Baw Baw Shire Council

Yarragon Flood Modelling & Drainage Strategy




December 2013

V2000_043

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EXECUTIVE SUMMARY

This study was in response to a recommendation made in a high level review of the Yarragon drainage system completed in 2011 which stated that a detailed analysis based on hydraulic modelling of the Yarragon drainage system was required. The key objectives of this study are:

- Collation of existing information on the drainage system and obtain further information to fill gaps in the existing data set;
- Detailed analysis of the drainage system based on hydraulic modelling to identify constraints;
- Production of flood inundation maps for various rainfall and development scenarios;
- Consultation and sharing of information with the Yarragon community and other key stakeholders;
- Development of a plan to mitigate existing flooding issues;
- Assessment of the feasibility of expanding the town beyond its current 2030 boundary and identify the key stormwater infrastructure required for development; and
- Allow for improved planning and technical information available for future development.

The hydraulic model created as part of this study enabled a comprehensive analysis of the drainage system as well as the production of flood inundation maps. Consultation with the Yarragon community and other key stakeholders and a comprehensive collation and review of drainage data have formed vital inputs to the model and study outcomes.

Based on the outputs from the hydraulic model, information provided by Baw Baw Shire Council (BBSC) and observations gathered from the community consultation sessions, the following key issues and drainage system constraints have been identified:

- Princes Highway and the Railway Line create embankments and the culverts have limited capacity in major storms for flows towards the Moe River. Where there is insufficient culvert capacity for 100 year ARI flows there is ponding upstream of these embankments. The extents of upstream ponding for various ARI events are shown in the flood maps in **Appendix A**;
- The open drain on the western side of the township does not convey flow efficiently;
- Open drains on the northern side of the railway line do not have sufficient capacity;

- Some development has occurred in flood prone areas which are subject to overland flow from upstream, with inadequate measures to protect the development from inundation;

- Insufficient overland flow paths for 100 year ARI flows in some areas;

- Maintenance of key drainage infrastructure, particularly open drains, may not be occurring regularly enough; and

- The roles and responsibilities for management of the drainage system between BBSC and West Gippsland Catchment Management Authority (WGCMA) are not sufficiently defined or well communicated to the community.

A series of structural and non-structural measures have been identified that aim to improve the management and performance of the Yarragon drainage system. The hydraulic model has also been used to assess the feasibility of future development in Yarragon and to identify works to control the impact of development on the catchment.

The key recommendations made by this study are:

- An improved maintenance program is recommended. This is particularly important for open drains and culverts, which need to be cleared out regularly to ensure they can effectively convey flows.

- The definition of the roles and responsibilities of BBSC and WGCMA regarding management of drainage needs to be improved.

- Consider the use of Special Building Overlays (SBO) across the catchment to manage future development and to reduce the flood risk for new buildings. The use of SBOs is recommended as they do not have any capital cost and will result in an effective measure across the catchment.

- Structural mitigation works (as detailed in Section 5 of this report) should be constructed to reduce the impacts of flooding on existing development.

- Development of the three proposed residential areas is feasible, as the retarding basins proposed as part of this study will allow development without making downstream flooding worse.

- It is more of a challenge to provide adequate peak flow controls for the proposed industrial development. The proposed industrial area is relatively flat, which makes controlling flows through retarding basins more difficult.

Table I summarises the estimated costs of the structural mitigation works investigated as part of this study. Refer to the layout plan in **Appendix B** for the proposed locations of these works.

Table I Mitigation works cost estimates

Item	Estimated Cost	Contingencies (40%)	Total (rounded to nearest $1k)
Hazeldean Road Retarding Basin	$ 677,496	$ 270,998	$ 948,000
Blackshaw Rd open drain	$ 404,423	$ 161,769	$ 566,000
Gas transmission line open drain	$ 140,832	$ 56,333	$ 197,000
Clean-out / reinstatement of drain downstream of Hazeldean Road (and north of Princes Highway)	$ 408,600	$ 163,440	$ 572,000
Clean-out / reinstatement of Gordon Road open drain	$ 105,000	$ 42,000	$ 147,000
172 Loch Street duplicate pipeline	$ 40,698	$ 16,279	$ 57,000
Rollo Street & Leongatha - Yarragon Road retarding basin	$ 518,965	$ 207,586	$ 727,000
Open drain adjacent to Rollo Street	$ 86,198	$ 34,479	$ 121,000
Rollo Street & Princes Highway retarding basin	$ 452,880	$ 181,152	$ 634,000
Open drain on eastern side of Leongatha - Yarragon Road	$ 331,612	$ 132,645	$ 464,000
Factory Road open drain upgrade	$ 280,320	$ 112,128	$ 392,000
Yarragon - Shady Creek Road open drain upgrade	$ 359,010	$ 143,604	$ 503,000
Totals	$ 3,806,035	$ 1,522,414	**$5,328,000**

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1. INTRODUCTION

1.1 Study Background and Objectives

A high level review of the Yarragon drainage system was completed (by others) in 2011. One of the recommendations of the review was that a more detailed study was required to analyse and model the drainage catchment. It was also recognised that a feasibility study would be required prior to future rezoning of land for potential residential and industrial development.

In 2012 Baw Baw Shire Council (BBSC) engaged Engeny Water Management (Engeny) to conduct the Yarragon Flood Modelling and Drainage Strategy. The key objectives of this study are:

- Collation of existing information on the drainage system and obtain further information to fill gaps in the existing data set;
- Detailed analysis of the drainage system based on hydraulic modelling to identify constraints;
- Production of flood inundation maps for various rainfall and development scenarios;
- Consultation and sharing of information with the Yarragon community and other key stakeholders;
- Development of a plan to mitigate existing flooding issues;
- Assessment of the feasibility of expanding the town beyond its current 2030 boundary and identify the key stormwater infrastructure required for development; and
- Allow for improved planning and technical information available for future development.

1.2 Catchment Description

Yarragon's current 2030 township boundary covers an area of 1.3 square kilometres. The township is situated on relatively flat terrain, with the north face of Strzelecki Ranges forming the southern catchment boundary. Agricultural farmland lies to the east and west of Yarragon, and the Princes Highway and railway line running east west separate the town into two, with residential areas being located predominantly south of the Princes Highway and industrial areas to the north. There are commercial and retail properties along the southern side of the Princes Highway.

The main waterway that conveys runoff from the southern catchment flows along the south-western corner of the township. The waterway then flows through culverts under the Princes Highway and the railway line 200 metres east of Gordon Road and outflows into the Moe River. There is also a more minor waterway that runs alongside the eastern side of the township, and five pipe or culverts crossings of the Princes Highway and railway line within the township boundary. All runoff from the town flows into either the Moe River or the Contour Drain.

Figure 1.1 provides a layout plan showing key features of the township.

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0 200 400
Scale in meters (1:10,000 @ A3)

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Yarragon Flood Modelling & Drainage Strategy

Township Layout Plan

Figure 1.1

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1.3 Study Methodology

Figure 1.2 illustrates the key steps undertaken to achieve the objectives of this study.

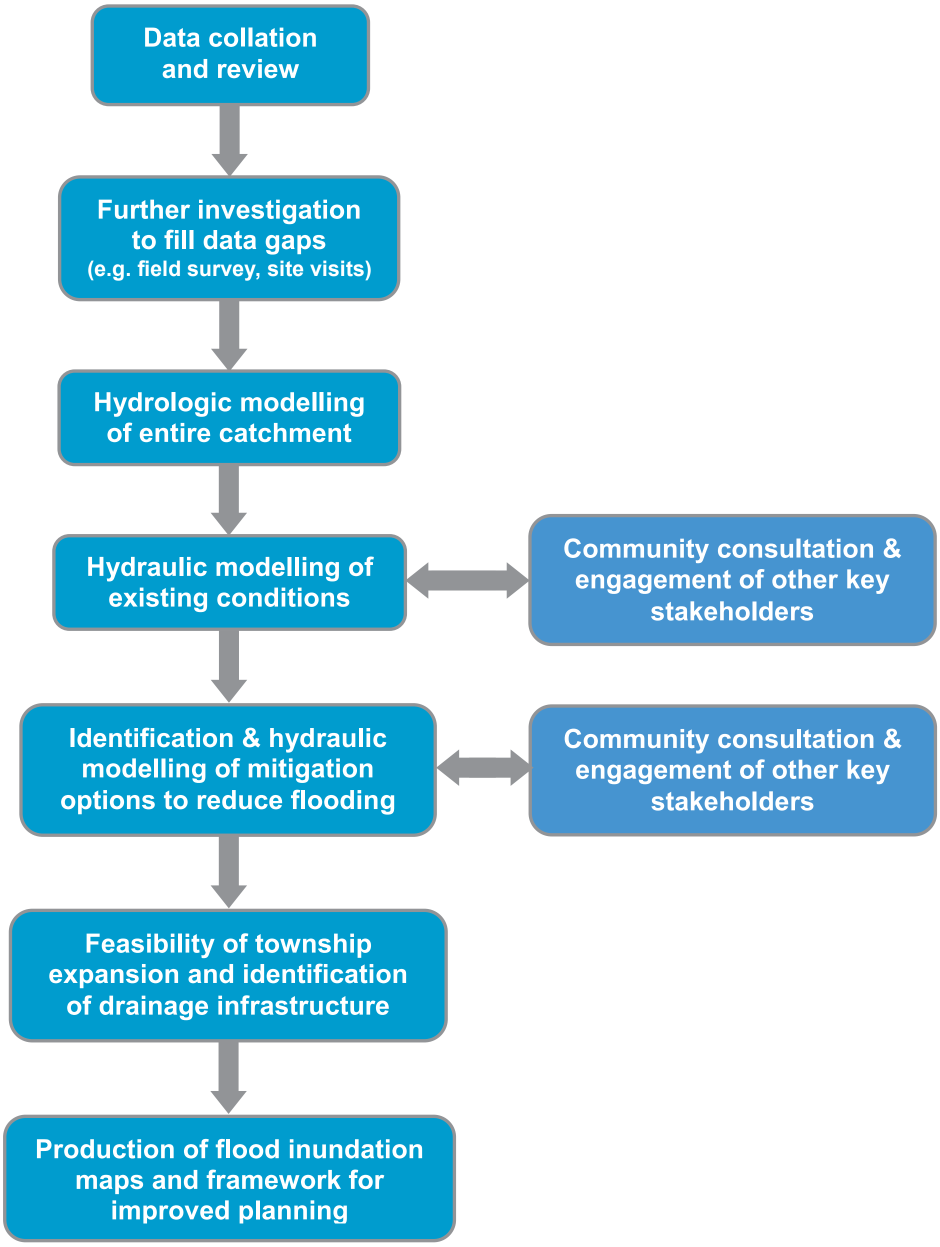


Figure 1.2 Study methodology flow chart

2. DATA COLLATION AND REVIEW

2.1 Sources of data

BBSC provided a combination of GIS and other technical data for the Yarragon township and catchment. This data included the following relevant information:

- Aerial photography;
- Pit and pipe asset data;
- As-constructed drawings of some drainage assets;
- Limited survey of drainage pits from 2006;
- Planning schemes and overlays;
- Watercourse alignments and water bodies;
- Cadastral boundaries and road alignments;
- 10 metre interval topography contours; and
- Yarragon Stormwater Drainage Review Stage 1 report (October 2011).

Information provided by others for use in the study included:

- LiDAR (aerial survey) – provided by West Gippsland Catchment Management Authority (WGCMA);
- Additional drainage data for pipes crossing Princes Highway – provided by VicRoads;
- Locations of sewer pump stations – provided by Gippsland Water

In several instances, the above sources of data were insufficient to adequately define the drainage system to the level required for this study. For these areas, further investigation was conducted to provide the necessary information. This investigation is discussed in Section 2.2.

2.2 Review of Data

2.2.1 Drainage Data

Engeny conducted a thorough review of the pipe and culvert diameters and connectivity provided in BBSC's drainage asset database. This assessment identified some areas in the catchment where diameters were missing or connectivity was uncertain as the database appeared to be missing data. This was a particular issue for the drainage assets crossing under Princes Highway, as these are often VicRoads maintained assets, for which BBSC's records of asset details were incomplete.

To rectify this, field survey of drainage assets within some areas of the catchment was conducted by specialist surveyors to collect missing data or verify existing data. Additionally, BBSC provided valuable assistance in further checking sections of the drainage network. VicRoads also provided additional drainage information for some of their assets. Engeny conducted site visits to verify the connectivity of some areas of the catchments.

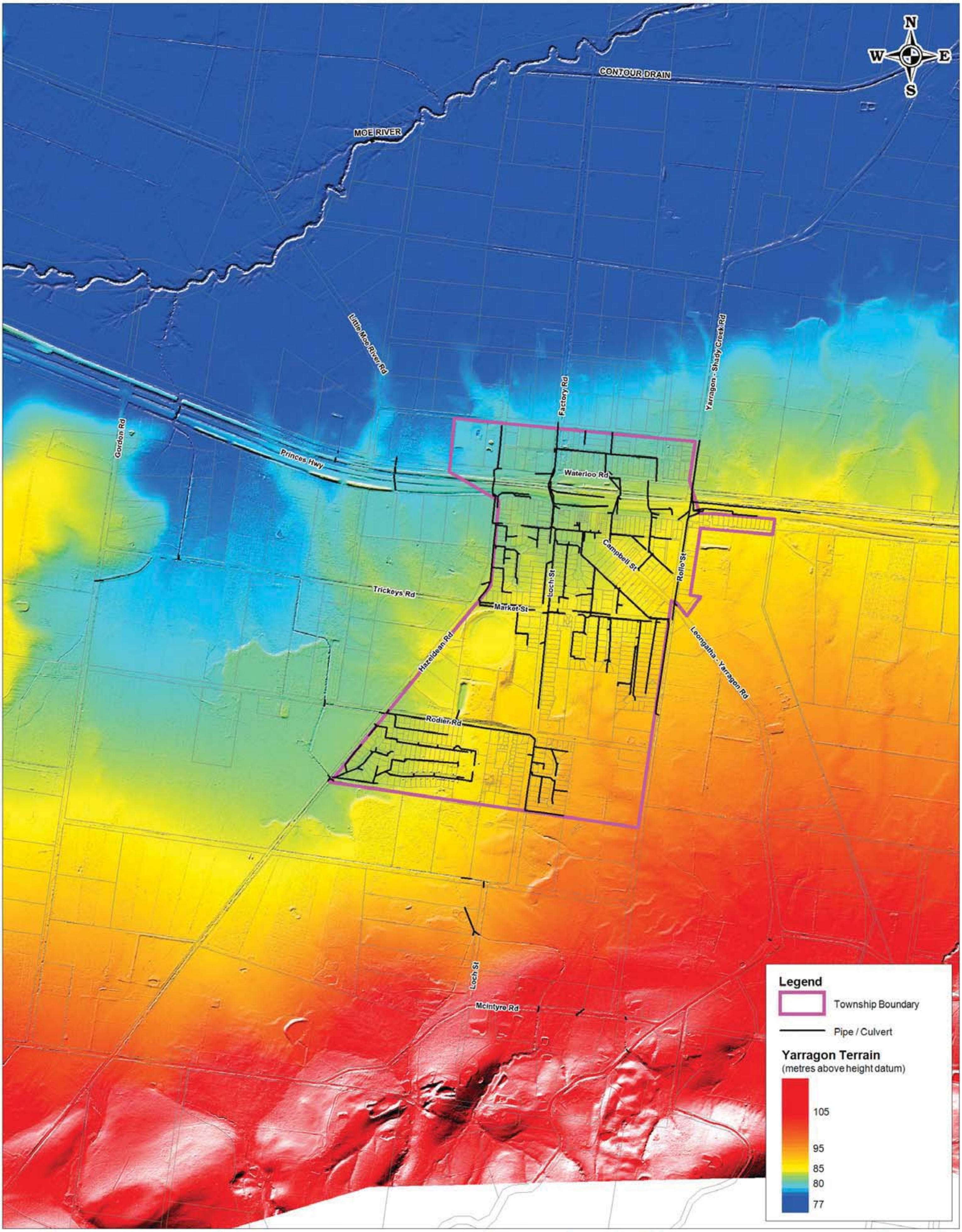
The outcome of the drainage data collation and review is a comprehensive drainage asset database available for this study that has been utilised to conduct a detailed analysis of the system.

2.2.2 Topography

WGCMA provided LiDAR (Light Detection And Ranging) covering the study area. LiDAR is an airborne surveying technology that provides a regularly spaced grid (one metre horizontal interval in this case) of ground levels over the study area. Engeny used this data to produce a digital terrain model (DTM), which allows for the catchment's waterways and other key topographical features to be defined in the hydraulic model.

Figure 2.1 shows the DTM developed for the catchment.

The DTM defines the high sections of the catchment to the south, the low flat lands adjacent to Moe River and the low lying areas to the west of the township and east of Gordon Road.



Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
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Yarragon Flood Modelling & Drainage Strategy

Figure 2.1

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Digital Terrain Model

2.2.3 Previous Studies and Reports

Summaries of previous (and current) investigations of the Yarragon drainage system are provided below.

Yarragon Stormwater Drainage Review Stage 1 (October 2011)

The scope of the review was initially concerned with drainage issues within the boundary of the township. However, following community consultation and inundation experienced in and outside of the township boundary in early 2011, the review was expanded to investigate flooding in areas outside of the township boundary.

The study identified that flooding occurs in the area for the following reasons:

- Undersized pipes (insufficient capacity for a 5 year average recurrence interval (ARI) rainfall event in some locations);
- Insufficient pit capacity to capture flows;
- Tree roots blocking pipes;
- Inadequate maintenance; and
- Siltation and vegetation growth restricting the capacity of open waterways.

