Beaudesert Stormwater System Assessment and Improvement Plan

Final Report

Scenic Rim Regional Council

5 December 2014

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Executive summary

Aurecon have been engaged by Scenic Rim Regional Council (SRRC or 'Council' hereafter) to undertake an assessment of the stormwater network in the townships of both Beaudesert and Boonah. This project was commissioned in response to ongoing flooding issues that are present within these localities with the ultimate aim of understanding and reducing flood risk. Note that this report discusses the findings specific to Beaudesert only.

The study involves:

- Assessing the existing stormwater network to identify areas/locations where the drainage system is not performing adequately and is causing flooding issues
- Developing and testing mitigation strategies aimed at improving the performance of the drainage system in these areas
- In conjunction with Council, selecting a preferred mitigation solution to take forward to Council's next phase of evaluation (ie a future Capital Works Program)

This investigation has involved the development of hydrologic and hydraulic models for the local Beaudesert area which was successfully calibrated to two recent historic flood events in March and November 2013. These events caused considerable flooding in Brisbane Street, Beaudesert, whereas the rest of the locality did not appear to suffer any particular flooding of note.

An assessment of the return period of these events showed that:

- March 2013 had an ARI of approximately 2 years
- November 2013 had an ARI of approximately 5 years

These events can be expected to occur on a regular basis relatively speaking, and consequently the associated flooding is considered problematic. Accordingly at a System Assessment workshop held with SRRC personnel, the issue of flooding on Brisbane Street was identified for testing in the Options Assessment phase such that a more desirable level of service could be achieved for Brisbane Street.

The cause of the flooding is a lack of capacity within the existing town drain culvert and therefore numerous options were proposed which looked at providing additional capacity to mitigate the issue of surface flooding in Brisbane Street.

It became apparent that only two options (Option B and Option F – refer to Section 7 for option descriptions) could provide the desired level of service. With Option F being considerably more expensive, Option B (a pipe running along Short Street) was deemed the preferred concept to take forward to the final stage of analysis.

The Options Assessment workshop resulted in further development of Option B. This involved connecting the main town drain Reinforced Concrete Box Culvert (RCBC) to the trunk pipe that would be running through Brisbane Street and Short Street. This would be able to reduce the discharge running through the open drain section of the town drain (which generates flooding to the yards of business premises downstream of Brisbane Street) while also acting to convey the runoff that is making its way into the sag via a series of new inlets.

This option was optimised and costed such that a finalised preferred solution could be presented to Council. The final design attains a level of service of 10 year ARI in line with the QUDM guidelines and involves the construction of approximately 300 m of a 1.5 m RCP along Brisbane Street and Short Street. The cost associated with the works is estimated as being $1,870,000.

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1 Introduction

1.1 Background

Aurecon have been engaged by Scenic Rim Regional Council (SRRC or ‘Council’ hereafter) to undertake an assessment of the stormwater network in the townships of both Beaudesert and Boonah. This project was commissioned in response to ongoing flooding issues that exist within these localities with the ultimate aim of understanding and reducing flood risk.

Note that this report discusses the findings specific to Beaudesert only.

The study involves:

- Assessing the existing stormwater network to identify areas/locations where the local drainage system is not performing adequately and is causing flooding issues
- Developing and testing mitigation strategies aimed at improving the performance of the drainage system in these areas
- In conjunction with Council, selecting a preferred mitigation solution to take forward to Council’s next phase of evaluation (ie a future Capital Works Program)

The assessment has been completed using hydrologic and hydraulic models which have been developed specifically for this project (based on current catchment development levels including approved development application works ie not future catchment development levels). These computer models allow the prediction of surface and subsurface flow interaction, the results of which can be interrogated and visualised within GIS software. The development, parameterisation and performance of the models are presented later in the report.

Figure 1 shows the project area and key place-names/features discussed within this report.

Note that all cost estimates provided in this report are to be considered preliminary only.

Figure 1 Project location and key features

1.2 Objective of the study

As per the brief the objective of the study can be defined as:

- Determining the current performance of the stormwater system, and
- To recommend optimal solutions to improve these systems to deliver the desired level of service to the community

1.3 Catchment description

The town of Beaudesert is affected by multiple flood sources including Spring Creek (a regional flood source), as well as local creeks and ephemeral overland flowpaths through urban sub-catchments (local flood sources). Refer to Figure 2 which shows:

- A: Spring Creek (west branch) – regional flood source
- B: Spring Creek (east branch) – regional flood source
- C: Fishers Gully – local flood source
- D: Unnamed creek – local flood source

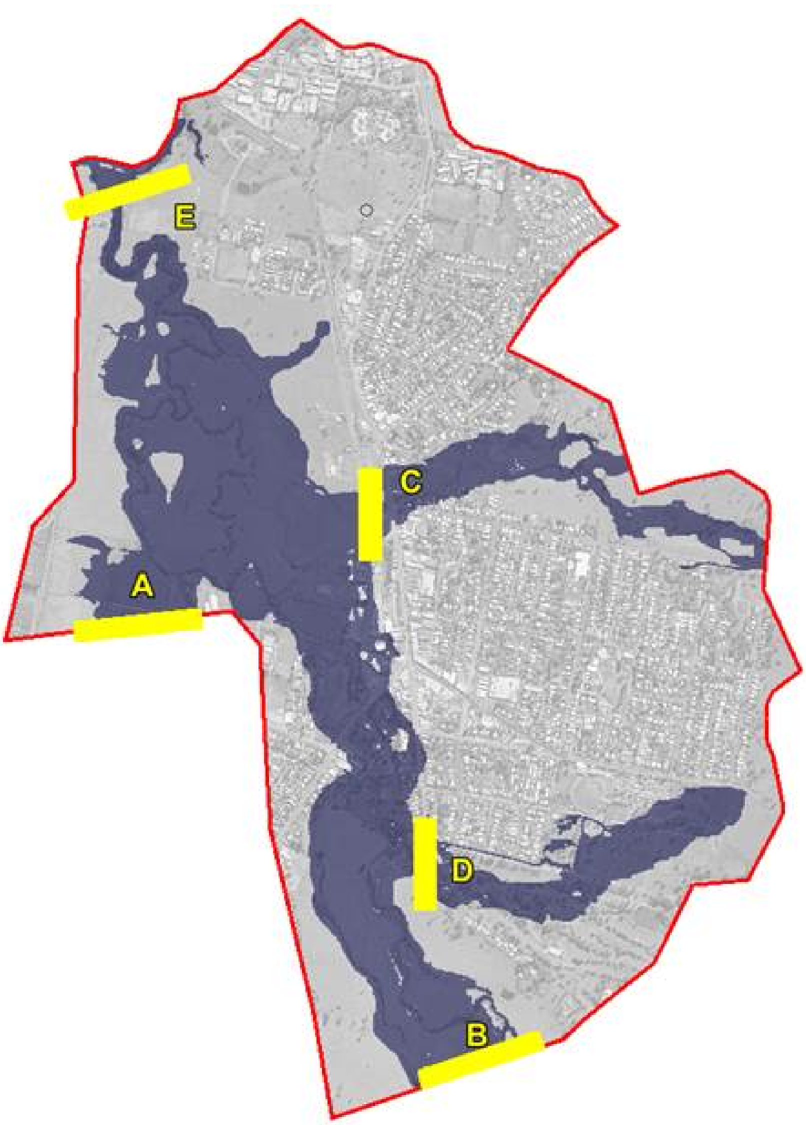


Figure 2 Flood sources and flow comparison locations

The Spring Creek catchment is approximately 67 km^2 in total area, mainly stretching to the south of Beaudesert. The creek flows in a predominantly northerly orientation before discharging to the Logan River 3 km north-west of Beaudesert (ie at location E).

The Fishers Gully catchment has an area of approximately 3.9 km^2 and in its upper, steeper reaches is mainly undeveloped bushland. The lower reaches of the catchment contain some urbanisation but this accounts for only 15% of the overall catchment area.

Likewise, the unnamed creek catchment has an area of approximately 3.5 km^2 and contains a mixture of ongoing development and bushland, as well as a golf course. Urbanisation accounts for almost 30% of the overall catchment area.

In the vicinity of the town centre, local urbanised sub-catchments east of Brisbane Street convey flow towards Spring Creek which during minor events is captured in the stormwater system. However during significant rainfall events when the capacity of the system is exceeded the excess runoff is conveyed via overland flow mechanisms.

2 Background data and project inception

2.1 Project inception and site visit

A project inception meeting was held on 14 May 2014 at SRRC offices in Beaudesert. Site visits were carried out for both Beaudesert and Boonah with Aurecon representatives accompanied by SRRC operations staff familiar with the Beaudesert and Boonah drainage systems. The SRRC personnel were able to offer their knowledge of the system's behaviour and performance during recent flood events. This was extremely beneficial as it provided a good understanding of where potential flooding issues should be observed when reviewing the modelling results once available.

The site visit also provided the opportunity to gain an accurate representation of the existing catchment conditions. It also aided in familiarising the project staff with the overall technical challenge and provided a better understanding of key elements that directly relate to the analysis process eg catchment topography, floodplain/channel vegetative cover, existing hydraulic structures, etc.

The site visit involved photographing and taking notes of the key features of the drainage system. Figure 3 shows a sample image taken of the open channel downstream of Brisbane Street in Beaudesert.

Figure 3 Image of the town drain downstream of Brisbane Street

Following completion of the site visits to Beaudesert and Boonah, Aurecon's Project Leader met with key Council personnel who would be involved in running the study. The meeting discussed several key aspects of the project including:

- Data requirements
- Communication protocols
- Scope
- Project management and client liaison/updates
- Analysis techniques and methodologies
- Timeframes

2.2 Data collation and review

A study of this nature requires a substantial amount of data to be collated during the initial stages of the project. SRRC had already provided significant amounts of data to Aurecon as part of a separate study (the Logan River Flood Study Upgrade) for which permission was granted to use for this project. This included:

- Topographic data (current SRRC LiDAR)
- Aerial imagery
- Cadastral boundary data

In addition SRRC provided the following information specific to this project:

- Images of features within catchment
- Structural survey data
- Stormwater GIS layers for Beaudesert
- Previous report information (Preliminary Review of the Main Town Drain, Kinhill Cameron McNamara, April 1990, Hydraulic Assessment Report – Beaudesert Town Centre and Inner Beaudesert Bypass Flood Modelling, Aurecon. June 2011)
- Current development application data/reports that may affect the drainage system performance
- Historical storm data (photos, anecdotal information)

This data was used in the development, calibration and verification of the hydrologic/ hydraulic models.

2.3 Client communication

Throughout the course of the project regular contact was maintained with SRRC's Project Manager. This included email and phone communication as well as three meetings (ie a project inception meeting, a System Assessment workshop and an Options Assessment workshop).

SRRC's Project Manager also assisted in visiting and photographing key features within the project area at the request of Aurecon's Project Leader to help clarify and understand instances of uncertainty such that the model could be developed as accurately as possible. This included the culvert beneath Helen Street and the rear of the Coles shopping centre.

Project feedback was also communicated regularly to SRRC outlining project progress with respect to its financial performance and program.

The regular and open communication lines that were established added to the efficiency with which the study could be carried out.

3 Hydrologic analysis

The hydrologic analysis can be broken into three parts:

- The major regional flood hydrology (ie Spring Creek)
- The local creek hydrology (ie Fishers Gully and the unnamed creek south of Beaudesert – see Figure 1)
- The local sub-catchment hydrology contributing to the pipe network within the town

These were modelled using the RAFTS hydrologic modelling software. RAFTS is a non-linear runoff routing model used extensively throughout Australia. It has been shown to work well on catchments ranging in size from a few square metres to thousands of square kilometres of both urban and rural nature, and is therefore suitable for use in this project.

3.1 Spring Creek

The RAFTS hydrologic model developed by Aurecon as part of the *Hydraulic Assessment Report – Beaudesert Town Centre and Inner Beaudesert Bypass Flood Modelling* (Jun 2011) was used to extract design event flows for Spring Creek. Refer to this report for further information on the hydrologic modelling of Spring Creek.

It was found that the 2011 study was based on the Gold Coast City Council (GCCC) temporal patterns for its design storms. The standard temporal patterns that are typically used are those of the Australia Rainfall and Runoff (AR&R) Guidelines. As discussed with and requested by Council, this is the preferred approach and was adopted for this study. It is also consistent with the update to the Logan River study which Aurecon are currently carrying out for Council.

Aurecon completed sensitivity testing using both sets of temporal patterns and the results from the hydrologic model are very similar, thereby indicating that the choice will in no way significantly affect the overall study findings. The difference in peak flows on Spring Creek is typically in the region of +/-3% or less (refer to Table 1 and Figure 2). This would translate to a minimal variation in terms of predicted flood levels.

Table 1 Peak flow comparison between temporal patterns – Spring Creek

Location	Waterway	100 year ARI peak flow		% Difference
		GCCC temporal pattern	AR&R temporal pattern	
A	Spring Creek (east)	226	230	2%
B	Spring Creek (west)	239	231	-3%
E	Spring Creek	455	439	-4%

3.2 Local creeks

The RAFTS hydrologic model developed by Aurecon as part of the *Hydraulic Assessment Report – Beaudesert Town Centre and Inner Beaudesert Bypass Flood Modelling* (Jun 2011) was used to extract design inflows for Fishers Gully. Refer to this report for further information on the hydrologic modelling of Fishers Gully.

A separate RAFTS hydraulic model was developed for the unnamed creek south of the town (refer to Table 2 and Figure 2).

The standard AR&R temporal patterns were also used for the RAFTS modelling of the local creek catchments. Aurecon completed sensitivity testing using both sets of temporal patterns and the results extracted from the hydrologic model are very similar, thereby indicating that the choice will in no way significantly affect the overall study findings. The difference in peak flows is typically in the region of +/-5% (refer to Table 2 and Figure 2). This would translate to a minimal variation in terms of predicted flood levels.

Table 2 Peak flow comparison between temporal patterns – local creeks

Location	Waterway	100 year ARI peak flow		% Difference
		GCCC temporal pattern	AR&R temporal pattern	
C	Fishers Gully Creek	100	105	5%
D	Unnamed creek	77	85	9%

3.2.1 Model parameterisation

The model that was developed by Aurecon for the unnamed creek south of the town was parameterised as per the Fishers Gully RAFTS hydrologic model developed by Aurecon as part of the *Hydraulic Assessment Report – Beaudesert Town Centre and Inner Beaudesert Bypass Flood Modelling* (Jun 2011).

Figure 4 shows the sub-catchment discretisation for the new model that was developed, as well as the Fishers Gully model. Table 3 summarises the key sub-catchment parameters.

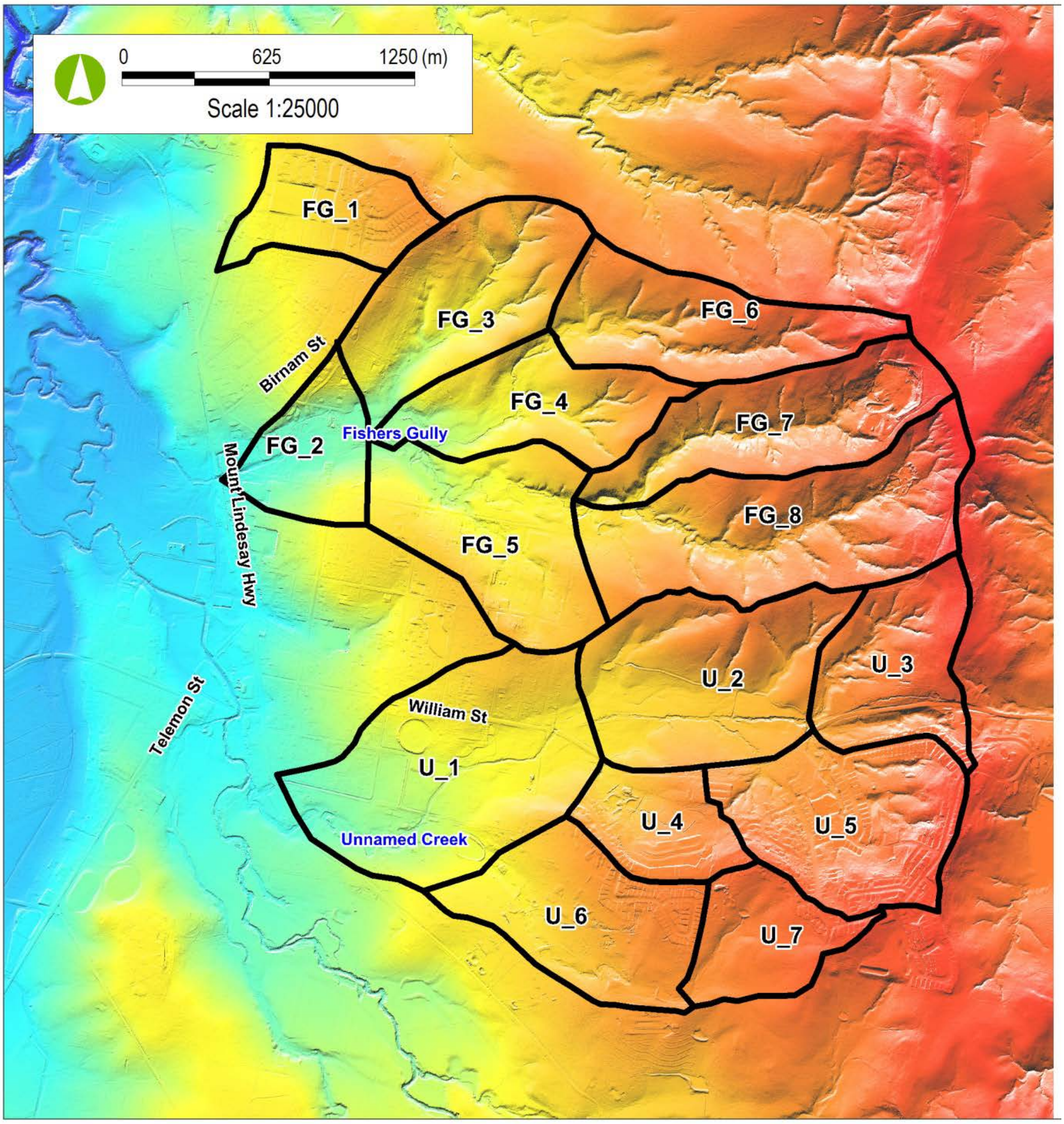


Figure 4 Sub-catchment discretisation of local creeks

Table 3 Sub-catchment parameterisation

Catchment ID	Total area (ha)	Catchment Mannings 'n' (in value)	Percentage impervious (%)	Vectored slope (%)
FG_1	31	0.037	34	3.7
FG_2	28	0.048	25	6.2
FG_3	58	0.070	5	5.3
FG_4	44	0.070	5	5.5
FG_5	60	0.045	27	3.1

Catchment ID	Total area (ha)	Catchment Mannings ‘n’ (in value)	Percentage impervious (%)	Vectored slope (%)
FG_6	52	0.070	5	6.7
FG_7	56	0.070	5	7.7
FG_8	89	0.070	5	9.0
U_1	89	0.057	17	1.5
U_2	69	0.070	5	2.6
U_3	42	0.070	5	5.5
U_4	27	0.025	45	6.6
U_5	62	0.025	45	5.8
U_6	54	0.062	12	3.1
U_7	30	0.070	5	5.1

Note that initial and continuing losses were set to 0 mm and 1.1 mm/hr respectively as per the values used in the previous study.

3.3 Local sub-catchment hydrology contributing to the pipe network

The hydrology of the local sub-catchments contributing to the pipe network was not modelled using RAFTS. Instead the rainfall was applied directly to the 2D domain of the TUFLOW hydraulic model. Accordingly the routing of the flow occurs within the hydraulic model. This is termed a ‘direct rainfall’ or ‘rain-on-grid’ approach and is commonly used for studies of this nature. Refer to Section 4 for further information regarding the hydraulic model.

3.4 Review of current development application data

SRRC provided Aurecon with information relating to current development applications so that it could be factored into the hydrologic analysis. Five sites were considered at the request of Council and the outcome of Aurecon’s review is summarised in Table 4.

Table 4 Summary of development application review

Item No.	Site	Comment	Outcome
1	James St	It would be beneficial to get the 3D design of the proposed earthworks pad so that it can be incorporated into our model if it is easily acquired by Council. It is not crucial however, so if it is not easily obtained, or will take some time to obtain then we will proceed without it. It is not located near, nor will it affect, the main problem area on Brisbane St/Mt Lindsay Hwy	Not to be included at Councils request – will have no major bearing on model results

Item No.	Site	Comment	Outcome
2	Brookland Stage 1	This development falls outside of the limits of the hydraulic model and will therefore be accounted for in the hydrologic model. It will be incorporated as a fully developed site within the hydrologic model. Note that no detailed representation of any detention basins/stormwater infrastructure will be included as it is not expected that they would measurably affect the overall subcatchment behaviour. The scale of the flows on a sub-catchment scale will dominate. Furthermore it essentially implies that any development detention facilities are at capacity on commencement of a flood event which is a prudent and conservative approach used as standard on studies of this nature	Aurecon to incorporate development – no further information required
3	Banksia Greens	As per item 2	Aurecon to incorporate development – no further information required
4	Beaudesert Heights	As per item 2	Aurecon to incorporate development – no further information required
5	St Mary's School	Minor development on fringe of floodplain - it will have no measurable effect on hydraulic behaviour. Not to be incorporated	No action required

3.5 Design event modelling

Having updated the previous and newly developed hydrologic models with the AR&R temporal patterns, and incorporated current development application information where necessary the hydrologic models can be reliably used to extract discharge information for use as boundary conditions in the hydraulic model.

As per the brief, the following design events were simulated within the hydrologic model:

- 2 year ARI
- 5 year ARI
- 10 year ARI
- 50 year ARI
- 100 year ARI

Note also that an assessment of the critical storm duration on Spring Creek in terms of peak discharge was carried out based on a review of the hydrologic model results. This showed that a 4.5 hour event yielded the peak discharge at Beaudesert. This was further confirmed within the hydraulic model.

Critical duration analysis of the local creek and town catchments was also undertaken and showed that the critical duration for these catchments was 1 hour. This is a more intense but shorter rainfall event than the 4.5 hour event, and is typical of the type of event that will cause issues for urban pipe systems.

Accordingly, the modelling analysis used the following combinations for a given ARI when looking at the performance of the drainage network in Beaudesert:

- A 4.5 hour storm on Spring Creek and on local catchments (ie leading to high tailwater levels but low discharge within the pipe system)
- A 1 hour storm on Spring Creek and on local catchments (ie leading to low tailwater levels but high discharge within the pipe system)

This therefore takes into account the potential for high tailwater levels in Spring Creek to affect the pipe network capacity.

3.6 Historic event modelling

An calibration/verification of the model was undertaken for two historical events at the request of Council. These were both short, intense rainfall bursts that lasted between 30 and 45 minutes, a duration which could be expected to generate flash flooding on the local catchments in and around the township of Beaudesert. The events occurred on:

- The afternoon of (approximately 5:00pm) 24 March 2013 (30 minutes duration approximately, with 30 mm of precipitation recorded)
- The evening of (approximately 8:00pm) 23 November 2013 (45 minutes duration approximately, with 46 mm of precipitation recorded)

Rainfall data was obtained from the Bureau of Meteorology for these events from the Drumley Street rain gauge and was incorporated into the RAFTS hydrologic model. This gauge is located on the outskirts of the town centre and consequently gives a good indication of the localised rainfall that would have fallen across the nearby catchments. This was the only station in the vicinity which had data for these events.

In comparing this data against IFD data for the town of Beaudesert, indicates that the events had the following ARI:

- March 2013 had an ARI of approximately 2 years
- November 2013 had an ARI of approximately 5 years

The discharge information was then extracted from the hydrologic model and used within the hydraulic model. This is further discussed in Section 4.6 of this report.

4 Hydraulic model development

A TUFLOW hydraulic model was developed by Aurecon to represent and assess the hydraulic behaviour within the project area. TUFOW is a widely used, reputable and robust software that is routinely used for projects of this nature.

The approach to the modelling was to build a combined 1D-2D model such that interaction between surface (2D domain) and sub-surface (1D pipe network domain) flows can occur. The development and parameterisation of the model is discussed in the following sections.

4.1 Simulation information

The hydraulic model has been developed to run as an unsteady simulation, thereby taking into account temporal variation in discharge and incorporating the effects of storage in the propagation of the flood through the drainage system. A cell size of 5 m was selected and the simulation ran with a timestep of 1 second. Based on the maximum depths of flow within Spring Creek this was deemed a suitable approach. The ratio of the grid-size to timestep is within industry norms thereby leading to manageable runtimes (in the order of 3 to 6 hours depending on the event duration being modelled).

4.2 2D domain and model extent

The 2D overland model domain was based on a Digital Elevation Model generated from the SRRC LiDAR data that was provided to Aurecon for use in the current Logan River Flood Study upgrade. The model contains over 4 km of Spring Creek's main channel as well as portions of the local catchments east of Brisbane Street. In total the domain covers an area of approximately 5 km^2. Refer to Figure 5 which shows the model extent.

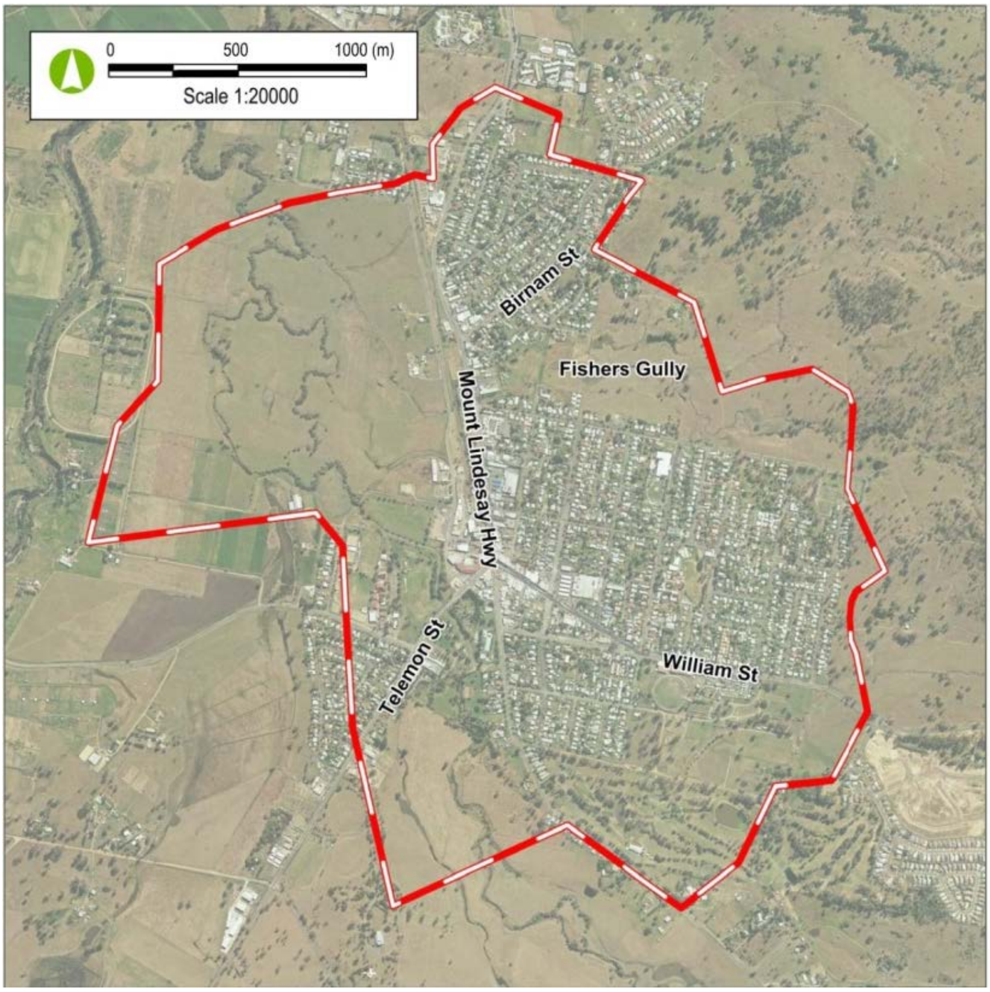


Figure 5 Hydraulic model extent

4.3 1D domain

The 1D pipe network domain is based on SRRC's pipe network GIS layer and is shown in Figure 6 – this includes pits, manholes, pipes and culverts, albeit a refined representation of the entire system to focus on the key components of the network. This has been hydrodynamically linked to the 2D overland domain to allow interaction between surface and sub-surface flows. The pipe system was incorporated using a TUFLOW '1d_nwk' layer.

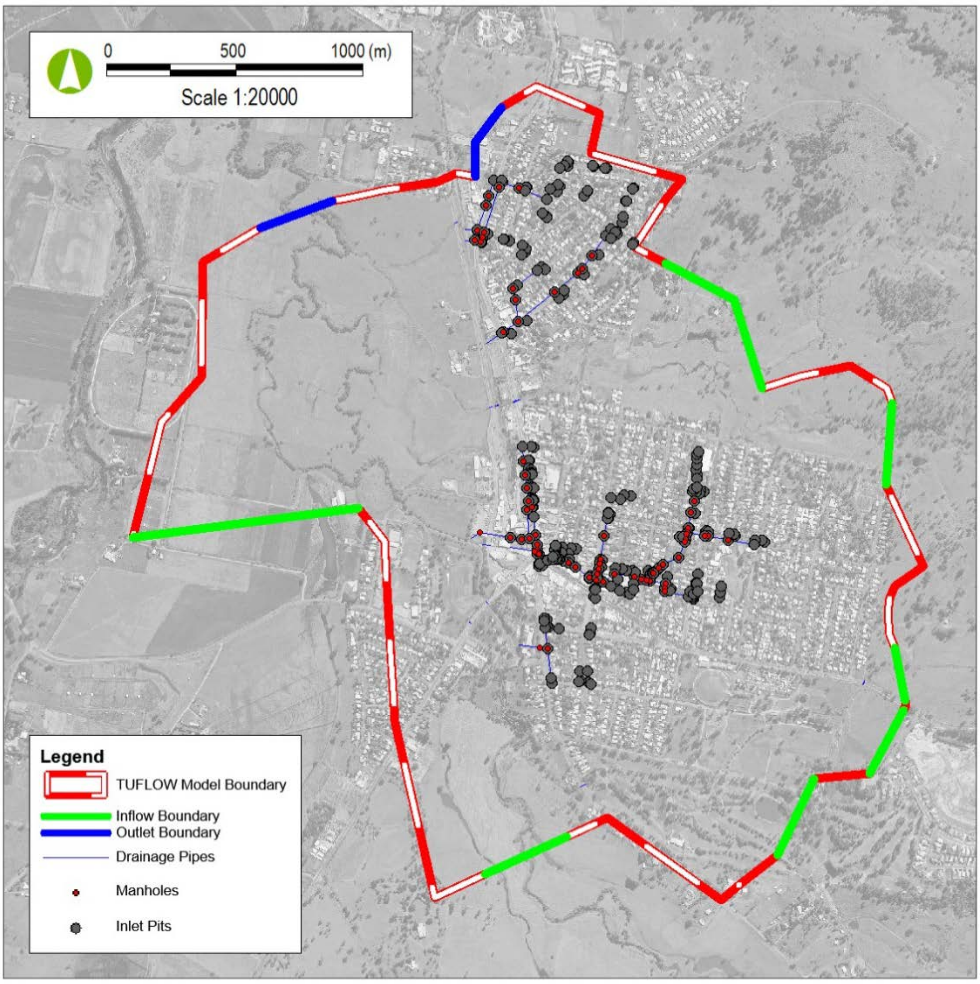


Figure 6 Model 1D network domain

4.4 Roughness discretisation

The digitisation of land use was based on the aerial imagery provided to Aurecon for use in the current Logan River Flood Study upgrade. Refer to Figure 7 which shows the land use digitisation within the model domain and adopted Manning's n values.

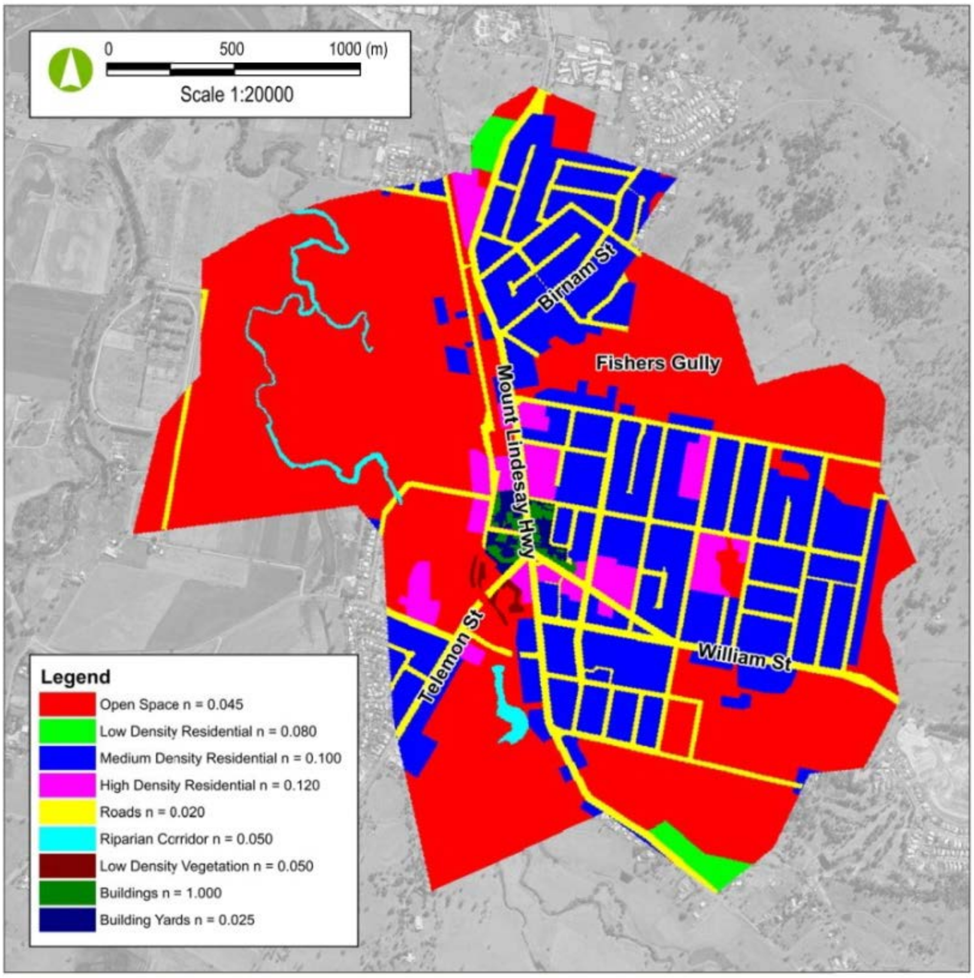


Figure 7 Model roughness discretisation

4.5 Structural representation

All major culverts and bridges within the model domain were incorporated into the model. Data was extracted from the 2011 study where possible but certain data was required due to it either being missing or recently upgraded. SRRC organised a survey of the structures to collate this data and provided it to Aurecon. This is summarised in Table 5.

Table 5 Summary of model cross-drainage structures

Location ID	Structure	Data required
1	Mt Lindsay Culverts – Fishers Gully	No (available from June 2011 Study)
1a	Pedestrian bridge	Yes (provided by SRRC)
2	Helen St Rail Culverts – Fishers Gully	No (available from June 2011 Study)
3	Helen St Road Culverts – Fishers Gully	No (available from June 2011 Study)
4	Hereford St Bridge	No (available from June 2011 Study)
5	Telemon St – upgraded recently (to culverts)	Yes (provided by SRRC)
5a	Telemon St secondary culvert – upgraded recently	Yes (provided by SRRC)
6	Pedestrian Bridge in Park between McKee St & Telemon St	Yes (provided by SRRC)

Location ID	Structure	Data required
7	McKee St Bridge	No (available from June 2011 Study)
8	Brisbane St/Kerry Rd culvert	Yes (provided by SRRC)
9	Albert Street culvert	Yes (provided by SRRC)

4.6 Model boundary conditions

Inflows were extracted from the hydrologic model and applied within the hydraulic model as shown in Figure 8. Also direct rainfall was applied to the local sub-catchments within the model domain as per Figure 8. A normal depth water slope was applied at the downstream boundary following standard practice.

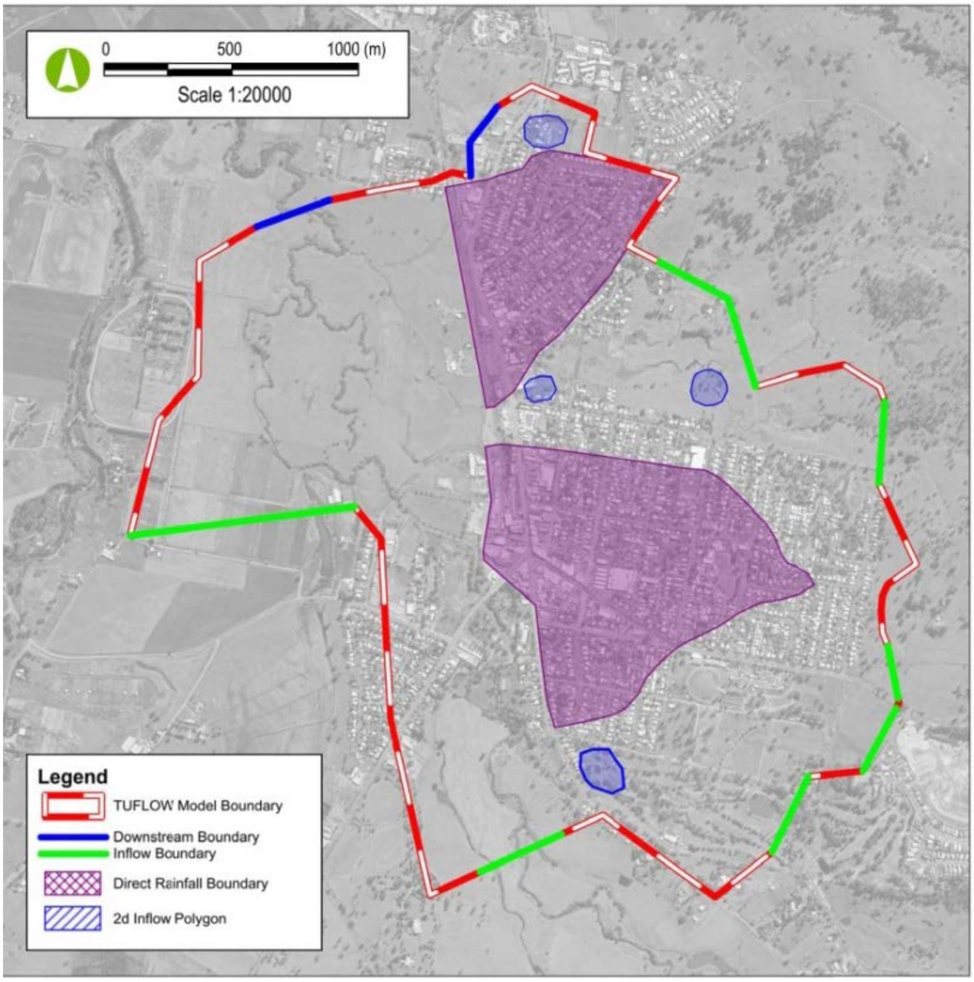


Figure 8 Model boundary layout

4.7 Stability, robustness and predictive accuracy

The model is complex in terms of its build and contains a significant amount of detail. It has been checked to ensure it performs in a stable manner. A check of the 1D pipe network domain shows excellent stability, similarly for the 2D domain. The overall mass balance is approximately 0.1% which is indicative of a robust and reliable model. The flood profile along Spring Creek was also compared against the June 2011 results (which covered a much larger length of channel) and excellent agreement was observed – typically the flood levels were within a tolerance of 0.05 to 0.10 m.

A successful calibration/verification exercise was also carried out – this is discussed in Section 5.

4.8 Refinement of model for iterative testing

As outlined in Section 7.2, the model extent was refined and reduced for the iterative testing of the various mitigation options to focus on the key problem area identified during the System Assessment phase of the project.

This involved trimming the model boundary to only contain the sub-catchment causing the flooding at the problem location. The refined model was then run on a smaller grid (3 m) and time-step of 1 second thereby increasing its accuracy and resolution. Note that the calibration events were re-run through this refined model and generated the same flood depths as the larger model showing excellent consistency between both (refer to Section 5 for discussion of the calibration).

The advantage of creating the refined localised model for the iterative testing and optimisation of a preferred solution was that the model run times were reduced dramatically. This allowed multiple permutations and iterations of mitigation options to be undertaken efficiently – if these had been done in the larger model where a single run could take almost an entire work day progress would have been far too slow.

5 Calibration and verification

A calibration/verification of the model was undertaken for two historical events. These were both short, intense rainfall bursts that lasted between 30 and 45 minutes, a duration which could be expected to generate flash flooding on the local catchments in and around the township of Beaudesert. The events occurred on:

- 24 March 2013 (30 minutes duration approximately, with 30 mm of precipitation recorded)
- 23 November 2013 (45 minutes duration approximately, with 46 mm of precipitation recorded)

Rainfall data was obtained from the Bureau of Meteorology for these events from the Drumley Street rain gauge (this is located on the outskirts of the town centre and consequently gives a good indication of the localised rainfall that would have fallen across the nearby catchments). This was the only station in the vicinity which had data for these events.

In comparing this data against IFD data for the town of Beaudesert the events had the following ARI:

- March 2013 had an ARI of approximately 2 years
- November 2013 had an ARI of approximately 5 years

Generally speaking the catchments and drainage system coped well with both of these events and no significant flooding in urbanised areas was predicted in the model, with the exception of Brisbane Street. Following a site visit to the area in the company of SRRC personnel it was confirmed that the model predictions agreed with the anecdotal evidence and recollection of these past events, ie there were no major issues apart from flooding that occurred on Brisbane Street. Note that no gauge data or recorded flood level marks were available.

Photographic evidence from the March 2013 event (refer to Figure 9) suggests that flood depths of approximately 0.3 m on the western footpath on Brisbane Street were experienced. Therefore at the road gutter (ie stepping down from the kerb) this would have been approximately 0.4 m.

Figure 9 Photo taken on Brisbane Street on 24 March 2013 (courtesy of SRRC). Note the depth of flooding at bench on footpath – estimated to be approximately 0.3m (assumed to be at or close to the peak of the flood)

The model predictions show peak depths of flooding in Brisbane Street of approximately 0.4 m during the March 2013 event. A peak depth of 0.5 m was predicted for the November 2013 event, which is expected considering it was a more severe event. Refer to the flood mapping provided in Appendix B.

The model is therefore deemed to be accurately predicting the hydraulic behaviour within the town of Beaudesert. The model predictions as to where urbanised flooding is prone to occur is in agreement with what has been observed during past events, and the extent and depth of flooding in Brisbane Street is in general agreement with what can be garnered from reviewing anecdotal and photographic evidence.

6 System assessment

6.1 Overview

A System Assessment workshop was held at SRRC offices on 30 June 2014 (minutes are provided in Appendix G). This workshop was used to present the findings of the hydrologic and hydraulic modelling that had been completed to date. This included discussion of the data collation, the model development phase, and the calibration/verification of the hydraulic model.

Having presented the findings to the SRRC project team members there was consensus that the model was replicating the historic flooding adequately and that it was suitable for use in assessing design events and mitigation options.

Discussion then moved on to identifying the key problem areas within the project area.

Based on a review of the various design event flood modelling outputs it was apparent that generally (with the exception of Brisbane Street) the network copes quite well with event magnitudes that stormwater systems are generally designed to cater for (ie 2 year to 10 year ARI flows). Refer to the flood mapping presented in Appendix A which outlines the peak flood depths experienced throughout the modelled area.

Storm events of these magnitudes do not lead to significant overland flow, or concentrated depths of flow that affect properties other than Brisbane Street. This is in agreement with the information obtained through the site visit to Beaudesert with an SRRC operational staff member who had a good understanding of the drainage system and could recall the historical flood events of 2013.

The primary problem area where pipe capacity and/or inlet capacity within the stormwater system is leading to significant overland flow is the trunk drainage that collects runoff from the sub-catchment east of the Brisbane Street sag as shown in As witnessed during the historical events and as predicted by the hydraulic model, significant overland flow ponds at the sag point in the street, close to where the main town culvert runs.

The stormwater network consists of a 2.4 m x 1.2 m RCBC between Anna Street and Brisbane Street, which then transitions to a 3.6 m x 1.35 m RCBC downstream of Brisbane Street before discharging to Spring Creek via a section of open channel with a culvert beneath Helen Street.

Overland runoff is observed to make its way south down Brisbane Street, and also from William Street. However with the pipes running along Brisbane Street being of limited capacity (approximately 0.3 m and 0.45 m RCP), coupled with the main town drain RCBCs flowing full, the runoff cannot enter the sub-surface drainage system quickly enough compared to the volume that is arriving and ponding at the sag.

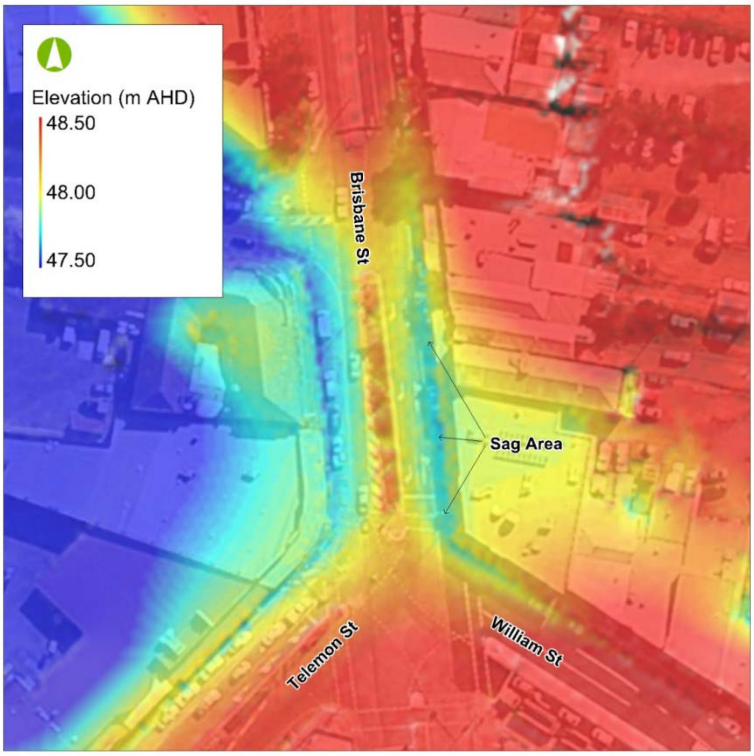


Figure 10 Brisbane Street sag

To mitigate this flooding problem the capacity of the underground network through this location needs to be increased or detention/diversion provided upstream to reduce the peak discharge arriving at Brisbane Street.

6.2 Required level of service

Based on the historic calibration it is clear that flooding on Brisbane Street occurs following relatively low magnitude rainfall events, with a 2 year ARI flood causing considerable inundation to the roadway and adjacent business premises.

Another issue which compounds the flooding associated with lack of system capacity is traffic passing through the ponded runoff generating significant wave action which propagates into the business premises.

Accordingly, an improved level of service is required. The Queensland Urban Drainage Manual (QUDM – Table 7.3.1) recommends that 'Central business and commercial' development be provided with 10 year ARI flood immunity.

In discussions with SRRC, it was agreed that at a minimum the level of service being targeted would mitigate the flooding that has been experienced at Brisbane Street following the recent flood events of 2013. With the November 2013 event being approximately a 5 year ARI, this was set as the minimum level of service to be attained, with a desirable immunity of 10 year ARI being preferred.

6.3 Summary of identified deficiencies for options assessment

The primary area where a problematic deficiency in the Beaudesert stormwater system occurs is at Brisbane Street. This has been witnessed following two historic flood events of approximately 2 year and 5 year ARI magnitude that occurred in March and November of 2013.

The flood modelling that Aurecon has carried out reinforces this fact and excellent correlation is achieved between the anecdotal flood records and the TUFLOW model predictions.

The outcome of the System Assessment workshop was that the SRRC personnel were satisfied that the Options Assessment phase of the project should focus on the Brisbane Street issue with a view to mitigating the flooding in line with the desired levels of service.

7 Preliminary options assessment

7.1 Overview

Following on from the System Assessment workshop a number of options were identified to be taken forward for consideration as part of the Options Assessment phase (refer to minutes provided in Appendix H). The options are outlined in the following sections with an approximate cost estimation also having been developed to assist in selecting a preferred mitigation strategy. In discussions with the Council, the level of service that the options were tested against was the 5 year ARI storm (ie similar to the November 2013 event). This provided an adequate baseline return period against which to identify and compare feasible and practicable solutions to the problem of flooding on Brisbane Street for this phase of the study.

7.2 Options methodology

As discussed in Section 4.8 a refined hydraulic model was developed to allow efficient testing, iteration and optimisation of the various mitigation options.

The extent of the refined model is shown below in Figure 11.

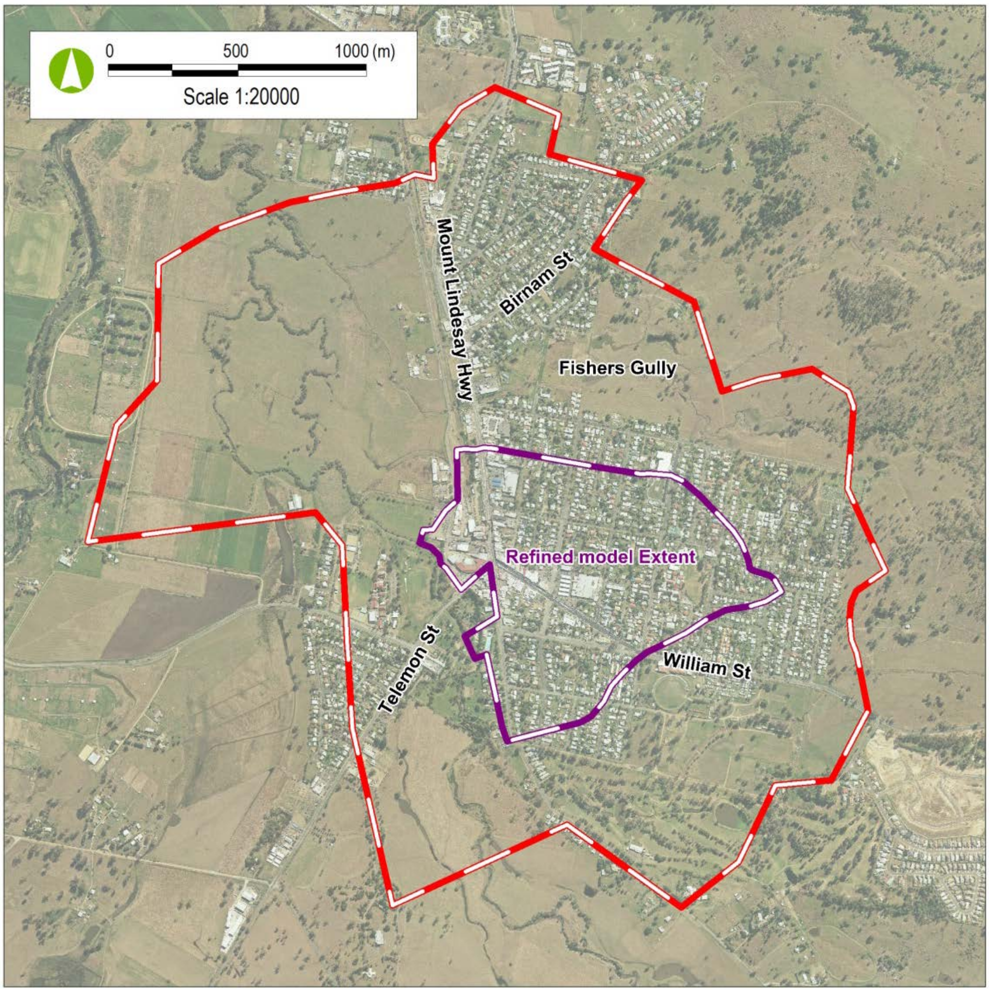


Figure 11 Extent of refined model for options testing

7.3 Options for consideration

The following seven options were identified and tested within the TUFLOW model, with the results of the analysis being presented in Appendix C:

- Option A – Provision of trunk drainage along Eaglesfield Street
- Option B – Provision of trunk drainage along Brisbane Street/Short Street and additional inlets
- Option C – Provision of trunk drainage along Anna Street/Albert Street
- Option D – Upgrade to Brisbane Street pipe (currently a 0.3 m/0.45 m diameter RCP) and provision of additional inlets
- Option E – Upgrade to Helen Street Culvert
- Option F – Combination of Option C and Option D
- Option G – Cutting slots through the median planting on Brisbane Street at the sag to allow water drain across the road and then away down Short Street

7.3.1 Option A: Provision of trunk drainage along Eaglesfield Street

This option involves running a pipe approximately (0.6 m diameter RCP) along Eaglesfield Street for 1 km as shown in Figure 12. Its purpose is to reduce the load on the main town drain by intercepting the upper catchment flows.

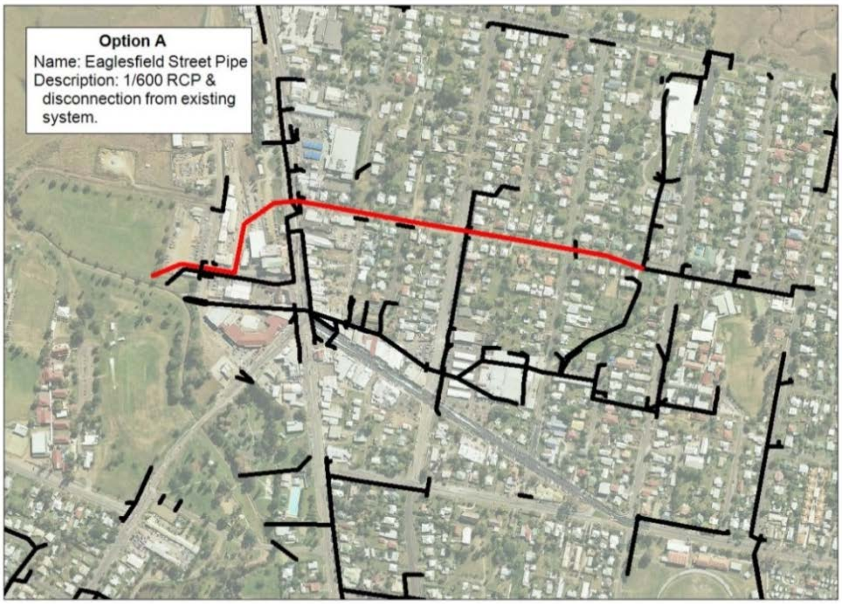


Figure 12 Option A schematisation

7.3.2 Option B: Provision of trunk drainage along Brisbane Street/Short Street and additional inlets

This option involves running a pipe (approximately a 1.2 m RCP) along Brisbane Street and Short Street (approximately 350 m) as shown in Figure 13. An additional six pits on Brisbane Street are also provided.

