

City of Unley Urban Flood Mapping Study

Hydrologic and Hydraulic modelling report

City of Unley

30 September 2019

Ref: 20181425R002



Document History and Status

Rev	Description	Author	Reviewed	Approved	Date
A	For client comment	JDN	KSS	KSS	30 Sep 2019



Contents

Project: City of Unley Urban Flood Mapping Study | Hydrologic and Hydraulic modelling report
Client: City of Unley
Ref: 20181425R002

1	Hydrologic modelling	5
1.1	Introduction	5
1.2	Catchment description	5
1.3	Sub-catchment properties	7
1.4	Rainfall estimation	8
1.5	Catchment runoff estimation	10
2	Hydraulic modelling	11
2.1	Introduction	11
2.2	Modelling software	11
2.3	Digital elevation model	11
2.4	Model setup	11
2.5	Boundary and initial conditions	13
2.6	Drainage network preparation	13
2.7	Bed resistance	14
2.8	Model uncertainty	15
2.9	Simulations	15
2.10	Model verification	16
2.11	Model validation	16
2.12	Model outputs	16
3	Review of proposed works	17
3.1	Introduction	17
4	References	21

Tables

Table 1.1	Measured impervious area within sample residential regions	7
Table 1.2	Adopted impervious area percentages	8
Table 1.3	Loss parameters used for urban catchments	10
Table 1.4	Fixed inflow rate for Brown Hill Creek at boundary of 2D model	10
Table 2.1	Adopted bed resistance parameters	15
Table 3.1	Commentary on proposed works	17



Figures

Figure 1.1 Catchment contributing to study area.....	6
Figure 1.2 Catchment directly connected impervious proportion.....	9
Figure 2.1 LiDAR derived digital elevation model	12
Figure 3.1 Location of proposed stormwater upgrades.....	20

Appendices

Appendix A – Flood depth and hazard maps	
--	--



1 Hydrologic modelling

1.1 Introduction

Modelling of runoff within the urban area was undertaken using the ILSAX hydrological model. The ILSAX model requires the catchment to be divided into smaller sub-catchments, each of which is assigned a directly connected impervious area percentage, an indirectly connected impervious area percentage and a remaining pervious area.

The directly connected impervious area represents paved and roof areas within the catchment from which runoff is discharged directly to the street drainage system. The indirectly connected impervious area represents paved and roof areas within a catchment that are not directly connected to the street drainage system but may travel overland across a pervious surface before reaching the street. The pervious area largely represents the remaining grass and gardens areas.

For each sub-catchment, the model requires input of travel times, which when convolved with rainfall enables the generation of a runoff hydrograph using the time-area method.

For catchment external to the study area, such as where Brownhill Creek and Glen Osmond Creek enter the detailed flood modelling area, inflow hydrographs were generated using separate hydrological models.

A description of the parameters used to undertake the modelling within each of these models is provided in the following sections of this report.

1.2 Catchment description

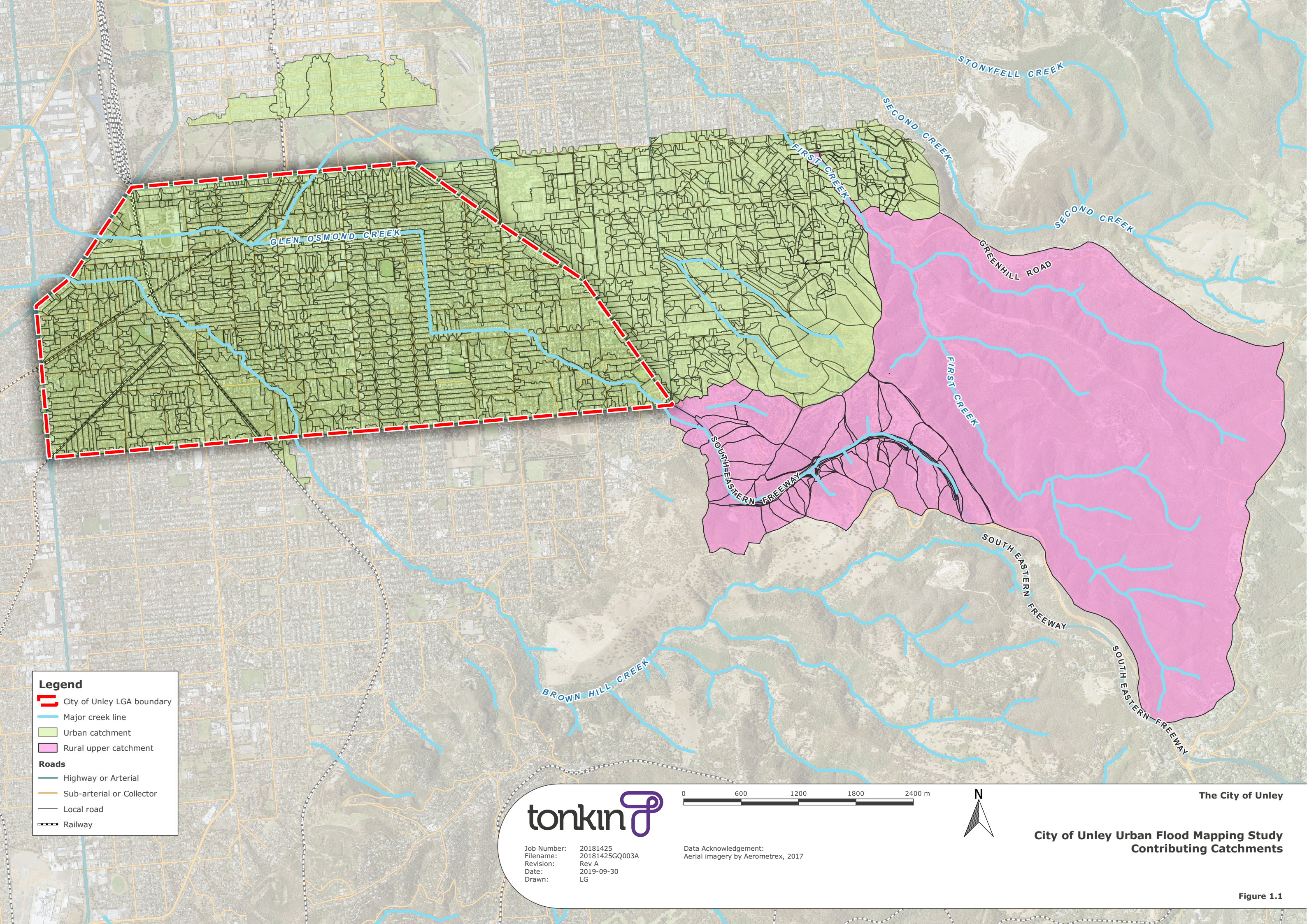
Management of flooding within the City of Unley is largely facilitated by an underground drainage network that discharges into the Brownhill–Keswick Creek system.

The underground drainage systems and the creeks have catchments that have their headwaters to the south and southeast of the council area within the City of Burnside and City of Mitcham. As a result, while the focus of this investigation has been on the production of floodplain maps for the City of Unley, the arrangement of the catchments has of necessity required a consideration of runoff likely to be generated from a much broader area. Figure 1.1 shows the contributing catchment areas around the Study Area.

The catchment can be readily divided into an upper and lower area delineated by the highly urbanised city suburbs and the predominantly rural upper catchment. These areas have two distinct modes of runoff generation.

Rainfall from short-duration, high-intensity storms causes rapid runoff generation from impervious surfaces in urban areas but may not generate significant runoff from the upper rural catchment. Conversely, rainfall from longer duration, low-intensity storms may only produce small flows from urban areas but will generally saturate the upper catchment resulting in significant runoff which can produce flooding along the main creek lines.

Within the urban area the creeks lines have been highly modified, with long sections converted to run through underground conduits or along concrete lined channels so that very little of the natural creeks remain. The creeks are the main pathways for conveying runoff through the urban areas and receive runoff from the many local underground drainage systems within the study area. The creeks convey runoff through suburbs west of the study area before discharging to the ocean via the Patawolonga Lake.