The report identified several measures to reduce flooding in the catchment, as well as recommending that a more detailed drainage study, including hydraulic modelling, should be conducted.

La Trobe River Study and existing overlays

At the time of this report, WGCMA had engaged a consultant to conduct the La Trobe River Study. The scope of that study includes the flooding from the Moe River.

The outputs from the La Trobe River Study were not available for use in the Yarragon Study. Engeny was provided with some results from the La Trobe River Study towards the conclusion of the Yarragon Drainage Strategy, which indicate that the Yarragon township is not expected to be directly inundated by flooding of the Moe River.

There are existing overlays (Flood Overlay (FO) and Land Subject to Inundation Overlay (LSIO)) for the Moe River, which were implemented in the planning scheme prior to the La Trobe River Study. These overlays are shown in Figure 2.2. The overlays are based on the expected area of inundation when the Moe River is flooding for a 100 year ARI rainfall event and may be revised based on the outcomes of the La Trobe River Study. The overlays show that it is not expected for the township area of Yarragon to be affected, but the area south of the Princes Highway and east of Gordon Road is impacted by Moe River flooding.

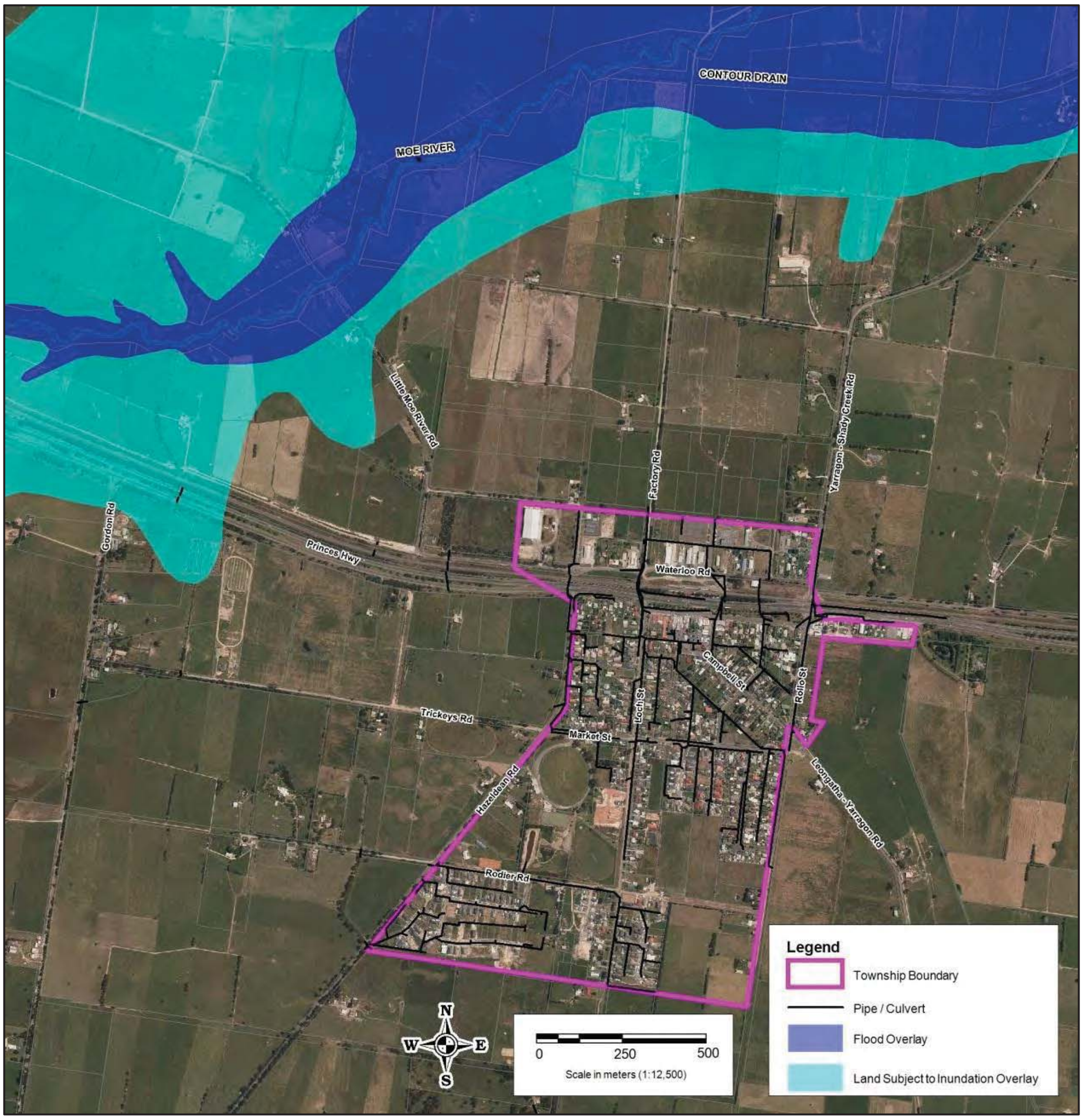


Figure 2.2 Flood Overlay and Land Subject to Inundation Overlay

2.2.4 Site Visits

Engeny conducted multiple site visits of key areas of the catchment in order to gain appreciated for the site conditions and verify some sections of the drainage network. Figure 2.3 and Figure 2.4 provide photos taken on the site visits.

Figure 2.5, Figure 2.6 and Figure 2.7, provided to Engeny by BBSC, were taken after a rainfall event on 23 August 2013. The nearest Bureau of Meteorology rainfall station (Yarragon South) recorded 24.6 millimetres of rainfall on this day. The rainfall station indicates there were several days of wet weather leading up to this event, resulting in an already wet catchment prior to the onset of rainfall. Based on the depth of rainfall and observation from BBSC that the rain fell over several hours, it is likely that this rainfall event has an ARI of less than 1 year.

Figure 2.3 Princes Highway culverts, east of Gordon Road (upstream side)

Figure 2.4 Recent development on eastern side of Hazeldean Road

Figure 2.5 Looking east from Hazeldean Road, small swale is protecting development

Figure 2.6 Looking into 151 Hazeldean Road from north-west corner

Figure 2.7 Open drain downstream of Hazeldean Road

2.3 Stakeholder Engagement

2.3.1 Community Consultation

BBSC and Engeny facilitated two community consultations sessions during the study, which were conducted on 13 June 2013 and 19 August 2013. The first consultation session was attended by representatives from various areas of BBSC, the Engeny study team and approximately 26 members of the Yarragon community. There was keen interested from the community at the first session and therefore a second session was held later in the study to keep the community informed on the progress of the study and allow for further input from community to guide the study. The second session was also attended by a representative of the WGCMA.

Some of the key objectives of the community consultation sessions were to:

- Share information on the scope and objectives study with the community, particularly with those who may have been adversely impacted by flooding or drainage issues.
- Obtain valuable information and observations from the community. This information was used to verify the results of the hydraulic model or in some instances improve the accuracy of the hydraulic model by targeting areas that needed further investigation.
- Allow for members of the community to view and annotate hard copy flood maps and ask questions.

- Present preliminary findings and flood mitigation options and seek feedback on potential alternative mitigation options.

Table 2.1 provides some of the key feedback from the community consultation sessions and how the feedback was used in the study. Table 2.1 also includes feedback from some residents that was provided to Engeny after the draft Yarragon Drainage Strategy had been made available for public comment.

Table 2.1 Community consultation feedback and the study response

Community comment / feedback	Study response - how the feedback has been used
Community is tired of being consulted and asked questions over recent years and want to see solutions and good outcomes.	The current study will provide the necessary information to ensure that future funding is spent efficiently and will result in improved outcomes for the community.
Some existing open drains haven't been cleaned out since 1992. Reeds and weeds are blocking the drains and causing flooding issues.	Based on feedback, an improved maintenance program is a recommendation of this study.
Lack of mowing along edges of drains has meant that tree regrowth has occurred which has blocked water flows through drains.	Based on feedback, an improved maintenance program is a recommendation of this study.
Loch Street residents commented that trees have been cut down from drains but the wood has been placed in the drain by BBSC contractor, which has caused blockages in the drainage system.	An improved maintenance program is a recommendation of this study so that these blockages either do not occur or are removed.
The Gordon Road roadside drain is heavily vegetated with a lot of flow on the road during large rainfall events	This drain has been identified for improvement works, with vegetation to be removed. Regular maintenance will also be required.
Clarification needed on whether maintenance of open drains is responsibility of WGCMA or BBSC.	A recommendation of this study is for improved communication between BBSC and WGCMA and setting out of roles and responsibilities. This process has already commenced.
Concern that drainage infrastructure in recent developments has only been big enough for the development and has not considered the broader catchment or future development nearby. Recent developments have not had adequate controls to prevent an increase in downstream flooding.	This study identifies recommends infrastructure to cater for future development as well as for existing development, which takes into account broad catchment objectives and aims to improve or not worsen downstream flooding. Mitigation options have also been recommended to protect recent developments from flooding.

Community comment / feedback	Study response - how the feedback has been used
No more subdivisions should be approved until such time as existing drainage issues are fixed.	Works to reduce flooding have been recommended in this study. However, it should be noted that there is an opportunity to provide works in future developments that may benefit downstream properties.
Four culverts under Hazeldean Road are undersized.	These culverts have been assessed as part of the flood mitigation plan.
Factory Road and Shady Creek drains are not functioning properly, which needs to be investigated.	These drains have been assessed as part of the flood mitigation plan.
Improving the drainage system requires an holistic approach, improving the downstream outlet drains as well as assets to divert or control runoff from the township	The modelling conducted as part of this study allows for the holistic approach, with the impact of works in one section of the catchment on the performance of drains downstream having been analysed. Works on downstream drains are a recommendation of the study.
Need a clean main drain to get water from south of town to the Moe River.	This drain has been assessed as part of the flood mitigation plan.
1934 flood mentioned as the largest flood residents are aware of in Yarragon. Comment that the 100 year flood mapping doesn't reflect the level reached by the 1934 flood and therefore the modelling needs to be amended.	The flood modelling is limited to a 100 year flood. The 1934 flood is understood to be bigger flood than a 100 year flood, so its effects were more severe. Additionally, inundation in the 1934 flood was likely due to flows from the Moe River, which is being assessed in a separate study.
Many community members stated that the flood inundation shown by the modelling was a good reflection of their recent observations.	This feedback gives confidence to the reliability of the modelling.
Retardation basin at Dowton Park on the north side of Rodier Road is not in a good location and should have been placed outside the town to prevent water from entering urban area.	This basin was constructed to take pressure off the main underground pipe running east-west along Rodier Road and to provide water to be used for irrigation of the sports grounds. The basin does provide some benefit for smaller rainfall events, but is not particularly effective for larger events.
Will climate change impacts on rainfall be taken into consideration?	The outputs from this study can be used to set minimum floor levels for future houses in flood-prone areas. The floor levels include a 'margin of error', which would provide protection against long-term increased rainfall intensities due to climate change. A specific climate change analysis has not been conducted as part of this study.

Community comment / feedback	Study response - how the feedback has been used
Request that Engeny/BBSC present back to community with findings, recommendations and suggested solutions to drainage problems.	A second community consultation was conducted to present this information.
Proposed retarding basin on north-west corner of 151 Hazeldean Road should instead be located on the western side of Hazeldean Road.	This alternative option has been investigated, and it was found that a large culvert(s) would have to be constructed across the Hazeldean Road to convey the flow to the alternative site. Also, as the basin would have to be very deep, then it would mean that obtaining an outlet would be difficult, water in the basin at the alternative location is likely to backflow through the culvert to the low lying area east of the Hazeldean Road which would adversely impact landowners.
Retarding basins should be designed to provide multifunctional benefits such as being used as sporting fields	It is agreed that where possible, retarding basins should provide other functions as for the majority of time they will not be inundated. During detailed design of retarding basins, consideration should be given to whether sporting fields, wetlands or other functions are possible in the base of the retarding basin.
Large embankments may be unpopular with the community for aesthetic reasons.	The construction of retarding basins will involve a combination of excavating below existing surface levels and embankments to provide additional storage. The detailed design should give consideration to carefully landscaping the embankments so that they fit in with the surroundings.
The presence of yabbies in the area could cause problems with the maintenance of retarding basins and open drains.	As part of detailed design of retarding basins, ecological and geotechnical investigations will be carried out so that measures such as lining the base of retarding basins are implemented, where appropriate.
There is an open drain and a 150 cubic metre retarding basin (that has now filled with sediment and vegetation) on a property on between Leongatha-Yarragon Road and Rollo Street.	The topographical information provided by West Gippsland CMA that was used in the modelling was based on data captured in 2010/2011. This information shows a faint definition of this drain, but the predominant flow path is shown to be to the north, as predicted by the modelling. It is not known what the purpose of the retarding basin is or who is responsible for maintenance given that it is on private property without an easement. The modelling does show that this ex-retarding basin is in a flood prone area, and therefore if it was reinstated it could provide some benefit for flood mitigation. However, the proposed Rollo St & Leongatha Rd retarding basin (as part of the drainage strategy discussed in this report) is likely to be a more effective site.

Community comment / feedback	Study response - how the feedback has been used
An underground pipe was constructed by BBSC in Rollo Street and the pipe is undersized.	The modelling confirms that this 600 millimetre pipe does not have sufficient capacity for major storm events. The open drain that runs north along Rollo Street will accept some of the excess flow, and this report recommends improved maintenance of open drains so that they have capacity to convey flows.

2.3.2 Other Key Stakeholders

Other key stakeholders have been consulted during this study to obtain other information and ensure that the study allowed for a co-ordinated approach to infrastructure in the area. A meeting was held with representatives from BBSC, WGCMA, Gippsland Water and Engeny. Some of the key outcomes from this consultation were:

- WGCMA commented that their study on the La Trobe River system was still in progress and no results were available for use in the Yarragon study.
- WGCMA attended the second community consultation session to provide information to the community.
- Gippsland Water provided information on constraints on its systems, particularly the sewer system, which would need to be taken into account for future development planning.
- Gippsland Water provided photos of flooding that has occurred near some of its assets.
- Gippsland Water requested flood inundation information be provided so that they can target which sewer manholes to prioritise for repair and sealing.

3. HYDROLOGIC MODELLING

3.1 Purpose

The purpose of creating a hydrological model for the Yarragon catchment is to determine runoff flow rates throughout the entire catchment for a wide range of rainfall events and to generate sub-catchment hydrographs that can be used as an input to the hydraulic model.

3.2 Model Development

3.2.1 Methodology

Engeny constructed a hydrologic model covering the Yarragon catchment using hydrologic modelling software RORB. RORB is industry standard software and is one of Australia's leading flood hydrograph modelling tools.

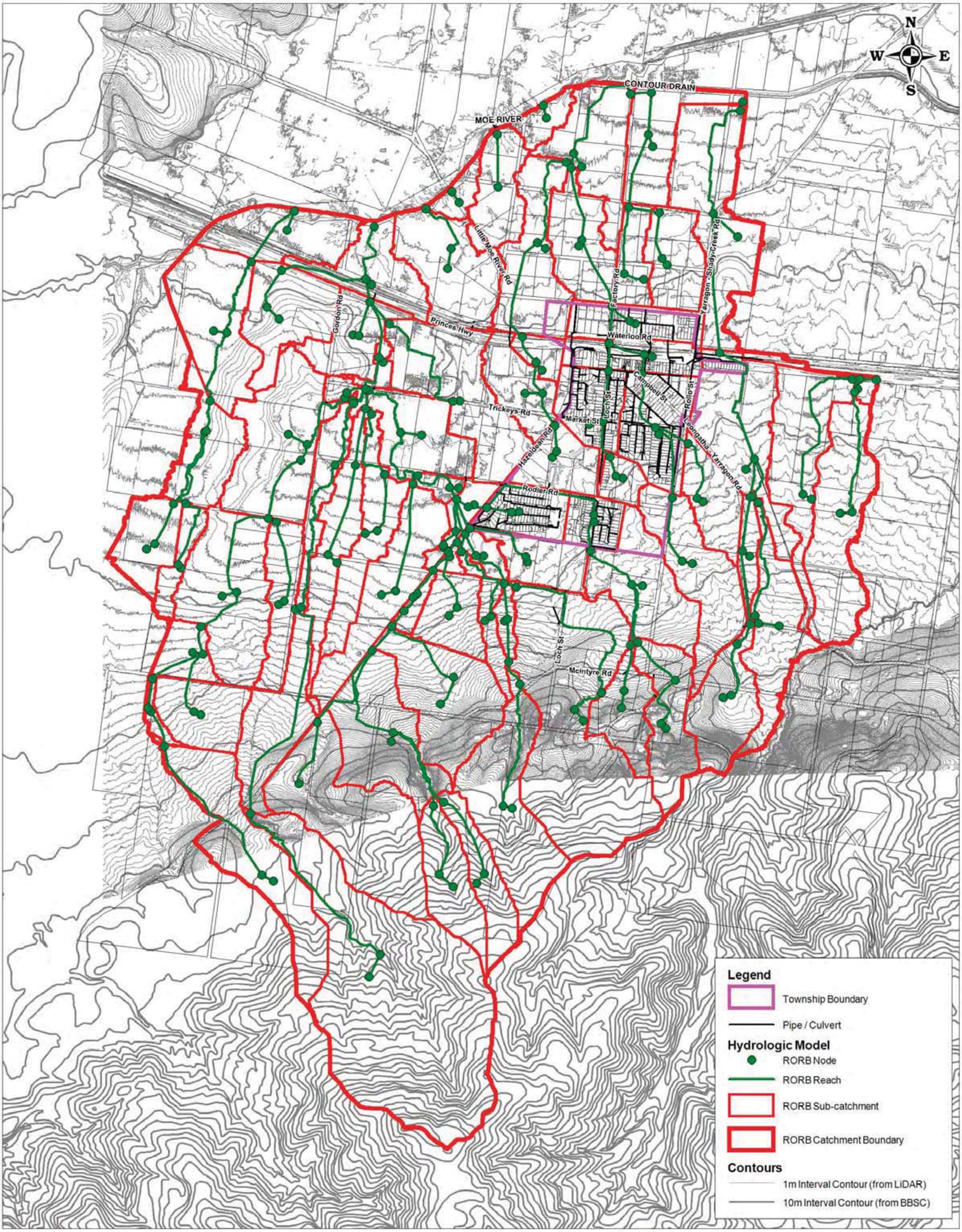
The RORB model has been created in accordance with Melbourne Water's Guidelines and Technical Specifications (November 2012), in particular with regards to:

- Catchment boundary is based on 100 year ARI flood behaviour;
- Definition of RORB sub-catchment boundaries and reach alignments to Melbourne Water specifications; and
- RORB model parameters as per Melbourne Water's Guidelines and Technical Specifications (November 2012).

