Appendix B – Hydraulic modelling summary report

Gawler and Surrounds Stormwater Management Plan

Hydrologic and Hydraulic Modelling Report

Town of Gawler, Light Regional Council, Barossa Council

June 2018

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Document History and Status

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1 Introduction

1.1 Study area

This report is concerned with the preparation of a 2D hydrodynamic model of the Gawler township and surrounding areas relevant to the preparation of the Gawler and Surrounds Stormwater Management Plan (SMP). The study area is presented in Figure 1.1.

The primary purpose of the work undertaken has been to define the extent and magnitude of flooding during events of differing annual exceedance probability (AEP) and to identify areas of significant inundation relevant to the preparation of the SMP. The risk to public safety, otherwise known as the 'flood hazard' has also been categorised for some of the flood events investigated.

1.2 Scope of works

The general scope of works for the study was to determine the extent of flood inundation during various flood events within the Gawler urban areas and surrounding rural living zones, including the Gawler Belt. The project included the following tasks:

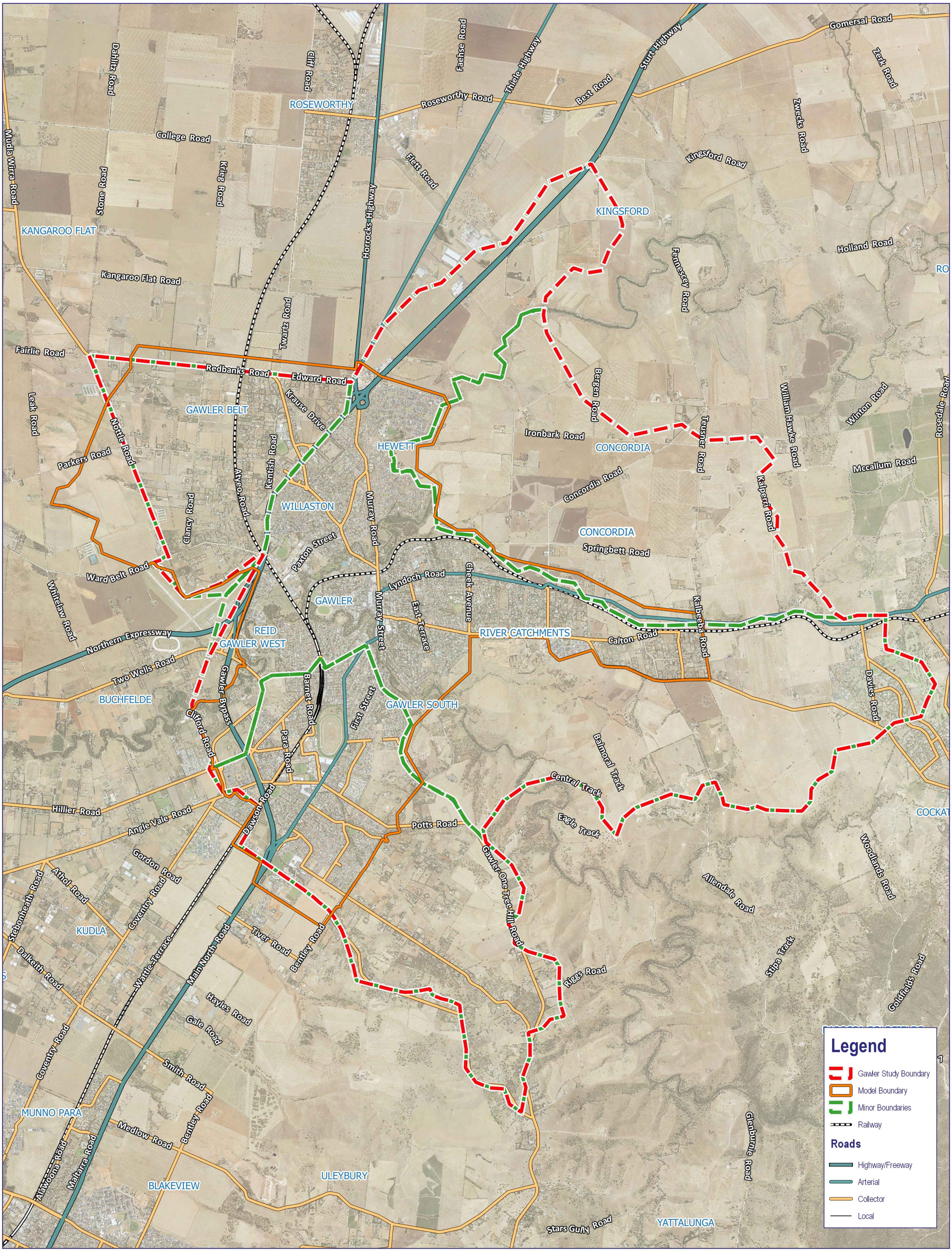
- Hydrological modelling of external inflows.
- Obtaining details of the hydraulic structures, including underground pipe systems and flood detention basins.
- Obtaining an accurate digital elevation model (DEM) across the study area.
- Preparing a combined 1D–2D hydrodynamic computer model of the study area based on the existing and long-term levels of development,.
- Analysing the resulting flooding for the following storm events:
  - 20% AEP storm event
  - 5% AEP storm event
  - 1% AEP storm event
  - 0.2% AEP storm event
- Alter the long-term model to include proposed mitigation measures.
- Producing flood inundation and hazard zone maps for various specified flood events within the study area.
- Issuing a modelling report and associated flood maps.

1.3 Study tasks

The project tasks consisted of the following:

- Topographic information
  - Obtain DEM data across the study area.
  - Modify DEM data where necessary to reproduce known flooding behaviour.
- Hydrological modelling
  - Delineating sub-catchments internal and external to the hydraulic model extents.
  - Obtaining approvals for the methodology to produce hydrographs for all events.
  - Determine sub-catchment properties, such as impervious surface coverage and response time for various development scenarios.

  - Prepare hydrographs for input to the hydraulic model from both internal and external catchments.
- Hydraulic modelling
  - Collating hydraulic structure data (inverts and dimensions) and infilling missing data.
  - Developing a TUFLOW model of the study area.
  - Conducting initial model runs and resolving any stability issues.
  - Review and validate model outputs.
  - Conducting final model runs.
- Flood mapping
  - Creating flood inundation maps.
  - Creating flood hazard maps.



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Aerial Imagery from Metromap, 2017
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Town of Gawler, Light Regional Council and The Barossa Council

STUDY AREA AND MODEL BOUNDARY

Figure 1.1

2 Hydrologic modelling

2.1 Overview

The hydrologic modelling aims to determine the rate of runoff given a particular rate of rainfall. This information is then applied to the hydraulic model which dynamically models the path of runoff through the study area.

The hydrologic modelling for this study involves determining runoff from local, predominantly urban catchments, and from external, predominantly rural catchments. For local catchments a Time-Area method was applied to create hydrographs for each sub-catchment. For external catchments runoff-routing models were developed to produce inflow hydrographs at the boundary of the hydraulic model.

All components of the hydrological modelling were assessed and approved by the Steering Committee prior to flood modelling being undertaken.

A full discussion of the hydrology applied in this study can be found in the *Hydrology Discussion Paper* (Appendix A).

2.2 Catchment description

The catchment is mostly urban with some rural living and hills face areas. The topography is relatively steep and dominated by the North Para and South Para rivers which join to form the Gawler River.

There is a well-documented history of issues caused by flooding from the main rivers, but little has been recorded about flooding urban centre and surrounding rural living areas.

2.3 Parameters used in hydrologic modelling

Development of the hydrologic parameter values is discussed in the *Hydrology Discussion Paper* (Appendix A). Hydrologic parameters for the long term development scenario are discussed in a second discussion paper (Appendix B).

3 Two dimensional hydraulic modelling

3.1 Introduction

Hydraulic modelling uses the outputs of hydrologic modelling to determine the extent, depth and behaviour of flood flows within the study area. The resulting outputs provide an estimate of areas subject to flooding.

A detailed 1D–2D flood model was created for this study. The model was run to simulate storm events within the study area and generate flood inundation and hazard maps for the existing level of development an agreed predicted future development scenario.

3.2 Modelling software

The modelling was carried out using the TUFLOW computer program. The program simulates depth averaged, two and one-dimensional, free surface flows.

TUFLOW has the ability to dynamically link to the 1D model ESTRY, which enables the creation of models containing both 1D and 2D domains. The TUFLOW simulation engine is based on a finite difference, alternating direction implicit (ADI) scheme that solves the full 2D free surface flow equations. The ESTRY component is based on a numerical solution of the unsteady momentum and continuity fluid flow equations.