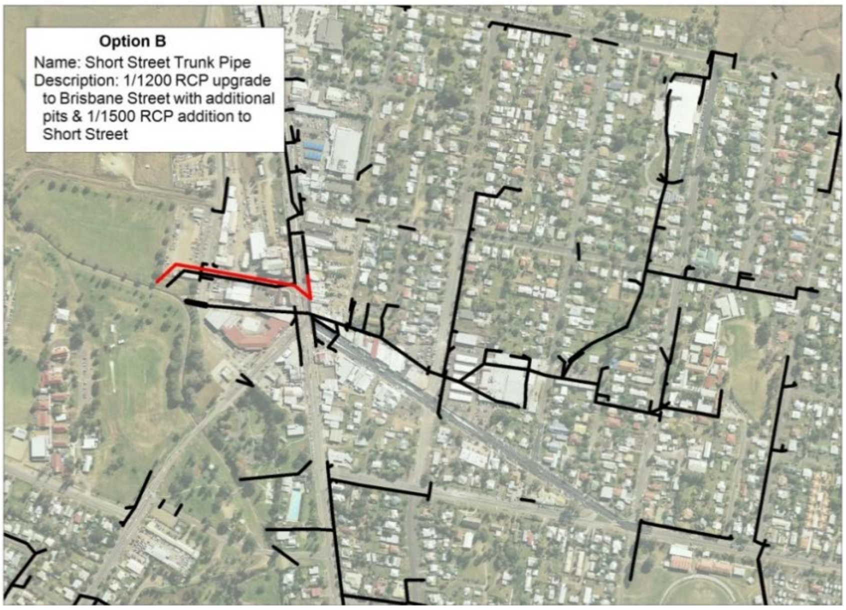


Figure 13 Option B schematisation

7.3.3 Option C: Provision of trunk drainage along Anna Street/Albert Street

This option involves running pipes (approximately 2/1.5 m diameter RCPs) along Anna Street and Albert Street as shown in Figure 14. This reduces the flow passing through Brisbane Street by diverting it further upstream within the catchment. This may require some reasonably deep excavation due to running the pipe against grade for a portion of its length.

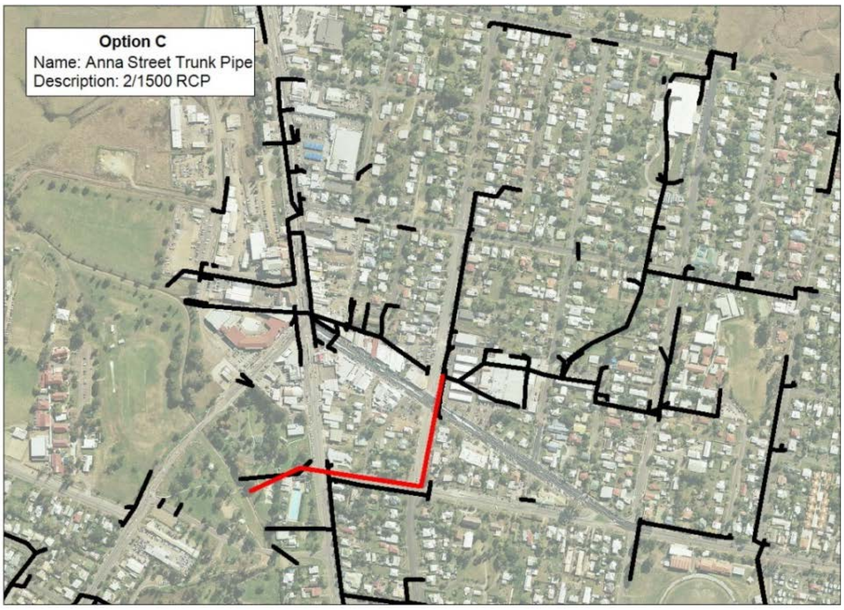


Figure 14 Option C schematisation

7.3.4 Option D: Upgrade to Brisbane Street pipe and provision of additional inlets

This option involves upgrading the main pipe draining the pits on the eastern side of Brisbane Street and connecting it into the main town drain culvert (a 1.2 m diameter RCP for a distance of approximately 140 m). Refer to Figure 15. The existing pipe is under capacity (ie varying between a 0.3 m/0.45 m RCP) and there is not enough inlet capacity. An additional six inlets along Brisbane Street are proposed.

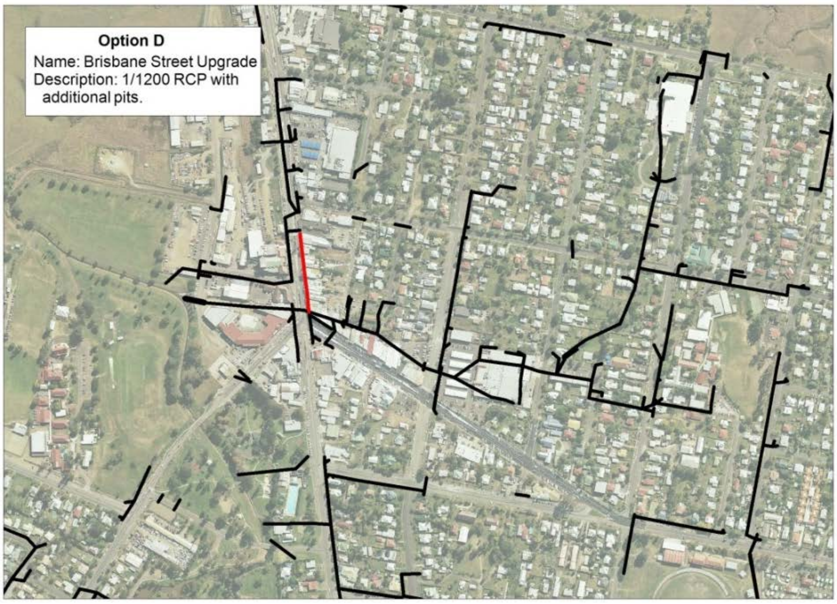


Figure 15 Option D schematisation

7.3.5 Option E: Upgrade to Helen Street culvert

This option involves upgrading the culverts at Helen Street from their current configuration of 4/1.2 m diameter RCPs. Refer to Figure 16.

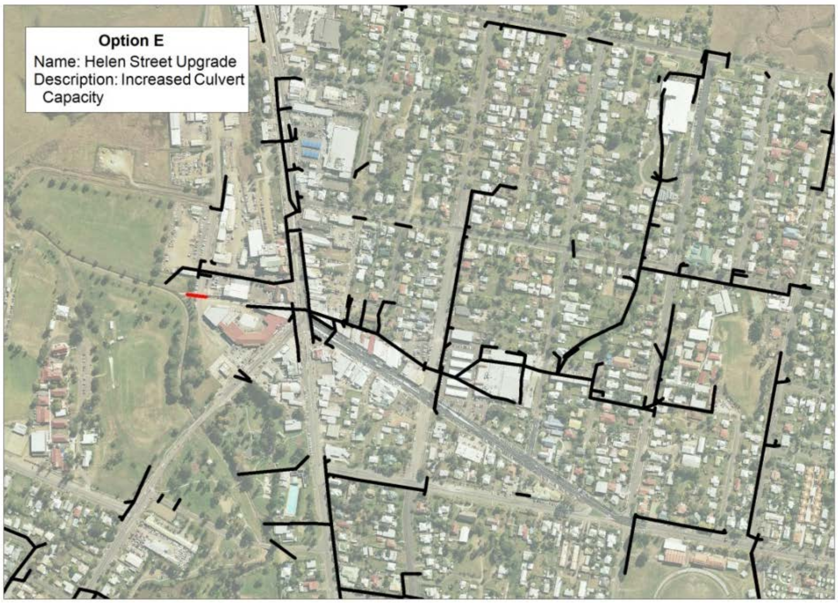


Figure 16 Option E schematisation

7.3.6 Option F: Combination of Option C and Option D

Refer to Options C and D for information. This combination was assessed because Option D by itself, even though it provides additional capture capacity in Brisbane Street, with the main drain running full its effectiveness is limited. However by diverting the flow from the upstream catchment along Anna Street and Albert Street, the flow rate within the main town drain at Brisbane Street is reduced thereby maximising the effectiveness of Option C.

7.3.7 Option G: Cutting slots through the median planting on Brisbane Street

In interrogating the DEM provided by Council and assessing the flood behaviour on Brisbane Street, it would appear that the median plantation ‘traps’ water on the eastern side of the road and prevents it from draining. This obviously may contribute to the flooding of the shops facing the street. The median plantation extends through the sag and therefore cutting a number of slots through this would allow water to drain across to the western side of the road before being conveyed down Short Street, thereby alleviating the flooding on the eastern side of the road. This may lead to reductions in flood levels of 0.10 to 0.15 m (ie the height of the median strip) during certain flood events. However consideration needs to be given to any adverse effects that could be experienced on the opposite side of the median to which the water is transferred.

7.4 Options comparison

Table 6 summarises the reduction in peak flood levels experienced in Brisbane Street as a result of each of the options outlined in Section 7.3. This relates to a 5 year ARI flood event (similar in magnitude to the November 2013 event).

Table 6 Hydraulic modelling results

Option	Name	Reduction in flood level at Brisbane Street (m)	Remaining inundation flood depth (m)
A	Eaglesfield St Trunk	<0.01	0.45
B	Short St Trunk	0.35	0.10 (gutter flow only)
C*	Anna Street Trunk*	0.06	0.40
D	Upgrade of Brisbane St	0.11	0.35
E	Upgrade of Helen St culverts	0	0.46
F*	Combination of Options C + D*	0.35	0.10 (gutter flow only)
G	Cutting slots in median strip	0.1m estimated approximately	0.35

*Also very beneficial in reducing flooding near the open drain west of Brisbane Street.

The options have been categorised in terms of their hydraulic performance/benefit as per Table 7.

Table 7 Summary of overall performance

Option	Name	Mitigation performance rating for Brisbane Street flooding
A	Eaglesfield St Trunk	Poor
B	Short St Trunk	Excellent
C*	Anna Street Trunk*	Fair *
D	Upgrade of Brisbane St	Fair
E	Upgrade of Helen St culverts	Poor
F*	Combination of Options C + D*	Excellent*
G	Cutting slots in median strip	Fair

*Also very beneficial in reducing flooding near the open drain west of Brisbane Street.

Table 8 summarises the initial cost estimates for each option. Note that these are indicatively only and have been undertaken purely on a high-level basis. Costing details are provided in Appendix E. Option E was not costed as it has no benefit in reducing flood levels in Brisbane Street. Option G was not costed at this stage – it is recognised that it is a comparatively cheap exercise.

Table 8 Summary of costing

Option	Name	Indicative Cost
A	Eaglesfield St Trunk	$ 1,061,000
B	Short St Trunk	$ 1,465,000
C	Anna Street Trunk	$ 4,995,000
D	Upgrade of Brisbane Street Pipes	$ 554,000
E	Upgrade of Helen St culverts	Not costed
F	Combination of Options C + D	$ 5,542,000
G	Cutting slots in median strip	Not costed

The results of the Options Assessment as presented show that varying levels of success are achieved through the various mitigation strategies that could be employed to alleviate the flooding problem in Brisbane Street. The cost of any drainage upgrade project also needs to be taken into account in selecting a preferred strategy.

Based on a review of the outcomes, the following options were deemed worthy of further consideration/discussion ahead of selecting a preferred option:

- Option B – Provision of trunk drainage along Brisbane Street/Short Street and additional inlets
- Option C – Provision of trunk drainage along Anna Street/Albert Street
- Option D – Upgrade to the Brisbane Street pipe (currently a 0.3 m/0.45 m diameter RCP) and provision of additional inlets
- Option F – combination of Option C and Option D

Option B and Option F yield a similar outcome (ie mitigation of ponded floodwater in Brisbane Street) but with Option B being much cheaper it was recommended as the preferred option. However, it was also noted that Option C and F are beneficial in reducing flood impacts at the open drain west of Brisbane Street by reducing peak discharges.

The options which were deemed unviable are:

- Option A – Provision of trunk drainage along Eaglesfield Street
- Option E – Upgrade to Helen Street Culvert

The expected limited cost of Option G (ie incorporating a few slots in the median strip) compared with the potential reductions in flood levels that may be achievable means this is also a recommended measure that could be employed by SRRC.

7.5 Preferred option

The Options Assessment workshop was held on 15 July 2014 at SRRC offices. The various mitigation strategies presented in Section 7.3 were presented to Council for their consideration.

It became apparent that only Option B and Option F (ie the Short Street trunk pipe, and the combination of drainage along Anna Street/Albert Street in conjunction with an upgrade to Brisbane Street respectively) could provide the desired level of service.

However with Option F being significantly more expensive, Option B was deemed the preferred solution.

In turning the focus to Option B at the workshop, the assembled SRRC personnel further developed the concept behind Option B to improve the overall design solution. This is further discussed in Section 8.

8 Detailed option assessment

8.1 Overview

The Options Assessment workshop resulted in the identification of a preferred concept to mitigate the issue of flooding in Brisbane Street. This was further developed during the workshop to formalise the finalised preferred option to be taken forward to the last stage of analysis.

The preferred option involves connecting the main town drain RCBC to the trunk pipe that would be running through Brisbane Street/ Short Street (refer to Figure 17 below which shows the schematisation of the preferred option).

This in turn would be able to reduce the discharge running through the open drain section of the town drain (which generates flooding to the yards of business premises) while also acting to convey the runoff that is making its way into the sag via a series of new inlets.

A series of hydraulic model runs were undertaken to optimise the design and the size of the infrastructure to meet the levels of service outlined in Section 6.2.

The final design attains a level of service of 10 year ARI in line with the QUDM guidelines and can be summarised as follows:

- Connection of a 1.2 m RCP into the town drain RCBC (approximately 25 m in length)
- Provision of a trunk 1.5 m RCP running along Brisbane Street before turning to run along Short Street. It then discharges to Spring Creek (total length of approximately 295 m)
- Connection of a 0.525 m RCP into the existing stormwater pipe as shown (approximately 20 m in length)
- Construction of six new manholes
- Construction of approximately eight new inlets
- Construction of a headwall at the outlet to Spring Creek

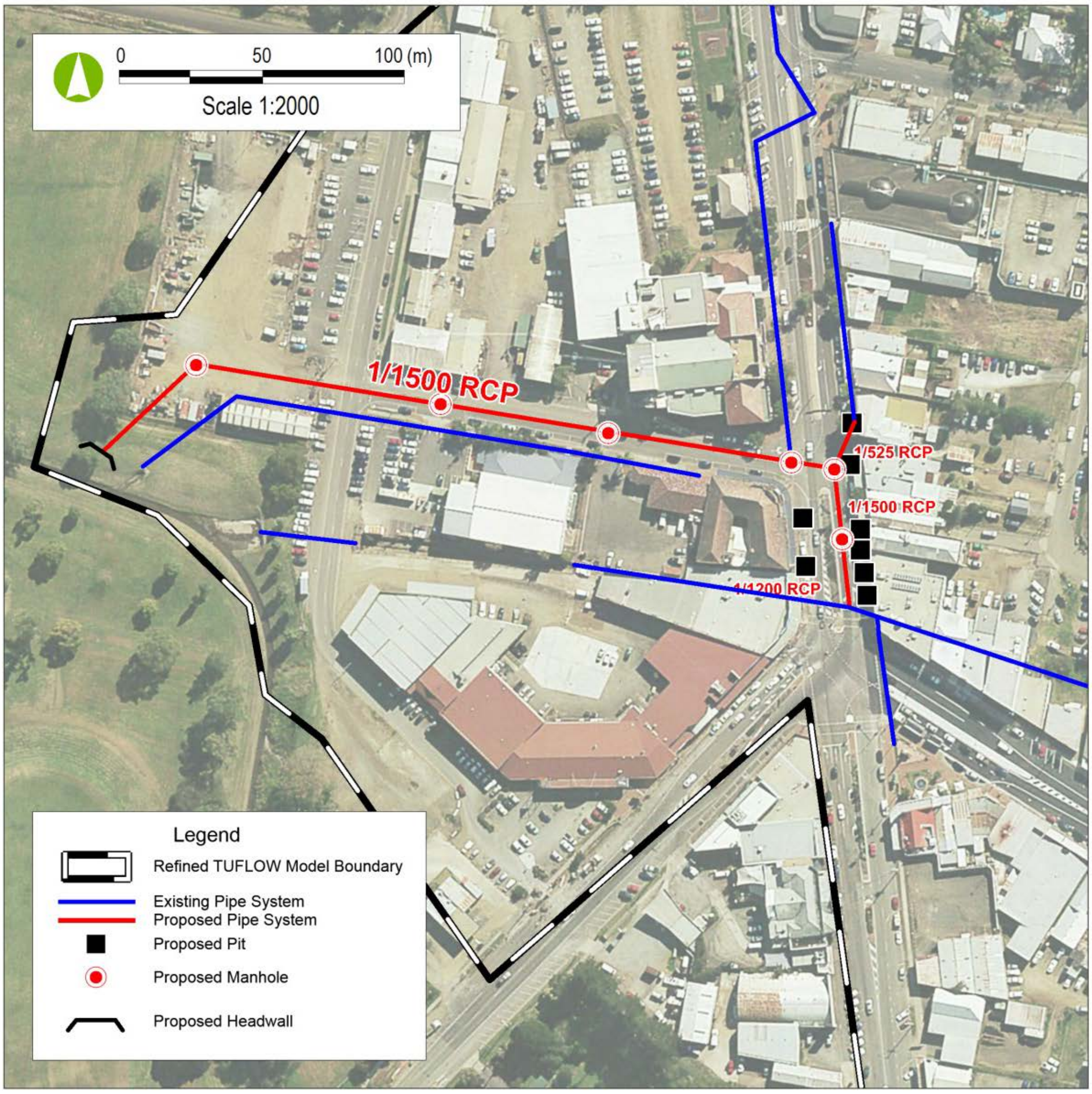


Figure 17 Schematic of preferred option

As mentioned the 10 year ARI level of service is in line with the QUDM guidelines – however, it should be noted that in terms of cost, provision of a 5 year ARI level of service for instance, will not lead to hugely significant savings. This is because it will most likely only result in the use of a slightly smaller, (and only marginally cheaper) pipe, yet trench construction costs, traffic management, etc, will still remain the same.

Flood mapping showing the outcomes of the preferred option modelling is presented in Appendix D for the 2, 5, 10, 50 and 100 year ARI events.

8.2 Site and route assessment

The preferred option will required works to be undertaken in Brisbane Street which will generate traffic management issues due to the importance of the route for freight and general vehicular movement in the region. This will require careful consideration by SRRC as to how this can be managed to minimise the potential impacts it may create in the locality. Safety of pedestrians and other road users is paramount but minimising disruption to traffic movement, the community and businesses in the area will also be factors in how this is managed.

Short Street is a secondary route that only serves local traffic travelling between Helen Street and Brisbane Street. Accordingly, while the bulk of the construction will occur along this street, its potential for disruption is reduced and consequently should be easier to manage. During the Options Assessment workshop this was noted as a benefit in undertaking construction works along this route.

The final 90 m of the 1.5 m RCP is to be constructed through what appears to be an unsealed Council yard before discharging to Spring Creek near the St Mary's school playing fields.

Excavations throughout the works area should not be excessive with typical trench depths of 3 m or less being required to place the pipes. A connection will also need to be made into the existing town drain RCBC in Brisbane Street which will involve breaking into the existing culvert or any chambers that exist. The details of this connection would be developed at the detailed design phase of the project.

Note that providing detailed traffic management/construction advice/plans is beyond the scope of the current engagement and would only be considered at detailed design phase.

8.3 Cost estimates

A detailed cost estimate of the preferred option was completed. As expected the overall cost of the works has increased compared to the initial estimate that was prepared in the Options Assessment phase.

The cost associated with the preferred option is estimated as being $1,870,000.

Note that this is a Class 3 estimate implying a +/- 30% confidence interval in the quoted price of the works. All costs are also quoted based on current rates – these should be reviewed and indexed accordingly based on future price inflation.

Refer to Appendix F where the details of the cost estimate for the preferred option are presented.

8.4 Risk assessment

A risk assessment of the preferred option highlights a number of items that would need to be considered when taking the project to detailed design phase. It is envisaged that these risks would be addressed and mitigated in so far as is possible at that stage. As this engagement targets the development of a preferred solution to a concept design phase the following key risks do not comprise an exhaustive list, and their mitigation/reduction is envisaged to be addressed at the next phase of design:

- Managing required traffic deviations for all road users, pedestrians, cyclists and construction workers
- Construction of trenches, manholes and inlets in an area used by the community
- Use of heavy machinery in close proximity to the general public and road users
- Trenched construction in close proximity to building foundations
- Construction in an area where multiple services are located
- Potential flood events occurring during construction

The risks associated with a project of this nature are numerous and a thorough assessment would need to be undertaken at detailed design stage in advance of the construction commencing. This would include discussions with the contractor and the preparation of Safe Work Method Statements (SWMS) for the individual construction activities associated with the project. It is envisaged that a risk register would also be developed to track risks and address them in a systematic manner such that they can be alleviated or reduced in so far as is possible.

9 Conclusions

A thorough assessment of the existing stormwater system in Beaudesert has been completed. This involved the development of hydrologic and hydraulic models for the area which were successfully calibrated to two recent historic flood events. These events caused considerable flooding in Brisbane Street whereas the rest of the locality did not appear to suffer any particular flooding of note.

Photographic evidence from the March 2013 event suggested that depths of approximately 0.3 m on the eastern footpath on Brisbane Street were experienced. Therefore at the road gutter (ie stepping down from the kerb) this would have been approximately 0.4 m. The model predictions are in agreement with this.

An assessment of the return period of these events showed that:

- March 2013 had an ARI of approximately 2 years
- November 2013 had an ARI of approximately 5 years

Considering the magnitude of these events flooding of this nature is considered problematic. Accordingly at a System Assessment workshop held with SRRC personnel the issue of flooding on Brisbane Street was identified for testing in the Options Assessment phase such that a more desirable level of service could be achieved for Brisbane Street.

The cause of the flooding is lack of capacity within the existing town drain and therefore numerous options were proposed which looked at providing additional capacity to mitigate the issue of surface flooding at Brisbane Street.

It became apparent that only Option B and Option F (ie the Short Street trunk pipe, and the combination of drainage along Anna Street/Albert Street in conjunction with an upgrade to Brisbane Street respectively) could provide the desired level of service. With Option F being considerably more expensive, Option B was deemed the preferred concept to take forward to the final stage of analysis.

The Options Assessment workshop resulted in further development of this option. This involved connecting the main town drain RCBC to the trunk pipe that would be running through Brisbane Street and Short Street. This would be able to reduce the discharge running through the open drain section of the town drain (which generates flooding to the yards of business premises) while also acting to convey the runoff that is making its way into the sag via a series of new inlets.

This option was optimised and costed such that a finalised preferred solution could be presented to Council. The final design attains a level of service of 10 year ARI in line with the QUDM guidelines and involves the construction of approximately 300 m of a 1.5 m RCP along Brisbane Street and Short Street. The cost associated with the works is estimated as being $1,870,000.

10 Assumptions, limitations and recommendations

The following assumptions apply to the study:

- The calibration and verification exercise was only undertaken for the local catchment and creek runoff. It did not involve the Spring Creek catchment. Accordingly, for the March and November 2013 events the tailwater conditions in Spring Creek were achieved by running a 2 year 30 minute and 5 year 45 minute ARI storm event through the Spring Creek hydrologic model to extract the required discharge hydrographs. Note that as the flooding in Brisbane Street was controlled by the localised runoff and not by tailwater levels this was deemed an adequate approach that would not affect the quality of the calibration
- The hydrologic model assumes existing development conditions, notwithstanding the alterations made for current development applications
- Mitigation of flooding in Brisbane Street targets alleviating the significant ponding of runoff that occurred at the sag point. Some ponding within the roadway is still likely to occur due to the presence of the kerbing
- The aim of this study is to provide a concept mitigation strategy only. Detailed design will still be required to establish the full range of constraints related to the preferred option, and to undertake the final design taking these constraints into account

The following limitations relate to the study:

- The LiDAR data from which the topographic DEM was developed has been post-processed at building locations to strip out any vertical anomalies caused by the LiDAR hitting roofs, building walls etc. Accordingly, the DEM may not be providing an accurate representation of floor levels within the buildings
- The aforementioned limitation is inherent to the hydraulic behaviour of runoff to the rear of the buildings on the eastern side of Brisbane Street (and if/how it is conveyed in this area). More detailed modelling of this area would be required to ascertain exactly how runoff behaves and would most likely require additional localised survey and building survey details
- The representation of buildings within 2D hydraulic models, and the consequent effect they have on flow patterns, is an ongoing area of research and development within the hydraulic modelling community. The approach used in this study is in line with current industry practices but may still not fully represent real flood behaviour as it interacts with buildings
- The representation of the 1D pipe network has been simplified as agreed with Council to only incorporate the key trunk stormwater pipes and major branch connections. This is deemed adequate for the purposes of this study

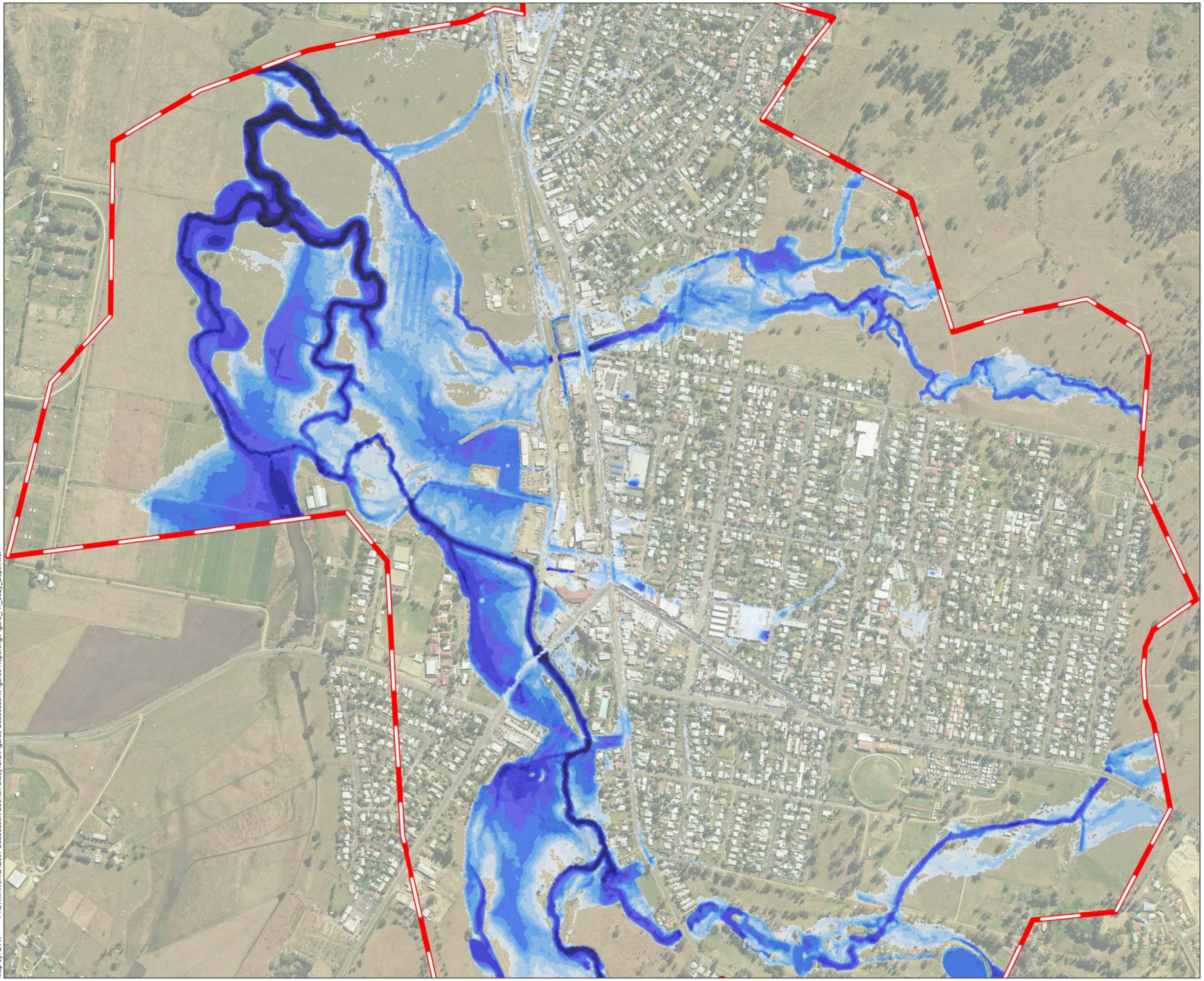
- All costs are also quoted based on current rates – these should be reviewed and indexed accordingly based on future price inflation

The following recommendations are made in regard to future analysis that may be undertaken:

- Should the preferred option be progressed to detailed design and construction phase then additional hydraulic analysis should be undertaken to ensure the design is represented accurately in the model
- The buildings on the eastern side of Brisbane Street should be incorporated more accurately into the hydraulic model. This would require detailed building survey to be undertaken in this area
- SRRC could consider providing some form of Maximum Height Gauge (MHG) in Brisbane Street if possible to record peak flood depths

Appendices

Appendix A
Base case flood mapping



aurecon

Legend

TUFLOW Code Boundary

Depth (m)

0.00 to 0.10
0.10 to 0.20
0.20 to 0.30
0.30 to 0.40
0.40 to 0.50
0.50 to 0.75
0.75 to 1.00
1.00 to 1.50
1.50 to 2.00
2.00 to 2.50
> 2.50

Notes:

Map by: BVW   P:\SWMI\Work\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_A1_002y_Depth.wor

A3 scale 1:10,000

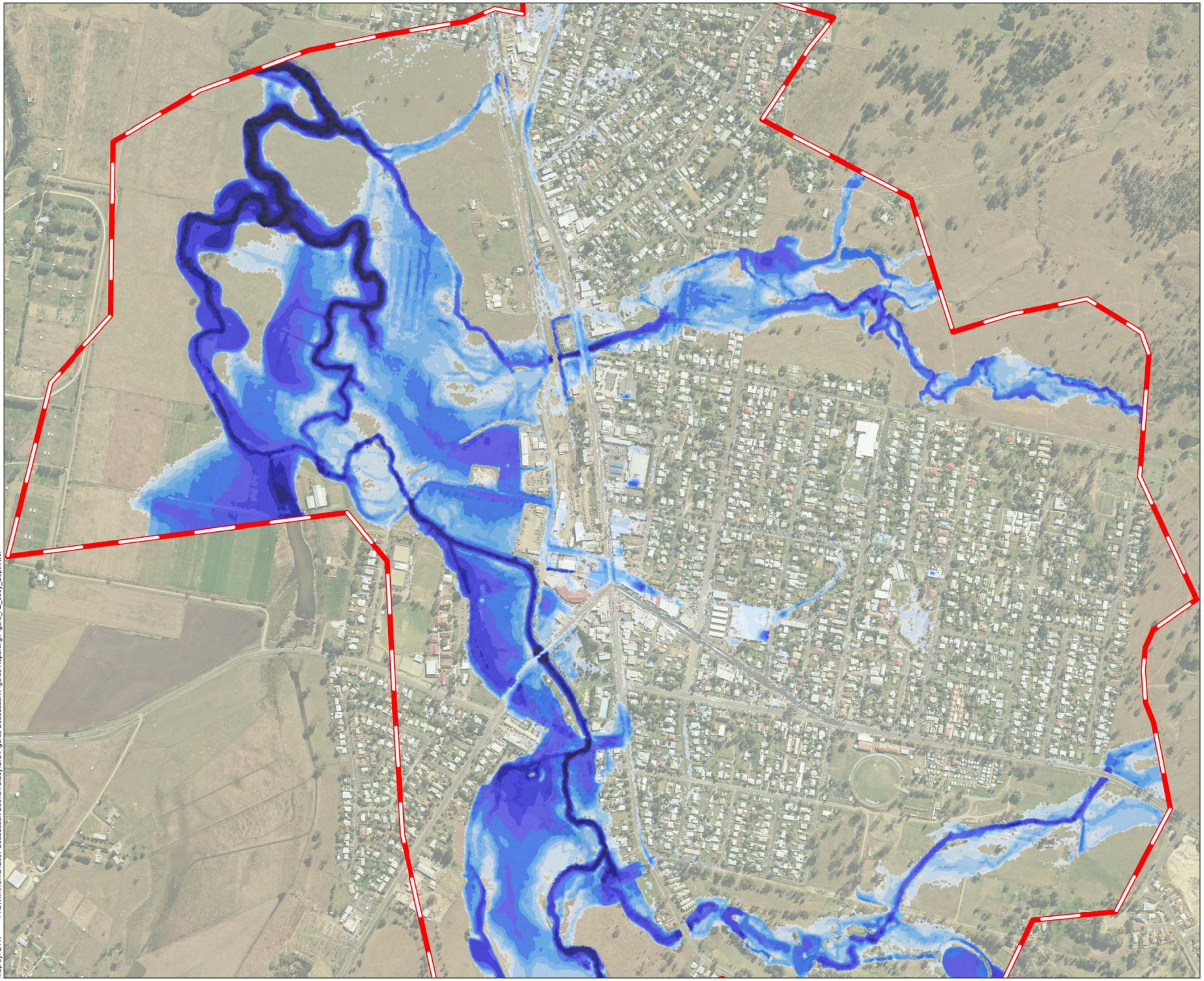
0   250 m   500 m

Date: 04/12/2014   Version: 0   Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure A1: 2 year ARI Event - Existing Case - Peak Depth



Legend

TUFLOW Code Boundary

Depth (m)

- 0.00 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 2.50
- > 2.50

Notes:

Map by: BVW P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_A2_005y_Depth.wor

A3 scale 1:10,000

0 250 m 500 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure A2: 5 year ARI Event - Existing Case - Peak Depth

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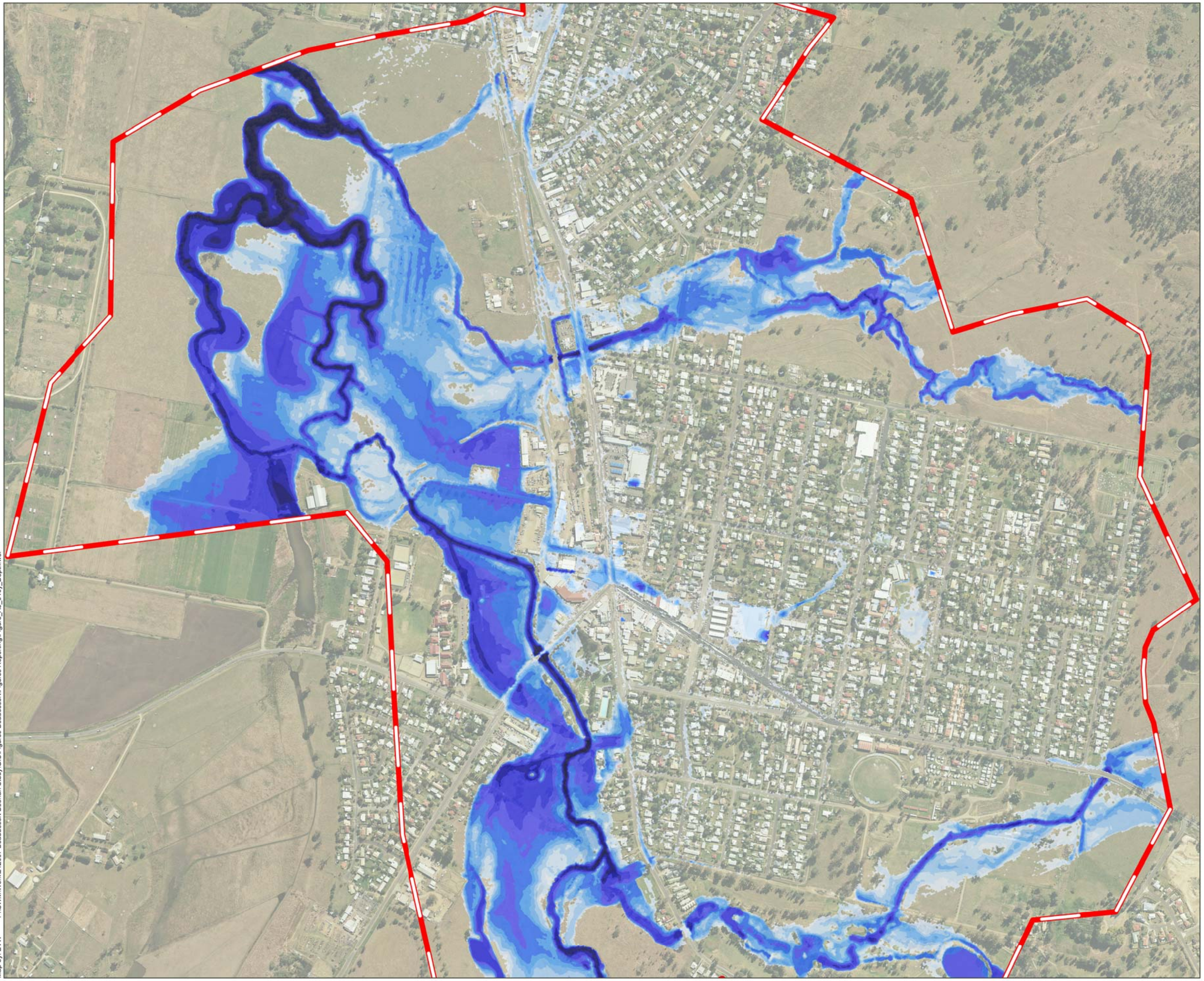


Legend

TUFLOW Code Boundary

Depth (m)

0.00 to 0.10	0.75 to 1.00
0.10 to 0.20	1.00 to 1.50
0.20 to 0.30	1.50 to 2.00
0.30 to 0.40	2.00 to 2.50
0.40 to 0.50	> 2.50
0.50 to 0.75	

Notes:

Map by: BVW P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_A3_010y_Depth.wor

A3 scale 1:10,000

0 250 m 500 m

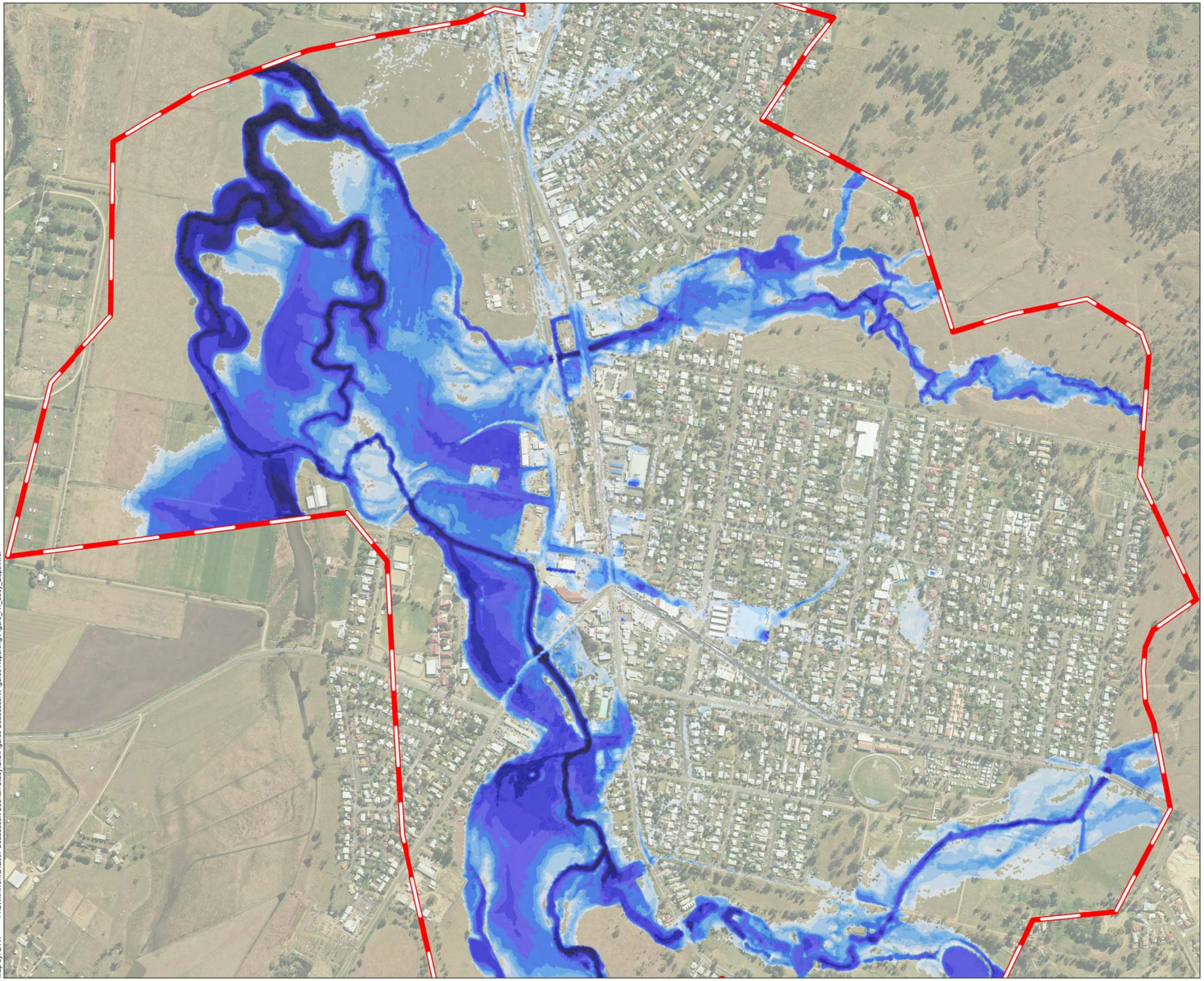
Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure A3: 10 year ARI Event - Existing Case - Peak Depth

aurecon



Legend

TUFLOW Code Boundary

Depth (m)

0.00 to 0.10	0.75 to 1.00
0.10 to 0.20	1.00 to 1.50
0.20 to 0.30	1.50 to 2.00
0.30 to 0.40	2.00 to 2.50
0.40 to 0.50	> 2.50
0.50 to 0.75	

Notes:

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A3 scale 1:10,000

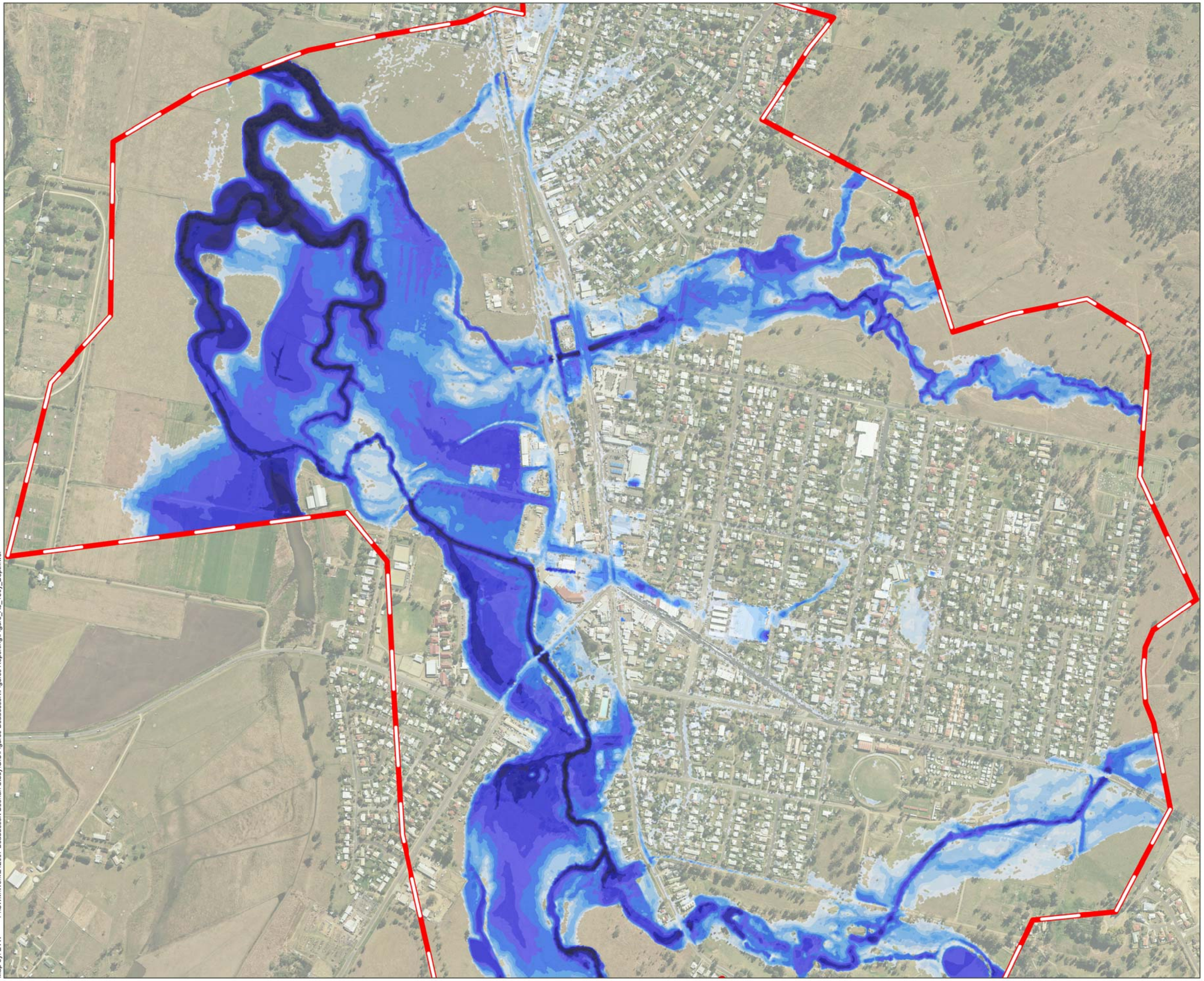
0   250 m   500 m

Date: 04/12/2014   Version: 0   Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure A4: 50 year ARI Event - Existing Case - Peak Depth



Map by: BVW P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_A5_100y_Depth.wor

aurecon

Legend

TUFLOW Code Boundary

Depth (m)

- 0.00 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 2.50
- > 2.50

Notes:

A3 scale 1:10,000

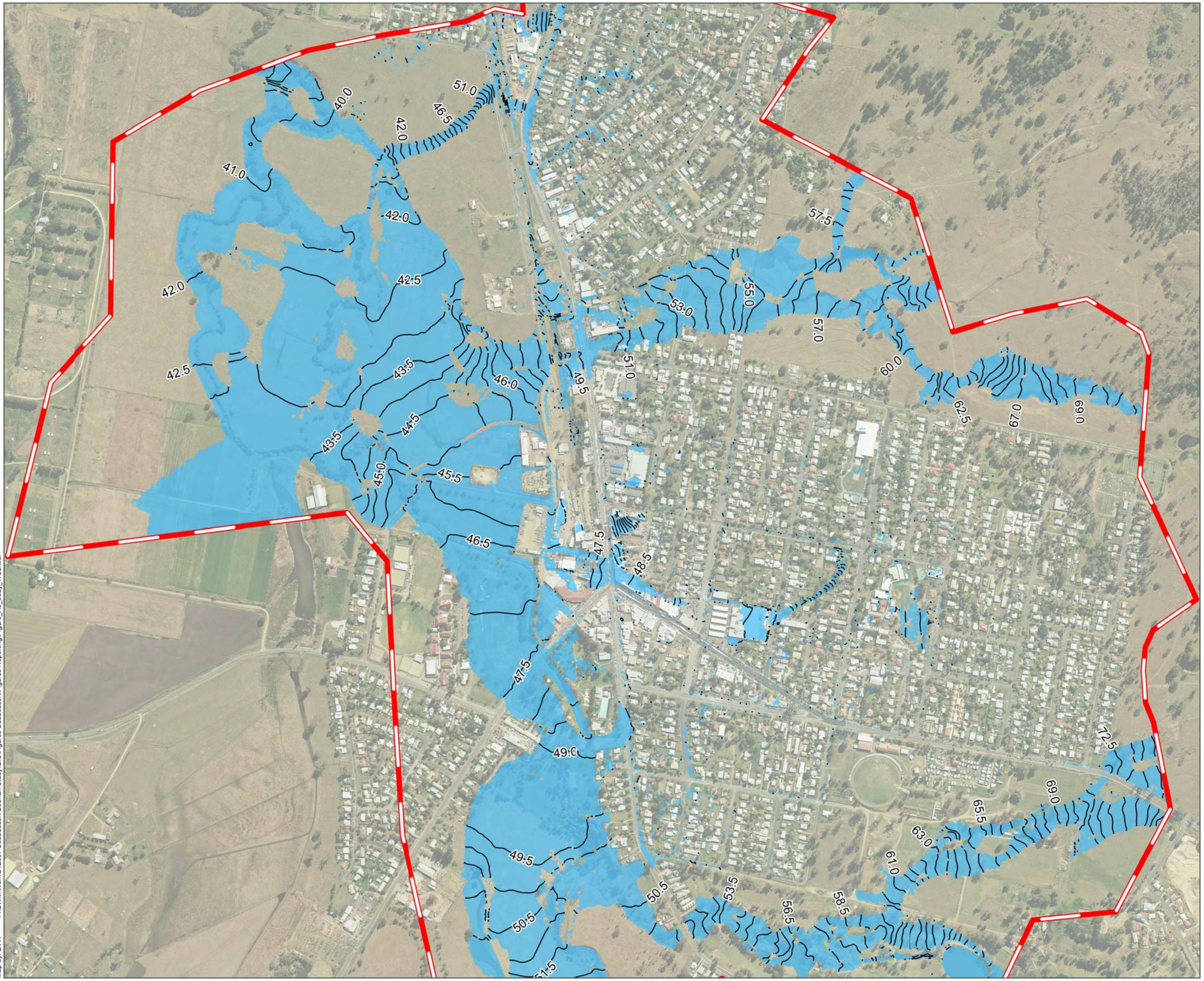
0 250 m 500 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure A5: 100 year ARI Event - Existing Case - Peak Depth



Legend

TUFLOW Code Boundary

Peak Water Surface Level (m AHD)

Peak Inundation Extent

Notes:

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Map by: BVW

A3 scale 1:10,000

0 250 m 500 m

Date: 04/12/2014 Version: 0 Job No: 242007

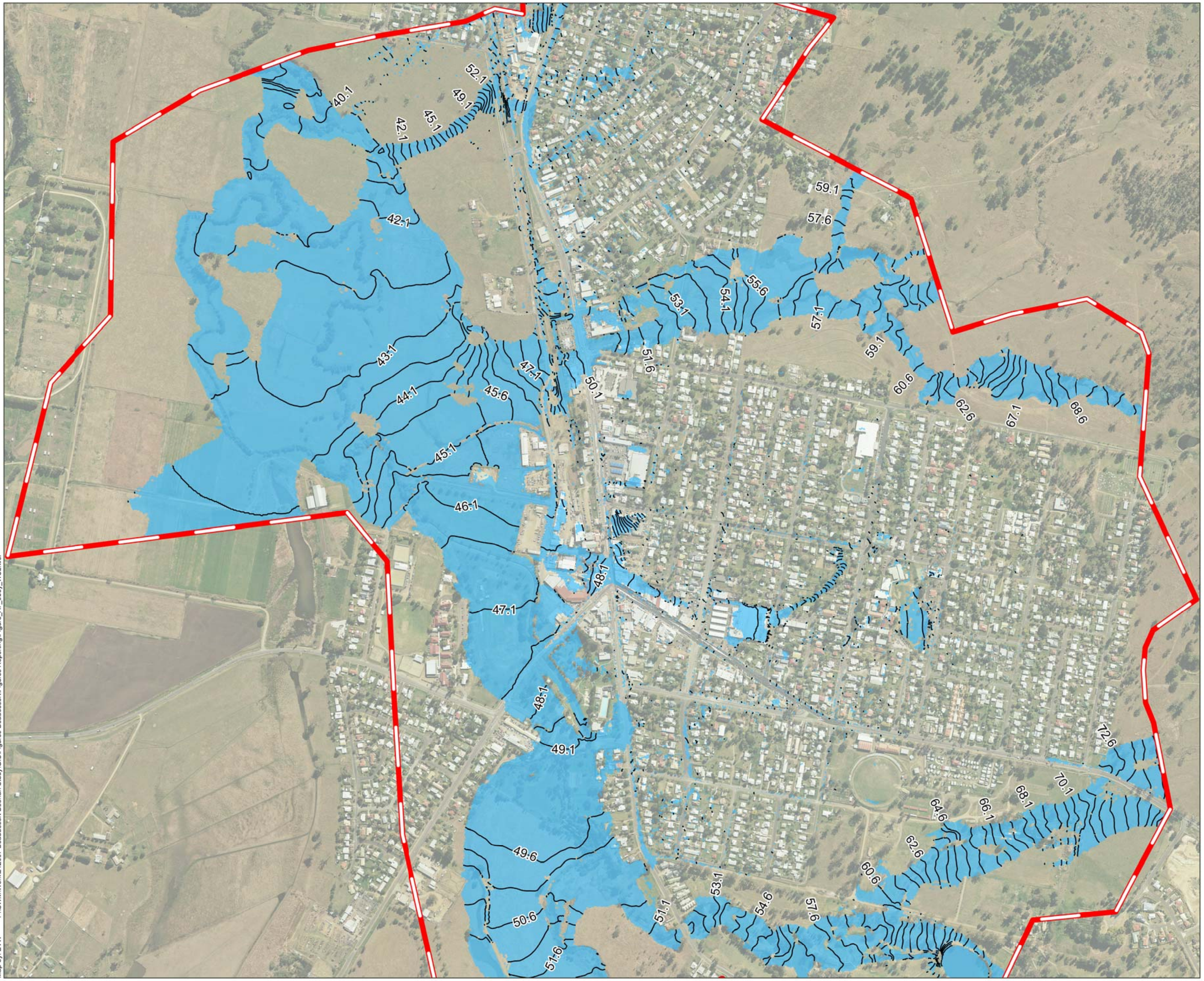
Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure A6: 2 year ARI Event - Existing Case

Peak Water Surface Levels

aurecon



Legend

- TUFLOW Code Boundary
- Peak Water Surface Level (m AHD)
- Peak Inundation Extent

Notes:

Map by: BVW P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_A7_005y_WSL.wor