3.2.2 Catchment Boundary

The catchment boundary for the Yarragon catchment has been determined in order to allow for 100 year ARI flood behaviour to be accurately defined, as well as smaller rainfall events. The catchment boundary has been determined using a combination of the digital terrain model generated from LiDAR and contour information provided by BBSC.

Figure 3.1 provides the Yarragon hydrologic catchment boundary and structure of the RORB model.



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Map Projection: Universal Transverse Mercator
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Yarragon Flood Modelling
& Drainage Strategy

Hydrologic Model Layout Plan

Figure 3.1

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3.2.3 Sub-catchment Boundaries

Sub-catchment boundaries have been defined based on contours, pipe alignments, and property boundaries. It is important that the catchment hydrology resolution is detailed enough to ensure accurate inflows at the pit level for the hydraulic model, while also allowing overland flow paths from the upstream catchment to be effectively modelled.

The RORB model sub-catchment boundaries are shown on Figure 3.1. **Appendix D** provides a table with the key data for each sub-catchment and other details adopted in the hydrology model.

3.2.4 Fraction Impervious

Fraction impervious is a vital component of the hydrological model as it is a key parameter in the process of converting rainfall into the runoff. Engeny assigned a fraction impervious value to RORB sub-catchments based on typical fraction impervious values for the type of development within each sub-catchment. The typical values are based on fraction impervious provided in Melbourne Water's MUSIC guidelines.

Fraction impervious values applied for typical land uses within the catchment include:

- Residential (standard) - 45% impervious
- Residential (higher density) - 60% impervious
- Open parklands & reserves - 10% impervious
- Local roads & car parks - 60% impervious
- Major roads - 70% impervious
- Commercial & industrial - 90% impervious
- Railway - 50% impervious

The fraction impervious value for a sub-catchment was obtained by calculating a weighted average of the fraction imperviousness of land types within the sub-catchment. These results were then checked using aerial photography and some adjustments made where necessary.

3.3 Intensity-Frequency-Duration (IFD) Data

Intensity-Frequency-Duration (IFD) data for Yarragon was sourced from the Bureau of Meteorology. This data provides design rainfall events for Yarragon for a range of ARIs that can then be used in the hydrological and hydraulic model.

This Bureau of Meteorology provided the IFD variables shown in Table 3.1. The resultant IFD table that these factors produced is shown in Table 3.2.

Table 3.1 Yarragon IFD Parameters

Parameter	Value
Intensity - 1 hour duration, ARI = 2 years (${}^{2}I_{1}$)	18.30
Intensity - 12 hour duration, ARI = 2 years (${}^{2}I_{12}$)	3.98
Intensity - 72 hour duration, ARI = 2 years (${}^{2}I_{72}$)	1.19
Intensity - 1 hour duration, ARI = 50 years (${}^{50}I_{1}$)	34.84
Intensity - 12 hour duration, ARI = 50 years (${}^{50}I_{12}$)	7.79
Intensity - 72 hour duration, ARI = 50 years (${}^{50}I_{72}$)	2.37
Skew (G)	0.37
F2	4.24
F50	15.08

Table 3.2 IFD Table for Yarragon

Rainfall event duration	Average rainfall intensity for each ARI				
	2 years	5 years	10 years	20 years	100 years
10 mins	45.9	62.2	73.4	88.3	127.5
15 mins	38.1	51.0	59.8	71.5	102.0
20 mins	33.0	43.9	51.1	60.8	86.0
25 mins	29.4	38.8	45.0	53.4	75.1
30 mins	26.6	35.0	40.5	47.9	67.0
45 mins	21.2	27.6	31.8	37.5	52.0
1 hour	17.9	23.2	26.7	31.4	43.4
1.5 hours	14.0	18.1	20.8	24.5	33.7
2 hours	11.8	15.2	17.4	20.5	28.2
3 hours	9.2	11.9	13.6	16.0	22.1
4.5 hours	7.1	9.2	10.6	12.5	17.3
6 hours	6.0	7.8	8.9	10.5	14.6
9 hours	4.6	6.1	7.0	8.2	11.5
12 hours	3.9	5.1	5.9	6.9	9.6
18 hours	3.0	3.9	4.6	5.4	7.5
24 hours	2.5	3.3	3.8	4.5	6.3
30 hours	2.2	2.8	3.3	3.9	5.4
36 hours	1.9	2.5	2.9	3.4	4.8
48 hours	1.6	2.1	2.4	2.8	4.0
72 hours	1.2	1.5	1.8	2.1	3.0

3.4 RORB Model Validation

A key step in the development of the hydrologic model is the validation process. This process ensures that appropriate model parameters are adopted to reflect how runoff is routed through the catchment.

There are various methods available to verify the hydrologic model, including:

- Rural Rational Method as per Australian Rainfall and Runoff;
- DVA plot of k_c versus catchment area, based on previous calibrations; and
- DSE regression plot for 100 year ARI flow for rural and urban catchments, based on models and observed floods.

Based on an assessment of these methods, Engeny believes that the Dandenong Valley Authority (DVA) equation is the most valid approach. This method is based on actual calibrations in the south-east of Greater Melbourne. The equation provides the main RORB model parameter (k_c) as a function of the catchment area ($k_c = 1.53A^{0.55}$).

The RORB 100 year ARI peak flow rate was also checked against the DSE Regression plot of Flood Flows versus Catchment Areas in Victoria rural catchments along and adjacent to the Great Diving Range, as well as the Rural Rational Method.

Table 3.3 summarises the hydrologic model validation process.

Table 3.3 RORB model validation

Parameter	Value
Catchment area	17.31 km^2
Adopted k_c (from DVA equation)	7.34
Rational method time of concentration	135 minutes
RORB model critical duration	12 hours
RORB Q_{100} (100 year ARI flow)	30.1 m^3/s
Rural Rational Method Q_{100}	13.2 m^3/s
DSE Regression Curve Q_{100}	41.1 m^3/s

The results in Table 3.3 show that the peak 100 year ARI flow from the RORB model developed for the Yarragon catchment falls within the range indicated by the Rural Rational Method and the DSE Regression Curve. The RORB model would be far too conservative if the Rural Rational Method was adopted as the method of validation and Engeny believes that validation using the DVA Equation is the best approach.

Other key RORB parameters adopted in the model (based on Melbourne Water's Guidelines and Technical Specifications (November 2012)) are:

- m = 0.8
- Initial loss = 15 mm
- k_c = 7.34
- Runoff coefficients:
  - 100 year ARI runoff coefficient = 0.60
  - 50 year ARI runoff coefficient = 0.55
  - 20 year ARI runoff coefficient = 0.45
  - 10 year ARI runoff coefficient = 0.35
  - 5 year ARI runoff coefficient = 0.25
  - 2 year ARI runoff coefficient = 0.20

4. HYDRAULIC MODELLING

4.1 Purpose

The purpose of creating a hydraulic model for Yarragon is to produce a tool that enables a comprehensive analysis of the drainage system. The hydraulic model uses the outputs from the hydrologic model to determine the inundation due to the various rainfall events.

Engeny adopted TUFLOW as the hydraulic modelling software to undertake this work. TUFLOW is Melbourne Water's preferred 2D hydraulic modelling package. TUFLOW allows for flows in pipes to be modelled (in the 1-D domain) and overland flows to be modelled (in the 2-D domain) as part of a combined model.

Hydraulic modelling allows:

- Assessment of flood extents for a range of storm event recurrence intervals and durations;
- Identification of properties at risk of flooding;
- Assessment of the impact of future development on the existing drainage system; and
- Identification of opportunities to mitigate existing flood risk within the catchment for existing and future scenarios.

4.2 Model Development

4.2.1 Model Extent

The extent of the hydraulic model is based on enabling the key topographical features of the catchment (such as open drains and roadside kerbs) to be modelled at a high level of resolution. It is not possible to model the entire hydrologic catchment as this would require a reduction in the resolution of the model. Also, LiDAR data, required to develop the digital terrain model used in the hydraulic model, is not available for the entire catchment.

The extent of the hydraulic model is sufficient to ensure that runoff through the township is accurately modelled, as well as known flooding areas west of the existing township as well as the industrial area on the northern side of Princes Highway.

Figure 4.1 shows the extent of the hydraulic model.

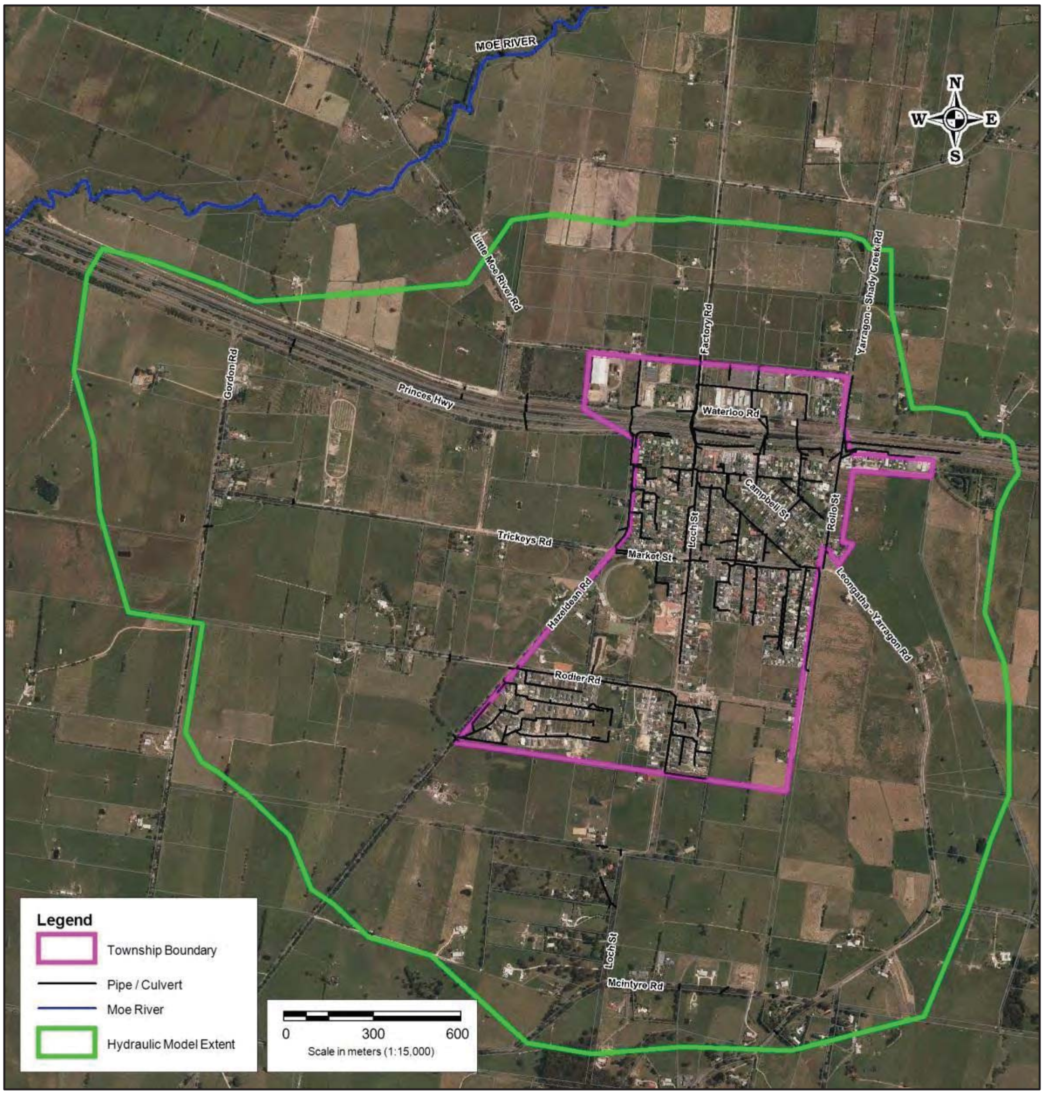

Figure 4.1 Extent of the Yarragon hydraulic model

4.2.2 Topography

The hydraulic model uses the digital terrain model (refer to Figure 2.1) to assign elevations throughout the model. Engeny has adopted a model resolution (grid size) of three metres, resulting in definition of elevation every 3 horizontal metres in the model. This grid size is in accordance with recommendations in Melbourne Water's Guidelines and Technical Specifications (November 2012) and allows for key catchment features such as open drains, retarding basins, roads and kerbs to be defined in the model.

4.2.3 Drainage Assets

Engeny has modelled all assets identified in BBSC's GIS and gone to significant effort to capture additional drainage assets so that they can be included in the model. Particularly emphasis was placed on accurately modelling the drainage assets that convey flow under Princes Highway and the railway line.

The hydraulic model requires invert levels at upstream and downstream ends of all pipes and culverts. This information is not available for most pipes in Yarragon (as is the case for most drainage networks). Engeny estimated invert levels by adopting the following formula:

- Invert level = Ground level RL – 600mm (pipe cover) – pipe diameter

The estimated invert levels were then checked to ensure that they were connected appropriately with the inverts of upstream and downstream pipes, producing a downward grade.

4.2.4 Open Channels

The Yarragon catchment includes numerous open drains that run through farmland or alongside roads. As the LiDAR provides a satisfactory definition of these drains it was determined that the drains can be effectively modelled in the 2-D domain. Several culverts have been included in the model along the waterways, with the culverts modelled as pipes in the 1-D domain.

4.2.5 Dowton Park Retarding Basin, North of Rodier Road

BBSC provided a layout plan of the Rodier Road Retarding Basin to Engeny to allow for the storage provided by the basin to be included in the hydraulic model. The basin receives runoff that drains from the adjacent sporting facilities and receives flow from the 750 millimetre pipe on Rodier Road via a 450 millimetre connecting pipe during high flow events. Water can then drain back into the Rodier Road pipe once the flow in the pipe has fallen.

4.2.6 Surface Roughness

The hydraulic model includes a land use (materials) layer that reflects the surface roughness (Manning's 'n') throughout of the catchment. The surface roughness defines how much resistance there is to flow passing over different areas of the catchment. For instance, high surface roughness values are found in residential properties due to the buildings and other structures that impede the flow of water, while flow through a paddock will have a lower surface roughness value. Additionally, surface roughness values for open drains can be altered to reflect the degree of weeds and vegetation that has built up and is preventing efficient flow through the drain.

Table 4.1 provides the Manning's 'n' roughness values applied to the Yarragon hydraulic model. These values are based on Melbourne Water's Guidelines and Technical Specifications (November 2012) and were verified on our site visits and from aerial photographs.

Table 4.1 Hydraulic model surface roughness values

Land Use	Manning's n
Standard density residential property	0.35
Low density residential property	0.2
Commercial or industrial	0.5
Open paddock / parkland – minimal vegetation	0.035
Open paddock / parkland – moderate vegetation	0.06
Open paddock / parkland – high density vegetation	0.09
Railway line	0.12
Car parks and roads	0.03
Open waterways	0.035-0.09

4.2.7 Boundary Conditions

The TUFLOW model includes a series of boundary conditions to control points where flow enters or leaves the model. HQ (head versus flow) boundaries were drawn at the catchment boundaries to allow overland flow to leave the model at the catchment outlets based on the shape of the topography and the downstream longitudinal grade.

All boundary conditions assume that there is no impact of tail water levels in the Moe River on drainage from Yarragon. The size of the Yarragon catchment compared to the larger size of the Moe River catchment means that by the time the Moe River reaches its peak, the peak flow from Yarragon will have already occurred and therefore not modelling the tail water level in Moe River is reflective of what happens in a rainfall event. Also the extent of the land subject to inundation overlay area for the Moe River is outside the area of the 2-D Yarragon flood model (with the exception of an area near Gordon Road), so backwater effects are unlikely to impact on our model boundary conditions.

4.2.8 Simulation Parameters

The Yarragon hydraulic model has been simulated with a 1-D time step of 0.25 seconds and 2-D time step of 1 second. Melbourne Water guidelines recommend that the 2-D time step should generally be one quarter to one half of the TUFLOW grid size. As the grid size of the model is three metres, the Yarragon model satisfies this recommendation.

4.3 Model Validation

Engeny has validated the model by checking that flows and water depths produced by the TUFLOW model are reasonable. Any unexpectedly large or small flow results were investigated to understand whether or not they were reasonable.

Model result files were used to check that pipes are flowing full in the 5 year event and if not flowing full then to confirm that the level of overland flow was minor. The pipe flows in the 100 year event were also checked to ensure that the network had been modelled correctly and that there were no 'brick walls' where pipes had not been correctly connected to the next pipe downstream. Results were also checked to ensure that TUFLOW was not producing high velocities or depths where they are not expected.