TUFLOW was initially developed to model tidal estuaries. However, Tonkin Consulting assisted in pioneering the use of TUFLOW for urban flood inundation mapping. The drainage network is modelled in 1D and dynamically linked at each inlet/outlet structure to the floodplain represented in 2D. This allows for the integrated modelling of the drainage network and floodplain.

3.3 Digital elevation model

A digital elevation model (DEM) of the study area was prepared by AAM Pty Ltd using data captured by LiDAR in May 2015. LiDAR is a remote sensing method that uses laser pulses to measure the distance to features in the terrain. The laser pulses are obtained and processed to create a 3D model of the landscape.

Tonkin Consulting reviewed the DEM to ensure it was free of major errors. This review found some issues around bridge structures, which were fixed before the DEM was used for modelling.

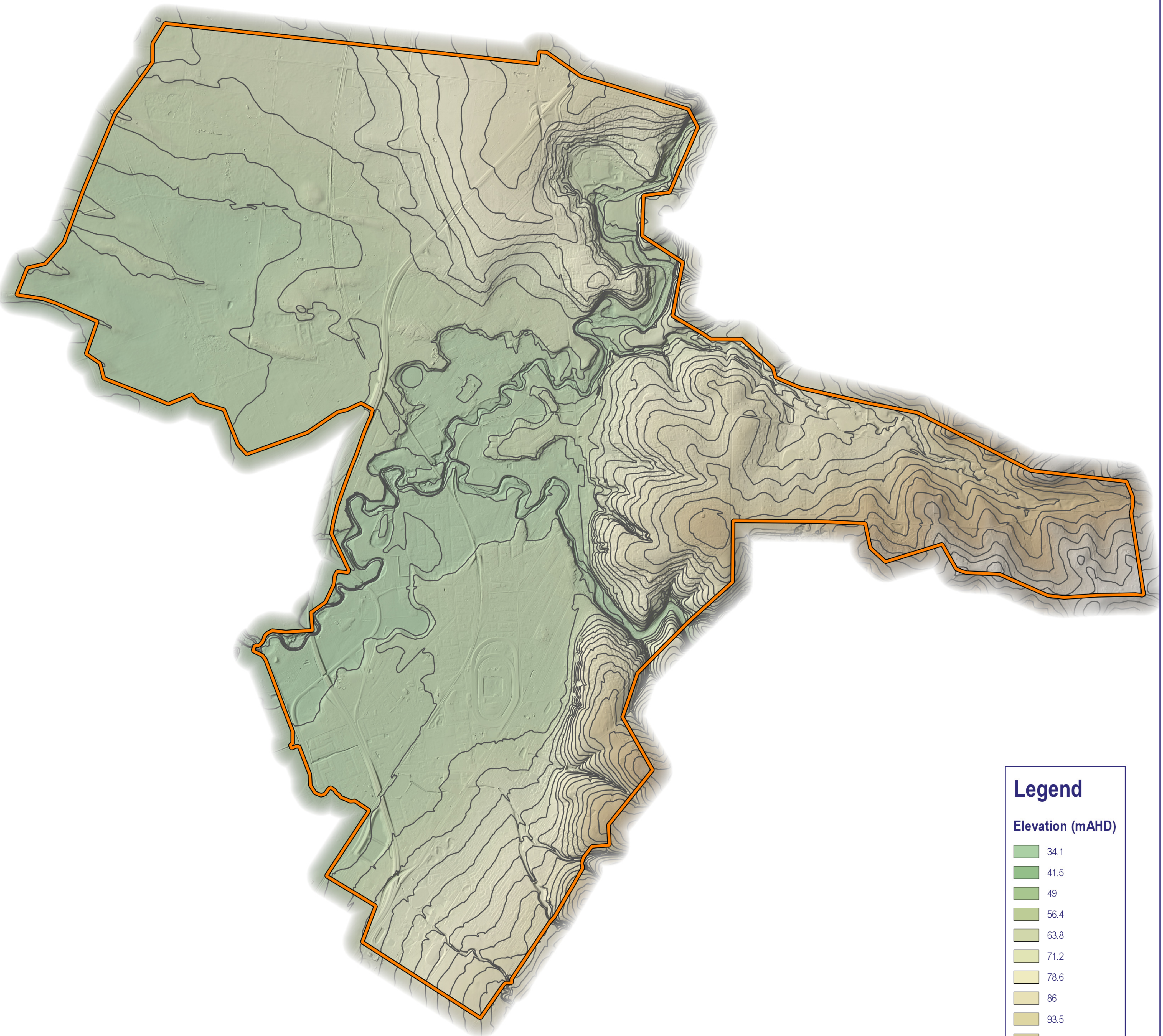
The full DEM obtained (before modification) is presented in Figure 3.1

3.4 TUFLOW model setup

3.4.1 Computational grid cell size

Determining an appropriate cell size for the computation grid used by TUFLOW requires a compromise between the resolution of flood mapping and the simulation time and memory required to run the models. Smaller 2D cell sizes more accurately reproduce detailed topography and the hydraulic behaviour, but significantly increase the amount of memory and computational power required to run the model. An understanding of the specific requirements for each study is needed in order to select an appropriate 2D cell size.

A cell size of 4 m is considered by Tonkin Consulting as a good compromise between resolution and computational power and has been used for many studies previously undertaken by Tonkin Consulting. A cell size of 4 m was considered suitable to adequately represent the hydraulic behaviour of the rural areas and surface flood flows within the urban street network.



Legend

Elevation (mAHD)

- 34.1
- 41.5
- 49
- 56.4
- 63.8
- 71.2
- 78.6
- 86
- 93.5
- 101
- 108
- 116
- 123
- 131
- 138
- 145
- 153
- 160
- 168
- 175

500 0 500 1000 1500 m

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Digital Elevation Model provided by AAM, 2015

Town of Gawler, Light Regional Council and The Barossa Council

DIGITAL ELEVATION MODEL

Figure 3.1

3.4.2 Computational time step

The selection of an appropriate time step for the 2D domain of TUFLOW is critically important to the accuracy of the model output. Time steps that are too large may result in overestimation of the derivatives within the model which decreases the numerical accuracy of the computations. The choice of a smaller time step helps prevent numerical diffusion but increases the simulation time of models. An appropriate time step will balance simulation time with the model's stability and numerical accuracy.

For this study, a time step of 1 second was adopted for the 2D domain. This achieved an acceptable balanced between simulation time and stability of the model results.

Ninety nine percent of computational effort is expended solving the 2D surface flow equations and very little effort is needed to resolve the 1D domain. Consequently, the 1D domain time step has a negligible impact on simulation times. A time step of 0.1 seconds was used for the 1D domain.

3.5 Boundary and initial conditions

3.5.1 Outflow boundary conditions

Where water interacts with the boundaries of the model, special attention is required to ensure the correct hydraulic conditions at the boundary are recreated.

Where shallow sheet flow was expected to reach a model boundary, the boundary condition at that location was set to allow flow to freely leave the model. For channelised flows, the boundary condition was set to represent the hydraulic conditions downstream using an automatically generated, stage–discharge relationship based on the topography and expected hydraulic grade at that location.

For this model there were few boundaries that required special attention. South of the Gawler Bypass, the study area is highly incised by water courses which drain into the main river channels. Consequently, only the Gawler River channel crosses the downstream boundary of the model. This boundary was assigned an automatically generated, stage–discharge relationship based on the expected hydraulic grade. Of note is that this boundary is so removed from any of the drainage infrastructure that its effects on flood behaviour are negligible. North of the Gawler Bypass, in the Gawler Belt area, the landscape falls to an obvious low spot and there are no deep channelised outflow locations, therefore, sheet flow boundary conditions were set.

3.5.2 Inflow boundary conditions

Inflow hydrographs were generated for each AEP and duration of storm event analysed, as outlined in *Hydrology Discussion Paper* (refer Appendix A). The inflows for each sub-catchment were applied to each inlet pit, grate, or headwall throughout the catchment. Inlet capacity tables were used to provide an approximate inlet capacity for each inlet type. This allowed the inflows to pass directly into the drainage network until the pit or pipe capacity was exceeded, with the excess spilling into the street network (2D floodplain).

Where no drainage infrastructure was present within the sub -catchment (i.e. creek channels, basins, wetlands and the north-western agricultural areas), the inflow was applied directly over regions of the 2D model surface. Flow is initially applied to the lowest grid cell in the region. As the flood level increases the inflow is distributed over the flooded area.

Inflow hydrographs for the creeks along the upstream boundary of the study area were extracted from the RORB models (see Section 3.6).

3.5.3 Initial conditions

The catchment was assumed to be “dry” before the onset of rainfall. Consequently, it was not necessary to apply any initial conditions to the model.