Legend

- City of Unley LGA boundary
- Major creek line
- Urban catchment
- Rural upper catchment

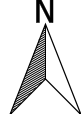
Roads

- Highway or Arterial
- Sub-arterial or Collector
- Local road
- Railway



Job Number: 20181425
Filename: 20181425GQ003A
Revision: Rev A
Date: 2019-09-30
Drawn: LG

Data Acknowledgement:
Aerial imagery by Aerometrex, 2017



The City of Unley

**City of Unley Urban Flood Mapping Study
Contributing Catchments**

Figure 1.1



1.3 Sub-catchment properties

1.3.1 Sub-catchment boundary delineation

Sub-catchment boundary delineation was performed for the detailed flood modelling area using a LiDAR derived digital elevation model (DEM) (see Section 2.3). A single sub-catchment was delineated for each inlet to the urban drain system. Within areas without many inlets, large sub-catchments were further subdivided to ensure good representation of flooding along the road network.

1.3.2 Catchment imperviousness

The predominant land use within the Study Area is residential. Inspection of aerial photography indicated that the impervious area of residential allotments varied across the study area. Lower impervious area percentages were typically associated with larger allotments whilst higher impervious area percentages were typically associated with smaller allotments and newer development.

In order to gain an understanding of the likely range of the residential impervious area fractions within the study area, ten sample regions, with various residential development density, were chosen for more detailed measurement impervious area. The location of these areas is shown in Figure 1.2. Within each sample region it was assumed that roofs and driveways could be classified as being directly connected, whereas sheds and paving (other than driveways) could be classified as being indirectly connected. Table 1.1 below shows the results of this analysis.

Table 1.1 Measured impervious area within sample residential regions

Area Number	Direct Impervious (%)	Indirect Impervious (%)	Total Impervious (%)
1	38	10	48
2	46	9	55
3	35	6	41
4	44	9	53
5	36	6	42
6	37	6	43
7	31	3	34
8	48	10	58
9	43	8	51
10	38	5	43

In examining the data, it can be seen that the existing residential development across the study area has a relatively high total imperviousness ranging from 34% to 58%. Ultimately, four densities of residential development were adopted based primarily on the clustering of estimated indirect impervious area.



Impervious area percentages were assigned to each allotment depending on land use. The adopted percentages are shown in Table 1.2 below. Figure 1.2 shows the distribution of directly connected impervious area

Table 1.2 Adopted impervious area percentages

Land Use	Directly Connected Impervious (%)	Indirectly Connected Impervious (%)
Residential	34 – 46 ¹	4 – 9 ¹
Driveways /Carparks	100	0
Commercial and Industrial	85	5
Schools	20	18
Public Institutions	70	10
Road Reserves	100	0
Public Reserves	1	5

Note 1: Dependent on suburb

1.3.3 Catchment response time

The time of travel is the time after the commencement of rainfall at which the whole sub-catchment is contributing to flow at the outlet. For urban sub-catchments, the time of travel for directly connected impervious areas was calculated using the slope and distance between the sub-catchment outlet and a point on the sub-catchment boundary furthest from the outlet.

An additional five minutes for roof-to-gutter travel time for residential sub-catchments and 10 minutes for commercial/industrial sub-catchments was added as recommended in *Stormwater Drainage Design in Small Urban Catchments: A Handbook for Australian Practice* (Argue, 1986). The resultant time of travel for urban sub-catchments ranged from 5 to 35 minutes. An additional 15 minutes was added to the travel time of pervious areas within urban sub-catchments to account for the longer response time of these areas.

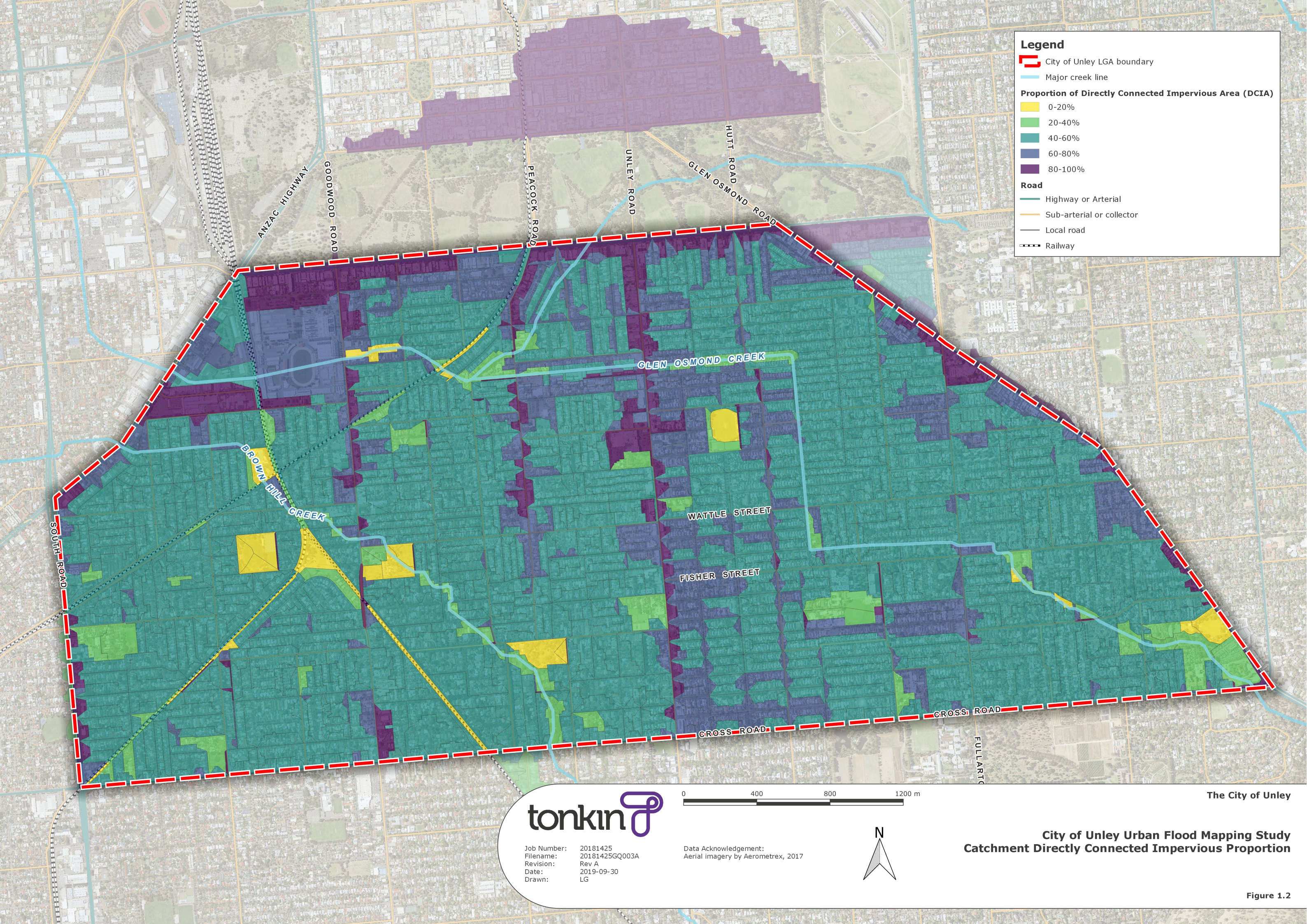
1.4 Rainfall estimation

1.4.1 Rainfall depth and intensity

The rainfall Intensity-Frequency-Duration (IFD) data used by the hydrological models was sourced from the Australian Bureau of Meteorology. The 2016 IFD estimates were used. Due to the higher average rainfall of the Mount Lofty Ranges, different IFD data was used for the urban and rural areas.

1.4.2 Rainfall temporal distribution

An ensemble of storms approach was adopted which accounts for the variability of rainfall due to differing meteorological conditions. The ensemble of storms approach is recommended by Australian Rainfall and Runoff 2019 (Ball, et al., 2019). Ten differing temporal patterns were simulated.



