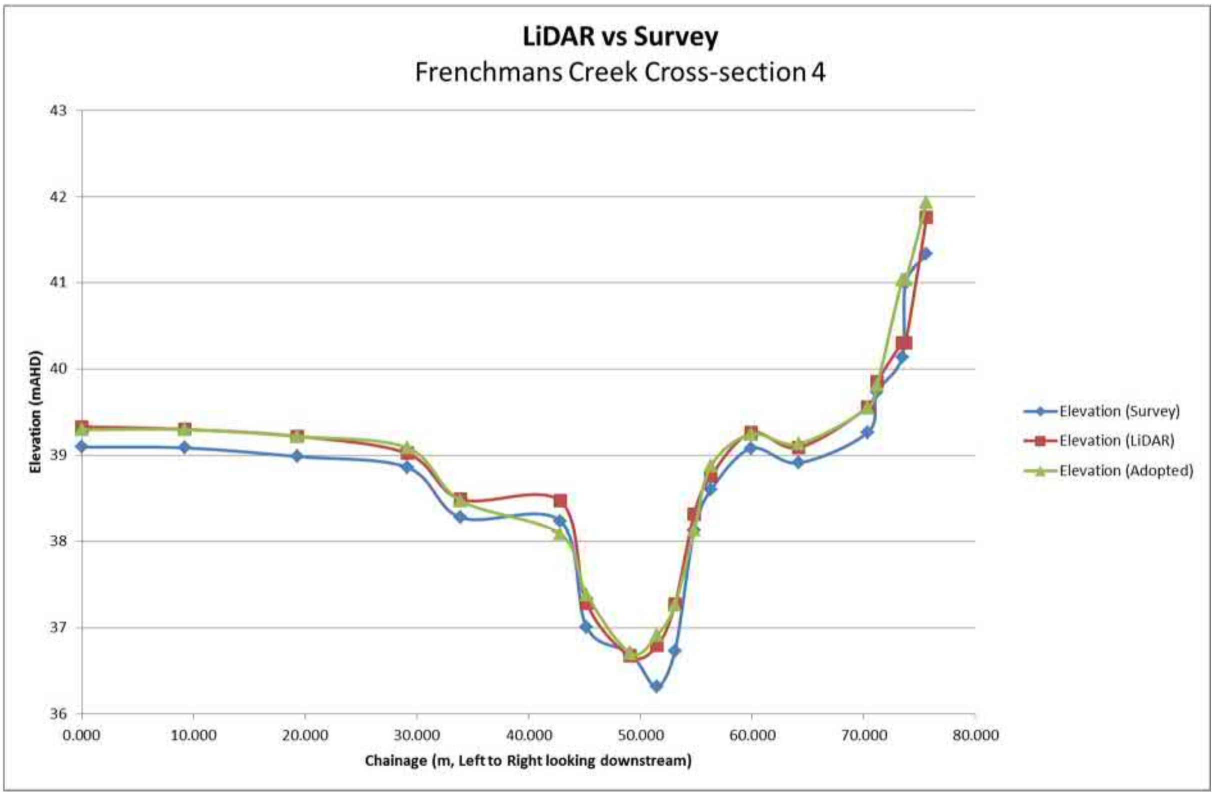


Figure 66 LiDAR verses Survey comparison at FRE_Cross-section 4

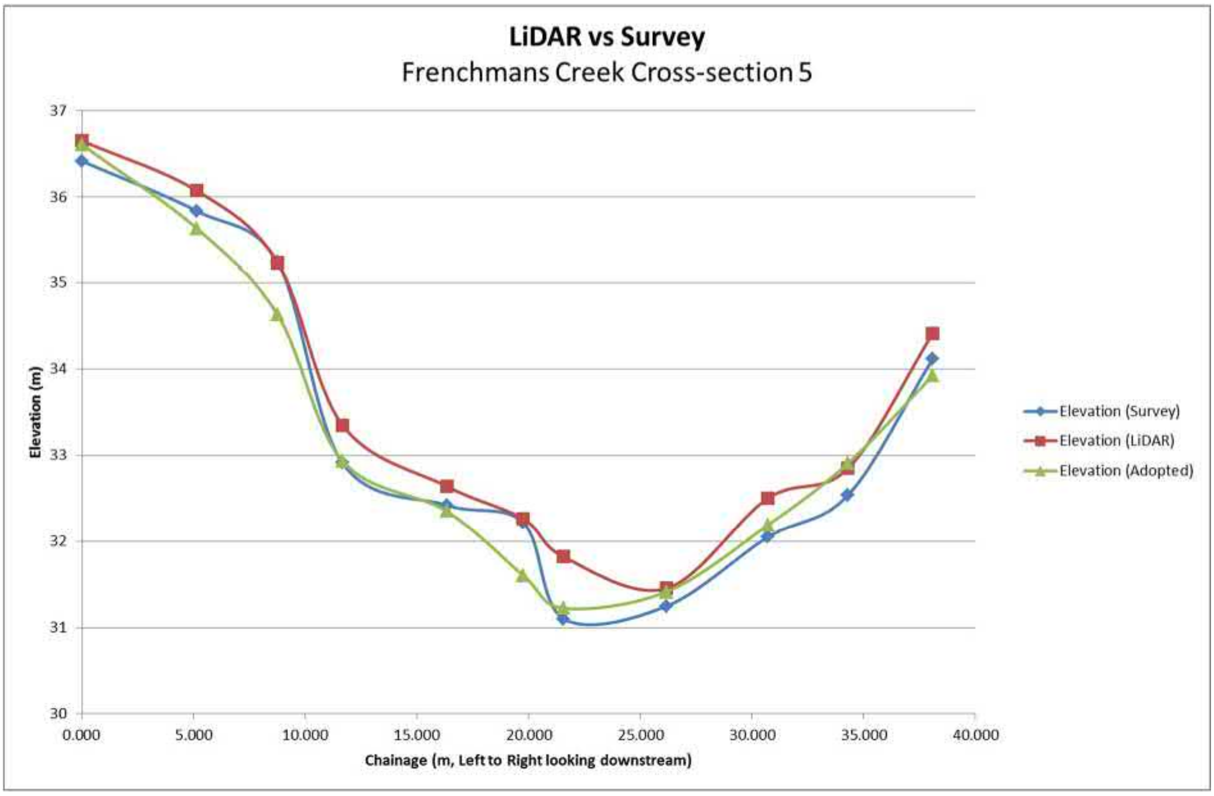


Figure 67 LiDAR verses Survey comparison at FRE_Cross-section 5

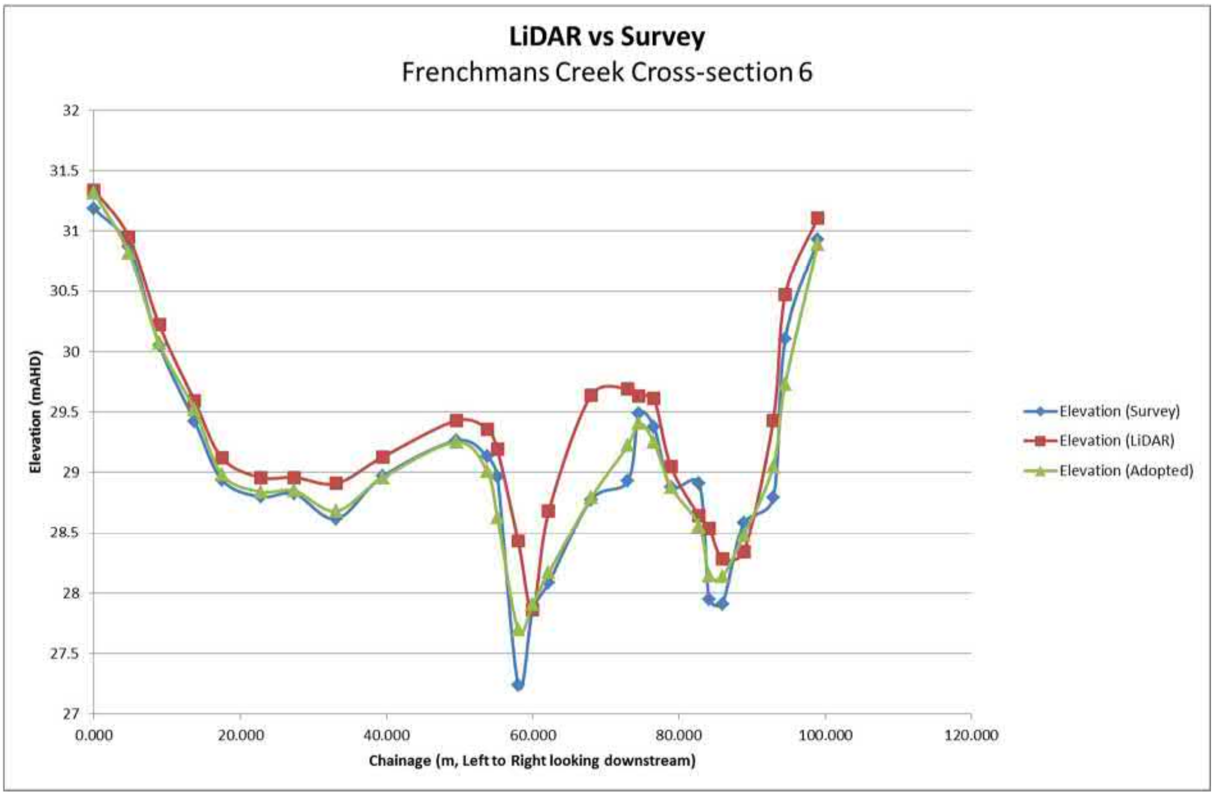


Figure 68 LiDAR verses Survey comparison at FRE_Cross-section 6

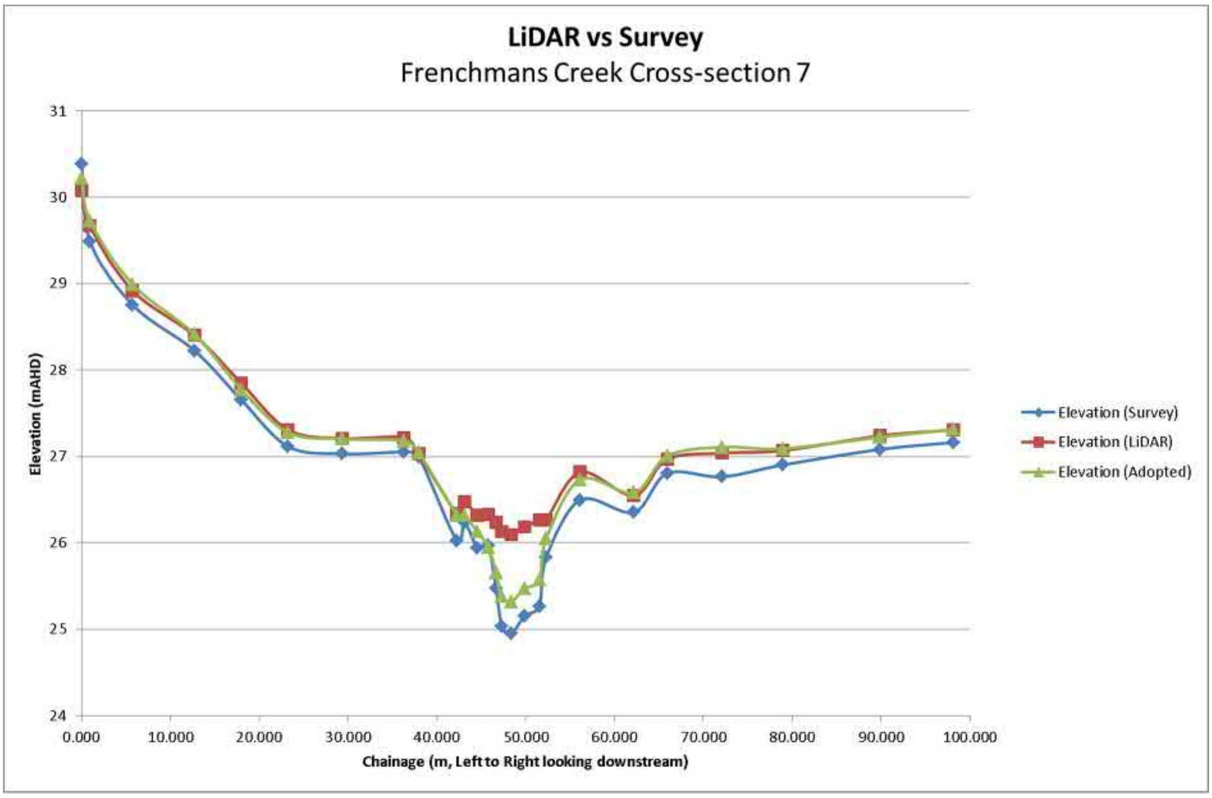


Figure 69 LiDAR verses Survey comparison at FRE_Cross-section 7

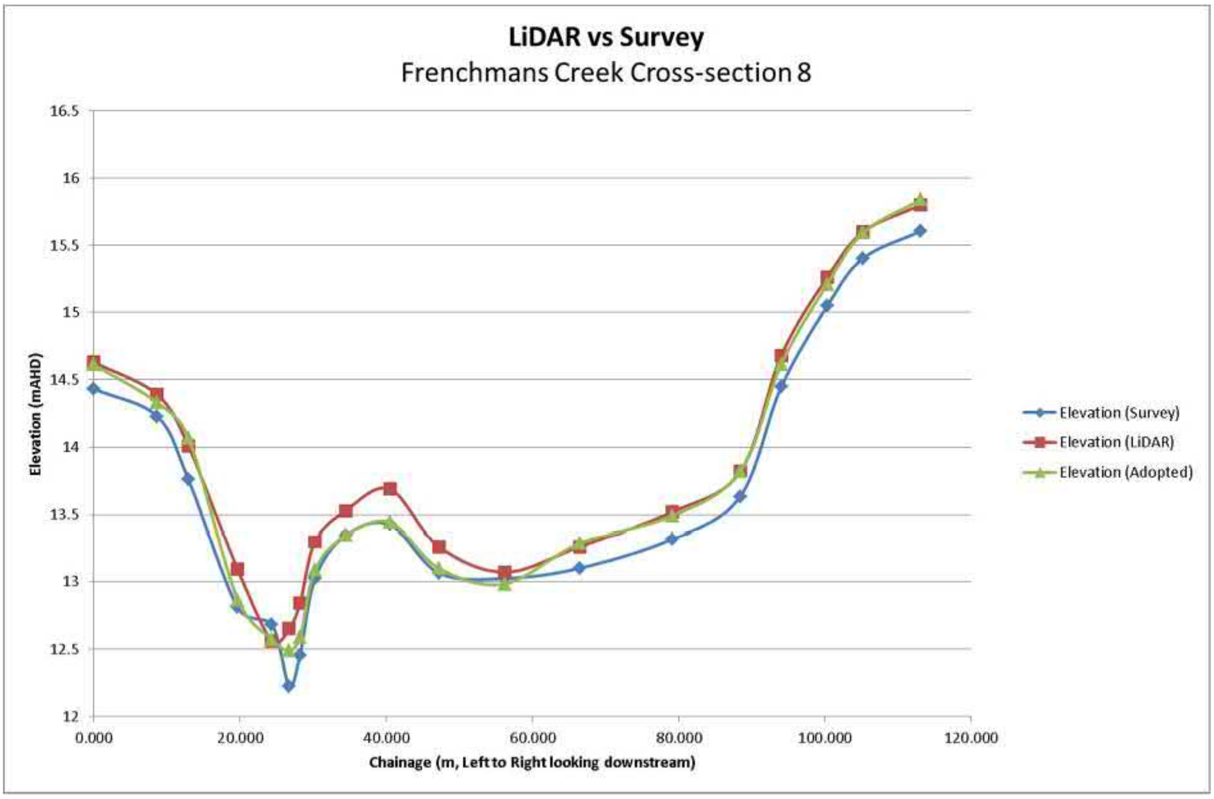


Figure 70 LiDAR verses Survey comparison at FRE_Cross-section 8

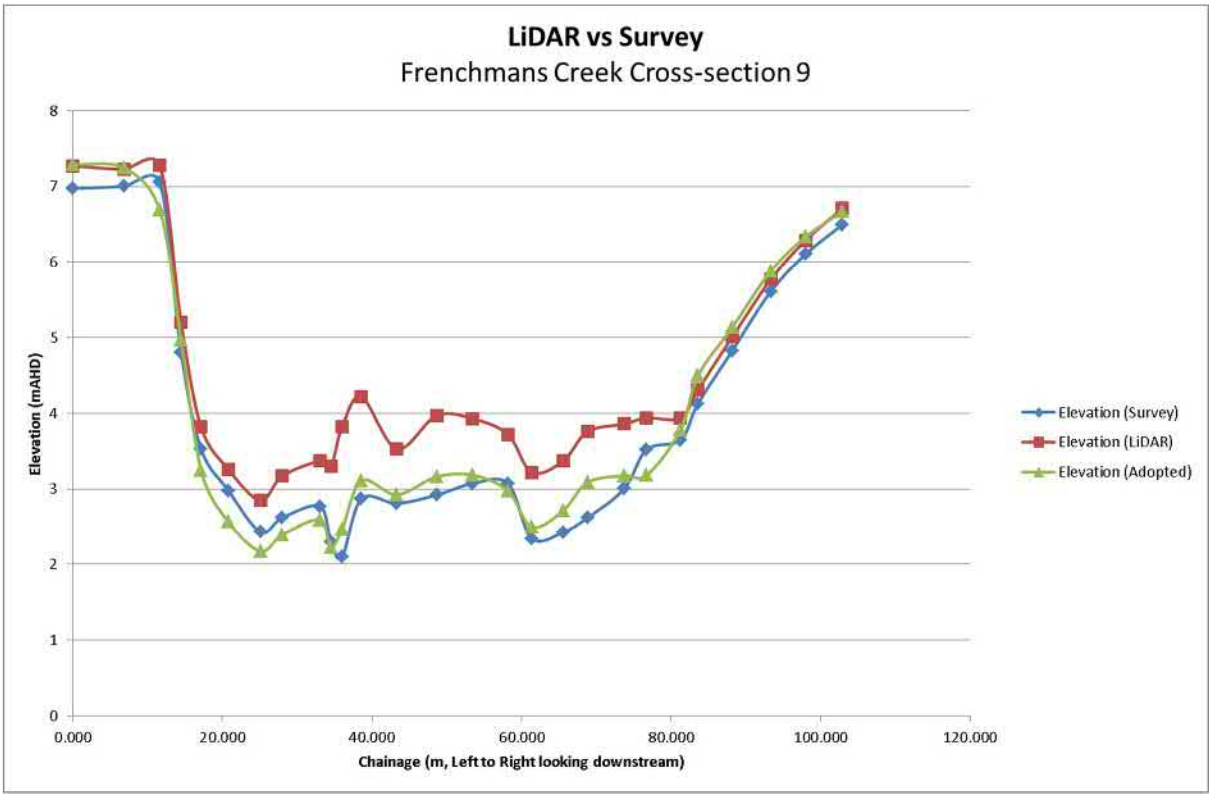