3.6 Existing stormwater drainage infrastructure

3.6.1 Modelling of the pipe network

The drainage network consists mostly of underground drainage network discharging directly to the North Para, South Para or Gawler rivers. There are also a number of wetlands and detention basins within the drainage network, as well as a few major flood protection basins on the upper slopes of the catchment.

Base drainage infrastructure data (conduits and inlet structures) was provided by each of the three Councils. This data was extensively reviewed and updated to correct obvious errors.

Where previously unidentified drains were added or there were uncertainties within the drainage database, locations and sizes were discussed with Council and either confirmed on site or taken from design drawings.

Invert elevations for the underground drainage were absent from the Light Regional Council (LRC) and Barossa Council's GIS data. Invert elevations for these Council areas were instead assumed based on the surface level of the DEM and dimensions of the pipe.

In the Gawler Council area, many drainage pits had depth measurements which allowed some pipe networks to be assigned invert elevations with greater certainty. Gaps in the depth data were filled in the same manner as the LRC and Barossa Council areas. The final assigned inverts for all pipes were then reviewed and manipulated to ensure all drainage networks graded downhill.

In addition to the above, the drainage network was checked as follows:

- Pipe diameters and box culvert sizes were reviewed to check for consistency with standard dimensions and to ensure that sizes generally increased in the downstream direction.
- Checks were carried out to ensure all drains were digitised in the downstream direction. For flood modelling it is preferable that drains be drawn in the downstream direction, so that flow results are positive in the downstream direction.
- Checks were made to ensure connectivity of the drainage network.

The review and modifications resulted in a greatly improved GIS database of drainage infrastructure for the study area, and allowed the development of a TUFLOW model to represent the drainage infrastructure to an appropriate level of accuracy for the flood mapping study.

Department of Transport drawings were sourced to better model the drainage of the Gawler Bypass, Northern Expressway, and Sturt Highway. Of particular importance was the proper representation of the large culvert that leads from Trinity College beneath the Gawler Bypass to the Dawson Road detention basins.

3.6.2 Modelling of the inlet pits

Inlet pits were modelled using head-flow relationships to provide a good estimate of the inlet capacity of each pit. Different curves were created for single, double and triple side entry pits (SEPs) as well as 900×900 and 450×450 grated inlet pits (GIPs).

3.6.3 Modelling of open channels

There are a number open channels across the study area. While the larger of these channels can be adequately represented within the 2D model domain, the smaller channels were modelled as 1D channel structures with cross section data to ensure they were represented accurately within the TUFLOW model.

Particular attention was given to the Clifford Road outfall channel and the unnamed creek channel passing under Main North Road near the Gawler Park shopping complex.

3.6.4 Gutter flows

While the grid cell size was demonstrated to provide sufficient detail to model the urban environment in the flatter areas, errors were identified in the steeper regions of the model area. It was found that where roads ran across the slope, the model resolution was not sufficient to accurately represent the kerb profile. This resulted in flow travelling downhill rather than travelling along the road kerb. To counteract this, the cells on the lower side of the roads in the affected areas were artificially raised to approximately 0.15 m above the closest road level. This pushed low flows along the road kerbs and allowed for the kerb capacity to be appropriately represented in the model.

3.6.5 Allowance for blockages

During large storm events, objects could be swept into inlet pits, headwalls and creek channels, exacerbating flooding in the local area. Siltation could also reduce the capacity of the stormwater network exacerbating flooding in the local area. Due to the broad scale objective of this flood study, no specific allowance has been made to account for blockages that may occur during storm events.

3.7 Future drainage infrastructure

After the existing and long-term development scenarios were completed a set of mitigations measures were devised to reduce flood inundation in the modelled area. After initial assessments of effectiveness, selected mitigation measures were added to a modified version of the TUFLOW model.

3.8 Bed resistance

The TUFLOW model requires bed resistance be specified by the modeller. In this model a GIS layer of Manning's n roughness coefficients is used to define the bed resistance. The bed resistance is the primary determinant of water depth within the 2D model domain.

Roughness values in urban areas were based on cadastral information and aerial photography. Buildings were modelled using high bed resistance values applied to residential and commercial areas.

The Manning's n roughness coefficients used in this model are listed in Table 3.1. These values were selected based on current literature and the prior experience of Tonkin Consulting.

Table 3.1 Adopted bed resistance parameters

Land Use	Manning's n
Houses/Residential areas, obstructions to flow	0.200
Medium and high density residential and commercial areas	0.300
Parklands with scattered trees	0.045
Grassed areas and bare ground	0.035
Roads (including verges)	0.020
Unlined creek channels	0.040–0.065
Plastic pipes	0.011
Brick-lined conduits	0.019
Concrete pipes and box culverts	0.013

3.9 Modelling uncertainty

While every care has been taken in preparation of the TUFLOW model and the choice of the adopted parameters, all hydrological and hydraulic modelling has an inherent level of uncertainty. This inherent uncertainty is due a number of factors which may include any of the following:

- The accuracy and resolution of the DEM used and the interpretation of this information by the hydraulic model
- Dynamic changes to topography due to erosion or deposition of soil during a flood event; which can lead to changes in the distribution of flow. These processes have not been included in this model.
- Uncertainty in the rainfall pattern and catchment conditions prior to a flood. Actual flood events are dependent on the antecedent moisture conditions prior to rainfall, initial detention storage levels at the beginning of rainfall runoff and the intensity and uniformity of the rainfall event itself. The floods modelled by this study are based on design storm bursts which attempt to reproduce the expected average temporal pattern of a storm burst within specified rainfall zones (see ARR2016 for greater explanation). As such, individual rainfall events may exhibit a differing temporal pattern than those modelled.
- Estimation of input parameters to the model (such as runoff coefficients, time of concentration, Manning's roughness, entry and exit losses, and accuracy of the drainage network provided).

3.10 TUFLOW simulations

3.10.1 Events modelled

Five different flood events were modelled in 2D:

- 20% AEP flood event
- 5% AEP flood event
- 1% AEP flood event
- 0.2% AEP flood event

For each flood event, a number of different storm durations were modelled in order to obtain the peak flood level at different points within the catchment. The durations modelled were:

- 30 minutes
- 1 hour
- 3 hours
- 6 hours
- 9 hours
- 12 hours
- 24 hours

3.10.2 Scenarios modelled

For each set of ARIs and durations above three different scenarios were modelled. A scenario is a combination of hydraulic and hydrologic inputs to the model. The scenarios modelled included:

- Existing infrastructure combined with existing development levels.
- Existing infrastructure combined with predicted long-term development levels.

- Existing infrastructure with proposed modifications and upgrades combined with predicted long-term development levels.

A single long-term post mitigation model was used to reduce the computational expense and duration of the modelling undertaken.

4 One dimensional hydraulic modelling

4.1 Introduction

A DRAINS model of the urban catchments of Gawler was also developed. The model was developed to a standard of accuracy sufficient for broad scale stormwater risk management and planning. The following sections describe how elements of the model were developed.

4.2 Catchments and hydrology

Hydrology parameters and sub-catchment properties were assigned as per the methods outlined in the *Hydrology Discussion Paper* (Appendix A). The only modification was the replacement of three small RORB models with rural catchments within the DRAINS model at the southern end of the model. Losses for these rural catchments were assigned according to Table 4.4 of the *Hydrology Discussion Paper* (Appendix A).

4.3 Drainage network

The layout and attributes of the drainage network were developed from the drainage network prepared for the 2D flood model.

The elements of the DRAINS model were created using the process outlined in the following sections.

4.3.1 Stormwater Inlets

The location and type of inlet was copied from the network prepared for the 2D flood model. "Sag" or "On-grade" classifications were assigned to all pits based on surface contours and the digital elevation model (DEM). All sag pits were assigned a default ponding depth of 0.25 m and a ponding volume of 10 m^3. The surface elevation at inlets was extracted from the DEM.

4.3.2 Junction boxes

Known junction boxes and their properties were copied from Council GIS datasets. The surface elevation at all junction boxes was extracted from the DEM. All pipe junctions modelled with pits or junction boxes were initially assigned a junction loss factor (k_u) of 1.5. The loss factors were then revised iteratively using the QUDM charts implemented in DRAINS.

4.3.3 Junctions and other intersections

Nodes were added at the following locations: at the junction of two pipes (if a pit/junction box was not known to exist at that location); at the outlet of a catchment if there was no associated inlet pit; at the outlet of all drainage branches; and at confluences along open channels and overflow routes. The surface elevation at all nodes was extracted from the DEM.