The TUFLOW model was reviewed internally at different stages of its development using QA processes developed by Engeny to ensure that consistent best practice modelling has been applied and that the model is as accurate as reasonably possible.

Engeny has also been able to validate the model using information gained from the community consultation sessions and from photos provided by BBSC.

4.4 Model Outputs

4.4.1 Critical Duration Storm Event

For each ARI, Engeny has modelled a range of rainfall events to ensure that critical flooding levels are captured throughout the entire catchment. Some sections of the catchment are sensitive to long rainfall events with lower average rainfall intensities but a higher overall rainfall volume, while other parts of the catchment will be more sensitive to shorter duration high intensity rainfall events.

Standard duration events ranging from 10 minutes duration to 24 hours have been modelled. The 100 year ARI results have been analysed to determine the rainfall events that cause critical flood levels. Table 4.2 summarises this analysis, providing the percentage of the model that has a critical flood level for each rainfall event duration.

Table 4.2 Critical duration rainfall event analysis

Event Duration	Proportion of model that rainfall event duration results in peak flood elevation
10 minutes	0.0%
15 minutes	2.7%
20 minutes	0.4%
25 minutes	6.4%
30 minutes	0.6%
45 minutes	0.6%
1 hour	1.4%
1.5 hours	10.1%
2 hours	13.8%
3 hours	1.0%
4.5 hours	8.2%
6 hours	2.2%

Event Duration	Proportion of model that rainfall event duration results in peak flood elevation
9 hours	44.5%
12 hours	7.5%
18 hours	0.3%
24 hours	0.2%

The results show that overall the 9 hour event is critical for the Yarragon catchment, which is consistent with expectations for a catchment of this size and the current design rainfall patterns in Australian Rainfall and Runoff.

4.4.2 Flood Inundation Mapping

Filters have been applied to the raw TUFLOW results in order to produce flood inundation maps. The aim of the filters is to remove areas of non-critical inundation from the final flood extents. Typically the areas of non-critical flooding are small areas of shallow water. The applied filters are in accordance with Melbourne Water filtering guidelines and have been adopted by Councils in Victoria.

For each modelled ARI a flood extent has been produced, with data included in the flood inundation map if it meets the following conditions:

- Depth ≥ 0.05m or Velocity × Depth ≥ 0.008 m^2/s
- Area of Flooding > $100m^2$ (to remove small and shallow isolated areas of flooding)
- Surrounded dry islands < $100m^2$ included in the flood extent

The flood inundation maps for each ARI are a combination of the critical results from all modelled rainfall event durations for the particular ARI.

Appendix A provides flood inundation maps for the 5 year, 10 year and 100 year ARI events for existing development conditions. **Appendix A** also provides a flood inundation map for the probable maximum flood, which is an estimate of the largest likely flood for the catchment. The probable maximum flood inundation map is provided for information purposes only, and has not been used for assessing the performance of the drainage network.

4.4.3 Flooding Issues and Drainage System Constraints

Based on the outputs from the hydraulic model, information provided by BBSC and observations gathered from the community consultation sessions, the following key flooding issues and system constraints have been identified:

- Princes Highway and Railway Line

In several areas the Princes Highway and the Railway Line create an embankment and the culverts have limited capacity in major storms for flows towards the Moe River. Where there is insufficient culvert capacity for 100 year ARI flows there is ponding upstream of these embankments. The extents of upstream ponding for various ARI events are shown in the flood maps in **Appendix A**. This issue is particularly evident at the culvert crossing to the east of Gordon Road, where ponding in excess of 1.5 metres deep is predicted for the 100 year ARI event.

- Open drain on the western side of the township

The open drain that runs through farmland on the western side of Hazeldean Road has insufficient capacity and overflows during major storm events. Feedback obtained during the community consultation sessions and from site visits indicate that this drain is poorly maintained. Some sections of the drain have sufficient grade, but there also are some very flat sections. Improvement works on this drain have been recommended in the flood mitigation plan.

- Gordon Road open drain

Feedback from BBSC and the community consultation sessions identified that this drain is heavily vegetated and therefore is not hydraulically efficient. During large rainfall events significant flows along Gordon Road have been observed by members of the community. Improvement works on this drain have been recommended in the flood mitigation plan.

- Open drains on the northern side of the Railway Line

There are open drains alongside Yarragon-Shady Creek Road and Factory Road that convey flow towards the Contour Drain and Moe River. Feedback obtained during the community consultation and from the site visits indicate that these drains are poorly maintained. The hydraulic model also predicts that the drains do not have sufficient capacity for large rainfall events.

- Pipe Capacity

BBSC's current drainage design standard is that an underground pipe should have sufficient capacity to convey a minimum of the 5 year ARI event. The flood inundation map for the 5 year ARI event shows that the drainage network within the township generally meets this standard, with few areas of inundation shown. There are some residential properties on the northern side of Burnett Street that the model predicts are flooded in the 5 year ARI event due to inadequate pipe capacity.

- Development in naturally flood prone areas

Engeny was advised that flooding of the recent residential development near the corner of Rodier Road and Hazeldean Road has occurred. The hydraulic model supports these observations, with the development shown to be flood prone for events of 5 year ARI and above. Improvement works to reduce flooding of this development have been identified as part of the mitigation plan.

- Insufficient overland flow path for 100 year ARI flows

One of the main underground drainage lines through the township starts from the eastern extent of Market Street, runs north-west behind residential properties, then runs along Hanns Lane and then Loch Street before crossing the Princes Highway. While this pipe generally has sufficient capacity for a 5 year ARI rainfall event, in a 100 year ARI rainfall event there is significant overland flows above the pipe. While there is a small easement for some sections of this pipe, the 100 year ARI overland flows are predicted to inundate some properties and dwellings.

5. MITIGATION PLAN FOR EXISTING CONDITIONS

5.1 Identified Structural Works

In consultation with BBSC, Engeny has identified and modelled several flood mitigation measures to reduce existing flooding issues in Yarragon. **Appendix B** provides a layout plan showing the locations and alignments of the works. The locations of the retarding basins and other mitigation works are concept only, and may be modified during detailed design to provide suitable offset from existing properties and to account for other design constraints, such as geotechnical issues, safe slopes, maintenance access and flora and fauna.

The following mitigation works have been identified:

- Blackshaw Road open drain / floodway, 300 metres south of the Rodier Road residential area.
  - The objective of this drain is to protect the Rodier Road residential area.
  - Preliminary dimensions for the drain are 1m deep, base width of 3m, top width of 13m. Additional freeboard may be added to the drain during functional design.
- Gas transmission line easement open drain, located in the gas transmission line easement between Rodier Road and Blackshaw Road.
  - The objective of this drain is to also protect the Rodier Road residential area. The drain can also be used for future development to the south of the Rodier Road residential area.
  - Preliminary dimensions for the drain are 0.5m deep, base width of 3m, top width of 8m.
- Hazeldean Road Retarding basin, south of the Rodier Road residential area.
  - This retarding basin will receive flow from the two open drains proposed above and provide improved flood protection for low lying areas west of Hazeldean Road.
  - The retarding basin has been preliminarily sized to provide 39,800 cubic metres of storage for a 100 year ARI event.
  - A new pipe outlet from the retarding basin is required, and the culverts under Hazeldean Road are to be re-built.
- Clean-out / reinstatement of the existing drain downstream of Hazeldean Road (including the continuation of the drain north of the Princes Highway major culverts)
  - These works are required to clean out the drain and potentially increase the drain cross-section in some regions to improve the efficiency of flow through the drain.
  - These works will also be required on the drain on the northern side of the Princes Highway.

- Channel works on the Gordon Road drain
    - These works are required to improve the capacity of the drain by removing heavy vegetation. Regular maintenance of the drain after the works are completed will be required.
- Increased pipe capacity for drains through 172 Loch Street
    - The existing pipe does not have sufficient capacity to convey flow from the upstream catchment.
    - Existing 600 millimetre pipe to be duplicated.
- Rollo Street & Leongatha - Yarragon Road retarding basin
    - The retarding basin will help reduce main overland flow path through town.
    - The retarding basin has been preliminarily sized to provide 24,000 cubic metres of storage for a 100 year ARI event.
    - A pipe outlet is required to the existing drain in Rollo Street.
    - Minor open drain and pipe are also required to convey overland flows into the retarding basin. Preliminary sizing of the open drain is depth of 0.75m, base width of 1m and top width of 8.5 metres.
- Rollo Street & Princes Highway retarding basin
    - The retarding basin will reduce flooding of properties on the southern side of the Princes Highway and help to control the volume of flow conveyed to the open drains north of the railway line.
    - The retarding basin has been preliminarily sized to provide 28,630 cubic metres of storage for a 100 year ARI event.
    - A pipe outlet is required to the existing drain in Rollo Street.
    - An open drain is also required to convey runoff into the retarding basin. Preliminary sizing of the open drain is depth of 1m, base width of 3m and top width of 13m.
- Upgrade of Factory Road open drain
    - Open drain is to be cleaned out and expanded where sufficient space is available. Land acquisition could be investigated if there is not sufficient space in the road reserve for the expanded drain.
    - Preliminary sizing of the drain is depth of 0.7m, base width of 2m and top width of 6.2m.
- Upgrade of Yarragon - Shady Creek Road open drain
    - Open drain is to be cleaned out and expanded where sufficient space is available. Land acquisition could be investigated if there is not sufficient space in the road reserve for the expanded drain.
    - Preliminary sizing of the drain is depth of 0.7m, base width of 2m and top width of 6.2m.

5.2 Example Works

Figure 5.1 and Figure 5.2 provide examples of how the proposed mitigation works may look in the Yarragon catchment. It should be noted that these are only examples, and the appearance of mitigation works in Yarragon will depend on detailed design to be conducted at a later stage. It may be possible to also utilise the area required for the retarding basins for other purposes such as sporting fields or permanent wetlands. The construction of embankments will be required in order to provide the required flood storage in the retarding basins. The detailed design should give consideration to carefully landscaping the embankments so that they fit in with the surroundings.

Figure 5.1 Example of open drain / floodway

Figure 5.2 Example of retarding basin (including optional permanent pond / wetland)

5.3 Performance of the Mitigation Works

Appendix B provides flood inundation maps for the 5 year, 10 year and 100 year ARI rainfall events with the proposed mitigation works included in the model.

The channel and retarding basin works south of the Rodier Road residential development provide a significant reduction in flooding of this area, with negligible flooding of the development in 5 and 10 year ARI rainfall events and only minor flooding in a 100 year ARI event.

The improvement works on the channel downstream of Hazeldean Road provide improved flow conveyance for smaller rainfall events (5 year ARI). In a 100 year ARI event, the area west of Hazeldean Road is still heavily inundated. This is the main low lying area of the catchment on the south side of the Prince Highway, and therefore inundation for large rainfall events is unavoidable. Works to control development upstream of this area are required so that existing flooding issues are not made worse.

The two retarding basins and open drains east of Rollo Street provide improved flood protection for the areas downstream of the retarding basins. The retarding basin on the eastern side of Leongatha - Yarragon Road is able to fully contain a 100 year ARI flood, while some overflow occurs for the retarding basin south of Princes Highway in a 100 year ARI flood.

The upgraded open drains along Factory Road and Yarragon-Shady Creek Road provide much better flow conveyance for smaller rainfall events (5 year ARI). For larger rainfall events, such as the 100 year ARI event, there is still overflow occurring through paddocks on either side of the open drains as the drains are unable to convey all flow.

The duplicated pipe through 172 Loch Street does not provide a significant reduction in overland flows in this area. The difficulty in piping flows through these properties is being able to effectively capture flow into the pipe.

5.4 Preliminary Costing

The cost of the mitigation works have been estimated using Melbourne Water's standard rates for Developer Services Schemes (drainage schemes). Table 5.1 summarises the cost of each identified set of works. The cost estimates do not include land acquisition, which may be required for the retarding basins.

The estimated cost for improvement works on the channel downstream of Hazeldean Road includes drain reinstatement costs only. This accounts for the works required for the clean out and re-vegetation.

The open drain upgrades along Factory Road and Yarragon-Shady Creek Road have been costed as new drains as the size of existing drains needs to be increased. While only a section of these drains are within the hydraulic model extent, the cost estimates include works to upgrade improve the drains all the way to Contour Drain.

Table 5.1 Mitigation works cost estimates

Item	Estimated Cost	Contingencies (40%)	Total (rounded to nearest $1k)
Hazeldean Road Retarding Basin [1]	$ 677,496	$ 270,998	$ 948,000
Blackshaw Rd open drain	$ 404,423	$ 161,769	$ 566,000
Gas transmission line open drain	$ 140,832	$ 56,333	$ 197,000
Clean-out / reinstatement of drain downstream of Hazeldean Road (and north of Princes Highway)	$ 408,600	$ 163,440	$ 572,000
Clean-out / reinstatement of Gordon Road open drain	$ 105,000	$ 42,000	$ 147,000
172 Loch Street duplicate pipeline	$ 40,698	$ 16,279	$ 57,000
Rollo Street & Leongatha - Yarragon Road retarding basin [1]	$ 518,965	$ 207,586	$ 727,000
Open drain adjacent to Rollo Street	$ 86,198	$ 34,479	$ 121,000
Rollo Street & Princes Highway retarding basin [1]	$ 452,880	$ 181,152	$ 634,000
Open drain on eastern side of Leongatha - Yarragon Road	$ 331,612	$ 132,645	$ 464,000
Factory Road open drain upgrade	$ 280,320	$ 112,128	$ 392,000
Yarragon - Shady Creek Road open drain upgrade	$ 359,010	$ 143,604	$ 503,000
Totals	$ 3,806,035	$ 1,522,414	**$5,328,000**

[1] Estimated costs for the retarding basins exclude land acquisition costs

5.5 Non-Structural Measures

Non-structural measures are a cost effective way to improve drainage management. The following non-structural measures are recommended:

- Special Building Overlays (SBOs) are appropriate for identifying overland flow paths for 100 year ARI storms. Use of SBOs across the catchment is recommended to manage future development and to reduce the flood risk for new buildings. The use of

SBOs are considered a high priority for the catchment as they do not have any capital cost and will result in an effective measure across the catchment.

- Based on feedback in the community consultation sessions and observations during site visits, an improved maintenance program is recommended. This is particularly important for open drains, which need to be cleared out regularly to ensure they can effectively convey flows.
- Improved definition of the roles and responsibilities of BBSC and WGCMA regarding management of drainage. Defining the roles for each organisation and communicating this information with the community is a priority.

6. FEASIBILITY OF TOWN EXPANSION

6.1 Township Development Areas

BBSC provided information to Engeny detailing the areas and type of future development that may occur in Yarragon as part of the township expansion. Three potential residential development areas have been identified, all south of the Princes Highway, and there is a potential industrial development area

Engeny has assessed the feasibility of these areas developing from a drainage perspective. Other constraints will also need to be assessed, such as transport, water supply and the sewerage system.

Figure 6.1 shows the potential development areas in Yarragon.

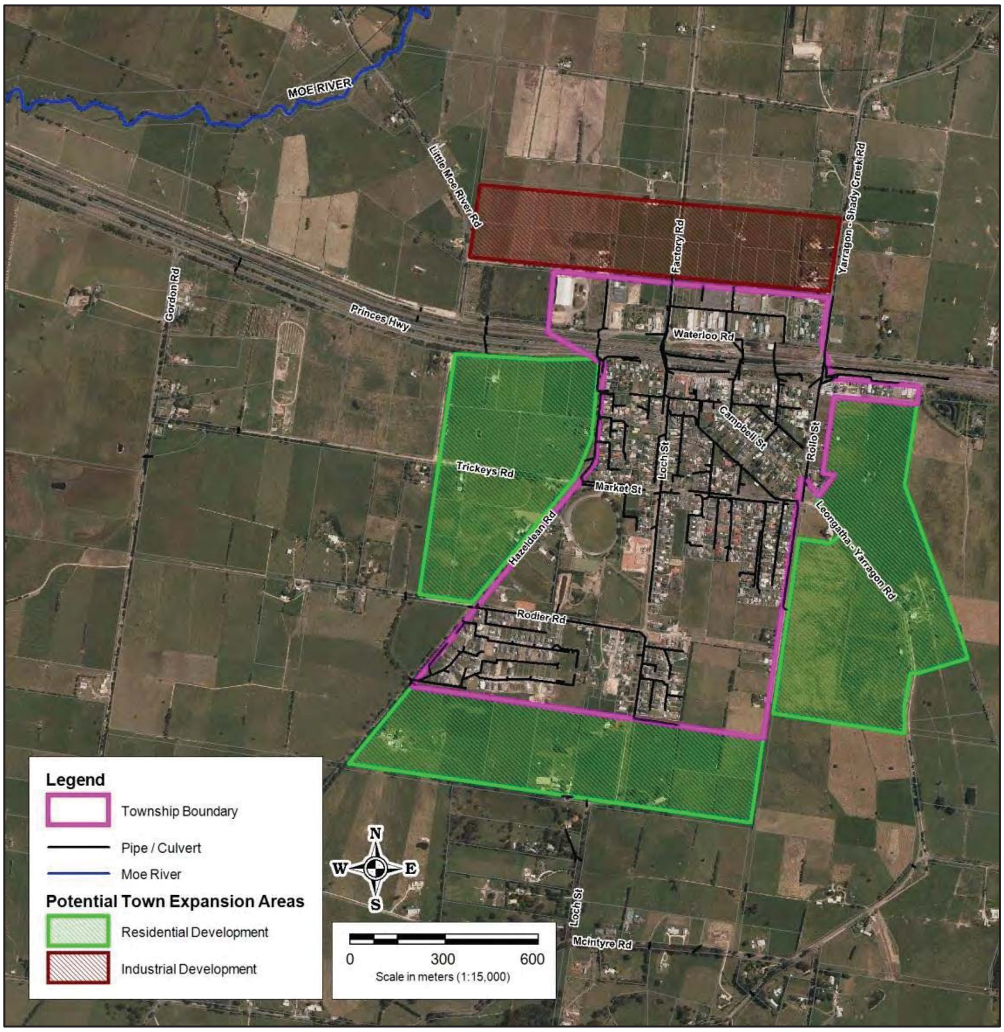

Figure 6.1 Potential development areas in Yarragon

6.2 Drainage Objectives

The key objective Engeny has assessed for each of the development areas is whether it is possible to develop each area without increasing flooding downstream of the development. This objective is in line with the peak flow control requirement which is set out in Clause 56 of the Victorian Planning Provisions.