Figure 71 LiDAR verses Survey comparison at FRE_Cross-section 9

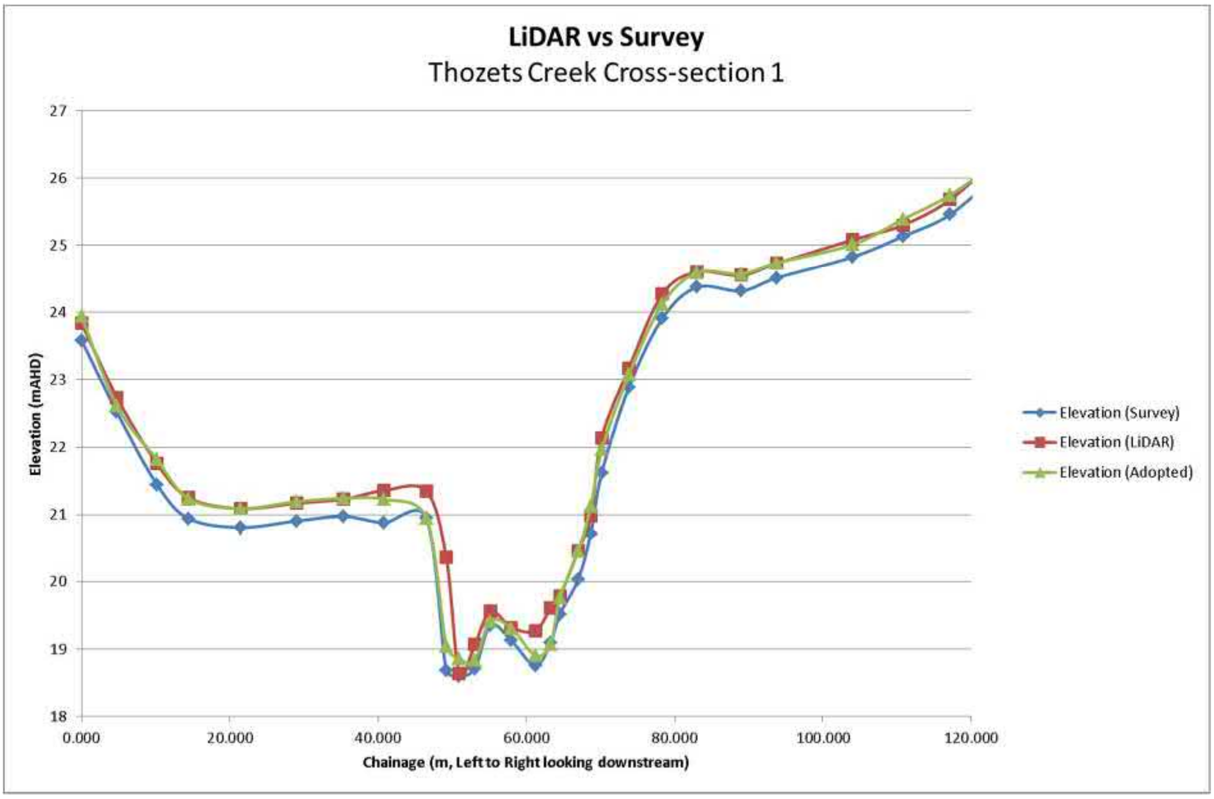


Figure 72 LiDAR verses Survey comparison at THO_Cross-section 1

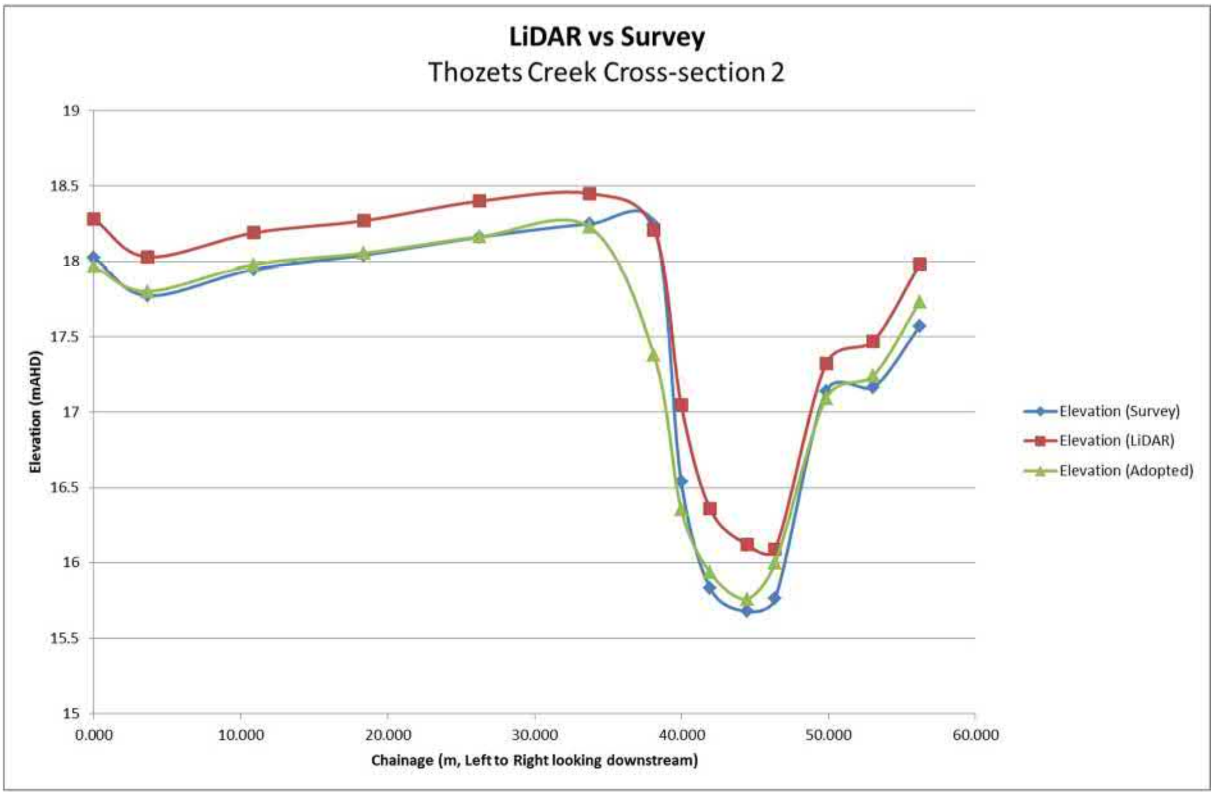


Figure 73 LiDAR verses Survey comparison at THO_Cross-section 2

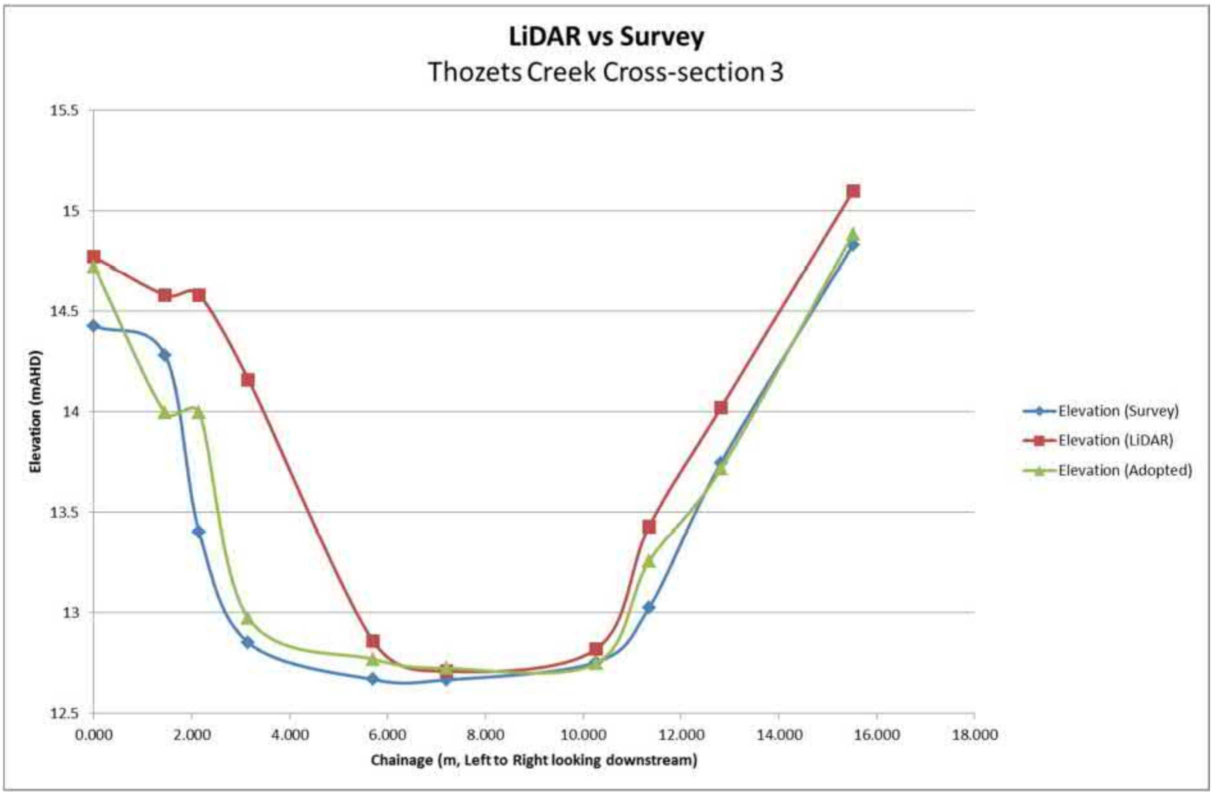


Figure 74 LiDAR verses Survey comparison at THO_Cross-section 3

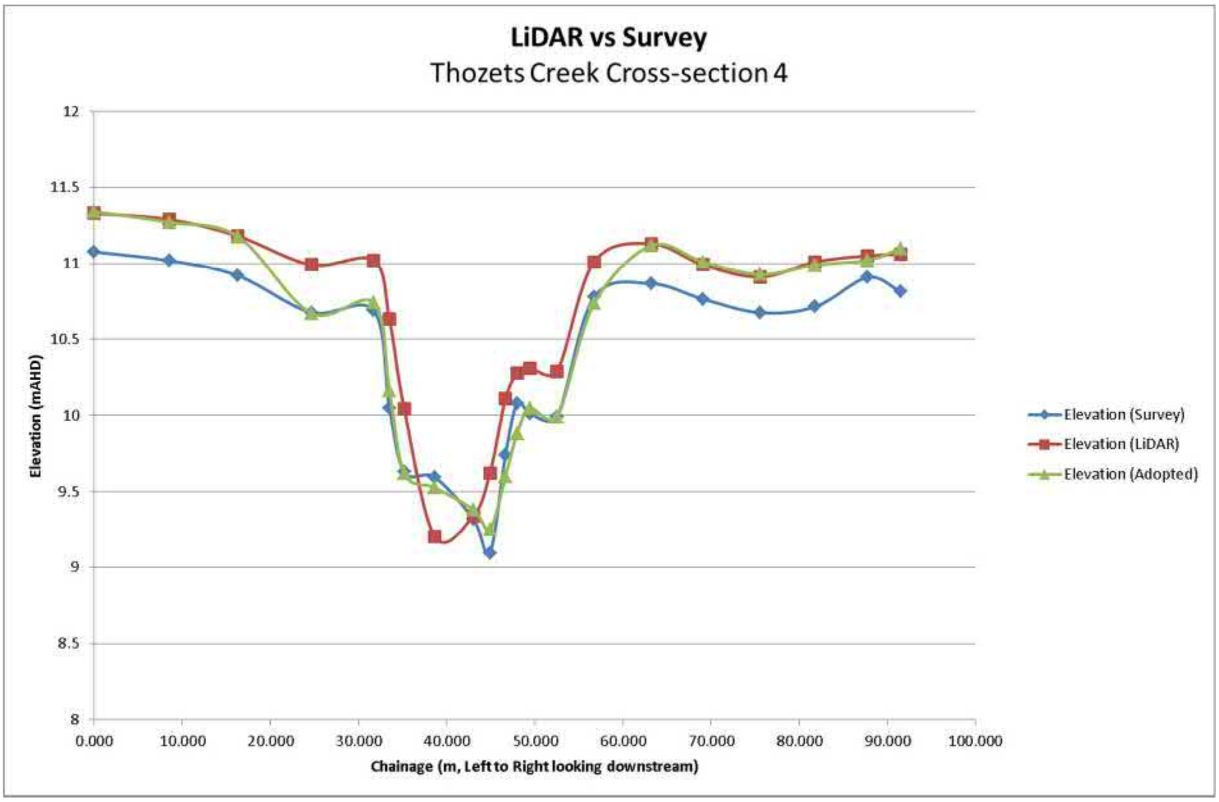


Figure 75 LiDAR verses Survey comparison at THO_Cross-section 4

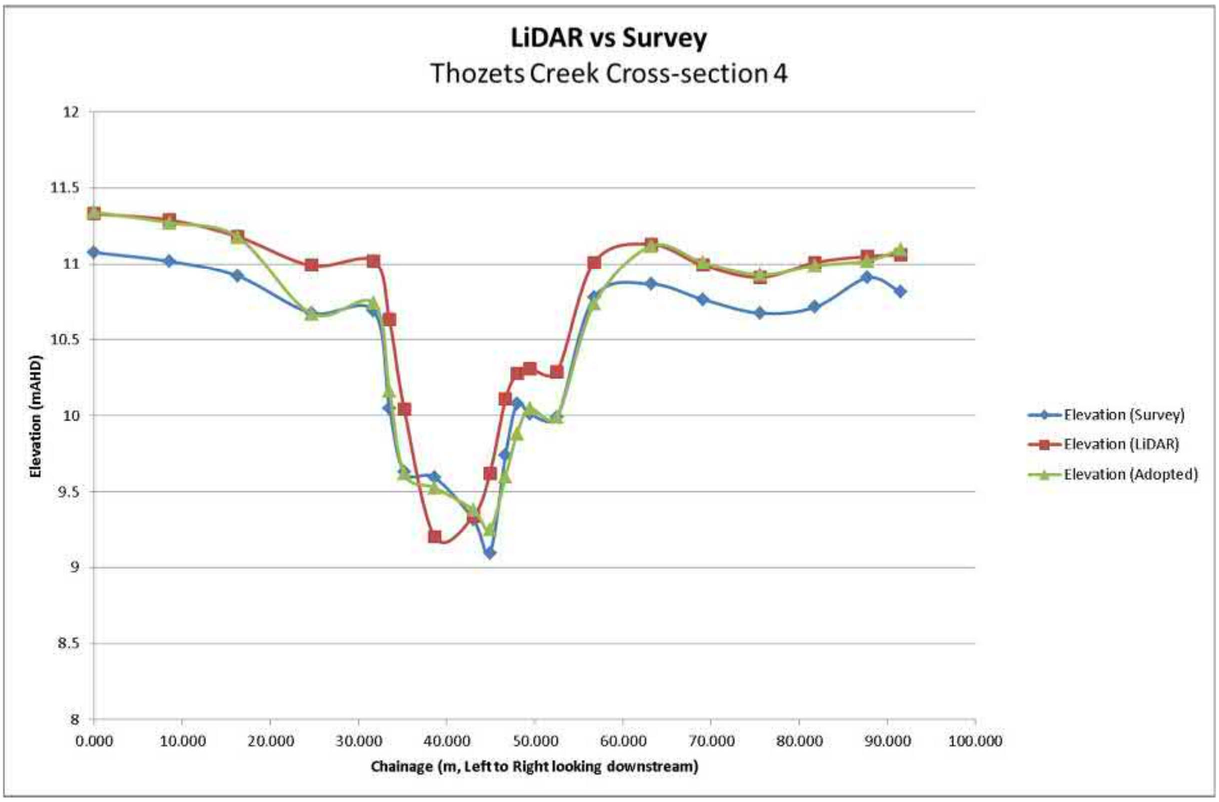


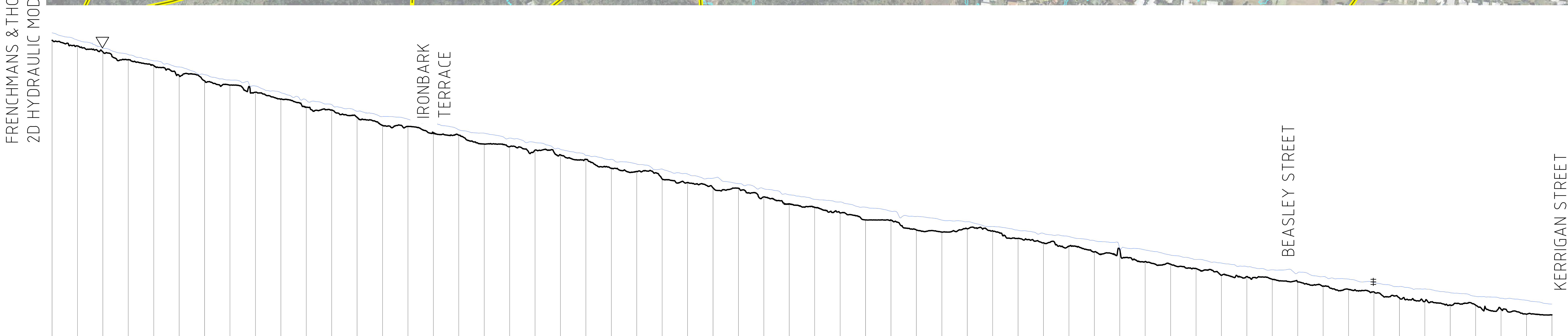
Figure 76 LiDAR verses Survey comparison at THO_Cross-section 5