A3 scale 1:10,000

0 250 m 500 m

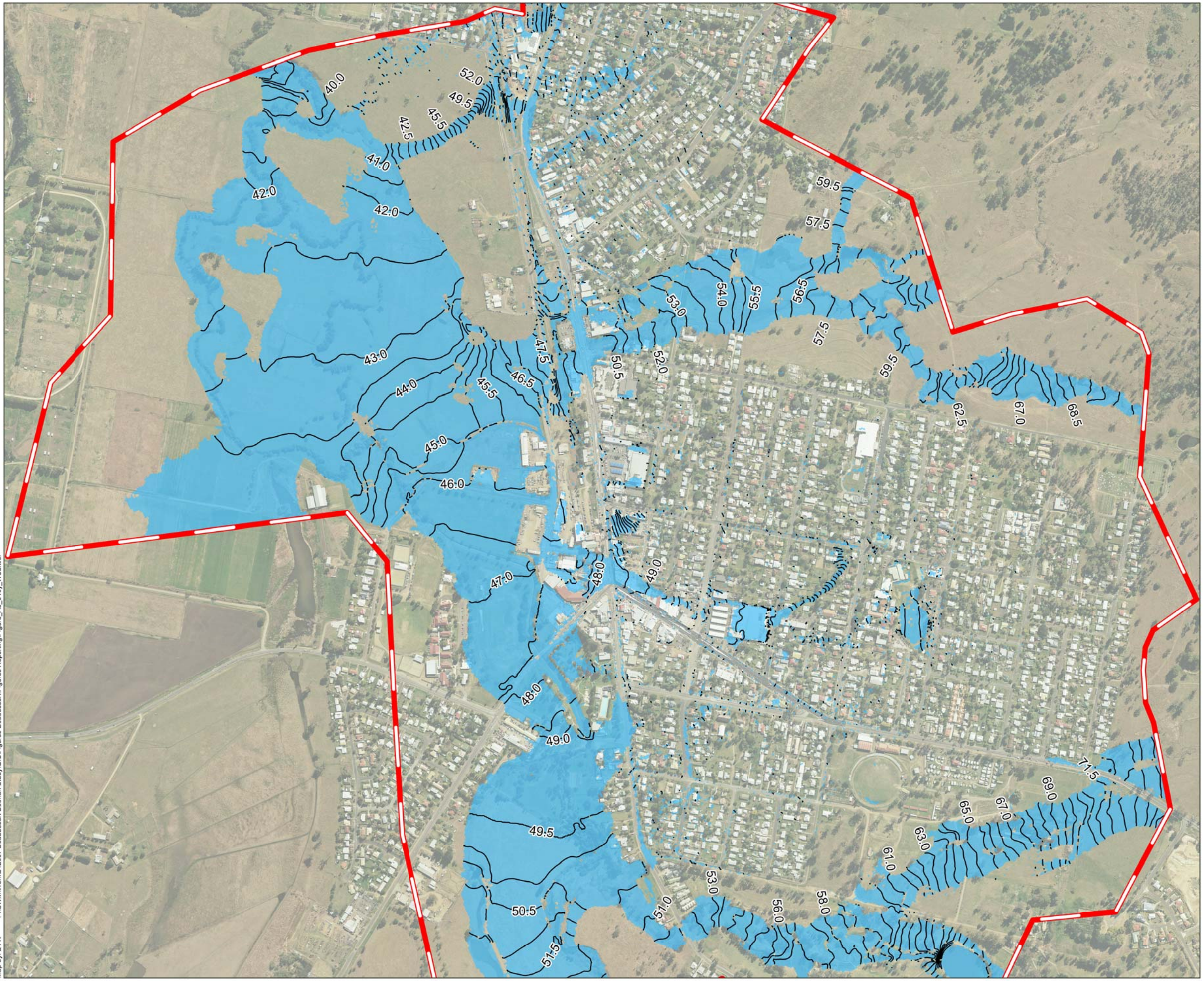
Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure A7: 5 year ARI Event - Existing Case
Peak Water Surface Levels

aurecon



Map by: BVW P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_A8_010y_WSL.wor

Legend

TUFLOW Code Boundary

Peak Water Surface Level (m AHD)

Peak Inundation Extent

Notes:

A3 scale 1:10,000

0 250 m 500 m

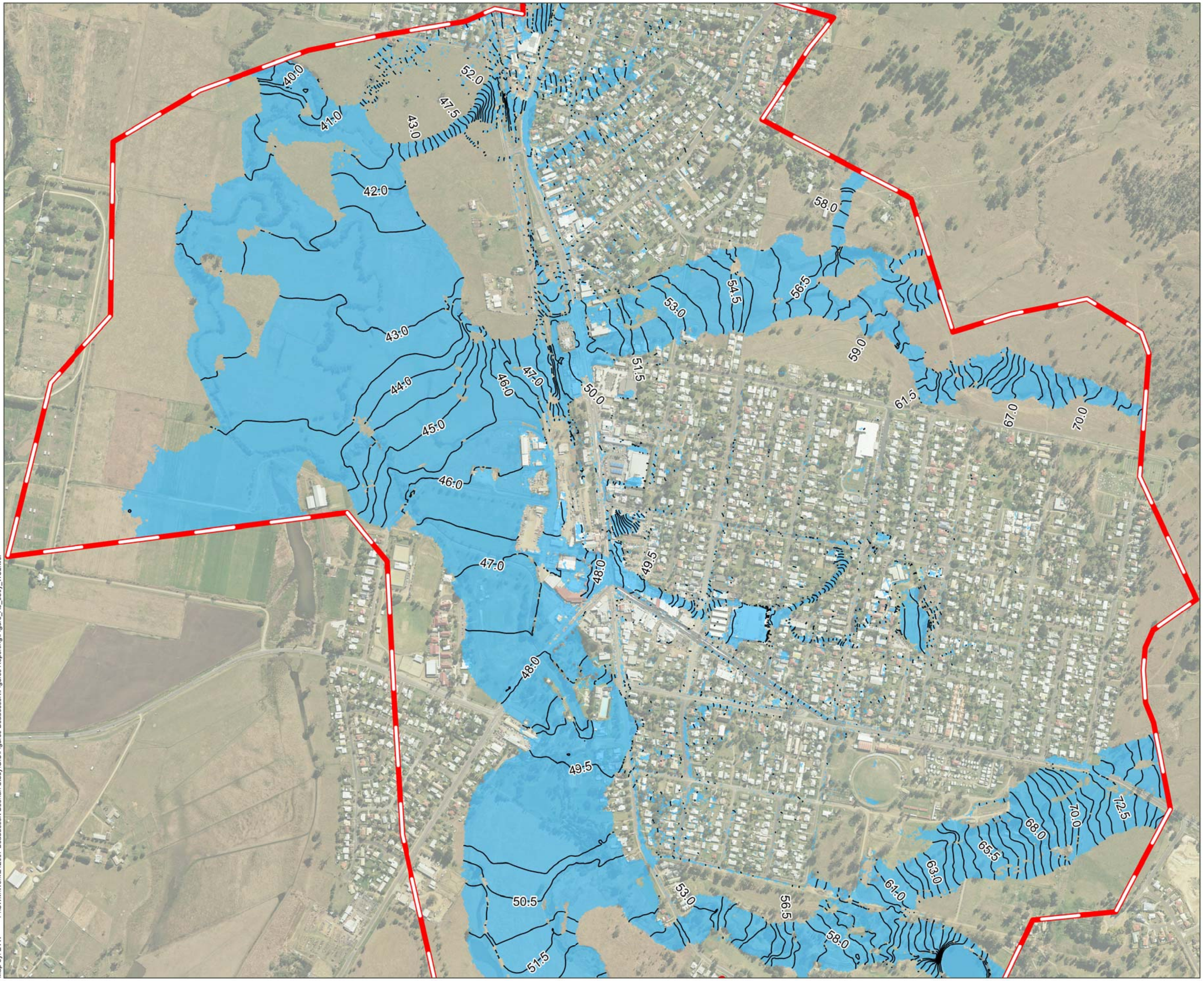
Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure A8: 10 year ARI Event - Existing Case

Peak Water Surface Levels



aurecon

Legend

TUFLOW Code Boundary

Peak Water Surface Level (m AHD)

Peak Inundation Extent

Notes:

P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_A9_050y_WSL.wor

Map by: BVW

A3 scale 1:10,000

0 250 m 500 m

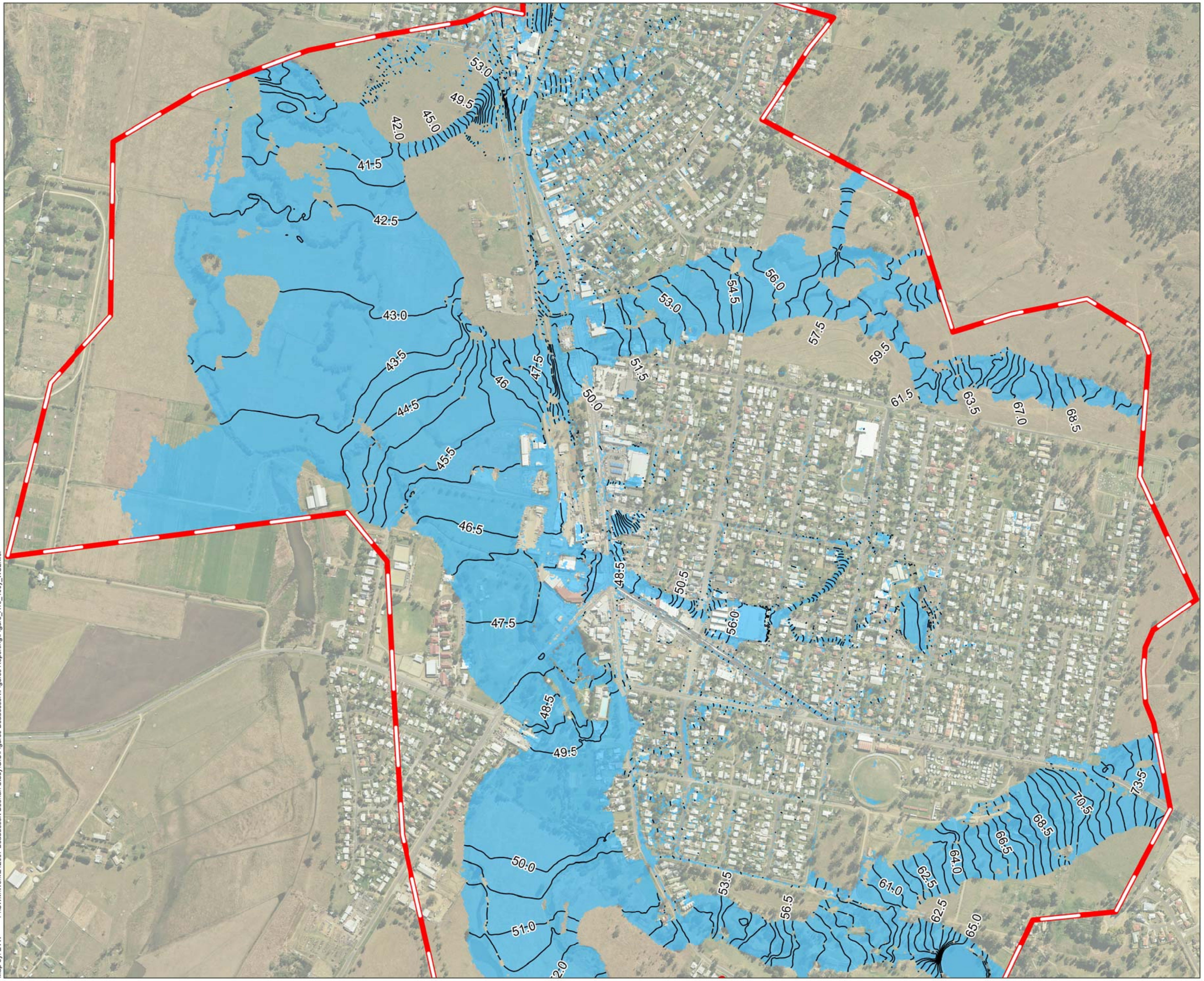
Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure A9: 50 year ARI Event - Existing Case
Peak Water Surface Levels

aurecon



Legend

TUFLOW Code Boundary

Peak Water Surface Level (m AHD)

Peak Inundation Extent

Notes:

Map by: BVW P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_A10_100y_WSL.wor

A3 scale 1:10,000

0 250 m 500 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure A10: 100 year ARI Event - Existing Case
Peak Water Surface Levels

Appendix B
Calibration events flood mapping

aurecon

Legend

TUFLOW Code Boundary

Depth Reporting Location (m)

Depth (m)

0.00 to 0.10
0.10 to 0.20
0.20 to 0.30
0.30 to 0.40
0.40 to 0.50
0.50 to 0.75
0.75 to 1.00
1.00 to 1.50
1.50 to 2.00
2.00 to 2.50
> 2.50

Notes:

A3 scale 1:2,500

0 37.5 m 75 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure B1: March 2013 Historical Event - Peak Depth

Legend

TUFLOW Code Boundary

Depth Reporting Location (m)

Depth (m)

0.00 to 0.10	0.75 to 1.00
0.10 to 0.20	1.00 to 1.50
0.20 to 0.30	1.50 to 2.00
0.30 to 0.40	2.00 to 2.50
0.40 to 0.50	> 2.50
0.50 to 0.75	

Notes:

Map by: BVW P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_B2_November_2013_Depth.wor

A3 scale 1:2,500

0 37.5 m 75 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure B2: November 2013 Historical Event - Peak Depth

Appendix C
Options assessment flood mapping

Map by: BVW   P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_C1_005y_Mit_B_Depth.wor

aurecon

Legend

TUFLOW Model Boundary

Depth (m)

- 0.00 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 2.50
- > 2.50

Notes:

A3 scale 1:1,500

0   37.5 m   75 m

Date: 04/12/2014   Version: 0   Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure C1: 5 year ARI Event - Mitigation Option B

Peak Depth

aurecon

Legend

TUFLOW Model Boundary

Depth (m)

0.00 to 0.10	0.75 to 1.00
0.10 to 0.20	1.00 to 1.50
0.20 to 0.30	1.50 to 2.00
0.30 to 0.40	2.00 to 2.50
0.40 to 0.50	> 2.50
0.50 to 0.75	

Notes:

Map by: BVW   P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_C2_005y_Mit_C_Depth.wor

A3 scale 1:1,500

0   37.5 m   75 m

Date: 04/12/2014   Version: 0   Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure C2: 5 year ARI Event - Mitigation Option C

Peak Depth

aurecon

Map by: BVW P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_C3_005y_Mit_D_Depth.wor

Legend

TUFLOW Model Boundary

Depth (m)

0.00 to 0.10	0.75 to 1.00
0.10 to 0.20	1.00 to 1.50
0.20 to 0.30	1.50 to 2.00
0.30 to 0.40	2.00 to 2.50
0.40 to 0.50	> 2.50
0.50 to 0.75	

Notes:

A3 scale 1:1,500

0 37.5 m 75 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure C3: 5 year ARI Event - Mitigation Option D
Peak Depth

aurecon

Legend

TUFLOW Model Boundary

Depth (m)

- 0.00 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 2.50
- > 2.50

Notes:

P:\SWMWork\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_C4_005y_Mit_F_Depth.wor

Map by: BVW

A3 scale 1:1,500

0 37.5 m 75 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure C4: 5 year ARI Event - Mitigation Option F
Peak Depth

Appendix D
Preferred option flood mapping

Map by: BVW   P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_D1_002y_Depth.wor

aurecon

Legend

TUFLOW Code Boundary

Depth (m)

0.00 to 0.10	0.75 to 1.00
0.10 to 0.20	1.00 to 1.50
0.20 to 0.30	1.50 to 2.00
0.30 to 0.40	2.00 to 2.50
0.40 to 0.50	> 2.50
0.50 to 0.75	

Notes:

A3 scale 1:2,500

0   37.5 m   75 m

Date: 04/12/2014   Version: 0   Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure D1: 2 year ARI - Existing Case (refined model) - Peak Depth

aurecon

Map by: BVW P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_D2_005y_Depth.wor

Legend

TUFLOW Code Boundary

Depth (m)

0.00 to 0.10	0.75 to 1.00
0.10 to 0.20	1.00 to 1.50
0.20 to 0.30	1.50 to 2.00
0.30 to 0.40	2.00 to 2.50
0.40 to 0.50	> 2.50
0.50 to 0.75	

Notes:

A3 scale 1:2,500

0 37.5 m 75 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure D2: 5 year ARI - Existing Case (refined model) - Peak Depth

aurecon

Legend

TUFLOW Code Boundary

Depth (m)

- 0.00 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 2.50
- > 2.50

Notes:

Map by: BVW

P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_D3_010y_Depth.wor

A3 scale 1:2,500

0 37.5 m 75 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure D3: 10 year ARI - Existing Case (refined model) - Peak Depth

Legend

TUFLOW Code Boundary

Depth (m)

- 0.00 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 2.50
- > 2.50

Notes:

Map by: BVW P:\SWMIWork\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_D4_050y_Depth.wor

A3 scale 1:2,500

0 37.5 m 75 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure D4: 50 year ARI - Existing Case (refined model) - Peak Depth

aurecon

Legend

TUFLOW Code Boundary

Depth (m)

0.00 to 0.10	0.75 to 1.00
0.10 to 0.20	1.00 to 1.50
0.20 to 0.30	1.50 to 2.00
0.30 to 0.40	2.00 to 2.50
0.40 to 0.50	> 2.50
0.50 to 0.75	

Notes:

Map by: BVW P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_D5_100y_Depth.wor

A3 scale 1:2,500

0 37.5 m 75 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure D5: 100 year ARI - Existing Case (refined model) - Peak Depth

aurecon

Legend

TUFLOW Code Boundary

Depth (m)

- 0.00 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 2.50
- > 2.50

Notes:

A3 scale 1:2,500

0 37.5 m 75 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure D6: 2 year ARI - Preferred Option (refined model) - Peak Depth

Map by: BVW P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_D7_005y_Pref_Option_Depth.wor

aurecon

Legend

TUFLOW Code Boundary

Depth (m)

0.00 to 0.10	0.75 to 1.00
0.10 to 0.20	1.00 to 1.50
0.20 to 0.30	1.50 to 2.00
0.30 to 0.40	2.00 to 2.50
0.40 to 0.50	> 2.50
0.50 to 0.75	

Notes:

A3 scale 1:2,500

0 37.5 m 75 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure D7: 5 year ARI - Preferred Option (refined model) - Peak Depth

Legend

TUFLOW Code Boundary

Depth (m)

- 0.00 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 2.50
- > 2.50

Notes:

Map by: BVW P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_D8_010y_Pref_Option_Depth.wor

A3 scale 1:2,500

0 37.5 m 75 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure D8: 10 year ARI - Preferred Option (refined model) - Peak Depth

Legend

TUFLOW Code Boundary

Depth (m)

- 0.00 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 2.50
- > 2.50

Notes:

Map by: BVW

P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_D9_050y_Pref_Option_Depth.wor

A3 scale 1:2,500

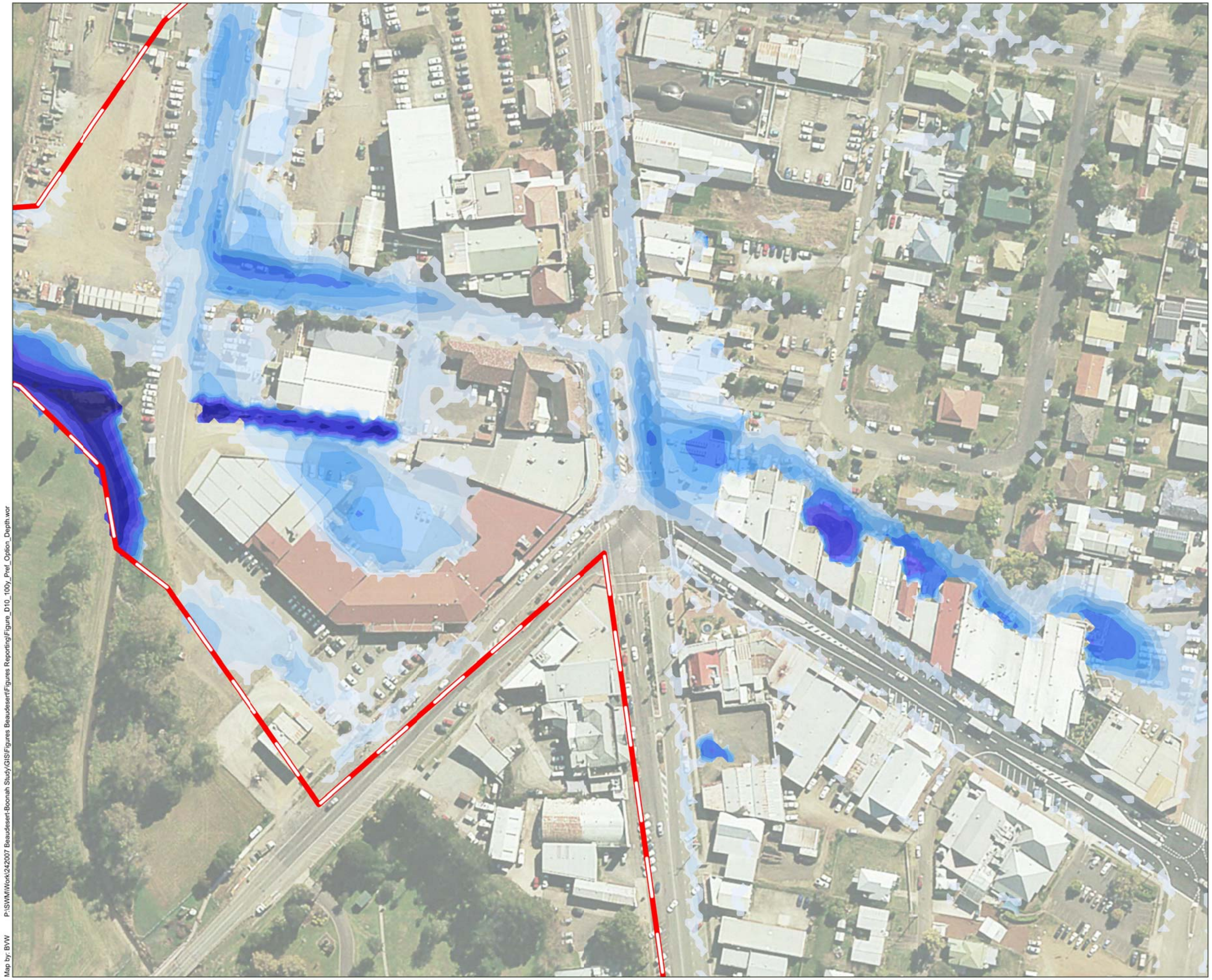
0 37.5 m 75 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure D9: 50 year ARI - Preferred Option (refined model) - Peak Depth



aurecon

Legend

TUFLOW Code Boundary

Depth (m)

0.00 to 0.10	0.75 to 1.00
0.10 to 0.20	1.00 to 1.50
0.20 to 0.30	1.50 to 2.00
0.30 to 0.40	2.00 to 2.50
0.40 to 0.50	> 2.50
0.50 to 0.75	

Notes:

A3 scale 1:2,500

0 37.5 m 75 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure D10: 100 year ARI - Preferred Option (refined model) - Peak Depth

aurecon

Legend

TUFLOW Code Boundary

Afflux (mm)

- < -300
- -300 to -200
- -200 to -100
- -100 to -10
- -10 to 10
- 10 to 100
- 100 to 200
- >200
- Was wet now dry
- Was dry now wet

Notes:

Map by: BVW   P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_D11_002y_Pref_Option_Afflux.wor

A3 scale 1:2,500

0   37.5 m   75 m

Date: 04/12/2014   Version: 0   Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure D11: 2 year ARI - Preferred Option *(refined model)* - Afflux

aurecon

Legend

TUFLOW Code Boundary

Afflux (mm)

< -300	10 to 100
-300 to -200	100 to 200
-200 to -100	>200
-100 to -10	Was wet now dry
-10 to 10	Was dry now wet

Notes:

A3 scale 1:2,500

0 37.5 m 75 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure D12: 5 year ARI - Preferred Option *(refined model)* - Afflux

P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_D12_005y_Pref_Option_Afflux.wor

Map by: BVW

aurecon

Legend

TUFLOW Code Boundary

Afflux (mm)

- < -300
- -300 to -200
- -200 to -100
- -100 to -10
- -10 to 10
- 10 to 100
- 100 to 200
- >200
- Was wet now dry
- Was dry now wet

Notes:

A3 scale 1:2,500

0 37.5 m 75 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure D13: 10 year ARI - Preferred Option *(refined model)* - Afflux

aurecon

Legend

TUFLOW Code Boundary

Afflux (mm)

- < -300
- -300 to -200
- -200 to -100
- -100 to -10
- -10 to 10
- 10 to 100
- 100 to 200
- >200
- Was wet now dry
- Was dry now wet

Notes:

Map by: BVW P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_D14_050y_Pref_Option_Afflux.wor

A3 scale 1:2,500

0 37.5 m 75 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure D14: 50 year ARI - Preferred Option (*refined model*) - Afflux

aurecon

Legend

TUFLOW Code Boundary

Afflux (mm)

< -300	10 to 100
-300 to -200	100 to 200
-200 to -100	>200
-100 to -10	Was wet now dry
-10 to 10	Was dry now wet

Notes:

Map by: BVW   P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Beaudesert\Figures Reporting\Figure_D15_100y_Pref_Option_Afflux.wor

A3 scale 1:2,500

0   37.5 m   75 m

Date: 04/12/2014   Version: 0   Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Beaudesert Study Area

Figure D15: 100 year ARI - Preferred Option *(refined model)* - Afflux

Appendix E
Options assessment cost estimation

aurecon

Client:	-	Rev	0
Project:	Beaudesert Stormwater Assessment	Date	14/07/2014
Project Number:	242007		
Title:	Summary - 3Q 2014 Class 5 Estimate of Capex Options	Accuracy	+/- 50%
Estimator:	Rowland Lampard		

ESTIMATED COSTS

ITEM	DESCRIPTION		OPTION STUDY REF A AUD $	B AUD $	C AUD $	D AUD $	F AUD $	
DIRECT JOB COSTS								
Direct Costs	*See back-up sheet*							
A1	Direct Materials & Labour		545,000	758,000	2,591,000	284,000	2,875,000	
SUBTOTAL Construction Directs			545,000	758,000	2,591,000	284,000	2,875,000	(1)
INDIRECT JOB COSTS								
Indirect Costs	*Prorated from Direct Costs*	%						
B1	Establishment & Mob/Demob	20%	109,000	152,000	519,000	57,000	575,000	
B2	Contractor's OH&P	11%	60,000	84,000	286,000	32,000	317,000	
B3	Construction Management	6%	33,000	46,000	156,000	18,000	173,000	
SUBTOTAL Construction Indirects			202,000	282,000	961,000	107,000	1,065,000	(2)
TOTAL Directs & Indirects			747,000	1,040,000	3,552,000	391,000	3,940,000	(3)=(1)+(2)
SERVICES COSTS								
Services								
C1	Surveys	0.5%	3,000	4,000	13,000	2,000	15,000	
C2	Eng / Design / Project Mgmt [as a % of (3)]	7.5%	57,000	78,000	267,000	30,000	296,000	
C3	Traffic Management		Included C5	Included C5	Included C5	Included C5	Included C5	
C4	Provision for traffic		Included C5	Included C5	Included C5	Included C5	Included C5	
C5	Traffic Management & Plan		10,000	5,000	8,000	3,000	10,000	
C6	Environmental Management		Included C10	Included C10	Included C10	Included C10	Included C10	
C7	Environmental Inspections		Included C10	Included C10	Included C10	Included C10	Included C10	
C8	Develop Environmental Management Plan (Construction)		Included C10	Included C10	Included C10	Included C10	Included C10	
C9	Implement Environmental Management Plan (Construction)		Included C10	Included C10	Included C10	Included C10	Included C10	
C10	Environmental Licences, Permits and Approvals	8%	57,000	78,000	267,000	30,000	296,000	
C3	Owners Costs		Excluded	Excluded	Excluded	Excluded	Excluded	
SUBTOTAL Services Costs			127,000	165,000	555,000	65,000	617,000	(4)
TOTAL BASE PROJECT COSTS			874,000	1,205,000	4,107,000	456,000	4,557,000	(5)=(3)+(4)
ALLOWANCE COSTS								
Allowances								
D1	Risk and Contingency [as a % of (3)]	25%	187,000	260,000	888,000	98,000	985,000	
D2	Escalation	0%	Excluded	Excluded	Excluded	Excluded	Excluded	
ESTIMATED PROJECT COST + ALLOWANCES			187,000	260,000	888,000	98,000	985,000	(6)
OTHER COSTS								
Others								
E1	Other Costs		Excluded	Excluded	Excluded	Excluded	Excluded	
SUBTOTAL Other Costs			0	0	0	0	0	(7)
Goods & Services Tax (GST) NIL ALLOWED			0	0	0	0	0	(8)
TOTAL ESTIMATED PROJECT COST			**1,061,000**	**1,465,000**	**4,995,000**	**554,000**	**5,542,000**	(5)+(6)+(7)+(8)
		Index	1.00					

Option A	**Range**	**530,500**	**to**	**1,591,500**
Option B	**Range**	**732,500**	**to**	**2,197,500**
Option C	**Range**	**2,497,500**	**to**	**7,492,500**
Option D	**Range**	**277,000**	**to**	**831,000**
Option F	**Range**	**2,771,000**	**to**	**8,313,000**

OPTION A - Eaglesfield St Trunk

Item	Quantity	Unit	Rate	Total
Pipe				
525 RCP [average depth 2m]	316	m	$ 470	$ 149,000
600 RCP [average depth 2m]	645	m	$ 520	$ 336,000
Pits				
525 RCP pit	9	No	$ 1,950	$ 18,000
600 RCP pit	12	No	$ 1,950	$ 24,000
Road Crossings				
525 RCP road crossing traffic management	4	No	Summary Sheet	Summary Sheet
Break into and reinstate road	96	m2	$ 150	$ 15,000
Connection into Existing Pipe				
525 RCP connection	1	No	$ 440	$ 1,000
Head Wall and Apron				
525 RCP head wall and apron	1	No	$ 1,800	$ 2,000
Total				**$ 545,000**

OPTION B - Short St Trunk

Item	Quantity	Unit	Rate	Total
Pipe				
1200 RCP [average depth 2m]	40	m	$ 1,570	$ 63,000
1500 RCP [average depth 2m]	292	m	$ 2,230	$ 652,000
Pits				
1200 RCP pit	6	No	$ 2,925	$ 18,000
Break Out Existing Pipe				
1200 RCP pipe and fill	40	m	$ 300	$ 12,000
Road Crossings				
1200 RCP road crossing traffic management	2	No	Summary Sheet	Summary Sheet
Break into and reinstate road	48	m2	$ 150	$ 8,000
Connection into Existing Pipe				
1200 RCP connection	2	No	$ 1,000	$ 2,000
Head Wall and Apron				
1200 RCP head wall and apron	1	No	$ 2,400	$ 3,000
Total				**$ 758,000**

OPTION C - Anna Street Trunk

Item	Quantity	Unit	Rate	Total
Pipe				
1500 RCP [average depth 4m] 2No pipes in one trench [1,016m pipe]	508	m	$ 4,980	$ 2,530,000
Pits				
1500 RCP pit	6	No	$ 6,350	$ 39,000
Road Crossings				
1500 RCP road crossing traffic management	3	No	Summary Sheet	Summary Sheet
Break into and reinstate road	108	m2	$ 150	$ 17,000
Connection into Existing Pipe				
1500 RCP connection	1	No	$ 1,350	$ 2,000
Head Wall and Apron				
1500 RCP head wall and apron	1	No	$ 3,000	$ 3,000
Total				**$ 2,591,000**

OPTION D - Upgrade of Brisbane St

Item	Quantity	Unit	Rate	Total
Pipe				
1200 RCP [average depth 2m]	139	m	$ 1,570	$ 219,000
Pits				
1200 RCP pit	6	No	$ 2,925	$ 18,000
Break Out Existing Pipe				
1200 RCP pipe and fill	139	m	$ 300	$ 42,000
Road Crossings				
1200 RCP road crossing traffic management	1	No	Summary Sheet	Summary Sheet
Break into and reinstate road	24	m2	$ 150	$ 4,000
Connection into Existing Pipe				
1200 RCP connection	1	No	$ 1,000	$ 1,000
Total				**$ 284,000**

Appendix F
Preferred option cost estimation

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Client:	**Beaudesert Council**	Rev. **0**
Project:	**Beaudesert Stormwater Pipe**	Date **30/07/2014**
Project Number:	**242007**	
Title:	**Summary - 3Q 2014 Class 3 Estimate of Capex Options**	**+/-30% Accurancy**
Estimator:	**Rowland Lampard**	

ESTIMATED COSTS

ITEM	DESCRIPTION	%	OPTION STUDY REF 1 AUD $	
DIRECT JOB COSTS				
Direct Costs	*See back-up sheet*			
A1	Direct Materials & Labour		936,000	
SUBTOTAL Construction Directs			936,000	(1)
INDIRECT JOB COSTS				
Indirect Costs	*Prorated from Direct Costs*	%		
B1	Establishment & Mob/Demob	20%	187,000	
B2	Contractor's OH&P	10%	94,000	
B3	Construction Management	6%	56,000	
SUBTOTAL Construction Indirects			337,000	(2)
TOTAL Directs & Indirects			1,273,000	(3) = (1) + (2)
SERVICES COSTS				
Services				
C1	Surveys	0.5%	5,000	
C2	Eng / Design / Project Mgmt [as a % of (3)]	7.5%	95,000	
C3	Traffic Management		Included C5	
C4	Provision for traffic		Included C5	
C5	Traffic Management Plan	9%	115,000	
C6	Environmental Management		Included C10	
C7	Environmental Inspections		Included C10	
C8	Develop Environmental Management Plan (Construction)		Included C10	
C9	Implement Environmental Management Plan (Construction)		Included C10	
C10	Environmental Licences, Permits and Approvals	10%	127,000	
C11	Owners Costs		Excluded	
SUBTOTAL Services Costs			342,000	(4)
TOTAL BASE PROJECT COSTS			1,615,000	(5) = (3) + (4)
ALLOWANCE COSTS				
Allowances				
D1	Risk and Contingency [as a % of (3)]	20%	255,000	
D2	Escalation	0%	Excluded	
ESTIMATED PROJECT COST + ALLOWANCES			255,000	(6)
OTHER COSTS				
Others				
E1	Other Costs		Excluded	
SUBTOTAL Other Costs			-	(7)
Goods & Services Tax (GST) NIL ALLOWED			0	(8)
TOTAL ESTIMATED PROJECT COST			**1,870,000**	(5) + (6) + (7) + (8)
		Index	1.00	

Range	**1,309,000**	**vrs**	**2,431,000**

Item	Quantity	Unit	Rate	Total
Excavation/Fill				
Break out existing road surface	708	m2	$ 8.00	$ 5,664.00
Excavate trench to lay pipe	2903	m3	$ 50.00	$ 145,150.00
Formwork to side of trench	2000	m2	$ 25.00	$ 50,000.00
Backfill trench with excavated spoil	812	m3	$ 15.00	$ 12,180.00
Remove spoil from site	1976	m3	$ 20.00	$ 39,520.00
Pipe Laying				
Bedding material (Assumed 300mm depth) [978 m2]	293	m3	$ 185.00	$ 54,205.00
RCP Pipe				
Under Busy Road				
525 RCP [average depth 2m]	20	m	$ 260.00	$ 5,200.00
1200 RCP [average depth 3m]	25	m	$ 1,150.00	$ 28,750.00
1500 RCP [average depth 3m]	40	m	$ 1,700.00	$ 68,000.00
Under Quite Road				
1500 RCP [average depth 3m]	165	m	$ 1,620.00	$ 267,300.00
Under Yard				
1500 RCP [average depth 3m]	90	m	$ 1,620.00	$ 145,800.00
Road Surfacing				
150mm Road subbase	106	m3	$ 60.00	$ 6,360.00
150mm Road base	106	m3	$ 60.00	$ 6,360.00
150mm Asphalt surface	106	m3	$ 120.00	$ 12,744.00
Seal PMB S4.55 1.3L/m2 10mm at 125m2/m3	708	m2	$ 14.00	$ 9,912.00
Pits Max 3m Deep				
525 RCP pit with sealed metal cover	1	No	$ 2,925.00	$ 2,925.00
1200 RCP pit with sealed metal cover	1	No	$ 4,390.00	$ 4,390.00
1500 RCP pit with sealed metal cover	4	No	$ 5,150.00	$ 20,600.00
Gully Inlets				
1500 RCP Gully inlet	8	No	$ 2,400.00	$ 19,200.00
Break Out Existing Pipe				
Excavate trench to remove 900 RCP [average depth 3m]	240	m3	$ 50.00	$ 12,000.00
Formwork to side of trench	24	m2	$ 25.00	$ 600.00
Backfill trench with excavated spoil and 115m3 excavated fill from elsewhere on site	240	m3	$ 20.00	$ 4,800.00
Remove 900 RCP pipe [average depth 3m]	40	m	$ 210.00	$ 8,400.00
Break into Existing Pipe and Connect				
Minor pipes	2	No	$ 320.00	$ 640.00
Major pipe (breaking into a chamber of 2.4 x 1.2 RCBC)	1	No	$ 1,250.00	$ 1,250.00
Traffic Management				
Traffic Management - Major Road	3	No	Included on summary sheet	Included on summary sheet
Traffic Management - Minor Road	2	No	Included on summary sheet	Included on summary sheet
Head Wall and Apron				
1500 RCP Head wall and 2m apron	1	No	$ 3,000.00	$ 3,000.00
Rock Protection				
Imported rock protection to spillway	10	m2	$ 50.00	$ 500.00
Geofabric to spillway	10	m2	$ 10.00	$ 100.00
Total				**$ 935,550.00**

Appendix G
System assessment workshop meeting minutes

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Meeting Record

Project number	**242007**	Meeting date	**30 June 2014**
Project name	**Beaudesert Boonah SSAIP**	Recorded by	**Brian Sexton**
Meeting/subject	**System Assessment Workshop**	Total pages	**2**

Present	Apology	Copy	Name	Organisation	Contact details
☒	☐	☐	Brian Sexton (BS)	Aurecon	
☒	☐	☒	Patrick Murphy (PM)	SRRC	patrick.m@scenicrim.qld.gov.au
☒	☐	☒	Joshua Canaris (JC)	SRRC	joshua.c@scenicrim.qld.gov.au
☒	☐	☒	Craig Heck (CH)	SRRC	craig.h@scenicrim.qld.gov.au
☒	☐	☒	Chris Gray (CG)	SRRC	Christopher.G@scenicrim.qld.gov.au
☒	☐	☒	Shaun Anderson (SA)	SRRC	shaun.a@scenicrim.qld.gov.au
☐	☒	☒	Noel Todd (NT)	SRRC	noel.t@scenicrim.qld.gov.au
☐	☐	☐			
☐	☐	☐			
☐	☐	☐			

Item	Topic	Action by	Action due	Action complete
1	Site visit debrief provided to those in attendance by BS – the main problem area identified during that visit was flooding in Brisbane Street.	-		
2	CH pointed out that it would still be beneficial to make mention of any other areas that may be subjected to any minor/shallow overland flow during flood events in the final report. Noted.	BS	23 July 2014	
3	PM and CH discussed the potential detention basins that are proposed in the Fishers Gully and adjoining creek sub catchment to the south. The model could be used to assess these once provided to Council but not as part of this project scope.	-		
4	The design surface of the Telemon Rd upgrade has not been received to date but after interrogating results on screen during the workshop it almost certainly will not have any significant effect on flooding in Brisbane St. JC has been in contact with TMR to obtain the design surface data to include in the model but if this is not forthcoming in the very near future it is proposed to continue without – JC to advise on this.	JC	8 July 2014	

Item	Topic	Action by	Action due	Action complete
5	The calibration of the model was outlined to the meeting attendees. The general consensus was that the modelling is replicating these flood events satisfactorily and that it is fit for purpose in moving forward with the study.	-		
6	The meeting attendees then discussed potential mitigation measures to alleviate the flooding issue at Brisbane St. Moving forward these will include: - Construction of a trunk pipe along Eaglesfield St - Construction of a trunk pipe along Short St to provide additional capacity downstream of Brisbane St - Construction of a trunk pipe along Anna Street (south of William St) and Albert Street - Sealing the pits on and around Brisbane St for the existing drain to ensure no surcharging (I suspect however that this will only serve to relocate the problem elsewhere – other measures [i.e. additional capacity] would still be required) - As discussed with Josh following on from the workshop, upgrading the culverts leading from the open drain to Spring Creek. Most likely won't add a great deal of benefit but will test to confirm. These measures will be tried in a number of permutations to work towards an overall drainage solution.	BS	11 July 2014	

Next meeting: Tuesday, 15 July 2014

Appendix H
Options assessment workshop meeting minutes

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Meeting Record

Project number	242007	Meeting date	15 July 2014
Project name	Beaudesert Boonah SSAIP	Recorded by	Brian Sexton
Meeting/subject	Beaudesert SSA&IP Options Assessment Workshop	Total pages	2

Present	Apology	Copy	Name	Organisation	Contact details
☒	☐	☐	Brian Sexton (BS)	Aurecon	Brian.sexton@aurecongroup.com
☒	☐	☒	Patrick Murphy (PM)	SRRC	patrick.m@scenicrim.qld.gov.au
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☐	☐	☐			
☐	☐	☐			
☐	☐	☐			

Item	Topic	Action by	Action due	Action complete
1	BS outlined the modifications made to the model (actions from the System Assessment workshop)	-		
2	BS outlined the results of the options modelling – it is clear that several options made no real improvement i.e. Option A, C, D and E.	-		
3	Option B and F were deemed worthy of further consideration	-		
4	Examination of the costs ruled out Option F – accordingly Option B was selected as the preferred option	-		
5	Further discussion and refinement of the Option B approach led to an improved, formalised final option. The preferred option involves connecting the main town drain RCBC to the trunk pipe that would be running through Brisbane Street/ Short Street – this is to be modelled going forward	-		

Next meeting: None required

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Boonah Stormwater System Assessment and Improvement Plan

Final Report

Scenic Rim Regional Council

5 December 2014

Revision: 1

Reference: 242007

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Document control record

Document prepared by:

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Document ID			**Project number**		242007	
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Client		Scenic Rim Regional Council	**Client contact**		Josh Canaris	
Rev	**Date**	**Revision details/status**	**Prepared by**	**Author**	**Verifier**	**Approver**
0	31 October 2014	Draft for Client Review	C Smyth	B Sexton	T Graham	C Berry
1	5 December 2014	Final Issue	C Smyth	B Sexton	T Graham	C Berry
Current revision		**1**				

Approval			
Author signature		Approver signature	
Name	Brian Sexton	Name	Craig Berry
Title	Senior Civil Engineer	Title	Water Services Leader, Brisbane

Boonah Stormwater System Assessment and Improvement Plan

Date 5 December 2014
Reference 242007
Revision 1

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Executive summary

Aurecon have been engaged by Scenic Rim Regional Council (SRRC or 'Council' hereafter) to undertake an assessment of the stormwater network in the townships of both Beaudesert and Boonah. This project was commissioned in response to ongoing flooding issues that are present within these localities with the ultimate aim of understanding and reducing flood risk. Note that this report discusses the findings specific to Boonah only.

The study involves:

- Assessing the existing stormwater network to identify areas/locations where the drainage system is not performing adequately and is causing flooding issues
- Developing and testing mitigation strategies aimed at improving the performance of the drainage system in these areas
- In conjunction with Council, selecting a preferred mitigation solution to take forward to Council's next phase of evaluation (ie a future Capital Works Program)

A thorough assessment of the existing stormwater system in Boonah has been completed. This involved the development of hydrologic and hydraulic models for the area.

An interrogation of available field data showed that no historical information was available with which to undertake a calibration/validation exercise for the Boonah hydraulic model. However, the successful calibration of the Beaudesert model gave confidence that the Boonah model should have a similar level of predictive accuracy – the Boonah model adopts the same hydrologic/hydraulic modelling approach as the Beaudesert model, the parameterisation is also consistent, and the terrain/land usage is not markedly different. Overall it can be reasonably assumed that the model outputs should be of a similar accuracy to those taken from the Beaudesert model.

The key objectives of the study were:

- To determine the current performance of the stormwater system, and
- To recommend optimal solutions to improve these systems to deliver the desired level of service to the community

Note that in carrying out the system assessment, generally speaking the performance of the pipe network was found to be satisfactory. However two areas were identified as being problematic. They were:

- Overland flooding at Arthur Terrace near Devin Drive
- Overland flooding through properties near Mount French Road/McBean Street

The efficient and effective mitigation of both of these flooding issues can be achieved through some minor earthworks. At Mount French Road the approximate extent of the work is summarised as being:

- Total Volume = 325 m^3 of earthworks
- Length = 63 m
- Average Height = 0.9 m

At Arthur Terrace the bund earthworks include:

- Total Volume = 461 m^3 of earthworks
- Length = 148 m
- Average Height = 0.8 m

In both cases the effect of this is to mitigate the flood risk to the property in all events up to and including the 100 year ARI event. No adverse impacts are predicted to occur as a result of this proposed mitigation measure.

Another scenario which was investigated as part of the Options Assessment phase of the project was the proposed development that is set to occur north of Devin Drive and Bartholomew Avenue (refer to Figure 19). The hydrologic model was modified to account for this area being made into a residential zone as opposed to its current greenfield usage. Initially this scenario was tested with no mitigation of developed conditions flows. Increases in flood levels of 0.3 m were observed to affect localised areas with an average increase of 0.2 m evident along a significant stretch of the downstream floodplain.

Using the hydrologic model is was possible to determine the approximate dimensions/configuration of three detention basins required to mitigate the increase in discharge such that it was reduced to pre-development conditions. This information is presented in Section 7.

Contents

Appendices

Figures

Tables

1 Introduction

1.1 Background

Aurecon have been engaged by Scenic Rim Regional Council (SRRC or 'Council' hereafter) to undertake an assessment of the stormwater network in the townships of both Beaudesert and Boonah. This project was commissioned in response to ongoing flooding issues that exist within these localities with the ultimate aim of understanding and reducing flood risk.

Note that this report discusses the findings specific to Boonah only.

The study involves:

- Assessing the existing stormwater network to identify areas/locations where the local drainage system is not performing adequately and is causing flooding issues
- Developing and testing mitigation strategies aimed at improving the performance of the drainage system in these areas
- In conjunction with Council, selecting a preferred mitigation solution to take forward to Council's next phase of evaluation (ie a future Capital Works Program)

The assessment has been completed using hydrologic and hydraulic models which have been developed specifically for this project based on current catchment development levels including approved development application works ie not future catchment development levels). These computer models allow the prediction of surface and subsurface flow interaction, the results of which can be interrogated and visualised within GIS software. The development, parameterisation and performance of the models are presented later in the report.

Figure 1 shows the project area and key place names/features discussed within this report.

Note that all cost estimates provided in this report are to be considered preliminary only.

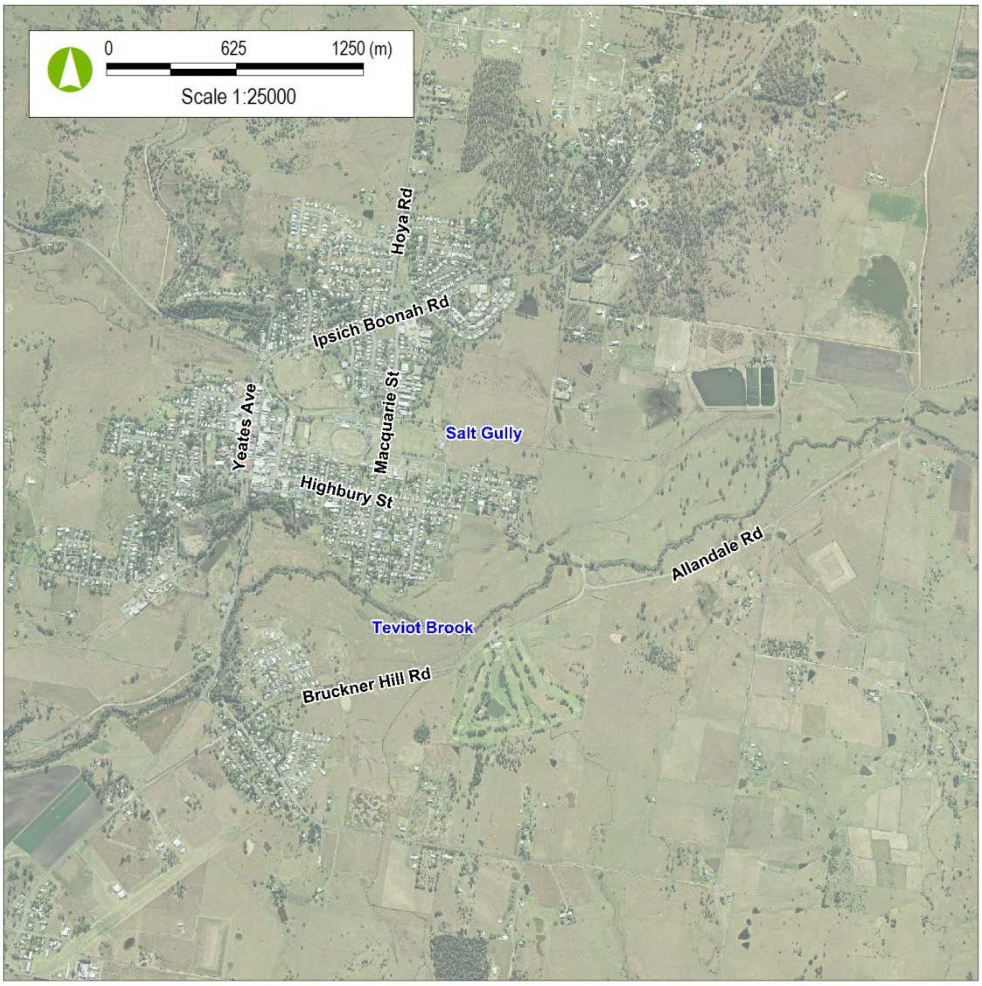


Figure 1 Project location and key features

1.2 Objective of the study

As per the brief the objective of the study can be defined as:

- Determining the current performance of the stormwater system, and
- To recommend optimal solutions to improve these systems to deliver the desired level of service to the community

1.3 Catchment description

The town of Boonah is affected by multiple flood sources including Teviot Brook (a regional flood source), as well as local creeks and ephemeral overland flowpaths through urban sub-catchments (local flood sources). Refer to Figure 2 which shows:

- A: Salt Gully
- B: Teviot Brook

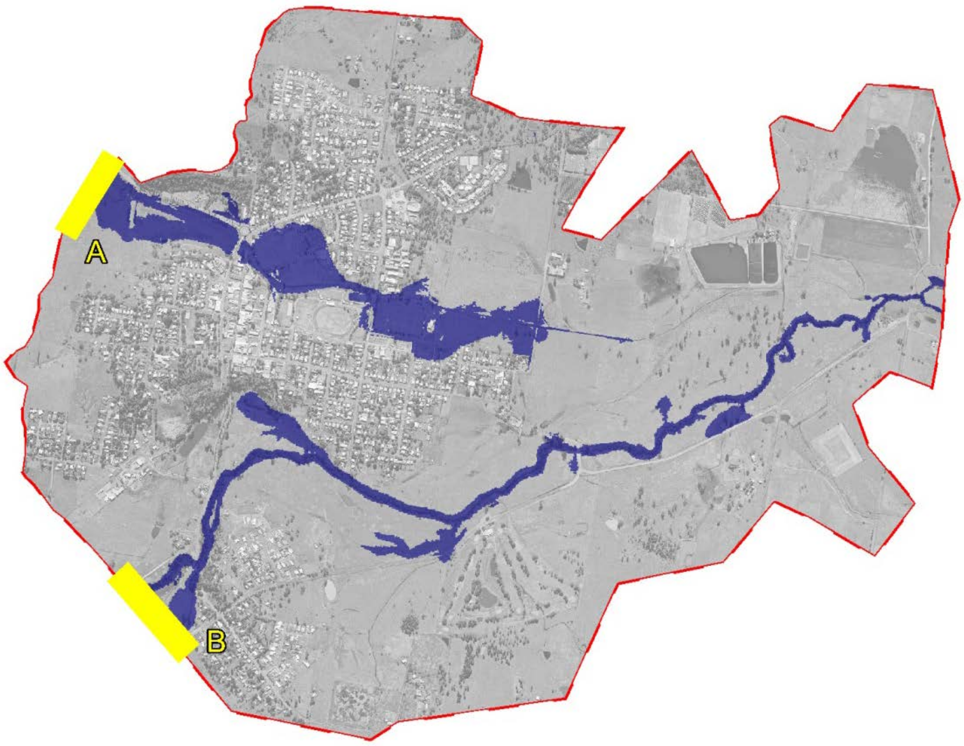


Figure 2 Flood sources and flow comparison locations

The Teviot Brook catchment is approximately 550km^2 in total area upstream of Wyaralong Dam, mainly stretching to the south-west of Boonah covering undeveloped pasture/agricultural land. The creek flows in a predominantly north-easterly orientation before discharging in to Lake Wyaralong approximately 15 km downstream of Boonah. Teviot Brook continues to flow out of Lake Wyaralong until the confluence with the Logan River near Kilmoylar Road.

The Salt Gully catchment has an area of approximately 40 km^2 and in its upper, steeper reaches is mainly undeveloped bushland. The lower reaches of the catchment are mainly rural. Its confluence with Teviot Brook is located 2 km downstream of Boonah.

2 Background data and project inception

2.1 Project inception and site visit

A project inception meeting was held on 14 May 2014 at SRRC offices in Beaudesert. Site visits were carried out for both Beaudesert and Boonah with Aurecon representatives accompanied by SRRC operations staff familiar with the Beaudesert and Boonah drainage systems. The SRRC personnel were able to offer their knowledge of the systems behaviour and performance during recent flood events. This was extremely beneficial as it provided a good understanding of where potential flooding issues should be observed when reviewing the modelling results.

The site visit also provided the opportunity to gain an accurate representation of the existing catchment conditions. It also aided in familiarising the project staff with the overall technical challenge and provided a better understanding of key elements that directly relate to the analysis process eg catchment topography, floodplain/channel vegetative cover, existing hydraulic structures, etc.

The site visit involved photographing and taking notes of the key features of the drainage system. Figure 3 shows a sample image taken of Salt Gully near Elliot Road.

Figure 3 Lower reaches of Salt Gully near Elliot Road

Following completion of the site visits to Beaudesert and Boonah, Aurecon's Project Leader met with key Council personnel who would be involved in running the study. The meeting discussed several key aspects of the project including:

- Data requirements
- Communication protocols
- Scope
- Project management and client liaison/updates
- Analysis techniques and methodologies
- Timeframes

2.2 Data collation and review

A study of this nature requires a substantial amount of data to be collated during the initial stages of the project. SRRC had already provided significant amounts of data to Aurecon as part of a separate study (the Logan River Flood Study Upgrade) for which permission was granted to use for this project. This included:

- Topographic data (current SRRC LiDAR)
- Aerial imagery
- Cadastral boundary data

In addition SRRC provided the following information specific to this project:

- Structural survey data
- Stormwater GIS layers for Boonah
- Previous report and model information (Boonah Flood Hazard Model Upgrade, DHI, 2013; Flood Hazard Mapping – Boonah (Bundle 5), DHI, 2013)

This data was used to assist in the development of the hydrologic/ hydraulic models.

2.3 Client communication

Throughout the course of the project regular contact was maintained with SRRC's Project Manager. This included email and phone communication as well as three meetings (ie a project inception meeting, a System Assessment workshop and an Options Assessment workshop).