Other drainage objectives that will need to be considered are:

- Internal sizing of drainage assets – this can be investigated once a development layout is proposed by the developer

- Runoff quality (also a requirement of Clause 56) – this township feasibility analysis has not specifically modelled water quality for the new development, but it will be possible to provide water treatment in the form of a wetland in the base of the retarding basins proposed for the developments.

6.3 Required Infrastructure

Internal drainage has not been investigated as this is highly dependent on the layout of each development. Engeny has added some open drains within the developments in order to convey flow into retarding basins. This is so that the performance of the retarding basins can be assessed. The alignment of the open drains is likely to change should development occur.

Appendix C provides a layout plan showing the works identified for the development areas. All works proposed as part of the mitigation plan (refer to Section 5) have been included, with some of the works expanded to allow for the increased runoff from the development areas. Some additional works have also been identified.

The altered or additional works compared to the mitigation works for existing conditions are:

- Hazeldean Road retarding basin expanded to account for residential development south of the gas transmission line easement;

- Rollo Street & Princes Hwy retarding basin expanded to account for residential development east of the existing township;

- Rollo Street & Leongatha - Yarragon Road retarding basin expanded to account for residential development east of the existing township;

- New Western Residential Development Area retarding basin to cater for residential development site near Trickeys Road; and

- Two new retarding basins (Factory Road West and Factory Road East) to cater for the potential Factory Road industrial development site.

6.4 Performance of the Town Expansion Works

Appendix C provides flood inundation maps for the 5 year, 10 year and 100 year ARI rainfall events with the proposed town expansion works included in the hydraulic model. The inflows to the hydraulic model have been increased to reflect the increased runoff that will occur due to the increased imperviousness of the developments.

Table 6.1 provides details of the retarding basin storage volumes, peak depths and approximate land requirements. The land requirement for each retarding basin includes the area that will be inundated as well as an allowance for embankments and batters that will be required to construct the retarding basin.

Table 6.1 also provides the retarding basin requirements for the mitigation works for existing conditions, compared to the township expansion scenario. This provides an indication of difference in the scale of works required for mitigation works if the development within the catchment occurs.

Table 6.1 Retarding basin storages, depths and land areas

Retarding Basin	Mitigation Works for Existing Conditions			Mitigation Works for Town Expansion		
	Depth (m)	Storage Vol (m^3)	Area (m^2)	Depth (m)	Storage Vol (m^3)	Area (m^2)
Rollo Street & Princes Hwy RB	3.7	28,630	14,500	3.8	45,970	18,300
Rollo Street & Leongatha - Yarragon Road RB	2.0	23,970	19,000	2.0	28,300	23,100
Hazeldean Road RB	1.9	39,800	38,460	1.9	48,390	43,600
Western Residential Development Area RB	-	-	-	1.2	18,470	22,000
Factory Road West RB	-	-	-	0.8	1,990	4,250
Factory Road East RB	-	-	-	1.0	2,120	3,750

6.5 Costing

The cost of the retarding basins required for the town expansion has been estimated using Melbourne Water's standard rates for Developer Services Schemes (drainage schemes). Table 6.2 summarises the costs. The cost estimates do not include land acquisition, which may be required.

Table 6.2 Town expansion retarding basin cost estimates

Item	Estimated Cost	Contingencies (40%)	Total (rounded to nearest $1k)
Hazeldean Road RB (southern development) [1]	$ 1,002,746	$ 401,098	$1,404,000
Rollo Street & Leongatha - Yarragon Road RB (eastern development) [1]	$ 694,715	$ 277,886	$ 973,000
Rollo Street & Princes Hwy RB (eastern development) [1]	$ 684,840	$ 273,936	$ 959,000
Western Residential Development Area RB [1]	$ 325,360	$ 130,144	$ 456,000
Factory Road West RB (northern industrial development) [1]	$ 41,915	$ 16,766	$ 59,000
Factory Road East RB (northern industrial development) [1]	$ 51,000	$ 20,400	$ 71,000
Totals	$ 2,800,576	$ 1,120,230	**$3,921,000**

[1] Estimated costs exclude land acquisition costs

Should the identified areas develop, these expanded retarding basin works would effectively replace the retarding basins identified in the existing mitigation analysis. Combined with the works other than retarding basins proposed as part of the mitigation plan for existing conditions (open drains and pipe upgrades), the total cost of works for the town expansion and to mitigate existing conditions flooding is $6,940,000 (including contingencies).

6.6 Feasibility Summary

Based on the results of the hydraulic modelling and preliminary sizing of the retarding basins, it is possible to develop the three residential areas without making downstream flooding worse. Some refining of the proposed retarding basins may be required during functional design when further development layout information is available.

It is more of a challenge to provide adequate peak flow controls for the industrial development. The proposed industrial area is relatively flat, which makes controlling flows through retarding basins more difficult. The hydraulic model's results show that the proposed retarding basins do not have sufficient capacity to cater for the increased runoff from the industrial development. An alternative solution would be to only store flows for small rainfall events, and for larger events construct outlet pipelines all the way to the Moe

River. As the industrial area is at the downstream end of the catchment, the peak flow discharged from this area would be well before the peak from the remaining catchment, and therefore there may be no increase in flood levels in the Moe River immediately downstream. As this alternative option does not comply with Clause 56 provisions and the effect further downstream has not yet been analysed, the option would need to be negotiated with WGCMA prior to further investigation.

7. CONCLUSION AND RECOMMENDATIONS

This study was in response to a recommendation made in a high level review of the Yarragon drainage system completed in 2011 which stated that a detailed analysis based on hydraulic modelling of the Yarragon drainage system was required.

The hydraulic model created as part of this study has enabled a comprehensive analysis of the drainage system as well as the production of flood inundation maps. Consultation with the Yarragon community and other key stakeholders and a comprehensive collation and review of drainage data have formed vital inputs to the model and study outcomes.

Based on the outputs from the hydraulic model, information provided by BBSC and observations gathered from the community consultation sessions, the following key issues and drainage system constraints have been identified:

- Princes Highway and the Railway Line create embankments and the culverts have limited capacity in major storms for flows towards the Moe River. Where there is insufficient culvert capacity for 100 year ARI flows there is ponding upstream of these embankments;
- The open drain on the western side of the township does not convey flow efficiently;
- Open drains on the northern side of the railway line do not have sufficient capacity;
- Development has occurred in flood prone areas, with inadequate measures to protect the development from inundation;
- Insufficient overland flow paths for 100 year ARI flows;
- Maintenance of key drainage infrastructure, particularly open drains, is not occurring regularly; and
- The roles and responsibilities for management of the drainage system between BBSC and WGCMA are not sufficiently defined or well communicated to the community.

A series of structural and non-structural measures have been identified that aim to improve the management and performance of the Yarragon drainage system. The hydraulic model has also been used to assess the feasibility of future development in Yarragon and to identify works to control the impact of development on the catchment.

The key recommendations made by this study are:

- An improved maintenance program is recommended. This is particularly important for open drains, which need to be cleared out regularly to ensure they can effectively convey flows.

- The definition of the roles and responsibilities of BBSC and WGCMA regarding management of drainage needs to be improved.

- Consider the use of Special Building Overlays (SBO) across the catchment to manage future development and to reduce the flood risk for new buildings. The use of SBOs is recommended as they do not have any capital cost and will result in an effective measure across the catchment.

- Structural mitigation works (as detailed in Section 5 of this report) should be constructed to reduce the impacts of flooding on existing development.

- Development of the three proposed residential areas is feasible, as the retarding basins proposed as part of this study will allow development without making downstream flooding worse.

- It is more of a challenge to provide adequate peak flow controls for the proposed industrial development. The proposed industrial area is relatively flat, which makes controlling flows through retarding basins more difficult.

8. QUALIFICATIONS

a. In preparing this document, including all relevant calculation and modelling, Engeny Management Pty Ltd (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b. Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

c. Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:

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    (ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

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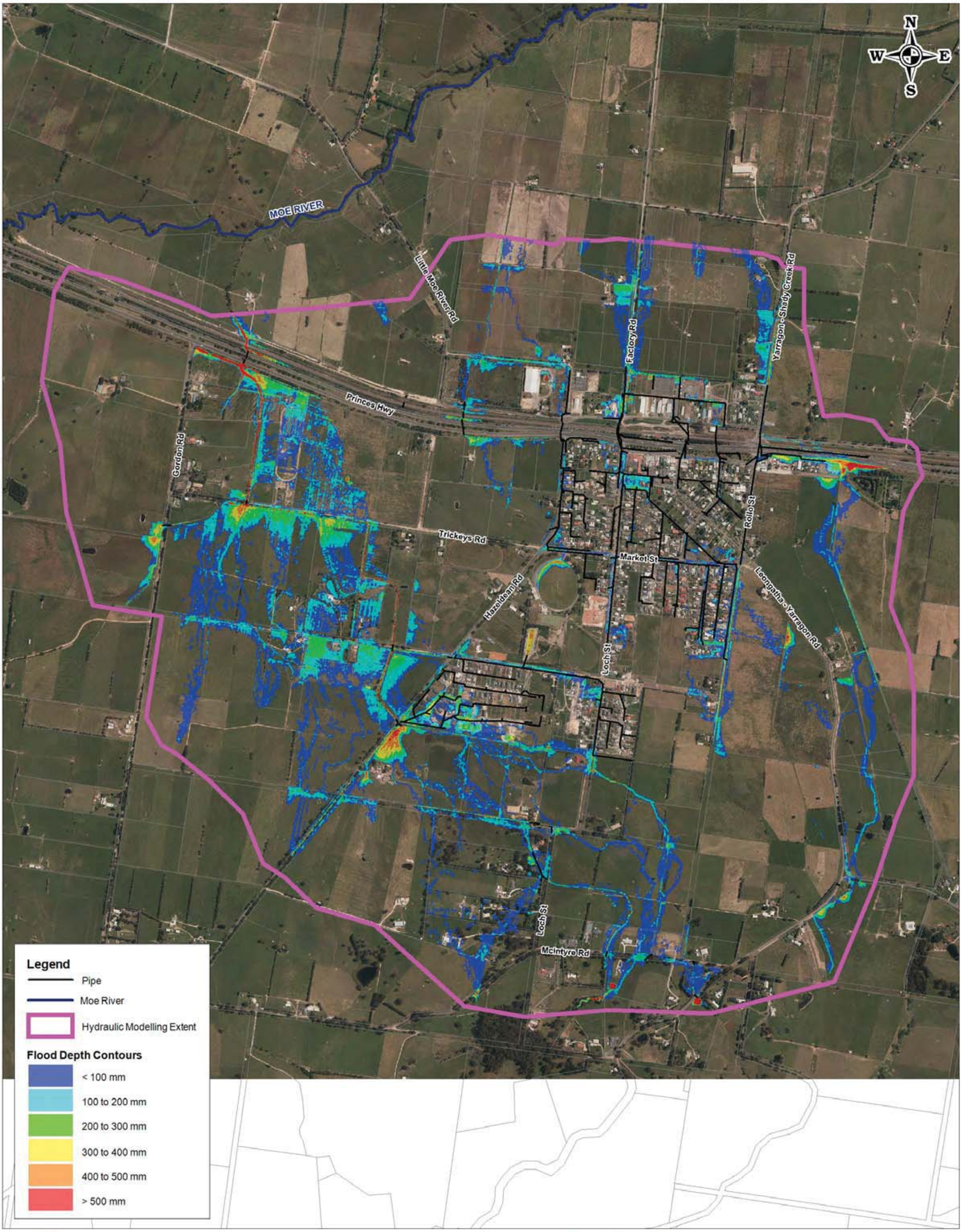
APPENDIX A

Flood Inundation Maps for Existing Conditions



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BAW BAW SHIRE COUNCIL

0 250 500

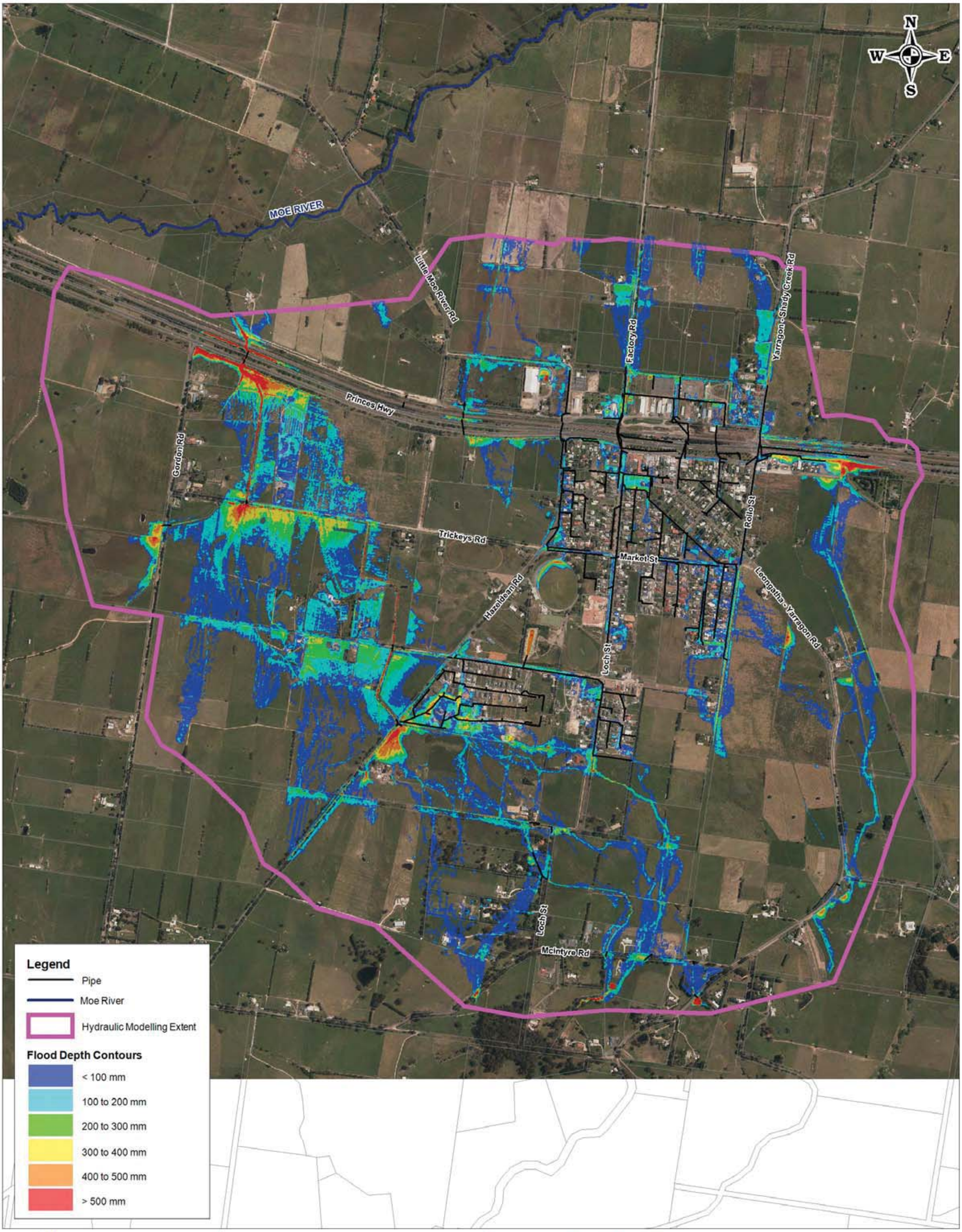
Scale in meters (1:12,500 @ A3)

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Yarragon Flood Modelling and Drainage Strategy