Appendix C

Water Surface Profiles for Historic Events

AECOM

PLAN VIEW
1:5000 (A1)



DATUM 29.0

CHAINAGES	2013 MODELED PWSE	CREEK INVERT LEVEL
0.00	89.773	88.288
50.00	88.324	87.181
100.00	86.725	86.018
150.00	85.485	84.516
200.00	84.246	83.360
250.00	83.050	81.371
300.00	81.539	80.322
350.00	80.493	79.499
400.00	79.320	78.092
450.00	78.012	76.707
500.00	76.538	75.153
550.00	75.674	74.560
600.00	74.349	73.167
650.00	73.315	71.592
700.00	72.808	71.409
750.00	72.320	70.076
800.00	70.722	69.663
850.00	70.048	67.916
900.00	69.091	67.401
950.00	68.219	66.726
1000.00	66.873	65.787
1050.00	65.718	64.890
1100.00	64.888	63.124
1150.00	63.986	62.547
1200.00	63.002	61.070
1250.00	62.035	60.320
1300.00	61.211	59.311
1350.00	60.157	59.232
1400.00	59.129	57.527
1450.00	57.949	56.195
1500.00	57.053	55.454
1550.00	56.551	54.378
1600.00	55.515	53.029
1650.00	54.729	52.997
1700.00	53.703	51.030
1750.00	52.992	50.645
1800.00	52.664	51.273
1850.00	51.733	50.878
1900.00	50.994	49.386
1950.00	50.368	48.522
2000.00	49.760	47.881
2050.00	48.949	46.743
2100.00	47.336	47.165
2150.00	47.117	44.851
2200.00	46.114	44.316
2250.00	45.243	43.476
2300.00	44.543	42.156
2350.00	43.848	41.887
2400.00	43.217	41.367
2450.00	42.651	40.856
2500.00	41.887	39.980
2550.00	41.408	39.388
2600.00	40.707	38.881
2650.00	39.942	37.704
2700.00	39.465	37.000
2750.00	38.723	36.308
2800.00	38.020	36.269
2850.00	37.643	35.472
2900.00	37.237	34.504
2950.00	36.488	34.374

LONGITUDINAL SECTION
1:5000 (A1)

LEGEND
- UPPER BOUND
- RECORDED LEVEL
- LOWER BOUND
- 2013 MODELLED FLOOD EXTENTS
- CALIBRATION POINT

NOTE:
1. CREEK INVERT LEVELS ARE APPROXIMATE AND DERIVED FROM 2016 LIDAR AND SURVEY (WHERE AVAILABLE)
2. PWSE - PEAK WATER SURFACE ELEVATION

CAD REF:P:\605X\60534898\5. CAD\25-SKETCHES\60534898_SK_08.DWG
LAST MODIFIED:7/24/2017 11:19 AM

14/07/2017

MODELLED PEAK WATER SURFACE PROFILE
2013 FLOOD EVENT-FRENCHMANS CREEK
ROCKHAMPTON REGIONAL COUNCIL
SK-08

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AECOM

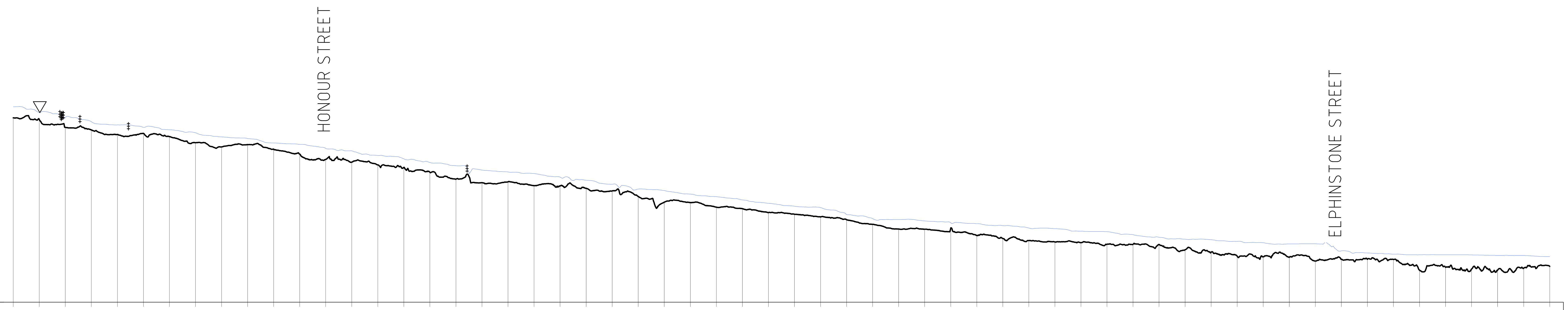
PLAN VIEW
1:5000 (A1)

LEGEND

- UPPER BOUND / RECORDED LEVEL / LOWER BOUND
- 2013 MODELLED FLOOD EXTENTS
- CALIBRATION POINT

NOTE:

1. CREEK INVERT LEVELS ARE APPROXIMATE AND DERIVED FROM 2016 LIDAR AND SURVEY (WHERE AVAILABLE)
2. PWSE - PEAK WATER SURFACE ELEVATION



DATUM -1.0

2013 MODELED PWSE	36.488	35.402	34.434	33.636	33.009	32.555	32.077	31.495	30.726	30.419	29.558	29.280	28.510	28.029	27.154
CREEK INVERT LEVEL	34.374	34.056	32.554	32.051	31.170	31.388	30.780	29.608	28.799	29.246	28.375	27.415	26.407	25.881	25.340
CHAINAGES	2950.00	3000.00	3050.00	3100.00	3150.00	3200.00	3250.00	3300.00	3350.00	3400.00	3450.00	3500.00	3550.00	3600.00	3650.00

2013 MODELED PWSE	26.496	25.797	25.178	24.354	23.995	23.689	22.997	22.398	21.628	20.697	20.409	19.729	19.247	18.618	17.970
CREEK INVERT LEVEL	24.864	23.941	22.620	21.935	22.092	21.368	21.297	20.851	20.350	19.283	18.181	18.112	17.238	16.939	16.192
CHAINAGES	3700.00	3750.00	3800.00	3850.00	3900.00	3950.00	4000.00	4050.00	4100.00	4150.00	4200.00	4250.00	4300.00	4350.00	4400.00

2013 MODELED PWSE	17.421	17.161	15.818	15.032	14.859	14.599	14.242	14.056	13.700	13.228	13.104	12.627	12.526	11.962	11.457
CREEK INVERT LEVEL	15.861	15.366	14.835	13.944	13.039	12.999	13.178	11.817	11.213	10.818	10.557	10.430	10.099	10.095	10.068
CHAINAGES	4450.00	4500.00	4550.00	4600.00	4650.00	4700.00	4750.00	4800.00	4850.00	4900.00	4950.00	5000.00	5050.00	5100.00	5150.00

2013 MODELED PWSE	11.088	10.979	10.671	10.407	10.197	10.204	8.855	8.439	8.219	8.089	8.100	8.065	7.968	7.960	7.727
CREEK INVERT LEVEL	9.057	8.591	7.813	7.709	7.607	6.907	7.210	7.244	7.204	5.136	5.713	5.361	5.156	5.524	5.863
CHAINAGES	5200.00	5250.00	5300.00	5350.00	5400.00	5450.00	5500.00	5550.00	5600.00	5650.00	5700.00	5750.00	5800.00	5850.00	5900.00

CONTROL LINE

LONGITUDINAL SECTION
1:5000 (A1)

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LAST MODIFIED:7/24/2017 11:19 AM

14/07/2017

MODELLED PEAK WATER SURFACE PROFILE
2013 FLOOD EVENT-FRENCHMANS CREEK
ROCKHAMPTON REGIONAL COUNCIL
SK-09

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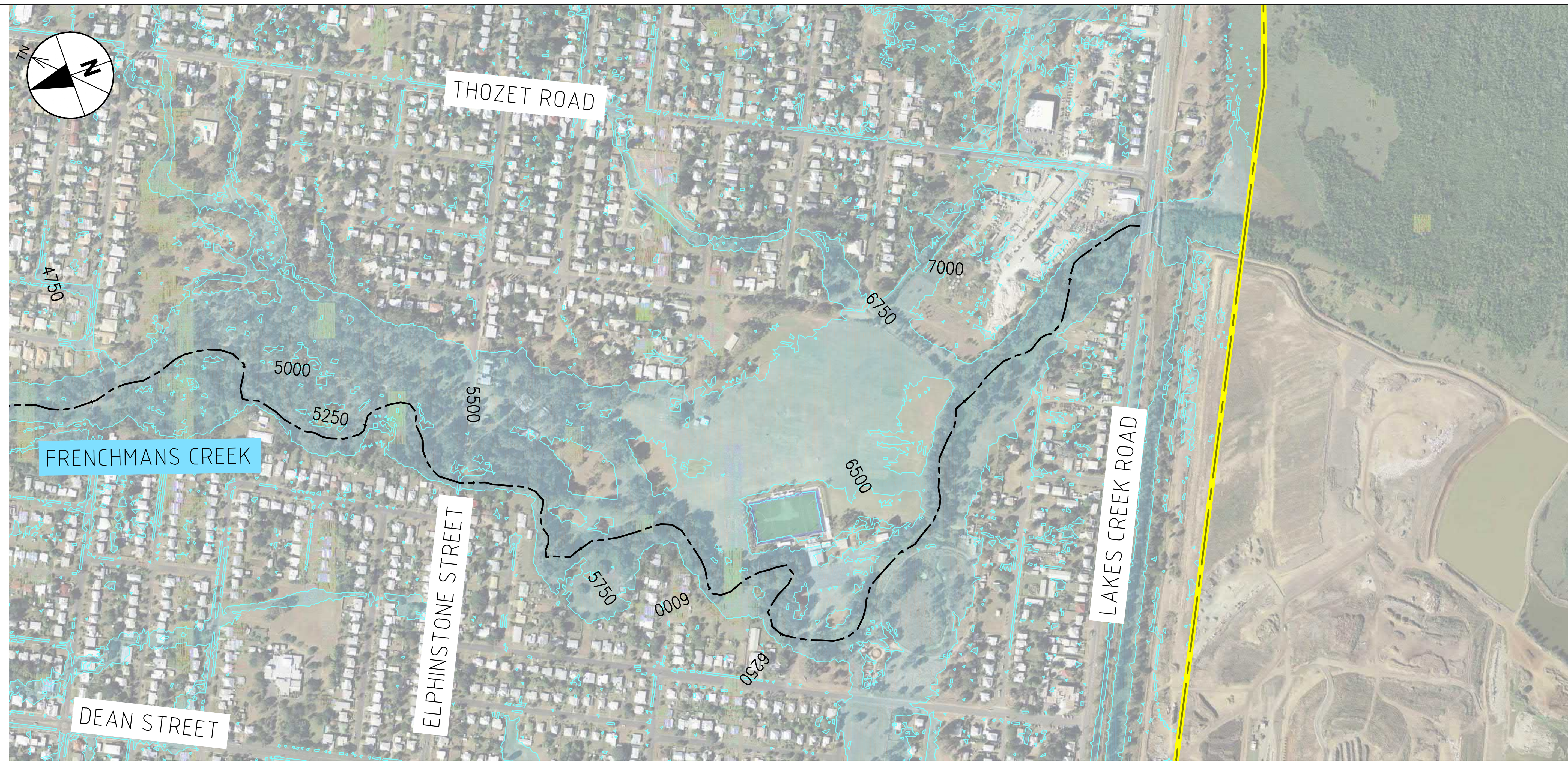
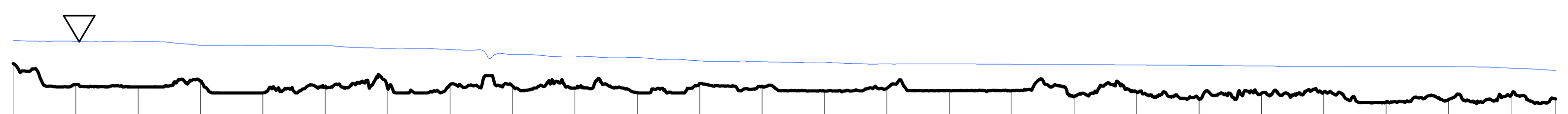


PLAN VIEW

1:5000 (A1)



FRENCHMANS & THOZETS CREEK
2D HYDRAULIC MODEL EXTENT

DATUM -3.0

2013 MODELED PWSE	7.727	7.665	7.650	7.339	7.334	7.340	7.107	7.008	6.602	6.482	6.361	6.095	6.029	5.944	5.850	5.848	5.821	5.802	5.764	5.733	5.687	5.650	5.648	5.632	5.501	5.296
CREEK INVERT LEVEL	5.863	4.185	4.000	4.457	3.503	4.027	3.868	4.162	4.067	3.890	3.530	4.275	4.041	3.656	3.881	3.702	3.685	3.218	3.569	3.013	3.468	3.581	2.779	2.986	3.308	3.015
CHAINAGES	5900.00	5950.00	6000.00	6050.00	6100.00	6150.00	6200.00	6250.00	6300.00	6350.00	6400.00	6450.00	6500.00	6550.00	6600.00	6650.00	6700.00	6750.00	6800.00	6850.00	6900.00	6950.00	7000.00	7050.00	7100.00	7135.76

LONGITUDINAL SECTION

1:5000 (A1)

LEGEND

- UPPER BOUND
- RECORDED LEVEL
- LOWER BOUND
- 2013 MODELLED FLOOD EXTENTS
- CALIBRATION POINT

NOTE:

1. CREEK INVERT LEVELS ARE APPROXIMATE AND DERIVED FROM 2016 LIDAR AND SURVEY (WHERE AVAILABLE)
2. PWSE - PEAK WATER SURFACE ELEVATION

CAD REF:P:\605X\60534898\5. CAD\25-SKETCHES\60534898_SK_10.DWG

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14/07/2017

MODELLED PEAK WATER SURFACE PROFILE

2013 FLOOD EVENT-FRENCHMANS CREEK

ROCKHAMPTON REGIONAL COUNCIL

SK-10

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AECOM

PLAN VIEW

1:5000 (A1)

LEGEND

- UPPER BOUND / RECORDED LEVEL / LOWER BOUND
- 2015 MODELLED FLOOD EXTENTS
- CALIBRATION POINT

NOTE:

1. CREEK INVERT LEVELS ARE APPROXIMATE AND DERIVED FROM 2016 LIDAR AND SURVEY (WHERE AVAILABLE)
2. PWSE - PEAK WATER SURFACE ELEVATION

2015 MODELED PWSE	90.062	88.569	86.930	85.694	84.356	83.257	81.818	80.728	79.628	78.234	76.854	76.038	74.612	73.733	73.139
CREEK INVERT LEVEL	88.288	87.181	86.018	84.516	83.360	81.371	80.322	79.499	78.092	76.707	75.153	74.560	73.167	71.592	71.409
CHAINAGES	0.00	50.00	100.00	150.00	200.00	250.00	300.00	350.00	400.00	450.00	500.00	550.00	600.00	650.00	700.00

2015 MODELED PWSE	72.918	71.249	70.579	69.425	68.392	67.164	66.068	65.233	64.255	63.351	62.399	61.791	60.443	59.516	58.381
CREEK INVERT LEVEL	70.076	69.663	67.916	67.401	66.726	65.787	64.890	63.124	62.547	61.070	60.320	59.311	59.232	57.527	56.195
CHAINAGES	750.00	800.00	850.00	900.00	950.00	1000.00	1050.00	1100.00	1150.00	1200.00	1250.00	1300.00	1350.00	1400.00	1450.00

2015 MODELED PWSE	57.386	57.013	55.932	55.243	54.011	53.428	52.866	51.969	51.331	50.633	49.937	49.245	47.418	47.311	46.463
CREEK INVERT LEVEL	55.454	54.378	53.029	52.997	51.030	50.645	51.273	50.878	49.386	48.522	47.881	46.743	47.165	44.851	44.316
CHAINAGES	1500.00	1550.00	1600.00	1650.00	1700.00	1750.00	1800.00	1850.00	1900.00	1950.00	2000.00	2050.00	2100.00	2150.00	2200.00

2015 MODELED PWSE	45.931	44.983	44.170	43.517	42.885	42.313	41.835	41.227	40.453	39.815	39.152	38.602	38.185	37.743	36.758
CREEK INVERT LEVEL	43.476	42.156	41.887	41.367	40.856	39.980	39.388	38.881	37.704	37.000	36.308	36.269	35.472	34.504	34.374
CHAINAGES	2250.00	2300.00	2350.00	2400.00	2450.00	2500.00	2550.00	2600.00	2650.00	2700.00	2750.00	2800.00	2850.00	2900.00	2950.00

LONGITUDINAL SECTION

1:5000 (A1)

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LAST MODIFIED:7/24/2017 11:48 AM