Job Number: 20181425
Filename: 20181425GQ003A
Revision: Rev A
Date: 2019-09-30
Drawn: LG

Data Acknowledgement:
Aerial imagery by Aerometrex, 2017

0 400 800 1200 m



The City of Unley

City of Unley Urban Flood Mapping Study
Catchment Directly Connected Impervious Proportion

Figure 1.2



1.5 Catchment runoff estimation

1.5.1 Urban catchments

Runoff from urban catchments was estimated using an Initial Loss – Continuing Loss model. This model supposes an initial catchment wetting phase which absorbs rainfall (the initial loss) followed by a continuing, steady infiltration of rain over the pervious areas for the remainder of the event (the continuing loss). The initial and continuing losses are surface type dependent. The adopted loss parameters are presented in Table 1.3. The values listed are consistent with those used for modelling a range of urban catchments across Adelaide.

Table 1.3 Loss parameters used for urban catchments

Parameter	Value
Directly connected impervious area initial loss	1 mm
Indirectly connected impervious area initial loss	1 mm
Pervious area initial loss	45 mm
Pervious area continuing loss	3 mm/hr

1.5.2 Glen Osmond Creek

A RORB model was configured to produce peak flows at Cross Road similar to those of the Department of Planning, Transport, and Infrastructure's (DPTI) RRR model used for the Brown Hill Keswick Creek 2016 Stormwater Management Plan. The RORB model was necessary to produce hydrographs for all durations, temporal patterns and AEPs used in this study because the Brown Hill Keswick Creek stormwater project did not consider the same set of events.

1.5.3 Brownhill Creek

A fixed inflow at Cross Road was adopted based on mitigated peak flows described in Appendix 9 of the Brown Hill Keswick Creek 2016 Stormwater Management Plan report (BHKC Stormwater Project, 2016). The inflow adopted for the 20% and 10% AEPs was derived by scaling the 1% AEP peak flow using a ratio of rainfall intensities. Table 1.4 lists the adopted inflow values.

Table 1.4 Fixed inflow rate for Brown Hill Creek at boundary of 2D model

Event	Adopted inflow (m ³ /s)	Source
20% AEP	10.3	0.47 × 1% AEP inflow.
10% AEP	12.8	0.58 × 1% AEP inflow.
1% AEP	22.0	Appendix 9 of SMP report.



2 Hydraulic modelling

2.1 Introduction

Hydraulic modelling uses the outputs of the hydrological modelling to determine the extent, depth and behaviour of floodwater. The resulting outputs provide an estimate of areas subject to flooding.

A detailed flood model was created for the study area, which included both one and two dimensional components. The model was run to simulate storm events within the study area and generate flood inundation maps.

2.2 Modelling software

The hydraulic modelling was carried out using the TUFLOW modelling software. The software simulates depth averaged, two-dimensional free surface flows such as those that occur during floods. TUFLOW has the ability to dynamically link to the ESTRY one-dimensional (1D) model (if needed), which enables the creation of models containing both 1D and 2D domains.

For this study the TUFLOW HPC solver has been used to solve the full 2D shallow water flow equations. The HPC solver is a fixed grid 2D hydrodynamic solver that uses an explicit finite volume solution scheme that is 2nd order in space and 4th order in time. The solution scheme includes viscosity and sub-grid turbulence terms that other solution schemes do not. Consequently, the HPC solver is well suited to reproducing accurate flood behaviour.

The HPC solver is designed for efficient computation using Graphics Processing Units (GPUs); substantially reducing simulation time. This is advantageous when running large numbers of simulations due to the number of temporal patterns, AEPs or climate scenarios being considered.

2.3 Digital elevation model

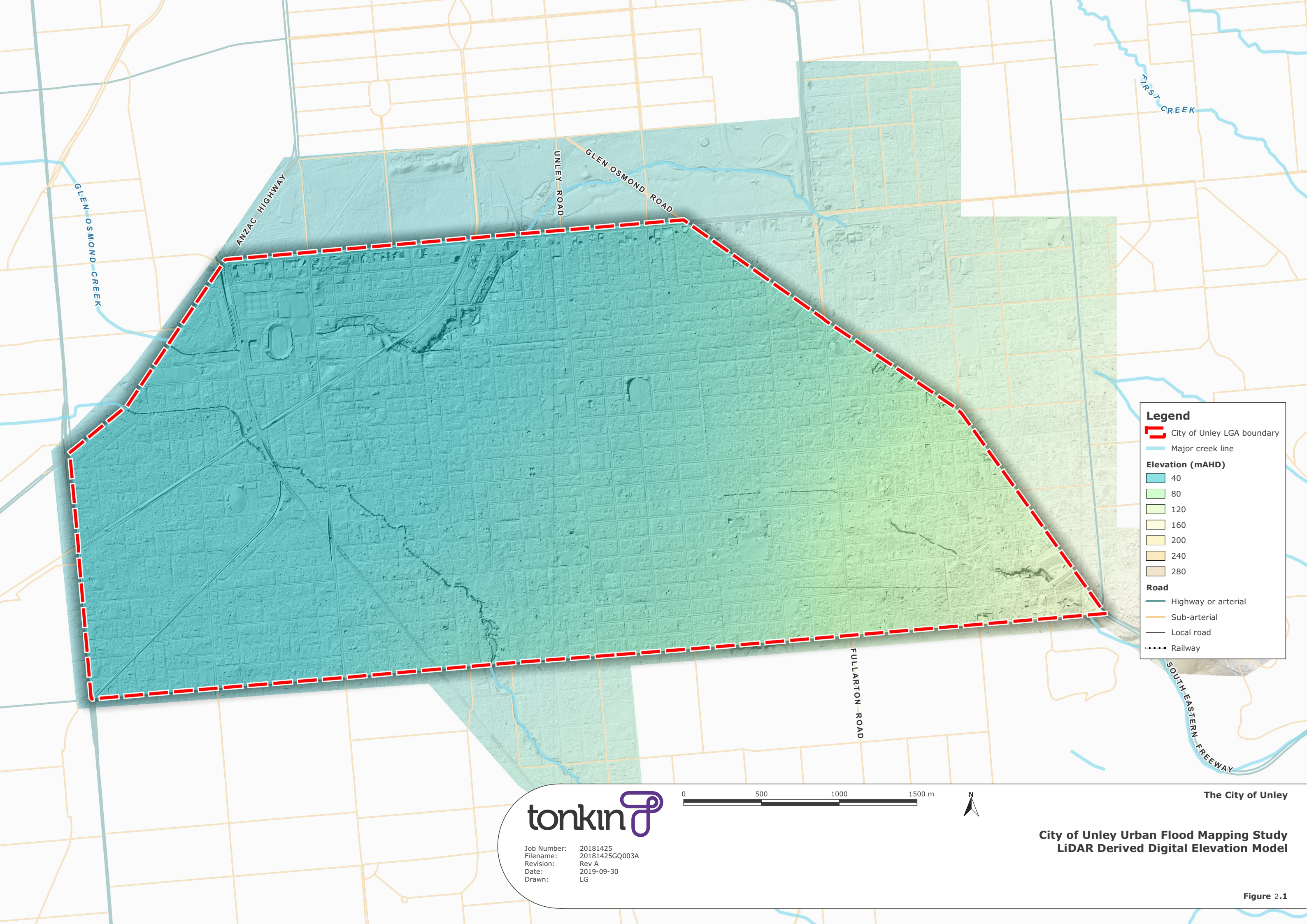
A digital elevation model (DEM) of the study area was prepared using data from LiDAR survey undertaken in early 2019. LiDAR is a remote sensing method that uses laser pulses to measure the distance to features in the terrain. The laser pulses are obtained and processed to create a 3D model of the landscape. Tonkin reviewed the DEM to ensure it was free of major errors. This review found some issues along creek lines and some roads where dense tree canopy cover was present. Where possible these issues were corrected using past survey or interpolation from unaffected areas. The final DEM obtained for the study is presented in Figure 2.1.