Flood Inundation Map
Existing Conditions
5 year ARI Storm Event

Job Number: V2000_043
Revision: 0
Drawn: PC
Checked: AP
Date: 13 Sept 2013



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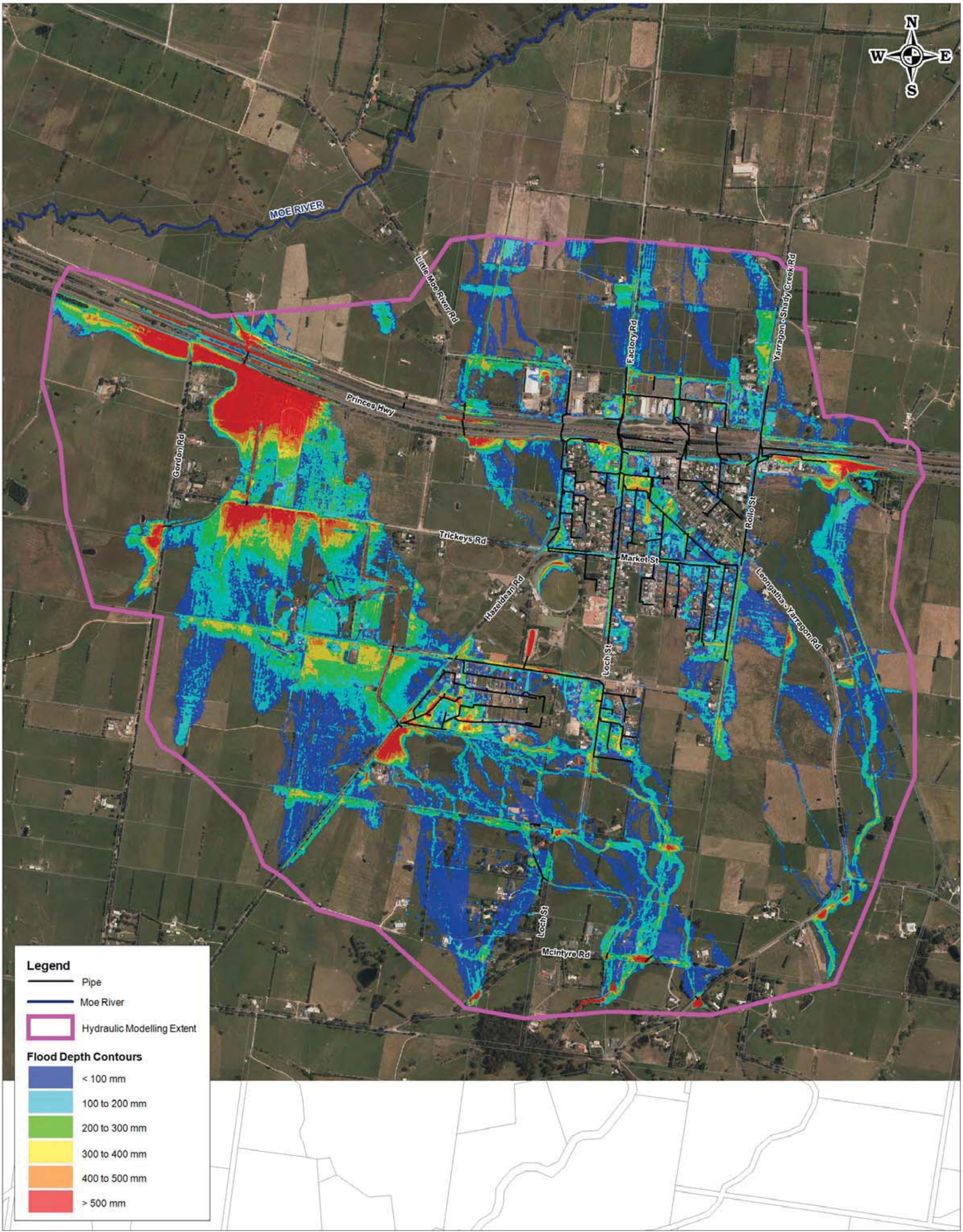
Grid: Map Grid of Australia, Zone 55

Yarragon Flood Modelling and Drainage Strategy

Flood Inundation Map
Existing Conditions
10 year ARI Storm Event

Job Number: V2000_043
Revision: 0
Drawn: PC
Checked: AP
Date: 13 Sept 2013



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0 250 500

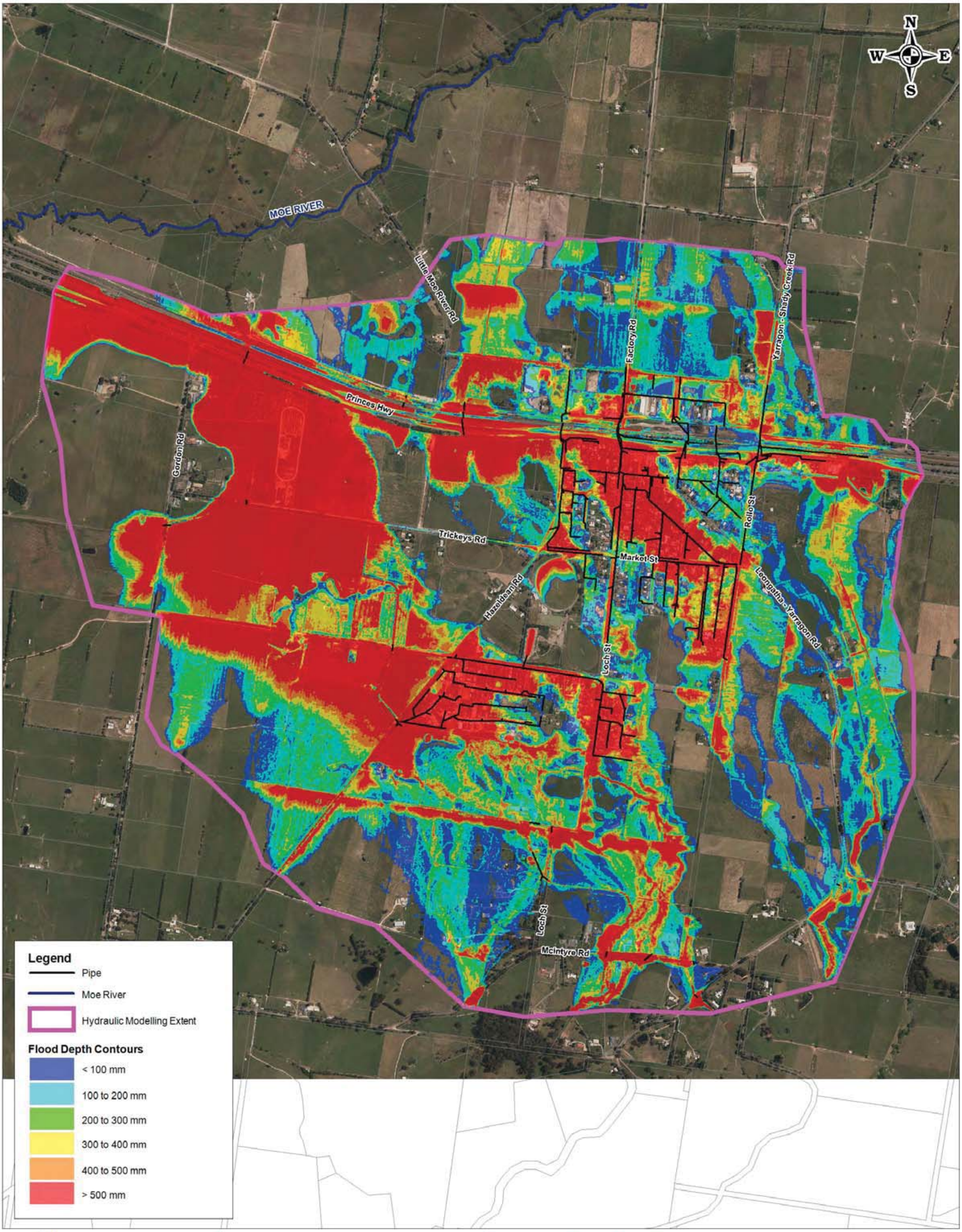
Scale in meters (1:12,500 @ A3)

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Yarragon Flood Modelling and Drainage Strategy

Flood Inundation Map
Existing Conditions
100 year ARI Storm Event

Job Number: V2000_043
Revision: 0
Drawn: PC
Checked: AP
Date: 13 Sept 2013



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0 250 500

Scale in meters (1:12,500 @ A3)

Map Projection: Universal Transverse Mercator
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Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

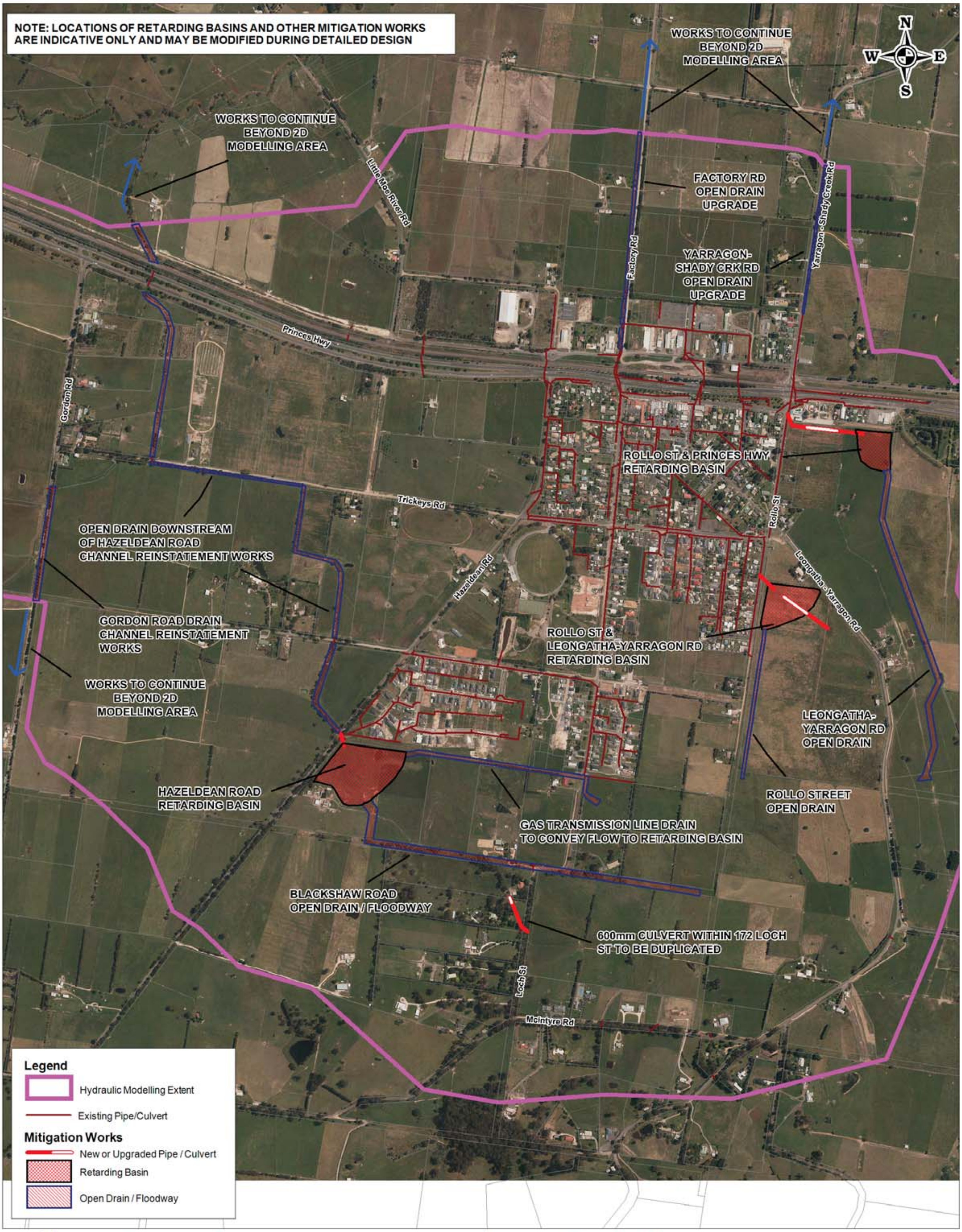
Yarragon Flood Modelling and Drainage Strategy

Flood Inundation Map
Existing Conditions
Probable Maximum Flood

Job Number: V2000_043
Revision: 0
Drawn: PC
Checked: AP
Date: 6 Dec 2013

APPENDIX B

Mitigation Works for Existing Conditions and Revised Flood Inundation Maps



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0 200 400

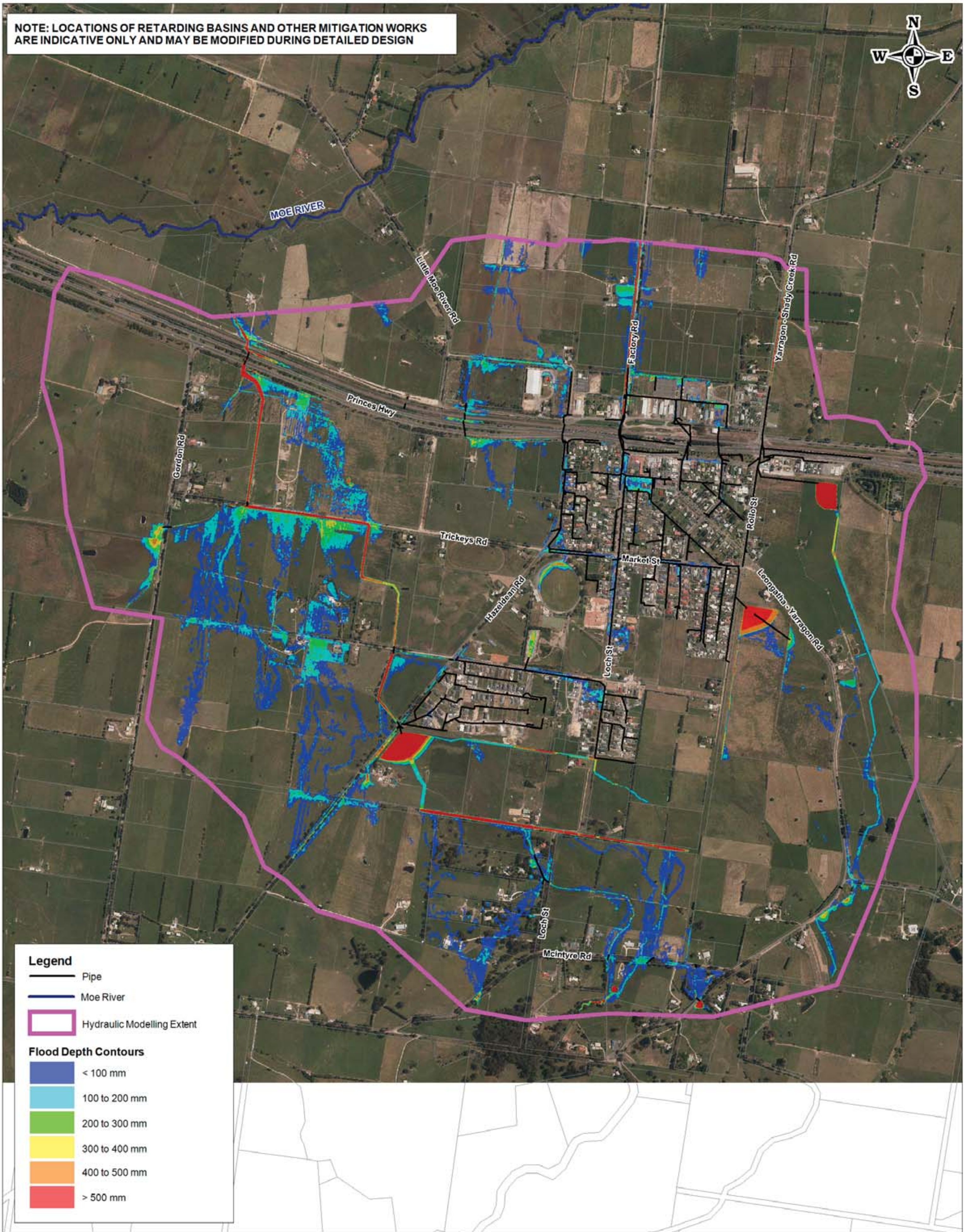
Scale in meters (1:10,000 @ A3)

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Yarragon Flood Modelling and Drainage Strategy

Mitigation Works for Existing Conditions

Job Number: V2000_043
Revision: 0
Drawn: PC
Checked: AP
Date: 9 Dec 2013



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0 250 500

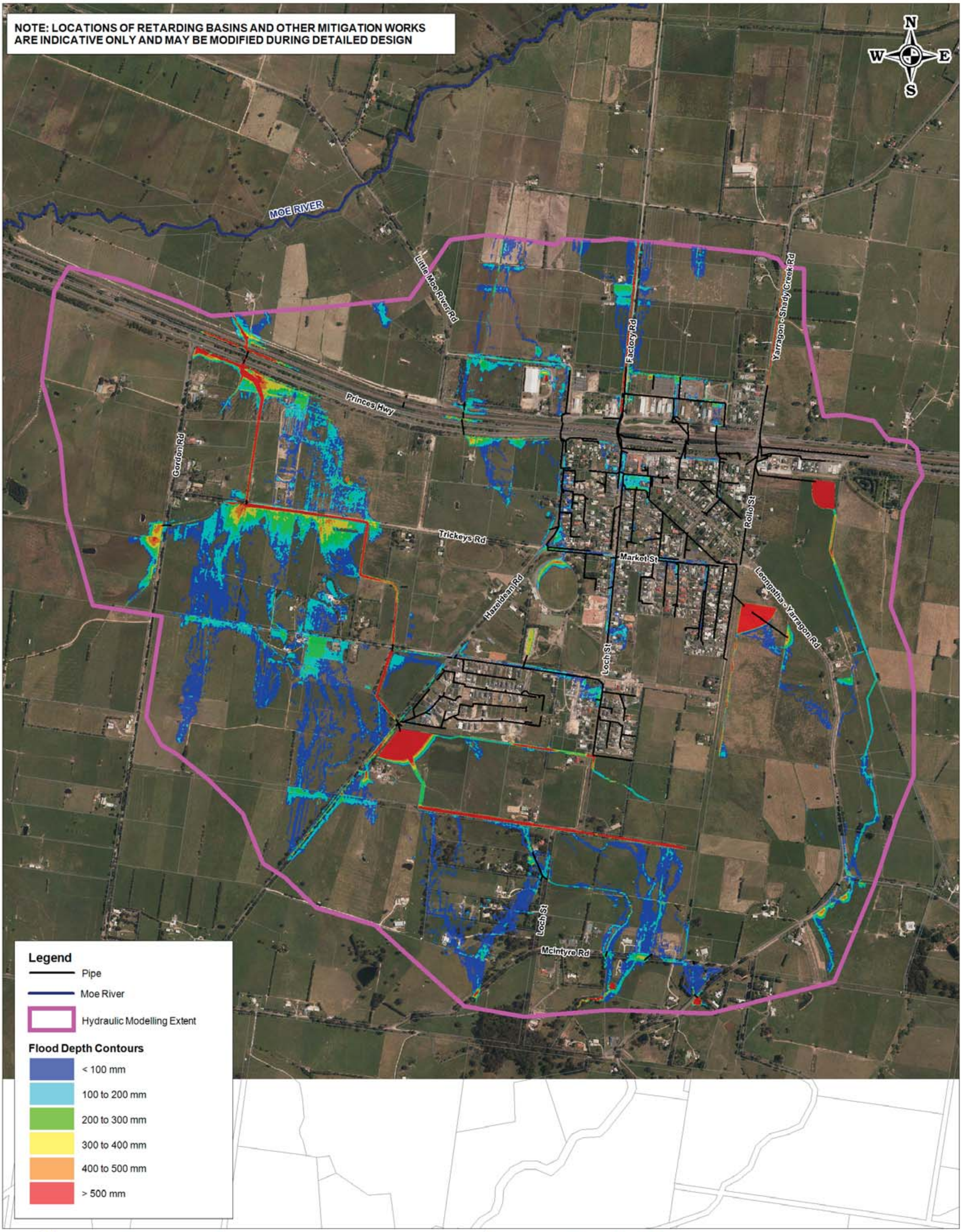
Scale in meters (1:12,500 @ A3)