4.3.4 Headwalls

Headwalls were added at the upstream end of a drainage network if there was no inlet pit. An entry loss factor of 0.5 was adopted for all headwalls. The surface elevation at all headwalls was extracted from the DEM.

4.3.5 Detention basins

A height–storage relationship was determined from the DEM for each detention basin. An entry loss factor of 0.5 was adopted for pipe outlets from basins.

4.4 Overflow routes

Overflow routes were digitised between pits, nodes, headwalls and basins, based on surface contours and the DEM. The length of the routes were assigned from GIS data and the upstream and downstream invert levels were extracted from the DEM. All overflow routes were assigned the “7.5 m roadway with 3% crossfall and barrier kerb” cross-section profile.

The following weir properties were adopted for all overflow routes leaving a headwall or basin:

- crest length of 3 metres,
- weir coefficient of 1.67,
- crest level as appropriate from the DEM.

4.5 Open channels

A number of open channels were selected and modelled as channel elements in DRAINS. All other channels were modelled as overflow routes. The cross section for each channel element was extracted from the DEM at the appropriate location. Where necessary, the depth of the cross section was exaggerated to contain all flows within the channel. The Manning’s roughness coefficient for each channel element was determined from aerial imagery.

5 Modelling results

During each model run, the peak flooding depth and hazard category (20 and 100 year ARI events only) was recorded across the 2D model domain. Once modelling was complete, the results from each duration were spliced together to create a maximum depth and hazard envelope for each flood event modelled.

Flood inundation and hazard maps were produced so that the impact of flooding could be visually analysed. The flood inundation and hazard data was overlaid onto aerial imagery, with the drainage network and street names shown to allow for easy identification and assessment of flooding. The flood depth data was classified into discrete intervals to allow for easy discrimination of flood depths. Flooding less than 25 mm deep is not shown as it is not considered relevant to the wider flood map.

5.1 Model verification

A number of techniques were employed to verify the model implementation. Manual and automated checks of the pipe network to detect connectivity issues in addition to comparison of recorded peak flow against expected pipe capacity (based on size and longitudinal grade) ensured confidence in the correct modelling of the pit and pipe network.

5.2 Validation of results

To help validate the TUFLOW model results, the peak recorded flow rate in key drains was compared with the theoretical capacity of the drains. In the majority of cases, the results compared favourably, providing confidence in the modelling of the underground drainage network. A small number of conduits were found to be incorrectly sized, due to erroneous dimensions recorded in the Council's GIS database. Council staff were tasked with re-measuring these conduits. The updated dimensions were then added to the model.

As discussed in Section 3.6.4 visual inspection of the results showed that gutter flows in steeper areas were poorly modelled. Modifications were made to the DEM to better represent the full capacity of roadside gutters and the flow of surface water along the street network.

Draft flood inundation results were discussed with Council staff to identify areas of unexpected flooding. These locations were then scrutinised to determine the cause of the model output. Modifications to the model were then made where necessary to achieve the historically observed flood behaviour.

Appendix A

Hydrology discussion paper

Gawler and Surrounds Stormwater Management Plan

Hydrology Discussion Paper

Town of Gawler, Light Regional Council, Barossa Council

September 2016

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Appendices

1 Introduction

The following paper provides the methodology and assumptions that will be used for various hydrologic calculations of the Gawler and Surrounds Stormwater Management Plan (SMP).

The intent of this discussion paper is to summarise the reasoning behind selection of parameter values for hydrologic modelling used to generate hydrology inputs to the hydraulic model.

The parameter values proposed relate to three different catchment development scenarios:

1. existing development scenario
2. future development scenario (50 year time horizon)
3. future development scenario with flood mitigation measures

2 Catchment properties

2.1 Boundary delineation

2.1.1 Urban areas

Sub-catchment delineation of urban areas will be performed manually using the following information for guidance:

- the digital elevation model (DEM) of the area
- contours derived from the DEM
- aerial photography
- GIS data including property boundaries (cadastre), road network, and stormwater inlets

At least one sub-catchment will be delineated for each inlet pit within the urban areas. Large sub-catchments will be divided into smaller sub-catchments to allow better representation of pluvial flooding in the street network.

2.1.2 Rural areas

Delineation of rural areas will be performed automatically using software. Adjustments to the automatically generated catchments will be made manually where required.

2.1.3 Hills face

Sub-catchment delineation of Hills face areas will be performed manually using the following information for guidance:

- the DEM of the area (where possible)
- contours derived from the DEM
- 1:50,000 scale topographic maps (in areas not covered by the DEM)

Catchments will be subdivided following the appropriate procedures outlined by the RORB manual. Particular attention will be applied to ensuring that sub-catchment areas are between 5% and 25% of the total catchment area, and that reaches are less than one third of the total length of the main stream.

2.2 Imperviousness

2.2.1 Existing development scenario

Imperviousness of the Study Area is predominantly characterised by residential development of varying density. As such, the estimation of catchment runoff will be most sensitive to the adopted imperviousness of the residential areas. Therefore, it is essential to estimate the impervious fraction of residential areas as accurately as possible.

The ILSAX hydrologic model splits the total impervious area (TIA) into directly and indirectly connected sub-types. Acceptable estimates of TIA can be made from inspection of aerial imagery, but estimating the proportion of directly connected impervious area (DCIA) can be difficult due to complicating factors. For residential areas in particular, the age of the development (more recent development is commonly required to be connected to the street), the presence of rainwater tanks (which frequently overflow to pervious land), the visibility of downpipes (limiting visual assessment of "connectedness"), and the presence of rear-of-allotment drains (which may or may not be utilised by the land owner) all contribute to the "connectedness" of impervious area.

To assist determination of the catchment properties Tonkin Consulting have selected several land-use types that are representative of the variation in imperviousness within the Study Area. This simplifies the process of specifying the relationship between TIA and DCIA. The land-use types are listed in Table 2.1. It was determined that only the residential land uses warranted special investigation of DCIA (see below for discussion). Other land uses were assigned DCIA proportions consistent with previous studies.

Table 2.1 Existing development scenario impervious area proportions

Land use type	Directly connected	Indirectly connected
Residential areas (medium density, recently developed)	0.60	0.05
Residential areas (low density, not recently developed)	0.25	0.10
Rural residential	0.00	0.10
Commercial	0.75	0.02
Industrial	0.75	0.02
Government Institutions	0.30	0.10
Education Institutions	0.20	0.18
Public Institutions	0.30	0.10
Open land	0.01	0.05
Road reserve	0.55	0.15

For each sub-catchment, the proportion of directly and indirectly connected impervious area will be calculated using a weighted average (by area) based on the land use types within a catchment. Some calculated proportions will be overridden based on visual inspection to properly represent the expected hydrological response of a sub catchment.

Special investigation of TIA for residential land-use types

To determine average TIA for residential areas, the impervious area of several sample sites was mapped (a similar process to that used in ARR Revision Project 6 (Phillips et al., 2014)). Appendix B shows the nine sample sites and the mapped impervious areas. The mapping of impervious area provided an estimate of average TIA for areas of different residential development density. A site survey was conducted to assess the connectedness of each sample site. The site survey determined the number of the properties directly connected to the street kerb. The proportion of properties with direct connection provides an indication of the DCIA for the sample sites. For medium density residential areas, average connectivity was 100%, whilst for low density areas, average connectivity was 75%. Rural residential areas were determined to have no direct connection to street kerbs. These proportions were then used to split TIA between directly and indirectly connected impervious area. The final adopted split between directly and indirectly connected impervious area is listed in Table 2.1.

2.2.2 Future development scenario

Changes to catchment imperviousness will be determined in discussion with the Steering Committee. Recommendations for parameter values will be made after reviewing the existing scenario results.

2.3 Time of concentration

2.3.1 Urban areas

The time of concentration for each sub catchment in the urban areas will be calculated within MapInfo (a GIS software) based on the following information:

- The distance between the inlet pit receiving runoff and the most distant vertex of the digitised sub-catchment boundary from that pit.
- The change in elevation between the two aforementioned points.

During past flood studies conducted by Tonkin Consulting it was noted that the actual flow path is on average 10% longer than a direct line between the most distant vertex and the receiving inlet. Therefore, the automatically determined flow path length will be multiplied by a factor of 1.1 to account for this difference.

The flow path slope will be calculated by dividing the change in elevation across the catchment by the modified length of the flow path. A minimum slope of 0.2% is applied if the catchment slope is calculated to be less than this amount to prevent excessively large times and to represent likely minimum road grades.

In addition to the gutter-flow time, an allowance of 5 minutes for roof-to-gutter travel time for residential sub-catchments (or 10 minutes for commercial/industrial) will be included as recommended in *Stormwater Drainage Design in Small Urban Catchments: A Handbook for Australian Practice* (Argue, 1986).