2.4 Model setup

2.4.1 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 as the maximum cell size that offers an acceptable compromise between resolution and computational power and has been used for many studies previously undertaken by Tonkin. Due to the large number of narrow roads and laneways, as well as the intricate road network in the study area, a cell size of 2.5 m was considered necessary to adequately represent the hydraulic behaviour of surface flood flows within the urban road network.



Legend

 City of Unley LGA boundary

 Major creek line

Elevation (mAHD)

 40

 80

 120

 160

 200

 240

 280

Road

 Highway or arterial

 Sub-arterial

 Local road

 Railway



Job Number: 20181425
Filename: 20181425GQ003A
Revision: Rev A
Date: 2019-09-30
Drawn: LG



The City of Unley

**City of Unley Urban Flood Mapping Study
LiDAR Derived Digital Elevation Model**

Figure 2.1



2.4.2 Computational time step

The selection of an appropriate time step for the numerical solution scheme 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, use of the TUFLOW HPC solver meant that the timestep was adaptively selected by the solver as the simulation progressed.

2.5 Boundary and initial conditions

2.5.1 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 in the 2D domain 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 small underground drainage systems, a fixed water level boundary equal to the conduit obvert was used.

Where the main creeks exit the model via large underground conduits, custom rating tables were created. The conduits are assumed to flow at normal depth and rating tables were derived for the conduits using Manning's equation.

2.5.2 Inflow boundary conditions

Inflow hydrographs were generated for each AEP, temporal pattern and duration of storm event analysed. The inflow hydrograph for each urban sub-catchment was introduced to the 2D domain primarily by applying flow to each inlet pit, grate, or headwall throughout the catchment.

Inflow hydrographs for the creeks along the upstream boundary of the study area were extracted from the RORB models.

2.5.3 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.

2.6 Drainage network preparation

2.6.1 Modelling of the underground drainage network

The drainage network consists mostly of underground pipes and culverts with some open channels along creeks. Significant portions of Glen Osmond creek have been converted to underground culverts.

Base drainage infrastructure data (conduits and inlet structures) was sourced from Council's GIS database. This data was extensively reviewed. Where there were uncertainties within the drainage data, locations and sizes were discussed with Council and either confirmed on site or taken from design drawings. An extensive effort was made to ensure as much information as possible was obtained from design drawings, particularly in areas with known flooding issues.



Invert elevations were replaced with new estimates based on the surface level of the LiDAR DEM and dimensions of the drain, with a nominal cover of 500 mm. The estimated 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 full connectivity of the drainage network from one pipe to the next.
- Checks were made to ensure connectivity of the drainage network to the 2D domain.

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 that represented the drainage infrastructure to an appropriate level of accuracy.

2.6.2 Modelling of drainage 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 600×600 and 450×450 grated inlet pits (GIPs). 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).

2.6.3 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 majority of channels were modelled as with 1D channel elements with cross section data to ensure they were represented accurately within the TUFLOW model. Cross section dimensions were obtained primarily from the DEM but also from survey when this was available.

2.6.4 Kerb and gutter flow

While the grid cell size was demonstrated to provide sufficient detail to model the urban environment, in steep areas it was found that the model often did not capture flow along gutters. This was primarily a results of DEM quality beneath dense vegetation (such as trees). To address this, grid cells along kerbs were raised by 0.15 m to ensure water did not overtop kerbs early.

Additionally, some thin median kerbs were not well represented in the model grid. This resulted in floodwater flowing over road crowns earlier than was physically possible. To counteract this, the cells along roads with elevated medians were raised by 0.15 m. This ensured that flow along these roads was better represented by the model.

2.6.5 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.

2.7 Bed resistance

The TUFLOW model requires bed resistance be specified by the modeller. For this model a GIS layer of Manning's 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 roughness coefficients used in different areas of the model are listed in Table 2.1. These values were selected based on current literature and the prior experience of Tonkin.

Table 2.1 Adopted bed resistance parameters

Land Use	Manning's n
Residential areas	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	0.040–0.085
Plastic pipes	0.011
Concrete pipes and box culverts, and lined concrete channels	0.013

2.8 Model 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. 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).

2.9 Simulations

2.9.1 Events modelled

Several different flood events were modelled:

- 20% AEP flood event
- 10% AEP flood event
- 1% AEP flood event



For each flood event, a number of different storm durations were modelled in order to obtain the median peak flood level within the catchment. Ten temporal patterns were simulated for each storm duration.

The durations modelled were:

- 15, 30, 60, 90 minutes
- 2, 3, and 12 hours

2.10 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.

2.11 Model validation

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.

As discussed in Section 2.6.4 visual inspection of the results showed that flow along some roads with median kerbs were poorly represented. 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.

Preliminary 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.

2.12 Model outputs

During each model run, the peak flood depth and hazard category 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.

Flood inundation and hazard maps were produced so that the impact of flooding could be visually analysed. The flood depth data was classified into discrete intervals to allow for easy discrimination of flood depths. Flooding less than 35 mm deep is not shown as it is not considered relevant to the wider flood map.

The resulting floodplain maps are provided in Appendix A.



3 Review of proposed works

3.1 Introduction

To assist Council in prioritising drainage upgrade works we offer commentary in Table 3.1. Figure 3.1 illustrates the location of the proposed infrastructure and highlights (in green) which projects we believe will have the biggest impact on the 20% AEP event flooding (similar to a 5 year ARI event).