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Yarragon Flood Modelling and Drainage Strategy

Flood Inundation Map
Mitigation Works for Existing Conditions
5 year ARI Storm Event

Job Number: V2000_043
Revision: 0
Drawn: PC
Checked: AP
Date: 9 Dec 2013



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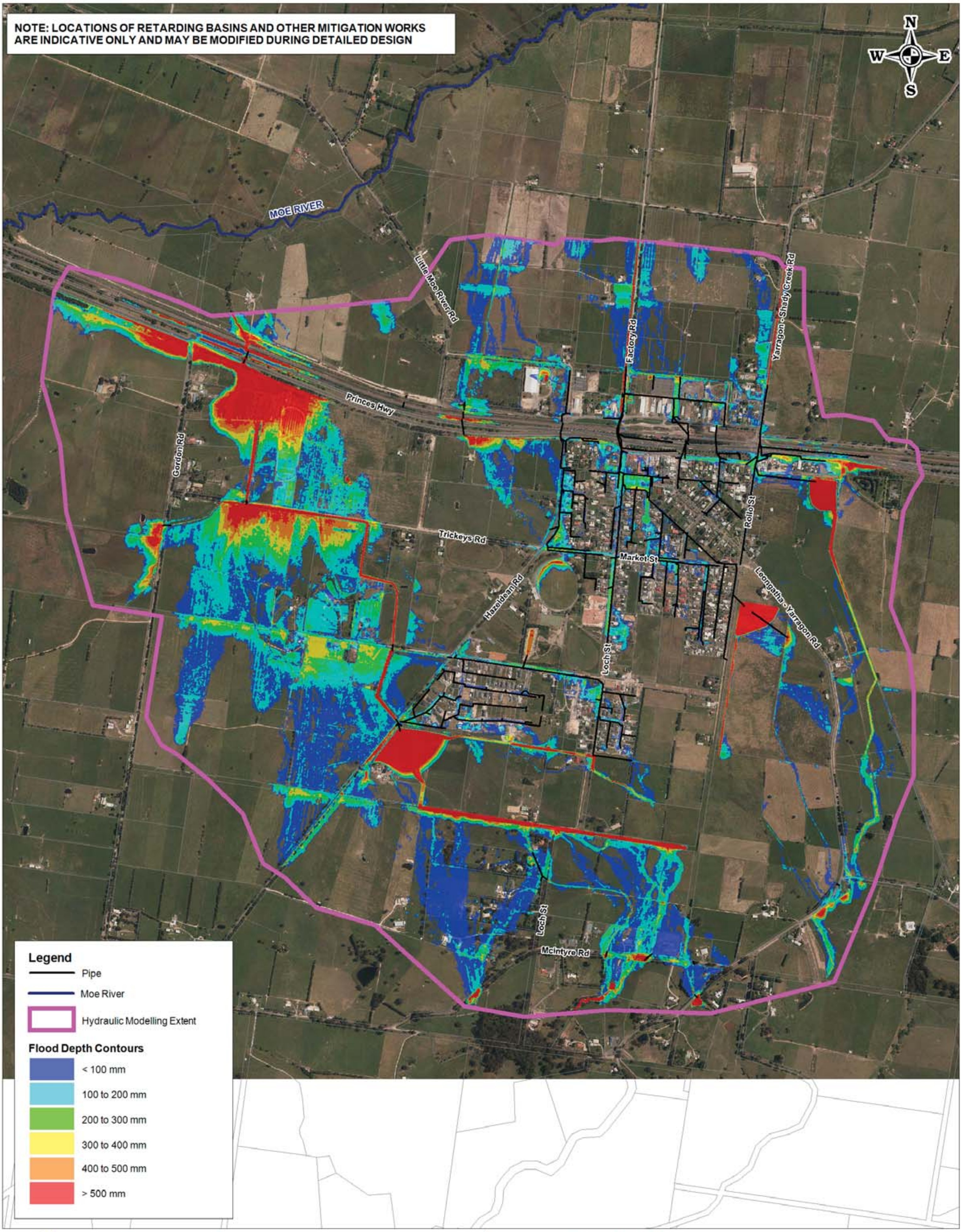
Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Yarragon Flood Modelling and Drainage Strategy

Flood Inundation Map
Mitigation Works for Existing Conditions
10 year ARI Storm Event

Job Number: V2000_043
Revision: 0
Drawn: PC
Checked: AP
Date: 9 Dec 2013



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Scale in meters (1:12,500 @ A3)

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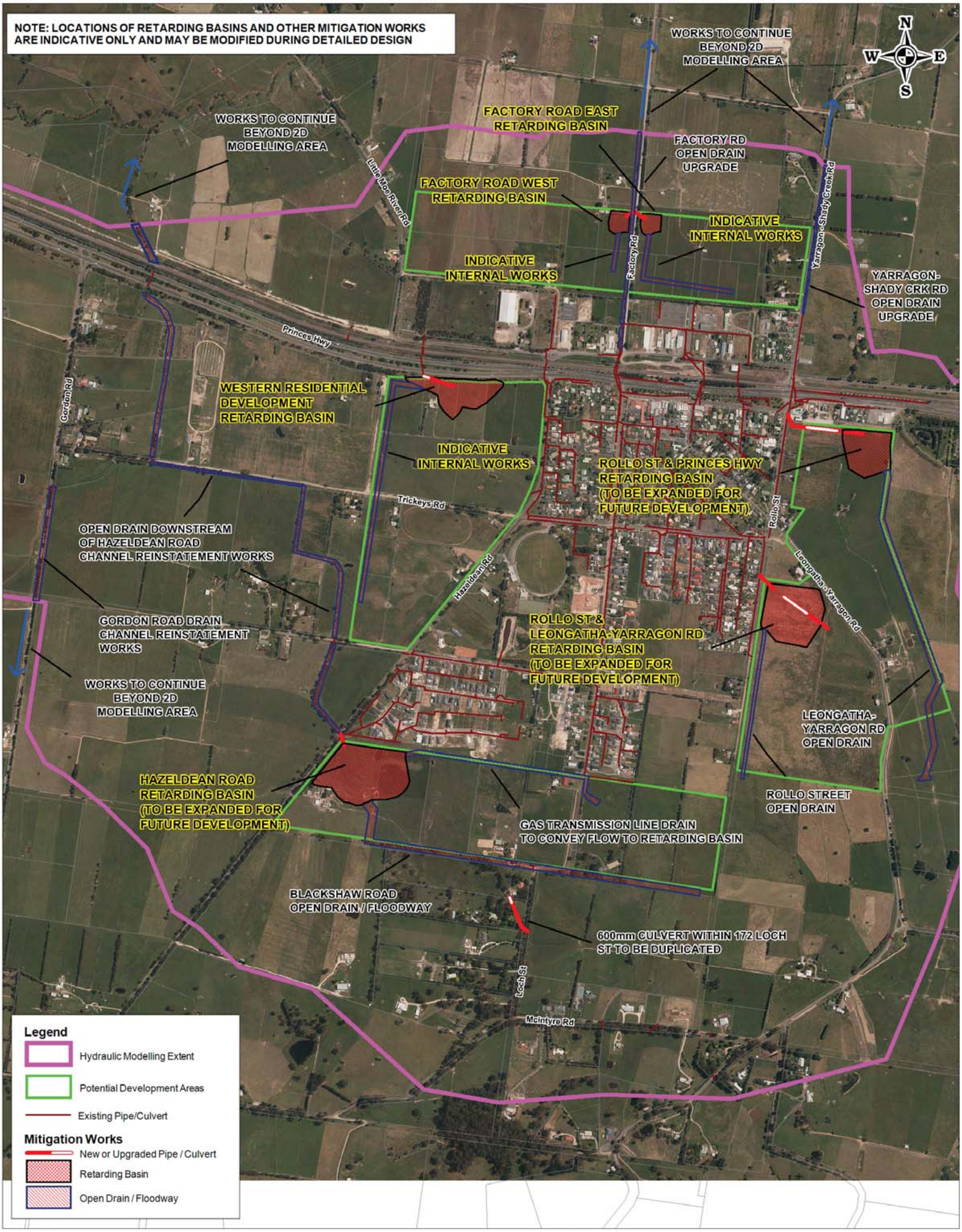
Yarragon Flood Modelling and Drainage Strategy

Flood Inundation Map
Mitigation Works for Existing Conditions
100 year ARI Storm Event

Job Number: V2000_043
Revision: 0
Drawn: PC
Checked: AP
Date: 9 Dec 2013

APPENDIX C

Mitigation Works for Township Expansion and Revised Flood Inundation Maps



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Scale in meters (1:10,000 @ A3)

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Yarragon Flood Modelling and Drainage Strategy

Mitigation Works for Township Expansion

Job Number: V2000_043
Revision: 0
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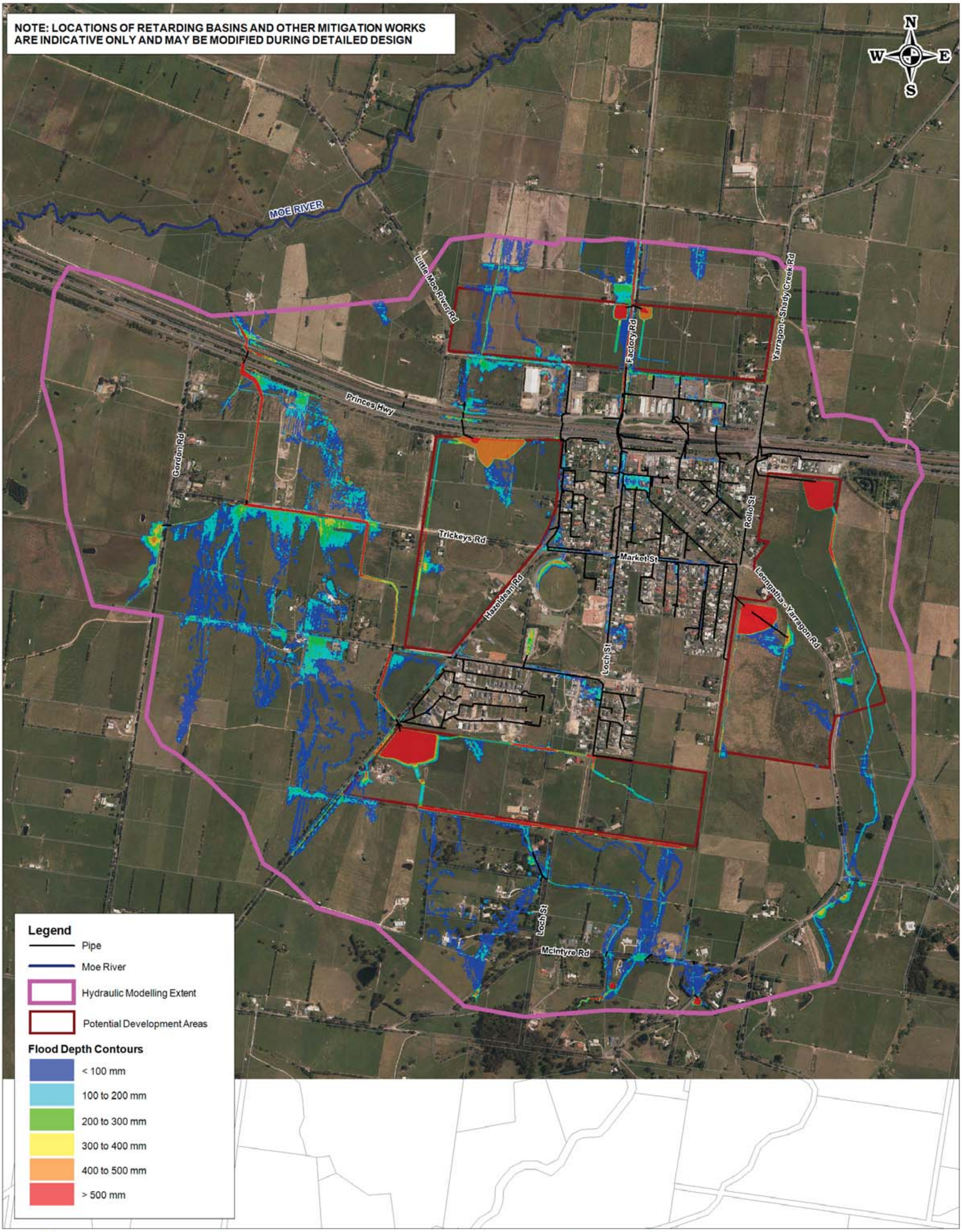
Date: 9 Dec 2013



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Scale in meters (1:12,500 @ A3)

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia 1994. (GDA94)
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Yarragon Flood Modelling and Drainage Strategy

Flood Inundation Map
Mitigation Works for Township Expansion
5 year ARI Storm Event

Job Number: V2000_043
Revision: 0
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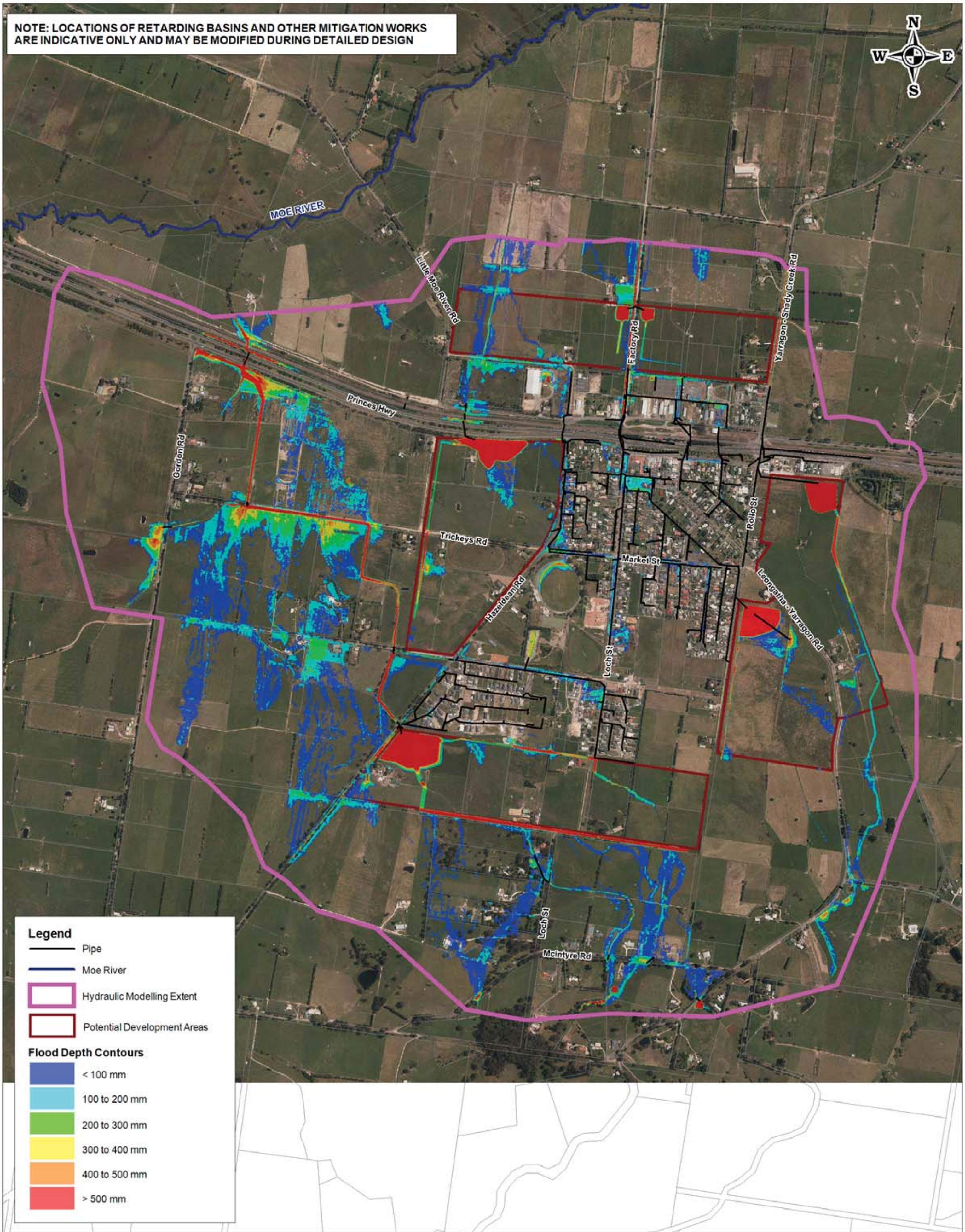
Checked: AP
Date: 9 Dec 2013