Project feedback was also communicated regularly to SRRC outlining project progress with respect to its financial performance and program.

The regular and open communication lines that were established added to the efficiency with which the study could be carried out.

3 Hydrologic analysis

The hydrologic analysis can be broken into three parts:

- The major regional flood hydrology (ie Teviot Brook and Salt Gully)
- The local sub-catchments contributing to the ephemeral overland flowpaths/waterways
- The local sub-catchment hydrology contributing to the stormwater system

3.1 Regional flood hydrology

There are two regional flood sources which generate flooding within the Boonah area namely Teviot Brook and Salt Gully. The Beaudesert model had a similar mechanism with Spring Creek generating regional creek flooding. For Beaudesert, in order to incorporate these flows into the hydraulic model the design discharge hydrographs were simply extracted from the existing Spring Creek hydrologic model.

This same approach was envisaged for the Boonah study with previous modelling having been carried out by DHI. However, having discussed the matter with DHI it is understood that the inflows obtained for use in their hydraulic modelling were not established using a hydrologic model. Instead they were obtained through a flood frequency analysis for Teviot Brook, with the Salt Gully discharges being simply a scaled down version of the Teviot Brook hydrograph (ie factored down to 31% of the peak with the same hydrograph shape – refer to Figure 4 taken from the Boonah DHI report).

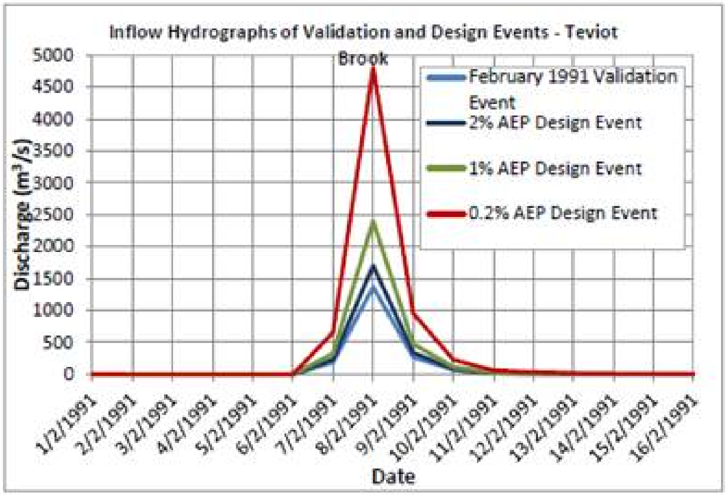


Figure 6 Inflow Hydrographs – Teviot Brook

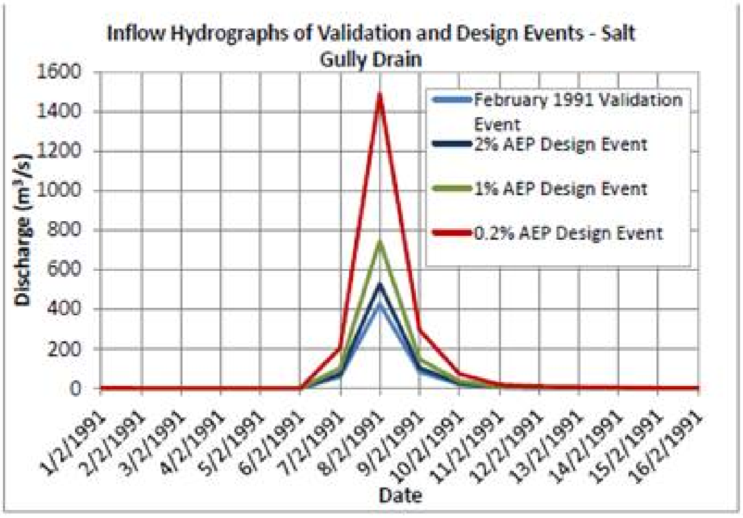


Figure 7 Inflow Hydrographs – Salt Gully Drain

Figure 4 Regional flood flow hydrographs

It is also noted that the design event discharge hydrographs have a long duration (spanning a few days) with this shape being based on the 1991 event. It could reasonably be expected that these catchments do take a comparatively longer time to respond due to their size, but use of these hydrographs and discharges in conjunction with the short duration local catchment critical hydrology is deemed conservative (ie simultaneous flooding of a given event magnitude on both local and regional catchments is very unlikely due to their differing response times).

Having examined preliminary model results three locations were identified where there are flooding issues, all of which are not affected by the creek/brook flooding. They include:

- Flooding near Yeates Avenue/High Street
- Some overtopping of Hoya Road near Devin Drive due to local runoff
- Overland flooding within properties near Mount French Road

All of these locations are not affected by Salt Gully/Teviot Brook tailwater levels due to the ground levels of each location being high and consequently analysis could proceed without requiring detailed information on the regional flood hydrology.

A number of other options in terms of how best to move forward were discussed with Council but the recommended and agreed approach was to assume a nominal discharge on both Teviot Brook and Salt Gully (eg extrapolate the 2 year ARI peak discharge) and apply this as a steady state flow in combination with the various event magnitudes on the local catchments (2 to 100 year ARI). This is not an unrealistic assumption or approach. This also ensured the project remained on track timewise and was focused on and aligned with the main objectives of this study.

Figure 5 below shows the extrapolation of the 2 year ARI peak flow for Teviot Brook. This was factored down to 31% for that of Salt Gully. Both were then applied as steady state inflows within the hydraulic model. The 2 year ARI discharges are:

- Teviot Brook – 270 m^3/s
- Salt Gully – 84 m^3/s

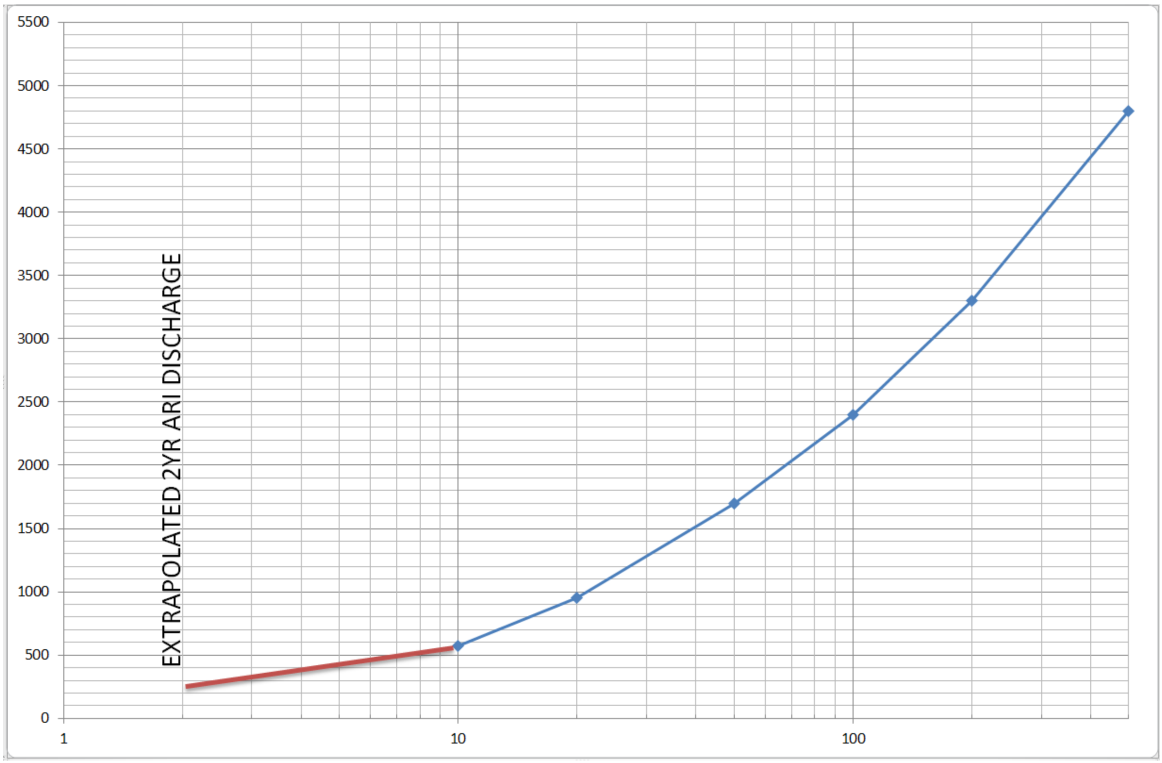


Figure 5 2 year ARI discharge extrapolation for Teviot Brook

3.2 Local sub-catchment hydrology

A RAFTS hydraulic model was developed to establish the local sub-catchment flows that propagate through the model domain and affect the stormwater system. The standard geo-specific AR&R temporal patterns were used for the RAFTS modelling of the local catchments as per the Beaudesert study approach.

RAFTS is a non-linear runoff routing model used extensively throughout Australia. It has been shown to work well on catchments ranging in size from a few square metres to thousands of square kilometres of both urban and rural nature, and is therefore suitable for use in this project.

3.2.1 Model parameterisation

Figure 6 shows the sub-catchment discretisation for the new model that was developed. Table 1 summarises the key sub-catchment parameters used for existing conditions. Table 2 summarises the key sub-catchment parameters used for developed conditions. This is further explained in Section 7.

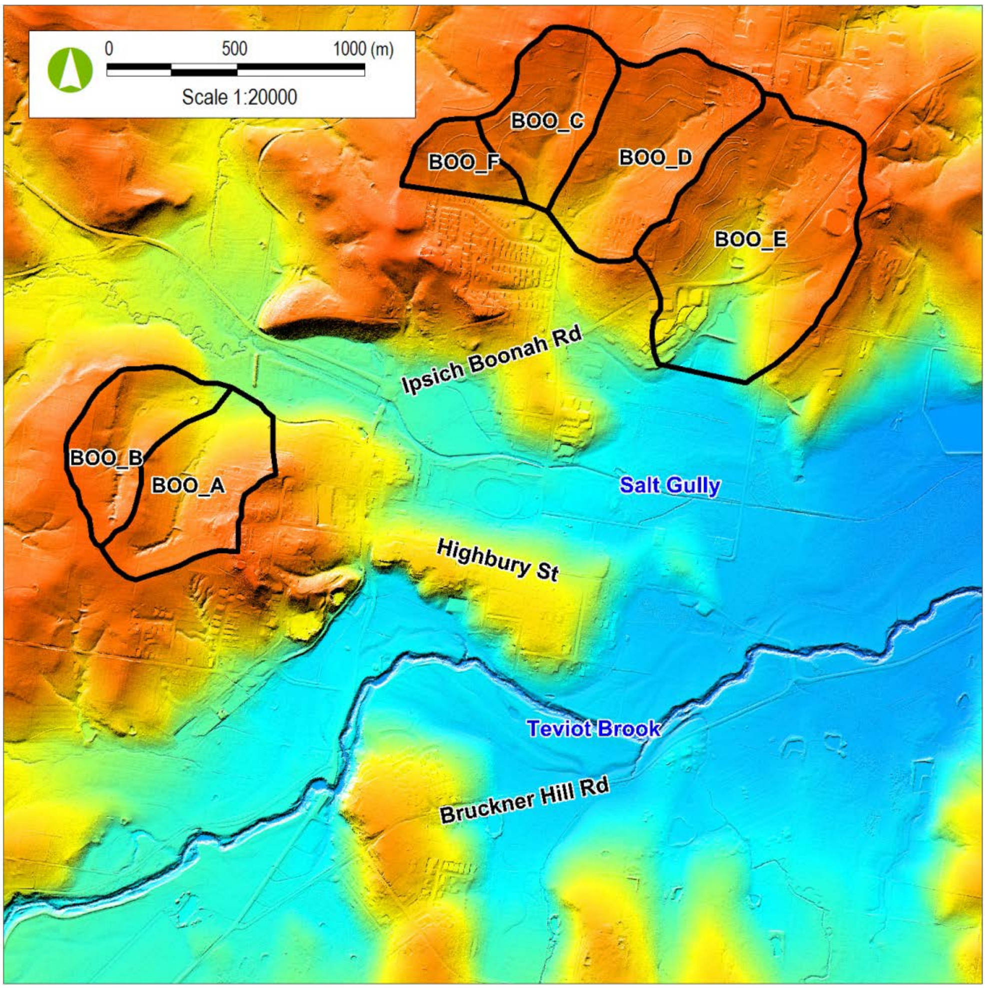


Figure 6 Sub-catchment discretisation of local creeks

Table 1 Sub-catchment parameterisation for existing conditions

Catchment ID	Total area (ha)	Catchment Mannings 'n' (in value)	Percentage impervious (%)	Vectored slope (%)
BOO_A	28	0.062	12	4.0
BOO_B	21	0.070	5	4.4
BOO_C	22	0.070	5	4.8
BOO_D	37	0.063	11	3.5
BOO_E	66	0.065	9	3.6
BOO_F	9	0.070	5	8.2

Table 2 Sub-catchment parameterisation for developed conditions

Catchment ID	Total area (ha)	Catchment Mannings 'n' (in value)	Percentage impervious (%)	Vectored slope (%)
BOO_A	28	0.062	12	4.0
BOO_B	21	0.070	5	4.4
BOO_C	22	0.040	32	4.8
BOO_D	37	0.047	26	3.5
BOO_E	66	0.065	9	3.6
BOO_F	9	0.025	45	8.2

Note that initial and continuing losses were set to 0 mm and 1.1 mm/hr respectively as per the values used in the Beaudesert study.

3.3 Local sub-catchment hydrology contributing to the pipe network

The hydrology of the local sub-catchments contributing to the pipe network was not modelled using RAFTS. Instead the rainfall was applied directly to the 2D domain of the TUFLOW hydraulic model. Accordingly the routing of the flow occurs within the hydraulic model. This is termed a 'direct rainfall' or 'rain-on-grid' approach and is commonly used for studies of this nature. Refer to Section 4 for further information regarding the hydraulic model.

3.4 Design event modelling

As per the brief, the following design events were simulated within the hydrologic model:

- 2 year ARI
- 5 year ARI
- 10 year ARI
- 50 year ARI
- 100 year ARI

Note also that an assessment of the critical storm duration on the local catchments in terms of peak discharge was carried out based on a review of the hydrologic model results. This showed that a one hour event yielded the peak discharge in the areas of interest within the model. This was further confirmed within the hydraulic model and is typical of the type of event that will cause issues in these areas.

3.5 Historic event modelling

An interrogation of available field data showed that no historical information was available with which to undertake a calibration/validation exercise for the Boonah hydraulic model. The nearest gauge to Boonah is located at Moogerah Dam which is still approximately 15 km away. When looking at localised, intense storm events this is a significant distance and measurements at this gauge may not be representative of what was actually experienced at Boonah.

Furthermore whilst local residents can recall major flooding on Teviot Brook and Salt Gully (eg 1991, 2013), these events are different in nature to the type of storm that generates urban stormwater flooding, which is the focus of this study. Those events are believed to have been predominantly regional as opposed to local flood events.

However, the successful calibration of the Beaudesert model gives confidence that the Boonah model should have a similar level of predictive accuracy – the Boonah model adopts the same hydrologic/hydraulic modelling approach as the Beaudesert model, the parameterisation is also consistent, and the terrain/land usage is not markedly different. The only difference between both models is that the rainfall IFD coefficients for the Boonah hydrologic model take into accounts its geographic location, and even then the difference is relatively minimal.

Overall it can be reasonably assumed that the model outputs should be of a similar accuracy to those taken from the Beaudesert model. Whilst being unable to undertake a calibration exercise is not ideal, in this instance (and for the reasons outlined above) it is not deemed an issue in terms of the reliability of the model predictions.

4 Hydraulic model development

A TUFLOW hydraulic model was developed by Aurecon to represent and assess the hydraulic behaviour within the project area. TUFOW is a widely used, reputable and robust software that is routinely used for projects of this nature.

The approach to the modelling was to build a combined 1D-2D model such that interaction between surface (2D domain) and sub-surface (1D pipe network domain) flows can occur. The development and parameterisation of the Boonah model is discussed in the following sections.

4.1 Simulation information

The hydraulic model has been developed to run as an unsteady simulation, thereby taking into account temporal variation in discharge and incorporating the effects of storage in the propagation of the flood through the model system. A cell size of 5 m was selected and the simulation ran with a timestep of 1 second. Based on the maximum depths of flow within the model domain this was deemed a suitable approach. The ratio of the grid-size to timestep is within industry norms thereby leading to manageable runtimes (in the order of 2 to 3 hours depending on the event being modelled).

4.2 2D domain and model extent

The 2D overland model domain was based on a Digital Elevation Model generated from the SRRC LiDAR data that was provided to Aurecon for use in the current Logan River Flood Study upgrade. The model contains over 4.5 km of Teviot Brook's main channel and 3.5 km of Salt Gully's main channel. In total the model domain covers an area of approximately 10 km^2. Refer to Figure 7 which shows the model extent.

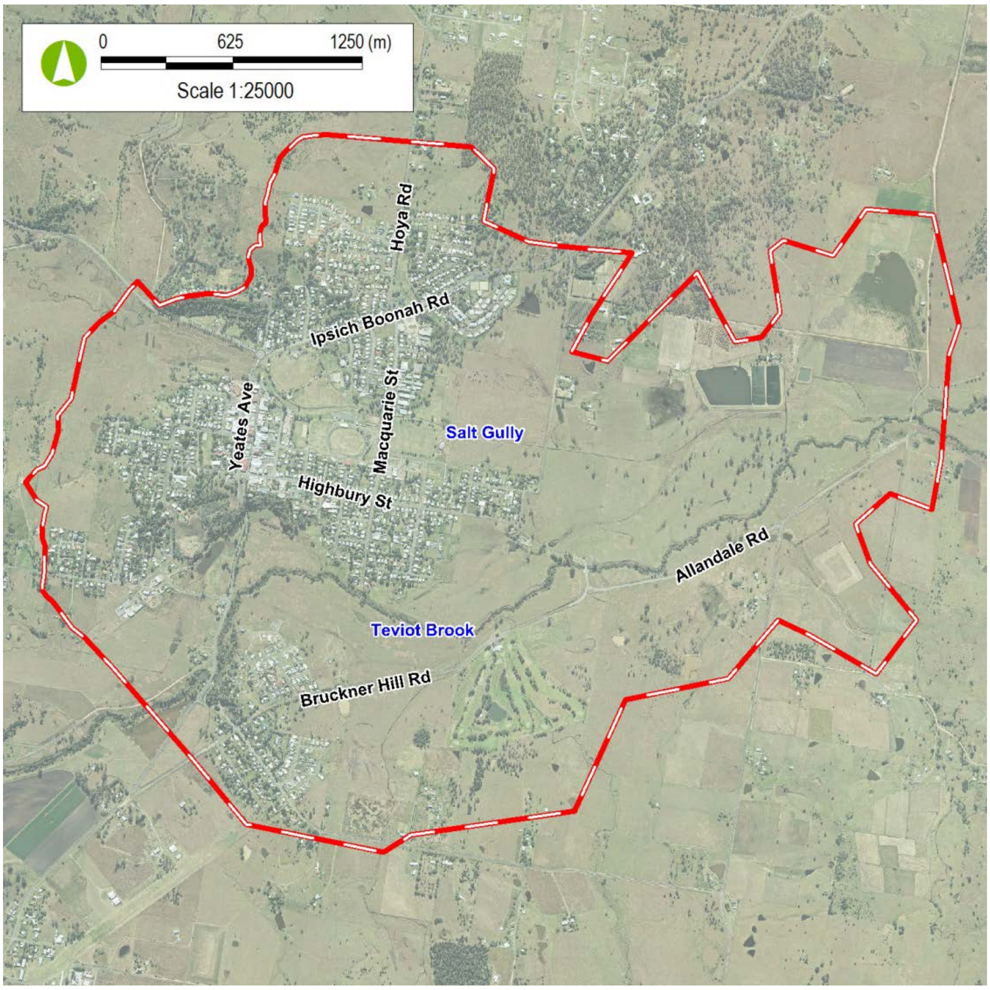


Figure 7 Hydraulic model extent

4.3 1D domain

The 1D pipe network domain is based on SRRC's pipe network GIS layer for Boonah and is shown in Figure 8 – this includes pits, manholes, pipes and culverts, albeit a refined representation of the entire system to focus on the key components of the network. This has been hydrodynamically linked to the 2D overland domain to allow interaction between surface and sub-surface flows. The pipe system was incorporated using a TUFLOW '1d_nwk' layer.

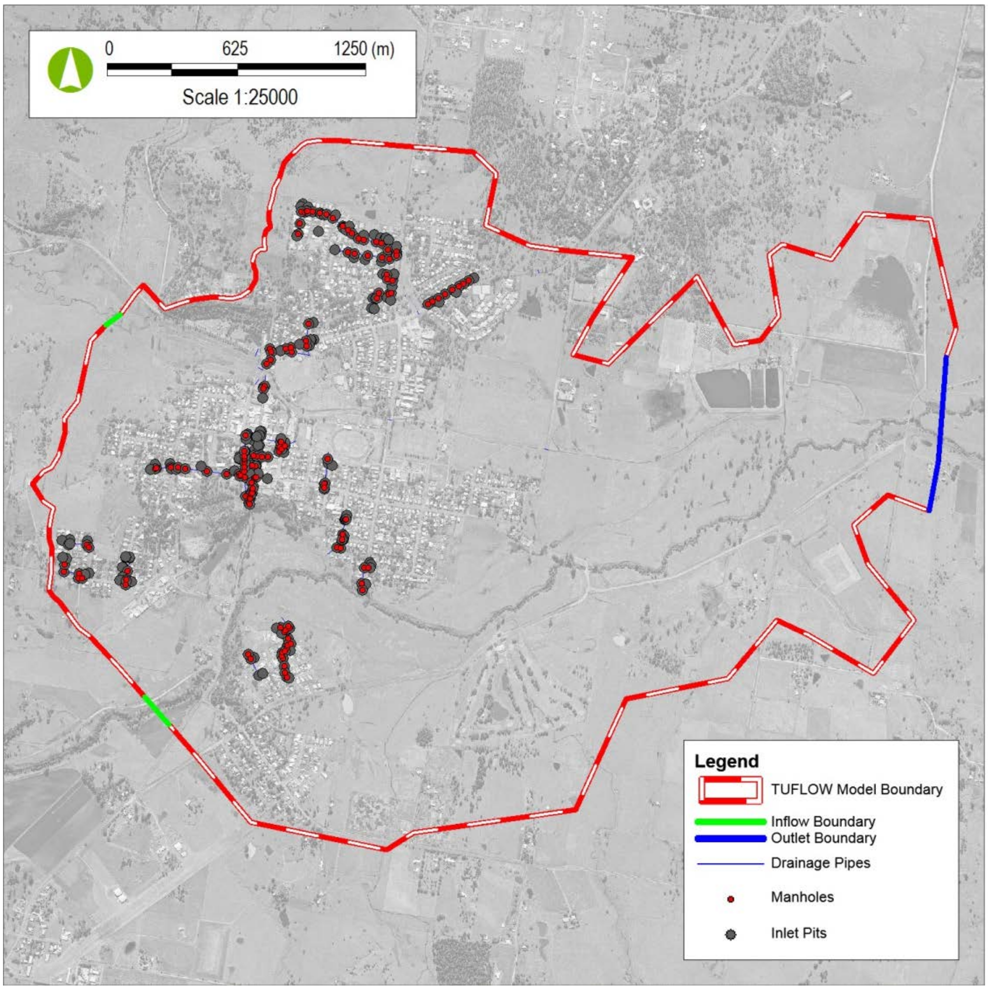


Figure 8 Model 1D network domain

4.4 Roughness discretisation

The digitisation of land use was based on the aerial imagery provided to Aurecon for use in the current Logan River Flood Study upgrade. Refer to Figure 9 which shows the land use digitisation within the Boonah model domain and adopted Manning's n values.

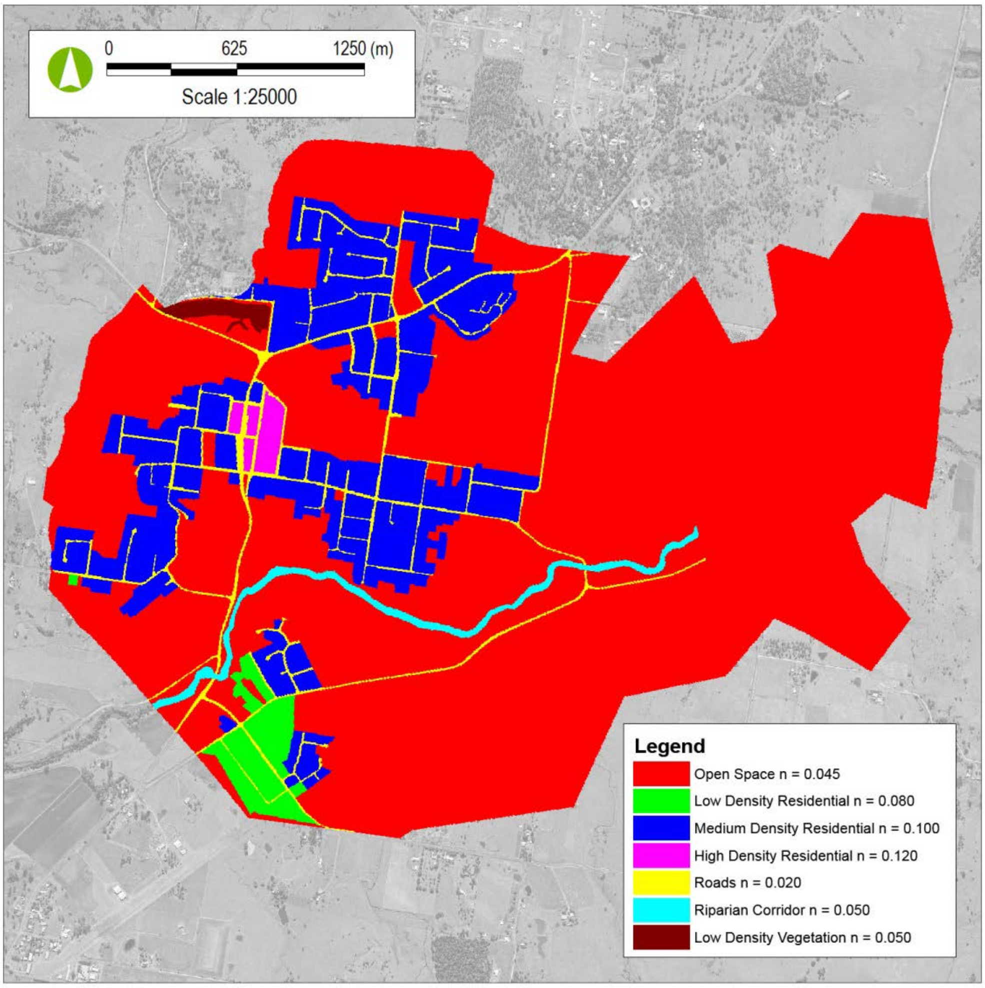


Figure 9 Model roughness discretisation

4.5 Structural representation

All major culverts and bridges within the model domain were incorporated into the model. Data was extracted from the DHI MIKE 21model where possible but certain data was still required due to it being missing. SRRC organised a survey of the structures to collate this data and provided it to Aurecon. This is summarised in Table 3.

Table 3 Summary of model cross-drainage structures

Watercourse	Structure location	Data source
Salt Gully	Yeates Avenue	MIKE 21 model
Salt Gully	Macquarie Street	MIKE 21 model
Unnamed tributary	Ipswich-Boonah Road (ID #3 – Figure 10)	Survey (provided by SRRC)
Salt Gully	Eliot Road (ID #4 – Figure 10)	Survey (provided by SRRC)
Unnamed tributary	Ipswich-Boonah Road (ID #5 – Figure 10)	Survey (provided by SRRC)
Teviot Brook	Boonah-Rathdowney Bridge	MIKE 21 model
Teviot Brook	Bruckner Rd Bridge	MIKE 21 model

Figure 10 Structures for which dimensions were taken by SRRC

4.6 Model boundary conditions

Inflows were extracted from the hydrologic model and applied within the hydraulic model as shown in Figure 11. Also direct rainfall was applied to the local sub-catchments within the model domain as per Figure 11. A normal depth water slope was applied at the downstream boundary following standard practice. The downstream boundary was located below the confluence of Teviot Brook and Salt Gully to ensure accurate computation of their interaction during flood events.

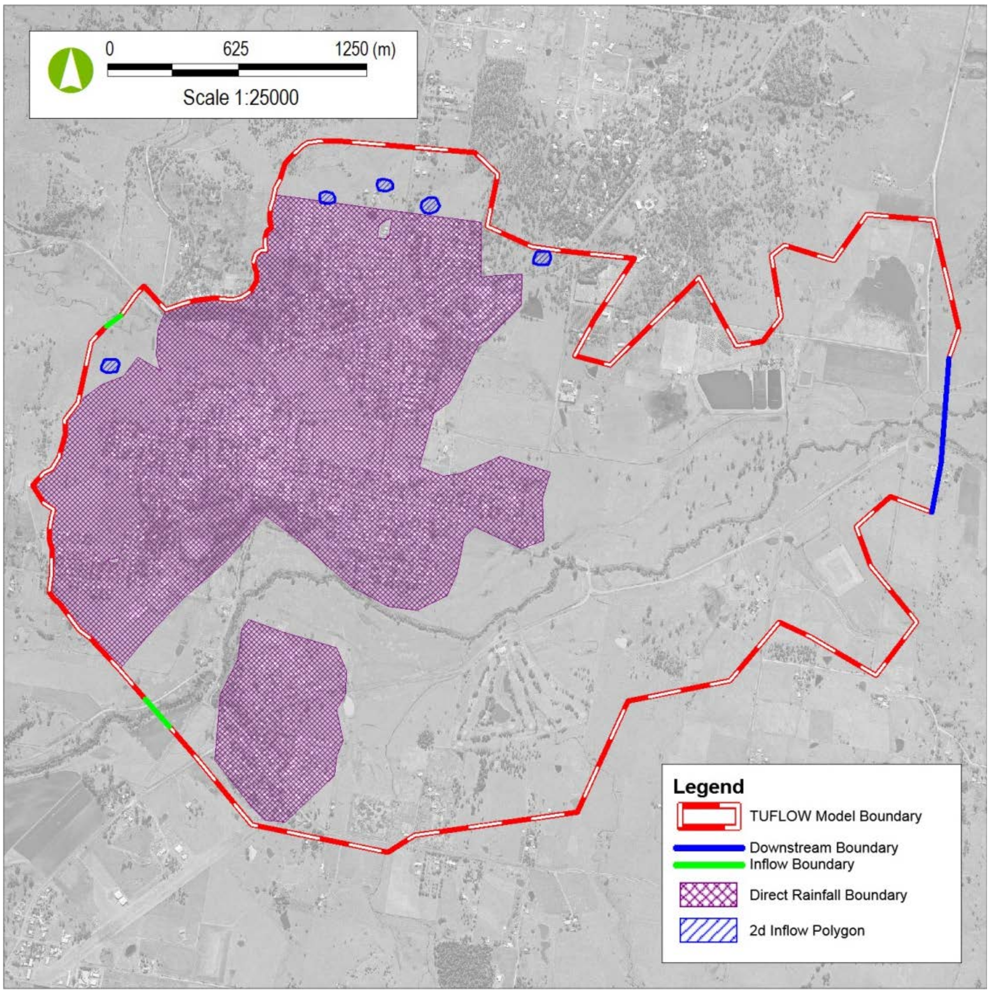


Figure 11 Model boundary layout

4.7 Stability, robustness and predictive accuracy

The model is complex in terms of its build and contains a significant amount of detail. It has been checked to ensure it performs in a stable manner. A check of the 1D pipe network domain shows excellent stability, similarly for the 2D domain. The overall mass balance is approximately 0.2% which is indicative of a robust and reliable model.

5 System assessment

5.1 Overview

A System Assessment workshop was held at SRRC offices in Boonah on 21 August 2014. Refer to Appendix F for the minutes of this meeting. This workshop was used to present the findings of the hydrologic and hydraulic modelling that had been completed to date. This included discussion of the data collation and the model development phase, as well as the assessment of the existing system.

Three problem areas were initially identified following the assessment of the existing system capacity modelling results. The areas were also pointed out as being problematic during the site visit. They are:

- Flooding near Yeates Avenue/High Street
- Overland flooding at Arthur Terrace near Devin Drive
- Overland flooding through properties near Mount French Road/McBean Street

  Refer also to the flood mapping in Appendices A and B. Note that generally speaking the performance of the pipe network appears to be satisfactory

  The issues are discussed in more detail below

  i) Flooding near Yeates Avenue/High Street: overland flow along a natural gully is predicted to inundate Yeates Avenue and High Street during significant flood events before discharging to Salt Gully downstream of Walter Street (refer to Figure 12)

Figure 12 10 year ARI flood extents near High Street

ii) Some overland flooding of Arthur Terrace near Devin Drive due to local runoff: local overland runoff is predicted to run along Devin Drive and Arthur Terrace before crossing Hoya Road (refer to Figure 13). This has previously caused issues by damaging the pavement wearing course on Arthur Terrace. Additionally, in large events there is flood risk to properties on Arthur Terrace

Figure 13 10 year ARI flood extents near Hoya Road

iii) Overland flooding through properties near Mount French Road/McBean Street (refer to Figure 14). This is predicted to affect residences and obviously poses a flood risk for persons, particularly children, at these dwellings

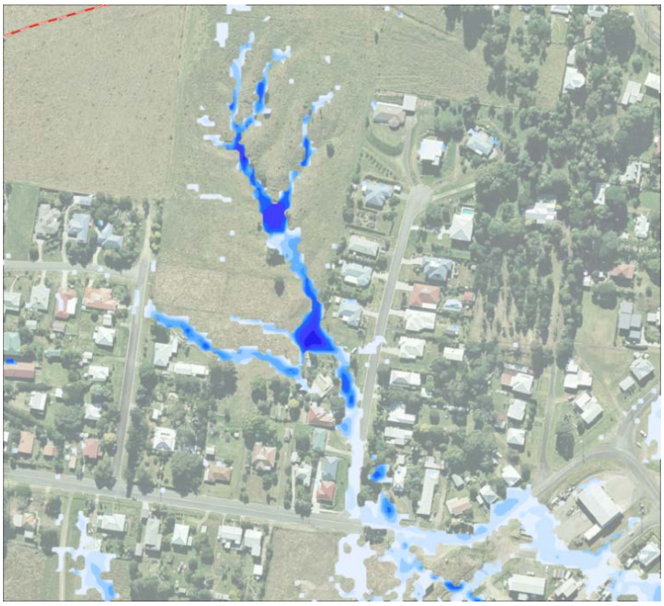


Figure 14 10 year ARI flood extents near Mount French Road

5.2 Summary of identified deficiencies for options assessment

The primary areas where a problematic deficiency exists in the overland drainage capacity have been identified. Accordingly these will be addressed in the Options Assessment phase of the project to develop mitigation solutions and comprise the following areas:

- Flooding near Yeates Avenue/High Street
- Overland flooding at Arthur Terrace near Devin Drive
- Overland flooding through properties near Mount French Road/McBean Street

6 Options assessment

6.1 Overview

Following on from the systems assessment workshop which was held at SRRC offices, Boonah on 21 August 2014, an options assessment workshop was held on 18 September 2014 to discuss the three locations that were originally identified for mitigation option testing (refer to Appendix G for the minutes of this meeting).These included Arthur Terrace/Devin Drive and Mt French Road/McBean Street. Both of these locations involved the provision of bunds to control and divert surface flows which were observed to cause flooding problems as per the model outputs and anecdotal historical evidence.

Note that another potential location which initial model predictions were showing generate flooding issues was Yeates Avenue/High Street (refer to Figure 15). Runoff from the catchment containing the school grounds was predicted to cross Yeates Avenue, then High Street and finally discharge to Salt Gully near the sports complex area.

Figure 15 Initial model predictions with missing pipe data - 10 year ARI flood extent shown

However, during the System Assessment Workshop SRRC personnel indicated that the network being used in the model (as per the GIS database for the stormwater system received by Aurecon) was incorrect. A 900 mm and 1200 mm RCP line which flows through the car-park located between the school buildings and Yeates Avenue had not been included. SRRC subsequently provided a sketch showing the indicative route and size of the drainage infrastructure which Aurecon then incorporated into the hydraulic model. This was observed to alleviate the flooding issue that was previously observed at this location (refer to Figure 16). Accordingly, mitigation testing was not required for this site.

Figure 16 Revised model predictions with missing pipe data included – 10 year ARI flood extent shown

Note however that no definitive survey was collected for this trunk main. It is recommended that in the future this be obtained and the model updated accordingly to ensure it is accurately represented.

6.2 Options assessment

The following sections show the effects of the flood mitigation measures which were identified and discussed at the System Assessment Workshop. Refer also to the flood mapping in Appendix C. Note that the bunds have been designed to allow for a 0.3 m freeboard above the 100 year ARI flood level.

6.2.1 Mt French Road/McBean Street

As per the flood mapping provided in Appendix C it is evident that surface flow being generated within a local catchment west of McBean Street flows through property gardens before crossing McBean Street and ultimately discharging downstream of Mt French Road.

However during significant flood events the run-off is predicted to exceed the capacity of the main ephemeral flowpath and is diverted via a secondary flowpath into the adjacent property with potential for the building to be affected.

To mitigate this issue it is proposed to undertake some minor channel realignment works combined with the construction of a bund on the southern side of the flowpath. The extent of the bund and channel works is shown in Figure 17.

Figure 17 Bund extent near McBean Street

The approximate extent of the work is summarised in the below bullet points:

- Total Volume = 325 m^3 of earthworks
- Length = 63 m
- Average Height = 0.9 m

The effect of this is to mitigate the flood risk to the property in all events up to and including the 100 year ARI event. No adverse impacts are predicted to occur as a result of this proposed mitigation measure.

6.2.2 Arthur Terrace/Devin Drive

The local catchments north of Devin Drive generate runoff which flows onto Devin Drive and Arthur Terrace before being conveyed across Hoya Road and into a natural watercourse.

The flow which runs into Arthur Terrace occurs in an uncontrolled manner and anecdotal evidence suggests it may affect adjoining properties. Accordingly, it is proposed to mitigate this flooding issue by managing the flow upstream of where it breaks onto Arthur Terrace.

The proposed strategy is to construct a bund to direct the flow into the detention basin on Devin Drive. This basin has a spillway and its design/location is such that its purpose is to direct run-off onto Devin Drive from where it flows within the road reserve towards Hoya Road. The properties bounding Devin Drive are well elevated and are not at risk of flooding from the run-off propagating along the pavement.

Figure 18 shows the extent of the bund north of Devin Drive/Arthur Terrace.

Figure 18 Bund extent near Arthur Terrace

The approximate extent of the work is summarised in the below bullet points:

- Total Volume = 461 m^3 of earthworks
- Length = 148 m
- Average Height = 0.8 m

The effect of this is to mitigate the flood risk to the property in all events up to and including the 100 year ARI event. No adverse impacts are predicted to occur as a result of this proposed mitigation measure.

6.3 Costing

The breakdown of the cost associated with the aforementioned bund works is provided in Appendix E. The total cost (preliminary only) for the earthworks at Arthur Terrace and McBean Street is estimated as being $201,000. This provides effective and efficient flood mitigation at these locations.

Note that the costing is based on current rates and, if taken forward to construction phase, should be recalculated based on updated/indexed rates.

7 Analysis of development upstream of Devin Drive

7.1 Overview

Another scenario which was investigated as part of the Options Assessment phase of the project was the proposed development that is set to occur north of Devin Drive and Bartholomew Avenue (refer to Figure 19). The hydrologic model was modified to account for this area being made into a residential zone as opposed to its current greenfield usage (refer to Table 2). The effect of this is to increase the volume and peak discharge of runoff which could subsequently have adverse impacts on downstream areas.

Figure 19 Indicative future residential area

Initially this scenario was tested with no mitigation of developed conditions flows. The results are provided in Appendix D. Increases in flood levels of 0.3 m are observed to affect localised areas with an average increase of 0.2 m evident along a significant stretch of the downstream floodplain.

Using the hydrologic model it was possible to determine the approximate dimensions/configuration of three detention basins required to mitigate the increase in discharge such that it was reduced to pre-development conditions. The indicative locations of these three basins (on three local subcatchments) are shown in Figure 20.

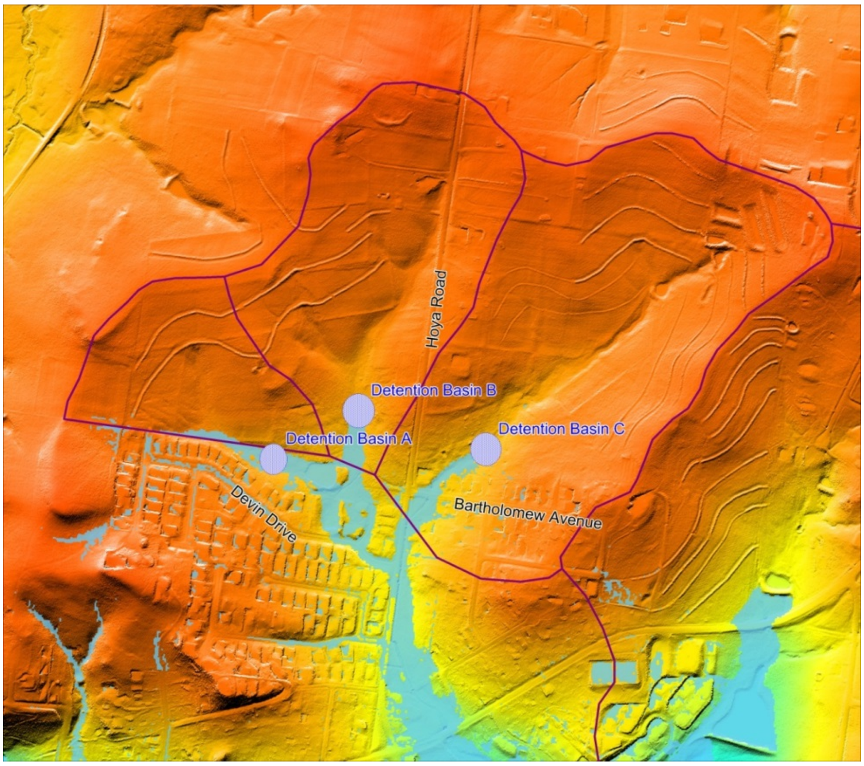


Figure 20 Indicative locations of detention basins

Table 4 also contains a summary of each basins dimensions/configuration. The proposed basins are observed to reduce the peak outflow to match the pre-development discharge. This reduces the risk of adverse impacts being generated downstream of the developed areas.

However, at the concept/detailed design phase of the developments when more information would be available a thorough analysis of the hydraulic behaviour would need to be undertaken as, in some rare instances, over-use of detention can in fact lead to negative impacts downstream due to the timing of the releases and how the hydrographs interact. Nonetheless this exercise gives a good indication of the scale of mitigation necessary to offset the proposed developments increased discharges.

Table 4 Detention basin details

Basin A						
Basin Specifications			Performance			
Volume (m^3)	Depth (m)	Outlet	Event	Existing Discharge	Developed Inflow	Mitigated Outflow
3500	1.5	2/900mm pipes	10 year ARI	2.4	4.3	2.0
			100 year ARI	3.6	6.1	3.2
Basin B						
Basin Specifications			Performance			
Volume (m^3)	Depth (m)	Outlet	Event	Existing Discharge	Developed Inflow	Mitigated Outflow
8750	1.5	3/1050mm pipes	10 year ARI	4.0	8.1	4
			100 year ARI	6.3	11.6	6.2
Basin C						
Basin Specifications			Performance			
Volume (m^3)	Depth (m)	Outlet	Event	Existing Discharge	Developed Inflow	Mitigated Outflow
12000	1.5	4/1200mm pipes	10 year ARI	6.8	11.1	6.9
			100 year ARI	10.9	16.8	11

8 Conclusions

A thorough assessment of the existing stormwater system in Boonah has been completed. This involved the development of hydrologic and hydraulic models for the area.

An interrogation of available field data showed that no historical information was available with which to undertake a calibration/validation exercise for the Boonah hydraulic model. The nearest gauge to Boonah is located at Moogerah Dam which is still in the order of 15 km away. Furthermore whilst locals can recall major flooding on Teviot Brook and Salt Gully (eg 1991, 2013), these events are different in nature to the type of storm that generates urban stormwater flooding, which is the focus of this study. Those events are believed to have been predominantly regional as opposed to local flood events.

However, the successful calibration of the Beaudesert model gives confidence that the Boonah model should have a similar level of predictive accuracy – the Boonah model adopts the same hydrologic/hydraulic modelling approach as the Beaudesert model, the parameterisation is also consistent, and the terrain/land usage is not markedly different. Overall it can be reasonably assumed that the model outputs should be of a similar accuracy to those taken from the Beaudesert model.

The key objectives of the study were:

- To determine the current performance of the stormwater system
- To recommend optimal solutions to improve these systems to deliver the desired level of service to the community

Note that in carrying out the system assessment, generally speaking the performance of the pipe network appears to be satisfactory. However two areas were identified as being problematic. They are:

- Overland flooding at Arthur Terrace near Devin Drive
- Overland flooding through properties near Mount French Road/McBean Street

The efficient and effective mitigation of both of these flooding issues can be achieved through some minor earthworks. At Mount French Road the approximate extent of the work is summarised as being:

- Total Volume = 325 m^3 of earthworks
- Length = 63 m
- Average Height = 0.9 m

At Arthur Terrace the bund earthworks include:

- Total Volume = 461 m^3 of earthworks
- Length = 148 m
- Average Height = 0.8 m

In both cases the effect of this is to mitigate the flood risk to the property in all events up to and including the 100 year ARI event. No adverse impacts are predicted to occur as a result of this proposed mitigation measure.

Another scenario which was investigated as part of the Options Assessment phase of the project was the proposed development that is set to occur north of Devin Drive and Bartholomew Avenue (refer to Figure 19). The hydrologic model was modified to account for this area being made into a residential zone as opposed to its current greenfield usage. Initially this scenario was tested with no mitigation of developed conditions flows. Increases in flood levels of 0.3 m are observed to affect localised areas with an average increase of 0.2 m evident along a significant stretch of the downstream floodplain.

Using the hydrologic model is was possible to determine the approximate dimensions/configuration of three detention basins required to mitigate the increase in discharge such that it was reduced to pre-development conditions. This information is outlined in Section 7 of the report.

9 Assumptions, limitations and recommendations

The following assumptions apply to the study:

- The base case hydrologic model assumes existing development conditions
- No detailed hydrologic assessment/information relating Teviot Brook and Salt Gully was available at the time this study was being completed
- The aim of this study is to provide a concept mitigation strategy only. Detailed design will still be required to establish the full range of constraints related to the preferred option, and to undertake the final design taking these constraints into account

The following limitations relate to the study:

- The LiDAR data from which the topographic DEM was developed has been post-processed at building locations to strip out any vertical anomalies caused by the LiDAR hitting roofs, building walls etc. Accordingly, the DEM may not be providing an accurate representation of floor levels within the buildings
- The representation of buildings within 2D hydraulic models, and the consequent effect they have on flow patterns, is an ongoing area of research and development within the hydraulic modelling community. The approach used in this study is in line with current industry practices but may still not fully represent real flood behaviour as it interacts with buildings
- The representation of the 1D pipe network has been simplified as agreed with Council to only incorporate the key trunk stormwater pipes and major branch connections. This is deemed adequate for the purposes of this study
- Note that the costing is based on current rates and, if taken forward to construction phase, should be recalculated based on updated/indexed rates

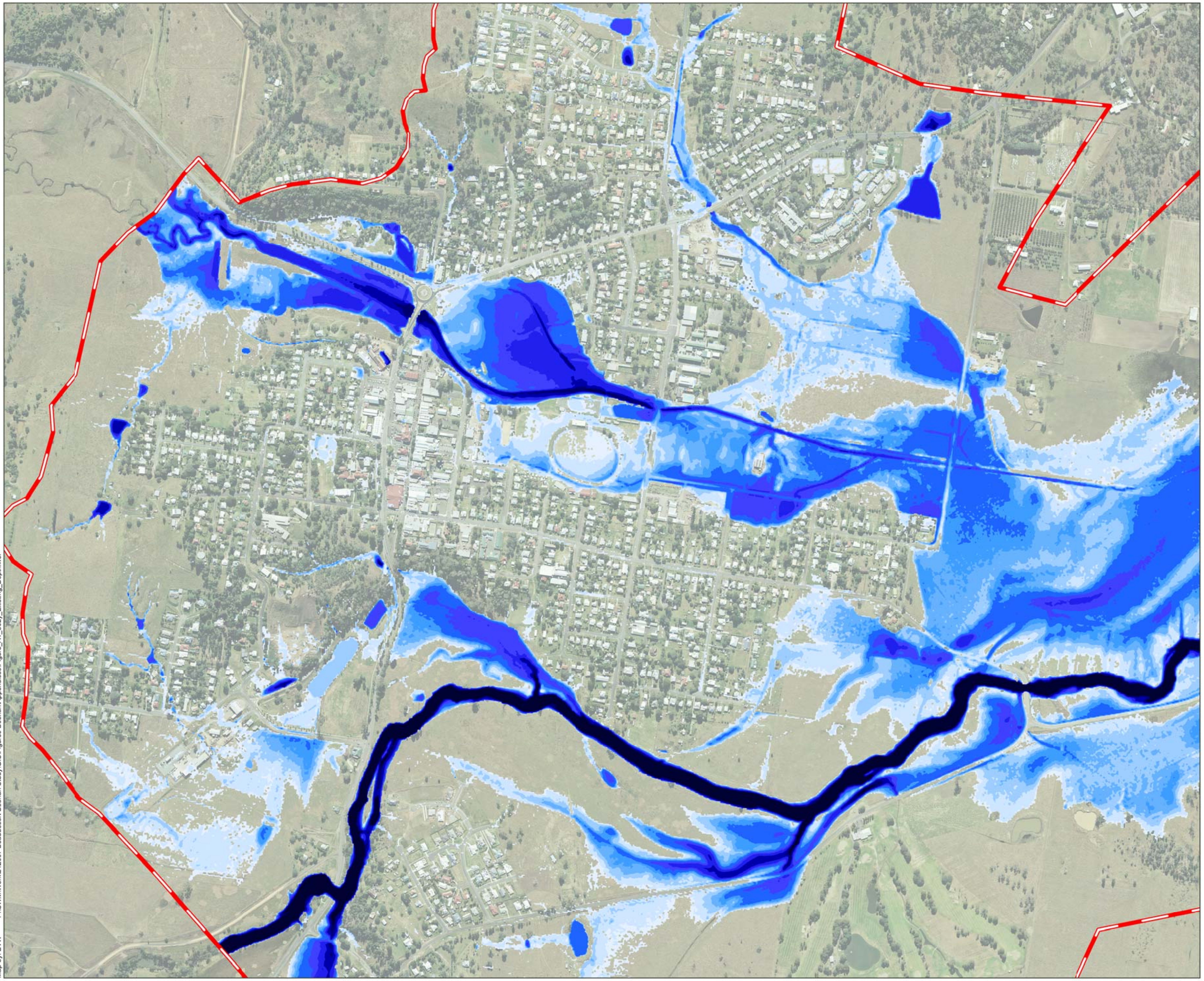
The following recommendations are made in regard to future analysis that may be undertaken:

- Should the preferred options be progressed to detailed design and construction phase then additional hydraulic analysis should be undertaken to ensure the design is represented accurately in the model
- SRRC could consider providing rain gauges in and around Boonah, as well as additional river height gauges on Salt Gully/Teviot Brook to record peak flood depths
- More detailed survey of the trunk drainage around Yeates Avenue should be undertaken and the model updated accordingly

Appendices

Appendix A
Base case flood mapping

aurecon



Legend

TUFLOW Model Boundary

Depth (m)

0.00 to 0.10	0.75 to 1.00
0.10 to 0.20	1.00 to 1.50
0.20 to 0.30	1.50 to 2.00
0.30 to 0.40	2.00 to 2.50
0.40 to 0.50	> 2.50
0.50 to 0.75	

Notes:

Map by: BVW P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Boonah\Appendices\Figure_A1_002y_Existing_Depth.wor

A3 scale 1:10,000

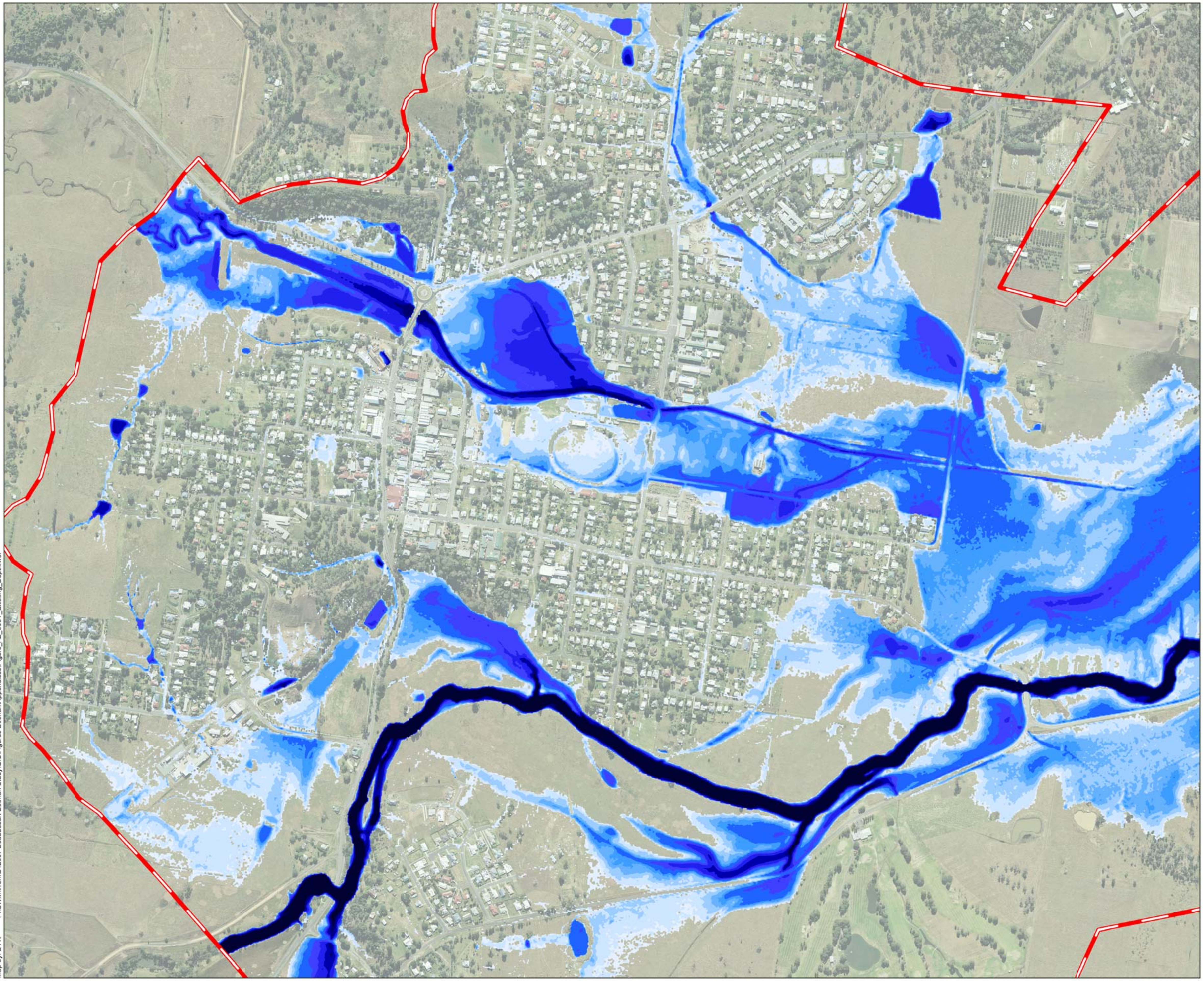
0 250 m 1,000 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Boonah Study Area