14/07/2017

MODELLED PEAK WATER SURFACE PROFILE

2015 FLOOD EVENT-FRENCHMANS CREEK

ROCKHAMPTON REGIONAL COUNCIL

SK-11

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FOR INFORMATION ONLY

AECOM

LEGEND

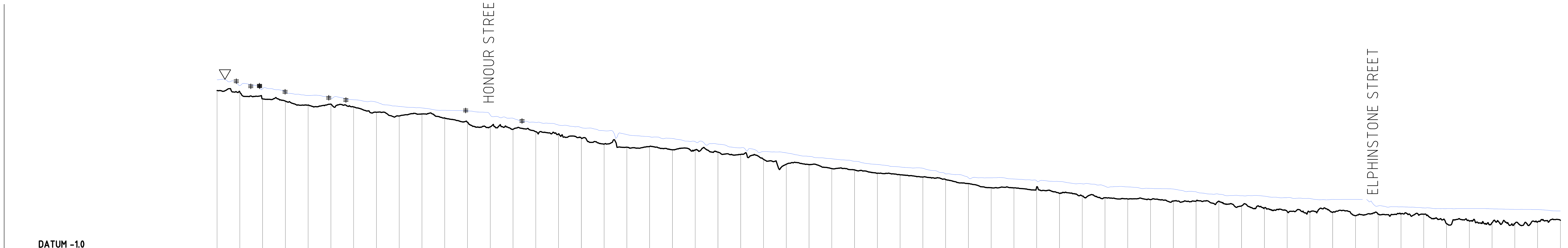
- UPPER BOUND
- RECORDED LEVEL
- LOWER BOUND
- 2015 MODELLED FLOOD EXTENTS
- CALIBRATION POINT

NOTE:

1. CREEK INVERT LEVELS ARE APPROXIMATE AND DERIVED FROM 2016 LIDAR AND SURVEY (WHERE AVAILABLE)
2. PWSE - PEAK WATER SURFACE ELEVATION

PLAN VIEW

1:5000 (A1)



2015 MODELED PWSE	36.758	35.478	34.769	34.070	33.301	32.651	32.352	31.830	30.884	30.555	30.030	29.887	28.980	28.287	27.371
CREEK INVERT LEVEL	34.374	34.056	32.554	32.051	31.170	31.388	30.780	29.608	28.799	29.246	28.375	27.415	26.407	25.881	25.340
CHAINAGES	2950.00	3000.00	3050.00	3100.00	3150.00	3200.00	3250.00	3300.00	3350.00	3400.00	3450.00	3500.00	3550.00	3600.00	3650.00

2015 MODELED PWSE	26.798	26.223	25.543	24.707	24.236	23.845	23.150	22.602	21.789	20.974	20.690	19.914	19.398	18.818	18.136
CREEK INVERT LEVEL	24.864	23.941	22.620	21.935	22.092	21.368	21.297	20.851	20.350	19.283	18.181	18.112	17.238	16.939	16.192
CHAINAGES	3700.00	3750.00	3800.00	3850.00	3900.00	3950.00	4000.00	4050.00	4100.00	4150.00	4200.00	4250.00	4300.00	4350.00	4400.00

2015 MODELED PWSE	17.587	17.304	16.055	15.216	15.203	14.949	14.531	14.384	13.892	13.360	13.205	12.881	12.742	12.123	11.605
CREEK INVERT LEVEL	15.861	15.366	14.835	13.944	13.039	12.999	13.178	11.817	11.213	10.818	10.557	10.430	10.099	10.095	10.068
CHAINAGES	4450.00	4500.00	4550.00	4600.00	4650.00	4700.00	4750.00	4800.00	4850.00	4900.00	4950.00	5000.00	5050.00	5100.00	5150.00

2015 MODELED PWSE	11.275	11.174	10.860	10.656	10.457	10.469	9.037	8.830	8.591	8.439	8.444	8.387	8.265	8.235	7.916
CREEK INVERT LEVEL	9.057	8.591	7.813	7.709	7.607	6.907	7.210	7.244	7.204	5.136	5.713	5.361	5.156	5.524	5.863
CHAINAGES	5200.00	5250.00	5300.00	5350.00	5400.00	5450.00	5500.00	5550.00	5600.00	5650.00	5700.00	5750.00	5800.00	5850.00	5900.00

CONTROL LINE

LONGITUDINAL SECTION

1:5000 (A1)

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LAST MODIFIED:7/24/2017 11:52 AM

14/07/2017

MODELLED PEAK WATER SURFACE PROFILE

2015 FLOOD EVENT-FRENCHMANS CREEK

ROCKHAMPTON REGIONAL COUNCIL

SK-12

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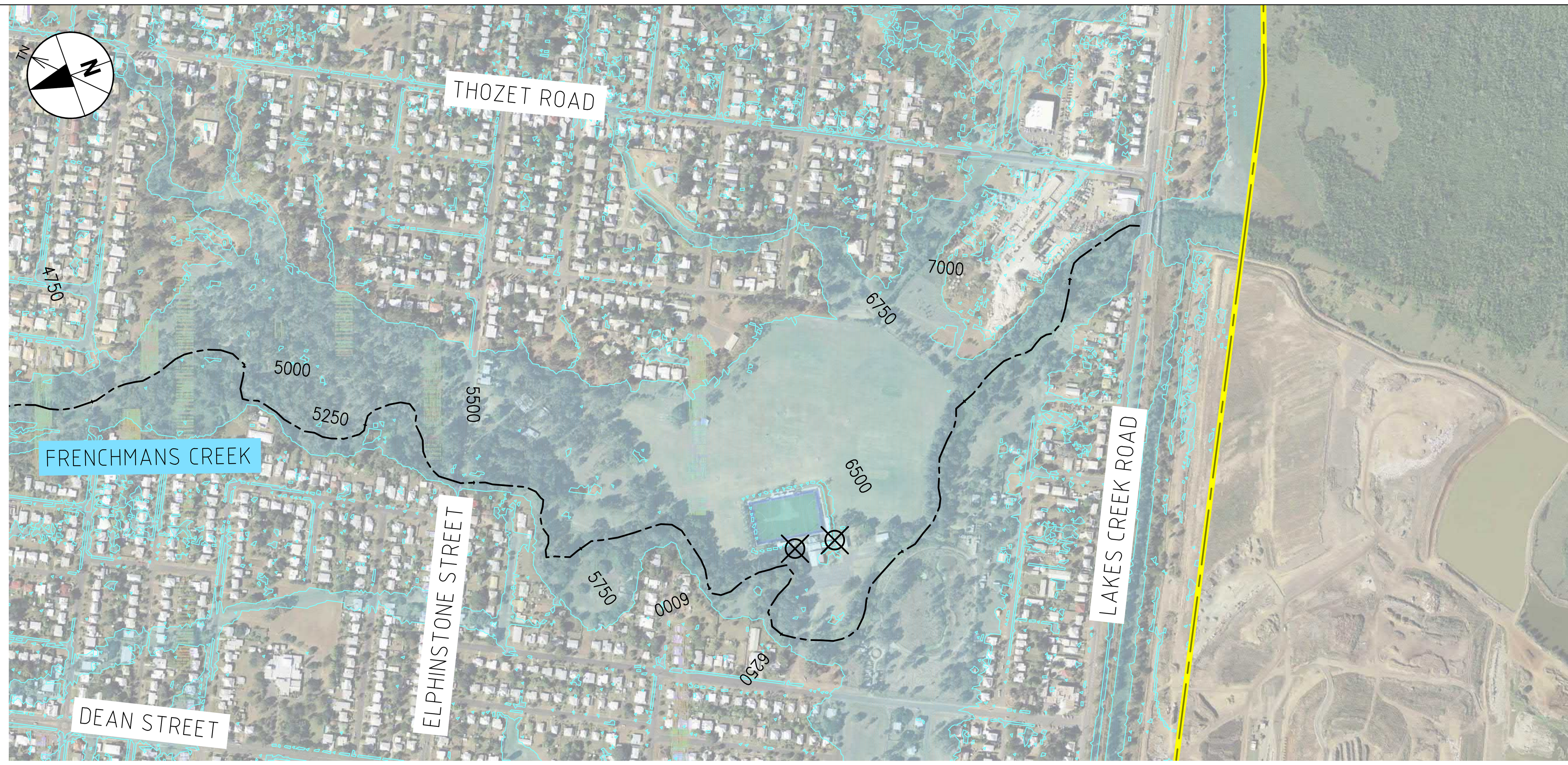


PLAN VIEW

1:5000 (A1)

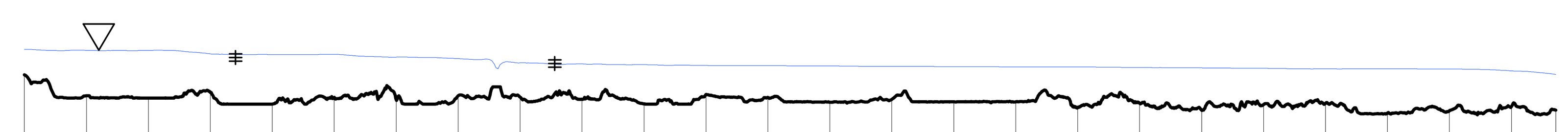
FRENCHMANS & THOZETS CREEK 2D HYDRAULIC MODEL EXTENT

LEGEND

- UPPER BOUND
- RECORDED LEVEL
- LOWER BOUND
- 2015 MODELLED FLOOD EXTENTS
- CALIBRATION POINT

NOTE:

1. CREEK INVERT LEVELS ARE APPROXIMATE AND DERIVED FROM 2016 LIDAR AND SURVEY (WHERE AVAILABLE)
2. PWSE - PEAK WATER SURFACE ELEVATION



DATUM -3.0

2015 MODELED PWSE	7.916	7.844	7.845	7.561	7.511	7.530	7.302	7.179	6.839	6.758	6.693	6.627	6.608
CREEK INVERT LEVEL	5.863	4.185	4.000	4.457	3.503	4.027	3.868	4.162	4.067	3.890	3.530	4.275	4.041
CHAINAGES	5900.00	5950.00	6000.00	6050.00	6100.00	6150.00	6200.00	6250.00	6300.00	6350.00	6400.00	6450.00	6500.00

2015 MODELED PWSE	6.587	6.548	6.534	6.515	6.502	6.466	6.434	6.393	6.352	6.355	6.340	6.189	5.892
CREEK INVERT LEVEL	3.656	3.881	3.702	3.685	3.218	3.569	3.013	3.468	3.581	2.779	2.986	3.308	3.015
CHAINAGES	6550.00	6600.00	6650.00	6700.00	6750.00	6800.00	6850.00	6900.00	6950.00	7000.00	7050.00	7100.00	7135.76

CONTROL LINE

LONGITUDINAL SECTION

1:5000 (A1)

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LAST MODIFIED:7/24/2017 12:04 PM

14/07/2017

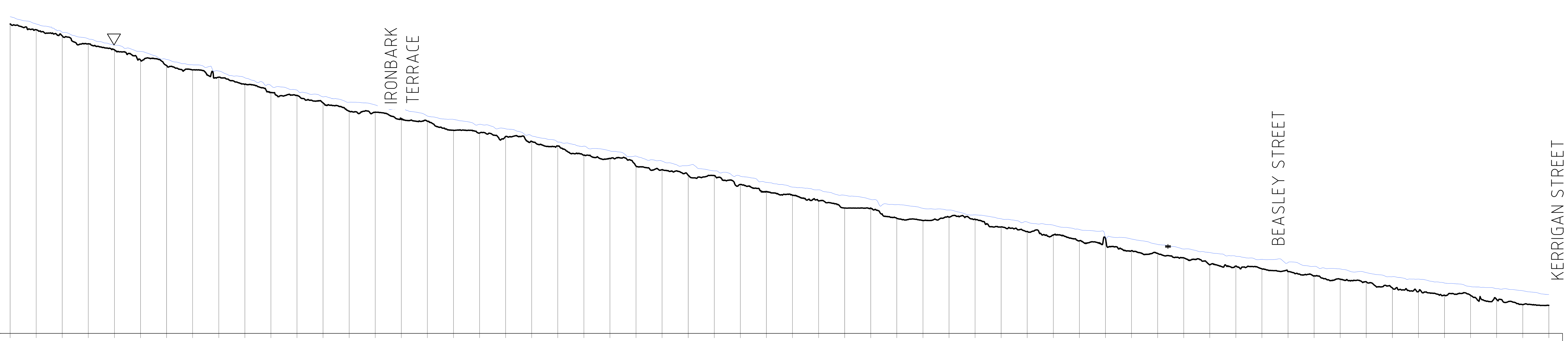
MODELLED PEAK WATER SURFACE PROFILE

2015 FLOOD EVENT-FRENCHMANS CREEK

ROCKHAMPTON REGIONAL COUNCIL

SK-13

PLAN VIEW
1:5000 (A1)



2017 MODELED PWSE	89.697	88.286	86.702	85.444	84.243	83.030	81.486	80.469	79.280	77.988	76.488	75.614	74.323	73.289	72.779
CREEK INVERT LEVEL	88.288	87.181	86.018	84.516	83.360	81.371	80.322	79.499	78.092	76.707	75.153	74.560	73.167	71.592	71.409
CHAINAGES	0.00	50.00	100.00	150.00	200.00	250.00	300.00	350.00	400.00	450.00	500.00	550.00	600.00	650.00	700.00

2017 MODELED PWSE	72.289	70.659	70.003	69.064	68.200	66.852	65.695	64.841	63.961	62.970	62.015	61.165	60.143	59.119	57.930
CREEK INVERT LEVEL	70.076	69.663	67.916	67.401	66.726	65.787	64.890	63.124	62.547	61.070	60.320	59.311	59.232	57.527	56.195
CHAINAGES	750.00	800.00	850.00	900.00	950.00	1000.00	1050.00	1100.00	1150.00	1200.00	1250.00	1300.00	1350.00	1400.00	1450.00

2017 MODELED PWSE	57.030	56.511	55.472	54.677	53.666	52.958	52.643	51.709	50.962	50.341	49.737	48.910	47.330	47.084	46.046
CREEK INVERT LEVEL	55.454	54.378	53.029	52.997	51.030	50.645	51.273	50.878	49.386	48.522	47.881	46.743	47.165	44.851	44.316
CHAINAGES	1500.00	1550.00	1600.00	1650.00	1700.00	1750.00	1800.00	1850.00	1900.00	1950.00	2000.00	2050.00	2100.00	2150.00	2200.00

2017 MODELED PWSE	45.164	44.487	43.784	43.174	42.586	41.843	41.349	40.645	39.863	39.400	38.644	37.975	37.575	37.168	36.439
CREEK INVERT LEVEL	43.476	42.156	41.887	41.367	40.856	39.980	39.388	38.881	37.704	37.000	36.308	36.269	35.472	34.504	34.374
CHAINAGES	2250.00	2300.00	2350.00	2400.00	2450.00	2500.00	2550.00	2600.00	2650.00	2700.00	2750.00	2800.00	2850.00	2900.00	2950.00

LONGITUDINAL SECTION
1:5000 (A1)

LEGEND

UPPER BOUND
RECORDED LEVEL
LOWER BOUND
2017 MODELLED FLOOD EXTENTS
CALIBRATION POINT

NOTE:
1. CREEK INVERT LEVELS ARE APPROXIMATE AND DERIVED FROM 2016 LIDAR AND SURVEY (WHERE AVAILABLE)
2. PWSE - PEAK WATER SURFACE ELEVATION

CAD REF:P:\605X\60534898\5. CAD\25-SKETCHES\60534898_SK_14.DWG

LAST MODIFIED:7/24/2017 11:57 AM

14/07/2017

MODELLED PEAK WATER SURFACE PROFILE
2017 FLOOD EVENT-FRENCHMANS CREEK
ROCKHAMPTON REGIONAL COUNCIL
SK-14

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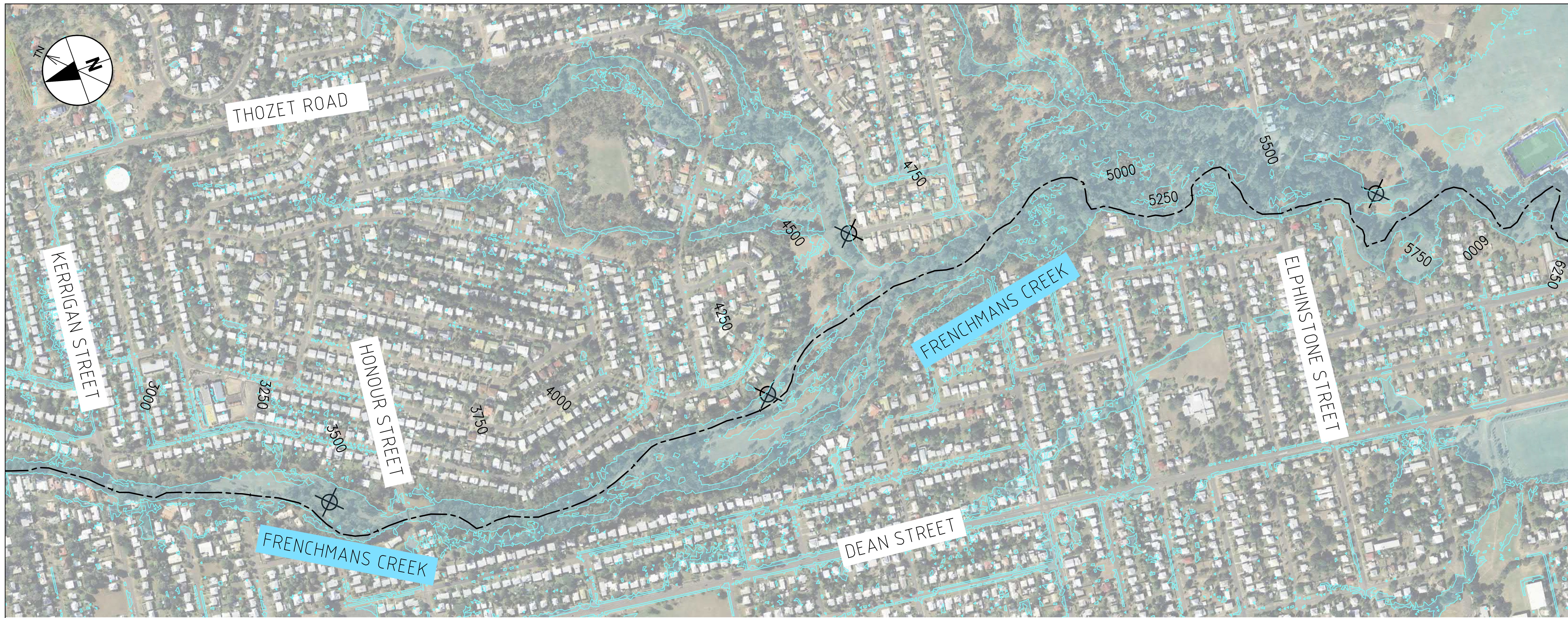
AECOM