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Scale in meters (1:12,500 @ A3)

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Yarragon Flood Modelling and Drainage Strategy

Flood Inundation Map
Mitigation Works for Township Expansion
10 year ARI Storm Event

Job Number: V2000_043
Revision: 0
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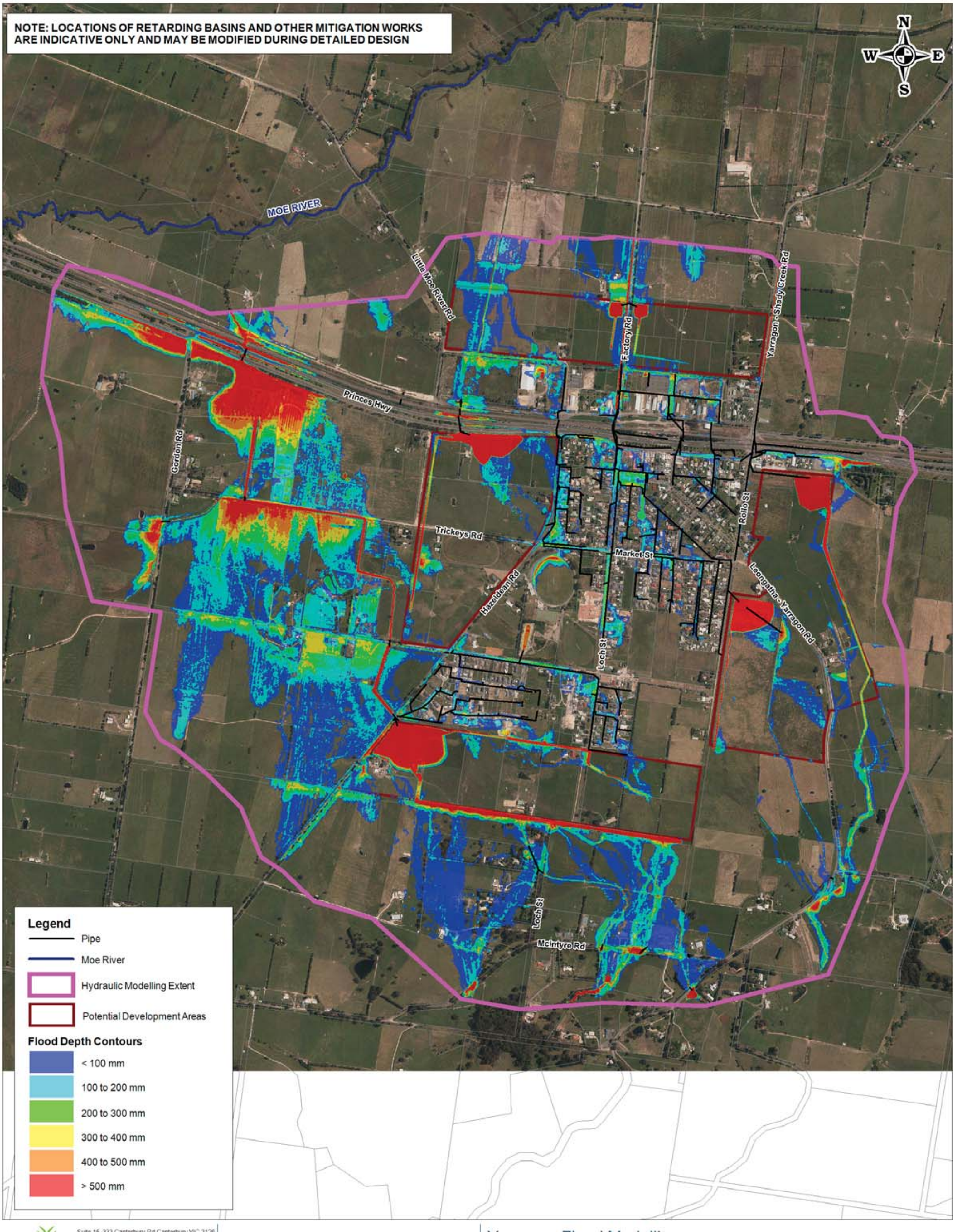
Checked: AP
Date: 9 Dec 2013



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Yarragon Flood Modelling and Drainage Strategy

Flood Inundation Map
Mitigation Works for Township Expansion
100 year ARI Storm Event

Job Number: V2000_043
Revision: 0
Drawn: PC
Checked: AP
Date: 9 Dec 2013

APPENDIX D

Hydrology Model Data Tables

Appendix D

Yarragon Hydrology Model: Sub-catchment Table

Subarea	Subarea Number	Area (km²)	Impervious Fraction
A	21	0.212	0.1
B	22	0.169	0.1
C	20	0.37	0.104
D	19	0.553	0.1
E	17	0.376	0.1
F	16	0.036	0.1
G	15	0.158	0.1
H	8	0.019	0.1
I	6	0.02	0.1
J	86	0.244	0.114
K	14	0.17	0.1
L	10	0.311	0.1
M	277	0.099	0.45
N	278	0.145	0.45
O	181	0.053	0.1
P	269	0.434	0.1
Q	283	0.041	0.1
R	12	0.913	0.113
S	7	0.05	0.1
T	9	0.084	0.1
U	11	0.151	0.1
V	4	0.035	0.161
W	1	0.321	0.1
X	2	0.246	0.1
Y	35	0.443	0.1
Z	34	0.029	0.1
AA	33	0.197	0.1
AB	262	0.101	0.1
AC	74	0.435	0.1

Subarea	Subarea Number	Area (km²)	Impervious Fraction
AD	75	0.175	0.1
AE	73	0.431	0.1
AF	25	1.339	0.1
AG	18	0.406	0.1
AH	122	0.238	0.1
AI	3	0.23	0.1
AJ	72	0.037	0.122
AK	77	0.033	0.1
AL	71	0.41	0.101
AM	76	0.181	0.105
AN	81	0.265	0.1
AO	264	0.211	0.1
AP	50	0.163	0.1
AQ	52	0.318	0.103
AR	275	0.252	0.489
AS	276	0.154	0.352
AT	123	0.065	0.252
AU	274	0.177	0.404
AV	279	0.163	0.7
AW	176	0.221	0.1
AX	180	0.15	0.155
AY	55	0.164	0.1
AZ	53	0.059	0.1
BA	60	0.315	0.161
BB	175	0.283	0.1
BC	121	0.186	0.158
BD	59	0.111	0.1
BE	153	0.228	0.1
BF	280	0.237	0.103

Subarea	Subarea Number	Area (km²)	Impervious Fraction
BG	281	0.07	0.1
BH	49	0.288	0.1
BI	63	0.381	0.121
BJ	62	0.481	0.103
BK	270	0.082	0.1
BL	271	0.169	0.1
BM	272	0.212	0.1
BN	282	0.365	0.1
BO	265	0.248	0.1
BP	48	0.338	0.1
BQ	57	0.411	0.1
BR	58	0.02	0.1
BS	80	0.315	0.1
BT	90	0.072	0.1
BU	260	0.176	0.1
BV	261	0.069	0.1

Appendix D

Yarragon Hydrology Model: Reach Table (1 of 2)

Reach Number	Reach Name	Reach Type	Length (km)
101	A-A1	1. Natural	0.113
102	A1-A2	1. Natural	0.456
113	A2-C1	1. Natural	0.572
103	B-B1	1. Natural	0.073
104	B1-B2	1. Natural	0.51
114	B2-C1	1. Natural	0.572
72	C-C1	1. Natural	0.055
71	C1-C2	1. Natural	0.686
69	D-D1	1. Natural	0.406
70	D1-C2	1. Natural	0.632
75	C2-E2	1. Natural	0.188
73	E-E1	1. Natural	0.187
74	E1-E2	1. Natural	0.521
199	E2-AZ3	1. Natural	0.117
198	AZ3-F1	1. Natural	0.13
196	F-F1	1. Natural	0.032
197	F1-F2	1. Natural	0.174
109	F2-H2	1. Natural	0.164
76	G-G1	1. Natural	0.07
77	G1-H2	1. Natural	0.36
55	H-H2	1. Natural	0.028
56	H2-H1	1. Natural	0.076
57	H1-I1	1. Natural	0.069
53	I-I2	1. Natural	0.016
54	I2-I1	1. Natural	0.118
58	I1-O1	1. Natural	0.192
92	J-J1	1. Natural	0.043
201	J1-J3	1. Natural	0.352
202	J3-J2	1. Natural	0.321
93	J2-L1	1. Natural	0.389
90	K-K1	1. Natural	0.102
91	K1-K2	1. Natural	0.28
94	K2-L1	1. Natural	0.376
81	L-L1	1. Natural	0.063
82	L1-L2	1. Natural	0.345
173	L2-M1	2. Excavated but unlined	0.219
140	M-M1	2. Excavated but unlined	0.042
141	M1-N2	2. Excavated but unlined	0.797
138	N-N1	2. Excavated but unlined	0.043
139	N1-N2	2. Excavated but unlined	0.15
171	N2-O2	1. Natural	0.112
49	O-O2	1. Natural	0.039
47	O2-O1	1. Natural	0.082
106	P-P3	1. Natural	0.053
107	P3-P2	1. Natural	0.799
200	P2-P1	1. Natural	0.163
174	P1-Q1	1. Natural	0.253
176	Q-Q1	1. Natural	0.022
175	Q1-Q2	1. Natural	0.213
95	R-R1	1. Natural	0.084
96	R1-R3	1. Natural	1.455
112	R3-Q2	1. Natural	0.077
111	Q2-S2	1. Natural	0.265

Reach Number	Reach Name	Reach Type	Length (km)
51	S-S2	1. Natural	0.046
52	S2-S1	1. Natural	0.142
78	T-T1	1. Natural	0.042
110	T1-T2	1. Natural	0.578
177	T2-S1	1. Natural	0.108
50	S1-O1	1. Natural	0.218
79	U-U1	1. Natural	0.031
108	U1-U2	1. Natural	0.419
80	U2-O1	1. Natural	0.192
48	O1-V2	1. Natural	0.081
46	V-V2	1. Natural	0.051
105	V2-V1	1. Natural	0.31
190	V1-X2	1. Natural	0.521
162	W-W1	1. Natural	0.088
163	W1-W2	1. Natural	0.648
193	W2-X2	1. Natural	0.556
183	X-X2	1. Natural	0.124
188	X2-X1	1. Natural	0.415
185	X1-AJ2	1. Natural	0.02
64	Y-Y2	1. Natural	0.077
65	Y2-Y1	1. Natural	1.009
66	Y1-Z1	1. Natural	0.259
59	Z-Z1	1. Natural	0.029
62	Z1-Z2	1. Natural	0.174
63	Z2-AB1	1. Natural	0.338
60	AA-AA1	1. Natural	0.043
61	AA1-AB1	1. Natural	0.397
41	AB-AB1	1. Natural	0.063
42	AB1-AB2	1. Natural	0.171
43	AB2-AC2	1. Natural	0.325
178	AC-AC2	1. Natural	0.088
179	AC2-AC1	1. Natural	0.642
67	AD-AD2	1. Natural	0.041
68	AD2-AD1	1. Natural	0.489
187	AD1-AC1	1. Natural	0.055
206	AC1-AE3	1. Natural	0.423
207	AE3-AE2	1. Natural	0.105
180	AE-AE2	1. Natural	0.127
189	AE2-AE1	1. Natural	0.534
192	AE1-AJ2	1. Natural	0.124
99	AF-AF1	1. Natural	0.146
100	AF1-AF2	1. Natural	1.271
115	AF2-AG3	1. Natural	1.438
3	AG-AG3	1. Natural	0.038
97	AG3-AG2	1. Natural	1.157
208	AG2-AG1	1. Natural	0.506
191	AG1-AJ2	1. Natural	0.128
184	AH-AH2	1. Natural	0.073
210	AH2-AH3	1. Natural	0.35
209	AH3-AH1	1. Natural	0.527
44	AH1-AI1	1. Natural	0.062
45	AI-AI3	1. Natural	0.07
211	AI3-AI2	1. Natural	0.558

Appendix D

Yarragon Hydrology Model: Reach Table (2 of 2)

Reach Number	Reach Name	Reach Type	Length (km)
212	AI2-AI1	1. Natural	0.345
186	AI1-AJ2	1. Natural	0.121
181	AJ-AJ1	1. Natural	0.034
182	AJ1-AJ2	1. Natural	0.119
128	AJ2-AK1	1. Natural	0.263
1	AK-AK1	1. Natural	0.038
167	AK1-AM1	1. Natural	0.346
2	AL-AL2	1. Natural	0.042
127	AL2-AL1	1. Natural	0.826
168	AL1-AM1	1. Natural	0.176
166	AM-AM2	1. Natural	0.035
169	AM2-AM1	1. Natural	0.21
170	AM1-AO1	1. Natural	0.14
4	AN-AN2	1. Natural	0.101
5	AN2-AN1	1. Natural	0.247
137	AN1-AO1	1. Natural	0.52
7	AO-AO1	1. Natural	0.048
6	AO1-AO2	1. Natural	0.401
85	AP-AP2	1. Natural	0.041
86	AP2-AP1	1. Natural	0.378
149	AP1-AR1	2. Excavated but unlined	0.219
83	AQ-AQ2	1. Natural	0.062
84	AQ2-AQ1	1. Natural	0.425
150	AQ1-AR1	2. Excavated but unlined	0.467
148	AR-AR1	1. Natural	0.047
151	AR1-AR2	2. Excavated but unlined	0.364
156	AR2-AS2	2. Excavated but unlined	0.119
155	AS-AS2	2. Excavated but unlined	0.049
157	AS2-AS1	2. Excavated but unlined	0.22
194	AT-AT2	1. Natural	0.043
195	AT2-AT1	1. Natural	0.119
153	AT1-AU1	2. Excavated but unlined	0.23
152	AU-AU1	1. Natural	0.085
154	AU1-AU2	2. Excavated but unlined	0.306
158	AU2-AS1	2. Excavated but unlined	0.165
161	AS1-AV2	2. Excavated but unlined	0.219
142	AV-AV1	2. Excavated but unlined	0.038
159	AV1-AV2	2. Excavated but unlined	0.137
160	AV2-AW2	1. Natural	0.438
23	AW-AW2	1. Natural	0.038
24	AW2-AW1	1. Natural	0.443
25	AW1-BB1	1. Natural	0.089
36	AX-AX2	1. Natural	0.043
37	AX2-AX1	1. Natural	0.153
38	AX1-AY1	1. Natural	0.216
39	AY-AY1	1. Natural	0.105
40	AY1-AZ1	1. Natural	0.209
34	AZ-AZ1	1. Natural	0.061
35	AZ1-AZ2	1. Natural	0.177
89	AZ2-BA1	1. Natural	0.638
20	BA-BA1	1. Natural	0.061
21	BA1-BA2	1. Natural	0.648
22	BA2-BB1	1. Natural	0.089
15	BB-BB1	1. Natural	0.093

Reach Number	Reach Name	Reach Type	Length (km)
16	BB1-BB2	1. Natural	0.66
17	BB2-BE2	1. Natural	0.125
26	BC-BC1	1. Natural	0.049
27	BC1-BC2	1. Natural	0.279
28	BC2-BD2	1. Natural	0.186
29	BD-BD1	1. Natural	0.124
30	BD1-BD2	1. Natural	0.401
31	BD2-BE3	1. Natural	0.455
33	BE-BE3	1. Natural	0.075
32	BE3-BE2	1. Natural	0.249
143	BF-BF1	1. Natural	0.05
203	BF1-BF3	1. Natural	0.339
204	BF3-BF2	1. Natural	0.148
145	BF2-BG2	1. Natural	0.443
144	BG-BG2	1. Natural	0.053
146	BG2-BG1	1. Natural	0.324
147	BG1-BI2	1. Natural	0.228
116	BH-BH2	1. Natural	0.123
205	BH2-BH3	1. Natural	0.056
117	BH3-BH1	1. Natural	0.816
118	BH1-BI2	1. Natural	0.299
87	BI-BI2	1. Natural	0.08
88	BI2-BI1	1. Natural	0.84
172	BI1-BJ1	1. Natural	0.831
164	BJ-BJ1	1. Natural	0.207
19	BJ1-BJ2	1. Natural	0.785
18	BJ2-BE1	1. Natural	0.054
131	BK-BK1	1. Natural	0.022
132	BK1-BK2	1. Natural	0.48
213	BK2-BL2	1. Natural	0.074
129	BL-BL1	1. Natural	0.058
130	BL1-BL2	1. Natural	0.264
134	BL2-BM2	1. Natural	0.56
133	BM-BM2	1. Natural	0.013
135	BM2-BM1	1. Natural	0.204
136	BM1-BN2	1. Natural	0.486
165	BN-BN2	1. Natural	0.078
98	BN2-BN1	1. Natural	0.559
11	BN1-BO1	1. Natural	0.4
10	BO-BO1	1. Natural	0.119
119	BP-BP2	1. Natural	0.058
121	BP2-BP1	1. Natural	0.962
125	BP1-BR1	1. Natural	0.052
120	BQ-BQ2	1. Natural	0.072
122	BQ2-BQ1	1. Natural	0.836
123	BQ1-BR1	1. Natural	0.089
124	BR-BR1	1. Natural	0.06
126	BR1-BR2	1. Natural	0.098
8	BS-BS1	1. Natural	0.121
9	BS1-BS2	1. Natural	0.367
12	BT-BT1	1. Natural	0.076
13	BU-BU1	1. Natural	0.313
14	BV-BV1	1. Natural	0.076