Thus, the equation to calculate time of concentration will be as follows:

$$Time\ of\ Concentration\ (mins) = \frac{1.1 \times Flow\ path\ length\ (m)}{39.6 \times \sqrt{Max[Flow\ path\ slope\ (\%), 0.2\%]}} + (5\ or\ 10\ mins)$$

For urban areas, the pervious area time of concentration will be calculated as the impervious area time of concentration plus 15 minutes.

2.3.2 Rural areas

For rural areas, a combination of sheet-flow time (determined by the Kinematic Wave equation) and the overland flow travel time will be used to determine a time of concentration for the pervious areas of each rural sub-catchment.

3 Rainfall estimation

3.1 Rainfall depth and intensity

This section describes the methodology to determine rainfall depth for each storm event. It is assumed that the Annual Exceedance Probability (AEP) of a storm event is preserved and the resulting flood event has an equal AEP.

The following terminology is used:

- Frequent events: events with an AEP greater than or equal to 1%
- Rare events: events with an AEP less than 1% and greater than or equal to 0.05%
- Extreme events: events with an AEP less than 0.05%

All parameters apply to a point nearest to the Study Area centroid as is possible for each data set.

3.1.1 Frequent events

Frequent event design rainfall will be determined from Intensity–Frequency–Duration (IFD) data updated in 2013. The rainfall depths will be sourced from the Australian Bureau of Meteorology (BoM) website.

3.1.2 Rare events

For rare events, point rainfall sourced from the BoM will be used for storm durations greater than 24 hours. For durations less than 24 hours the growth factors listed in ARR2016 will be used to extrapolate the 1% AEP rainfalls. As this study is only considering the 0.2% AEP rare event, a growth factor of 1.344 will be used (refer Book 8, Section 3.6.3, ARR2016).

3.2 Temporal distribution

3.2.1 Frequent events

Temporal patterns for frequent events will be sourced from AR&R 1987. Zone 6 temporal patterns will be used.

3.2.2 Rare events

The 0.2% AEP (500 year ARI) event will use temporal patterns tabled in the Bureau of Meteorology's Generalised Southeast Australia Method (GSAM) (Bureau of Meteorology, 2006) and General Short Duration Method (GSDM) (Bureau of Meteorology, 2003).

Storms with durations less than or equal to 3 hours will use the GSDM temporal pattern. Storms with durations greater than 3 hours will use the GSAM temporal patterns.

3.3 Spatial distribution

Due to the size of the Study Area, a uniform spatial pattern will be used for all events.

4 Runoff estimation

4.1 Urban and rural areas

Hydrographs will be created using the Time–Area method and the ILSAX hydrological model. The ILSAX hydrological model splits each sub catchment into three sub areas: directly and indirectly connected impervious area, and pervious area. The pervious area losses will be based on an Initial Loss – Continuing Loss model.

Different initial loss values will be used for rural and urban areas.

The initial and continuing losses will be varied depending on the type of event.

4.1.1 Frequent event losses

The rainfall loss parameters proposed are set out Table 4.1. A higher initial loss is used in the urban areas to account for additional losses incurred by urban features, such as fences, that retain water within the catchment. These values match those recommended by ARR 2016 and Kemp & Lipp (2013).

Table 4.1 Loss parameters used for frequent events

Parameter	Unit	Value
Impervious area depression storage	mm	1
Urban pervious area depression storage (equivalent to an initial loss)	mm	45
Rural pervious area depression storage (equivalent to an initial loss)	mm	30
Pervious area continuing loss	mm/hr	3

4.1.2 Rare event losses

The rainfall loss parameters proposed are set out in Table 4.2 were logarithmically interpolated in accordance with procedures in AR&R to provide a smooth transition between frequent and extreme events (refer section 3.1). The interpolation is based on Equation 7 of Book VI (p34) within AR&R (updated in 1998).

Table 4.2 Loss parameters used for the 0.2% AEP event

Parameter	Unit	Value
Impervious area depression storage	mm	1
Urban pervious area depression storage (equivalent to an initial loss)	mm	15.5
Rural pervious area depression storage (equivalent to an initial loss)	mm	11.1
Pervious area continuing loss	mm/hr	2.5

4.1.3 Extreme event losses

The rainfall loss parameters in Table 4.3 are provided for reference only. The values in Table 4.3 represent the lower bound for interpolation of the rare event losses (refer section 4.1.2).

Table 4.3 Loss parameters used for extreme events

Parameter	Unit	Value
Impervious area depression storage	mm	1
Urban and rural pervious area depression storage (equivalent to an initial loss)	mm	0
Pervious area continuing loss	mm/hr	1

4.2 Hills face catchments

Hydrographs for (external) Hills face catchments will be generated using RORB models and will be applied at the upstream boundary of the 2D hydraulic model. The Initial Loss – Continuing Loss model will be used to generate subarea runoff.

The following parameter values for the RORB model have been selected to be consistent with those of the *Dry Creek Floodplain Mapping Study* (Tonkin Consulting, 2008). The parameters of that study were based on calibration against gauged values. The hydrology report that was prepared received the approval of the AMLR NRM Board, the City of Salisbury, the Bureau of Meteorology and the Department of Planning, Transport and Infrastructure. Use of the same parameters is considered to be appropriate given the similar topography of the two areas.

4.2.1 Hills face losses

A continuing loss between 1 mm/hr and 3 mm/hr is proposed depending on the probability of the storm event. The initial loss will be varied depending on the probability of the storm. The proposed losses are tabled below.

Table 4.4 Loss parameters for RORB models

Event Type	AEP	ARI (years)	Initial loss (mm)	Continuing loss (mm/hr)
Frequent	≤ 5%	20	25	3
Frequent	2%	50	30	3
Frequent	1%	100	40	3
Rare	0.2%	500	20*	2.5
Extreme	*10^{-4}*	*PMF*	*0*	*1.0*

*Selected in discussion with the SMA

The PMF values are shown for reference only; they are used to interpolate the parameter values of the 0.2% AEP event.

4.2.2 RORB modelling parameters

The routing in RORB is based on two parameters – the non-linearity exponent, m, and the routing parameter, k_c.

The k_c value for each catchment will be derived using Equation 3.25 from AR&R (as follows):

$$k_c = 0.6A^{0.67}$$

This equation applies to the south eastern area of South Australia and provides a value of k_c for catchments with an area less than 100 km^2.

Calibration guidance in AR&R suggests that m should be held constant at 0.8, whilst k_c is varied, unless there is good data to suggest another value of m is more appropriate. Since the local Gawler catchments are ungauged it is considered that there is no evidence to available to suggest an alternative value. Therefore, a value of 0.8 for the non-linearity exponent is recommended for this project.

4.3 Gawler, North Para and South Para rivers

Inundation due to riverine flooding in the Gawler, North Para or South Para rivers is not within the scope of the Stormwater Management Plan. Local drainage systems will be modelled discharging to these river systems, however, no hydrologic inputs from these rivers will be included in the hydraulic modelling.