Figure A1: 2 year ARI Event - Existing Case - Peak Depth



Map by: BVW   P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Boonah\Appendices\Figure_A2_005Y_Existing_Depth.wor

Legend

TUFLOW Model Boundary

Depth (m)

0.00 to 0.10	0.75 to 1.00
0.10 to 0.20	1.00 to 1.50
0.20 to 0.30	1.50 to 2.00
0.30 to 0.40	2.00 to 2.50
0.40 to 0.50	> 2.50
0.50 to 0.75	

Notes:

A3 scale 1:10,000

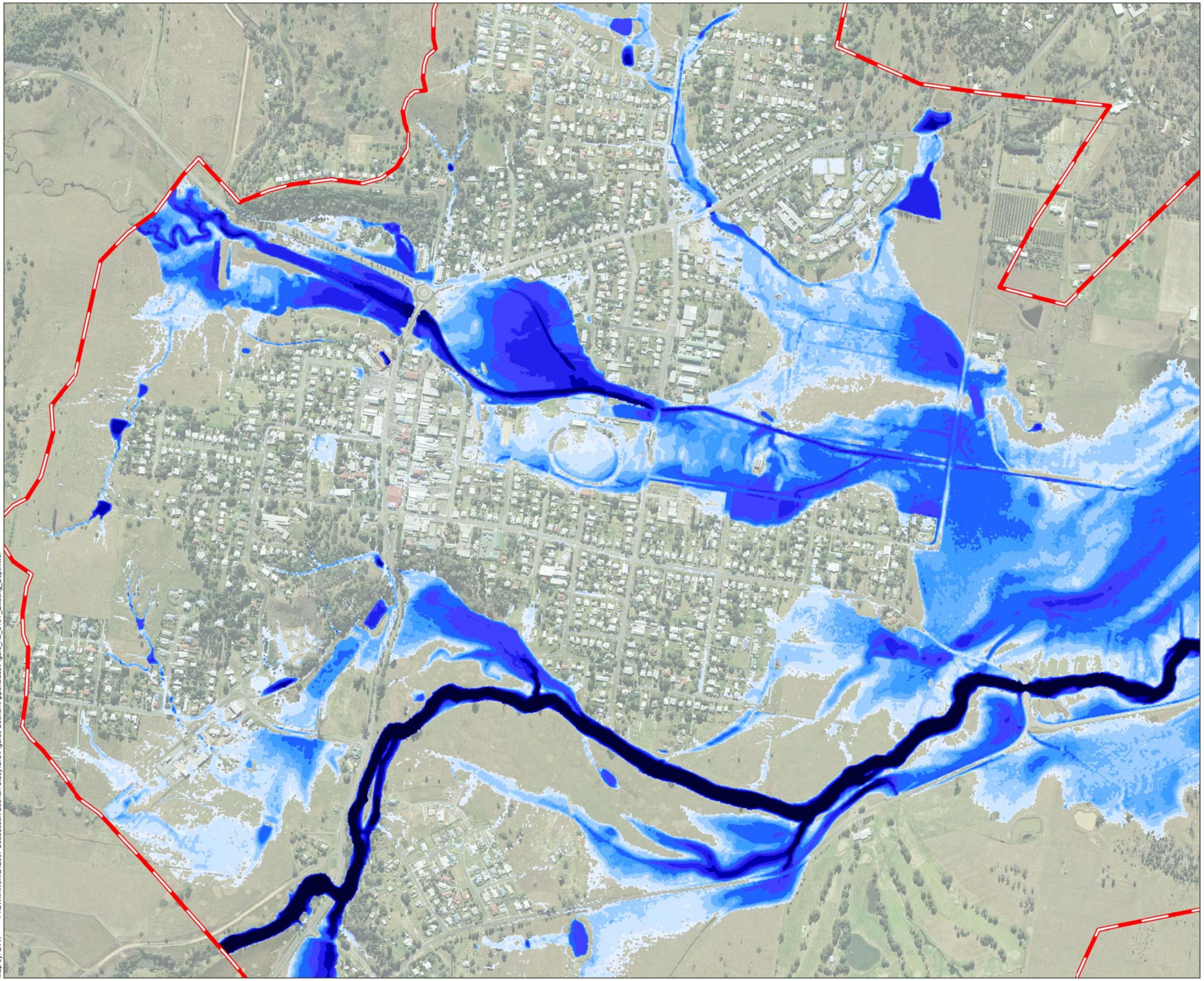
0   500 m   1,000 m

Date: 04/12/2014   Version: 0   Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Boonah Study Area

Figure A2: 5 year ARI Event - Existing Case - Peak Depth



aurecon

Legend

TUFLOW Model Boundary

Depth (m)

0.00 to 0.10	0.75 to 1.00
0.10 to 0.20	1.00 to 1.50
0.20 to 0.30	1.50 to 2.00
0.30 to 0.40	2.00 to 2.50
0.40 to 0.50	> 2.50
0.50 to 0.75	

Notes:

Map by: BVW P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Boonah\Appendices\Figure_A3_010Y_Existing_Depth.wor

A3 scale 1:10,000

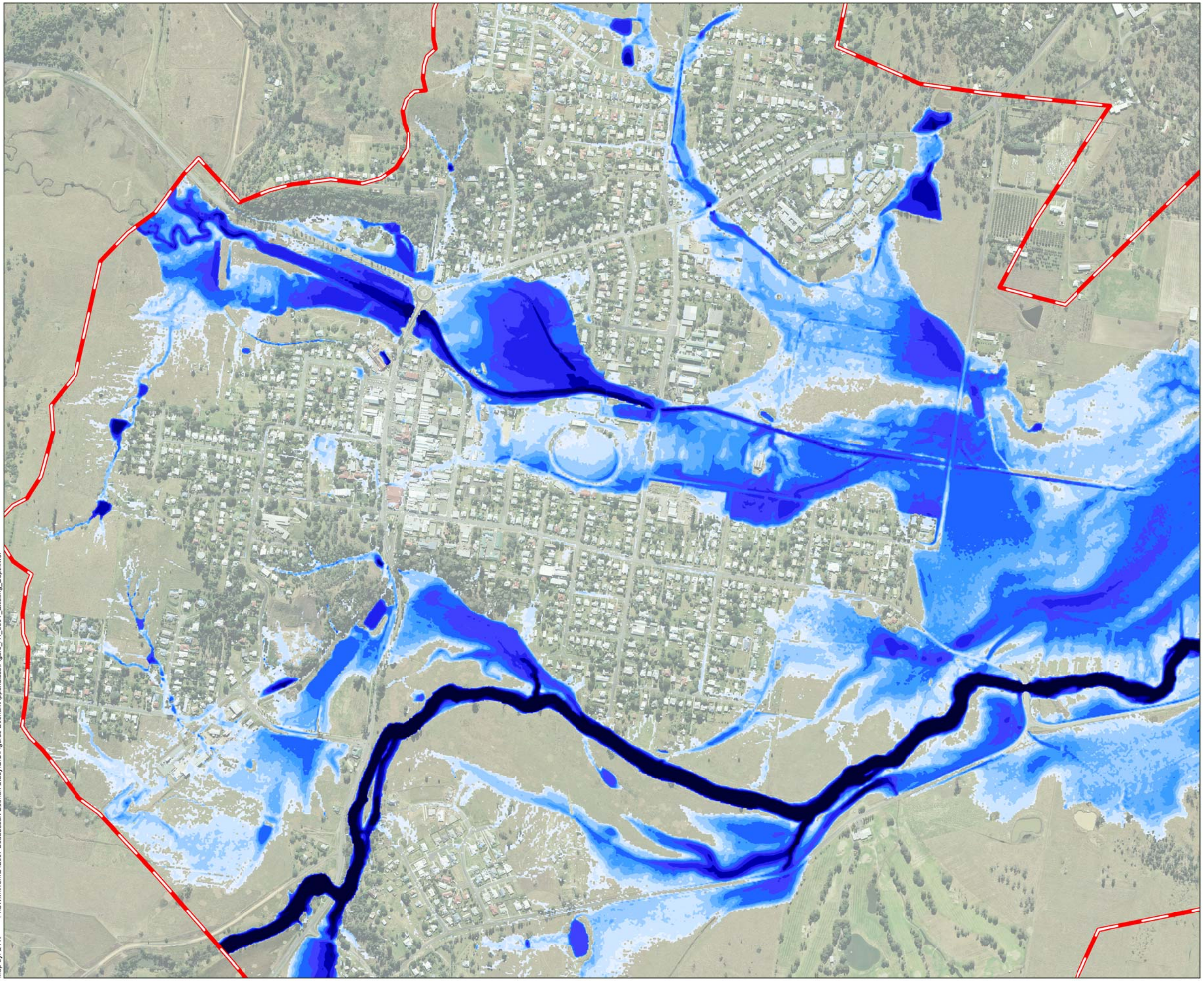
0 500 m 1,000 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Boonah Study Area

Figure A3: 10 year ARI Event - Existing Case - Peak Depth



aurecon

Legend

TUFLOW Model Boundary

Depth (m)

- 0.00 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 2.50
- > 2.50

Notes:

Map by: BVW

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A3 scale 1:10,000

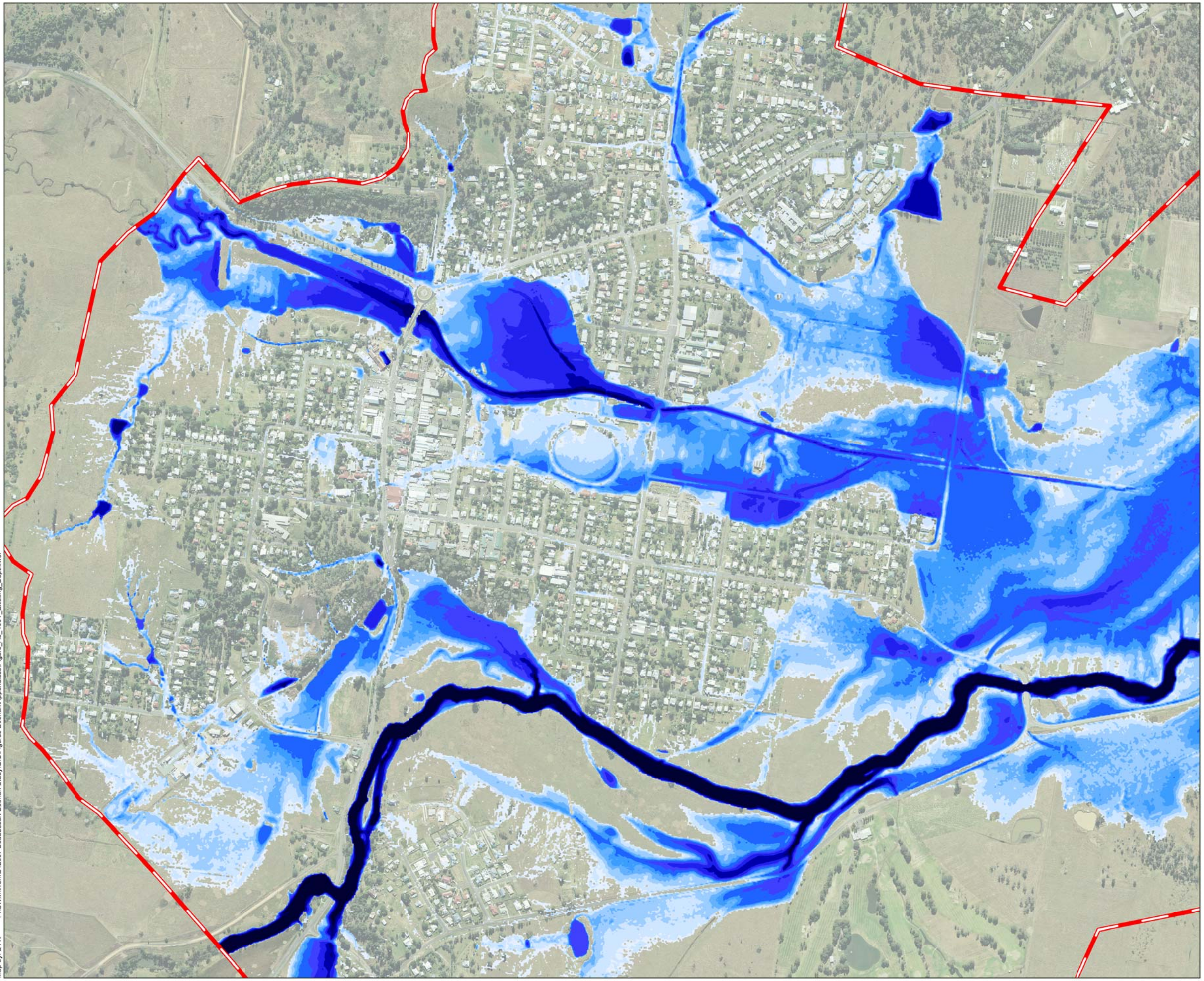
0 500 m 1,000 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Boonah Study Area

Figure A4: 50 year ARI Event - Existing Case - Peak Depth



Legend

TUFLOW Model Boundary

Depth (m)

- 0.00 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 2.50
- > 2.50

Notes:

Map by: BVW   P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Boonah\Appendices\Figure_A5_100Y_Existing_Depth.wor

A3 scale 1:10,000

0   500 m   1,000 m

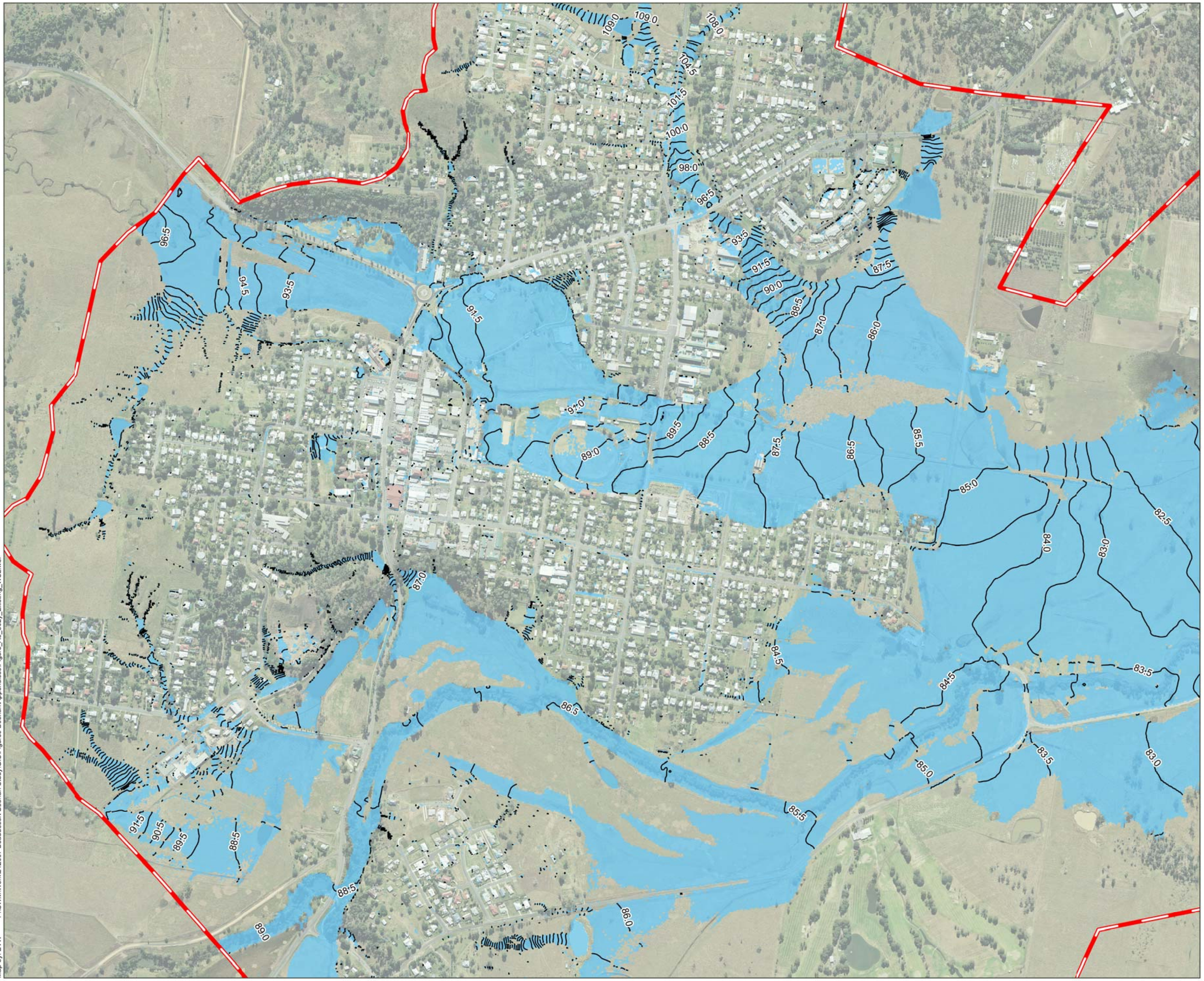
Date: 04/12/2014   Version: 0   Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Boonah Study Area

Figure A5: 100 year ARI Event - Existing Case - Peak Depth

aurecon



Legend

TUFLOW Model Boundary

Peak Water Surface Level Contour (m AHD)

Peak Inundation Extents

Notes:

Map by: BVW   P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Boonah\Appendices\Figure_A6_002y_Existing_WSL.wor

A3 scale 1:10,000

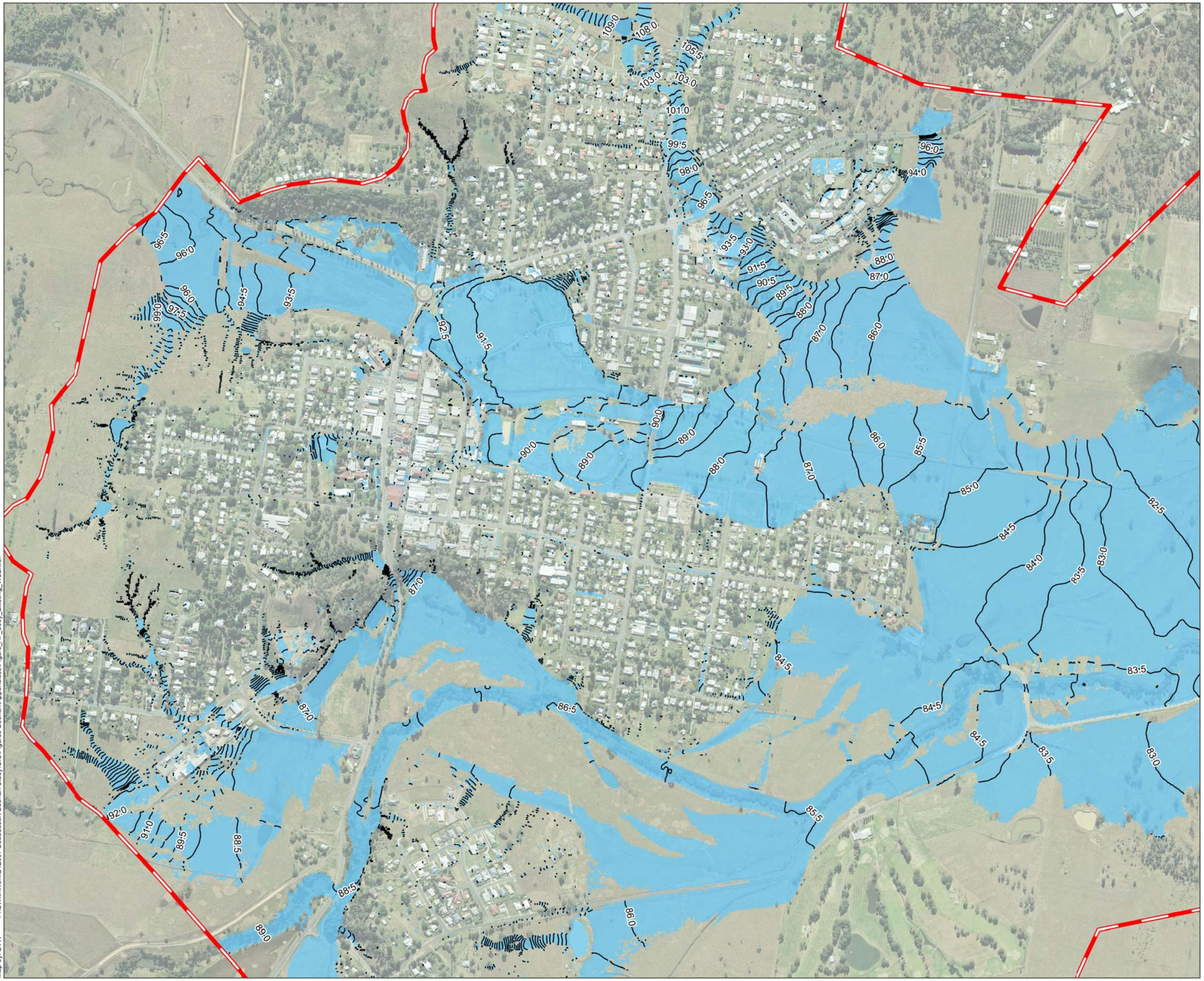
0   250 m   1,000 m

Date: 04/12/2014   Version: 0   Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Boonah Study Area

Figure A6: 2 year ARI Event - Existing Case
Peak Water Surface Levels



Map by: BVW   P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Boonah\Appendices\Figure_A7_005y_Existing_WSL.wor

aurecon

Legend

- TUFLOW Model Boundary
- Peak Water Surface Level Contour (m AHD)
- Peak Inundation Extents

Notes:

A3 scale 1:10,000

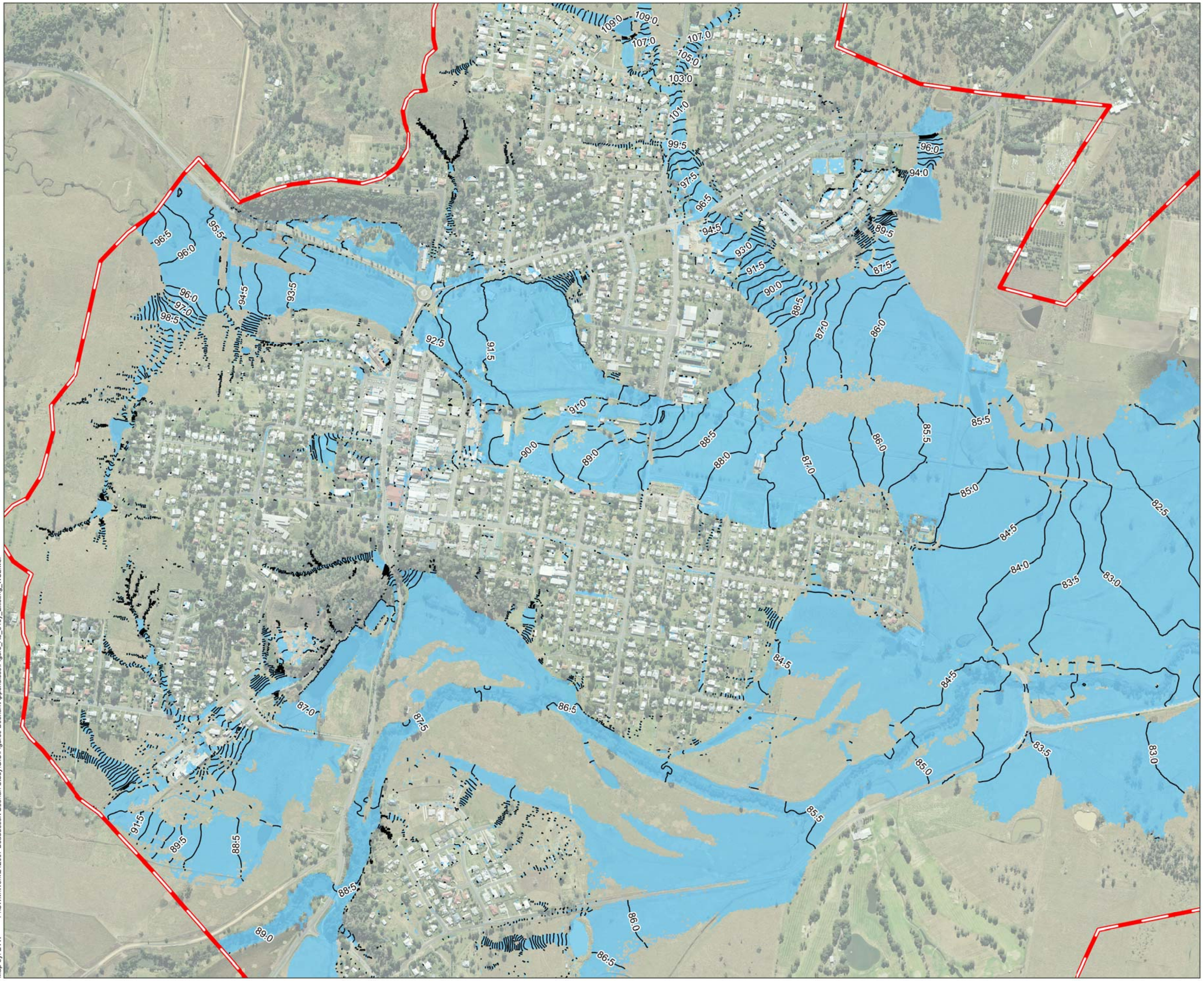
0   250 m   1,000 m

Date: 04/12/2014   Version: 0   Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Boonah Study Area

Figure A7: 5 year ARI Event - Existing Case
Peak Water Surface Levels



Map by: BVW P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Boonah\Appendices\Figure_A8_010y_Existing_WSL.wor

aurecon

Legend

TUFLOW Model Boundary

Peak Water Surface Level Contour (m AHD)

Peak Inundation Extents

Notes:

A3 scale 1:10,000

0 250 m 1,000 m

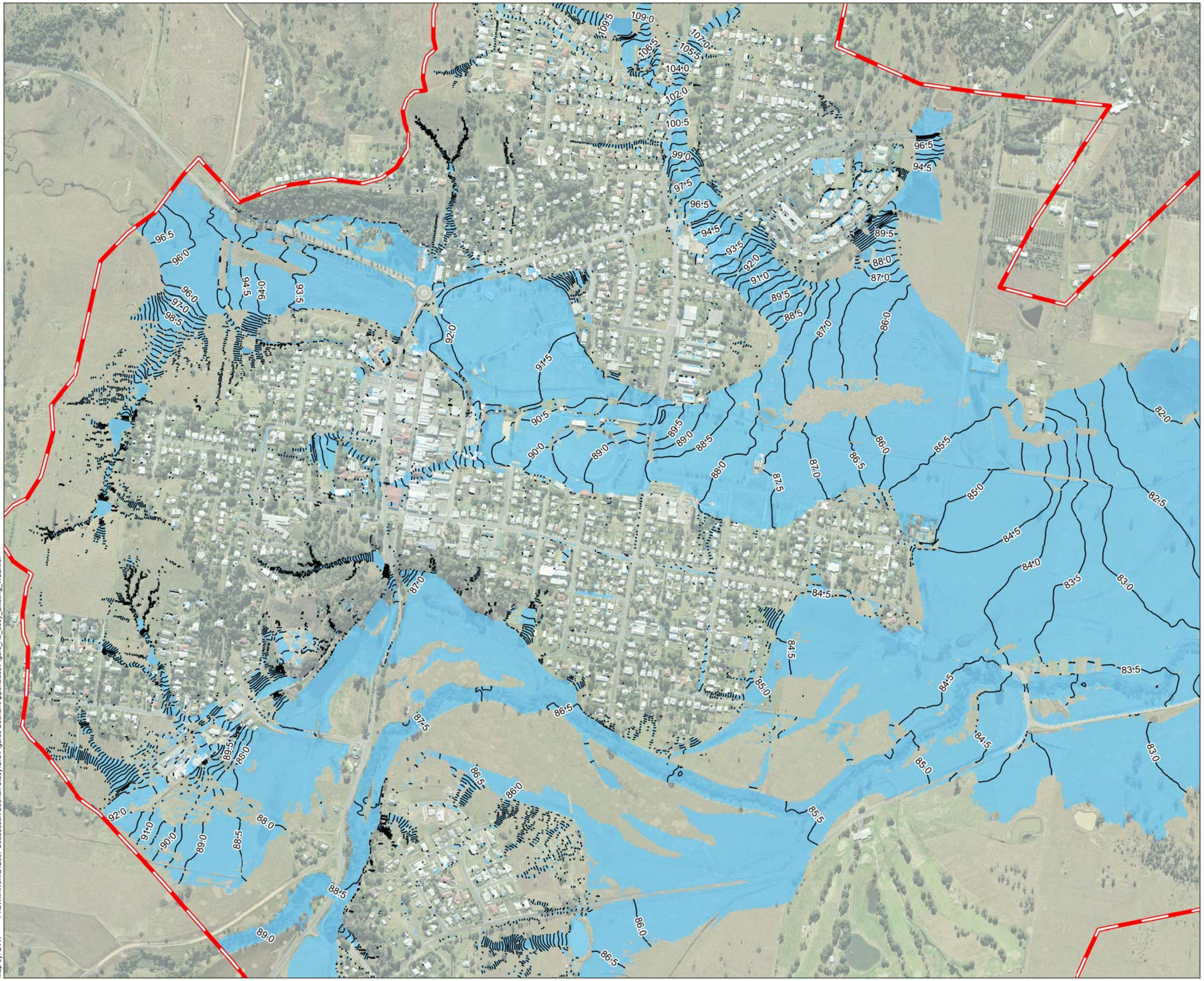
Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Boonah Study Area

Figure A8: 10 year ARI Event - Existing Case
Peak Water Surface Levels

aurecon



P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Boonah\Appendices\Figure_A9_050y_Existing_WSL.wor

Map by: BVW

Legend

TUFLOW Model Boundary

Peak Water Surface Level Contour (m AHD)

Peak Inundation Extents

Notes:

A3 scale 1:10,000

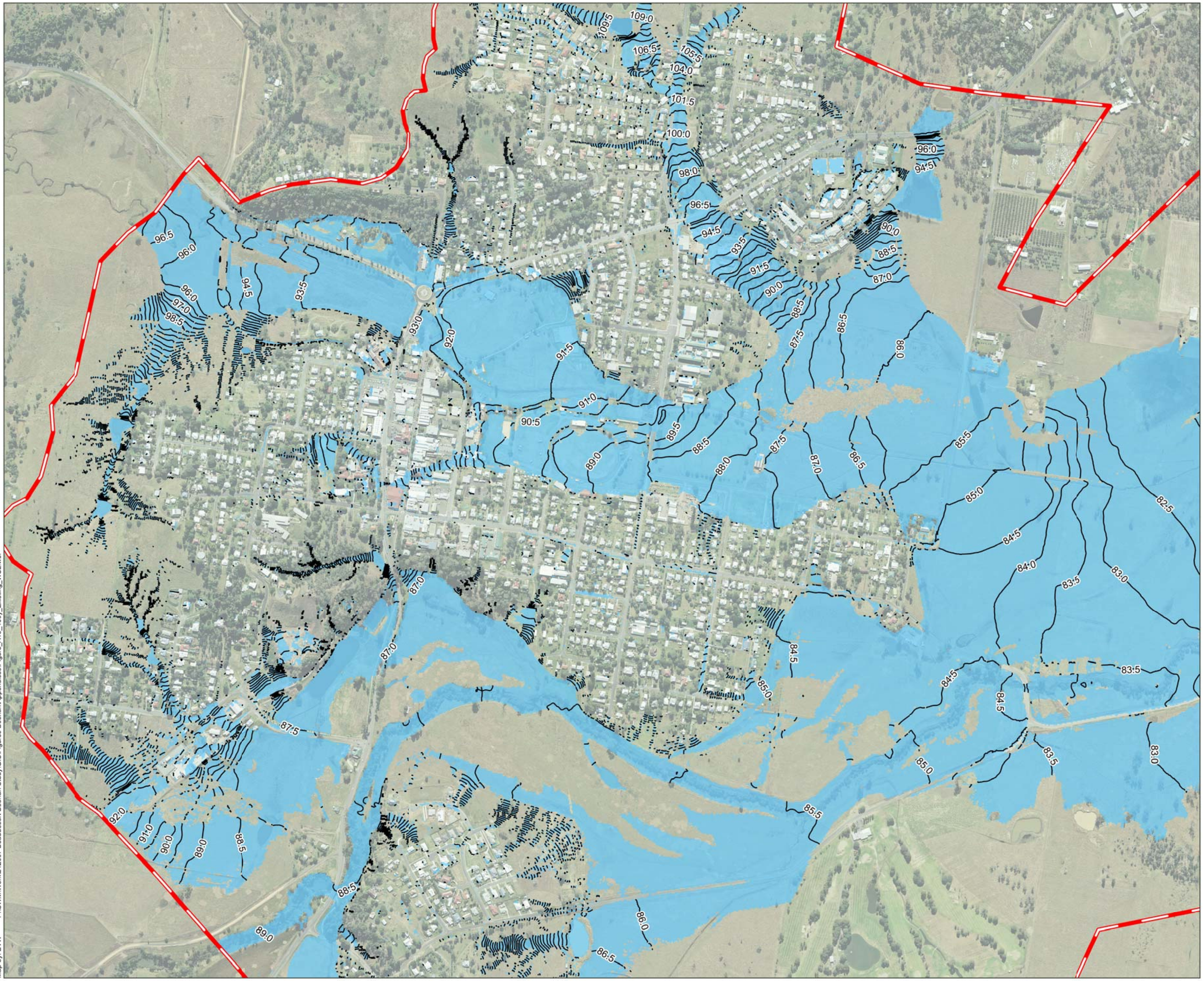
0 250 m 1,000 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Boonah Study Area

Figure A9: 50 year ARI Event - Existing Case
Peak Water Surface Levels



aurecon

Legend

TUFLOW Model Boundary

Peak Water Surface Level Contour (m AHD)

Peak Inundation Extents

Notes:

Map by: BVW P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Boonah\Appendices\Figure_A10_100y_Existing_WSL.wor

A3 scale 1:10,000

0 250 m 1,000 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Boonah Study Area

Figure A10: 100 year ARI Event - Existing Case
Peak Water Surface Levels

Appendix B
Base case flood mapping at problem locations

aurecon

Map by: BVW   P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Boonah\Appendices\Figure_B1_010y_Hoya_Rd_Existing_Depth.wor

Legend

Depth (m)

- 0.00 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 2.50
- > 2.50

Notes:

A3 scale 1:1,000

0 25 m 50 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Boonah Study Area

Figure B1: 10 year ARI Event - Hoya Road Existing Case - Peak Depth

aurecon

Legend

Depth (m)

- 0.00 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 2.50
- > 2.50

Notes:

Map by: BVW P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Boonah\Appendices\Figure_B2_100y_Hoya_Rd_Existing_Depth.wor

A3 scale 1:1,000

0 25 m 50 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Boonah Study Area

Figure B2: 100 year ARI Event - Hoya Road
Existing Case - Peak Depth

Map by: BVW   P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Boonah\Appendices\Figure_B3_010y_Mcbean_St_Existing_Depth.wor

aurecon

Legend

Depth (m)

0.00 to 0.10	0.75 to 1.00
0.10 to 0.20	1.00 to 1.50
0.20 to 0.30	1.50 to 2.00
0.30 to 0.40	2.00 to 2.50
0.40 to 0.50	> 2.50
0.50 to 0.75	

Notes:

A3 scale 1:1,000

0 25 m 50 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Boonah Study Area

Figure B3: 10 year ARI Event - Mcbean Street
Existing Case - *Peak* Depth

Legend

Depth (m)

- 0.00 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 2.50
- > 2.50

Notes:

Map by: BVW   P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Boonah\Appendices\Figure_B4_100y_Mcbean_St_Existing_Depth.wor

A3 scale 1:1,000

0   25 m   50 m

Date: 04/12/2014   Version: 0   Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Boonah Study Area

Figure B4: 100 year ARI Event - Mcbean Street
Existing Case - Peak Depth

Appendix C
Mitigated case flood mapping at problem locations

Legend

Bund

Depth (m)

0.00 to 0.10	0.75 to 1.00
0.10 to 0.20	1.00 to 1.50
0.20 to 0.30	1.50 to 2.00
0.30 to 0.40	2.00 to 2.50
0.40 to 0.50	> 2.50
0.50 to 0.75	

Notes:

Map by: BVW P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Boonah\Appendices\Figure_C1_010y_Hoya_Rd_Mitigated_Depth.wor

A3 scale 1:1,000

0 25 m 50 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Boonah Study Area

Figure C1: 10 year ARI Event - Hoya Road Mitigated Case - *Peak* Depth

Legend

Bund

Depth (m)

- 0.00 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 2.50
- > 2.50

Notes:

Map by: BVW P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Boonah\Appendices\Figure_C2_100y_Hoya_Rd_Mitigated_Depth.wor

A3 scale 1:1,000

0 25 m 50 m

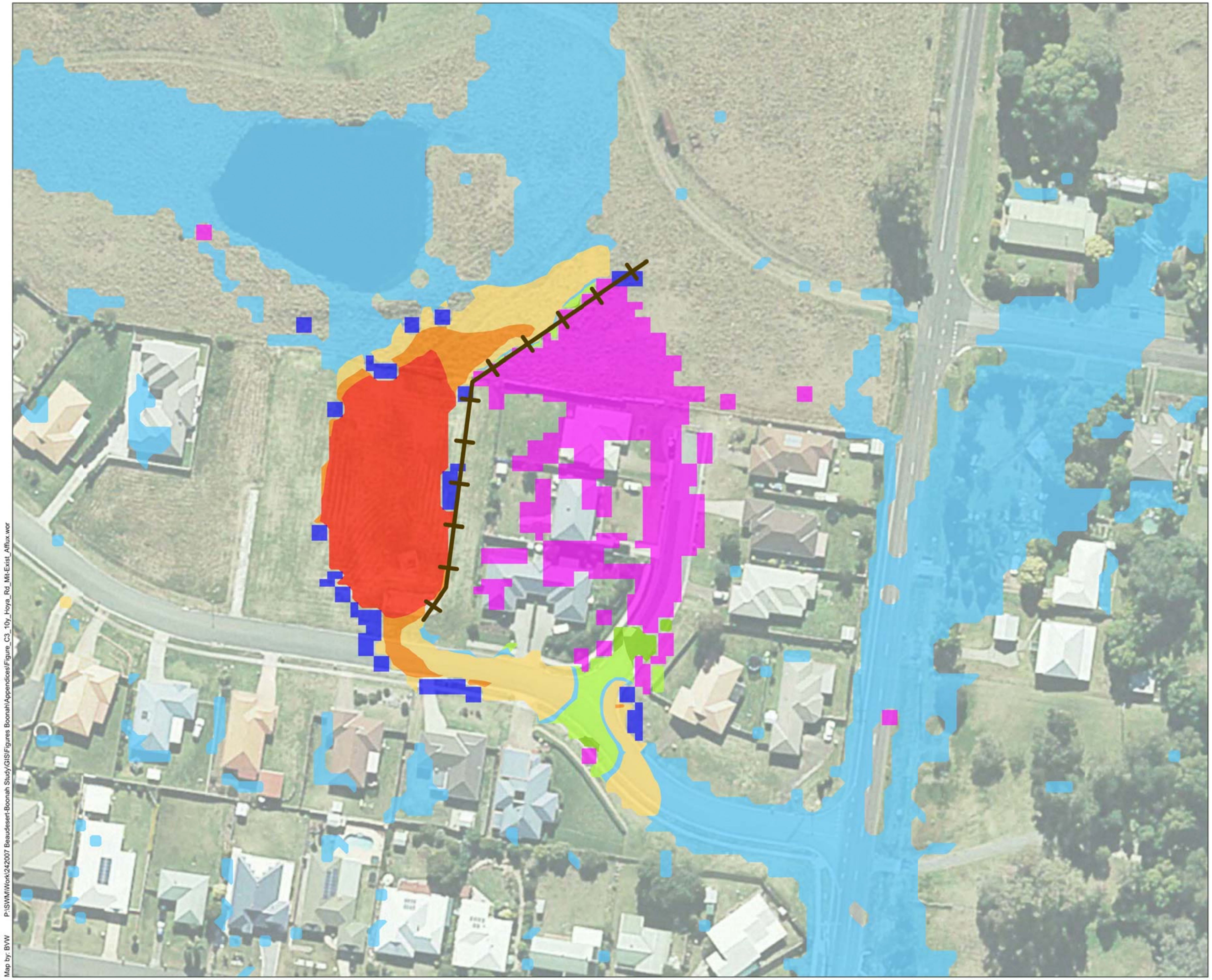
Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Boonah Study Area

Figure C2: 100 year ARI Event - Hoya Road Mitigated Case - *Peak* Depth

aurecon



Legend

Bund

Afflux (mm)

< -300	10 to 100
-300 to -200	100 to 200
-200 to -100	>200
-100 to -10	Was wet now dry
-10 to 10	Was dry now wet

Notes:

A3 scale 1:1,000

0 25 m 50 m

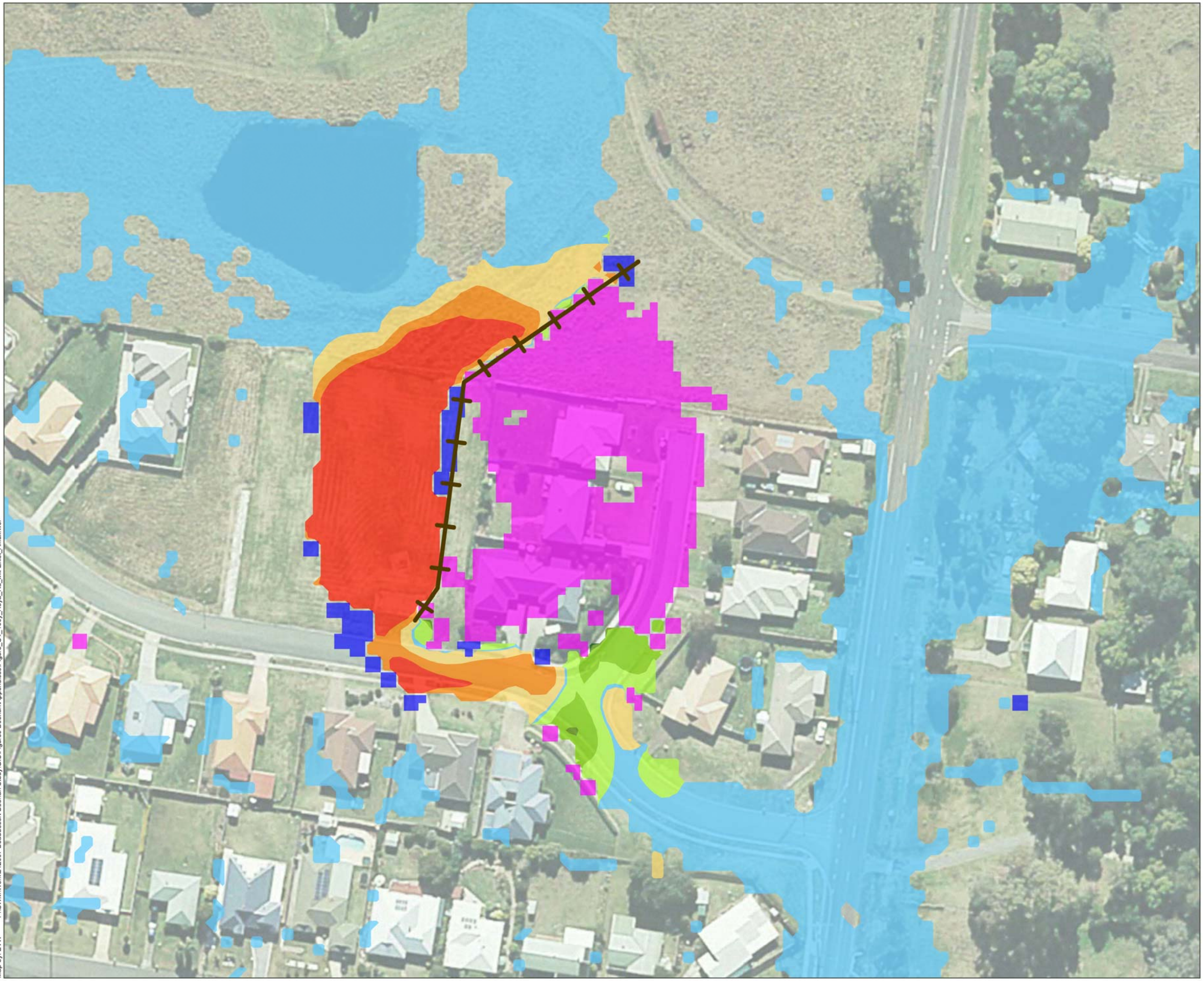
Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Boonah Study Area

Figure C3: 10 year ARI Event - Hoya Road

***Mitigated minus Existing* - Afflux**



Map by: BVW

P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Boonah\Appendices\Figure_C4_100y_Hoya_Rd_Mit-Exist_Afflux.wor

aurecon

Legend

Bund

Afflux (mm)

< -300	10 to 100
-300 to -200	100 to 200
-200 to -100	>200
-100 to -10	Was wet now dry
-10 to 10	Was dry now wet

Notes:

A3 scale 1:1,000

0 25 m 50 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Boonah Study Area

Figure C4: 100 year ARI Event - Hoya Road

***Mitigated minus Existing* - Afflux**

aurecon

Legend

Bund

Depth (m)

- 0.00 to 0.10
- 0.10 to 0.20
- 0.20 to 0.30
- 0.30 to 0.40
- 0.40 to 0.50
- 0.50 to 0.75
- 0.75 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 2.50
- > 2.50

Notes:

Map by: BVW

P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Boonah\Appendices\Figure_C5_010y_Mcbean_St_Mitigated_Depth.wor

A3 scale 1:1,000

0 25 m 50 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Boonah Study Area

Figure C5: 10 year ARI Event - Mcbean Street
Mitigated Case - *Peak* Depth

Legend

Bund	
Depth (m)	
0.00 to 0.10	0.75 to 1.00
0.10 to 0.20	1.00 to 1.50
0.20 to 0.30	1.50 to 2.00
0.30 to 0.40	2.00 to 2.50
0.40 to 0.50	> 2.50
0.50 to 0.75	

Notes:

Map by: BVW P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Boonah\Appendices\Figure_C6_100y_Mcbean_St_Mitigated_Depth.wor

A3 scale 1:1,000

0 25 m 50 m

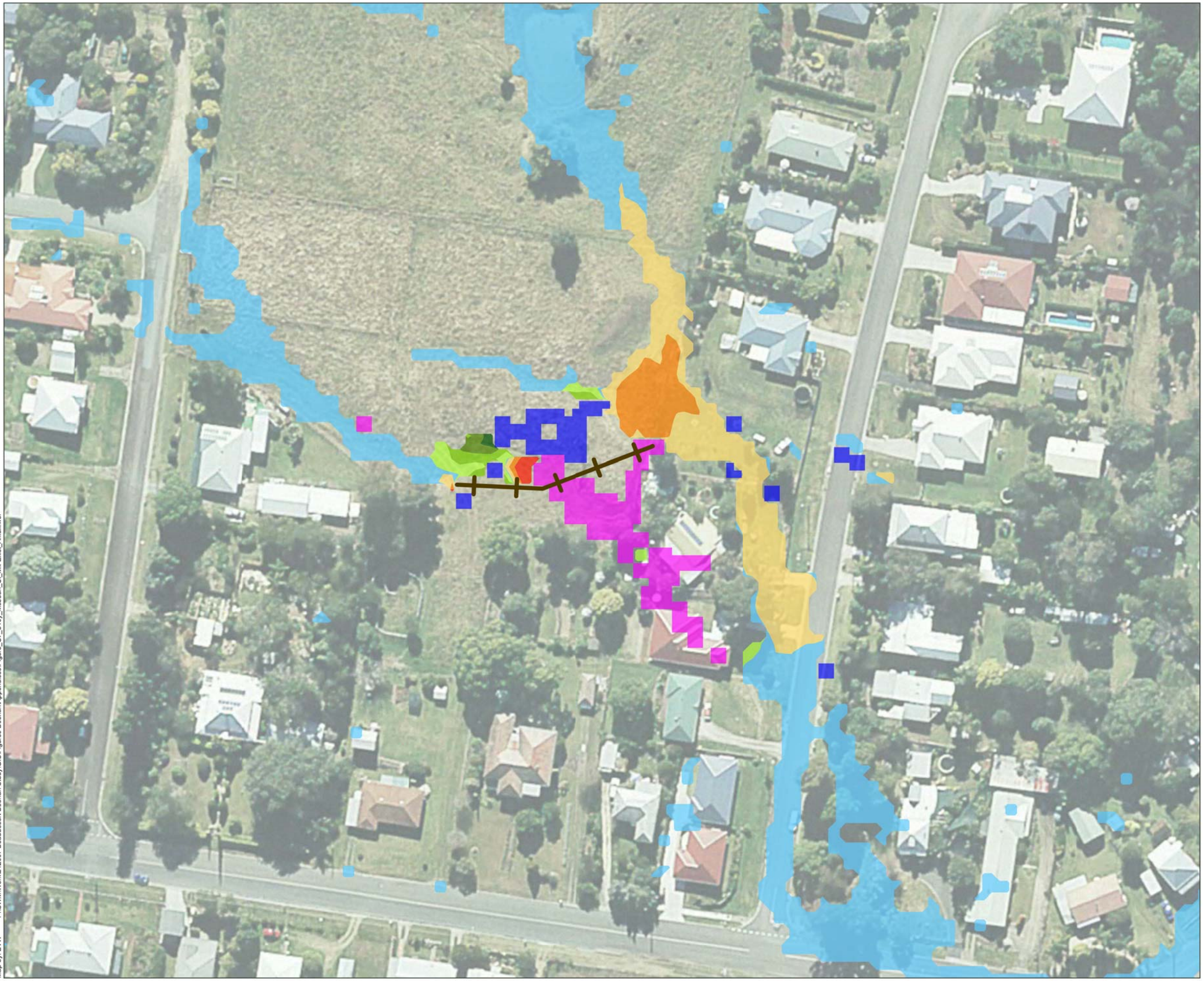
Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Boonah Study Area

Figure C6: 100 year ARI Event - Mcbean Street
Mitigated Case - *Peak* Depth

aurecon



Legend

Bund

Afflux (mm)

< -300	10 to 100
-300 to -200	100 to 200
-200 to -100	>200
-100 to -10	Was wet now dry
-10 to 10	Was dry now wet

Notes:

P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Boonah\Appendices\Figure_C7_010y_Mcbean_St_Mit-Exist_Afflux.wor

Map by: BVW

A3 scale 1:1,000

0 25 m 50 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Boonah Study Area

Figure C7: 10 year ARI Event - Mcbean Street

***Mitigated minus Existing* - Afflux**

aurecon

Legend

Bund

Afflux (mm)

< -300	10 to 100
-300 to -200	100 to 200
-200 to -100	>200
-100 to -10	Was wet now dry
-10 to 10	Was dry now wet

Notes:

Map by: BVW P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Boonah\Appendices\Figure_C8_100y_Mcbean_St_Mit-Exist_Afflux.wor

A3 scale 1:1,000

0 25 m 50 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Boonah Study Area

Figure C8: 100 year ARI Event - Mcbean Street

***Mitigated minus Existing* - Afflux**

Appendix D
Future developed case flood mapping

aurecon

Legend

Modelled Existing 100 year ARI Event Inundation Extents

Indicative Detention Basin Locations

Notes:

Map by: BVW

P:\SWMIWork\242007 Beaudesert-Boonah Study\GIS\Figures Boonah\Appendices\Figure_D1_Basin_Locality_Hoya_Rd.wor

A3 scale 1:4,000

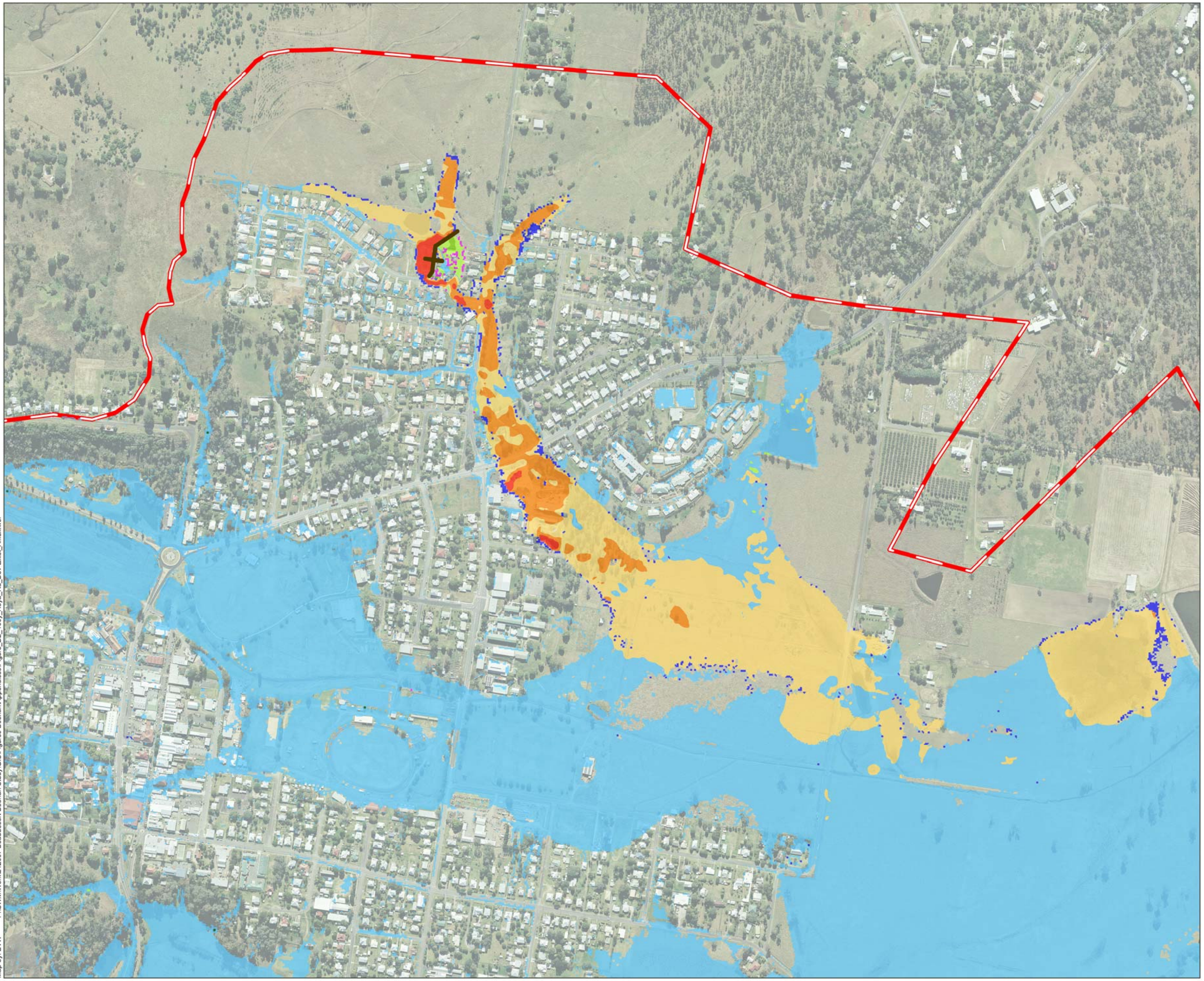
0 100 m 200 m

Date: 04/12/2014 Version: 0 Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Boonah Study Area