LEGEND

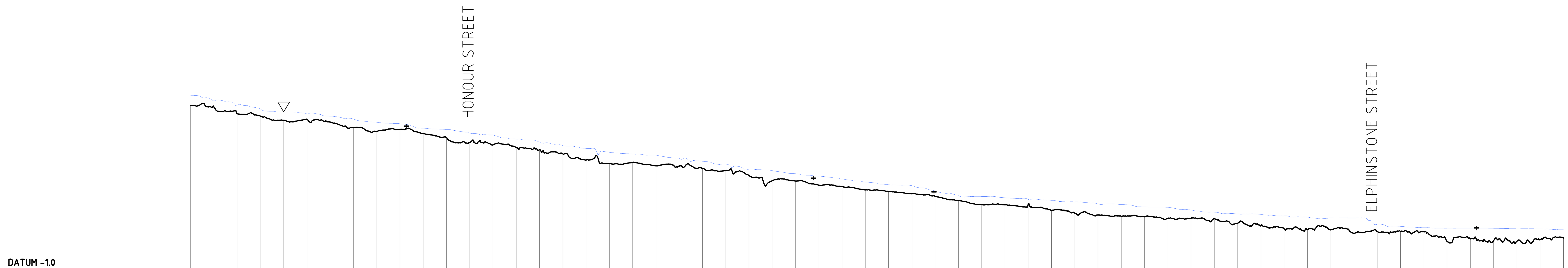
- UPPER BOUND
- RECORDED LEVEL
- LOWER BOUND
- 2017 MODELLED FLOOD EXTENTS
- CALIBRATION POINT

NOTE:

1. CREEK INVERT LEVELS ARE APPROXIMATE AND DERIVED FROM 2016 LIDAR AND SURVEY (WHERE AVAILABLE)
2. PWSE - PEAK WATER SURFACE ELEVATION

PLAN VIEW

1:5000 (A1)



CHAINAGES	2950.00	3000.00	3050.00	3100.00	3150.00	3200.00	3250.00	3300.00	3350.00	3400.00	3450.00	3500.00	3550.00	3600.00	3650.00
2017 MODELED PWSE	36.439	35.356	34.380	33.578	32.958	32.537	32.031	31.419	30.729	30.409	29.448	29.163	28.420	27.973	27.115
CREEK INVERT LEVEL	34.374	34.056	32.554	32.051	31.170	31.388	30.780	29.608	28.799	29.246	28.375	27.415	26.407	25.881	25.340

CHAINAGES	3700.00	3750.00	3800.00	3850.00	3900.00	3950.00	4000.00	4050.00	4100.00	4150.00	4200.00	4250.00	4300.00	4350.00	4400.00
2017 MODELED PWSE	26.446	25.704	25.113	24.277	23.938	23.660	22.963	22.346	21.597	20.633	20.351	19.686	19.162	18.535	17.872
CREEK INVERT LEVEL	24.864	23.941	22.620	21.935	22.092	21.368	21.297	20.851	20.350	19.283	18.181	18.112	17.238	16.939	16.192

CHAINAGES	4450.00	4500.00	4550.00	4600.00	4650.00	4700.00	4750.00	4800.00	4850.00	4900.00	4950.00	5000.00	5050.00	5100.00	5150.00
2017 MODELED PWSE	17.324	17.121	15.799	14.972	14.770	14.518	14.176	13.961	13.634	13.199	13.078	12.558	12.468	11.906	11.418
CREEK INVERT LEVEL	15.861	15.366	14.835	13.944	13.039	12.999	13.178	11.817	11.213	10.818	10.557	10.430	10.099	10.095	10.068

CHAINAGES	5200.00	5250.00	5300.00	5350.00	5400.00	5450.00	5500.00	5550.00	5600.00	5650.00	5700.00	5750.00	5800.00	5850.00	5900.00
2017 MODELED PWSE	11.050	10.936	10.638	10.355	10.164	10.184	8.822	8.368	8.089	7.976	7.984	7.953	7.868	7.862	7.659
CREEK INVERT LEVEL	9.057	8.591	7.813	7.709	7.607	6.907	7.210	7.244	7.204	5.136	5.713	5.361	5.156	5.524	5.863

CONTROL LINE

LONGITUDINAL SECTION

1:5000 (A1)

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MODELLED PEAK WATER SURFACE PROFILE

2017 FLOOD EVENT-FRENCHMANS CREEK

ROCKHAMPTON REGIONAL COUNCIL

SK-15

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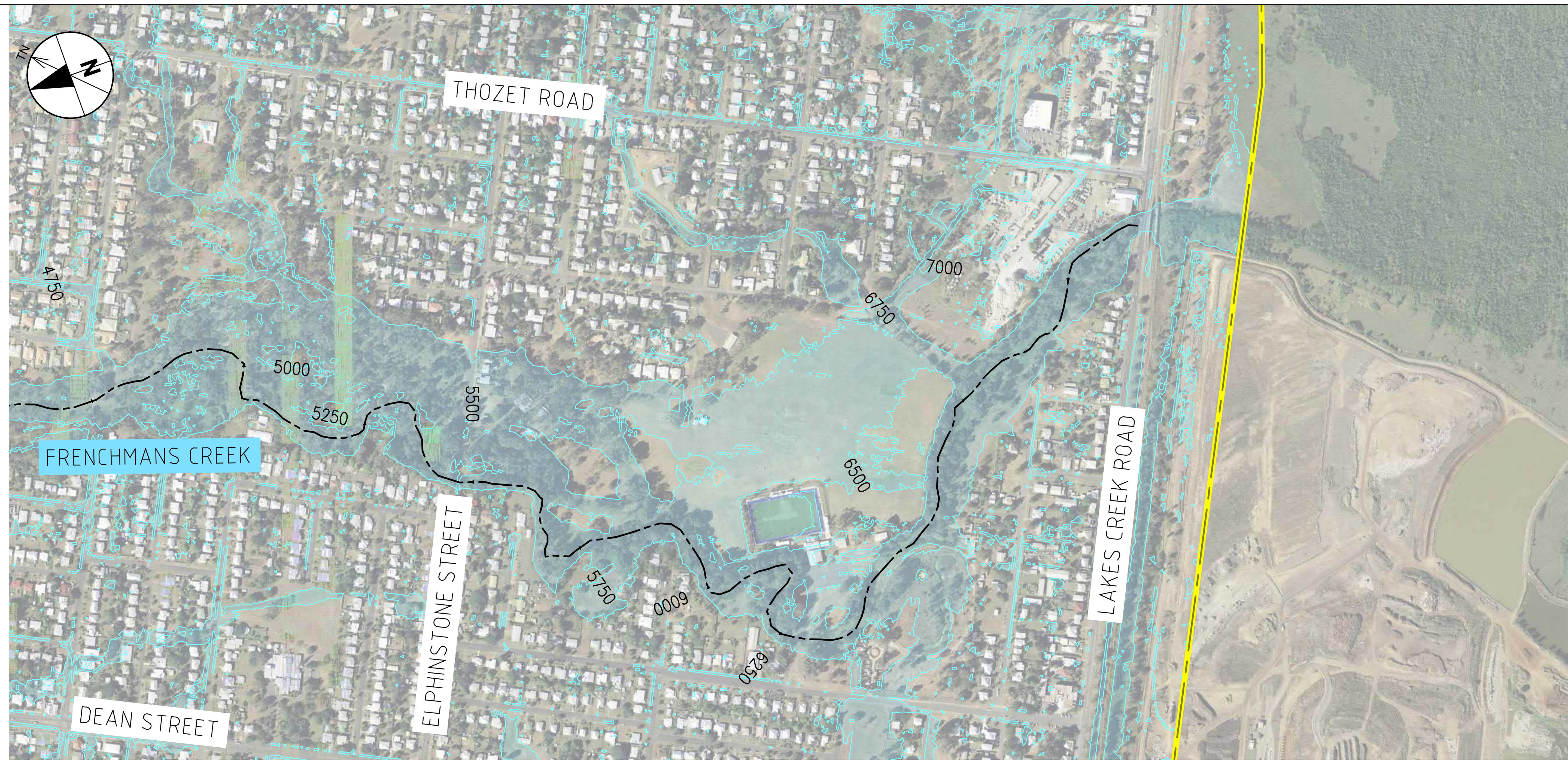


PLAN VIEW

1:5000 (A1)

FRENCHMANS & THOZETS CREEK

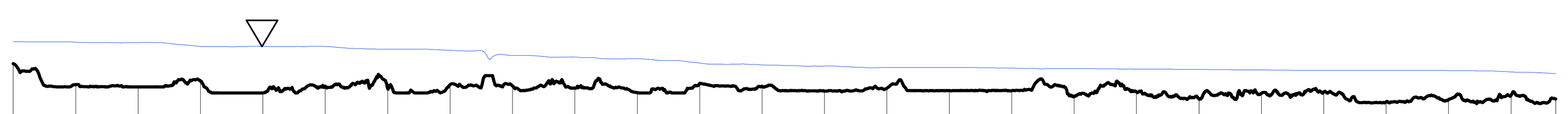
2D HYDRAULIC MODEL EXTENT

LEGEND

- UPPER BOUND
- RECORDED LEVEL
- LOWER BOUND
- 2017 MODELLED FLOOD EXTENTS
- CALIBRATION POINT

NOTE:

1. CREEK INVERT LEVELS ARE APPROXIMATE AND DERIVED FROM 2016 LIDAR AND SURVEY (WHERE AVAILABLE)
2. PWSE - PEAK WATER SURFACE ELEVATION



DATUM -3.0

2017 MODELED PWSE	7.659	7.597	7.574	7.251	7.262	7.261	7.032	6.946	6.525	6.406	6.277	5.915	5.770
CREEK INVERT LEVEL	5.863	4.185	4.000	4.457	3.503	4.027	3.868	4.162	4.067	3.890	3.530	4.275	4.041
CHAINAGES	5900.00	5950.00	6000.00	6050.00	6100.00	6150.00	6200.00	6250.00	6300.00	6350.00	6400.00	6450.00	6500.00

2017 MODELED PWSE	5.676	5.558	5.561	5.511	5.475	5.436	5.406	5.359	5.329	5.325	5.311	5.203	5.049
CREEK INVERT LEVEL	3.656	3.881	3.702	3.685	3.218	3.569	3.013	3.468	3.581	2.779	2.986	3.308	3.015
CHAINAGES	6550.00	6600.00	6650.00	6700.00	6750.00	6800.00	6850.00	6900.00	6950.00	7000.00	7050.00	7100.00	7135.76

CONTROL LINE

LONGITUDINAL SECTION

1:5000 (A1)

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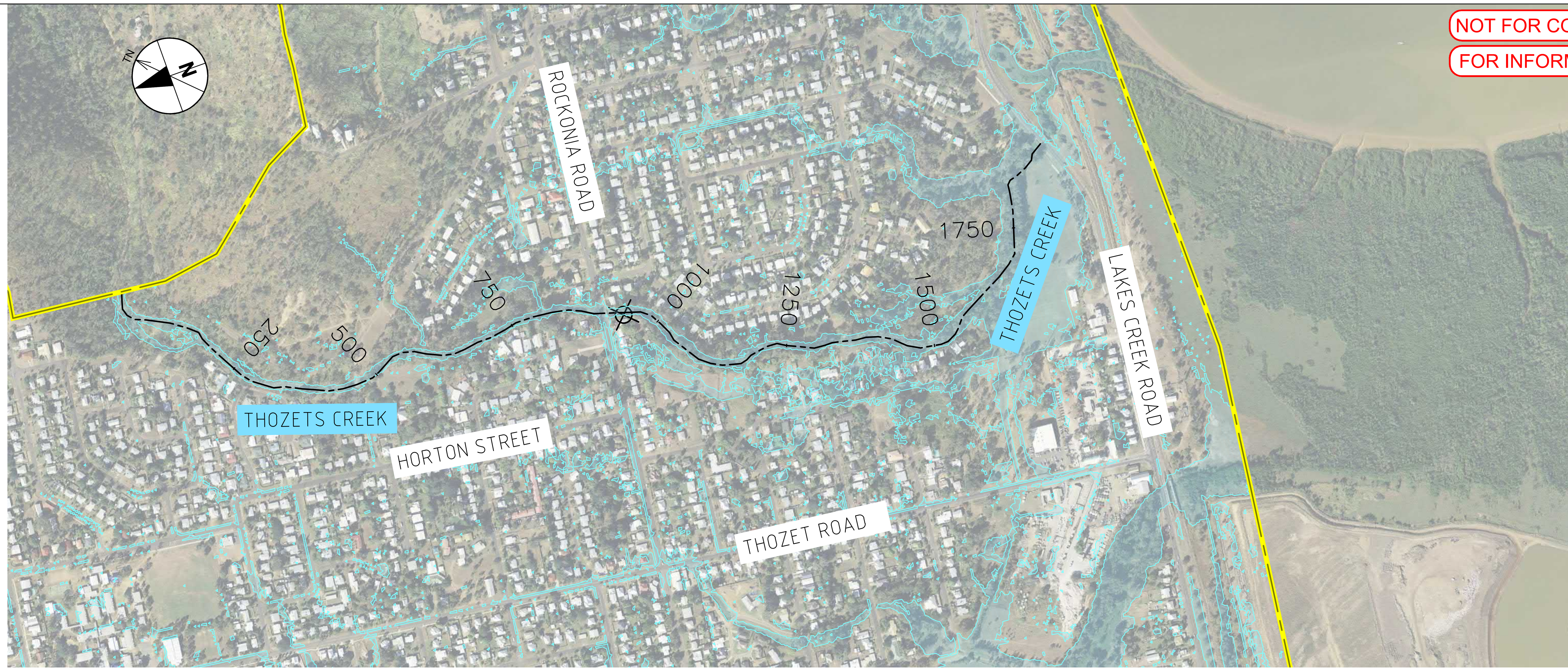
MODELLED PEAK WATER SURFACE PROFILE

2017 FLOOD EVENT-FRENCHMANS CREEK

ROCKHAMPTON REGIONAL COUNCIL

SK-16



PLAN VIEW
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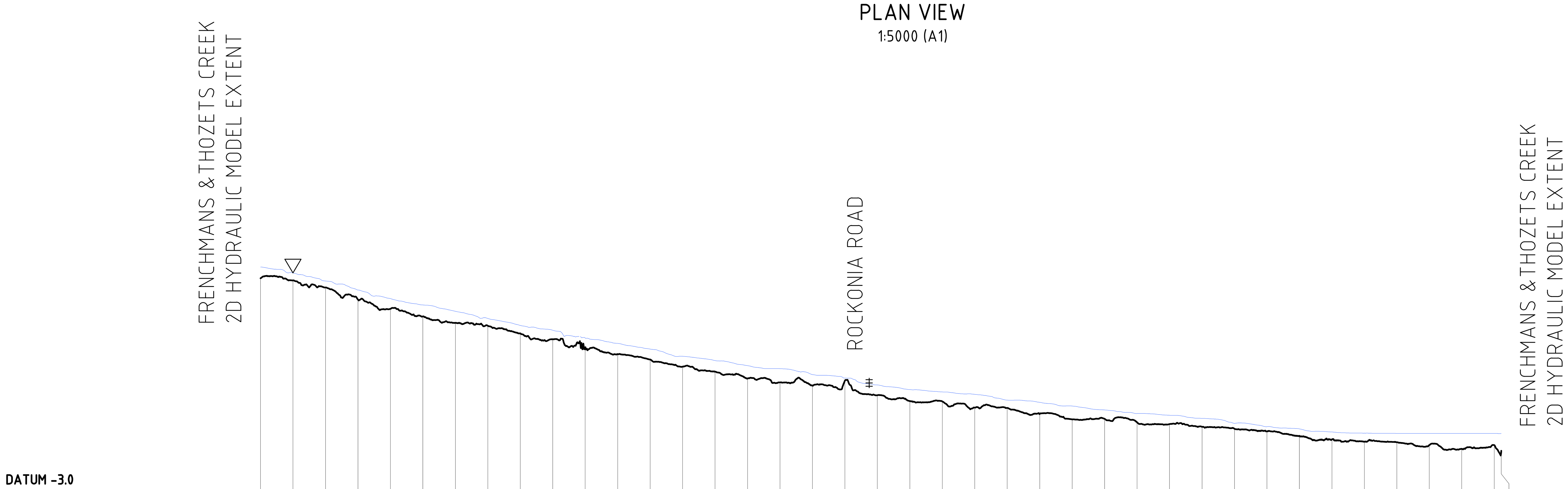

CHAINAGES	0.00	50.00	100.00	150.00	200.00	250.00	300.00	350.00	400.00	450.00
2013 MODELED PWSE	31.417	30.501	29.253	27.870	26.543	25.565	24.590	23.480	22.415	21.665
CREEK INVERT LEVEL	29.686	29.351	28.259	26.365	24.958	23.795	22.803	22.354	21.169	20.270

CHAINAGES	500.00	550.00	600.00	650.00	700.00	750.00	800.00	850.00	900.00	950.00
2013 MODELED PWSE	20.473	19.636	18.759	17.646	16.984	16.208	15.737	14.817	14.281	13.222
CREEK INVERT LEVEL	18.859	17.974	17.143	16.051	15.276	14.218	13.608	13.119	13.891	11.643

CHAINAGES	1000.00	1050.00	1100.00	1150.00	1200.00	1250.00	1300.00	1350.00	1400.00	1450.00
2013 MODELED PWSE	12.516	12.144	11.777	10.884	10.542	9.972	9.368	8.822	8.544	8.065
CREEK INVERT LEVEL	10.723	10.669	9.733	9.672	8.752	7.911	7.987	7.447	7.188	6.767