5 Bibliography

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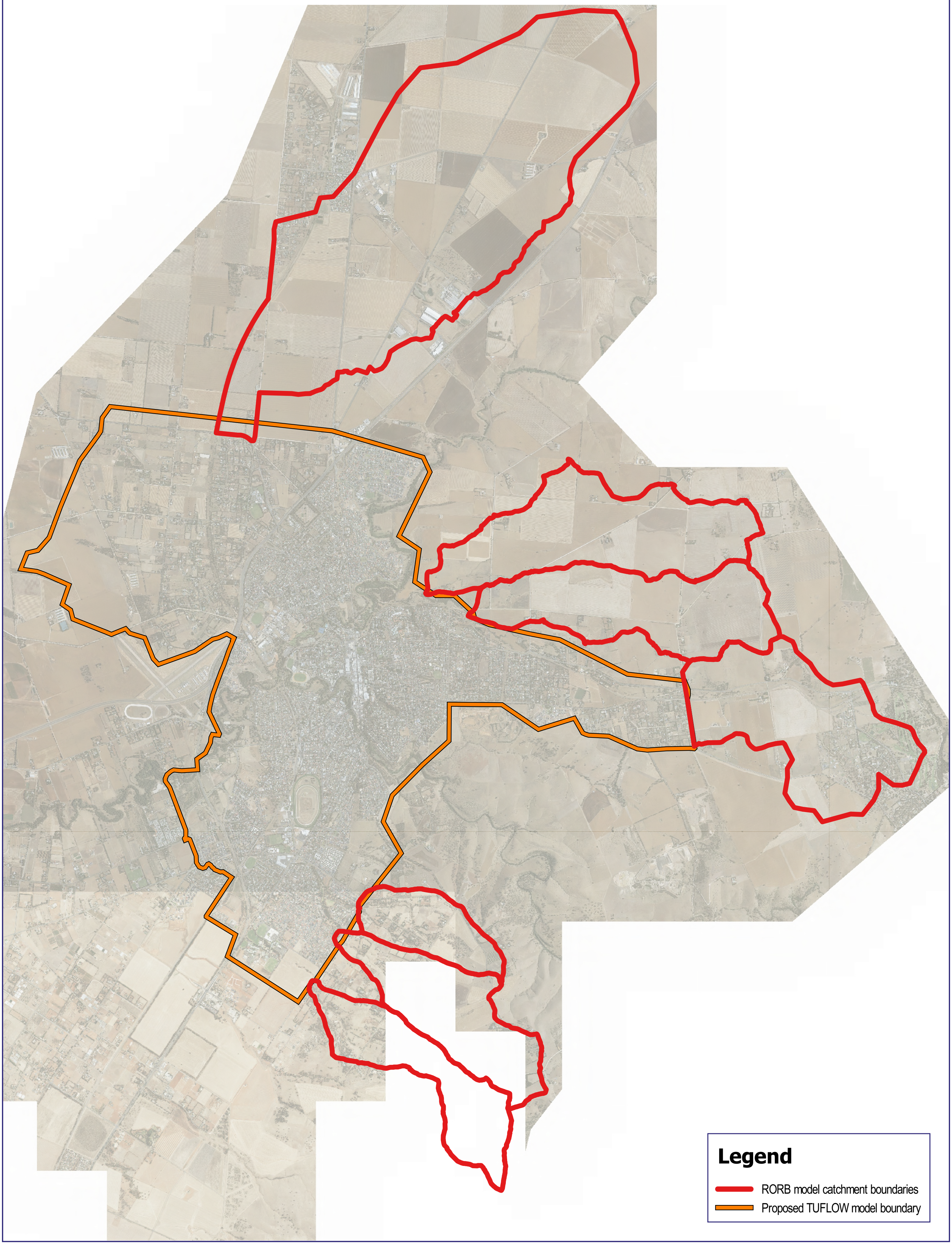
Appendix A

RORB model areas



Job Number: 2014.1387
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Revision: A
Date: June 2016
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Data Acknowledgement:
Various orthophotos from Aerometrex - combined by Tonkin Consulting and used with permission of Town of Gawler, Light Regional Council, and Barossa Council

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Town of Gawler

Gawler and Surrounds Stormwater Management Plan
External catchments

Map A.1

Appendix B

Residential Total Impervious Area Sample Sites

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Job Number: 2014.1387
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Data Acknowledgement:
Imagery from Aerometrex Pty Ltd
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Town of Gawler, Light Regional Council, Barossa Council

Gawler and Surrounds Stormwater Management Plan
Impervious area percentage

Figure B.1

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Town of Gawler, Light Regional Council, Barossa Council

Gawler and Surrounds Stormwater Management Plan
Impervious area percentage

Figure B.2

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Gawler and Surrounds Stormwater Management Plan
Impervious area percentage

Figure B.3

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Gawler and Surrounds Stormwater Management Plan
Impervious area percentage

Figure B.4

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Gawler and Surrounds Stormwater Management Plan
Impervious area percentage

Figure B.5

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Gawler and Surrounds Stormwater Management Plan
Impervious area percentage

Figure B.6

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Town of Gawler, Light Regional Council, Barossa Council

Gawler and Surrounds Stormwater Management Plan
Impervious area percentage

Figure B.7

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Town of Gawler, Light Regional Council, Barossa Council

Gawler and Surrounds Stormwater Management Plan
Impervious area percentage

Figure B.8

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Town of Gawler, Light Regional Council, Barossa Council

Gawler and Surrounds Stormwater Management Plan
Impervious area percentage

Figure B.9

Appendix B

Long term development scenario discussion paper

Memorandum

TO	Gawler and Surrounds SMP Steering Committee				
FROM	Tonkin Consulting	**DATE**	2017-05-16	**JOB NO.**	2014.1387
SUBJECT	Long Term Development Scenario				

For your information, please find attached a summary of the change in catchment imperviousness for the Long Term Development scenario based on the approved *Development Potential Assessment Discussion Paper* prepared by Jensen Planning+Design (now Jensen PLUS).

The Development Potential Assessment reviewed the current development planning policies and projected future development within the Study Area. The discussion paper concludes with a summary of the potential changes in development density and the likely impacts on catchment imperviousness. The discussion paper and its summary has been interpreted by Tonkin Consulting to arrive at specific estimates of changes in catchment imperviousness.

Table 4 (p. 55) of the *Development Potential Assessment Discussion Paper* is replicated and expanded here to demonstrate the process by which the adjusted long term impervious area values were determined.

Also included is a series of maps illustrating several attributes of the Development Zones and Policy Areas. Maps 1 and 2 show the average percent Directly Connected Impervious Area (DCIA) for each development zone. Map 1 shows the Existing Development Scenario and Map 2 the Long Term Development Scenario. Map 3 shows the change in DCIA between the Existing Development and Long Term Development scenarios (expressed as a percentage of the Existing DCIA).

In some zones the percent changes are very high (100-1000%). When examining the absolute values of DCIA, however, it becomes clear that the change is appropriate and commensurate with the findings of the Development Potential Assessment. Generally, this magnitude of change occurs in areas where there is little to no DCIA assigned in the Existing Development Scenario, such as rural areas or currently vacant land.

Kemp & Myers (2015) reviewed the hydrologic impacts of infill development within a gauged urban catchment of Glenelg using a calibrated hydrologic model. Kemp & Myers found close to a 15% change in directly connected impervious area over the 20 years between 1993 and 2013. This finding closely matched estimated increases in DCIA based on inspection of aerial photography of the catchment. In the catchment analysed infill development was projected to increase 0.65% per annum through to 2040, resulting in a further 17% increase in DCIA over 2013 levels. Interestingly, the authors appear to find little to no change in the mean indirectly connected impervious area between 1993 and 2013. The projected increase in DCIA in areas 3, 4, and 11 align closely with the findings of Kemp & Myers and gives some confidence in the process undertaken.

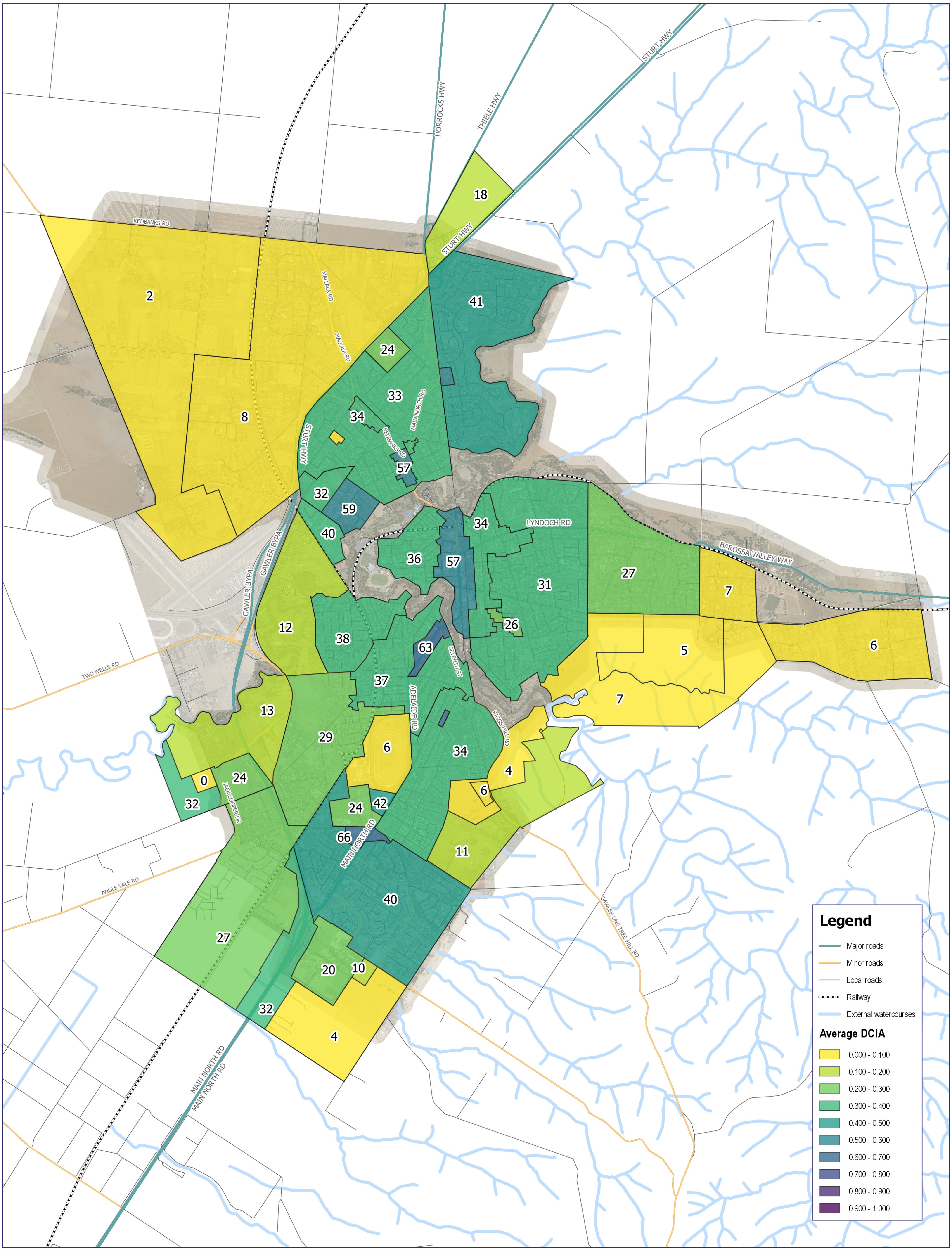
Finally, in zones that are already highly developed (such as Zone 1) there is very minimal change in DCIA. In residential areas, this reflects the existing levels of newer, medium density development on smaller allotments with little potential for infill. In commercial areas, this reflects to already high levels of impervious surface area from carparks and buildings.