Figure D1: Indicative Detention Basin Locations - Hoya Road



Map by: BVW   P:\SWM\Work\242007 Beaudesert-Boonah Study\GIS\Figures Boonah\Appendices\Figure_D2_100y_Hoya_Rd_Dev-Exist_Afflux.wor

aurecon

Legend

- TUFLOW Model Boundary
- Bund

Afflux (mm)

- < -300
- -300 to -200
- -200 to -100
- -100 to -10
- -10 to 10
- 10 to 100
- 100 to 200
- >200
- Was wet now dry
- Was dry now wet

Notes:

A3 scale 1:8,000

0   200 m   400 m

Date: 04/12/2014   Version: 0   Job No: 242007

Projection: MGA Zone 56

Stormwater System Assessment & Drainage Plan - Boonah Study Area

Figure D2: 100 year ARI Event - Hoya Road
Developed minus *Existing* - Afflux

Appendix E
Cost estimation

aurecon

Client:	**Boonah Council**		Rev.	**0**
Project:	**Boonah Bund**		Date	**TODAYS DATE**
Project Number:	**242,007**			
Title:	**Summary - 4Q 2014 Class 5 Estimate of Capex Options**	**Accuracy +/-**	50%	
Estimator:	**Rowland Lampard**			

ESTIMATED COSTS

ITEM	DESCRIPTION		OPTION STUDY REF 1 AUD $	2 AUD $	3 AUD $	
DIRECT JOB COSTS						
Direct Costs	*See back-up sheet*					
A1	Direct Materials & Labour		93,000			**THIS FIGURE COMES FROM THE BACK UP SHEET**
SUBTOTAL Construction Directs			93,000			(1)
INDIRECT JOB COSTS						
Indirect Costs	*Prorated from Direct Costs*	%				
B1	Establishment & Mob/Demob	30%	28,000			
B2	Contractor's OH&P	11%	10,000			
B3	Construction Management	6%	6,000			
SUBTOTAL Construction Indirects			44,000			(2)
TOTAL Directs & Indirects			137,000			(3) = (1) + (2)
SERVICES COSTS						
Services						
C1	Surveys - Allowance		5,000			
C2	Eng / Design / Project Mgmt [as a % of (3)]	10%	14,000			
C3	Traffic Management		Included C5			
C4	Provision for traffic		Included C5			
C5	Traffic Management Plan		Excluded			
C6	Environmental Management		Included C10			
C7	Environmental Inspections		Included C10			
C8	Develop Environmental Management Plan (Construction)		Included C10			
C9	Implement Environmental Management Plan (Construction)		Included C10			
C10	Environmental Licences, Permits and Approvals	7.5%	11,000			
C11	Owners Costs		Excluded			
SUBTOTAL Services Costs			30,000			(4)
TOTAL BASE PROJECT COSTS			167,000			(5) = (3) + (4)
ALLOWANCE COSTS						
Allowances						
D1	Risk and Contingency [as a % of (3)]	25%	34,000			
D2	Escalation	0%	Excluded			
ESTIMATED PROJECT COST + ALLOWANCES			34,000			(6)
OTHER COSTS						
Others						
E1	Other Costs		Excluded			
SUBTOTAL Other Costs			-			(7)
Goods & Services Tax (GST) NIL ALLOWED			0			(8)
TOTAL ESTIMATED PROJECT COST			**201,000**			(5) + (6) + (7) + (8)
		Index	1.00			
		Range Opt 1	**100,500**	**to**	**301,500**	**MANUALLY CHANGE**
		Range Opt 2				**MANUALLY CHANGE**
		Range Opt 3				**MANUALLY CHANGE**

Item - Bund A - McBean St	**Quantity**	**Unit**	**Rate**	**Total**
Earthworks				
Clearing and grubbing, (assume 1m beyond works)	848	m2	$ 1.50	$ 2,000
Ground surface treatment under embankment, standard	722	m2	$ 2.00	$ 2,000
Imported material place and compact	325	m3	$ 60.00	$ 20,000
Geofabric mesh to embankment	731	m2	$ 7.00	$ 6,000
Turf to embankment	731	m2	$ 10.00	$ 8,000
Total				**$ 38,000**

Item - Bund B -Devin Drive	**Quantity**	**Unit**	**Rate**	**Total**
Earthworks				
Clearing and grubbing, (assume 1m beyond works)	1449	m2	$ 1.50	$ 3,000
Ground surface treatment under embankment, standard	1153	m2	$ 2.00	$ 3,000
Imported material place and compact	461	m3	$ 60.00	$ 28,000
Geofabric mesh to embankment	1177	m2	$ 7.00	$ 9,000
Turf to embankment	1177	m2	$ 10.00	$ 12,000
				$ -
Total				**$ 55,000**

Appendix F
System assessment workshop minutes

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Meeting Record

Project number	**242007**	Meeting date	**21 August 2014**
Project name	**Beaudesert Boonah SSAIP**	Recorded by	**Brian Sexton**
Meeting/subject	**Boonah System Assessment Workshop**	Total pages	**2**

Present	Apology	Copy	Name	Organisation	Contact details
☒	☐	☐	Brian Sexton (BS)	Aurecon	Brian.sexton@aurecongroup.com
☒	☐	☒	Patrick Murphy (PM)	SRRC	patrick.m@scenicrim.qld.gov.au
☒	☐	☒	Joshua Canaris (JC)	SRRC	joshua.c@scenicrim.qld.gov.au
☒	☐	☒	Craig Heck (CH)	SRRC	craig.h@scenicrim.qld.gov.au
☒	☐	☒	Chris Gray (CG)	SRRC	Christopher.G@scenicrim.qld.gov.au
☒	☐	☒	Shaun Anderson (SA)	SRRC	shaun.a@scenicrim.qld.gov.au
☒	☐	☒	Tony Nykvist (TN)	SRRC	Tony.n@scenicrim.qld.gov.au
☐	☐	☐			
☐	☐	☐			
☐	☐	☐			

Item	Topic	Action by	Action due	Action complete
1	BS outlined the model development details and the data used in its build	-		
2	BS described the issues surrounding regional hydrology and the lack of a hydrologic model. Agreed that the approach taken is satisfactory as it is aligned with the objectives and aims of this project and the regional flood extents do not affect the problem areas identified.	-		
3	BS explained that no calibration data has been received. Issues include the fact that there is no rain gauge in the town (closest is at Moogerah Dam, 15kms away) and unsure if anecdotal records/evidence of flooding is available. No suitable storms identified as yet either.	-		
4	PM pointed out that the model extent would ideally be extended to capture two urbanised areas that are currently not included. Aurecon to address – BS stated that this is not an issue to fix.	BS	27 August 2014	
5	Generally agreed that model was predicting correct behaviour and is fit for purpose going forward	-		

Item	Topic	Action by	Action due	Action complete
6	CG identified that the existing GIS data provided to Aurecon was not fully correct in the area around the school at Yeates Ave. SRRC to arrange for the data to be collated and provided to Aurecon for inclusion in the model.	JC	27 August 2014	
7	At Hoya Street the proposed action is to: 1. mitigate the street flooding on Arthur Tce by directing flow into the adjacent detention basin 2. test the effect of development in the upstream and the consequent effect on flood levels, with a view to undertaking some preliminary basin sizing to offset any increases in flood risk downstream	BS	29 August 2014	
8	At Mt French Road the proposed action is to mitigate the secondary flow path that cuts through properties during large flood events by undertaking localised earthworks.	BS	29 August 2014	

Next meeting: TBC

Appendix G
Options assessment workshop minutes

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Meeting Record

Project number	**242007**	Meeting date	**18 September 2014**
Project name	**Beaudesert Boonah SSAIP**	Recorded by	**Brian Sexton**
Meeting/subject	**Boonah Options Assessment Workshop**	Total pages	**2**

Present	Apology	Copy	Name	Organisation	Contact details
☒	☐	☐	Brian Sexton (BS)	Aurecon	Brian.sexton@aurecongroup.com
☒	☐	☒	Patrick Murphy (PM)	SRRC	patrick.m@scenicrim.qld.gov.au
☒	☐	☒	Joshua Canaris (JC)	SRRC	joshua.c@scenicrim.qld.gov.au
☒	☐	☒	Craig Heck (CH)	SRRC	craig.h@scenicrim.qld.gov.au
☒	☐	☒	Chris Gray (CG)	SRRC	Christopher.G@scenicrim.qld.gov.au
☒	☐	☒	Shaun Anderson (SA)	SRRC	shaun.a@scenicrim.qld.gov.au
☐	☐	☐			
☐	☐	☐			
☐	☐	☐			
☐	☐	☐			

Item	Topic	Action by	Action due	Action complete
1	BS outlined the modifications made to the model (actions from the System Assessment workshop)	-		
2	BS outlined the results of the modelling which incorporates the new survey data at Yeates Ave. Essentially there is no flooding issue as a result which fits with the design based on its flood immunity criteria when it was originally constructed	-		
3	BS showed the results of the mitigation works proposed at Mt French Road – good outcome, flooding immunity increased, no adverse impacts to dwellings and an economical solution	-		
4	BS showed the results of the mitigation works proposed at Devin Drive – again, good outcome, flooding immunity increased, no adverse impacts to dwellings and an economical solution	-		

Next meeting: None required

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Scenic Rim Regional Council

Stormwater System Assessment & Improvement Plan Canungra Study Area

Project Report

CDM Smith

Scenic Rim Regional Council

Stormwater System Assessment & Improvement Plan Canungra and Kalbar Study Areas

Project Report

18 August 2016

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3	18 August 2016	MT	MT	18 August 2016	Final

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Executive Summary

CDM Smith was commissioned by Scenic Rim Regional Council (SRRC) to undertake a Stormwater System Assessment and Improvement Plan for the towns of Kalbar and Canungra. The objective of this study was to assess the stormwater systems contained within the defined study area, and produce methods for the efficient management of localised flooding, using accepted engineering methods and judgement to design a system improvement plan.

This report focuses on the Canungra study area, which comprises the two sections of town that feature underground stormwater assets, namely:

- The Riverbend Drive housing estate; and
- Canungra Township.

The two areas have no interaction from a drainage perspective, and were thus considered separately for the purposes of this report. The stormwater system assessment was carried out using a MIKE Urban model of the piped drainage network which was dynamically coupled to a MIKEFLOOD 1D/2D hydraulic model.

The Riverbend Drive housing estate stormwater network assessment identified no major problems via the hydraulic modelling, although it is noted that several of the drainage outfalls are impractically situated halfway up the creek banks, leading to localised scour issues. Consideration could be given to protecting the exposed outfalls with rip-rap or gabion baskets, but other than that no remedial or mitigative measures are recommended at this time.

The Canungra Township System Assessment hydraulic modelling identified that a key risk at Canungra was the lack of a viable overland flowpath should the inlet to the main town drain, at Franklin Street, become blocked with debris during a storm event. A minor nuisance drainage scenario was identified in the park, and was also assessed. A mitigation assessment was conducted for these two situations to investigation the most appropriate method to address these issues.

The recommendations that were identified to ensure an adequate stormwater network is maintained is outlined below.

1. *Address nuisance flooding at Christie Street.* Construction of an earth bund is a relatively cheap option and council should look to conduct these works using their in-house plant and equipment.
2. *General grated pit/inlet maintenance.* Council should continue to assess the condition of stormwater infrastructure and replace old or damaged pits as necessary.
3. *Internal inspection of the town drain.* The precise alignment of the town drain is not currently known, although it is suspected that there is at least one manhole/pit between the town drain inlet and the Christie Street outlet. Council should organise for and internal inspection (via remote video camera or similar) of the drain to assess its condition and map its alignment. Any accumulated debris could also be removed at this time.
4. *Further investigation of the detailed mitigation option before proceeding.* If Council is committed to addressing the risk of blockage and lack of overland flow path, more investigation is required to develop the idea from a concept into a detailed design. Council should discuss whether they wish to proceed with developing this idea further before committing any further funds to it.

Section 1 Introduction

1.1 Study Areas

CDM Smith was commissioned by Scenic Rim Regional Council (SRRC) to undertake a Stormwater System Assessment and Improvement Plan for the towns of Kalbar and Canungra. This report focuses on the Canungra study area, which comprises the two sections of town that feature underground stormwater assets, namely:

- Canungra Township – the original section of town extending from the western side of Canungra Creek, through the commercial area, to the catchment divide on the ridge; and,
- The Riverbend Drive housing estate – a relatively new residential estate located on the eastern side of Canungra Creek, approximately 500 metres north of Canungra town, on the Beaudesert Nerang Road.

The two areas have no interaction from a drainage perspective, and were thus considered separately for the purposes of this report. The study areas are shown below, in Figure 1-1

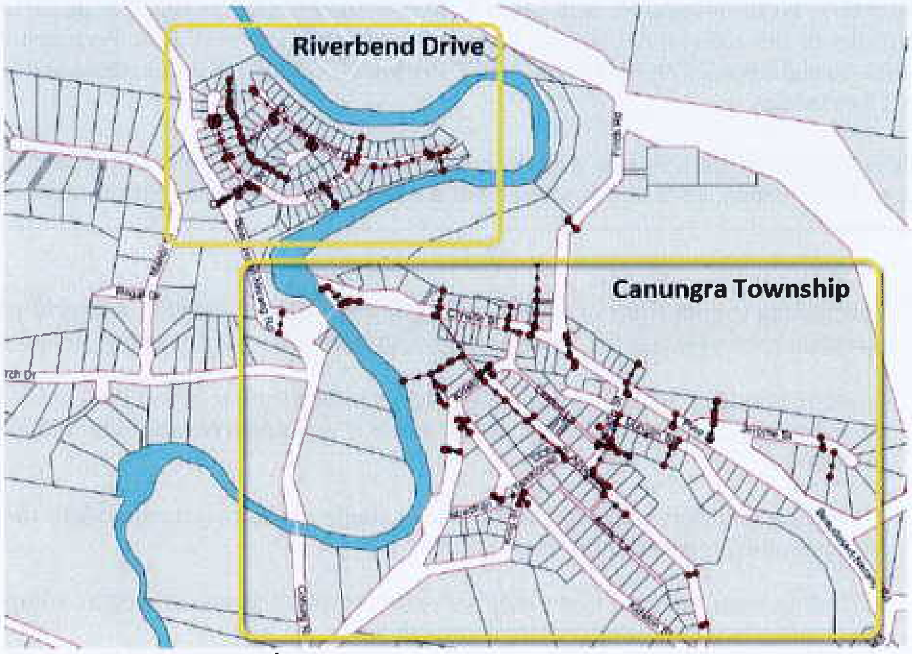

Figure 1-1 Canungra Study Areas

1.2 Objective

The objective of this study was to assess the stormwater systems contained within the defined study area, and produce methods for the efficient management of localised flooding, using accepted engineering methods and judgement to design a system improvement plan.

This was achieved by building a detailed hydraulic model of the study area, incorporating Council's GIS asset data to it, and then simulating various flooding scenarios in order to identify deficient areas. Options to improve deficiencies were developed through consultation with SRRC staff, and then tested for effectiveness in the model, with the goal of developing an improvement plan for capital works designed to address any identified issues and provide the desired level of service.

Section 2 Hydraulic Modelling

2.1 Setup

2.1.1 Input Data

The following data were used to build the hydraulic models:

- **Airborne Laser Survey (ALS).** Provided by SRRC to CDM Smith, the ALS data comprised 1 km x 1 km square tiles, at a grid resolution of 1 metre. The tiles were mosaicked into a seamless DEM and then exported to the hydraulic model's proprietary format.

- **Aerial Imagery.** A high quality, geo-referenced digital image of the study area was provided by SRRC, and was used primarily as part of the quality control exercise described below.

- **Stormwater Asset Data.** SRRC Technical Officers captured stormwater network data via handheld GPS, several assets via field survey at Appel Street, and a small number of assets from as-constructed data at Riverbend Drive. All known and accessible manholes, pits, grates and pipe diameters were measured and added to the database, creating a point-to-point representation of the stormwater network (ie. pipes running between pits were assumed to connect in a straight line). The Riverbend Drive stormwater network was established from as constructed drawings.

  A notable feature of the data was its description in terms of relative levels. To prepare the data for input to MIKE Urban, CDM Smith carried out a comprehensive GIS quality control exercise that involved:

  - Reconciling the location of each asset against the corresponding ALS grid point to translate relative levels (eg. "metres below surface") into the Australian Height Datum.
  - Cross-checking pit locations against the aerial image, Google Street View, and the ALS data, and manually adjusting locations where it was apparent that the GPS accuracy was low.
  - Combining multiple adjacent inlets into a single node, to accommodate the MIKE Urban modelling technique; and,
  - Excluding from the final input data several very small pipes, as well as a number of pipes and pits where connectivity was unclear.
  - Requesting SRRC to collect additional asset data in cases where the initial measurements were unclear or appeared erroneous.

  In total, four iterations were performed of the tasks outlined above. The finalised pipe network configurations are shown visually in Appendix A.

2.1.2 Software

The stormwater system assessment was carried out using the "MIKE by DHI" water modelling software. Specifically, a MIKE Urban model of the piped drainage network was dynamically coupled to a MIKEFLOOD 1D/2D hydraulic model, in a configuration that has the ability to:

- Represent small open channel elements and hydraulic structures in the 1D domain;

- Account for complex overland flowpaths and breakouts in the 2D domain;
- Accurately model the piped network and its interaction with surface waters, specifically with regard to energy losses at inlets, manholes and pits;
- Couple the 1D, 2D and piped-network elements in a single integrated modelling environment;
- Natively account for precipitation, and therefore runoff, via a rain-on-grid method, and;
- Easily test the effects of changing the topography or drainage configuration on network performance.

2.1.3 Modelled Area

A summary of key aspects of the hydraulic models is shown below in Table 2-1and Table 2-2 for Riverbend Drive and Canungra, respectively. Figures detailing the models' geographic extents, topographic variation, and pipe network schematisation are found in Appendix A.

Table 2-1 Hydraulic Model Details – Riverbend Drive

Name	Details
2D Domain	
Map Projection	GDA 1994, MGA Zone 56
Grid Origin (lower left corner)	515478 m East, 6901070 m North
Grid Resolution	1 m
Grid Dimensions (width x height)	764 cells x 380 cells
Grid Rotation (clockwise from North)	0 degrees
1D Domain	
No. Pipe Elements	53
No. Manhole Elements (pits, gullies, grates)	63
No. Culvert Elements	2
1D-2D Connectivity	
No. 1D-2D linkages	63

Table 2-2 Hydraulic Model Details – Canungra

Item	Details
2D Domain	
Map Projection	GDA 1994, MGA Zone 56
Grid Origin (lower left corner)	515438 m East, 6900019 m North
Grid Resolution	1 m
Grid Dimensions (width x height)	1580 cells x 1050 cells
Grid Rotation (clockwise from North)	0 degrees
1D Domain	
No. of Pipe Elements	80
No. of Manhole ~~Elements (pits, gullies, grates)~~	~~108~~
No. of Culvert Elements	7
1D-2D Connectivity	
No. of 1D-2D linkages	92

2.1.4 Hydraulic Roughness

A spatially-distributed roughness map was developed to reflect the variance in resistance to surface flow based on land use. Land use areas were identified from the high-resolution aerial image, and augmented with photographs from the site visits and some information from Google Street View. The Manning's n values chosen for the model are within the commonly accepted ranges for rain-on grid modelling, and are summarised in the table below:

Table 2-3 Adopted Manning's n Roughness Values

Land Use	Value
Roof Areas	0.200
Roads and Paved Areas	0.018
Short Grass	0.035
Long Grass	0.050
Forested Areas	0.800

A relatively high roughness value was used to represent the footprints of buildings; in addition, building footprints were raised by 0.2m with respect to the underlying terrain values. The raised topography simulates the obstruction to flow created by buildings, providing a more realistic pattern of flooding around structures without removing rainfall volume from the model (as would be the case if building footprints were "blocked-out" from the simulation entirely), whilst the reduced conveyance introduced by the high roughness value simulates the time taken for rainfall to travel from the roof to the ground.

2.1.5 Blockage Factors

Grated pits, side inlets, and culverts can become blocked by debris during rainfall events, reducing their capacity to capture water and direct it to the piped network. The degree to which blockage occurs for any given flood is generally regarded to be a function of the type of structure, and the availability of source blockage material in the upstream catchment.

QUDM suggests, in Table 7.5.1, to apply blockage factors of 50%, 20% and 20% for grated inlets, side inlets and culvert inlets respectively. During field investigations at Kalbar, CDM Smith noted several side inlets and grated pits that were partially blocked as a result of a recent small storm, as shown in Figure 2-2. Canungra has the same types of inlets and grates, so we could reasonably expect similar blockage to occur. In any case, it is clear that some degree of blockage is likely to occur during a rainfall event, and we have therefore adopted the QUDM recommendations for use in the hydraulic modelling.

Figure 2-2 Example of Blocked Stormwater Inlets

2.1.6 Design Event Rainfall

Design rainfall intensities were sourced from the Bureau of Meteorology (BOM), via the online Intensity-Frequency-Duration (IFD) generator. At the current time, two choices of IFD data are available to the hydrologist – those based on the Australian Rainfall and Runoff project from 1987 (AR&R87) and the recently released 2013 project carried out by the BOM. Although the 2013 IFD's are more data rich, containing almost 30 extra years of information from an additional 2300 rainfall gauges, there remains uncertainty surrounding the methodology of deriving, selecting, and applying the accompanying design temporal patterns.

In contrast, despite some criticisms that they can be unrealistically weighted, the AR&R87 temporal patterns are well understood, and can be easily implemented. For this reason, the AR&R87 IFD data and temporal patterns were adopted for use in this study. In any case, given that the objective of the study is to investigate stormwater network performance and test possible mitigation options, the focus naturally falls on *differences* arising from proposed changes in the catchment, as opposed to the calculation of absolute flood levels. As such, determining the magnitude of the rainfall depth is of lesser importance than it would be with, say, a large river study whose goal was to calculate the 100 year Average Recurrence Interval (ARI) flood level.

A comparison of old and new IFD values is presented below in Table 2-4:

Table 2-4 Ratio of Rainfall Intensities - 1987 data compared to 2013 data

Duration	Average Recurrence Interval			
	10 year	20 year	50 year	100 year
10 min	0.95	0.96	0.96	0.96
15 min	0.95	0.93	0.93	0.92
30 min	0.92	0.93	0.92	0.92
60 min	0.87	0.88	0.90	0.91
120 min	0.85	0.87	0.90	0.92

* value less than one signifies 2013 intensity is less than corresponding 1987 intensity.

It can be seen the 2013 revision has resulted in design rainfall intensities that are in the order of 5% to 10% lower than the older estimates at the town of Canungra.

2.1.7 Rain on Grid Modelling

This approach is so named because rainfall is applied directly to each individual grid cell in the 2D hydrodynamic domain as an inflow volume source. This obviates the need to develop an external hydrologic model, and has the benefit of applying rainfall everywhere on the grid, allowing concentration of runoff to occur and flowpaths to develop in a more realistic fashion. An important note is that by merging the hydrologic and hydraulic domains into one, the model domain must necessarily cover the entire catchment to the most downstream point of interest.

MIKE21 has the capability to apply the grid-based rainfall with variations both spatially and temporally. Spatial variation of rainfall is typically reserved for larger catchments, particularly where calibration is concerned. For the purposes of this study, the design rainfall depths are assumed to be invariant in space, changing only with time (ie. according the design temporal patterns).

2.2 System Assessment – Riverbend Drive

2.2.1 System Performance

An indication of the performance of below-ground stormwater network can be gained by calculating the number of surcharging pits for a given Average Recurrence Interval(ARI). Given that the piped network is adequate most of the time to drain everyday rainfall events and prevent nuisance ponding, it is unrealistic to expect it to entirely contain the peak discharge for even a small ARI storm; however a system with relatively few surcharging pits could be said to have better minor drainage performance than a system with many surcharging pits. Recurrence intervals from 5 years to 100 years were simulated in the model; results are presented in Table 2-5.

Table 2-5 Surcharging Pits by Average Recurrence Interval – Riverbend Drive

Average Recurrence Interval	Number of Pits Surcharging	% of Surcharging Pits
5 years	8 of 57	14
10 years	9 of 57	16
20 years	11 of 57	19
50 years	11 of 57	19
100 years	11 of 57	19

2.2.2 Analysis of Results

The stormwater network in this newer housing estate performed much better than the legacy infrastructure in the main township. It is clear from the pipe network layout and grading of the lots and road corridors that stormwater drainage was considered as part of the planning phase. Roads generally sit lower than lots, and act as efficient overland flow paths in the major storm events. The subsurface and above ground drainage paths work together, aided by the cut/fill pattern of the development, to remove rainfall runoff quickly and without unduly impacting private property.

Consequently, no major problems were found via the hydraulic modelling, although it is noted that several of the drainage outfalls are impractically situated halfway up the creek banks, leading to localised scour issues. Consideration could be given to protecting the exposed outfalls with rip-rap or gabion baskets, but other than that no remedial or mitigative measures are recommended at this time. As such, no further investigations were carried out with regards to the assessment of potential mitigation options.

2.3 System Assessment – Canungra

There are twelve separate piped networks throughout the town, each with a different degree of interconnectivity to overland flow paths and to each other. For this reason, a single critical storm duration (ie. that duration which produces the worst flooding at a particular point of interest) cannot easily be identified, as the answer may change depending on which part of the catchment one is interested in observing.

Instead, the hydraulic model was first run using the 50 year ARI design storm event for the 6 standard storm durations from 15 minutes to 2 hours, with the goal of qualitatively nominating a single storm duration for use in the assessment that:

- Was representative of the duration of a typical summer thunderstorm;

- Loaded a large portion of the total rainfall into a single temporal time step; and,
- Introduced a large volume of water to the model;

For these reasons, the 60-minute storm event (and associated temporal pattern) was adopted as the reference storm for the following analyses. The choice of reference storm duration is discussed further in Section 2.2.3.

2.3.1 System Performance

As with the Riverbend Drive housing estate, performance of the underground system is indicated by the proportion of surcharging pits for a given ARI, as detailed in Table 2-6, below:

Table 2-6 Surcharging Pits by Average Recurrence Interval

Average Recurrence Interval	Number of Pits Surcharging	% of Pits Surcharging
1 year	22 of 78	28
2 years	24 of 78	30
5 years	27 of 78	35
10 years	29 of 78	37
20 years	30 of 78	38
50 years	33 of 78	42
100 years	33 of 78	42

The large number of surcharging pits is indicative of the age and piecemeal nature of the drainage system. The individual pipe networks are largely separate from one another, are generally of a small diameter, and are linked to the surface with numerous older-style grated pit inlets that are of low flow capacity and prone to blockage. The town has relatively few modern style side-inlet pits.

Despite this, the town is generally aligned quite well to the natural terrain so that the majority of storm water runoff is carried efficiently overland via the paved road surface. This is an expected outcome from an old system in a steep landscape. The peak depth maps in Appendix A highlight the effectiveness of the road corridor as the major drainage path, as it is here that the highest peak velocities and depths are found.

2.3.2 Analysis of Results

Franklin Street Drain

The one instance where the natural contours have been disregarded is at the inlet to the town drain at Franklin Street. At this location, the entirety of the upstream natural catchment, plus the discharge from two adjacent pipe networks, is funnelled to the inlet of the town drain, a single 600mm diameter culvert that travels for approximately 300 m in a north-westerly direction, daylighting on the northern side of Christie Street next to the Outpost Café.

When the 20% blockage factor was applied to this culvert, the inlet quickly reached capacity, and in the absence of a dedicated major overland flow path, water was ponded at the inlet until it overtopped the road, flowing down Lawton Lane and through several private properties as it returned to the original overland flow path. The hydraulic model was interrogated to calculate the overtopping flow across the road crest at Franklin Street, with peak rates presented below in Table 2-7.

Table 2-7 Predicted Flow Over Road Crest at Franklin Street*

Average Recurrence Interval	Peak Flowrate (m^3/s)
1 year	0.04
2 years	0.67
5 years	1.48
10 years	1.98
20 years	2.68
50 years	3.53
100 years	4.22

*With 20% blockage of town drain inlet

The catchment upstream of the Franklin Street drain inlet comprises some 19 hectares of bushland, and is likely to provide abundant source material with which to block the culvert inlet. The potential effects of blockage, and possible mitigation options are explored in more detail in Section 2.4.

An additional risk, identified by Council during the System Assesment workshop, relates to the change of pipe geometry that occurs where the town drain passes beneath Christie Street. At this location, the configuration changes from a single 1200 mm diameter pipe to twin 800mm high box culverts, presumably due to cover issues. The risk is that a relatively large piece of debris may be sucked into the pipe only to become lodged at the box culverts, causing partial or total blockage, even though the pipe inlet at Franklin Street may appear to be free of debris.

Christie Street and DJ Smith Park

During the System Assessment workshop, investigation of the animated model results confirmed to the Council the existence of a nuisance flooding issue affecting several properties on Christie Street. The properties at 29 and 31 Christie Street each have a shed that is located on the boundary with the park. The model results indicated that runoff, including from upstream areas, travels through the park via a flowpath that leads to the aforementioned properties. This appears to be another case of the natural drainage lines being neglected during development, and is also investigated further in Section 2.4

2.3.3 Comparison to XP-RAFTS model

As no calibration data were available against which to assess the performance of the rain on grid approach, a comparison to a small XP-RAFTS model was carried out to test the shape and magnitude of the predicted hydrographs reporting to the entrance of the town drain (ie. the left-most green node on the figure below), and to validate the choice of the 60-minute design storm for use in the assessment. The XP-RAFTS model schematic is shown in Figure 2-3; a summary of runoff rates against duration in Table 2-8; and the comparison to the hydraulic model hydrographs in Figure 2- 4.

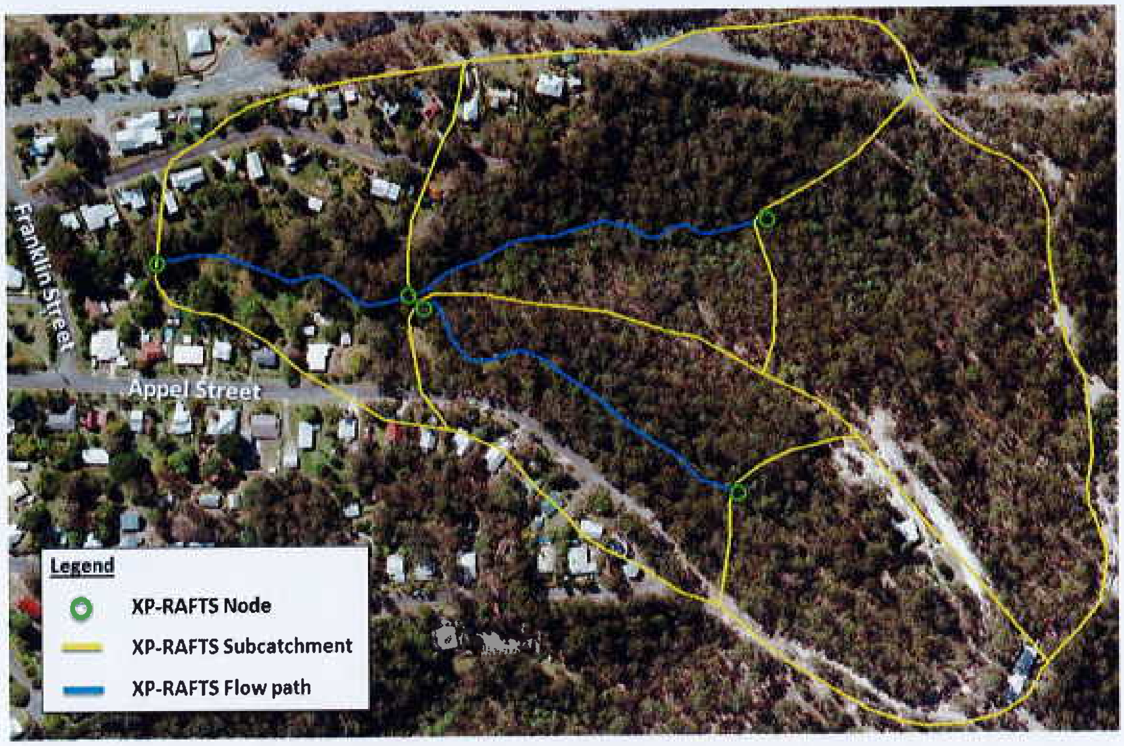

Figure 2-3 XP-RAFTS Model Schematic

Table 2-8 XP-RAFTS Model Peak Runoff Estimates

Storm Duration (50 year ARI event)	Peak Discharge
15 minutes	2.9 m^3/s
30 minutes	4.3 m^3/s
45 minutes	4.7 m^3/s
60 minutes	**5.1 m^3/s**
90 minutes	4.9 m^3/s
120 minutes	4.7 m^3/s

The XP-RAFTS model predicted that when measured at the entrance to the town drain, the 60-minute storm holds the critical duration. Given the importance of this drain as the trunk line for most of the town's piped drainage, the choice of the 60-minute duration event for the system assessment and options assessment has validity.

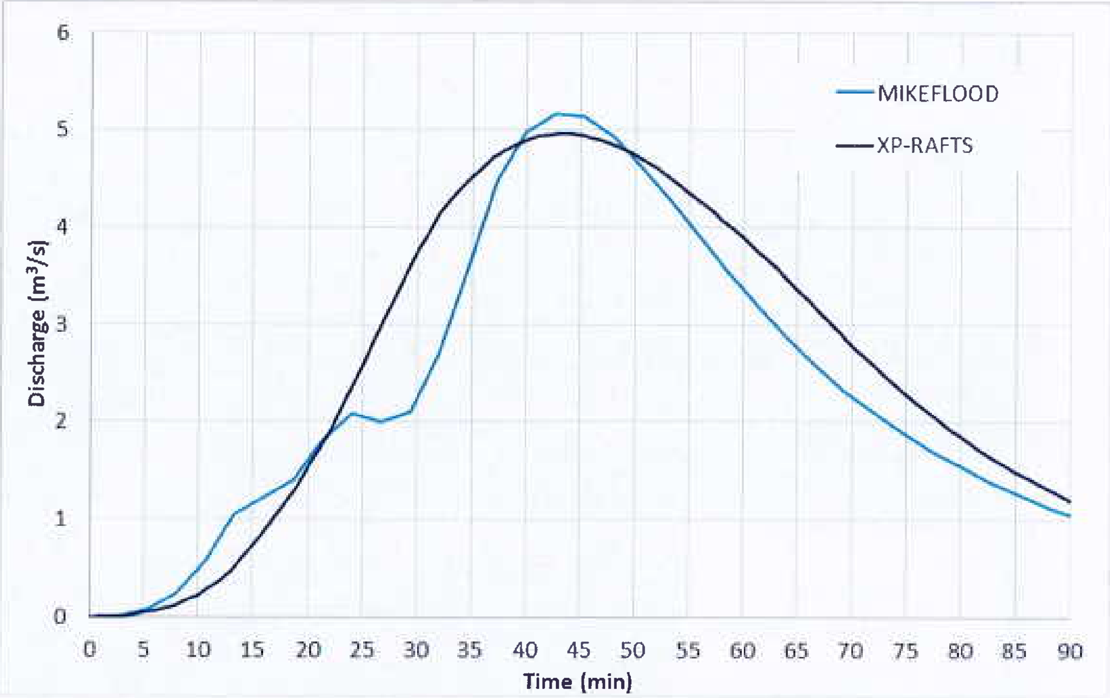

Figure 2- 4 Comparison Between XP-RAFTS and MIKEFLOOD Hydrographs

Using the 50 year ARI, 60-minute duration design event as the comparison storm, a good level of agreement was achieved with the hydraulic model. A difference of less than 0.2 m^3/s was predicted at the peak of the hydrograph, with minor differences in timing. The MIKEFLOOD hydrograph produced a slightly lower total volume (ie. area under the curve) than the XP-RAFTS model, which suggests the interception and capture of rainfall by small depressions in the terrain. Overall the result suggests that for the purposes of modelling the Canungra stormwater system, the topographic definition and adopted Manning's n values allow for the rain-on-grid method to be used with confidence in lieu of the traditional lumped-catchment method utilised by XP-RAFTS (and other similar software programs).

2.4 Mitigation Options Assessment

This section of the report describes the process of identifying and testing mitigation options during the Mitigation Options phase of the study. The mitigation options tested below were developed out of the System Assessment workshop and tested in the hydraulic model, with the aim of quantifying both the effectiveness of each option and an order-of-magnitude capital cost to implement it.

The System Assessment hydraulic modelling identified that a key risk at Canungra was the lack of a viable overland flowpath should the inlet to the main town drain, at Franklin Street, become blocked with debris during a storm event. As there is no feasible option to reinstate the natural flowpath (short of compulsorily resuming several properties on Lawton Lane), mitigation options were focussed on providing physical infrastructure solutions. A minor nuisance drainage scenario was identified in the park, and was also assessed. An overview of each option is provided, followed by an analysis of the model results, and finally an indicative cost estimate. Costs were adopted from Rawlinson Australian Construction Handbook, and/or from prices tendered to CDM Smith on recent construction management projects.

2.4.1 Scenario 1 – Complete Blockage of Town Drain

Overview

To establish the worst case flooding scenario, the inlet parameters were changed within MIKE Urban to simulate complete blockage of the culvert inlet. No other changes were made to the base case model. Unsurprisingly, excluding flow from entering the culvert resulted in rapid ponding immediately upstream, followed by the overtopping of Franklin Street. The overtopping flow was predicted to travel generally in a north-easterly direction, entering the property at 24 Lawton Lane, as well as travelling down the Lawton Land road corridor.

Model Results

In comparison to the base simulation case (ie. the QUDM-recommended setting of 20% culvert blockage), the 100% blockage case predicted peak water levels to increase by up to 100mm near the intersection of Franklin St and Lawton Lane, and by up to 150 mm in the area behind the fire station; results that arise due to shifting water from one flowpath (town drain) to another (Lawton Street). Consequently, a decrease in peak water levels of up to 200mm was predicted near the open channel outlet of the town drain.

Cost Estimate

As this is a theoretical test case with no physical changes, no cost estimate applies.

2.4.2 Scenario 2 – Flow Barrier at Franklin Street

Overview

Having established a "worst-case" scenario for flooding via complete blockage of the town drain inlet, the effects of physical mitigation were assessed. In this case, a contiguous group of cells was "blocked-out" from the model topography to simulate the effects of constructing some type of flood wall or barrier around the property boundary at 24 Lawton Street. In this type of setup, no height is specifically given to the blocked out cells, rather, the maximum predicted height of water against them is used to inform design levels. A model schematic is shown below in Figure 2-5:

Figure 2-5 Model Schematic - Scenario 2

Model Results

Two variations were considered. The first, with the town drain 100% blocked, showed that water levels inside the property boundary at 24 Lawton Lane were reduced by up to 300mm, whilst water levels on the outside of the property boundary (and outside the conceptual "barrier") increased by a proportional amount. A second simulation was then run with the assumed town drain blockage factor reduced to 20%. Results were similar to, albeit less pronounced than, the full-blockage case, which is the expected result when a larger portion of the flood flow is permitted to enter the piped network.

Overall, the maximum height of water against the barrier was found to be approximately 500mm, suggesting that a relatively low-height structure (such as several courses of masonry blocks topped with a standard wire mesh fence) could be constructed.

Importantly though, of the area which showed an increase in water levels, a significant portion occurs on the neighbouring property at 26-28 Appel Street, and to a lesser extent at 22-24 Appel Street. Such increases will likely neither be acceptable to the residents of these properties, nor meet the QUDM guidelines for no-worsening. So whilst the construction of some type of flow barrier solves one issue, it appears to push a large part of the problem on to nearby properties.

Cost Estimate

A cost effective construction could take the form of a small masonry wall to form a small barrier on the property-boundary side. An indicative estimate is provided below:

Table 2-9 Schedule of Rates - Scenario 2

Item	Rate	Unit	Qty	Cost
Identify and relocate water and telecoms	$ 5,000	ea	1	$ 5,000
Survey and set out control points	$ 1,000	ea	1	$ 1,000
600mm high masonry flood wall ^	$ 700	per metre	40	$ 28,000
			Total	**$ 33,000**

^ Constructed of core-filled masonry blocks, including: stripping topsoil, excavation, blinding concrete, foundations, wall construction, fencing, backfill, compaction, topsoil, and grassing.

2.4.3 Scenario 3 – Flow Barrier behind Christie Street

Overview

During the System Assessment workshop, a potential nuisance drainage problem was identified whereby runoff originating within the Kidston Street park could cause minor inundation of two sheds at the back of 29-31 Christie Street, on the park's northern boundary. Mitigation was simulated by again "blocking out" a line of cells around the affected property boundaries, as well as manipulating the topography to ensure a free-draining path on the wet side of the barrier, to either the park or Christie Street, as depicted in Figure 2-6.

Figure 2-6 Model Schematic – Scenario 3

Model Results

This approach was found to be generally effective in preventing runoff from crossing the lot boundary into 29-31 Christie Street. Peak water level reductions of up to 150mm were predicted, whereas the wet side of the barrier saw increases of up to almost 400mm. The largest increases were noted on areas where the ground level was changed in the model (ie. to maintain free drainage, simulating the effects of excavating a channel). All affluxes were confined to Council owned land, suggesting that this mitigation option meets the "no-worsening" criterion of QUDM.

Cost Estimate

With the available space it is likely that cost effective construction could take the form of a small earthworks exercise, cutting an appropriate drainage channel and using the excavated material to form a small bund on the property-boundary side. Ideally the drainage channel would connect through to the small open channel that runs through the school, and which begins nearby. With that in mind, the cost will largely be a function of the availability and productivity of the work crew and machines at Council's disposal, however an indicative estimate is provided below:

Table 2-10 Schedule of Rates - Scenario 3

Item	Rate	Unit	Qty	Cost
Identify and relocate water lines	$ 5,000	ea	1	$ 2,000
Survey and set out control points	$ 1,000	ea	1	$ 1,000
Dismantle and remove picnic shelter	$ 1,000	ea	1	$ 1,000
Plant and Crew ^	$ 400	per hour	20	$ 8,000
New turf, laid, rolled and watered	$ 7	sq metre	110	$ 770
			Total	**$ 15,770**

^ One small excavator or backhoe, one footpath roller, two labourers.

2.5 Detailed Options Assessment

2.5.1 Hydraulic Modelling

Overview

Following the Mitigation Options workshop, Council proposed testing a modified version of Scenario 2 (Flow Barrier at Franklin Street) in which Lawton Lane could be modified to act as a new major overland flow path, allowing for controlled relief drainage in the event the town drain was to become overwhelmed or blocked with debris. This would involve some type of "channelization" of Lawton Lane, either by constructing a new raised kerb, or excavating to slightly lower the road surface with respect to adjacent ground levels, or a combination of both. Some type of flow barrier or flood wall would be provided around the property at 24 Lawton Lane, as per Scenario 2. For the purposes of this report, we have named the new option Scenario 4, a schematic of which is shown below:

Figure 2-7 Model Schematic – Scenario 4

This scenario was affected in the model by calling up the 2D structures routine, and implementing an arbitrarily high levee on either side of Lawton Lane, beginning at the Franklin Street intersection and extending the length of the lane to the intersection with Kidston Street. Like the previous scenarios, flow is prevented from crossing the levee, with the effect that overland flow is directed down Lawton Lane, thus simulating the effects of raising the kerb/lowering the road surface.

Model Results

The shape and extent of the implemented flow barriers were effective in directing the Franklin Street overtopping flow away from private property and down the road corridor towards the park. As a result, peak flood levels on Lawton Lane were predicted to increase by up to 350mm when compared to the base case, with increases observed along the length of the lane, across Kidston Street, through the park, and into the commercial properties on located on the southern side of Christie Street. And as expected, there was a marked reduction in peak water levels on the eastern side of Lawton Lane – this being the area through which flow would otherwise travel. Results are shown below in Figure 2-8; a more detailed A3 version is provided as Figure A-13 in Appendix A

Figure 2-8 Peak Water Depth Difference Map – Scenario 4 Compared Against Base Case

So whilst this option achieves the stated aims of reinstating a major overland flow path and reducing the risks associated with town drain blockage, it does cause an impact to private properties on Christie Street. Most of the impacts occur in the same area where the nuisance flooding was investigated in Scenario 3. Therefore, as a final hydraulic modelling simulation, these two scenarios were combined to create Scenario 5, testing if the previously identified mitigation option could serve a dual purpose. Results are shown in Figure 2-9, below:

Figure 2-9 Peak Water Depth Difference Map – Scenario 5 Compared Against Base Case

The results indicate that this Mitigation Option could form the basis for a design providing an overland flow path for the natural catchment to Franklin Street. As with the previous scenario, water levels increase throughout Lawton Lane, at the benefit of decreased water levels in the original flow path above the town drain. This mitigation option is conceptual in nature, and would require careful thought as it moved through the design stage. Items requiring consideration include, but are not limited to:

- Consultation with local stakeholders, to ensure they understand and are supportive of the changes;
- Identification of services and utilities, and engagement with local utility authorities to develop relocation plans. In CDM Smith's experience, changes to electricity infrastructure are costly and can often have a very long lead time;
- Refinement of the design concept, to determine what portion of the predicted water level increase on Lawton Lane should be accounted for by raised kerb, and what portion by lowering the road surface itself.

2.5.2 Site and Route Assessment

This option would require substantial road works to be undertaken along the length of Lawton Lane, as well as on a portion of Franklin Street. Works on Franklin Street would take place in the road corridor, but outside of the sealed surface, making it likely that construction could proceed with a single lane closure and adequate traffic control and monitoring of pedestrian access.

Lawton Lane is a minor road that serves to provide local access only, so works here, whilst disruptive to local residents, are likely to result in only minimal disruption to journeys undertaken throughout the rest of town. However, given the narrow width of the road corridor (approximately 6.5 metres) maintaining resident access during construction is likely to require careful planning. Similarly, the construction sequence should be carefully thought out, as there may not be sufficient space for two large construction vehicles to pass each other without encroaching upon private land.

No below-ground stormwater assets are known to exist in the Lawton Lane road corridor, however three grated pits exist at the intersection with Franklin Street, which are piped directly beneath that road to the entrance of the town drain. Details on whether or not this asset requires relocation would be developed at the detailed design stage.

2.5.3 Cost Estimate

The cost estimate detailed below is essentially a combination of the works outlined in Scenario 2 and Scenario 3, with the addition of road reconstruction (ie. lowering) at Lawton Lane.

Table 2-11 Schedule of Rates - Scenario 5

Item	Rate	Unit	Qty	Cost
Identify and relocate water and telecoms	$ 25,000	ea	1	$ 25,000
Survey and set out control points	$ 3,000	ea	1	$ 3,000
Dismantle and remove picnic shelter	$ 1,000	ea	1	$ 1,000
Plant and Crew to construct drain and bund in park +	$ 400	per hour	20	$ 8,000
New turf, laid, rolled and watered	$ 7	sq metre	150	$ 1,050
600mm high masonry flood wall ^	$ 700	metre	60	$ 42,000
Lower Lawton Lane by approximately 300mm *	$ 450	metre	220	$ 99,000
			Total	**$ 179,050**

+ One small excavator or backhoe, one footpath roller, two labourers.

^ Constructed of core-filled masonry blocks, including: stripping topsoil, excavation, blinding concrete, foundations, wall construction, fencing, backfill, compaction, topsoil, and grassing

* Composite price for: remove existing surface, exacavate, reprofile, reseal, new kerb and channel both sides.

2.5.4 Risk Assessment

The development of a comprehensive risk assessment is a task that is best completed during the detailed design stage as the finer points of the proposed works become known. However, general risks include, but are not limited to:

- Traffic management, ensuring that suitable plans are in place to protect vehicles, pedestrians and workers;
- Identification of underground services, and construction in their vicinity;
- Construction using heavy machinery in relatively confined spaces; and,
- The occurrence of severe weather during the construction period.

The points listed above should form the starting point for a comprehensive risk assessment to be undertaken at the commencement of the detailed design phase, and repeated (with a focus on the practical elements of construction risk) prior to works commencing. The identification of, and mitigation plan for risks should be captured in a "Safety in Design" register, and updated as required leading up to the commencement of construction.

It is expected that any construction contractor engaged to perform the works would have in place a thorough risk management strategy, including site specific project management plans to address risks relating to traffic, workplace health and safety, quality assurance, community, and the environment. These plans should be reviewed in conjunction with Council, and amended where necessary, prior to works commencing.

2.6 Findings and Recommendations

2.6.1 Riverview Drive

After building a hydraulic model and carrying out a system assessment, CDM Smith has found the following:

- The stormwater network in this newer housing estate performed well under severe rainfall events. It is clear from the pipe network layout and grading of the lots and road corridors that stormwater drainage was considered as part of the planning phase.
- For that reason, no major problems were found via hydraulic modelling, although it is noted that several of the drainage outfalls are impractically situated halfway up the creek banks, leading to localised scour issues.
- As such, no further investigations were carried out with regards to mitigation options.

We therefore make the following recommendations:

Recommendation 1: *Provision of Outlet Protection*. To prevent ongoing maintenance issues, Council should install rip-rap or gabion baskets to prevent further erosion at the outlets to the piped drainage network.

2.6.2 Canungra

At the township of Canungra, CDM Smith finds the following with respect to the stormwater system:

- The piped network is generally quite old and of low capacity, with many older style inlets prone to blockage. The piped system surcharged in the most minor storm event (1yr ARI) considered during the assessment.
- The road corridor, therefore, carries the majority of stormwater runoff and appears to do so with little inconvenience or impact upon the residents of the town. This is an acceptable outcome for an old drainage network that pre-dates modern design standards. By corollary, it stands that improvement or upgrade works to the pipe network should only be carried out to address known issues/deficiencies.
- The hydraulic model confirmed the existence of a nuisance flooding issue affecting the sheds located behind commercial properties fronting Christie Street. Providing a flow barrier in the form of a small earth bund and local diversion drain was found to be an effective, low cost way to alleviate the problem.
- The major risk to the effective functioning of the stormwater system at Canungra is related to the absence of an alternative overland flowpath should the inlet to the town drain become blocked. The system assessment found that overtopping of Franklin Street could occur under

the 1 year ARI design storm event with the drain 20% blocked. A test case assuming total blockage resulted in the overtopping flow increasing accordingly. A related blockage risk is created due to the change in geometry from 1200mm pipe to 800 mm high box culvert where the town drain passes beneath Christie Street.

- If overtopping of Franklin Street were to occur, the property at 24 Lawton Lane (and to a lesser extent, Numbers 18 and 20-22 Lawton Lane) would be impacted. A mitigation option investigating the provision of a conceptual flood wall around Number 24 was found to be effective, however it pushed the problem of increased water levels on to adjacent properties and for this reason could not be recommended in isolation.

- The blockage and overtopping issues was addressed further as part of the Detailed Options Assessment. CDM Smith found that incorporating a channelisation/lowering of Lawton lane in concert with a floodwall (per Scenario 2), was an effective mitigation option that contained water levels increases almost entirely within the road reserve and park reserve.

- The concept described in the above bullet point pushed impacts onto the commercial properties on the southern side of Christie Street. This was addressed by undertaking a final design iteration in which the mitigation option described above was combined with that of Scenario 3. This was found to be an effective solution.

We therefore make the following recommendations:

Recommendation 1: *Address nuisance flooding at Christie Street.* Construction of the mitigation option described in Scenario 3 is relatively cheap, as it is predominately a landscaping exercise. Council should look to conduct these works using their in-house plant and equipment. In addition to the immediate protection conferred, there is also an element of future-proofing involved, as it serves to reduce the cost of the Detailed Mitigation Option, should it be built.

Recommendation 2: *General grated pit/inlet maintenance.* Council should continue to assess the condition of stormwater infrastructure and replace old or damaged pits as necessary.

Recommendation 3: *Internal inspection of the town drain.* The precise alignment of the town drain is not currently known , although it is suspected that there is at least one manhole/pit between the town drain inlet and the Christie Street outlet. Council should organise for and internal inspection (via remote video camera or similar) of the drain to assess its condition and map its alignment. Any accumulated debris could also be removed at this time.

Recommendation 4: *Further investigation of the detailed mitigation option before proceeding.* If Council is committed to addressing the risk of blockage and lack of overland flow path, more investigation is required to develop the idea from a concept into a detailed design. Council should discuss whether they wish to proceed with developing this idea further before committing any further funds to it.