Table 3.1 Commentary on proposed works

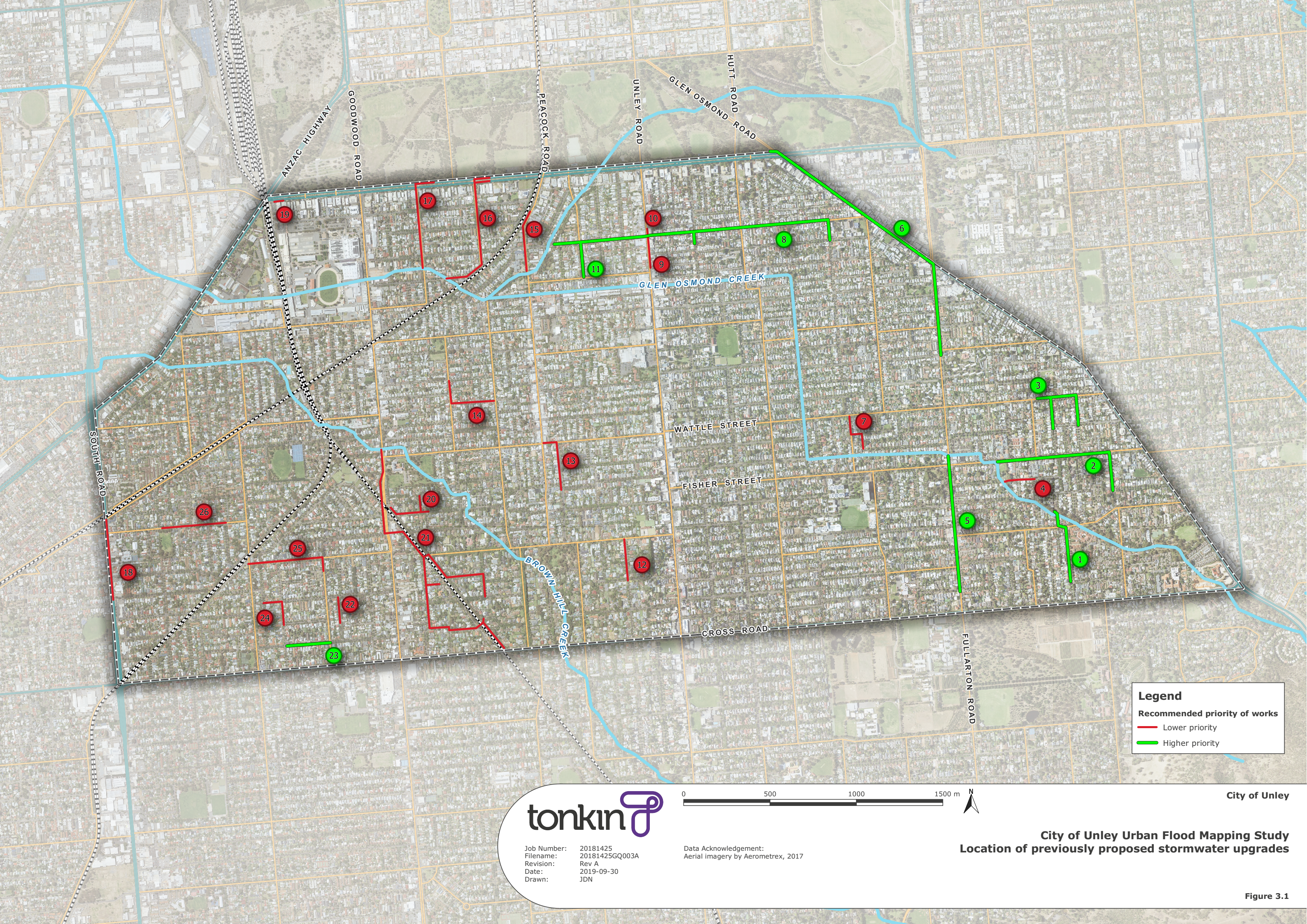
Location	Comments
1	Flooding along west side Urrbrae Avenue contributes to nuisance flooding along Ferguson Avenue. An upgrade here may only require upgrading the drain between Ferguson Ave to Glen Osmond Creek to stop surcharge from inlet pits in Urrbrae Avenue. Recommended that this option be given higher priority.
2	Recommend this option be given higher priority to help reduce surface flows reaching the intersection of Fullarton Road and Glen Osmond Road.
3	Recommend that this system be completed to control surface flow in Wattle Street. Stormwater capture here also helps reduce surface flows reaching the intersection of Fullarton Road and Glen Osmond Road.
4	There is minimal flooding in the location during the 20%AEP event. Recommended that this option be given lower priority.
5	Duplicate pipe system here would help manage flows along Fullarton Road and direct more stormwater into Glen Osmond Creek. Recommended that this option be given higher priority.
6	This system would significant relieve flooding of Fullarton Road and Young Street but would require extensive augmentation of the Glen Osmond Road drainage system. Recommended that this option be given higher priority due to its influence on flooding in Young Street.
7	There appears to be some significant flooding in Cross Street, most likely caused by stormwater which arrives from Woodfield Avenue. Building a system to Woodfield Avenue is only likely to address issues in Cross Street if the drains in Wattle Street are also considered for upgrade. Recommended that this option be given lower priority until finder detail modelling can be performed.
8	There is a reasonable amount of flooding along Young Street in 20% AEP event. A significant amount of flow originates from Glen Osmond Road which then contributes to flooding in Stamford Street and Jaffrey Street. Recommended that this option be given higher priority.
9	Flooding here is mainly caused by outflow from Glen Osmond creek. Would be better to upgrade Unley Road culvert and remove the constriction that causes overflows to occur. This option would also introduce additional stormwater to the Young Street system which discharges into Parklands Creek upstream of the King William culvert which also has capacity restraints. Recommended that this option be given lower priority.



Location	Comments
10	Flooding here is mainly caused by outflow from Glen Osmond creek. Would be better to upgrade Unley Road culvert and remove the constriction that causes overflows to occur. Recommended that this option be given lower priority.
11	If the Young Street system is upgraded Roberts Street would benefit from additional inlet pits and pipe system. Palmerston Road and Salisbury Streets would benefit from a similar treatment. Recommended that this option be given higher priority in conjunction with the duplication of the Young Street system.
12	There is little flooding during the 20%AEP event in this area. What little there is, originates from the north end of View Street (which is a trapped low spot) with limited drainage that is graded against natural surface. Recommended that this option be given lower priority and View Street is further investigated instead.
13	Some work already undertaken in Park Street, however, this was undertaken after flood modelling. Council GIS suggests a 400 mm diameter pipe which is now believed to be actually be a box culvert. This site needs further investigation of existing drainage before upgrade works should be commenced. Recommended that this option be given lower priority. An alternative may be to address overflow from Northgate Street.
14	Flood mapping shows little to no flooding at this location in the 20% or even 10% AEP events. Recommended that this option be given lower priority.
15	Flood mapping shows little to no flooding at this location in the 20% or even 10% AEP events. Recommended that this option be given lower priority.
16	Flood mapping shows little to no flooding along Clark Street in the 20% AEP event. Slightly more substantial flooding is shown on Joslin Street. One possible benefit of this system is diversion of stormwater away from Joslin Street, however, it is recommended that this option be given lower priority.
17	Council GIS shows a DN750 drain discharging to a DN675 drain along Joslin Street. This is an unusual arrangement. It is recommended that this option be given lower priority until a finer detail investigation be undertaken to confirm the arrangement and size of drains through to Keswick Creek.
18	There is substantial flooding along South Road in the 20% AEP event, however, upgrade works are of dubious value if no upgrades are made to the downstream pipe system in the City of Marion. Recommended that this option be given lower priority.
19	Flood mapping shows little to no flooding at this location in the 20% or even 10% AEP events. Recommended that this option be given lower priority.
20	Flood mapping shows little to no flooding at this location in the 20% AEP event. Recommended that this option be given lower priority, however, it is probably the only way to solve issues in the Parish Court trapped low-spot.
21	Due to the influence of the rail corridor it is suggested that a finer detail investigation is needed in this area to ascertain the benefit of the proposed system.
22	Flood mapping shows little to no flooding at this location in the 20% or even 10% AEP events. Recommended that this option be given lower priority.



Location	Comments
23	Flood mapping shows little to no flooding at this location in the 20% AEP event, however, it is probably useful to continue the William Street drain east along George Street to Churchill Avenue as proposed.
24	Flood mapping shows little to no flooding at this location in the 20% or even 10% AEP events. Recommended that this option be given lower priority.
25	Flooding along Mills Street in the 20% AEP minimal, however, Hammond Street experiences fairly deep flooding. Hammond Street is a trapped low spot which has problems draining to Churchill Ave. Suggest that this system be given further consideration to address flooding in Hammond Street.
26	Council GIS shows the Forrest Avenue drain changing from a DN675 to a DN525 at Selkirk Avenue. Under this arrangement stormwater surcharges from pits at the intersection of Forest Avenue and Selkirk Avenue. Suggest that drain sizes be reviewed before additional work is undertaken at this location. Upstream of Selkirk Avenue appears to have minimal flooding during the 20% AEP event.



Legend

Recommended priority of works

- Lower priority
- Higher priority



Job Number: 20181425
Filename: 20181425GQ003A
Revision: Rev A
Date: 2019-09-30
Drawn: JDN

Data Acknowledgement:
Aerial imagery by Aerometrex, 2017

City of Unley Urban Flood Mapping Study
Location of previously proposed stormwater upgrades

Figure 3.1



4 References

Argue, J. R., 1986. *Storm drainage design in small urban catchments: a handbook for Australian Practice*. Melbourne: Australian Road Research Board.

Ball, J. et al. eds., 2019. *Australian Rainfall and Runoff: A Guide to Flood Estimation*. 2019 ed. s.l.:Commonwealth of Australia (Geoscience Australia).

BHKC Stormwater Project, 2016. *Brown Hill Keswick Creek Catchment Stormwater Management Plan 2016*. [Online]

Available at: <https://bhkcstormwater.com.au/stormwater-management-plan/>
[Accessed April 2019].



Appendix A – Flood depth and hazard maps

Disclaimer

This map has been prepared to a standard of accuracy sufficient for broad scale flood risk management and planning. The flood extents are not based on actual historical floods. The map does not increase the risk or affect the level of flooding over an area or property. The limit of flooding shown on this map is not a boundary between flood prone and flood free land. Land outside the flood extent shown on this map could be affected by:

- Floods with a different Annual Exceedence Probability (AEP).
- Blockage in drainage systems, creeks or culverts caused by vegetation or other debris carried by floodwaters.
- Further development, earthworks and other changes to the catchment that alter the actual flood extents.