References

Kemp, DJ, and Myers, BR, 2015, A verification of the hydrological impact of 20 years of infill development in an urban catchment. In proceedings: *36th Hydrology and Water Resources Symposium: The art and science of water*, Engineers Australia, Barton, ACT, pp. 379-386.

Source: Table 4 from Development Potential Assessment Discussion Paper, Jensen Planning + Design, 2016.

Area	Zone/Policy Area	Potential for Change in Imperviousness	Tonkin interpretation
1	Gawler Belt Residential – Policy Area 7 (Light Regional Council)	Low – typical new suburban	This zone is mostly fully developed. Undeveloped vacant land is assumed to become fully developed and has been assigned 0.6 DCIA proportion. Existing low density allotments were increased from [0.25, 0.1] to [0.3, 0.15] direct-indirect proportions to account for minor infill over time.
2	Residential Zone - Willaston Policy Area	Medium – infill potential on many larger residential lots	Maximum site coverage for blocks < 300 m^2 in area is 55% according to current Town of Gawler policy (40% for blocks > 800 m^2). Therefore, all blocks have been assigned [0.45, 0.15] if < 300 m^2, [0.45, 0.05] if 300-450 m^2, and [0.45, 0.15] if greater than 800 m^2 on the assumption that these large allotments will eventually be subdivided.
2a	Residential Zone - Willaston Policy Area – Flood Risk	Low / medium – infill potential but within a flood risk area	Although technically with flood risk area existing development already exhibits high site coverage per allotment. It is assumed that this trend will continue in this area and proportions were assigned in the same way as Area 2.
3	Residential Zone – Gawler East Policy Area 6	Low / medium – infill potential but only on vacant (or larger) lots	Vacant allotments were assigned [0.45, 0.1] direct-indirect proportions (i.e. equalling 55% Town of Gawler policy). Existing lots changed from [0.25, 0.1] to [0.3, 0.1] to account for minor infill.
4	Residential Zone - Wheatsheaf Policy Area	Low – 2,000 m^2 minimum lot size and area is fully developed	This area is already fully developed. Minor infill and development of vacant land only. Therefore, increased existing low density development from [0.25, 0.1] to [0.3, 0.1]. Vacant land was also set to [0.3, 0.1] to account for minimum lot size of 2,000 m^2.
5	Residential (Gawler East) Zone	High – transition from greenfield to residential	Greenfield site with medium density housing. Mostly outside of modelled catchment area. Assigned [0.6, 0.05] direct-indirect to match other recent developments.
6	Residential Zone – Gawler West	Low – medium	This area has relatively high DCIA due to Maisonettes land use type. Therefore, updated low density allotments to [0.3, 0.1] up from [0.25, 0.1] to account for infill. Vacant allotments set to [0.45, 0.1] to equal Town of Gawler 55% site coverage allowance.
6a	Residential Zone – Gawler West – Flood Risk	Low – flood prone land but infill sites available	As per Area 6.
7	Residential Zone - Hillier Road Policy Area	Medium – infill potential on many larger residential lots	Existing infill development has been classed as medium density 0.6 direct runoff - new infill development would likely be similar. However, areas within the Gawler River Floodplain are prohibited from further infill. All remaining lots upgraded from 0.25 to 0.45 direct + 0.1 indirect (i.e. 55% Council allowance) - these lots are large and undergoing development to very high density.
7a	Residential Zone – Hillier Road Policy Area – Flood Risk	High – assuming development on flood risk vacant land is approved	This area is well within the Gawler River floodplain, therefore, it is assumed no development will be permitted to occur - no change in DCIA.
8	Residential Zone – Gawler South Policy Area	Low – fully developed newer homes	High coverage of newer homes. Therefore, residential allotments were set to [0.55, 0.1] direct-indirect to match.
8a	Residential Zone – Gawler South Policy Area	Low – fully developed new homes (minimum lot size of 2,000 m^2)	Due to minimum lot size, this area should have lower DCIA. Therefore, residential allotments set to [0.3, 0.1] direct-indirect proportion (similar to Area 4).
8b	Residential Zone – Gawler South Policy Area	Low / medium – infill potential on larger residential lots	Medium infill of vacant and large blocks. Therefore, residential allotments set to [0.4, 0.1] direct-indirect to account for slightly higher potential for subdivision.
9	Local Centre Zone	High – currently vacant	This area is zoned to be a local community hub with high density development, therefore, proportions [0.75, 0.15] to match other commercial areas in the study area.
10	Residential (Hills) Zone	High – assuming transition from rural living to residential	Entire area set to [0.6, 0.15] direct-indirect to represent medium density development similar to other recently developed sites.
11	Residential Zone – Evanston / Evanston Park Policy Area	Low – fully developed new homes	Minimal infill of vacant blocks. Proportions of residential allotments set to [0.35, 0.1] direct-indirect up from [0.25, 0.1].
12	Residential Zone – Evanston Gardens / Evanston South / Hillier Policy Area	High – mostly vacant (transition to residential)	New greenfield site. Area set [0.6, 0.1] direct-indirect to represent medium density new urban areas.
13	Town Centre Historic (Conservation) Zones	Low – fully developed	A few vacant allotments altered to match proportions of other commercial sites. Otherwise unchanged.
14	Residential Historic (Conservation) Zones	Low / medium – infill potential on larger sites and sites without heritage / contributory places, but within Historic (Conservation) Zone	All vacant residential allotments set to have medium density coverage [0.6, 0.1] direct-indirect. All other residential allotments set to have [0.27, 0.1] direct-indirect (changed from [0.25, 0.1]) to represent very minor infill of conservation allotments.
14a	Residential Historic (Conservation) Zones	Low	All vacant residential allotments set to medium density coverage [0.6, 0.1] direct-indirect.
14b	Residential Historic (Conservation) Zones	Low	All vacant residential allotments set to have medium density coverage [0.6, 0.1] direct-indirect. All other residential allotments set to have [0.27, 0.1] direct-indirect (changed from [0.25, 0.1]) to represent very minor infill of conservation allotments.
15	Rural Living Zones (including Light Regional Council)	Low – rural living, fully developed residential (although some additional land division may occur), flood prone	**Precinct 32:** Jensen Planning+Design suggests low increase due to subdivision. Ultimately, lot sizes will be similar to Precinct 31 (rural living east of railway), therefore, the imperviousness of allotments in Precinct 32 has been increased to similar levels (specifically 0.12 indirect, up from 0.03). Where the minimum allotment size is 4 ha, indirect changed to 0.05 since this area is mostly fully developed already. All Rural Living allotments were set to have 0.01 direct proportion to match Precinct 31. Final values for Rural Living allotments were [0.01, 0.12] direct-indirect. **Precinct 31:** Basically already fully developed. Vacant land and large agricultural allotments assumed to become Rural Living use, and some additional infill from sheds etc. Direct set to 0.01 and, indirect set to 0.15 up from 0.1.
16	Township Zone (Barossa Council)	High – further residential potential on 1,200 m^2 lots	Set to match medium density urban housing, [0.3, 0.1] direct-indirect. Limited affect on hydrology given size of surrounding catchment.
17	Rural Living – Precinct 21 Cockatoo Valley (Barossa Council)	Low - fully developed rural residential (minimum lot size of 1 ha)	No change.