Appendix A – Figures

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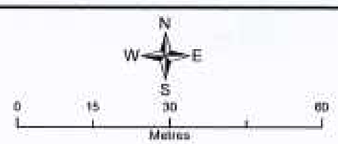

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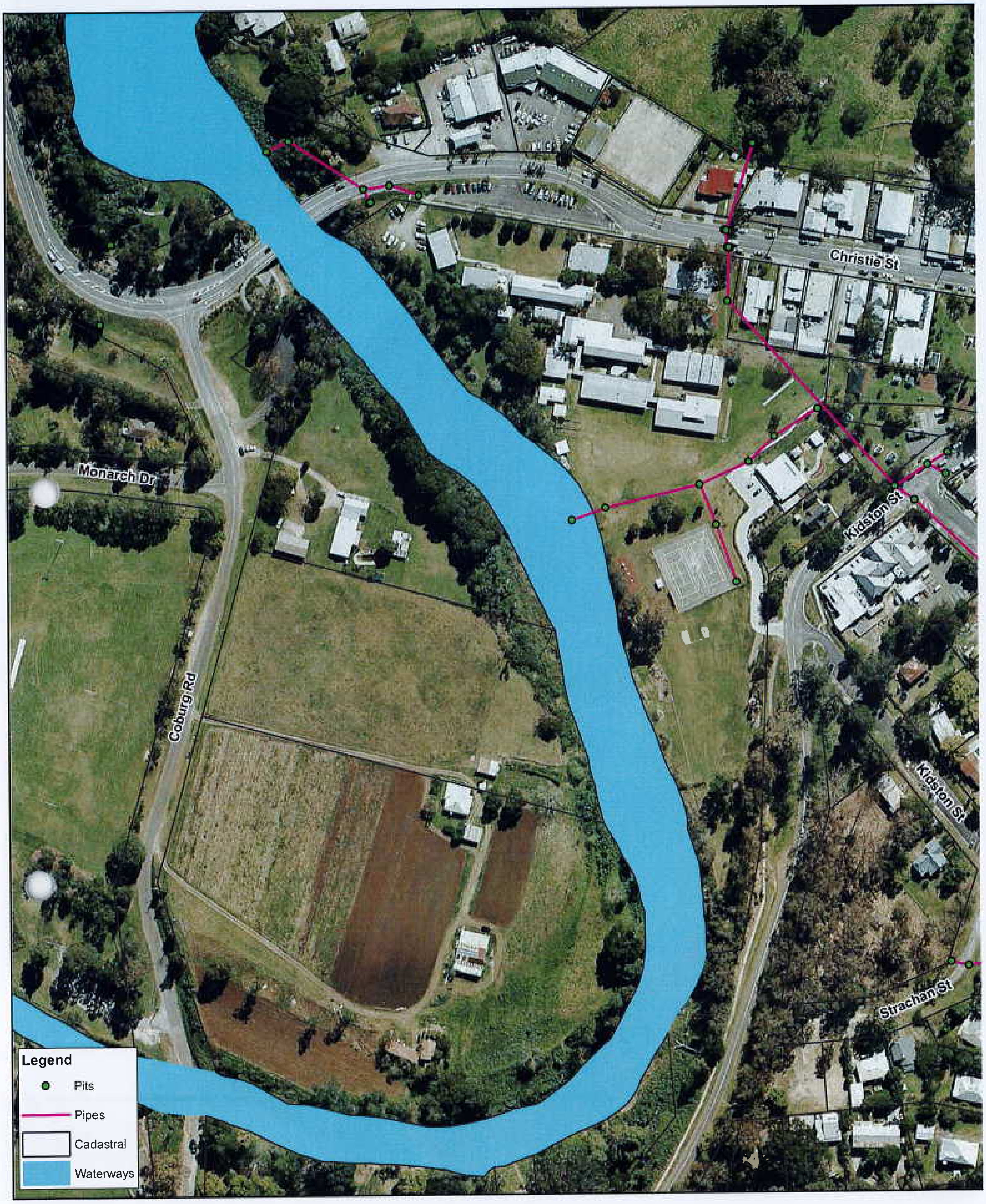

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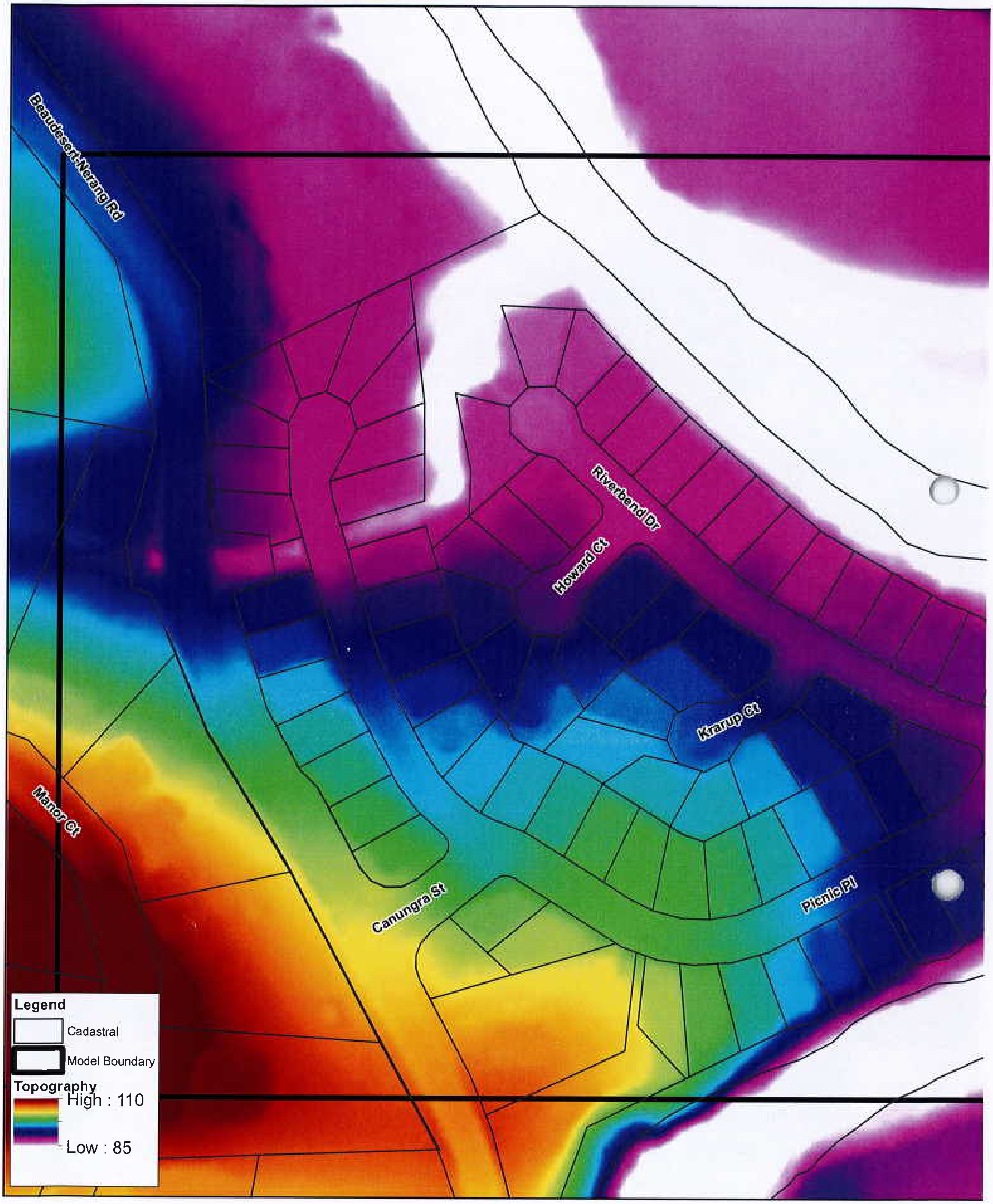

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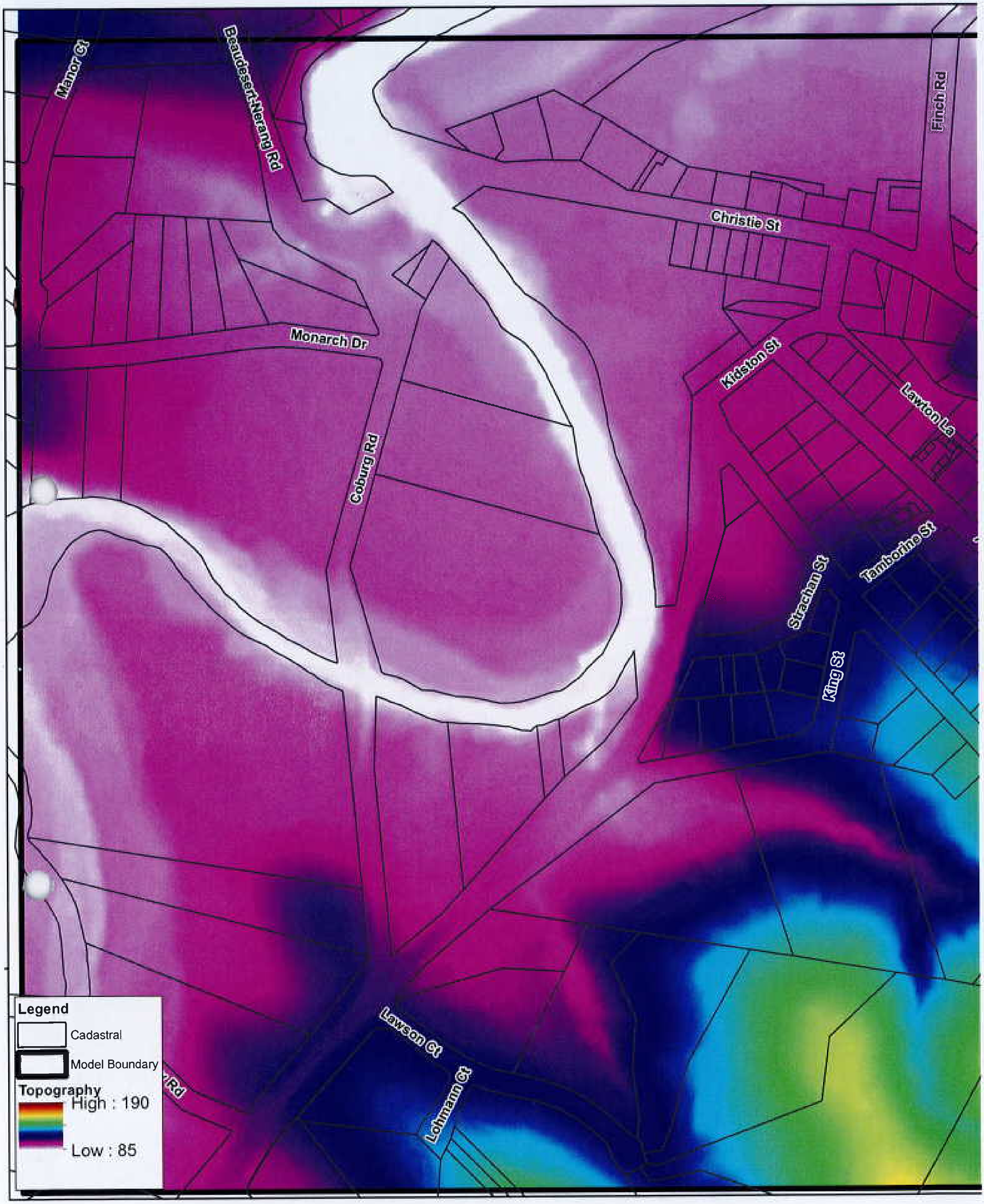

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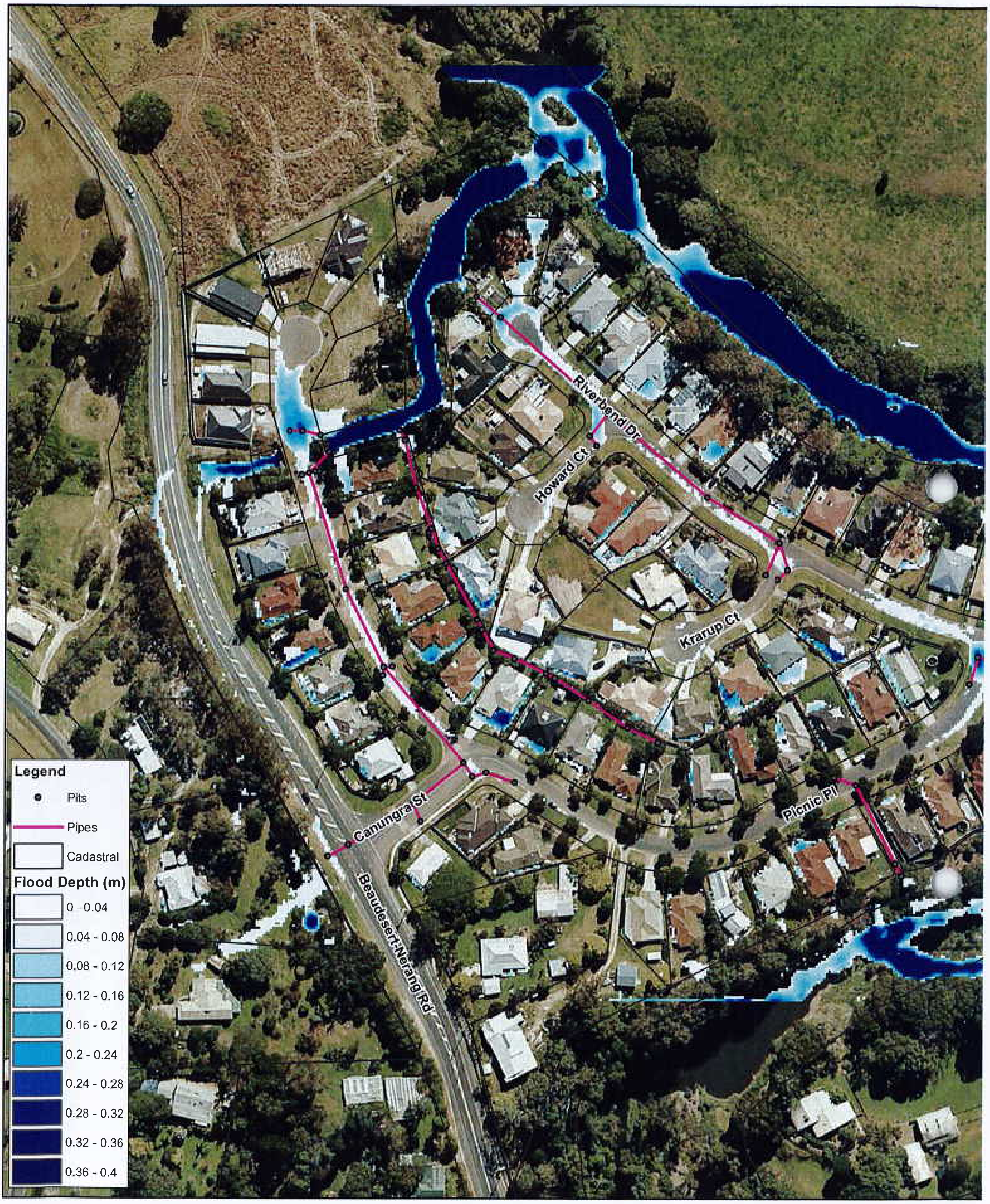

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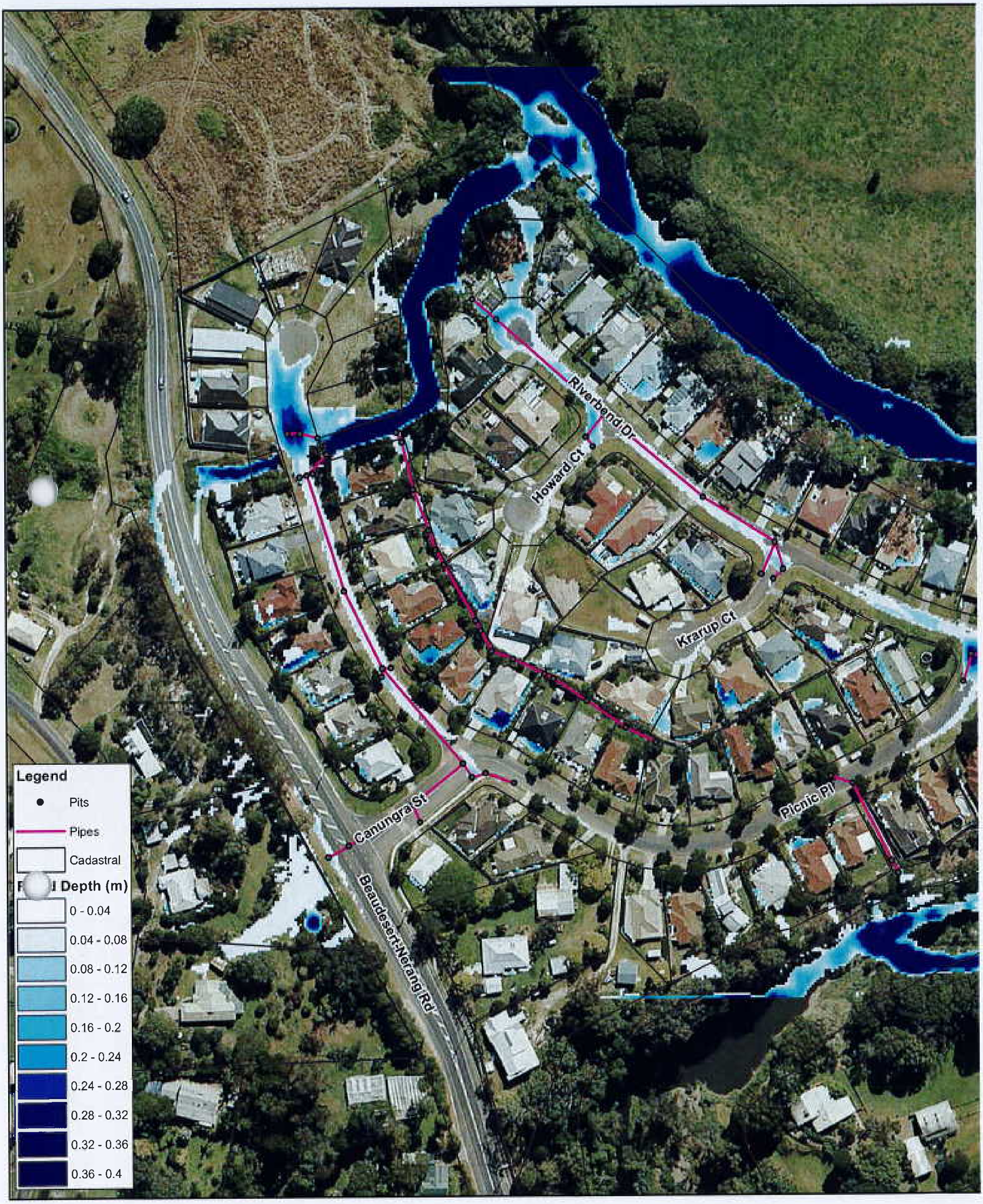

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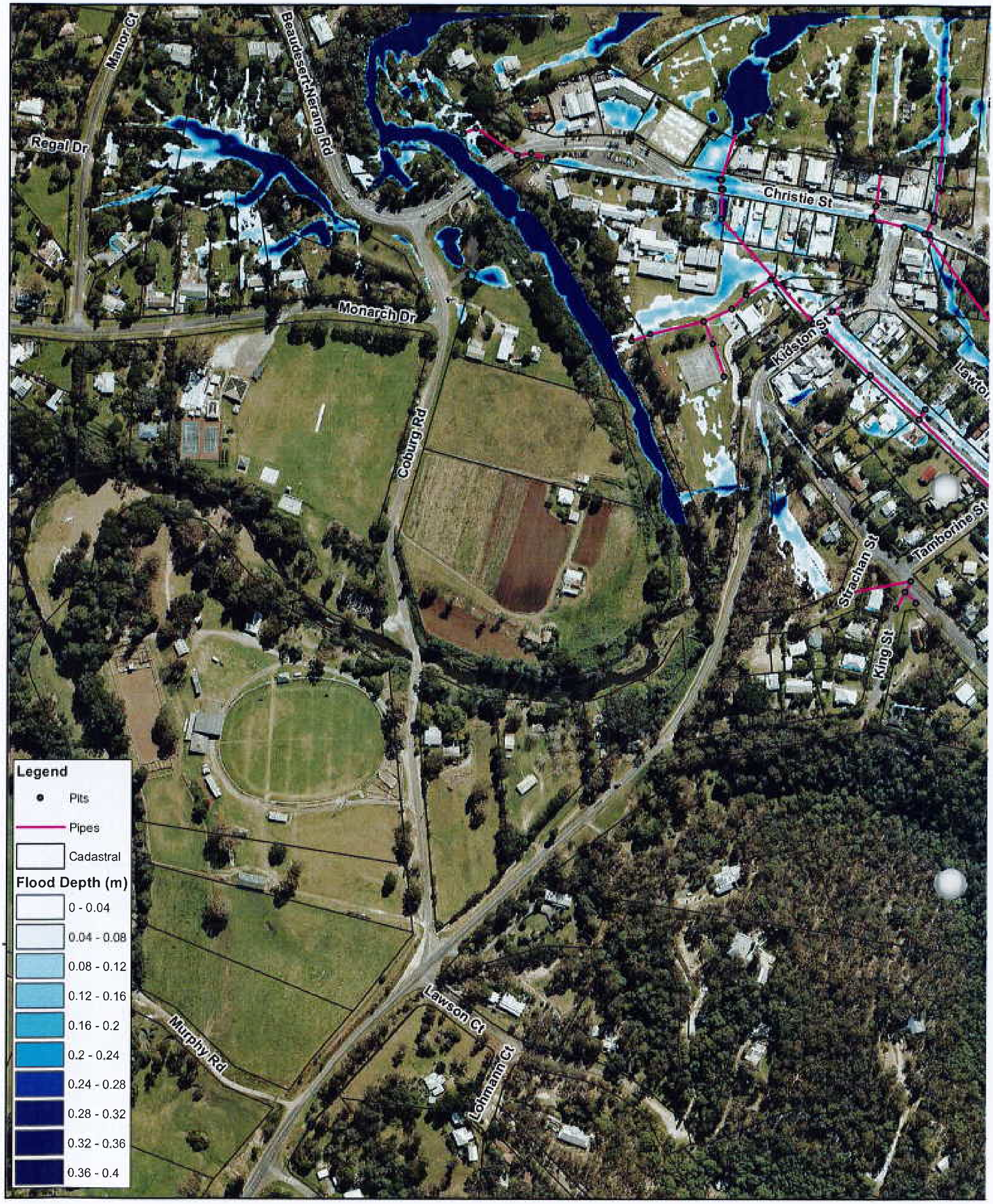

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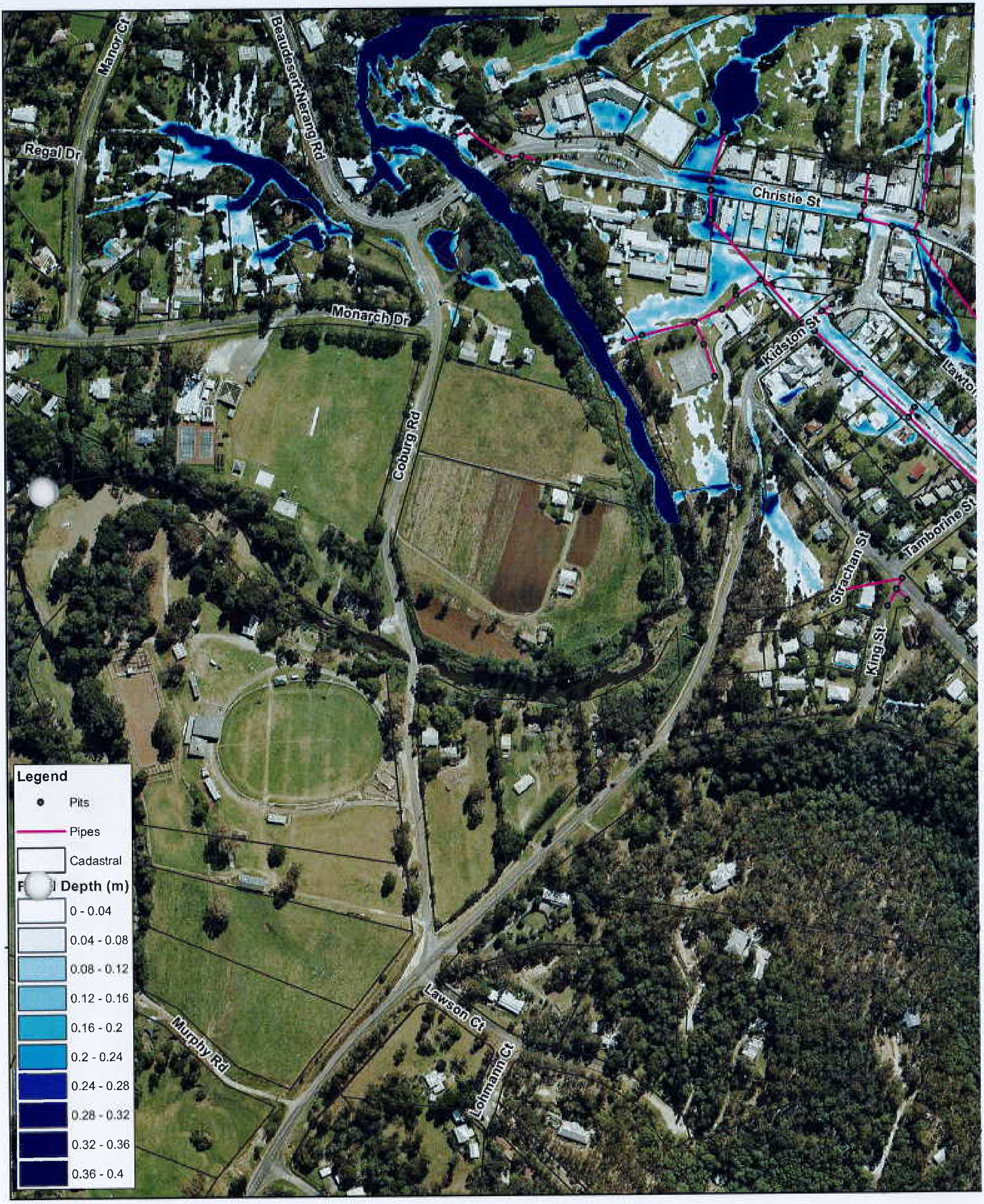

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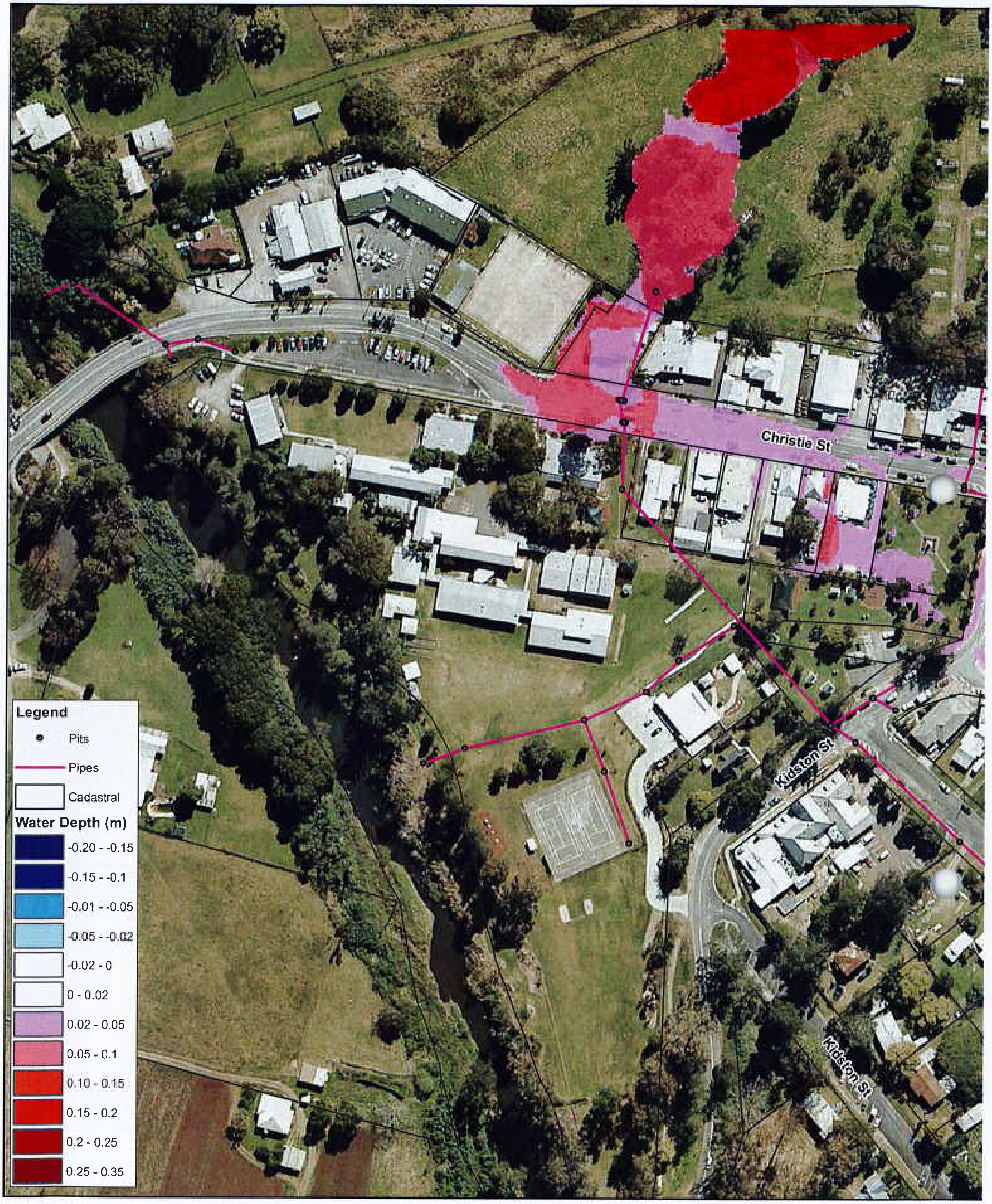

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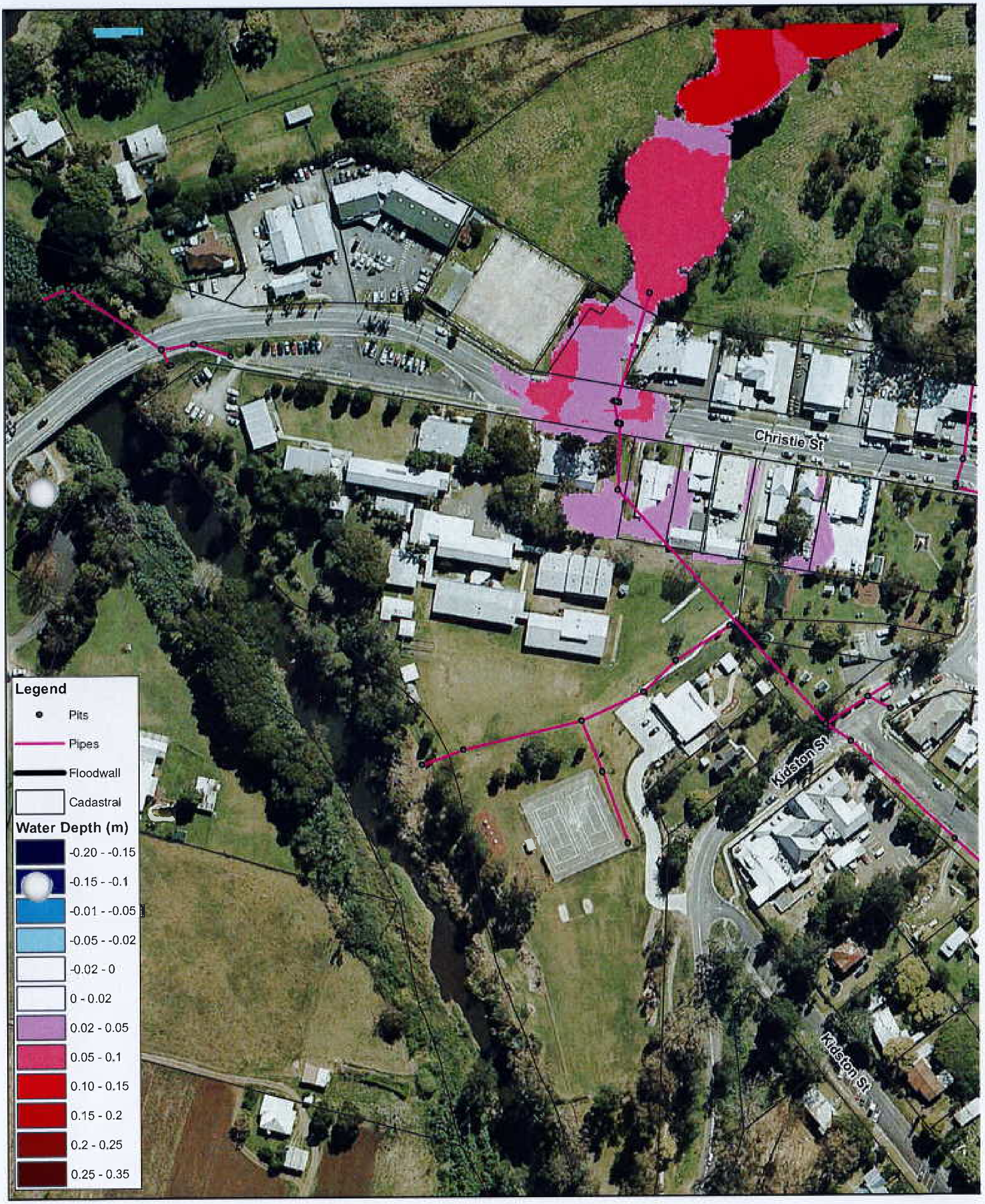

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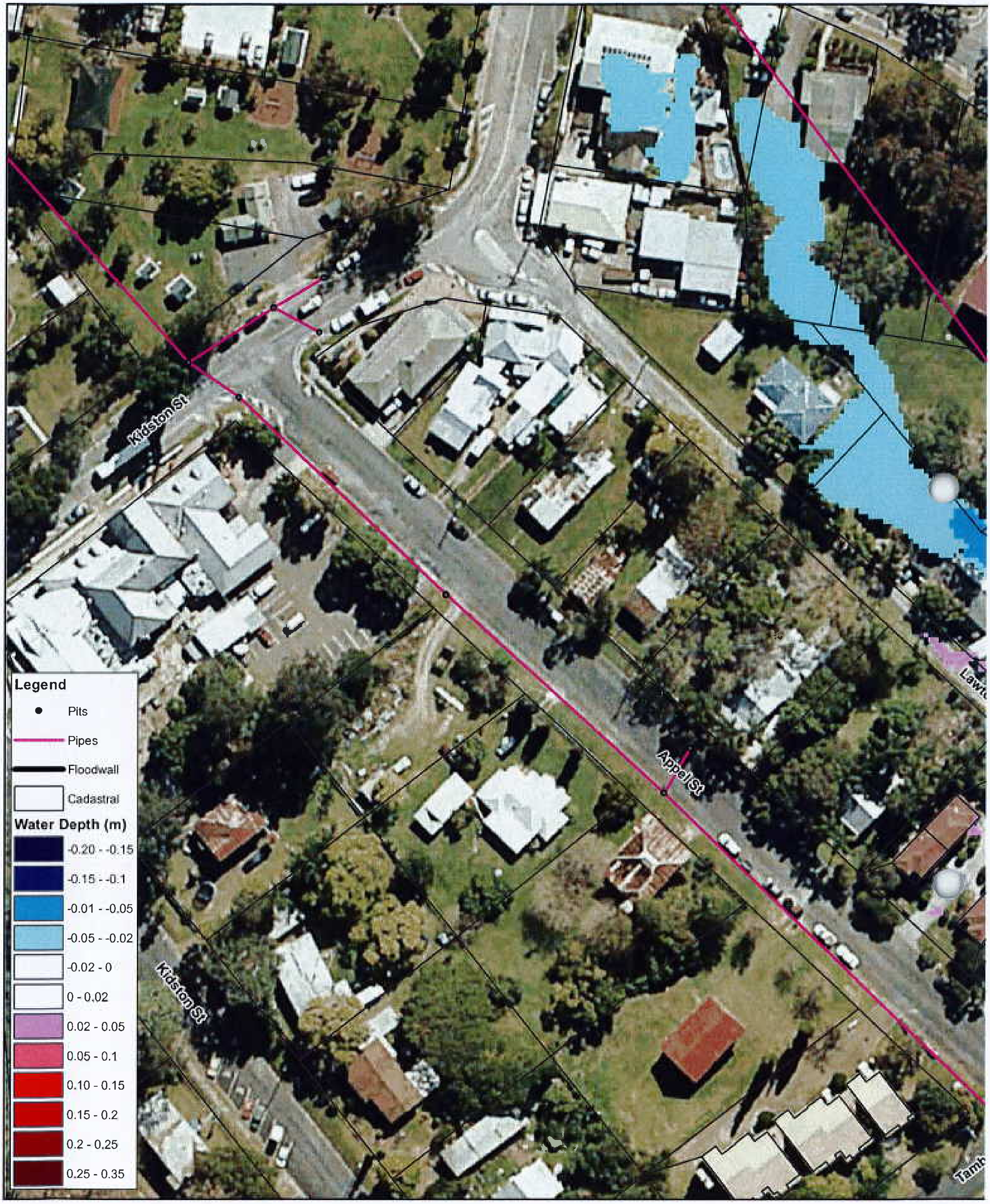

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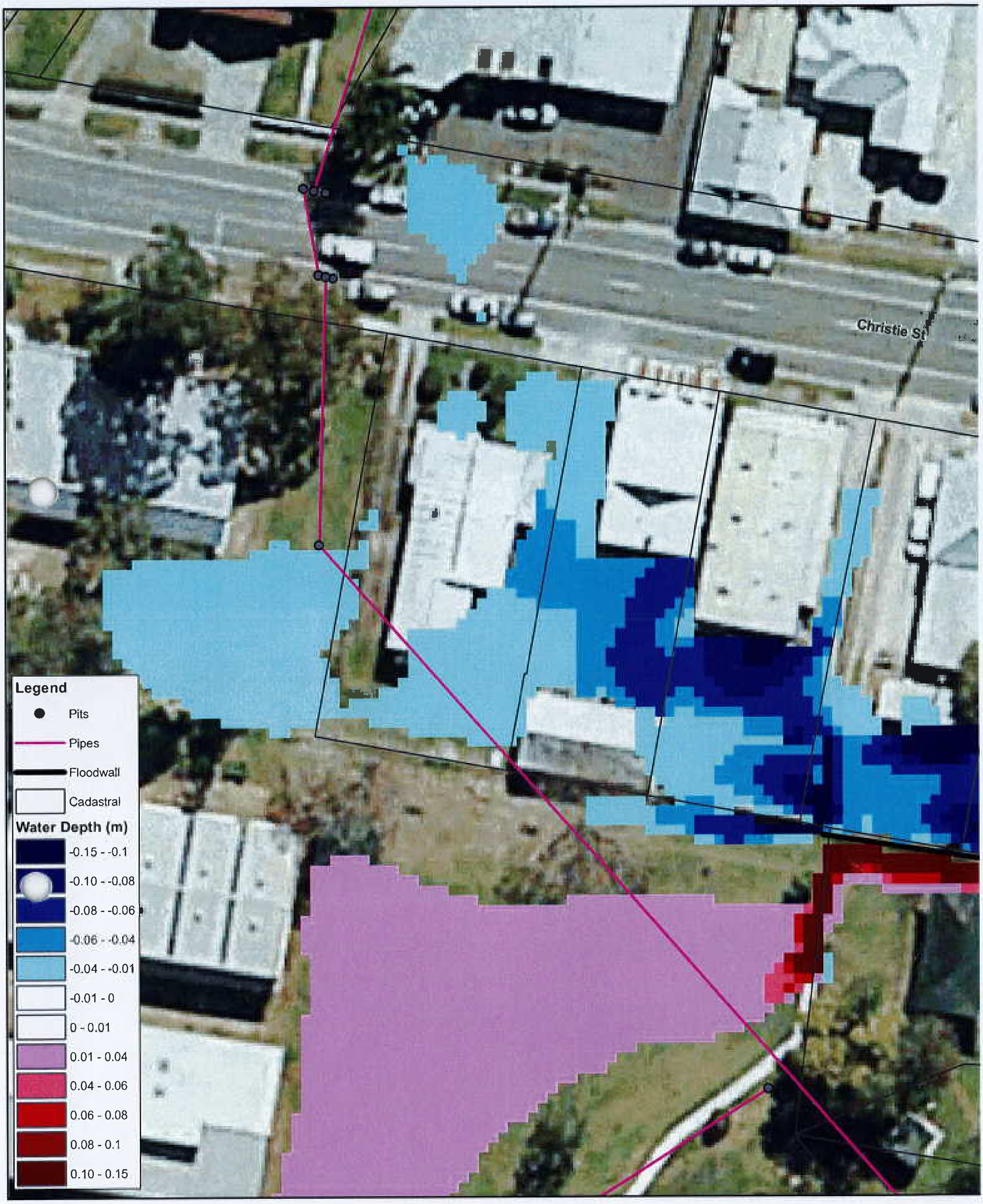

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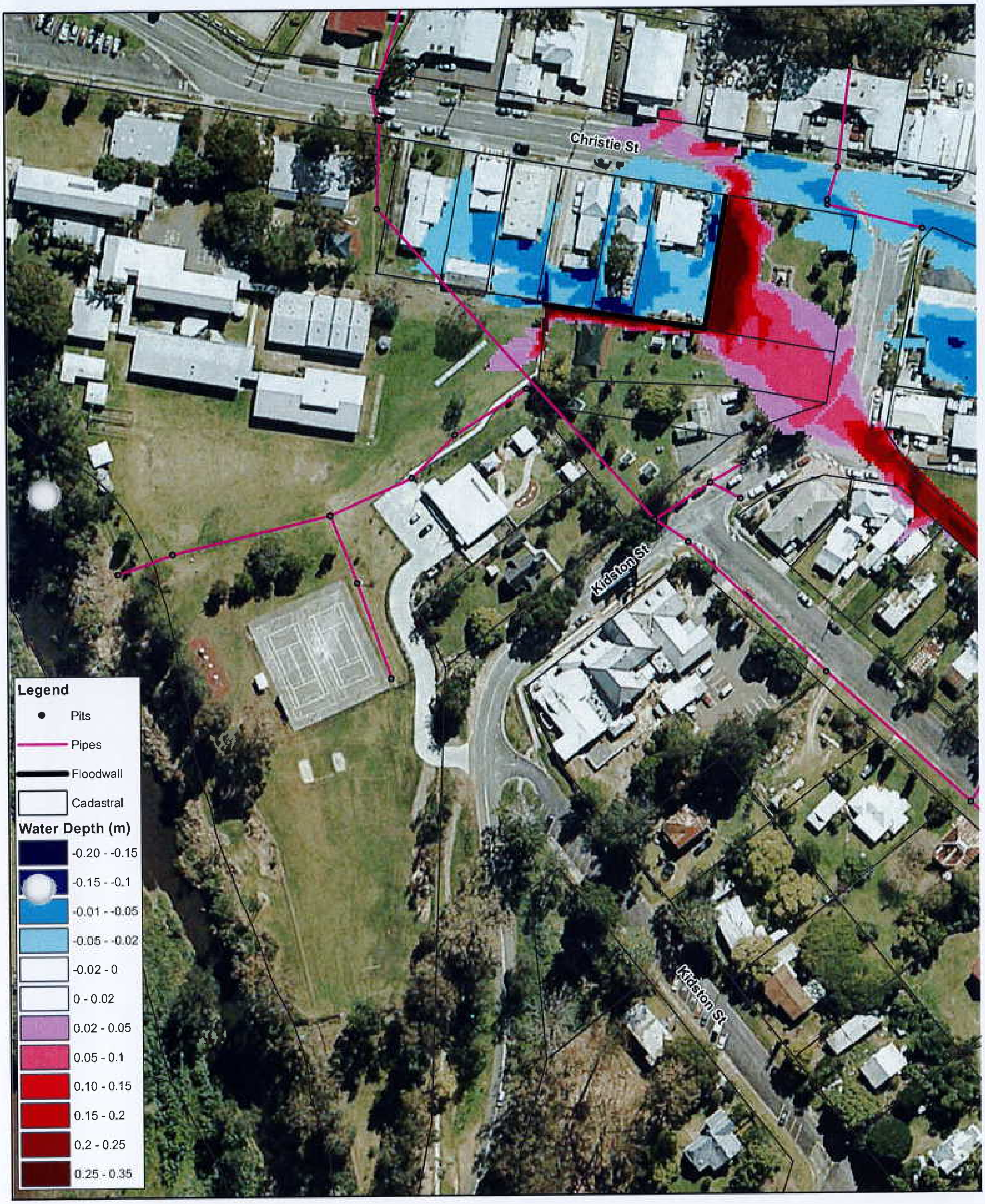

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Appendix B - Disclaimers

Disclaimer and Limitations

This report has been prepared by CDM Smith Australia Pty Ltd (CDM Smith) for the sole benefit of Scenic Rim Regional Council for the sole purpose of satisfying the requirement of the provision of a Project Report for "Stormwater System Assessment and Improvement Plan – Kalbar Study Area" Project.

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If further information becomes available, or additional assumptions need to be made, CDM Smith reserves its right to amend this report.

Scenic Rim Regional Council

Stormwater System Assessment & Improvement Plan Kalbar Study Area

Project Report

CDM Smith

Scenic Rim Regional Council

Stormwater System Assessment & Improvement Plan Kalbar Study Area

Project Report

18 August 2016

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Executive Summary

CDM Smith was commissioned by Scenic Rim Regional Council (SRRC) to undertake a Stormwater System Assessment and Improvement Plan for the towns of Kalbar and Canungra. The objective of this study was to assess the stormwater systems contained within the defined study area, and produce methods for the efficient management of localised flooding, using accepted engineering methods and judgement to design a system improvement plan.

This report focuses on the Kalbar study area. The stormwater system assessment was carried out using a MIKE Urban model of the piped drainage network which was dynamically coupled to a MIKEFLOOD 1D/2D hydraulic model.

The Kalbar stormwater network assessment identified two problem areas; the low point on Wiss street, and the nuisance sheet flow on Railway Street. Three mitigation options were investigated, namely: increasing the inlet size at Wiss Street; regrading Moffat Street, and; constructing a higher lipped kerb in Railway Street.

Based on the stormwater network assessment and the investigation of mitigation options, CDM Smith made the following recommendations:

1. *Address nuisance flooding at Railway Street.* Council should consider constructing a higher lipped kerb (>150mm) to mitigate this issue.
2. *Augment the inlet capacity at the Wiss Street sag.* This is a simple fix that has the benefit of being highly visible to local residents.
3. *General open-drain maintenance.* Increasing the inlet capacity should be carried out in conjunction with a program of clearing and regrading the earth V-drains on Wiss Street and Moffat Street, paying particular attention to achieving negative longitudinal grade.
4. *General grated pit/inlet maintenance.* Council should continue to assess the condition of stormwater infrastructure and replace old or damaged pits as necessary.
5. *Improvements to Driveway Access Points.* Council should act to discourage any new implementations of steel plates over the kerb and concrete wedges within the channel as these reduce the conveyance of kerb and channel; create blockage points, and; allow flow to escape on to private property, increasing nuisance drainage issues.
6. *Removal of "orphan" pipe networks.* If the opportunity arises (eg. during roadworks), these pipes and grates can be removed as they contribute nothing to performance of the overall system, but represent a maintenance burden to Council.
7. *Investigate further before regrading Moffatt Street.* A detailed road and drainage design, utilising surveyed levels, should be developed, with careful planning to ensure that driveway accesses are maintained and utilities are appropriately identified and relocated. It is recommended that further investigations only proceed if a cost-benefit analysis shows a positive outcome and it is probable that the requisite funds will be available for construction. No further action to develop this option is recommended at the current time.
8. *Look to reinstate the natural flow path at Moffat/Wiss Street.* In lieu of regrading Moffat Street, Council should consider taking an easement over the gully (ie. natural flowpath) from Moffat Street through to JEC Pennell Park, to ensure that no future development occurs on this drainage line.

Section 1 Introduction

1.1 Study Areas

CDM Smith was commissioned by Scenic Rim Regional Council (SRRC) to undertake a Stormwater System Assessment and Improvement Plan for the towns of Kalbar and Canungra. This report focuses on the Kalbar study area, which comprises the areas of town that feature underground stormwater assets, as shown in Figure 1-1:

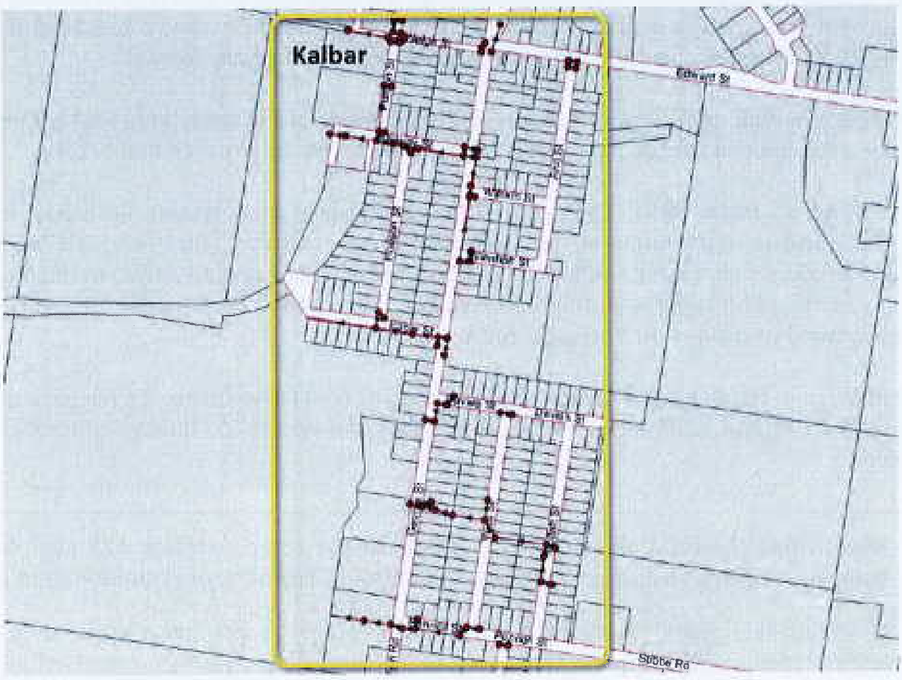

Figure 1-1 Kalbar Study Area

1.2 Objective

The objective of this study was to assess the stormwater systems contained within the defined study area, and produce methods for the efficient management of localised flooding, using accepted engineering methods and judgement to design a system improvement plan.

This was achieved by building a detailed hydraulic model of the study area, incorporating Council's GIS asset data to it, and then simulating various flooding scenarios in order to identify deficient areas. Options to improve deficiencies were developed through consultation with SRRC staff, and then tested for effectiveness in the model, with the goal of developing an improvement plan for capital works designed to address any identified issues and provide the desired level of service.

Section 2 Hydraulic Modelling

2.1 Setup

2.1.1 Input Data

The following data were used to build the hydraulic models:

- **Airborne Laser Survey (ALS).** Provided by SRRC to CDM Smith, the ALS data comprised 1 km x 1 km square tiles, at a grid resolution of 1 metre. The tiles were mosaicked into a seamless DEM and then exported to the hydraulic model's proprietary format.

- **Aerial Imagery.** A high quality, geo-referenced digital image of the study area was provided by SRRC, and was used primarily as part of the quality control exercise described below.

- **Stormwater Asset Data.** SRRC Technical Officers captured stormwater network data via handheld GPS (and a small number of assets via field survey at Riverbend Drive). All known and accessible manholes, pits, grates and pipe diameters were measured and added to the database, creating a point-to-point representation of the stormwater network (ie. pipes running between pits were assumed to connect in a straight line).

  A notable feature of the data was its description in terms of relative levels. To prepare the data for input to MIKE Urban, CDM Smith carried out a comprehensive GIS quality control exercise that involved:

  - Reconciling the location of each asset against the corresponding ALS grid point to translate relative levels (eg. "metres below surface") into the Australian Height Datum.

  - Cross-checking pit locations against the aerial image, Google Street View, and the ALS data, and manually adjusting locations where it was apparent that the GPS accuracy was low.

  - Combining multiple adjacent inlets into a single node, to accommodate the MIKE Urban modelling technique;

  - Excluding from the final input data several very small pipes, as well as a number of pipes and pits where connectivity was unclear.

  - Requesting SRRC to collect additional asset data in cases where the initial measurements were unclear or appeared erroneous; and,

  In total, four iterations were performed of the tasks outlined above. The finalised pipe network configurations are shown visually in Appendix A.

2.1.2 Software

The stormwater system assessment was carried out using the "MIKE by DHI" water modelling software. Specifically, a MIKE Urban model of the piped drainage network was dynamically coupled to a MIKEFLOOD 1D/2D hydraulic model, in a configuration that has the ability to:

- Represent small open channel elements and hydraulic structures in the 1D domain;

- Account for complex overland flowpaths and breakouts in the 2D domain;

- Accurately model the piped network and its interaction with surface waters, specifically with regard to energy losses at inlets, manholes and pits;
- Couple the 1D, 2D and piped-network elements in a single integrated modelling environment;
- Natively account for precipitation, and therefore runoff, via a rain-on-grid method, and;
- Easily test the effects of changing the topography or drainage configuration on network performance.

2.1.3 Modelled Area

A summary of key aspects of the hydraulic models is shown below in Table 2-1. Figures detailing the models' geographic extents, topographic variation, and pipe network schematisation are found in Appendix A.

Table 2-1 Hydraulic Model Details – Kalbar

Name	Details
2D Domain	
Map Projection	GDA 1994, MGA Zone 56
Grid Origin (lower left corner)	462570 m East, 6908240 m North
Grid Resolution	1 m
Grid Dimensions (width x height)	690 cells x 1510 cells
Grid Rotation (clockwise from North)	0 degrees
1D Domain	
No. Pipe Elements	61
No. Manhole Elements (pits, gullies, grates)	71
No. Culvert Elements	3
1D-2D Connectivity	
No. 1D-2D linkages	61

2.1.4 Hydraulic Roughness

A spatially-distributed roughness map was developed to reflect the variance in resistance to surface flow based on land use. Land use areas were identified from the high-resolution aerial image, and augmented with photographs from the site visits and some information from Google Street View. The Manning's n values chosen for the model are within the commonly accepted ranges for rain-on grid modelling, and are summarised in the table below:

Table 2-2 Adopted Manning's n Roughness Values

Land Use	Value
Roof Areas	0.200
Roads and Paved Areas	0.018
Short Grass	0.035
Long Grass	0.050
Forested Areas	0.800

A relatively high roughness value was used to represent the footprints of buildings; in addition, building footprints were raised by 0.2m with respect to the underlying terrain values. The raised topography simulates the obstruction to flow created by buildings, providing a more realistic pattern of flooding around structures without removing rainfall volume from the model (as would be the case if building footprints were "blocked-out" from the simulation entirely), whilst the reduced conveyance introduced by the high roughness value simulates the time taken for rainfall to travel from the roof to the ground.

2.1.5 Blockage Factors

Grated pits, side inlets, and culverts can become blocked by debris during rainfall events, reducing their capacity to capture water and direct it to the piped network. The degree to which blockage occurs for any given flood is generally regarded to be a function of the type of structure, and the availability of source blockage material in the upstream catchment.

The Queensland Urban Drainage Manual (QUDM) suggests, in Table 7.5.1, to apply blockage factors of 50%, 20% and 20% for grated inlets, side inlets and culvert inlets respectively. During field investigations, CDM Smith noted several side inlets and grated pits that were partially blocked as a result of a recent small storm, as shown in Figure 2-1. It is clear that some degree of blockage is likely to occur during a rainfall event, and we have therefore adopted the QUDM recommendations for use in the hydraulic modelling.

Figure 2-1 Blocked Stormwater Inlets at Kalbar

2.1.6 Design Event Rainfall

Design rainfall intensities were sourced from the Bureau of Meteorology (BOM), via the online Intensity-Frequency-Duration (IFD) generator. At the current time, two choices of IFD data are available to the hydrologist – those based on the Australian Rainfall and Runoff project from 1987 (AR&R87) and the recently released 2013 project carried out by the BOM. Although the 2013 IFD's are more data rich, containing almost 30 extra years of information from an additional 2300 rainfall gauges, there remains uncertainty surrounding the methodology of deriving, selecting, and applying the accompanying design temporal patterns.