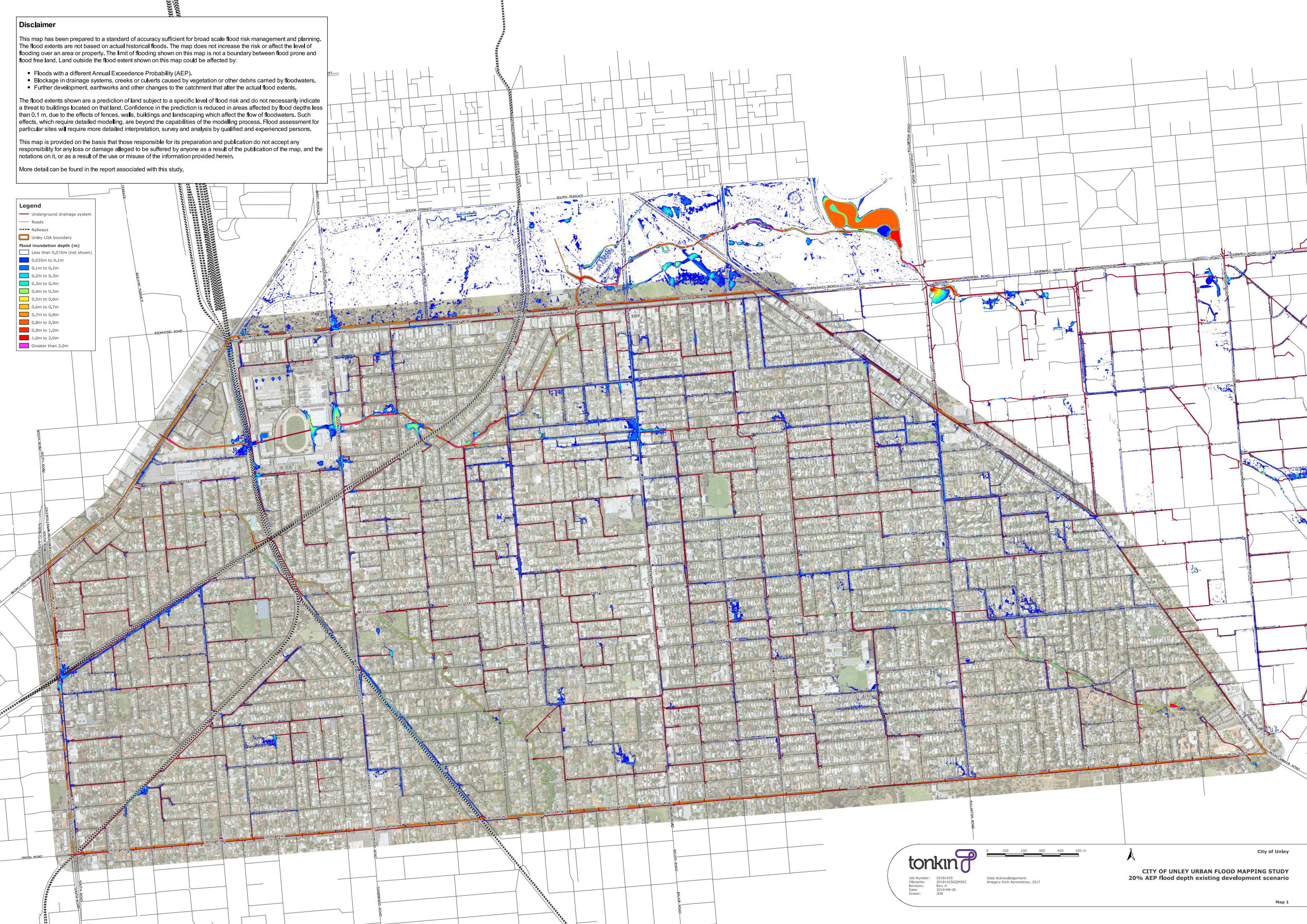
The flood extents shown are a prediction of land subject to a specific level of flood risk and do not necessarily indicate a threat to buildings located on that land. Confidence in the prediction is reduced in areas affected by flood depths less than 0.1 m, due to the effects of fences, walls, buildings and landscaping which affect the flow of floodwaters. Such effects, which require detailed modelling, are beyond the capabilities of the modelling process. Flood assessment for particular sites will require more detailed interpretation, survey and analysis by qualified and experienced persons.

This map is provided on the basis that those responsible for its preparation and publication do not accept any responsibility for any loss or damage alleged to be suffered by anyone as a result of the publication of the map, and the notations on it, or as a result of the use or misuse of the information provided herein.

More detail can be found in the report associated with this study.

Legend

- Underground drainage system
- Roads
- Railways
- Unley LGA boundary
- Flood inundation depth (m)
 - Less than 0.035m (not shown)
 - 0.035m to 0.1m
 - 0.1m to 0.2m
 - 0.2m to 0.3m
 - 0.3m to 0.4m
 - 0.4m to 0.5m
 - 0.5m to 0.6m
 - 0.6m to 0.7m
 - 0.7m to 0.8m
 - 0.8m to 0.9m
 - 0.9m to 1.0m
 - 1.0m to 2.0m
 - Greater than 2.0m



Job Number: 20181425
Filename: 20181425GQM001
Revision: Rev. A
Date: 2019-09-30
Drawn: JDN



Data Acknowledgement:
Imagery from Aerometrex, 2017



CITY OF UNLEY URBAN FLOOD MAPPING STUDY
20% AEP flood depth existing development scenario

Disclaimer

This map has been prepared to a standard of accuracy sufficient for broad scale flood risk management and planning. The flood extents are not based on actual historical floods. The map does not increase the risk or affect the level of flooding over an area or property. The limit of flooding shown on this map is not a boundary between flood prone and flood free land. Land outside the flood extent shown on this map could be affected by:

- Floods with a different Annual Exceedence Probability (AEP).
- Blockage in drainage systems, creeks or culverts caused by vegetation or other debris carried by floodwaters.
- Further development, earthworks and other changes to the catchment that alter the actual flood extents.

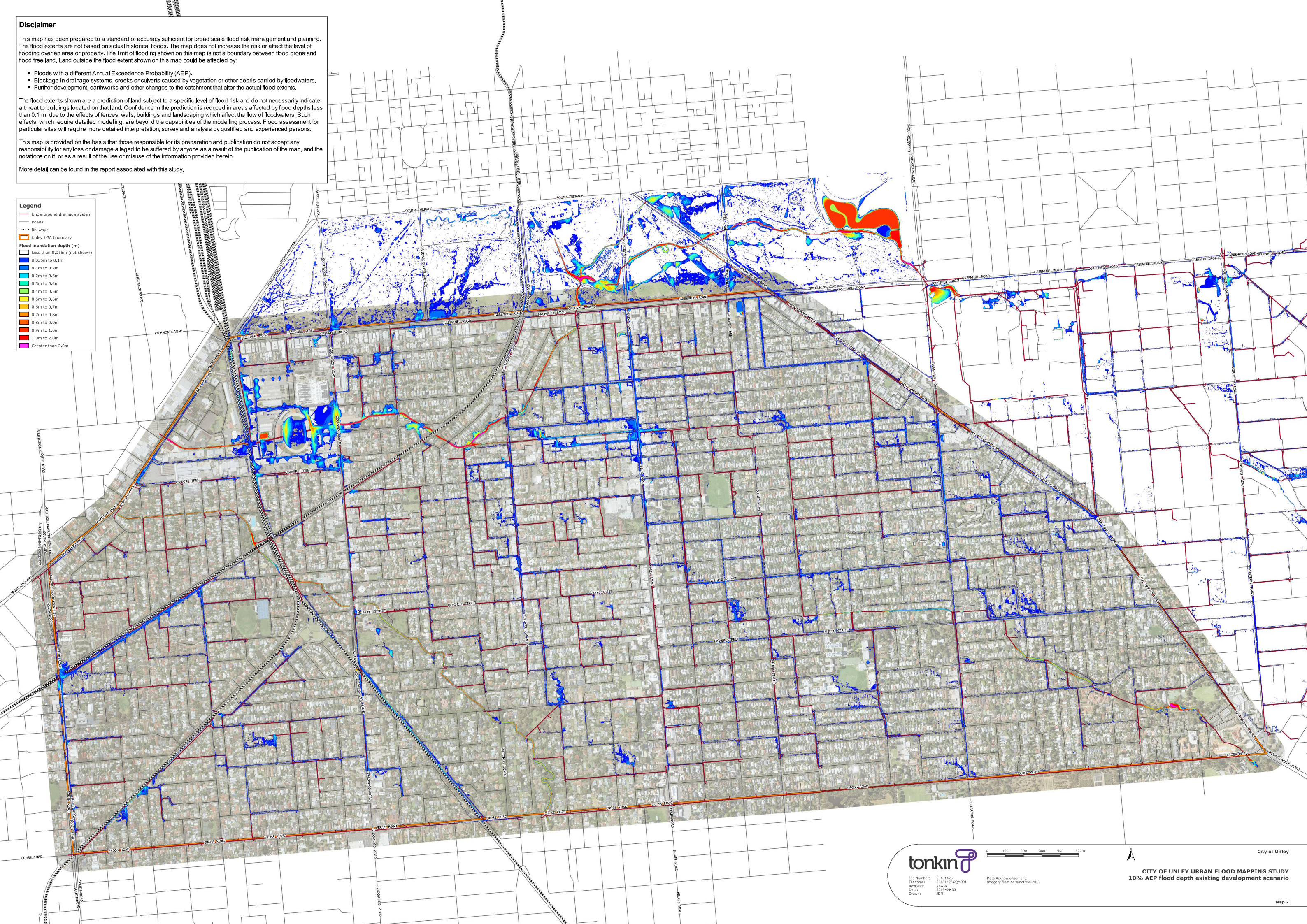
The flood extents shown are a prediction of land subject to a specific level of flood risk and do not necessarily indicate a threat to buildings located on that land. Confidence in the prediction is reduced in areas affected by flood depths less than 0.1 m, due to the effects of fences, walls, buildings and landscaping which affect the flow of floodwaters. Such effects, which require detailed modelling, are beyond the capabilities of the modelling process. Flood assessment for particular sites will require more detailed interpretation, survey and analysis by qualified and experienced persons.