CHAINAGES	1500.00	1550.00	1600.00	1650.00	1700.00	1750.00	1800.00	1850.00	1900.00	1910.90
2013 MODELED PWSE	7.295	6.785	6.443	5.971	5.793	5.750	5.744	5.741	5.732	5.733
CREEK INVERT LEVEL	6.469	6.077	5.358	4.825	4.467	4.380	3.947	3.364	3.946	3.075

LONGITUDINAL SECTION
1:5000 (A1)

LEGEND

- UPPER BOUND
- RECORDED LEVEL
- LOWER BOUND
- 2013 MODELLED FLOOD EXTENTS
- CALIBRATION POINT

NOTE:

1. CREEK INVERT LEVELS ARE APPROXIMATE AND DERIVED FROM 2016 LIDAR AND SURVEY (WHERE AVAILABLE)
2. PWSE - PEAK WATER SURFACE ELEVATION

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MODELLED PEAK WATER SURFACE PROFILE
2013 FLOOD EVENT-THO□ETS CREEK

ROCKHAMPTON REGIONAL COUNCIL

SK-17

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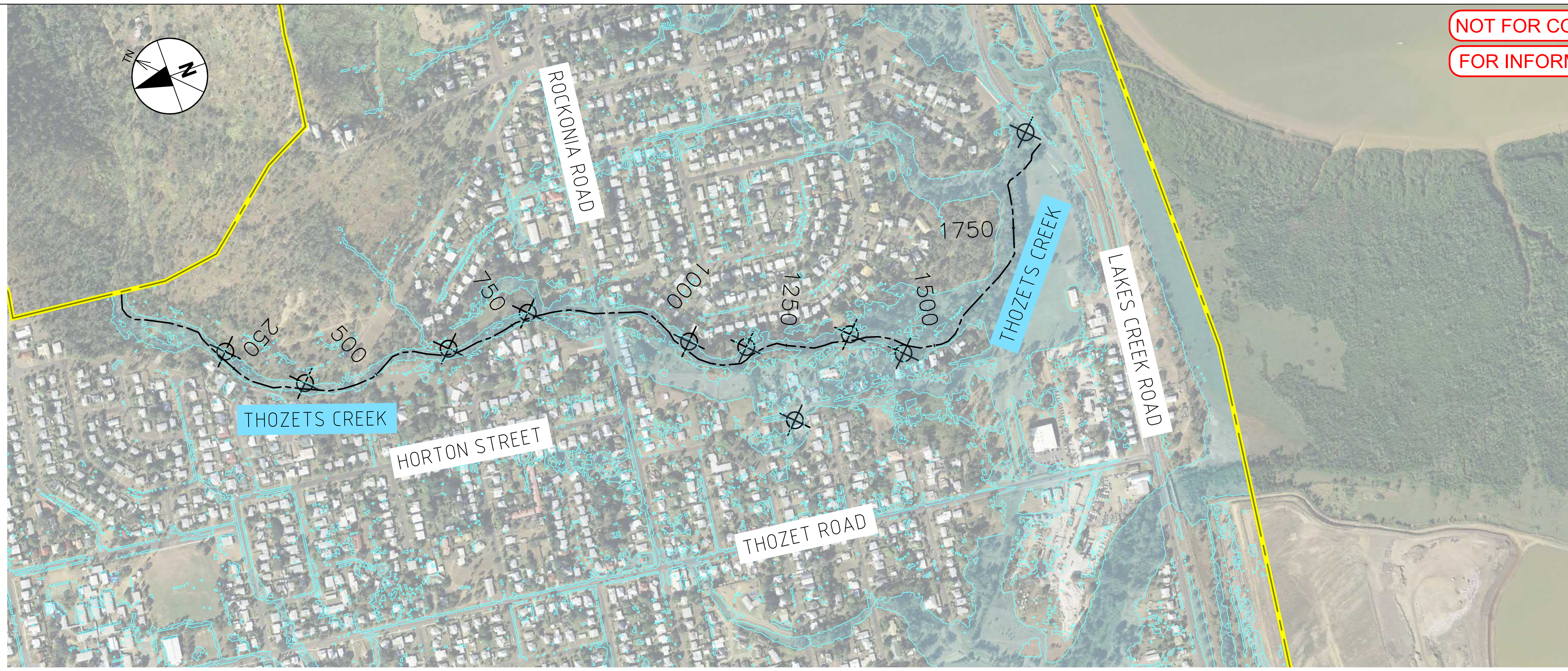
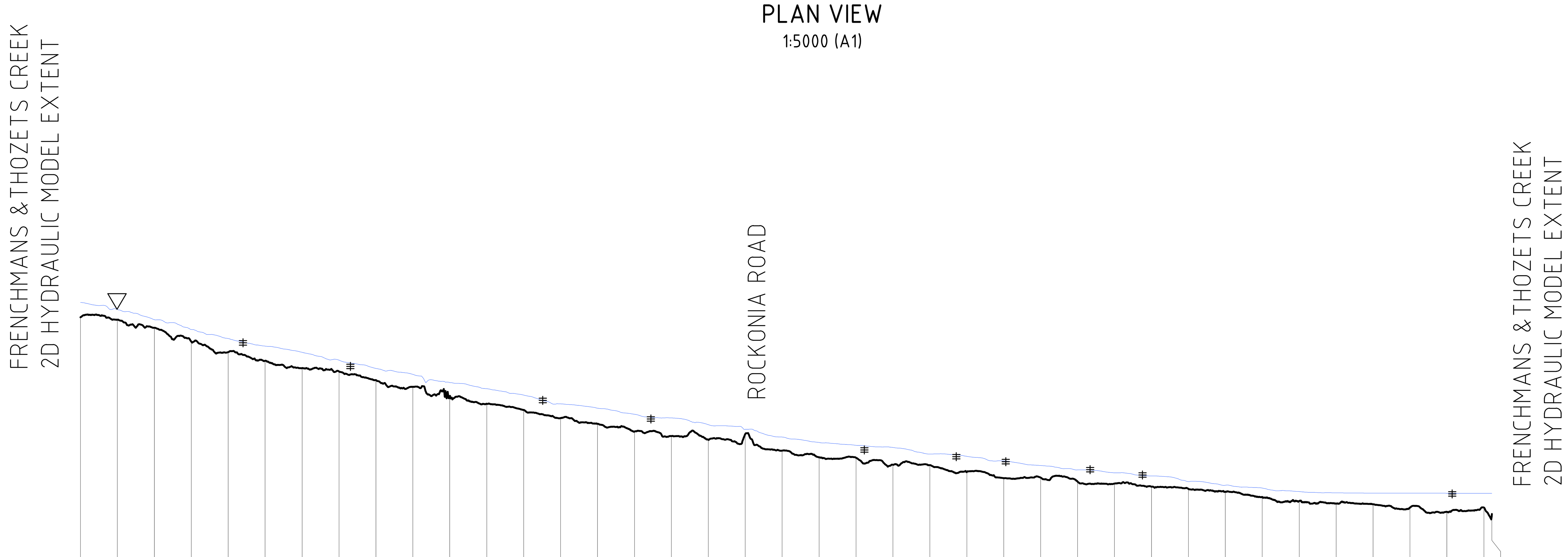


PLAN VIEW
1:5000 (A1)



2015 MODELED PWSE	31.687	30.736	29.355	28.026	26.808	25.782	24.940	23.875	22.762	21.954
CREEK INVERT LEVEL	29.686	29.351	28.259	26.365	24.958	23.795	22.803	22.354	21.169	20.270
CHAINAGES	0.00	50.00	100.00	150.00	200.00	250.00	300.00	350.00	400.00	450.00

2015 MODELED PWSE	20.844	20.020	19.155	17.974	17.383	16.556	16.067	15.156	14.514	13.475
CREEK INVERT LEVEL	18.859	17.974	17.143	16.051	15.276	14.218	13.608	13.119	13.891	11.643
CHAINAGES	500.00	550.00	600.00	650.00	700.00	750.00	800.00	850.00	900.00	950.00

2015 MODELED PWSE	12.743	12.363	12.066	11.179	10.866	10.252	9.631	9.033	8.642	8.219
CREEK INVERT LEVEL	10.723	10.669	9.733	9.672	8.752	7.911	7.987	7.447	7.188	6.767
CHAINAGES	1000.00	1050.00	1100.00	1150.00	1200.00	1250.00	1300.00	1350.00	1400.00	1450.00

2015 MODELED PWSE	7.456	6.956	6.574	6.107	5.936	5.891	5.882	5.878	5.868	5.873
CREEK INVERT LEVEL	6.469	6.077	5.358	4.825	4.467	4.380	3.947	3.364	3.946	3.075
CHAINAGES	1500.00	1550.00	1600.00	1650.00	1700.00	1750.00	1800.00	1850.00	1900.00	1910.90

LONGITUDINAL SECTION
1:5000 (A1)

NOTE:

1. CREEK INVERT LEVELS ARE APPROXIMATE AND DERIVED FROM 2016 LIDAR AND SURVEY (WHERE AVAILABLE)
2. PWSE - PEAK WATER SURFACE ELEVATION

LEGEND

- UPPER BOUND / RECORDED LEVEL / LOWER BOUND
- 2015 MODELLED FLOOD EXTENTS
- CALIBRATION POINT

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MODELLED PEAK WATER SURFACE PROFILE
2015 FLOOD EVENT-THOZETS CREEK
ROCKHAMPTON REGIONAL COUNCIL
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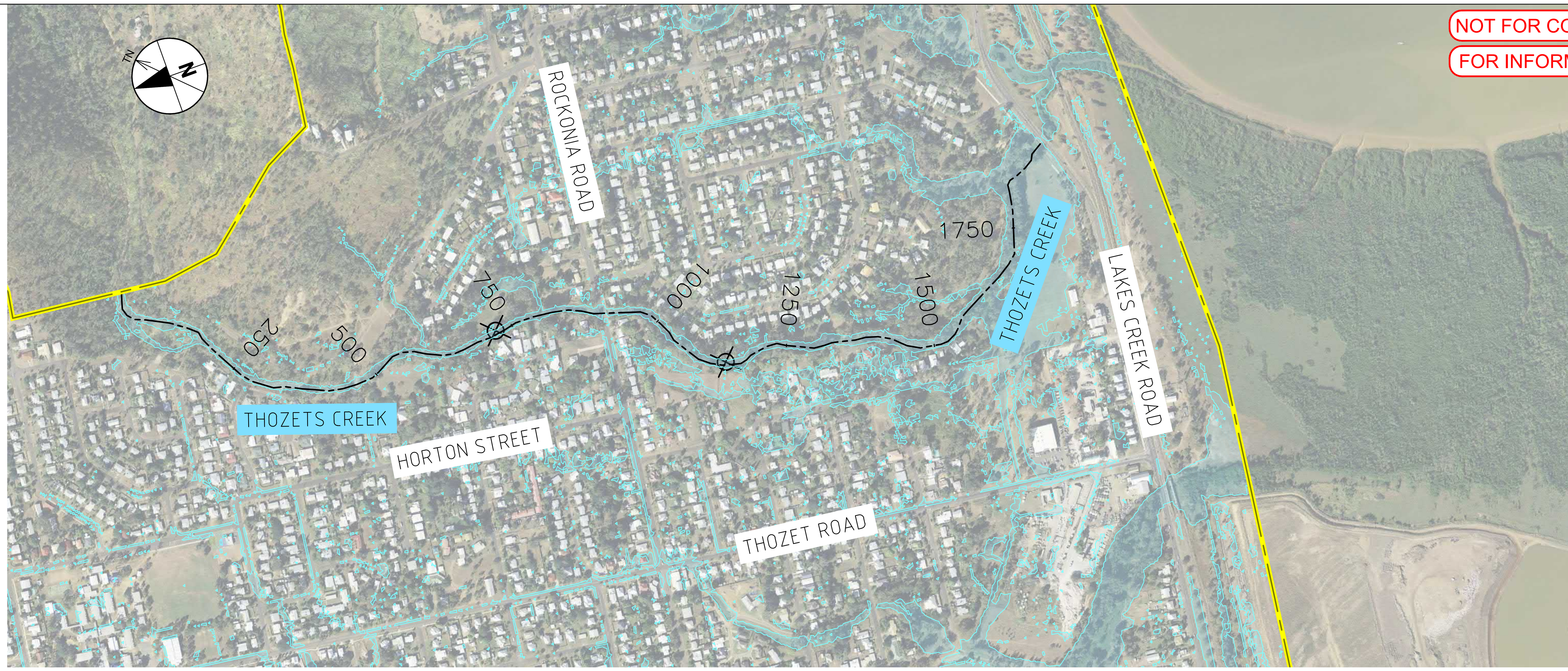

PLAN VIEW

1:5000 (A1)

FRENCHMANS & THOZETS CREEK 2D HYDRAULIC MODEL EXTENT

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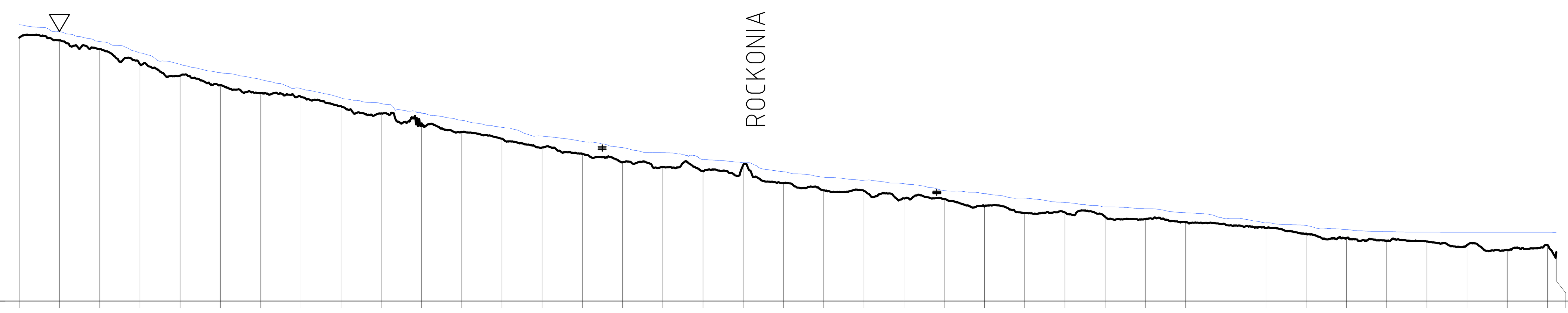
FRENCHMANS & THOZETS CREEK 2D HYDRAULIC MODEL EXTENT



DATUM -3.0

2017 MODELED PWSE	31.280	30.432	29.198	27.786	26.374	25.337	24.486	23.354	22.201	21.502
CREEK INVERT LEVEL	29.686	29.351	28.259	26.365	24.958	23.795	22.803	22.354	21.169	20.270
CHAINAGES	0.00	50.00	100.00	150.00	200.00	250.00	300.00	350.00	400.00	450.00

2017 MODELED PWSE	20.324	19.430	18.551	17.469	16.800	16.039	15.416	14.548	14.167	13.045
CREEK INVERT LEVEL	18.859	17.974	17.143	16.051	15.276	14.218	13.608	13.119	13.891	11.643
CHAINAGES	500.00	550.00	600.00	650.00	700.00	750.00	800.00	850.00	900.00	950.00

2017 MODELED PWSE	12.375	11.992	11.563	10.699	10.336	9.766	9.234	8.673	8.454	7.956
CREEK INVERT LEVEL	10.723	10.669	9.733	9.672	8.752	7.911	7.987	7.447	7.188	6.767
CHAINAGES	1000.00	1050.00	1100.00	1150.00	1200.00	1250.00	1300.00	1350.00	1400.00	1450.00

2017 MODELED PWSE	7.196	6.706	6.363	5.871	5.616	5.542	5.534	5.531	5.523	5.519
CREEK INVERT LEVEL	6.469	6.077	5.358	4.825	4.467	4.380	3.947	3.364	3.946	3.075
CHAINAGES	1500.00	1550.00	1600.00	1650.00	1700.00	1750.00	1800.00	1850.00	1900.00	1910.90

LONGITUDINAL SECTION

1:5000 (A1)

NOTE:

1. CREEK INVERT LEVELS ARE APPROXIMATE AND DERIVED FROM 2016 LIDAR AND SURVEY (WHERE AVAILABLE)
2. PWSE - PEAK WATER SURFACE ELEVATION

LEGEND

- UPPER BOUND
- RECORDED LEVEL
- LOWER BOUND
- 2017 MODELLED FLOOD EXTENTS
- CALIBRATION POINT

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MODELLED PEAK WATER SURFACE PROFILE

2017 FLOOD EVENT-THOZETS CREEK

ROCKHAMPTON REGIONAL COUNCIL

SK-19

Appendix D

Tangible Flood Damages Assessment Methodology

Appendix D Tangible Flood Damages Assessment Methodology

1.0 Introduction

As part of the Frenchmans / Thozets Creek Local Catchment Study, a flood damages assessment has been conducted to help quantify the financial burden borne by the community due to the local catchment flood damages. The flood damages assessment will also assist in assessing the potential economic benefits of the proposed mitigation options, in providing flood mitigation for the study area during local catchment flood events.

This flood damages assessment considers the financial impacts of flooding, comprising the costs associated with direct damages to property and infrastructure, and indirect costs associated with the disruptive impacts of flooding. This document presents the methodology used to assess flood damages, and the resulting estimates.

2.0 Estimating Flood Damages

2.1 Overview

Flooding can result in significant financial and social impacts on a community. A breakdown of the various types of flood damages is displayed in Figure 77. As intangible flood damages are difficult to quantify as a monetary value, they have not been included in this flood damages assessment. Therefore, reference to flood damages within this report refers to tangible flood damages only.