In contrast, despite some criticisms that they can be unrealistically weighted, the AR&R87 temporal patterns are well understood, and can be easily implemented. For this reason, the AR&R87 IFD data and temporal patterns were adopted for use in this study. In any case, given that the objective of the study is to investigate stormwater network performance and test possible mitigation options, the focus naturally falls on *differences* arising from proposed changes in the catchment, as opposed to the calculation of absolute flood levels. As such, determining the magnitude of the rainfall depth is of lesser importance than it would be with, say, a large river study whose goal was to calculate the 100 year ARI flood level.

A comparison of the old and new IFD values is presented below in Table 2-3.

Table 2-3 Ratio of Rainfall Intensities - 1987 data compared to 2013 data

Duration	Average Recurrence Interval			
	10 year	20 year	50 year	100 year
10 min	1.06	1.07	1.08	1.08
15 min	1.04	1.05	1.05	1.06
30 min	1.03	1.04	1.05	1.06
60 min	0.98	0.99	1.00	1.01
120 min	0.94	0.96	0.97	0.98

* value less than one signifies 2013 intensity is less than corresponding 1987 intensity.

It can be seen the 2013 revision has resulted in design rainfall intensities that are in the order of 5% greater to 6% lower than the older estimates at Kalbar, such that there is almost no change on average, across all durations and intensities.

2.1.7 Rain on Grid Modelling

This approach is so named because rainfall is applied directly to each individual grid cell in the 2D hydrodynamic domain as an inflow volume source. This obviates the need to develop an external hydrologic model, and has the benefit of applying rainfall everywhere on the grid, allowing concentration of runoff to occur and flowpaths to develop in a more realistic fashion. An important note is that by merging the hydrologic and hydraulic domains into one, the model domain must necessarily cover the entire catchment to the most downstream point of interest.

MIKE21 has the capability to apply the grid-based rainfall with variations both spatially and temporally. Spatial variation of rainfall is typically reserved for larger catchments, particularly where calibration is concerned. For the purposes of this study, the design rainfall depths are assumed to be invariant in space, changing only with time (ie. according the design temporal patterns).

2.2 System Assessment

There are nine separate piped networks throughout the town, each with a different degree of interconnectivity to overland flow paths and to each other. For this reason, a single critical storm duration (ie. that duration which produces the worst flooding at a particular point of interest) cannot easily be identified, as the answer may change depending on which part of the catchment one is interested in observing.

Instead, the hydraulic model was first run using the 50 year ARI design storm event for the 6 standard storm durations from 15 minutes to 2 hours, with the goal of qualitatively nominating a single storm duration for use in the assessment that:

- Was representative of the duration of a typical summer thunderstorm;
- Loaded a large portion of the total rainfall into a single temporal time step; and,
- Introduced a large volume of water to the model.

For these reasons, the 60-minute storm event (and associated temporal pattern) was adopted as the reference storm for the following analyses. The choice of reference storm duration is discussed further in Section 2.2.3.

2.2.1 System Performance

An indication of the performance of below-ground stormwater network can be gained by calculating the number of surcharging pits for a given Average Recurrence Interval (ARI), as detailed in Table 2-4. Given that the piped network serves most of the time to drain everyday rainfall events and prevent nuisance ponding, it is unrealistic to expect it to entirely contain the peak discharge for even a small ARI storm, however a system with relatively few surcharging pits could be said to have better minor drainage performance than a system with many surcharging pits.

Table 2-4 Surcharging Pits by Average Recurrence Interval

Average Recurrence Interval	Number of Pits Surcharging	% of Pits Surcharging
1 year	13 of 59	22
2 years	17 of 59	29
5 years	18 of 59	31
10 years	18 of 59	31
20 years	20 of 59	34
50 years	20 of 59	34
100 years	20 of 59	34

The large number of surcharging pits is indicative of the age and piecemeal nature of the drainage system. The individual pipe networks are largely separate from one another, are generally of a small diameter, and are linked to the surface with numerous older-style grated pit inlets that are of low capacity and prone to blockage. The town has relatively few modern style side-inlet pits.

At Valleyview Drive and Davies Street "orphan" pipe networks were found, that consisted of grated pits connected to each other beneath the road, but not to anything else. Unsurprisingly, the hydraulic model predicted these small pipe systems to have no effect whatsoever on improving road drainage.

As a result, the majority of rainfall runoff travels along the road corridor or otherwise overland. This is not an issue in and of itself; rather Council should simply recognise that older drainage networks that pre-date modern design standards (such as those outlined in QUDM) are unlikely to achieve the "level of service" provided by such modern networks.

In general, and with the exception of Wiss Street (which is discussed below), the town's roads are aligned quite well to the natural terrain so that the majority of storm water runoff is carried efficiently overland via the paved road surface. This is an expected outcome from an old system in a steep landscape. The peak depth maps in Appendix A highlight the effectiveness of the road corridor as major drainage path, as it is here that the highest peak depths are found.

2.2.2 Analysis of Results

Wiss Street Low Point

Unlike the remainder of the town, both Wiss Street and Moffat Street are aligned poorly with respect to the natural terrain, running *parallel* to the natural contours, rather than at an angle. Subsequently, where the streets cross a small gully, a sag point is created, to which all road runoff is directed. This is not unusual in older sub-divisions; however, such an occurrence is usually accompanied by a drainage easement that covers the entirety of the natural overland flowpath. No such easement exists at Kalbar.

Reviewing the animated flood model results, it could be seen that during the peak of the storm runoff was leaving the road corridor by overtopping the kerb, after which the flow travelled overland towards the park. This was not unexpected – Figure 2-2 shows two examples where concentrated runoff could easily leave the road corridor:

Figure 2-2 Wiss Street Kerb and Channel

The left side of Figure 2-2 shows a damaged section of kerb with a portion of the vertical wall missing, reducing the effective height in this location by perhaps 100 mm. The right hand side shows a typical driveway access plate. Unlike the damaged kerb, which was an isolated occurrence, many such steel driveway plates are found on Wiss Street, with their presence captured in the LiDAR and thus the hydraulic model topography. This type of driveway access presents a large obstruction to flow in the kerb, as they have little cross-sectional flow area beneath the plate and are consequently easily blocked. It is likely that these plates facilitate a large portion of the kerb overtopping predicted by the model.

Railway Street Nuisance Sheet Flow

Council had previously received a complaint from the resident of 6 Railway Street concerning runoff leaving the road corridor and creating a nuisance flooding problem inside the property. The model results were interrogated, and were found to agree with this view. During large rainfall events, the stormwater inlet at the intersection of Railway Street and Hudson Street could be expected to surcharge, joining the overland flow travelling down Hudson Street. This, combined with an unusual kerb configuration and road cross-sectional profile, allowed water to leave the road corridor. Thus, nuisance sheet flow through the resident's front yard could reasonably be expected during a severe storm event.

A summary of predicted peak flow rates (as measured through a section running parallel to the front property boundary) is presented in Table 2-5.

Table 2-5 Predicted Flow Through Yard at Railway Street

Average Recurrence Interval	Peak Flowrate (m^3/s)
1 year	0.04
2 years	0.67
5 years	1.48
10 years	1.98
20 years	2.68
50 years	3.53
100 years	4.22

2.2.3 Comparison to XP-RAFTS model

As no calibration data were available against which to assess the performance of the rain on grid approach, a comparison to a small XP-RAFTS model was carried out to test the shape and magnitude of the predicted hydrographs, as measured at the low end of JEC Pennel Park, and shown in Figure 2-3. The resulting graph is shown below in Figure 2-4:

Figure 2-3 XP-RAFTS Model Schematic

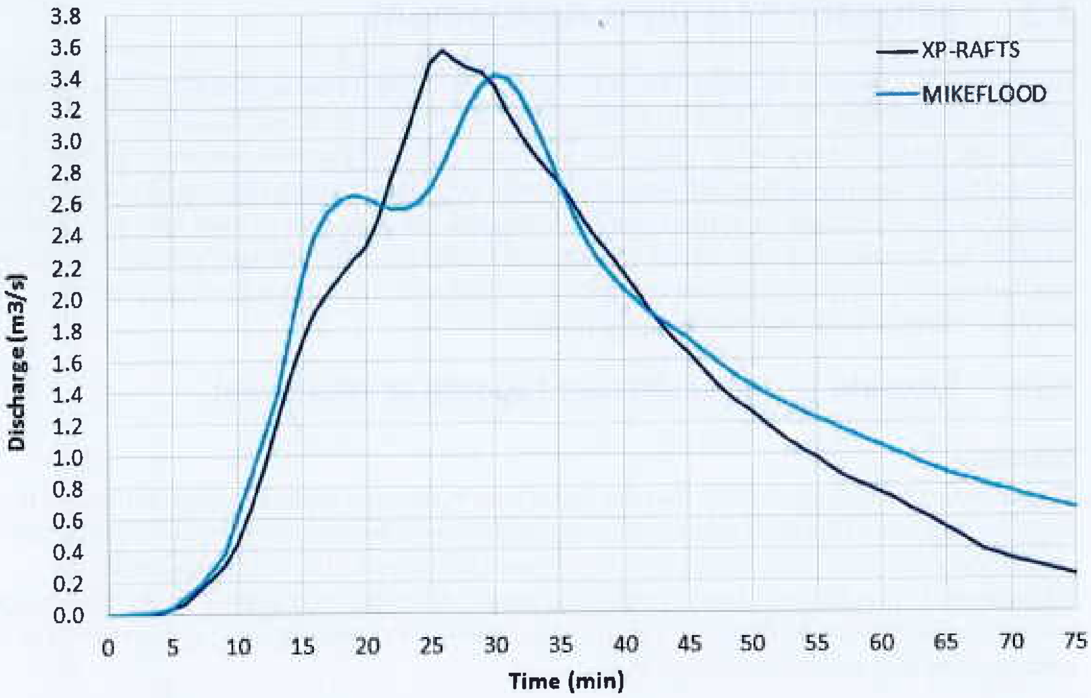

Figure 2-4 Comparison to XP-RAFTS Model

Using the 50 year ARI, 60-minute duration design event as the comparison storm, a good level of agreement was achieved. A difference of less than 0.2 m^3/s was predicted at the peak of the hydrograph, with minor differences in timing. The result suggests that for the purposes of modelling the Kalbar stormwater system, the topographic definition and adopted Manning's n values allow for the fully distributed hydrology of the rain-on-grid method to be used with confidence in lieu of the traditional lumped-catchment method utilised by XP-RAFTS (and other similar software programs).

The comparison against the XP-RAFTS model was also used to validate the choice of the 60-minute design storm for use in the system and mitigation options assessment. A summary of the predicted peak flows rates for the varying duration storms is shown below in Table 2-6.

Table 2-6 XP-RAFTS Model Peak Runoff Estimates

Storm Duration (50 year ARI event)	Peak Discharge
15 minutes	3.2 m^3/s
30 minutes	3.4 m^3/s
45 minutes	3.2 m^3/s
60 minutes	**3.6 m^3/s**
90 minutes	2.8 m^3/s
120 minutes	2.5 m^3/s

The table shows that the 60-minute storm produced the highest peak runoff value. This, combined with the large storm volume, makes it a sound choice for use as the reference storm for this study.

2.3 Mitigation Options Assessment

The system assessment at Kalbar broadly confirmed Council's understanding of the drainage network, namely that the sag points on Wiss Street and Moffat Street are leading to overland flow issues and resident complaints, whilst an unusual kerb configuration towards the low end of Railway Street can result in runoff leaving the road corridor and impacting upon the property at Number 6. Three mitigation options were investigated. An overview of each option is provided, followed by an analysis of the model results, and finally an indicative cost estimate. Costs were adopted from Rawlinson Australian Construction Handbook, and/or from prices tendered to CDM Smith on recent construction management projects.

2.3.1 Scenario 1 – Increased Inlet Capacity at Wiss Street

Overview

The modelling previously showed that the bottle neck in this part of the drainage network is most likely the capacity of the gully inlets at Wiss Street. Downstream the pipe is laid on a significant grade (approximately 10%), however its conveyance is limited by the upstream inlets. This scenario tested the effects of duplicating the existing 2400 length inlet at Wiss Street. The change was affected within the MIKE Urban portion of the model, by modifying the curve that governs the inlet capacity for a particular flow depth.

Model Results

The results showed that this change would increase the peak flow reporting to the pipe immediately downstream, from about 0.37 m^3/s to 0.54 m^3/s. Within the 2D model only minor changes to peak flood depths were observed, due likely to the fact that much of the effect is likely to be drowned out by the effects of the intense rainfall event. Nonetheless, this scenario showed that the capacity of the pipe system can be significantly increased through the provision of additional gully inlets, as shown in Figure 2-5, which plots the flow through the pipe link immediately downstream of the Wiss Street sag inlet:

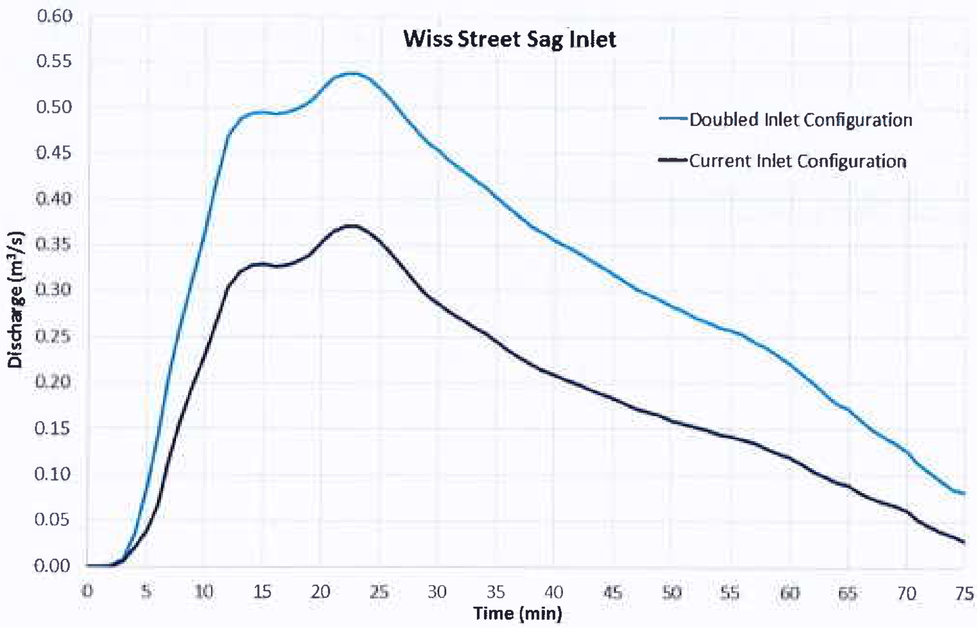

Figure 2-5 Effect of Inlet Configuration on Capacity

Even with a duplicated inlet, the pipe may still have excessive capacity. An estimate of pipe capacity can be found by consulting a Manning's pipe flow chart. Assuming the pipe is flowing full but not under head, the intersection of pipe diameter and longitudinal grade is found on the chart; a vertical line projected downwards from this intersection point to the x-axis gives the pipe capacity. For the Wiss Street pipe, results are shown in Table 2-7:

Table 2-7 Estimate of Pipe Capacity

Item	Value
Input Parameters	
Pipe Diameter	600 mm
Pipe Longitudinal Grade	10 %
Maninng's n	0.013
Output Variables (pipe flowing full, not under head)	
Flowrate	2.4 m^3/s
Velocity	8.5 m/s

The analysis is somewhat simplistic as it neglects entrance losses to the pipe, does not account for the unusual pipe outlet configuration in the park, and ignores blockage – all of which would serve to reduce the calculated flowrate and velocity. Nonetheless, the magnitude of the answer demonstrates that augmentation of the inlet at Wiss Street could be carried out beyond the duplication modelled above. Certainly, substituting the second 2400 length inlet for a 3600 or 4800 size would be possible without overwhelming the pipe. In practice, the mitigation option as constructed is likely to be driven by the cost of providing multiple large side inlets, balanced against the perceived benefits.

Cost Estimate

The cost will be highly dependent on the exact geometry of the existing pipe-pit configuration and thus how-much tie in work is required to bring a new pit online. An estimate is provided below, based on the modelled approach of supplying a second identical stormwater inlet.

Table 2-8 Schedule of Rates - Scenario 1

Item	Rate	Unit	Qty	Cost
Identify and relocate water and telecoms	$ 2,000	ea	1	$ 2,000
Supply new 2400 length side inlet & pit	$ 2,000	ea	1	$ 2,500
Plant and Crew to excavate, install pit, backfill, make good.	$ 400	Hour	5	$ 2,000
			Total	**$ 6,500**

2.3.2 Scenario 2 – Flow Barrier at Railway Street

Overview

During intense rainfall events, the piped network on Railway Street reaches capacity and surcharges near the intersection of Hudson Street. This, in combination with overland flow being conveyed within the road corridor and a low (mountable style) kerb on the northern side of the street, can result in flow entering the property located at Number 6. Mitigation feasibility was assessed by blocking out hydraulic model cells to exclude flow from passing.

Model Results

In this case, the action had the effect of reducing peak flood depths at 6-8 Railway Street by up to approximately 100mm. The corresponding increases, of up to 160mm, were observed on the neighbouring property at 4 Railway Street, although it should be noted that the increased depths occur along a concreted driveway and do not affect the building structure itself. Extending the barrier across the front of 4 Railway Street (and providing suitable driveway access) would eliminate this issue and contain any depth increases to the road corridor.

Cost Estimate

The absolute flood depths are relatively shallow in this region, and as such mitigation could occur via a combination of constructing a higher-lipped kerb (>150 mm) that ties into the downhill section of kerbing, and incorporating a small, trafficable earthen bund along the southern boundary of 8, 6, and 4 Railway Street, respectively.

Council noted during the Mitigation Options workshop that road works to re-seal and provide uniform kerb and channel along the length of Railway Street were currently being planned. Consideration should be given to carrying out the road works and mitigation works simultaneously.

Table 2-9 Schedule of Rates - Scenario 2

Item	Rate	Unit	Qty	Cost
Identify and relocate water and telecoms	$ 2,000	ea	1	$ 2,000
Survey and set out control points	$ 1,000	ea	1	$ 1,000
Supply and install new kerb and channel	$ 70	metre	50	$ 3,500
Reinstate driveway slab at 4 Railway Street	$ 2,000	ea	1	$ 2,000
Construct small bund (strip topsoil, supply & place fill, topsoil & seed)^	$ 400	hr	20	$ 8,000
			Total	**$ 16,500**

^ Plant and Crew comprising: One small excavator or backhoe, one footpath roller, two labourers.

2.3.3 Scenario 3 – Road Re-grade at Moffat Street

Overview

The entirety of the eastern side of Moffat Street currently drains to a central sag point, and thereafter in a westerly direction and downhill to the Wiss Street sag point. Given the mild longitudinal grades on Moffat Street, an opportunity exists to conduct a re-grading/road reconstruction exercise to make the entire length of the street drain southwards to (the very steep) Pennell Street. This option has the advantage of providing a defined overland flowpath for major flows (unlike the current configuration), but is also likely to be the most expensive, as it would require major changes to the road profile and road-side drainage over a length of about 430 metres.

This scenario was affected in the model by manually editing the topography to eliminate the sag point and produce a road profile that was free-draining towards the south. Simultaneously the kerb definition on the western side of the street was raised to ensure that no overtopping could occur, forcing all runoff to drain out to Pennell Street.

Model Results

Hydraulic modelling showed that under this scenario the reduced catchment area reporting to the sag point had the effect of lowering peak flood depths everywhere downstream. However, this came at the expense of flood depths along Moffat Street, which were predicted to increase by up to 500mm (although it should be noted that this comparison is somewhat trivial as the largest increased occurred on terrain that had been lowered to facilitate the scenario), and Pennell Street where depths were predicted to increase by up to approximately 150 mm.

This option represented a fundamental change to the drainage regime, and therefore resulted in a multitude of changes with respect to depths and flow rates. The changes have been assessed by considering 4 reporting locations, as indicated on Figure 2-6, below:

Figure 2-6 Scenario 3 Model Reporting Locations

Of the four results charts, Figure 2-7 and Figure 2-8 show how piped flows were predicted to change as a result of re-grading the road, whilst Figure 2-9 and Figure 2-10 demonstrate the alterations to the surface flow regime.

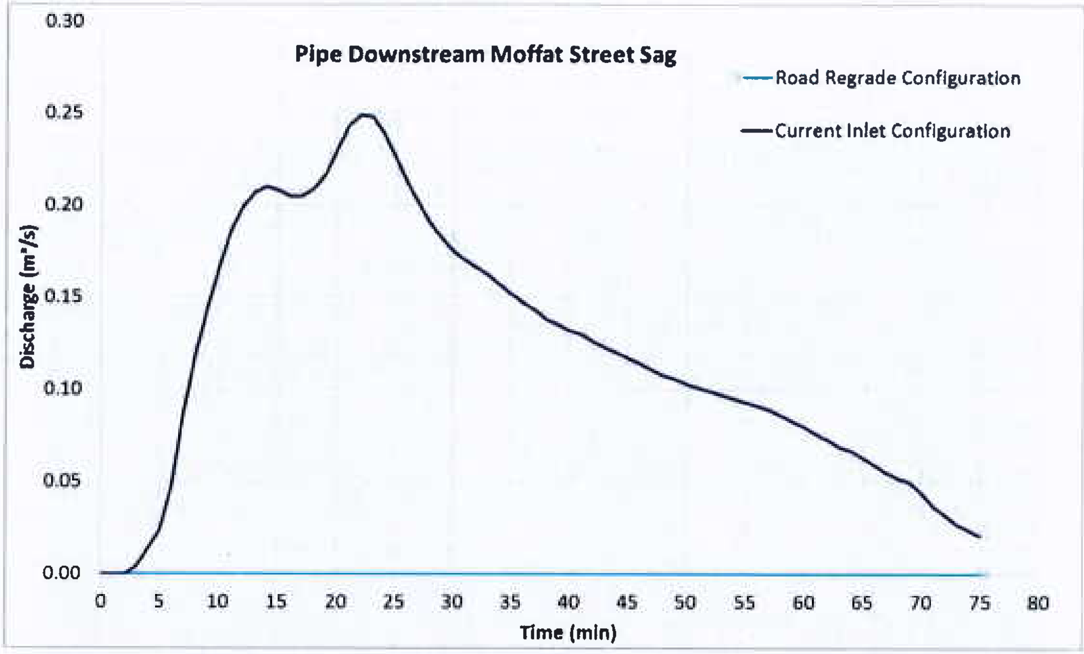

Figure 2-7 Flow Comparison at Downstream Moffat Street

The Moffat Street sag inlet was assumed to be blocked/removed as part of this analysis. Consequently, the inlet capture flows go to zero as a result of the proposed works, and the entire catchment upstream of Moffat Street is redirected south towards Pennell Street.

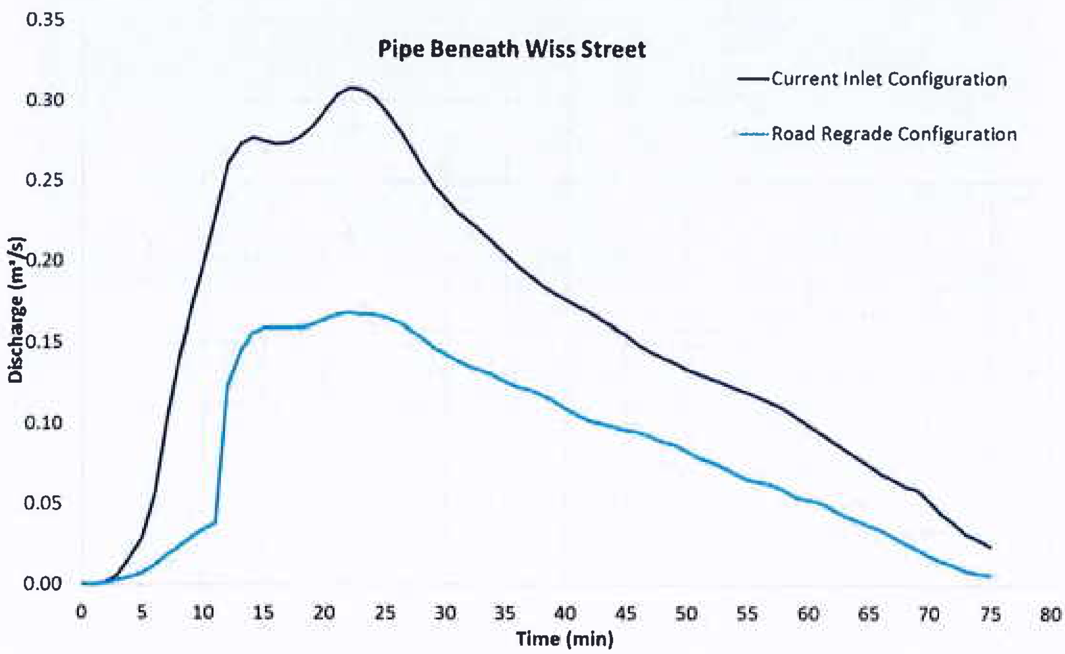

Figure 2-8 Flow Comparison at Wiss Street

The removal of piped capture from Moffat Street is seen clearly in the flow hydrograph in the pipe beneath Wiss Street, with peak discharge predicted to decrease by almost 50%.

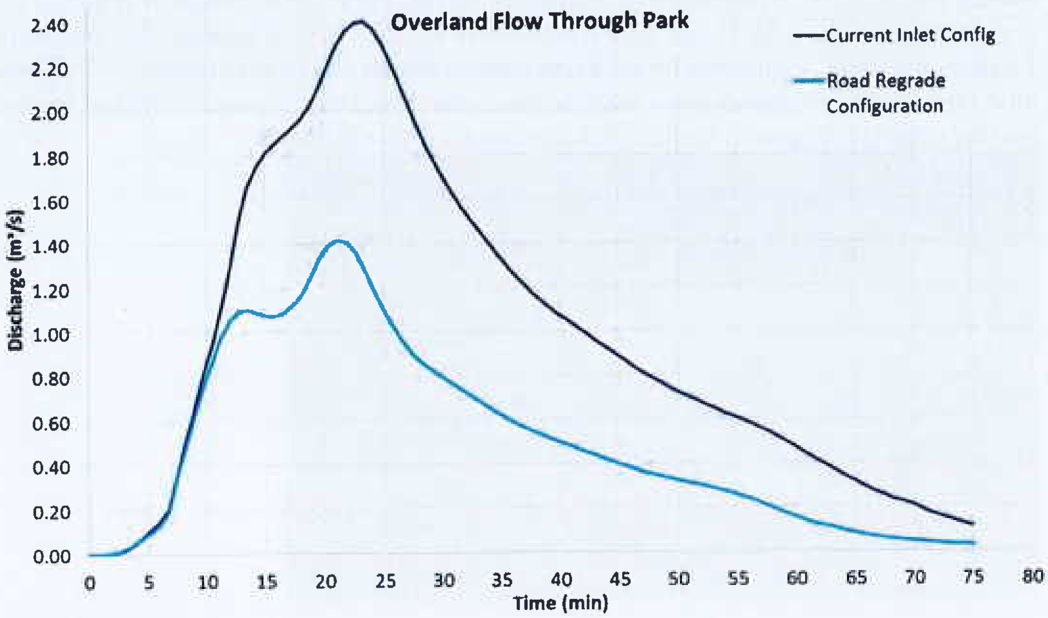

Figure 2-9 Flow Comparison Through JEC Pennell Park

Further downstream overland flow through the park is reduced as a result of the aforementioned changes.

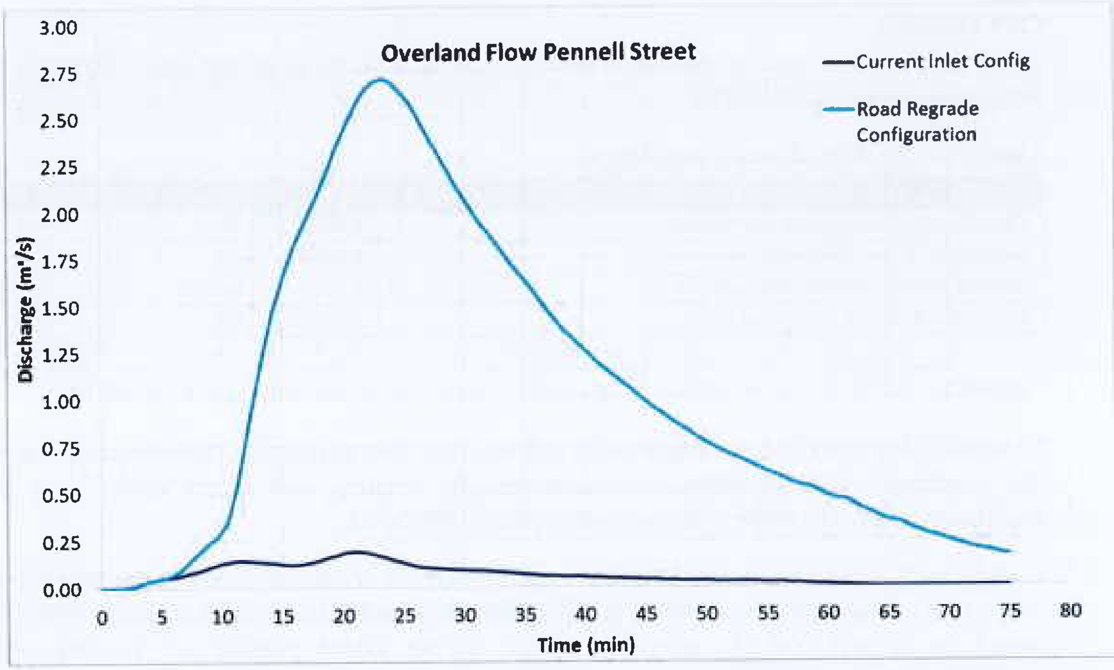

Figure 2-10 Flow Comparison Overland on Pennell Street

Meanwhile, discharge to Pennell Street greatly increases. Currently, only minimal catchment area exists uphill of the Penell/Moffat intersection, as indicated by the small flow rates of the existing configuration (dark blue line). Regrading Moffat Street would have the effect of redirecting several hectares of catchment and as a result the runoff volume increases markedly.

Overall this could be a very effective mitigation option, but careful thought is required as to the impacts of increasing the runoff on Pennell Street. In particular, it appears that the property at 1 Valleyview Drive is impacted by increased depths, arising due to a combination of the increased flow, the house pad being set lower than the road, and the fact that a concrete "wedge" has been cast into the concrete channel to facilitate vehicle clearance over the kerb:

Figure 2-11 Driveway at 1 Valleyview Drive

Removal of the wedge and replacement with a suitable driveway entrance (eg. flattened kerb section with bund behind) should suffice to resolve this issue. Levels would need to be surveyed to confirm effectiveness.

Cost Estimate

Given the length of road to be re-constructed, this was found to be the most expensive of the mitigations options considered.

Table 2-10 Schedule of Rates - Scenario 3

Item	Rate	Unit	Qty	Cost
Identify and relocate water and telecoms	$ 25,000	ea	1	$ 20,000
Survey and set out control points	$ 3,000	ea	1	$ 3,000
Regrade and reconstruct Moffat Street ^	$ 450	metre	400	$ 180,000
Driveway works at 1 Valleyview Drive	$ 2,000	ea	1	$ 2,000
			Total	**$ 205,000**

^ Composite price for: remove existing surface, exacavate, reprofile, reseal, new kerb and channel both sides.

So whilst being feasible from a hydraulics and construction perspective, this mitigation option has the drawbacks of being expensive and potentially creating new issues where none existed previously, due to the large volume of water that is redirected.

A more realistic and less capital intensive option may be to instead focus on obtaining drainage easements on the land between Wiss Street and Moffat Street. The overarching goal of this strategy would be to reinstate the natural flowpath to the extent possible, in keeping with the recommendations of QUDM.

2.4 Findings and Recommendations

After building a hydraulic model and carrying out a stormwater system assessment for the town of Kalbar, CDM Smith has found the following:

- The piped network is generally quite old and of low capacity, with many older style inlets prone to blockage. The piped system surcharged in the most minor storm event (1yr ARI) considered during the assessment.
- The road corridor, therefore, carries the majority of stormwater runoff and appears to do so with little inconvenience or impact upon the residents of the town. This is an acceptable outcome for an old drainage network that pre-dates modern design standards. By corollary, it stands that improvement or upgrade works to the pipe network should only be carried out to address known issues/deficiencies.
- Increasing the inlet capacity at the Wiss Street sag (Scenario 1) was found to be an effective way to achieve a meaningful increase to the capacity of the piped network. It has the benefits of being relatively simple, easy to construct, and low cost.
- Preventing nuisance flooding at Railway Street (Scenario 2) was found to be achievable through the provision of a redesigned kerb and a small earth bund. The works could be carried out in conjunction with Council's planned road works on Railway Street to realise time and cost efficiencies.
- Large scale works on Moffat Street (Scenario 3), whilst attractive on paper and feasible from a construction viewpoint, have the drawbacks of being expensive and potentially creating new issues where none existed previously, due to the large volume of water being redirected. Effort could be better spent on obtaining drainage easements to protect the natural flowpath.

We therefore make the following recommendations:

Recommendation 1: *Address nuisance flooding at Railway Street.* The flooding issue, as described and addressed through Scenario 2 is well within Council's abilities to rectify using in-house labour and plant. Provision should be made in the relevant Council budget to execute these works.

Recommendation 2: *Augment the inlet capacity at the Wiss Street sag.* This is a simple fix that has the benefit of being highly visible to local residents. Council has the capability to perform these works and should plan and budget them accordingly.

Recommendation 3: *General open-drain maintenance.* Increasing the inlet capacity should be carried out in conjunction with a program of clearing and regrading the earth V-drains on Wiss Street and Moffat Street, paying particular attention to achieving negative longitudinal grade.

Recommendation 4: *General grated pit/inlet maintenance.* Council should continue to assess the condition of stormwater infrastructure and replace old or damaged pits as necessary.

Recommendation 5: *Improvements to Driveway Access Points.* Steel plates over the kerb and concrete wedges within the channel are used around town to facilitate driveway access to private properties. These types of access points: reduce conveyance of kerb and channel; create blockage points, and; allow flow to escape on to private property, increasing nuisance drainage issues. Council should act to discourage any new implementations these types of access point, and work with residents to remove existing instances with less obstructive options.

Recommendation 6: *Removal of "orphan" pipe networks.* The cross-road drainage arrangements at Valleyview Drive and Davies Street contribute nothing to performance of the overall system, but represent a maintenance burden to Council. If the opportunity arises (e.g. during roadworks), theses pipes and grates can be removed.

Recommendation 7: *Investigate further before regrading Moffatt Street.* Although this option appeared superficially attractive, its expense and potential impacts warrant a more thorough investigation should Council be inclined to advance down this route. A detailed road and drainage design, utilising surveyed levels, should be developed, with careful planning to ensure that driveway accesses are maintained and utilities are appropriately identified and relocated. It is recommended that further investigations only proceed if a cost-benefit analysis shows a positive outcome and it is probable that the requisite funds will be available for construction. No futher action to develop this option is recommended at the current time.

Recommendation 8: *Look to reinstate the natural flow path at Moffat/Wiss Street.* In lieu of regrading Moffat Street, Council should consider taking a drainage easement over the gully (i.e. natural flowpath) from Moffat Street through to JEC Pennell Park, to ensure that no future development occurs on this drainage line. In combination with Recommendation 2, these are likely to be the most straight-forward solutions to addressing the drainage issues in this part of town.

Appendix A – Figures

CDM Smith

R	Details	Date
1	DRAFT	20/07/16
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DESIGNED	DS	CHECKED	EOB
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APPROVED	MT	DATE	20/07/16

Notes:

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0 40 80 160
Metres

Scale @ A3 - 1:3,200
GCS GDA 1994 MGA Zone 55

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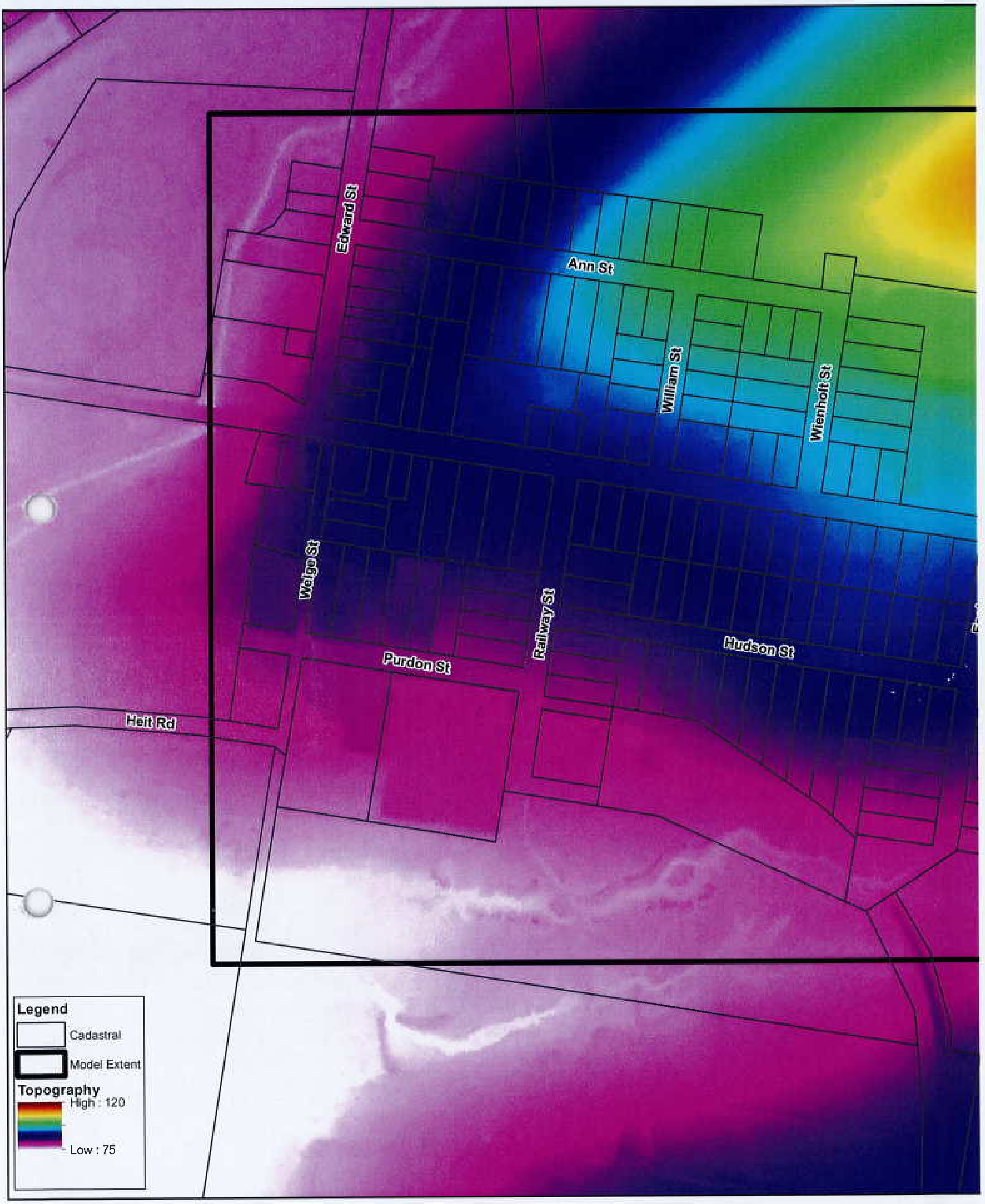

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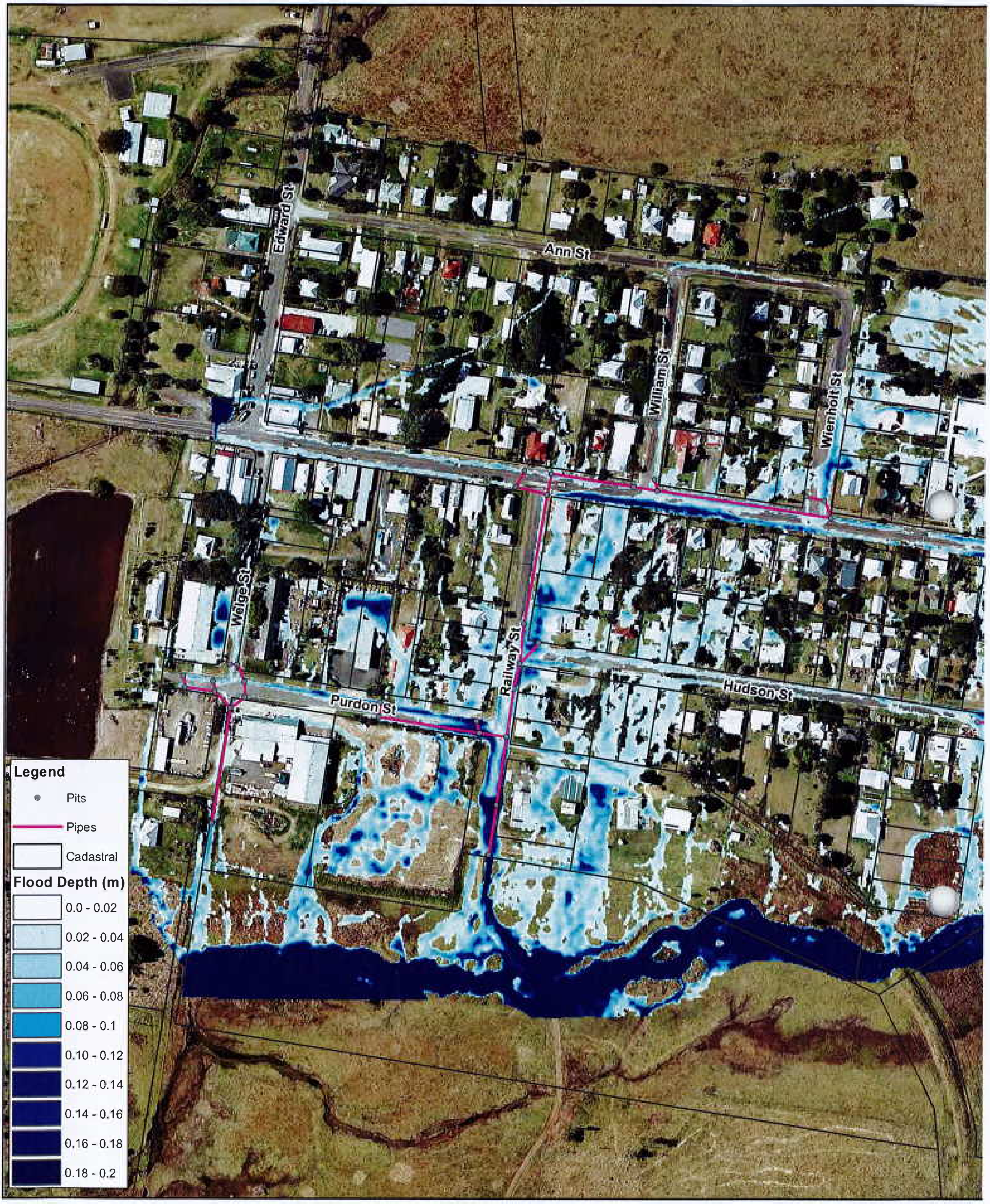

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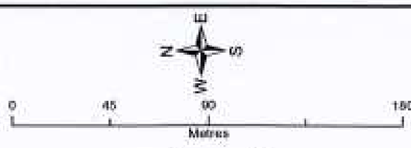

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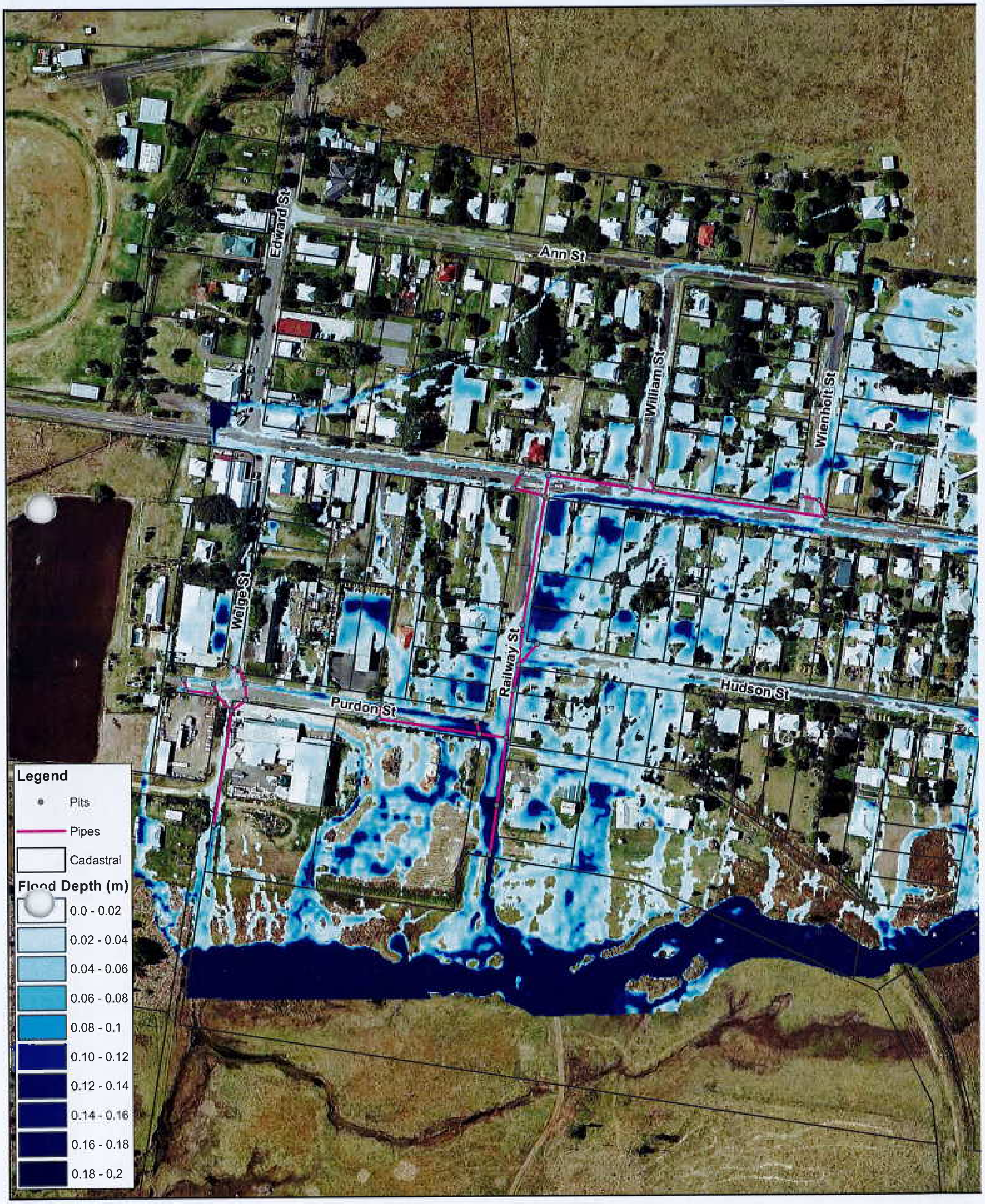

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GCS GDA 1994 MGA Zone 55

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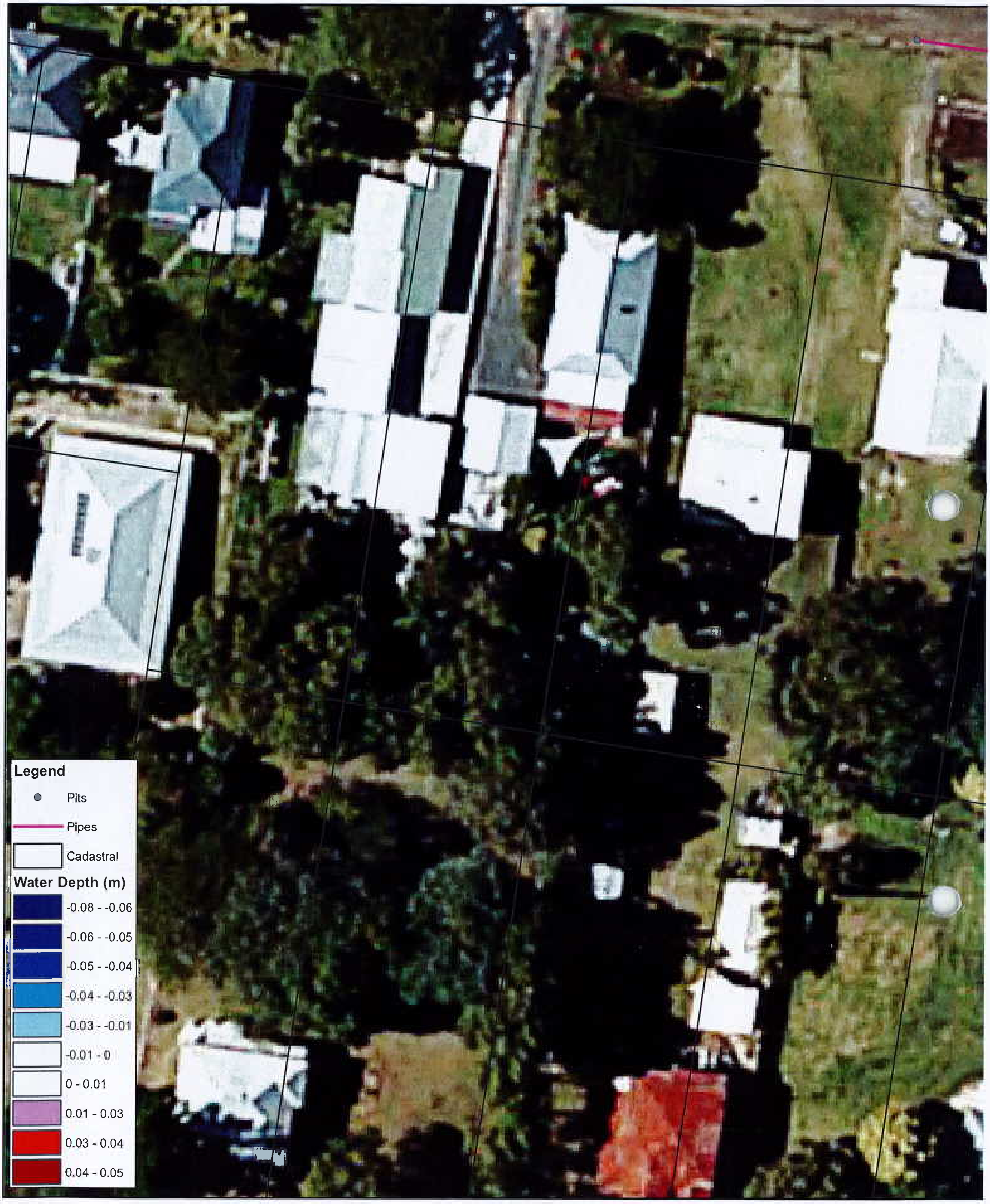

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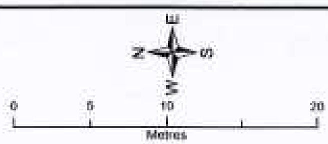

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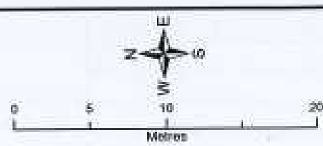

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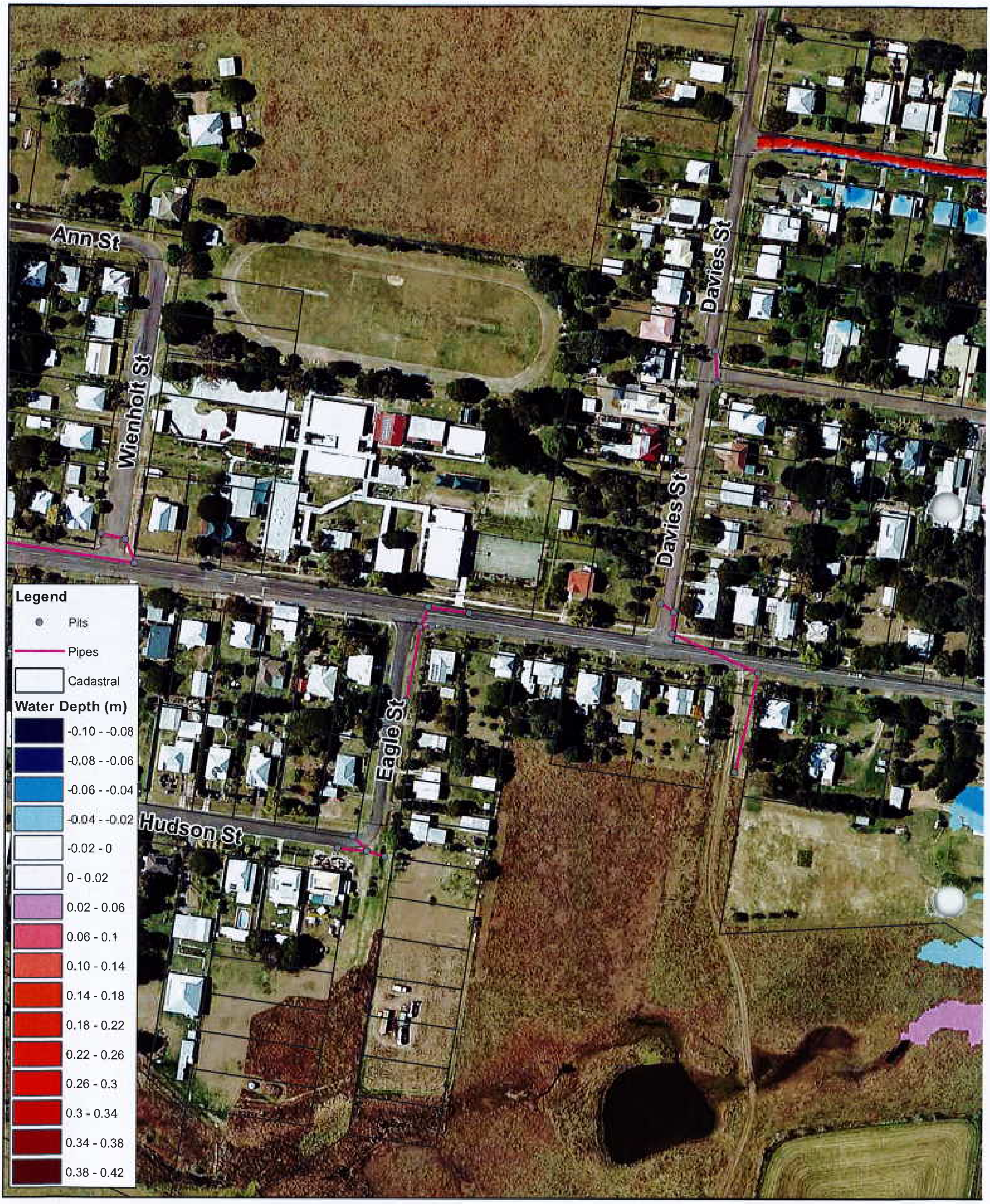

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Appendix B – Disclaimer and Limitations