This map is provided on the basis that those responsible for its preparation and publication do not accept any responsibility for any loss or damage alleged to be suffered by anyone as a result of the publication of the map, and the notations on it, or as a result of the use or misuse of the information provided herein.

More detail can be found in the report associated with this study.

Legend

- Underground drainage system
- Roads
- Railways
- Unley LGA boundary
- Flood inundation depth (m)**
 - Less than 0.035m (not shown)
 - 0.035m to 0.1m
 - 0.1m to 0.2m
 - 0.2m to 0.3m
 - 0.3m to 0.4m
 - 0.4m to 0.5m
 - 0.5m to 0.6m
 - 0.6m to 0.7m
 - 0.7m to 0.8m
 - 0.8m to 0.9m
 - 0.9m to 1.0m
 - 1.0m to 2.0m
 - Greater than 2.0m



Job Number: 20181425
Filename: 20181425GQM001
Revision: Rev. A
Date: 2019-09-30
Drawn: JDN



Data Acknowledgement:
Imagery from Aerometrex, 2017



City of Unley
CITY OF UNLEY URBAN FLOOD MAPPING STUDY
10% AEP flood depth existing development scenario

Disclaimer

This map has been prepared to a standard of accuracy sufficient for broad scale flood risk management and planning. The flood extents are not based on actual historical floods. The map does not increase the risk or affect the level of flooding over an area or property. The limit of flooding shown on this map is not a boundary between flood prone and flood free land. Land outside the flood extent shown on this map could be affected by:

- Floods with a different Annual Exceedence Probability (AEP).
- Blockage in drainage systems, creeks or culverts caused by vegetation or other debris carried by floodwaters.
- Further development, earthworks and other changes to the catchment that alter the actual flood extents.

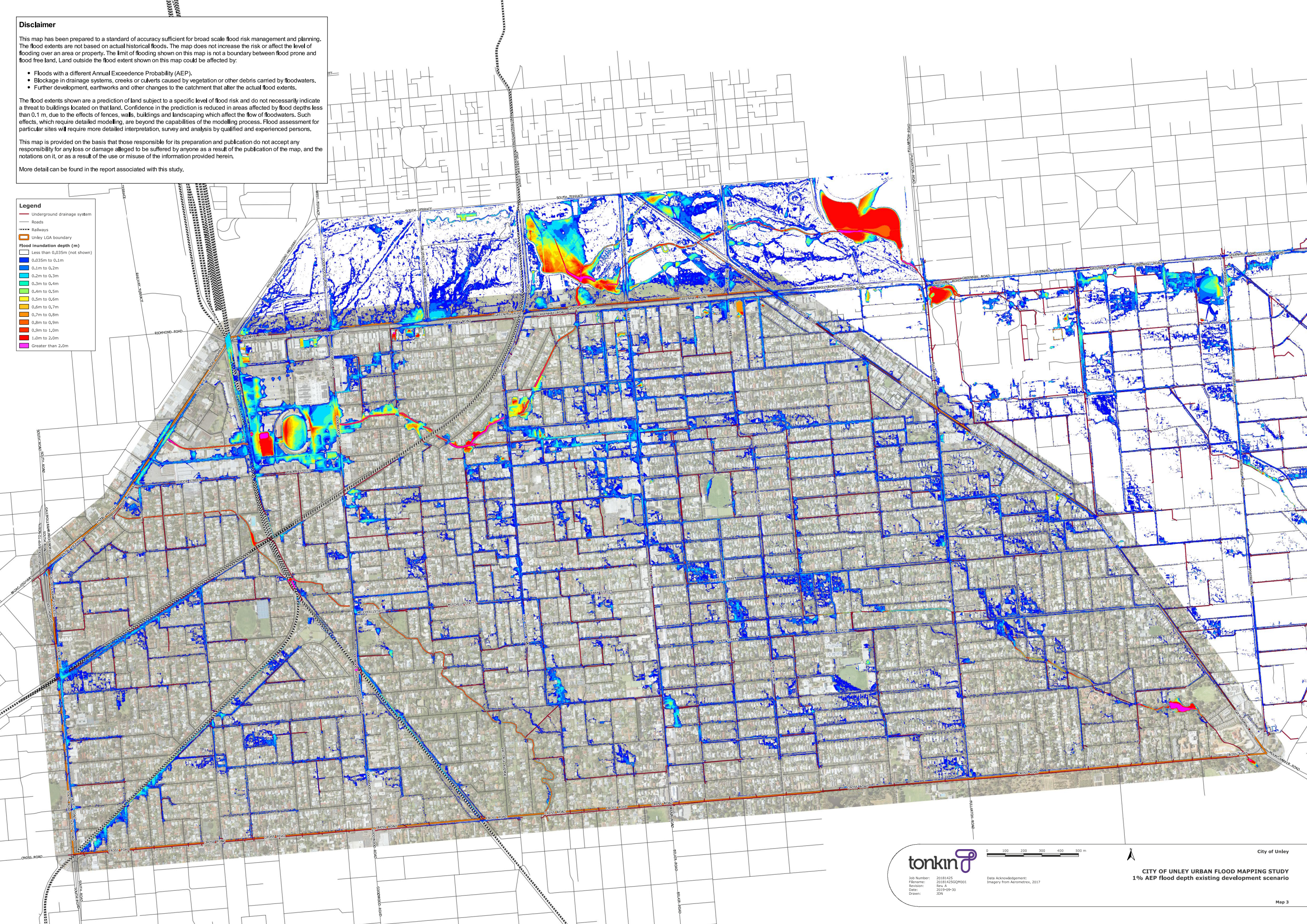
The flood extents shown are a prediction of land subject to a specific level of flood risk and do not necessarily indicate a threat to buildings located on that land. Confidence in the prediction is reduced in areas affected by flood depths less than 0.1 m, due to the effects of fences, walls, buildings and landscaping which affect the flow of floodwaters. Such effects, which require detailed modelling, are beyond the capabilities of the modelling process. Flood assessment for particular sites will require more detailed interpretation, survey and analysis by qualified and experienced persons.