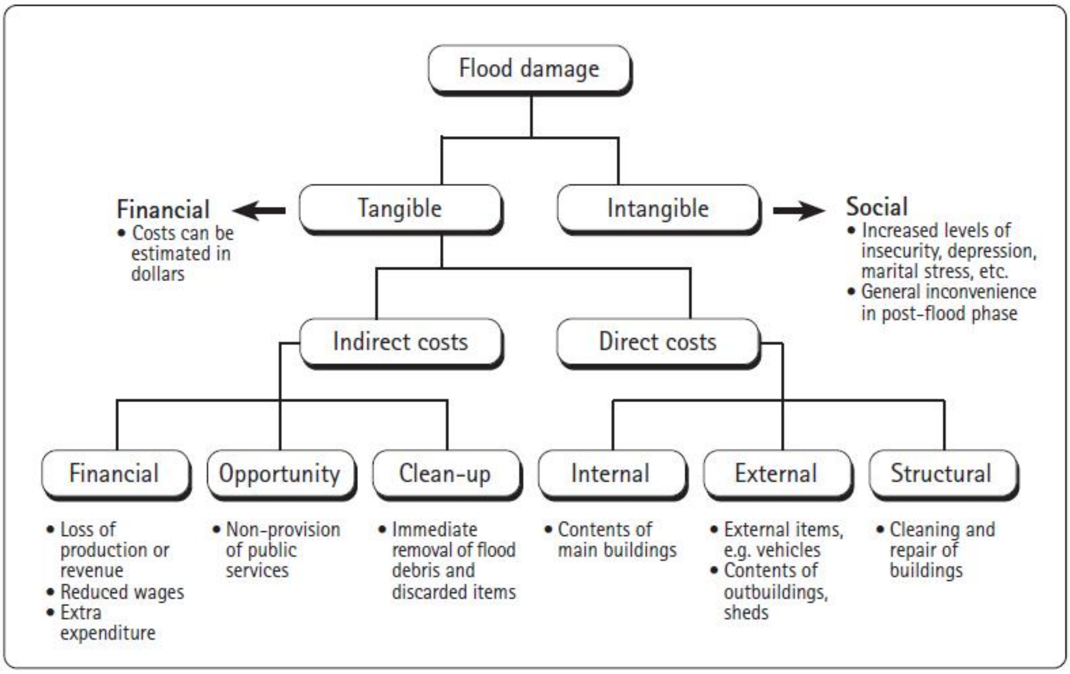

Figure 77 Breakdown of flood damage categories (source: DNRM, 2002)

2.2 General Methodology

Flood damages have been estimated through the application of stage-damage curves. These curves provide damage costs as a function of water depth, and are used to estimate direct flood damages for individual buildings based on the peak flood depth that the building experiences during a flood event. Indirect damages and infrastructure damage have been estimated as a percentage of the direct damage. The assessment has been undertaken using the results of the hydraulic modelling undertaken for the study area.

Alternative Approaches

Several approaches for estimating residential flood damages and stage-damage curves have been applied in Australia, including those by the Victorian Natural Resources and Environment, Risk Frontiers, WRM (for Sunshine Coast Regional Council) and O2 Environmental (for Ipswich City Council). While these approaches follow the same general approach, they use different estimates for stage-damage curves or consider damage types differently. A summary of literature relevant to these approaches is provided below. These provide detail on these alternative approaches.

Department of Infrastructure, Planning and Natural Resources (DIPNR) (2004) "Floodplain Management Guideline No 4 Residential Flood Damage Calculation", New South Wales Government, February 2004

Middelmann-Fernandes, M. H. (2010) "Flood Damage Estimation Beyond Stage-Damage Functions: an Australian Example", Geoscience Australia, Canberra, Australia, 2010, Journal of Flood Risk Management

Department of Natural Resources and Water (2002) "Guidance on the Assessment of Tangible Flood Damages", Queensland Government, 2002

O2 Environmental (2012) "Stage Damage Functions for Flood Damage Estimation – Interim Functions for 2012", Prepared for Ipswich City Council, April 2012

Sunshine Coast Regional Council (2010) "Estimation of Tangible Flood Damages (Maroochy River, Mountain Creek and Sippy Creek Catchments)", April 2010.

Smith, D. I. (1994) "Flood Damage Estimation – A Review of Urban Stage-Damage Curves and Loss Functions", Centre for Resource and Environmental Studies, Australian National University, Canberra, Australia, July 1994, Water SA

WRM Water & Environment (2006a) "Stage-Damage Relationships for Flood Damage Assessment in Maroochy Shire", WRM Water & Environment Pty Ltd, June 2006, prepared for Maroochy Shire Council

WRM Water & Environment (2006b) "Brisbane Valley Flood Damage Minimisation Study Brisbane City Flood Damage Assessment", WRM Water & Environment Pty Ltd, October 2006, prepared for Brisbane City Council City Design, submitted to the Queensland Floods Commission of Inquiry on 17 May 2011

The Queensland Department of Natural Resources and Mines (DNRM) recommends the use of the ANUFLOOD stage-damage curves for estimating potential flood damages; however there is a consensus that ANUFLOOD underestimates damage values for residential properties. For instance, DIPNR (2004) states:

"The Victorian Natural Resources and Environment, Rapid Assessment Method (RAM) for Floodplain Management, May 2000, indicates that ANUFLOOD estimates needed to be increased by 60% to be in the vicinity of Water Studies damages surveys. Even with this adjustment ANUFLOOD estimates are still well below those of Risk Frontiers."

A review of residential stage-damage curves was undertaken as part of the South Rockhampton Flood Levee project (AECOM, 2014). This review compares flood damages estimated using the ANUFLOOD stage-damage curves against two of the Australian methods mentioned above and one approach used in the USA, and demonstrates the variation in estimates of flood damages between different approaches. Based on this review, the WRM stage-damage curves and O2 Environmental stage-damage curves based on rebuilding costs have been adopted for estimating residential direct damages, to be presented as bounds of potential flood damages.

The ANUFLOOD stage-damage curves have been adopted for estimation of commercial direct damages due to the lack of alternatives.

Actual and Potential Damages

The stage-damage curves used during this study provide estimates of the potential flood damages which would occur during a flood event if no actions were taken to reduce the amount of damage.

During actual flood events, residents will usually take measures to reduce the amount of damage incurred, such as moving possessions to higher ground.

The reduction in flood damages resulting from such preventative measures is dependent on the warning time available during a flood, the experience of the community in preparing for flooding and whether or not it is possible to move possessions to safety.

Residents of the study area typically have very little notice prior to a local catchment flood event, as critical durations for the study area are short (in the order of 1 to 3 hours). Therefore the stage-damage curves were not adjusted using the ratios of actual to potential (A/P) flood damages recommended in DNRM (2002). An actual to potential damages ratio of 1 has been applied to all the damage curves.

2.3 Residential Damages

The following section describes the stage-damage curves that have been used to assess the value of residential flood damages for the assessment.

O2 Environmental Stage Damage Curves

Direct residential damages were estimated using the O2 Environmental (2012) stage-damage curves based on rebuilding costs, which are presented in Table 47 to Table 49. Individual curves are given for external, contents and structural damages. Figure 78 presents stage damage curves representing total flood damages (sum of external, contents and structural damages).The external and damage component is based on the WRM (2006a) curves adjusted to present day dollars (refer Section 2.6, Table 54), the contents damage component is based on the WRM (2006a) curves scaled to have a maximum value equal to the average household contents insurance value of $80,000, and the structural damage component is based on estimates of rebuilding costs (O2 Environmental, 2012) also adjusted to present day dollars.

Damage calculations were carried out separately for the external, contents and structural damage components and combined to give total damages. This allowed a range of raised building heights to be easily assessed, with external damages increasing with over ground depth, and contents and structural damages increasing with over floor depth. Raised floor levels were estimated as described in Section 3.4.

All damage values have been adjusted to March 2017 Dollars, which corresponds to the most recent Consumer Price Index (CPI) values available. Details of the adjustment are provided in Section 2.6. No adjustment of Stage-Damage curves to represent actual / potential flood damages was undertaken, as described in Section 2.2.

Table 47 O2 Environmental Stage-Damage curves for residential external damage (March 2017 $)

Depth Over Ground (m)	Fully Detached			Semi or Non Detached		
	Vehicle Damages	Other Damages	Total Damages	Vehicle Damages	Other Damages	Total Damages
0	$0	$0	$0	$0	$0	$0
0.025	$0	$2,276	$2,276	$0	$1,024	$1,024
0.5	$13,528	$5,918	$19,446	$12,264	$6,373	$18,637
1	$33,252	$9,332	$42,583	$25,160	$8,763	$33,923
2	$33,378	$10,925	$44,303	$25,160	$9,787	$34,947

Table 48 O2 Environmental Stage-Damages curves for residential contents damage (March 2017 $)

Depth Over Floor (m)	Detached Single Storey	Detached Double Storey	Detached High Set	Multi-unit Single Storey	Multi-unit Double Storey
0	$0	$0	$5,000	$0	$0
0.025	$15,000	$10,000	$15,000	$15,000	$10,000
0.5	$40,000	$25,000	$40,000	$30,000	$20,000
1	$64,000	$40,000	$64,000	$48,000	$32,000
2	$80,000	$50,000	$80,000	$60,000	$40,000
2.75	$80,000	$60,000	$80,000	$60,000	$50,000
3.7	$80,000	$65,000	$80,000	$60,000	$55,000
4.7	$80,000	$80,000	$80,000	$60,000	$60,000

Table 49 O2 Environmental Stage-Damage curves for residential structural damage (March 2017 $)

Depth Over Floor (m)	Detached Single Storey ($200m^2$)	Detached Single Storey ($150m^2$)	Detached Double Storey (2 x $150m^2$)	High Set Queenslander ($200m^2$)	Multi-unit Single Storey	Multi-unit Double Storey
0	$0	$0	$0	$0	$0	$0
0.025	$10,796	$7,936	$10,796	$7,936	$7,337	$5,393
0.15	$19,694	$14,358	$20,429	$14,889	$13,397	$10,129
0.5	$85,060	$66,271	$87,480	$78,831	$57,838	$53,609
1	$141,259	$112,984	$112,860	$116,670	$96,060	$79,340
1.5	$141,259	$112,984	$117,540	$116,670	$96,060	$80,052
2	$141,259	$112,984	$122,232	$116,670	$96,060	$80,052
2.3	$141,259	$112,984	$122,232	$116,670	$96,060	$80,052
2.8	$154,927	$123,227	$135,889	$136,431	$105,353	$92,771
3	$176,701	$141,485	$157,900	$159,494	$120,152	$108,451
4	$176,701	$141,485	$157,900	$162,761	$120,152	$110,678
5	$176,701	$141,485	$157,900	$169,286	$120,152	$115,110
5.2	$176,701	$141,485	$157,900	$180,579	$120,152	$122,797
6	$176,701	$141,485	$157,900	$198,837	$120,152	$135,210

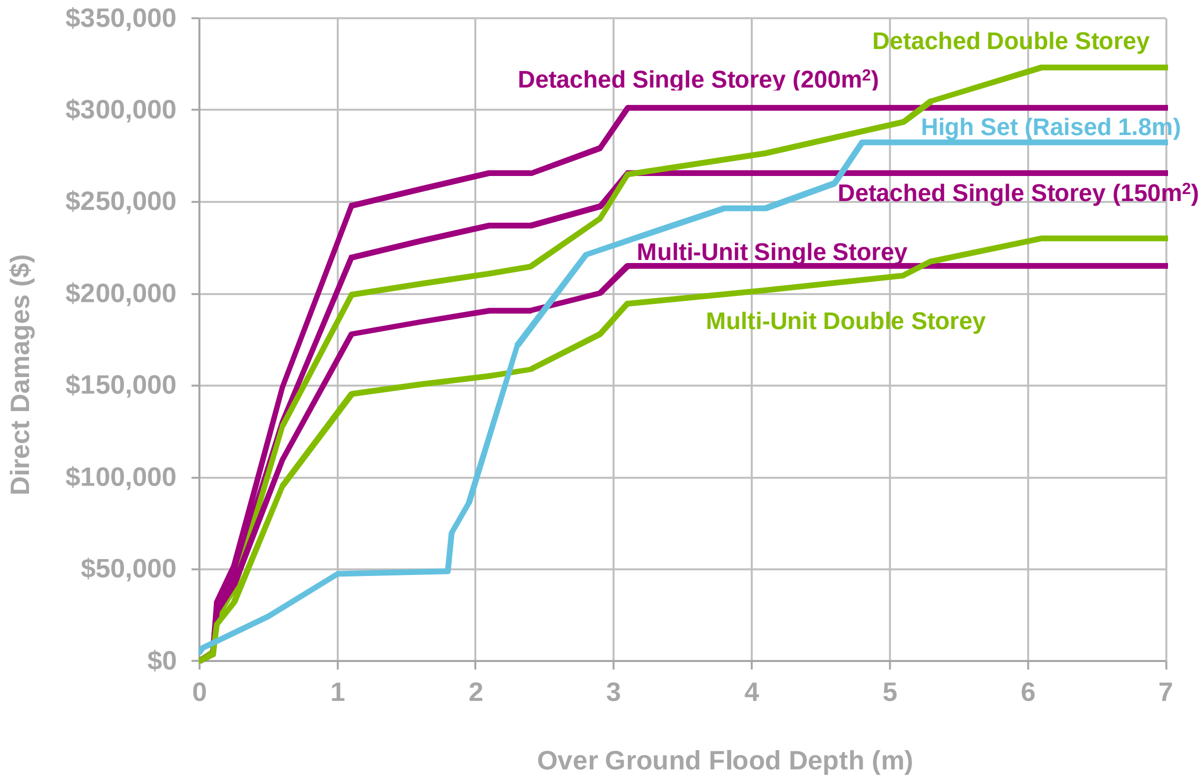

Figure 78 Total residential stage-damage curves based on O2 Environmental curves (March 2017 $)

WRM Stage Damage Curves

Direct residential damages were estimated using the WRM (2006a) stage-damage curves presented in Table 50 to Table 52. Individual curves are given for external, contents and structural damages, which were derived from stage-damage surveys conducted in Maroochy Shire on the Sunshine Coast. Figure 79 presents stage damage curves representing total flood damages (sum of external, contents and structural damages).

Damage calculations were carried out separately for the external, contents and structural damage components and combined to give total damages. This allowed a range of raised building heights to be easily assessed, with external damages increasing with over ground depth, and contents and structural damages increasing with over floor depth. Raised floor levels were estimated as described in Section 3.4.

All damage values have been adjusted to March 2017 Dollars, which corresponds to the most recent CPI values available. Details of the adjustment are provided in Section 2.60. No adjustment of Stage-Damage curves to represent actual / potential flood damages was undertaken, as described in Section 2.2.

Table 50 WRM Stage-Damage curves for residential external damage (March 2017 $)

Depth Over Ground (m)	Fully Detached			Semi or Non Detached		
	Vehicle Damages	Other Damages	Total Damages	Vehicle Damages	Other Damages	Total Damages
0	$0	$0	$0	$0	$0	$0
0.025	$0	$2,276	$2,276	$0	$1,024	$1,024
0.5	$13,528	$5,918	$19,446	$12,264	$6,373	$18,637
1	$33,252	$9,332	$42,583	$25,160	$8,763	$33,923
2	$33,378	$10,925	$44,303	$25,160	$9,787	$34,947

Table 51 WRM Stage-Damage curves for residential contents damage (March 2017 $)

Depth Over Floor (m)	Detached Single Storey	Detached Double Storey	Detached High Set	Multi-unit Single Storey	Multi-unit Double Storey
0	$0	$0	$0	$0	$0
0.025	$15,169	$11,900	$2,877	$6,669	$5,754
0.5	$36,746	$26,546	$7,192	$37,531	$14,515
1	$55,185	$41,454	$11,115	$47,731	$19,746
2	$66,300	$50,608	$13,338	$51,915	$22,362

Table 52 WRM Stage-Damage curves for residential structural damage (March 2017 $)

Depth Over Floor (m)	Detached Single Storey	Detached Double Storey	Detached High Set	Multi-unit Single Storey	Multi-unit Double Storey
0	$0	$0	$0	$0	$0
0.025	$13,648	$10,368	$4,200	$14,698	$7,743
0.5	$19,685	$15,092	$4,987	$19,817	$11,680
1	$24,803	$19,160	$6,955	$24,410	$13,517
2	$32,809	$25,066	$7,612	$24,803	$16,536

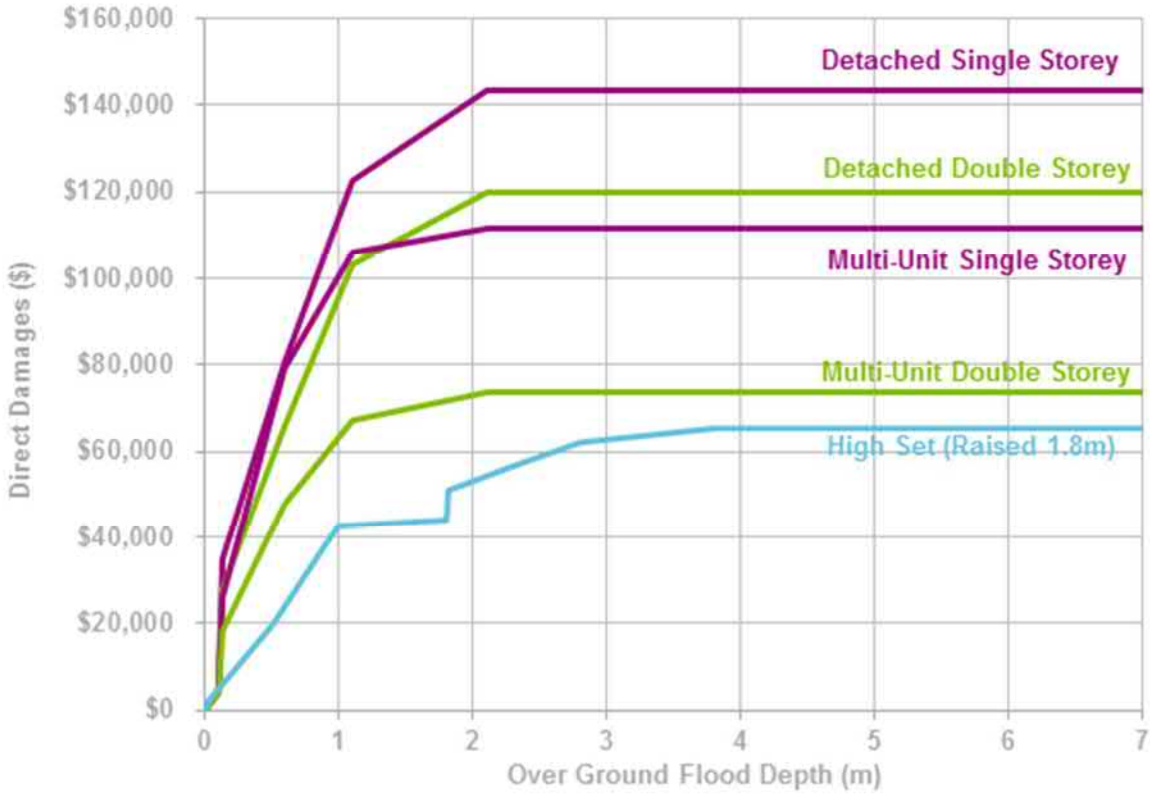

Figure 79 Total residential stage-damage curves based on WRM curves (March 2017 $)

Indirect Damages

Indirect residential damages were assumed to be 15% of the total direct residential damages (Department of Natural Resources and Mines, 2002).