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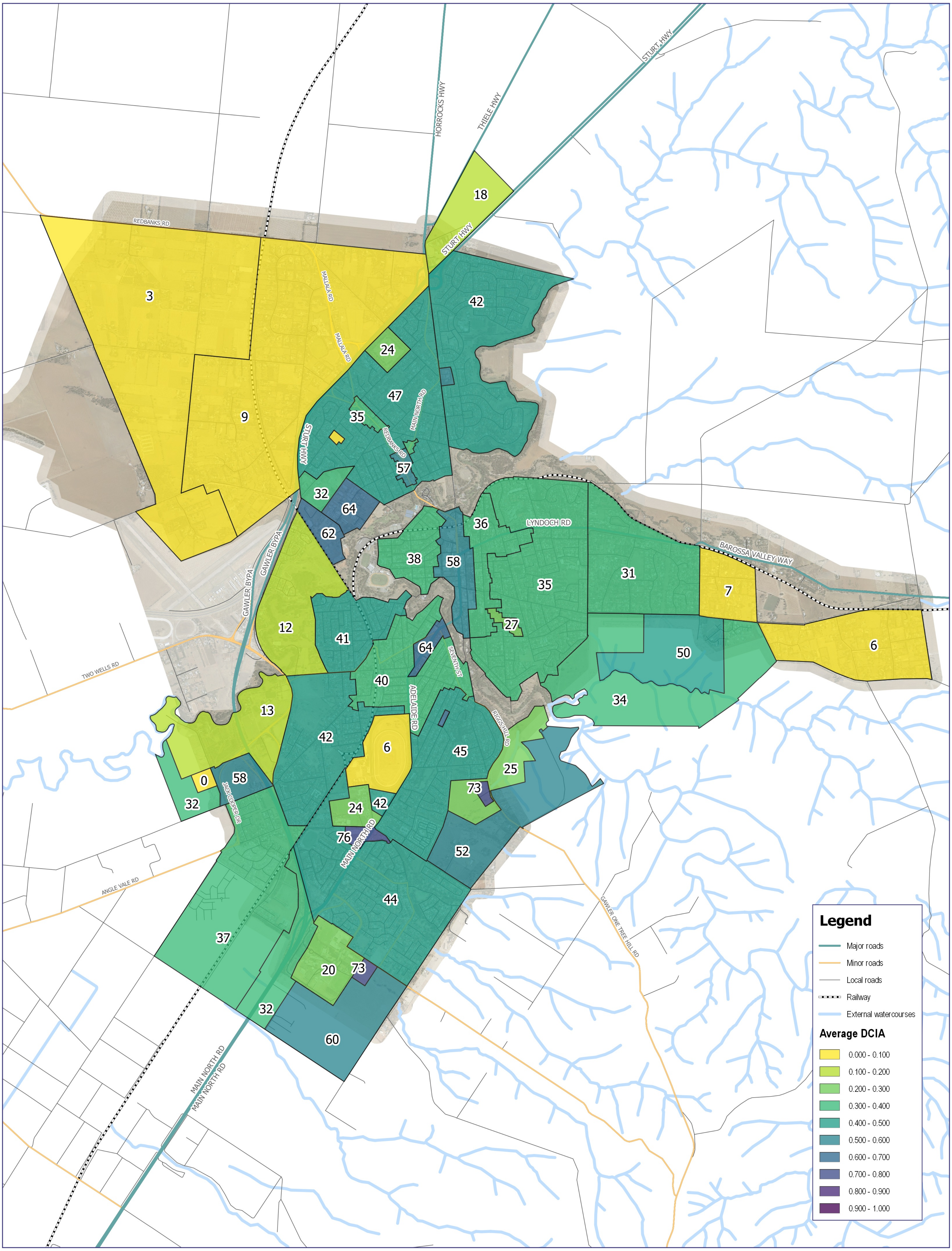
Development zones from DPTI, 2017, modified by Tonkin Consulting

TOWN OF GAWLER, LIGHT REGIONAL COUNCIL, and BAROSSA COUNCIL

GAWLER AND SURROUNDS STORMWATER MANAGEMENT PLAN

Average DCIA for Existing Development Scenario

Map 1



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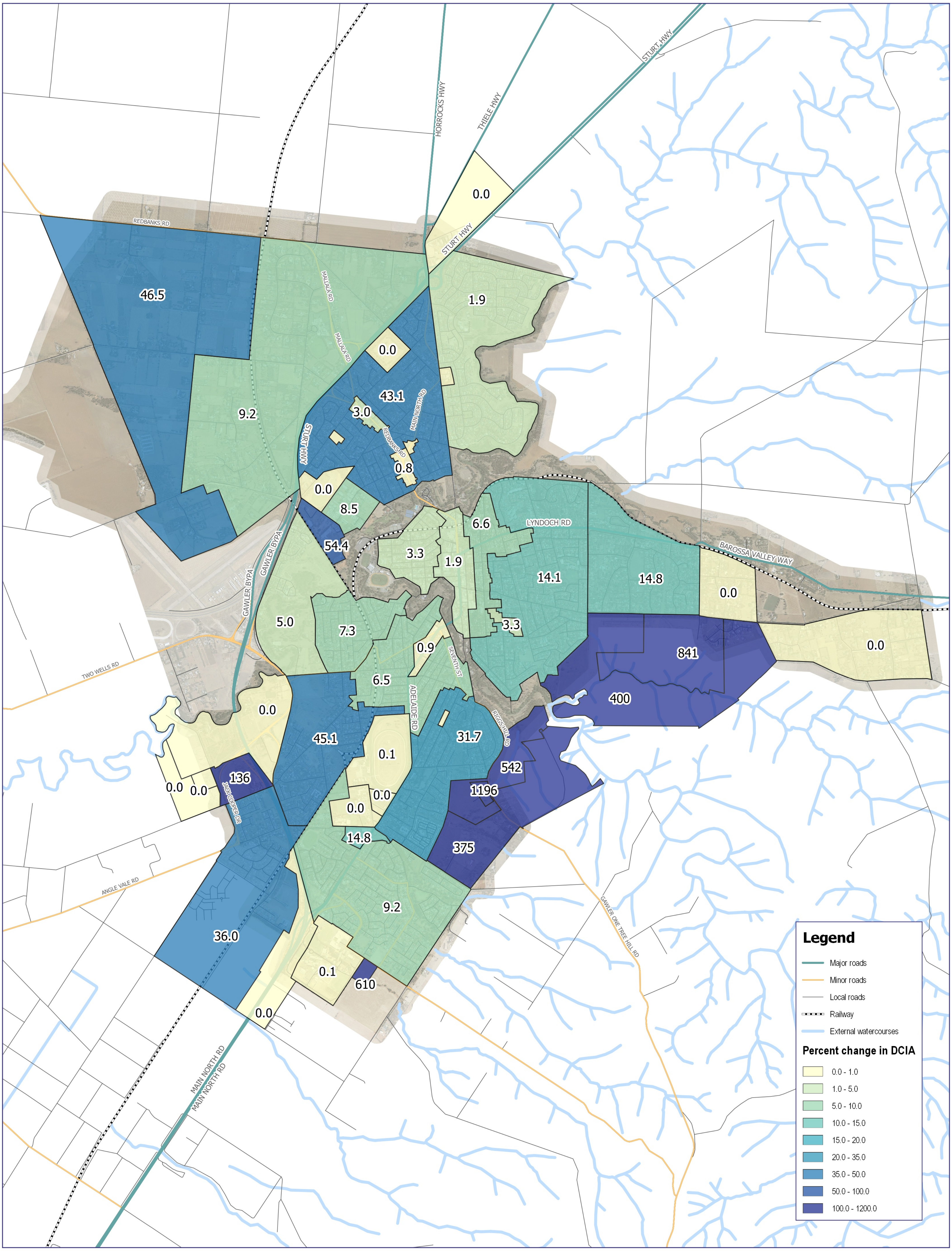
TOWN OF GAWLER, LIGHT REGIONAL COUNCIL, and BAROSSA COUNCIL

GAWLER AND SURROUNDS STORMWATER MANAGEMENT PLAN

Average DCIA Long Term Development Scenario

Map 2



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TOWN OF GAWLER, LIGHT REGIONAL COUNCIL, and BAROSSA COUNCIL

GAWLER AND SURROUNDS STORMWATER MANAGEMENT PLAN

Percent change in DCIA between Existing and Long Term scenarios

Map 3