This map is provided on the basis that those responsible for its preparation and publication do not accept any responsibility for any loss or damage alleged to be suffered by anyone as a result of the publication of the map, and the notations on it, or as a result of the use or misuse of the information provided herein.

More detail can be found in the report associated with this study.

Legend

- Underground drainage system
- Roads
- Railways
- Unley LGA boundary
- Flood inundation depth (m)**
 - Less than 0.035m (not shown)
 - 0.035m to 0.1m
 - 0.1m to 0.2m
 - 0.2m to 0.3m
 - 0.3m to 0.4m
 - 0.4m to 0.5m
 - 0.5m to 0.6m
 - 0.6m to 0.7m
 - 0.7m to 0.8m
 - 0.8m to 0.9m
 - 0.9m to 1.0m
 - 1.0m to 2.0m
 - Greater than 2.0m



Job Number: 20181425
Filename: 20181425GQM001
Revision: Rev. A
Date: 2019-09-30
Drawn: JDN



Data Acknowledgement:
Imagery from Aerialmetrix, 2017



CITY OF UNLEY URBAN FLOOD MAPPING STUDY
1% AEP flood depth existing development scenario

Disclaimer

This map has been prepared to a standard of accuracy sufficient for broad scale flood risk management and planning. The flood extents are not based on actual historical floods. The map does not increase the risk or affect the level of flooding over an area or property. The limit of flooding shown on this map is not a boundary between flood prone and flood free land. Land outside the flood extent shown on this map could be affected by:

- Floods with a different Annual Exceedence Probability (AEP).
- Blockage in drainage systems, creeks or culverts caused by vegetation or other debris carried by floodwaters.
- Further development, earthworks and other changes to the catchment that alter the actual flood extents.

The flood extents shown are a prediction of land subject to a specific level of flood risk and do not necessarily indicate a threat to buildings located on that land. Confidence in the prediction is reduced in areas affected by flood depths less than 0.1 m, due to the effects of fences, walls, buildings and landscaping which affect the flow of floodwaters. Such effects, which require detailed modelling, are beyond the capabilities of the modelling process. Flood assessment for particular sites will require more detailed interpretation, survey and analysis by qualified and experienced persons.

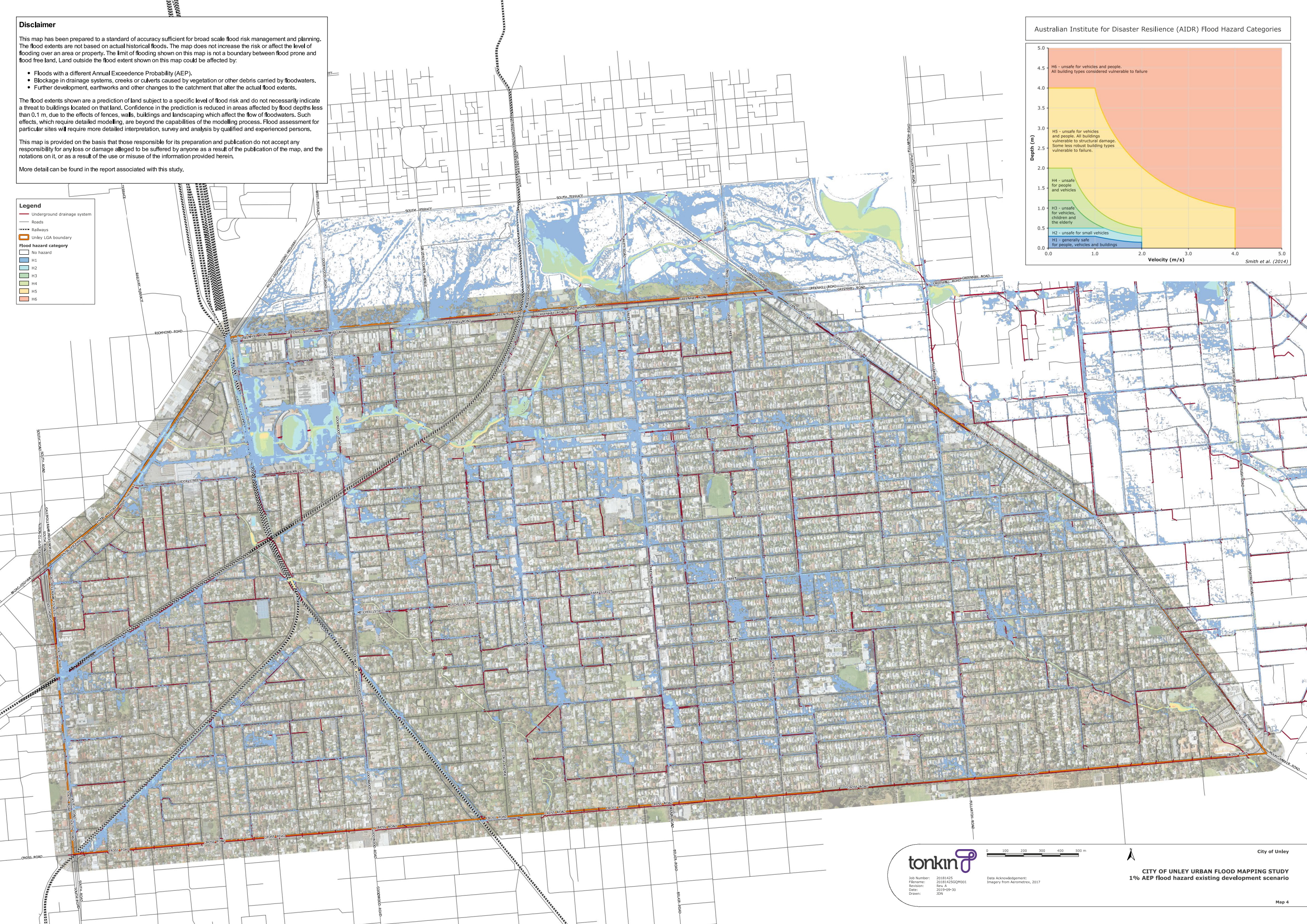
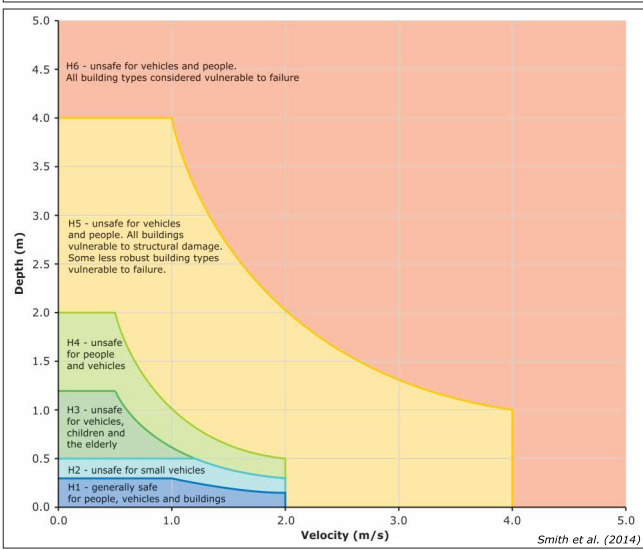
This map is provided on the basis that those responsible for its preparation and publication do not accept any responsibility for any loss or damage alleged to be suffered by anyone as a result of the publication of the map, and the notations on it, or as a result of the use or misuse of the information provided herein.

More detail can be found in the report associated with this study.

Legend

- Underground drainage system
- Roads
- Railways
- Unley LGA boundary
- Flood hazard category
 - No hazard
 - H1
 - H2
 - H3
 - H4
 - H5
 - H6

Australian Institute for Disaster Resilience (AIDR) Flood Hazard Categories



Job Number: 20181425
Filename: 20181425GQM001
Revision: Rev A
Date: 2019-09-30
Drawn: JDN



Data Acknowledgement:
Imagery from Aerometrex, 2017



CITY OF UNLEY
CITY OF UNLEY URBAN FLOOD MAPPING STUDY
1% AEP flood hazard existing development scenario