2.4 Commercial Damages

The following section describes the stage-damage curves that have been used to assess the value of commercial flood damages for the assessment.

ANUFLOOD Stage-Damage Curves

Commercial, industrial and public building damages were estimated using the ANUFLOOD commercial stage-damage curves summarized in Table 53 and Figure 80. Commercial buildings were assigned a value class based on their use. Details on building classification are presented in Section 3.3. It should be noted that large-classed building damages were estimated using area directly (i.e. the large-class building damage curves are in units of $/m2 vs. $).

Raised floor levels were estimated as described in Section 3.4. Estimated damages were assumed to remain constant after a depth over floor of 2m, corresponding to the maximum damage value provided in the ANUFLOOD literature.

All damage values have been adjusted to March 2017 Dollars, which corresponds to the most recent CPI values available. Details of the adjustment are provided in Section 2.6. No adjustment of Stage-Damage curves to represent actual / potential flood damages was undertaken, as described in Section 2.2.

Table 53 ANUFLOOD Stage-Damage curves for commercial properties (March 2017 $)

Depth Over Floor (m)	Small – Damages in $ (< 186 m²)					Medium – Damages in $ (186 - 650 m²)					Large – Damages in $/m² (> 650 m²)				
	Value Class					Value Class					Value Class				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
0.25	$3,197	$6,396	$12,791	$25,582	$51,165	$10,128	$20,253	$40,506	$81,011	$162,023	$10	$22	$46	$89	$177
0.75	$7,995	$15,988	$31,978	$63,956	$127,913	$24,516	$49,032	$98,066	$196,132	$392,263	$57	$113	$224	$447	$899
1.25	$11,991	$23,985	$47,967	$95,935	$191,868	$37,307	$74,616	$149,230	$298,501	$596,924	$118	$235	$473	$942	$1,883
1.75	$13,324	$26,648	$53,297	$106,594	$213,187	$41,303	$82,611	$165,220	$330,440	$660,880	$192	$388	$774	$1,546	$3,091
2	$14,123	$28,248	$56,494	$112,989	$225,978	$43,969	$87,941	$175,879	$351,759	$703,518	$231	$462	$923	$1,847	$3,695

* Note that damage costs for Large Commercial Properties are based on a 'dollars per m²' rate, whereas damage costs for Small and Medium Commercial Properties are based on a pure 'dollar' rate.

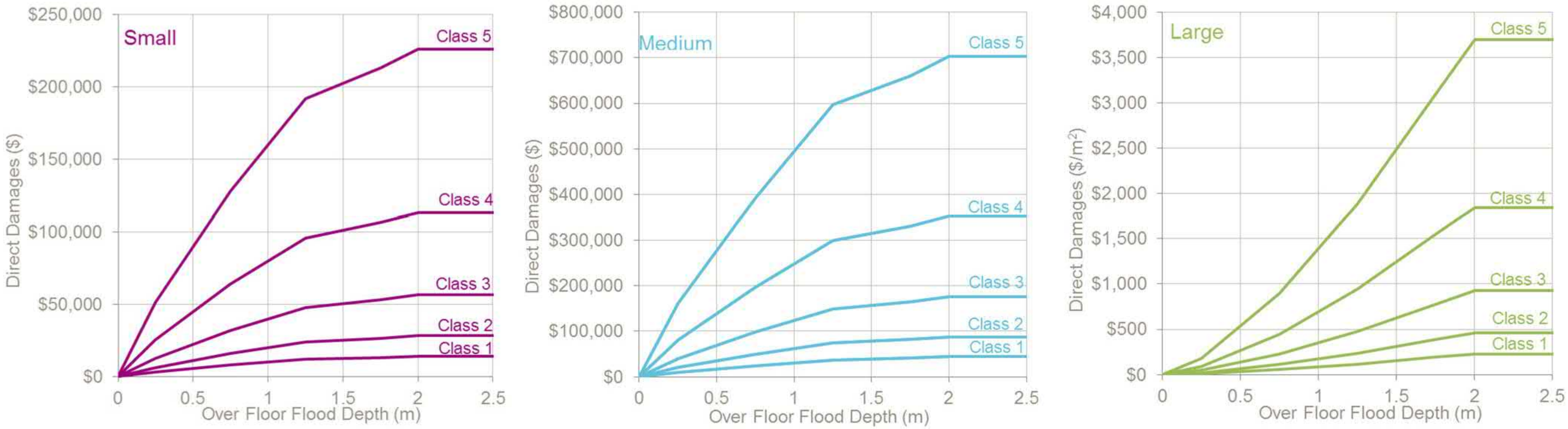

Figure 80 ANUFLOOD Stage-Damage curves for commercial properties (March 2017 $)

Indirect Damages

Indirect damages for commercial buildings were assumed to be 55% of the direct damages. This number is significantly higher than the indirect damage value for residential buildings due to the assumed loss of business revenue, as per DNRM (2002). It should be noted that this applies to all buildings classified as commercial, which includes community assets such as park facilities, schools, etc. which may not actually recognize business–related revenue.

2.5 Infrastructure Damages

Costs associated with damage to infrastructure such as roads, water and wastewater facilities, and utilities have been estimated as 15% of the total direct residential and commercial flood damages. This is consistent with the recommendations of the Office of Environment and Heritage (BMT WBM, 2011).

2.6 Consumer Price Index Adjustment

All stage-damage curves were adjusted to present day dollars based on CPI ratios. Current CPI values were taken from the most recent statistics available from the Australian Bureau of Statistics (ABS) dated March 2017.

The commercial ANUFLOOD damage curves were adjusted using the CPI for All Groups, as the allotment of ANUFLOOD damages to structure damages and contents damages is unknown. The external and structural components of O2 Environmental damages were adjusted separately using the relevant CPI's. The contents component of the O2 Environmental damages were not indexed, as the maximum value of $80,000 for residential contents damages is considered reasonable for the study area. Table 54 presents an overview of the CPI adjustments.

Table 54 CPI adjustment summary

Damage Curve	Relevant CPI Group	Reference	Reference CPI	Current CPI	CPI Increase
ANUFLOOD Commercial	All Groups	DNRW, 2002	76.1	110.5	45.2%
O2 Residential External *Motor Vehicle*	Maintenance and repair of motor vehicle	WRM, 2006	85.5	108.1	26.4%
O2 Residential External *Other Damage*	Tools and Equipment for house and garden	WRM, 2006	94.2	107.2	13.8%
O2 Residential Contents	N/A	O2 Environmental, 2012	---	---	---
O2 Residential Structural	Maintenance and repair of dwelling	O2 Environmental, 2012	99.6	112.6	13.1%
WRM External *Motor Vehicle*	Maintenance and repair of motor vehicle	WRM, 2006	85.5	108.1	26.4%
WRM External *Other Damage*	Tools and Equipment for house and garden	WRM, 2006	94.2	107.2	13.8%
WRM Contents	All Groups	WRM, 2006	84.5	110.5	30.8%
WRM Structural	Maintenance and repair of dwelling	WRM, 2006	85.8	112.6	31.2%

3.0 Building Classification

3.1 Introduction

Building data within the study area was supplied by RRC and classified using land use data provided. Information was generated at a planning level of detail considered adequate for the purpose of this study. Surveyed building flood levels were included where available. Other detailed building information such as entry location, structure and content values and actual businesses, was not included.

3.2 Footprints

Building footprints were supplied by Council. The area of the building footprint was used for classifying buildings into different size classes. For large commercial buildings, the stage-damage curves give damages in units of $/m^2, therefore building areas were used directly in the damage calculations.

3.3 Class

Buildings were assigned a building class which determined the damage curve applied to each building. To assign classes to buildings, the attribute data for each building footprint was used. Based on a combination of the structure type and land use data fields, buildings were categorized as either residential or commercial, while recognizing that ANUFLOOD includes commercial, industrial and public buildings all within the *commercial* building type.

<u>Residential Buildings</u>

Residential buildings were further classified based on size and raised height to align with the building classes presented in Section 2.3. Building classification was based on the structure type and number of storeys where available, otherwise it was based on land use. Buildings in residential or rural zones without any other data were categorised as detached single storey slab-on-ground houses. Detached, single storey, slab-on-ground houses were finally categorised by the area of the digitised building footprints.

<u>Commercial Buildings</u>

Commercial buildings were further classified based on size and value of the building contents to align with the classes presented in Section 2.4. The ANUFLOOD damage value classes for commercial buildings are shown in Figure 81.

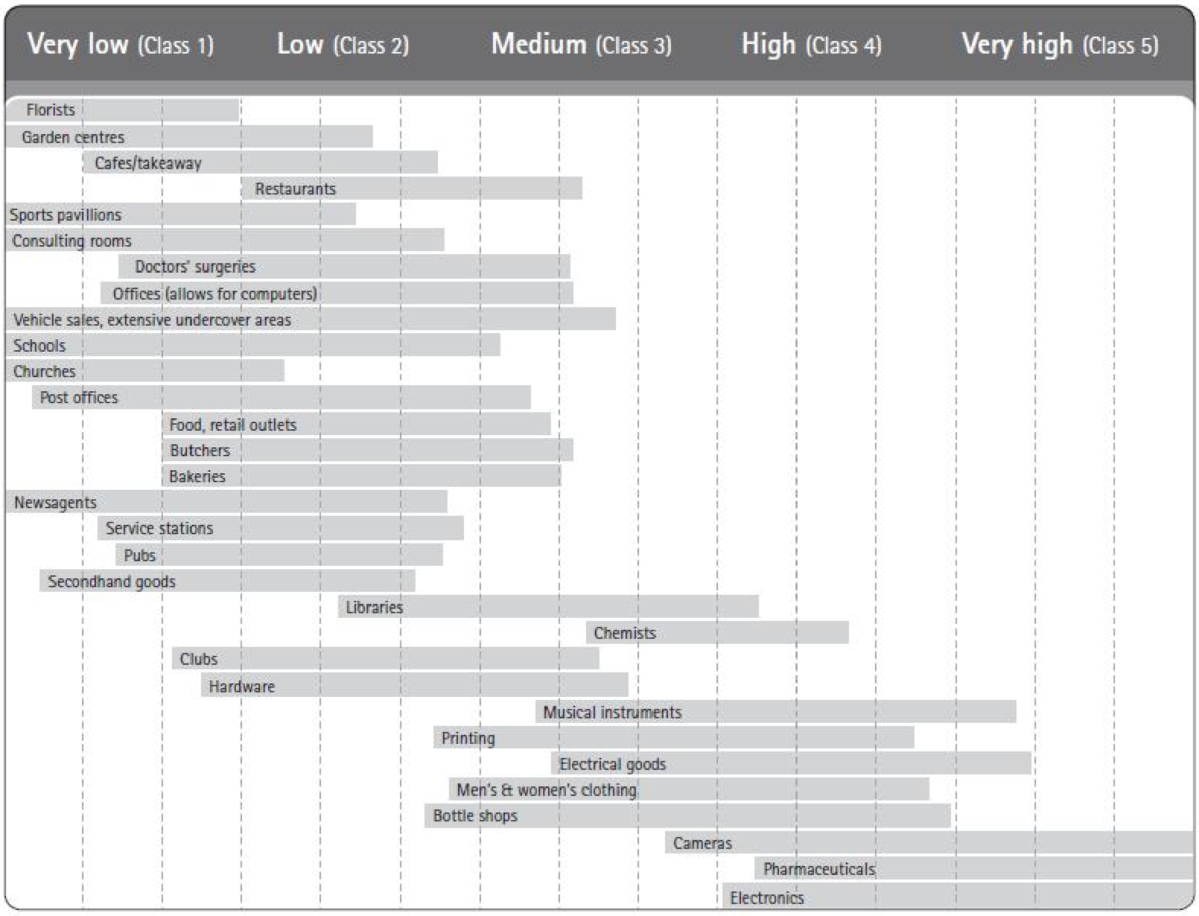

Figure 81 ANUFLOOD commercial damage value classes (source: DNRM, 2002)

As ANUFLOOD provides a range of property classes for each property type, a single value class has been assigned based on the land use field of the building footprints dataset. Where the land use did not correspond directly to an ANUFLOOD damage value class, a reasonable value class was assigned. Areas labelled as footpaths were assumed not to be buildings and were not classified. Sheds and Garages were given a classification based on land use data. Table 55 shows the value class assigned to each land use in the building footprints dataset. Where the land use of a commercial building was not known, the building was assigned class 3.

Table 55 Assignment of commercial damage class values based on Council land use dataset

Council Land Use	Class	Council Land Use	Class	Council Land Use	Class
Animals Special	3	Hospitals/Nursing Homes	2	Service Station	2
Builders Yards / Contractors Yard	3	Hotel/Tavern	2	Shop Single	3
Car Park	2	Iceworks	2	Shops 2 to 6	3
Car Yards etc	2	Heavy Industry	3	School	2
Caravan Parks	2	Horses	1	Service Station	2
Cattle Breeding/Fattening	2	Irrigation Small Corps	2	Shop Single	3
Cemeteries	1	Library	3	Shops Main Retail	3
Child Care Centre	1	Licenced Clubs	2	Shops over 6	3
Churches/Halls	1	Light Industry	3	Shops Secondary Retail	3
Clubs Non-Business	2	Motel	2	Showgrounds etc	2
Community Facilities	2	Noxious Industry	3	Sports Clubs	2
Council Owned	2	Nurseries	2	Theatre/Cinema	3
Defence Forces	4	Offices	2	Tourist Attraction	3
Drive Shopping Centre	3	Oil Depot	3	Transformers	3
Fire/Ambulance	3	Orchards	2	Transport Terminal	3
Flats with Shops	3	Parks & Gardens	1	Tropical Fruits	1
Funeral Parlours	1	Poultry	2	Uni/Schools etc	2
General Industry	3	Reservoirs etc	3	Vineyards	2
Guesthouse	2	Restaurant	2	Warehouses etc	3
Harbour Industries	3	Retail Warehouse	2	Welfare Homes	2

3.4 Levels

The ground level at each building was estimated based on the 1m LiDAR DEM provided for the project. Ground levels were assigned to the building footprints based on the average elevation of the DEM within the building extents.

Buildings were classified as one or two storey based on their attribute data. Buildings lacking data regarding number of storeys were assumed to be one storey. Buildings on slabs were assumed to have a minimum habitable floor level of 100mm above ground level. Low set buildings were assumed to have a minimum habitable floor level of 600mm above ground level and high set buildings were assumed to have a minimum habitable floor level of 1,800mm above ground level. Buildings lacking data regarding what type of floor they have were assumed to be on slabs.

4.0 Bibliography

AECOM. (2014). *South Rockhampton Flood Levee - Residential Depth-Damage Curve Review.* Rockhampton: AECOM Australia Pty Ltd.

Australian Bureau of Statistics. (2017, April 26). *6401.0 - Consumer Price Index, Australia, Mar 2017.* Retrieved June 9, 2017, from Australian Bureau of Statistics Web site: http://www.abs.gov.au/Ausstats/abs@.nsf/mf/6401.0

BMT WBM. (2011). *Belongil Creek Floodplain Risk Management Study and Plan - Discussion Paper 2: Flood Damages Assessment.* Brisbane: BMT WBM Pty Ltd.

Department of Infrastructure, Planning and Natural Resources. (2004). *Floodplain Management Guideline No 4 Residential Flood Damage Calculation.* Sydney: New South Wales Government.

Department of Natural Resources and Mines. (2002). *Guidance on the Assessment of Tangible Flood Damages.* Brisbane: The State of Queensland.

Middelmann-Fernandes, M. H. (2010, March). Flood Damage Estimation Beyond Stage-Damage Functions: an Australian Example. *Journal of Flood Risk Management, 3*(1), 88-96.

O2 Environmental. (2012). *Stage Damage Functions for Flood Damage Estimation – Interim Functions for 2012.* Fortitude Valley: O2 Environmental.

Smith, D. I. (1994, July). Flood Damage Estimation – A Review of Urban Stage-Damage Curves and Loss Functions. *Water SA, 20*(3), 231-238.

Sunshine Coast Regional Council. (2010). *Estimation of Tangible Flood Damages (Maroochy River, Mountain Creek and Sippy Creek Catchments).* Maroochydore: Sunshine Coast Regional Council.

WRM Water & Environment. (2006a). *Stage-Damage Relationships for Flood Damage Assessment in Maroochy Shire.* Spring Hill: WRM Water & Environment Pty Ltd.

WRM Water & Environment. (2006b). *Brisbane Valley Flood Damage Minimisation Study - Brisbane City Flood Damage Assessment.* Spring Hill: WRM Water & Environment Pty Ltd.